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24 April 1952

Report No. 546, Vol. II

L ENGINEERING SUMMARY REPORT
ON
FLIGHT TESTS
OF
INFRARED HOMING SET
AN/DAN-3(XN-1)

FOR

DEPARTMENT OF THE NAVY, BUREAU OF AERONAUTICS
WASHINGTON, D.C.

CONTRACT NOa(s) 51-196-c
ITEMS 1, 2, and 3

AEROJET ENGINEERING CORPORATION
AZUSA, CALIFORNIA
A Division of
THE GENERAL TIRE & RUBBER COMPANY

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DEPARTMENT OF THE NAVY
BUREAU OF AERONAUTICS
WASHINGTON 25, D. C.

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IN REPLY REFER TO
Aer-TD 411/997
2 AUG 1956

From: Chief, Bureau of Aeronautics
To: Bureau of Aeronautics Representative
Azusa, California

Subj: Technical data; request for

Ref: (a)

1. It is requested that the technical data listed in paragraph 2 be forwarded as indicated below:

☐ Chief, Bureau of Aeronautics, Department of the Navy, Washington 25, D. C. Attn: Aer-TD- (   )

✓ ☒ Commander, Armed Services Technical Information Agency
Document Service Center
Attn: TICSCA/22849
Knott Building
Dayton 2, Ohio

☐ Citing reference (a) in the forwarding letter.

2. The following technical data is requested: five copies of Aerojet General Corp. Final Engineering Summary Report, Volume II dated December 1950 to September 1951. Contract NOa(s) 51-196-c. "Flight Tests of Infrared Homing Set AN/DAN-3(XN-1).

3. It is requested that the following statements be included in the letter of transmittal: "To be distributed to Department of Defense activities and their contractors only". Two micro card copies of this report to be furnished the Bureau of Aeronautics when available. Release of this report to the Hughes Aircraft Corporation is approved.

4. It is also requested that a copy of the forwarding letter be furnished this bureau (atten: TD-411).

Copy to: ASTIA (TICSCA/22849)

A. H. BROWN
By direction

NAVAER-2534 (Rev. 9-52)

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24 April 1952

Report No. 516

No. of Pages: 130

FINAL ENGINEERING SUMMARY REPORT, VOL. II
ON
FLIGHT TESTS
OF
INFRARED HOMING SET AN/DAR-3(XN-1)

Contract NOa(s) 51-195-c
Items 1, 2, and 3

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Period Covered:

December 1950 to September 1951

This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794. The transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

AEROJET ENGINEERING CORPORATION

Azusa, California

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CONTRACT FULFILLMENT STATEMENT

This is the second of two volumes of the final engineering summary report submitted in partial fulfillment of Contract NOa(s) 51-196-c, Items 1, 2, and 3.

PART I

SECTION A: PURPOSE

1. INTRODUCTION.

In order to develop the Infrared Homing Set AN/DAN-3(XN-1) further and to adapt it to an air-to-air guidance system, with particular reference to the Sparrow missile, it was necessary to test the unit under actual flight conditions. Authorization was granted for conducting a series of flight, ground, and laboratory tests under the terms of Contract NOa(s) 51-196-c.

A preliminary investigation was carried out to determine the types of equipment, test setups, and design changes necessary in carrying out the program. Subsequently, an automatic spiral scanner was developed, a radiometer was constructed, and the infrared-homing-set control unit was modified. Several AN/DAN-3(XN-1)* units, together with the associated equipment, and power supplies were furnished to the U. S. Naval Air Missile Test Center (NAMTC) for use during flight tests at Pt. Mugu, California.

The stability of the tracking-system servo loop was investigated simultaneously (Reference a). The information obtained from this study was useful in verifying the over-all system response of the infrared homing set.

A series of ground, flight, and related laboratory tests were conducted for the purpose of determining the general performance of the AN/DAN-3(XN-1). Detailed information and technical data on the tests are included in this report.

2. PURPOSE OF THE PROJECT.

The purpose of the project authorized by Contract NOa(s) 51-196-c, Items 1, 2, and 3, was to conduct a series of ground, flight, and related laboratory tests on the Infrared Homing Set AN/DAN-3(XN-1) in accordance with the requirements set forth in this contract. The general objectives were to determine the workability and reliability of the AN/DAN-3(XN-1) as a homing device and its applicability to air-to-air missile-guidance systems, with particular consideration given to the adaptability of the unit to the Sparrow missile. The general test program covering the specific requirements of the contract is summarized as follows:

a. PERFORMANCE TESTS OF AN/DAN-3(XN-1).

(1) FLIGHT TESTS. - The flight tests were conducted for the purpose of determining the workability and the adaptability of the AN/DAN-3(XN-1) as a missile-guidance device. Additional tests were made to determine the applicability of the unit to automatic search, target acquisition, night-fighter fire control, tail or collision warning, and constant-bearing navigation systems.

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*Infrared homing set and AN/DAN-3(XN-1) have been used synonymously throughout this report.

The flight tests verified the pertinent laboratory and ground test results, and supplemented these with other tests which could not be conducted in laboratory or ground operations. In addition, various airborne-target characteristics were produced and maneuvers accomplished to simulate actual tactical conditions.

(2) LABORATORY AND GROUND TESTS. - The laboratory and ground tests consisted of determining the operating characteristics of the AN/DAN-3(XN-1) and broadening the laboratory and ground investigations conducted as acceptance tests under Contract NOa(s) 10231. These tests included the determination of external range-instrumentation, radiation, and signal-response characteristics of the unit, and measurement of tracking accuracy at high closing rates on the target.

b. TECHNICAL DIRECTION AND CONTROL. - All technical direction of the work covering the flight tests rested with the contractor, whereas technical control over the tests was vested in NAMTC, Pt. Mugu, California.

3. RESOLUTION OF THE PROBLEM.

The problem of determining the adaptability of the AN/DAN-3(XN-1) to an air-to-air guidance system resolved itself into the necessity of making various flight tests simulating operational conditions, with the view of verifying the investigations carried out simultaneously in the laboratory. Based on such an objective, a flight program was set up by joint efforts of the various representatives of the contractor, BuAer, and NAMTC. The Naval Air Missile Test Center, under authorization by BuAer, furnished all necessary flight equipment, aircraft, instrumentation facilities, and services; the contractor provided all technical direction necessary for making tests and obtaining data to evaluate the workability of the AN/DAN-3(XN-1) as an airborne guidance system. The technical phase of the program was then arranged into the following categories:

a. WORKABILITY OF AN/DAN-3(XN-1) AS A GUIDANCE DEVICE. - The description and the theory of operation of the Infrared Homing Set AN/DAN-3(XN-1) already have been discussed in the contractor's previous engineering summary reports (References a, b, and c). However, it may be restated that the AN/DAN-3(XN-1) is a passive device and relies for its operation on an infrared signal source external to the unit. Such a source is the target aircraft. The unit must, therefore, detect the infrared radiation from the target, continuously track the target, develop computed target-bearing signals, and feed these signals to a control system which dictates the direction of flight.

The characteristics pertaining to a workable guidance system are summarized and defined as follows:

(1) TRACKING-RANGE CHARACTERISTICS.

(a) Search and Acquisition.

1. Automatic. - Ability of the AN/DAN-3(XN-1) to scan automatically the maximum field of view, locate a target, terminate the scan, and commence tracking.

2. Manual. - Ability of the AN/DAN-3(XN-1) to lock on a target at various tracking ranges under diverse background and atmospheric conditions after the operator recognizes a signal on the monitoring oscilloscope.

(b) Maximum-Range Performance. - Adequate performance of the unit in tracking a target at extreme tracking ranges.

(c) Minimum-Range Performance. - Adequate performance of the unit at tracking ranges approaching the probable missile range of destruction.

(d) Signal vs Range. - The relationship between the signal strength and the tracking range, under a variety of atmospheric conditions and for various targets.

(e) Signal vs Aspect. - The relationship between the signal strength and the target aspect, for various targets.

(2) TRACKING CHARACTERISTICS.

(a) Tracking Ability. - General capability of the unit to track under all circumstances.

(b) Tracking Accuracy. - The accuracy with which the error between the indicated sightline from the missile to the target and the true sightline under various conditions can be measured.

(c) Resolution. - The ability of the unit to resolve discrete targets as the angle of separation increases from zero.

(d) Angle Noise, or Jitter. - The extent of random and erratic motions of the gyro spin axis.

(e) Jamming Sensitivity. - Freedom from interference by a false signal obtained by means of flares, smoke, or other radiation interference methods.

b. BASIC TEST SETUPS. - The characteristics defined under Paragraph 3-a represent desirable qualities of an infrared homing set which would establish the workability of the AN/DAN-3(XN-1) if they were used as performance criteria. Furthermore, the adaptability of the AN/DAN-3(XN-1) to various applications would be established, without further specific tests, by evaluation of the results obtained from test characteristics of the system. When such a basis was established, it was then necessary to set up a program of specific ground, flight, and laboratory tests and experiments by which these characteristics could be measured. Consequently, a number of tests were planned to achieve these objectives.

Only a few basic test setups were planned; these setups were flexible so that modifications could be introduced as necessary. The basic test setups were as follows:

(1) FLIGHT-TEST SETUP. - In this test setup, a parent airplane with the necessary instrumentation facilities and target airplanes of specified types were used. This arrangement permitted simulated tracking by an infrared homing set from a plane or missile. Although such an arrangement was basic, it was inherently difficult to set up because the target and the parent aircraft had to be permitted freedom of motion in all directions. Although tests conducted in this manner were in general successful, many other difficulties were encountered, such as radio communications, personnel discomfort due to oxygen equipment, difficulty in making rendezvous, radar trouble, and the like.

(2) MOBILE GROUND-TEST SETUPS. - Ground test setups were made to simulate air-to-air flight tests. The same type of instrumentation apparatus as that employed in the parent plane was installed on a truck so that the operations could be carried out by moving the truck and the target with respect to each other along the air-base taxi strip. Thus, air-to-air tests were simulated without encountering many of the difficulties experienced in actual air-to-air operations.

(3) STATIONARY GROUND-TEST SETUPS. - This type of test employed the infrared homing set mounted on a rotatable support, for ground-to-air tracking. A target plane was flown past the observation point to permit the necessary observations to be made.

The above-mentioned arrangements constituted the basic equipment setups used in evaluating the various characteristics of the AN/DAN-3(XN-1). In addition, it was found necessary to determine the radiation characteristics of the target and target background. For such measurements, a radiometer and a monochromator were required. Therefore, two additional test setups were arranged as follows:

(a) Radiometer Configuration. - A special radiometer was constructed which employed a lead sulfide receiver, a refractive optical system, and a radiation-beam chopper----all of which were mounted in a suitable case, which, in turn, was held in a rotatable mount. An a-c amplifier and a Brush recorder completed the equipment setup. The radiometer could be sighted at a target or background, as desired, to measure the total radiation intensity.

(b) Monochromator Configuration. - This unit consisted of a lead sulfide cell mounted in a Perkin-Elmer Universal Monochromator, which utilized salt windows, a salt prism, and a concave mirror in its optical system. A chopper, together with an a-c amplifier, modulated the signals, which were recorded on a Brush recorder.

SECTION B: GENERAL FACTUAL DATA

4. REFERENCES.

The following is a bibliography of the major reference material:

a. R. W. Powell and Norman L. Irvine, Stability Analysis of Infrared Homing Set AN/DAN-3(XN-1), Aerojet Engineering Corporation Report No. 546, Vol. I, 12 October 1951. Confidential.

b. E. M. Sevadjian, E. L. Mleczko and E. R. Bunker, Final Engineering Summary Report on the Development of Infrared Homing Set AN/DAN-3(XN-1), General Tire and Rubber Company of California Report No. 2056, 22 December 1950. Confidential.

c. Infrared Homing Set AN/DAN-3(XN-1), Workability Contract NOa(s) 51-196-c, Aerojet Engineering Corporation Progress Reports No. L2052-1 to L2052-13, December 1950 to December 1951. Confidential.

5. SYMBOLS.

a. GRAPHICAL SYMBOLS. - The graphical symbols employed in the drawings of this report are standard designations for electrical and mechanical components.

b. REFERENCE SYMBOLS. - Pertinent reference symbols or callouts are explained on each illustration.

6. MEASUREMENT PROCEDURES.

a. FLIGHT-TEST SETUPS ABOARD P2V-2N AIRPLANE.

(1) EQUIPMENT USED. - The following principal equipment was used for the air-to-air tests:

(a) Parent Plane, P2V-2N (Bureau No. 122465)

(b) Target Planes, F-80, TO-1, TO-2, and PB4Y-2

(c) Cameras, Bell & Howell 35-mm, Eyemo, Single-Shot Magazine Type

(d) Infrared Homing Sets AN/DAN-3(XN-1), Aerojet Serial Nos. 1 through 5

(e) Radiometer, Aerojet Model A-1

(f) Cathode-Ray Oscilloscope, Waterman Model 5-14A

(g) Radiometer Amplifier, Aerojet No. A-1

(h) Electronic Tachometer, Hewlett-Packard Model 505-A

(i) J-Scope

(k) Optical Sight

(l) Air Supply and Control

(m) APS-38 Radar

(n) Two Dual-Channel D-C Amplifiers, Brush Model BL-913

(o) Six-Channel Recording Oscillograph, Brush Model BL-6

(p) Chronometer

(q) Aerograph

(2) TEST SETUP. - The nose-tip structure of the P2V-2N airplane was modified to accommodate two cameras, one infrared homing set, and one radiometer-pickup head (see figure 1). The cameras were Bell & Howell 35-mm, single-shot magazine type; they were mounted behind the Plexiglas nose-tip, and triggered by a 28-volt d-c pulse originating from the radar. One camera had a telephoto lens with a field of view of ± 3° and the other had a field of view of approximately ± 15°.

The AN/DAN-3(XN-1) was mounted directly below the second camera and was boresighted, together with the cameras, relative to the centerline of the plane. The AN/DAN-3(XN-1) extended 8 inches beyond the Plexiglas nose tip, shown in figure 1. Alongside the AN/DAN-3(XN-1), an equal distance from the nose tip of the plane, was the radiometer which pointed upward at an angle of 5°. Copper shielding was used to line the nose tip to reduce vhf signals that interfered with proper radiometer operation.

Immediately behind the above-mentioned equipment were racks for mounting the AN/DAN-3(XN-1) control unit, an oscilloscope for monitoring the error-voltage signal, a radiometer amplifier, an electronic tachometer for measuring gyro speed, and power supplies for the units, figure 2. The air-supply control was behind the racks. An optical sight for visually aligning the P2V-2N with the target and a cross-pointer indicator showing the position of the tracking gyro were located in the pilot's compartment.

The parent plane was equipped with an APS-38 radar (figure 3), which was an x-band search-type unit. The PPI scope of this unit, a data card, a chronometer, and a film-frame counter were in direct view of a camera, which was triggered by the radar at submultiples of its scan frequency. An aerograph located in the radar compartment recorded the temperature, relative humidity, altitude, and air speed.

In the navigator's compartment were two dual-channel Brush d-c amplifiers and a six-channel Brush recording oscillograph (figure 4). Two of the channels were used to record the servo-output voltage of the AN/DAN-3(XN-1), a third, the output of the electronic tachometer, a fourth, the pulse which triggered all the cameras, a fifth, the radiometer-amplifier output voltages, and a sixth, the radiometer amplifier-gain setting.

In the tail section, a fourth camera was used to photograph an instrument panel, on which were a J-scope to indicate the precession-current intensity, a chronometer, film-frame counter, data card, attitude gyro, compass repeater, altimeter, and precession-current meter (figures 5 and 6).

(3) PROCEDURE. - Preparatory to all test flights, a routine check was made which included necessary calibrations of the equipment, bore-sight photographs, and inspections of the operation of all the equipment. This check was performed jointly by Aerojet and NAMTC personnel; Aerojet personnel assigned to the flight operation consisted of a flight-test engineer, a flight-test technician, and occasional observers.

The flight-test technician was stationed in the nose of the airplane to monitor the error-voltage signal of the AN/DAN-3(XN-1) and to operate the control unit, adjust the precession-current-gain control and the air supply, change the radiometer-filter wheel setting, and perform such other operations as necessary for obtaining an optimum performance. The flight-test engineer directed all the major test operations from the navigator's compartment.

Each of the flight-test personnel was equipped with an intercommunication set, and all radio and voice communications were recorded automatically on a wire recorder actuated by means of "push-to-talk" buttons at the sets. Because of frequent trouble encountered with this apparatus, it was replaced by a scribed-film recorder actuated by means of sound level. This new arrangement was satisfactory, but since the operation of the recorder was triggered by an initial voice, the first portion of the speech was clipped unless preceded by a prespeech voice signal.

Preparatory to each flight, the flight-test engineer selected and used the proper optical filter for the infrared homing set in accordance with the purpose and conditions of the flight.

After the P2V-2N became air-borne, the Brush recorder was turned on, and the radar was switched from "Stand-by" to "On" position; this switching was required because the radar provided the pulse signals actuating the cameras. The P2V-2N then ascended in a spiral pattern in order that the entire field of view of the sky could be observed. The radiometer was maintained in operation throughout the flight to obtain background information when desired.

During the ascent, the AN/DAN-3(XN-1) was energized electrically, but the precession current was off and the tracking gyro was caged. After the target was sighted, the caged gyro was brought up to normal speed, and the precession current switch was closed. When the oscilloscope indicated a target signal, showing that the infrared homing set was roughly aligned with the target, the gyro was uncaged to permit the unit to track. The target then was directed to fly in accordance with specified flight patterns. Both jet- and reciprocating-engine type targets were used (see figures 7 and 8).

At various time intervals during the run, the tracking was checked by opening the precession-current switch so that any noticeable change in the signal could be observed on the oscilloscope. In most cases, the test run was continued until the target was out of the range of the AN/DAN-3(XN-1). Thereafter, the target-plane speed was reduced to permit the parent plane to close on the target for another run. Both automatic and manual search methods of acquisition were used throughout the flight tests.

Usually the first run was made to determine the maximum tracking range under the specific conditions of the flight; the ensuing runs comprised target maneuvers, which included the following:

Target Motion	P2V-2N Plane	Purpose
Sinusoidal course	Pointing at target	To measure effect of changing target aspect
Sinusoidal course	Flying in straight line	To confirm and measure accuracy of tracking
First target in straight-line flight; second target in cross path to first	Straight line course	To determine resolution
First target in straight-line flight; second target flying parallel, then peeling off	Straight line course	To determine resolution
Evasive action	Pursuit course	Tracking ability in tactical applications

During the multiple-target runs, the tailpipe temperatures were varied, and in all other runs they were kept constant. In later flights a second AN/DAN-3(XN-1) was substituted for the radiometer so that the AN/DAN-3(XN-1) units with various modifications could be compared under identical conditions. Since the P2V-2N contained only sufficient equipment to operate one AN/DAN-3(XN-1) unit at a time, it was necessary to make successive runs, switching the cables and air supply from one AN/DAN-3(XN-1) unit to the other between the runs. Also, from time to time, other tests were improvised to check various components, as the need presented itself.

b. MOBILE GROUND-TEST SETUPS.

(1) EQUIPMENT USED.

(a) Chevrolet Stake-Body Truck

(b) Infrared Homing Set AN/DAN-3(XN-1), Aerojet Serial Nos. 1 through 5

(c) Infrared Homing Set AN/DAN-3(XN-1) Control Unit, Aerojet Serial Nos. 1 and 2

(d) Infrared Homing Set AN/DAN-3(XN-1) Power Supply, Aerojet Model PS-1 (1.5, 28, 75, and 250 volts)

(e) Infrared Homing Set AN/DAN-3(XN-1) Interconnecting Cables

(f) Infrared Homing Set AN/DAN-3(XN-1) Stand

(g) Six-Channel Brush Recording Oscillograph, Model BL-6

(h) Two-Channel Brush Amplifier, Model BL-913

(i) Hewlett-Packard Electronic Tachometer, Model 505-A

(j) Hewlett-Packard Voltmeter, Model 400-C

(k) Waterman Oscilloscope, Model 5-14A

(l) Radiometer Amplifier, Aerojet Model A-1

(m) Radiometer Power Supply, Aerojet Model PS-2

(n) Air Supply and Control

(o) Communications Equipment SCR-684

(p) Gasoline-Engine Generator, 7.5 kw, 120 volts, Single Phase, and 60 cycle

(q) 12-Volt Storage Battery

(r) Temperature and Humidity Recorder

(2) TEST SETUP. - The AN/DAN-3(XN-1) stand was mounted on a shelf in the forward part of the truck bed immediately behind the truck cab (figure 9). In this location, it was possible to rotate the AN/DAN-3(XN-1) through an angle of more than 180° in the forward horizontal plane, and to elevate and depress it in the vertical plane. The control unit, the voltmeter, the oscilloscope, and the radiometer amplifier were mounted on the top of a bench. The power supply and the electronic tachometer were located on a shelf underneath the bench. Facing forward in the truck another bench was located along the right side, on the top of which were the radiometer power supply, the six-channel Brush recording oscillograph, the two-channel Brush amplifier, and the SCR-684 communications unit (figure 10). A temperature and humidity recorder, and the a-c power supply for the communications unit were mounted underneath this bench.

While the truck was in motion, power was obtained from a gasoline-engine generator which was mounted on a trailer attached to the rear of the truck (figure 11). This trailer also carried the electric-powered air compressor which supplied the air to the tracking gyro.

(3) PROCEDURE. - The target airplane in use was "spotted" at the western end of the taxiway in a position which presented the desired aspect to the AN/DAN-3(XN-1). By using an odometer, the tracking range was measured and every one-tenth mile was identified by a visible marker in order that the distance from the stationary target airplane could be determined.

After proper calibrations and preliminary checks were made on the equipment and a suitable warm-up time was allowed, radio contact was established with the target airplane and the desired operating conditions of the target were requested.

"Lock-on" was established at a range slightly greater than nine tenths of a mile, and all equipment settings were adjusted and noted. The run was started as the truck passed the nine-tenth-mile marker, and the speed of the truck was maintained constant at 7 miles per hour. The runs were terminated at approximately 120 feet from the target airplane.

The error-signal voltage from the preamplifier output, available at the control unit, was measured by the Hewlett-Packard Model 400-C voltmeter and the needle deflection was kept on the lower two thirds of the scale to ensure linearity. The output of the voltmeter was amplified by the

(p) Gasoline-Engine Generator, 7.5 kw, 120 volts, Single Phase, and 60 cycle

(q) 12-Volt Storage Battery

(r) Temperature and Humidity Recorder

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The error-signal voltage from the preamplifier output, available at the control unit, was measured by the Hewlett-Packard Model 400-C voltmeter and the needle deflection was kept on the lower two thirds of the scale to ensure linearity. The output of the voltmeter was amplified by the radiometer amplifier and recorded on a Brush oscillograph. This system permitted the maintenance of the radiometer amplifier on a single scale for all measurements, the amplitude of the recorder signal being controlled by the step attenuator in the Model 400-C voltmeter.

A 12-volt battery provided d-c power for the filaments of the tubes in the radiometer amplifier, thus eliminating any gain change that might be due to possible variation of the filament emission in this amplifier.

The right-left and up-down servo-output recording channels were supplied with signals from the two-channel Brush amplifier, which was calibrated to permit a pen-motor deflection of 1 millimeter per 0.1 volt of signal.

Because of the exhaust gases issuing continuously from the jet targets and of the propwash from the PB4Y target, it was not possible to approach the target closer than approximately 100 feet. Slightly closer ranges were obtained when the target presented a 90° aspect, but this was limited by the turning radius of the truck-trailer combination.

c. GROUND-TEST SETUPS.

(1) EQUIPMENT USED. - The following equipment was used in setting up the apparatus for the ground test:

(a) Infrared Homing Set AN/DAN-3(XN-1), Aerojet Serial Nos. 1 through 5

(b) Power Supply for AN/DAN-3(XN-1), Aerojet Models PS-1 and PS-2

(c) Control Unit for AN/DAN-3(XN-1), Aerojet Serial Nos. 1 and 2

(d) Interconnecting Cables for AN/DAN-3(XN-1)

(e) Stand for AN/DAN-3(XN-1)

(f) Two-Channel Brush Recorder, Model BL-202

(g) Tachometer, General Radio

(h) Vacuum-Tube Voltmeter, Hewlett-Packard Model 400-C

(i) Cathode-Ray Oscilloscope, Du Mont Model 208

(j) Radiometer-Amplifier, Aerojet Model A-1

(k) Radiometer Power Supply, Aerojet Model PS-2

(l) Target Planes, F-80, TO-1, TO-2, and PB4Y-2

(m) Air Supply and Control

(n) Communications Equipment, ARC-1-VHF Transceiver

(o) Communications Van

(2) TEST SETUP. - The infrared homing set was placed on a suitable site at Pt. Mugu in order to command an unobstructed view of the surrounding area. The unit was held in a cradle on a stand which permitted its rotation through 135° azimuth and 45° elevation from the horizon. The stand, in turn, was mounted on a stationary support. Electrical connections were made from the infrared homing set to the control unit, and from the control unit to the power supply, tachometer, oscilloscope, and vacuum-tube voltmeter. The error-voltage signal was presented on the oscilloscope, and was measured simultaneously by a vacuum-tube voltmeter (see figure 12).

Communications were maintained with the tower, target airplane, and the SCR-584 radar plotting board, by means of the ARC-1 transceiver, which was mounted in the communications van. Considerable variations of test equipment and procedures were made in this particular test configuration.

(3) PROCEDURE. - The target-plane pilot was briefed regarding flight procedure preceding each test operation. The pilot was requested to fly the target aircraft directly over the test site on a fixed course and altitude, applying full thrust and lowering flaps to maintain a high tailpipe temperature at a constant velocity. Radio contact was maintained with the target at all times, so that any changes in the flight plan could be accomplished. Typical flight plans included a fixed elevation, fixed climb-angle, straightaway, and zigzag courses. Range was measured either by the use of radar or by timing the duration of the tracking and then computing the range from the known velocity of the plane.

The test procedure was as follows:

As the target passed over the test site, the pilot reported his altitude, indicated air speed and tailpipe temperature; if ground radar was used, its traces were marked at this time. If not, an operator started a stop watch while a second operator sighted the infrared homing set, on the plane, with the gyro caged, and announced when the unit was on target. A third operator, monitoring the signal at the oscilloscope, announced when a signal appeared on the screen. The second operator then continued the detection with the gyro caged, or the tracking, with the gyro uncaged, depending on the test. This procedure continued until the target was out of view as indicated by the loss of signal on the oscilloscope or Brush recorder. If radar was used, the recording trace was marked again; otherwise, the watch was stopped and pertinent information obtained from the jet pilot.

d. RADIOMETER-MONOCHROMATOR CONFIGURATION.

(1) EQUIPMENT USED.

(a) Radiometer, Aerojet Model A-1

(b) Radiometer-Amplifier, Aerojet Model A-1

(c) Radiometer Power Supply, Aerojet Model PS-2

(d) Radiometer Stand

(e) Two-Channel Brush Recorder Model BL-202

(f) Du Mont Oscilloscope, Model 241

(g) General Radio 35-mm Oscilloscope Camera

(h) Communications Van

(i) Gas-Engine Generator, 7.5 kw, 120 volt, Single Phase, 60 cycle

(j) Magnetic Compass

(k) Level

(l) Perkin-Elmer Universal Monochromator

(2) TEST SETUP. - The radiometer was equipped with a filter disc, which permitted the insertion of various filters in front of the lead sulfide detector cell. The radiometer stand was rotatable in azimuth and elevation. The Perkin-Elmer monochromator was modified to incorporate a lead sulfide detector, a wavelength drive motor, a 200-cps chopper, and a collecting mirror.

All the equipment used was mounted on one or more mobile tables. Depending on whether the monochromator or radiometer data were to be obtained, the particular unit was mounted so that it could be sighted at the target. The output signals were amplified by the radiometer amplifier, and recorded on one channel of the two-channel Brush recorder, while the other channel was used to identify the gain setting of the radiometer amplifier, figures 13 and 14. The power and communication facilities were provided by the communications van.

(3) PROCEDURE. - When the total energy of a target was to be measured, the radiometer was sighted at the target and its various operating conditions were noted.

In measuring the spectral distribution of the target radiation, the monochromator was aligned visually by sighting it on a flashlight held at the target source. The spectrogram of the radiation was then obtained by use of the radiometer amplifier and the Brush recorder. A PB4Y-2 airplane, as well as an F-80, TO-1, TO-2, or F-94 jet airplane, was used for target.

The spectral distribution of the sky radiation was also measured, using these test setups. In these tests, the monochromator was oriented to the north, and then the elevation and azimuth angles were scanned in 15° increments.

SECTION C: DETAIL FACTUAL DATA

7. CHRONOLOGICAL RESUME.

In the succeeding paragraphs are presented a general resume of events in their chronological order and preliminary information regarding the flight and laboratory tests.

a. CONTRACT NOa(s) 51-196-c. - Pursuant to the granting of Contract NOa(s) 51-196-c, dated 8 November 1950, a conference was held between the representatives of Aerojet and the Bureau of Aeronautics in the first week of December 1950, at which time the general problems of the flight and laboratory tests were discussed and a tentative program of instrumentation requirements was outlined.

On 25 January 1951, a second conference was held at NAMTC, Pt. Mugu, between the representatives of the Bureau of Aeronautics, NAMTC, and Aerojet Engineering Corporation to review the airplane requirements and instrumentation facilities available. It was then agreed that a P2V-2N airplane or its equivalent would be suitable for the parent airplane.

A request was made to the Navy for such a plane and suitable instrumentation facilities, and a P2V-2N (Bureau No. 122465) was allocated and delivered to NAMTC late in February. Having undergone routine acceptance procedures by the operations department at NAMTC, the airplane was made available for project use in March. Because of the late arrival of the airplane and the tentative date of its release in July, a compromise was made with regard to the instrumentation requirements, which resulted in various other problems.

b. PROVISION OF INSTRUMENTATION FACILITIES. - Among the problems encountered were the following: Not all of the facilities required for instrumentation were available, and construction of additional instruments was necessary. Since the AN/DAN-3(XN-1) operates as a null device, it was not feasible with the equipment then on hand to measure error-voltage signal from the detector; this would have been significant information, but it was decided that this measurement should be omitted until suitable equipment became available. It was also desirable to measure background intensities simultaneously with target tracking. In order to achieve this, a radiometer of the chopper type with an optical system similar to that of the AN/DAN-3(XN-1) and an appropriate amplifier with associated power supplies were constructed.

To determine the target acquisition characteristics of the AN/DAN-3(XN-1), the latter was modified to include a search and automatic acquisition system. After a number of scan configurations were considered, it was concluded that a spiral scanning method would be the simplest to achieve and the most complete in field coverage. The spiral scan was accomplished by applying to the precession amplifier an alternating voltage of the same frequency as that of the tracking-gyro spin. A source of voltage of correct frequency was already available in the manual tracking system of the AN/DAN-3(XN-1); a selsyn control transformer permitted the selection of a voltage of any phase angle by varying the position of its rotor. This rotor was rotated slowly by means of a motor to provide the required phase-change characteristics while the magnitude of the voltage was increased, thus causing the tracking gyro to scan in a spiral pattern.

c. FLIGHT-TEST PROGRAM. - In order to broaden the scope of the test program, conferences were held with the Bureau of Aeronautics representatives for the purpose of amending the basic contract. Due to lack of funds, this phase of the program could not be pursued. However, the final instrumentation arrangements were settled in a conference with NAMTC personnel at Pt. Mugu. Subsequently, flight-test schedules and data reduction procedures were established while the instrumentation matters were under way. An over-all master program was outlined for future flight planning. This program and related test methods resulted from conferences held at the Aerojet plant in March, and at NAMTC in April and May 1951.

The flight-test program was divided initially into six phases, based on the primary purpose of the tests to be conducted. The flights in each phase were arranged so that the maximum amount of information from various characteristics of each given flight could be obtained.

(1) PHASE I. - This phase consisted of flight-tests to familiarize the personnel who would take part in the flight-test program with the various aspects of instrumentation, the equipment to be used, and calibration and checkout of all equipment required. During this phase, the procedures to be used in the ensuing phases were also determined.

(2) PHASE II. - This phase included the flight tests for determining the maximum tracking range, minimum range response, acquisition ability of the AN/DAN-3(XN-1), and the variation of tracking range with respect to the target aspect.

(3) PHASE III. - During this phase of the program, the tracking ability and accuracy of the AN/DAN-3(XN-1) under simulated tactical conditions were determined, and the validity of the guidance data thus obtained was investigated.

(4) PHASE IV. - The primary purpose of Phase IV was to determine the effect of various background conditions on the performance of the AN/DAN-3(XN-1).

(5) PHASE V. - This phase mainly consisted of measurements of the response to multiple-target situations, and determining the resolution of the AN/DAN-3(XN-1).

(6) PHASE VI. - This phase was intended for determining the tactical conditions under which tracking might be possible; it also was to be devoted to additional flights as required to expand any of the tests of the preceding five phases.

Seventy-six flights were scheduled, of which 43 took place and the remaining 33 were deferred for various reasons, such as weather conditions, airplane or equipment difficulties. The deferment of some of the night operations was due to weather conditions at NOTS, Inyokern, where the jet airplane landed at night. Night landing by instruments was prohibited at NAMTC; consequently, occasional nights were spent at Inyokern by the entire flight-test crew. A more satisfactory arrangement for night operations was desirable.

d. INSTRUMENTATION PROBLEMS. - The major problems of flight-test installations in the P2V-2N had been overcome by June 13, and the first flight test was made. This test and succeeding orientation flight tests revealed that all data required could not be obtained as successfully as had been expected initially. The J-scope failed to record the tracking-error waveform properly; the target could not be photographed at night with the type of film used in the boresighted cameras; the pilot could not align the radiometer with the target because of its fixed offset angle with respect to the airplane centerline; the camera synchronization, at times, was intermittent and identification of the corresponding frames was difficult; voltage regulation for the radiometer amplifier was too inadequate to prevent gain changes arising from variable filament emission; and vhf communications interfered with the radiometer operations. In addition, no x-band radar beacons were available to solve the existing limited radar range problem. Since many of these difficulties could not be altered readily, compromises were made consistent with time and fund appropriations.

An additional restriction was imposed by the problem of verifications of tracking, since consistent verification was difficult and results were particularly hard to obtain in flight. In order to investigate the problems of verification, several ground-observation tests were made. Based on the results of these tests, other procedures were established to provide positive verification of tracking under various conditions.

During the early flights of Phase II in July, apparent erratic tracking ranges were obtained which could not be explained on the basis of atmospheric absorption. In addition, it was observed that the tracking range decreased as the flight continued, and this condition seemed to be related directly to the length of time air was supplied to the AN/DAN-3(XN-1). After investigation, it became evident that a very small difference between the ambient air temperature and the dew point existed during the nights when these flights took place. Since the compressors furnished atmospheric air which was not dehumidified, it was believed that condensation had occurred on the lens and mirror surfaces of the unit. Consequently, dehumidifiers were installed on the plane, and no recurrence of these effects was noted thereafter.

Most of the weather conditions during July made daylight tracking indeterminate, because background conditions were so varied that specific tracking ranges for particular backgrounds could not be confirmed. For this reason and due to the uncertain availability of the P2V-2N for project use, it was decided that ground observations, conducted in conjunction with the air-borne tests, would be the most practical approach to the problem. This arrangement would permit a control over a series of flights under a variety of operating and easily selectable conditions not possible in air-to-air operations.

e. GENERAL PROGRAM. - The ground tests were begun on 23 July 1951. Observations were made to determine the total radiation, spectral radiation, and spatial distribution of the radiations from both target airplanes and sky backgrounds. This information was also necessary to complement the radiation data obtained at Aerojet, from which data, filters for optimum contrast could be selected.

During the first week of August a series of jet-airplane failures occurred, which prevented the flights of these planes. Bad weather conditions interfered with daylight operations, as in July. During the second week of August, satisfactory results were obtained from both air-borne and ground tests. However, engine trouble discovered on the P2V-2N, in the course of a routine maintenance check, prevented the plane from flying during the week of 20 August. During the following week, impending winds of hurricane velocity necessitated the removal of many airplanes from NAMTC grounds; because of these circumstances the scheduled flight tests were again postponed.

In the course of the air-borne tests, it became necessary to alter the flight schedules, since the availability of the P2V-2N was known only on a week-to-week basis. September 15 was established as the final availability date.

During the first half of September, a group of government officials were at NAMTC, Pt. Mugu, to evaluate the program. Because of the importance of the visit of these officials, all operations were primarily for demonstration purposes.

In addition, the Bureau of Aeronautics desired to determine the relative merits of the characteristics of jet airplanes with and without afterburners, and arrangements were made to obtain an airplane with an afterburner. An F-94 Air Force plane was obtained which arrived after the completion date (September 15) of the test program. Because of the importance of the requested information, it was decided to continue the tests from the ground with the F-94 as an air-borne target. A combination of poor weather and airplane failure, however, limited the operations to one daylight flight of this airplane. Consequently, all tests for making comparative measurements of radiation intensities were ground-to-ground.

During the data-reduction phase of the test program, it became evident that additional data were required to verify many conditions about which little information existed, because data could not be recorded adequately during air-borne tests. A limited number of ground observations were then made.

The flight-test operations at Pt. Mugu were concluded on the night of 16 October 1951.

8. TECHNICAL DATA.

a. TRACKING-RANGE CHARACTERISTICS OF AN/DAN-3(XN-1).

(1) DISCUSSION.

(a) General. - The maximum effective range of a homing device is dependent on factors of the following categories: sensitivity and the performance of the tracking system, target radiation, background conditions, and atmospheric conditions.

(b) Character of Target and Background Radiations. - Since the parameters describing target and background radiations are identical, they cannot be discussed independently. Target radiation may be described completely by determining the magnitude and spectral distribution of the radiation. These functions vary further with the angular aspect at which the target is viewed, since they depend on the effective area, temperature, and emissivity of the infrared source. The emissivity, in turn, is a function of both the wavelength and the temperature.

It must be noted that unless an optical contrast exists, a target may not be distinguished from its background. Contrast is dependent on the difference in the intensity or the spectral distribution of the radiation, or both, between the target and the background. The present design of the AN/DAN-3(XN-1) is such that the unit responds only to positive contrast.* It is possible, however, to change the unit so that it can operate with negative contrast tracking, but both types cannot be used simultaneously.

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*Contrast is positive when the target-radiation intensity is at a higher level than the background, and it is negative when the converse is true.

The existence of any type of target background other than a completely dark background is detrimental in that (a) the contrast is decreased and, consequently, the signal, and (b) variations in the background intensity within the scanned field initiate a background noise which in effect increases the system noise level.

One method of increasing contrast and also decreasing the background noise (which was used in the tests) is the reduction of the beam width and the angular view of the scanning cone. The limits of this method are imposed by the available cell size and the angular scanning rate, and as yet the possibilities have not been completely investigated.

It was evident then that steps had to be taken to increase contrast and simultaneously decrease background noise by filtering the incident radiation. However, before a judicious selection of a proper filter or filter combination could be made, measurements of the magnitude and spectral distribution of typical sky-background radiations and target radiations had to be made. Such measurements were made, and data are included in Appendix C.

Other systems for discriminating between the target and the background are under development, whereby the effect of background noise may be further decreased; however, these methods were not sufficiently advanced to be included in the scope of the present work. Spurious targets, such as the sun or the moon, may occur in the background; eventually equipment will be built that can discriminate against these.

(c) Effects of Atmospheric Conditions. - The target radiation energy reaching the detector cell of the AN/DAN-3(XN-1) would be inversely proportional to the square of the tracking range, if the intervening medium had the properties of a vacuum. However, the atmosphere causes additional attenuation of the radiant energy because of scattering, and of the selective absorption of the radiation by atmospheric water vapor and CO_2. These effects also decrease the effective contrast between the target and the background and, consequently, the maximum effective range.

(d) Performance of AN/DAN-3(XN-1). - The radiation-reception efficiency of the AN/DAN-3(XN-1), which includes such factors as the gain of the optical system, the cell sensitivity, bias voltage, and load resistance, determines the magnitude of the signal voltage. The ultimate tracking range of the system will be one that corresponds to the minimum cell irradiation required to generate a voltage just greater than the inherent noise voltage. Against a dark background (night sky), it is always possible to increase the tracking range by increasing the optical gain or by decreasing the system noise. Consequently, the tracking range can be increased easily at night, whereas it is more difficult to increase this range during the day.

The amplitude of the tracking signal with range is of interest. Up to medium ranges of several miles (see figure 27), the signal is great and the target is tracked near the center of the reception beam pattern. As the signal decreases, the target image must then move to a position of higher sensitivity on the lobes of the reception beam pattern in order to override the noise signal in causing precession. The direction in which the image will ride out on the reception beam pattern (Reference b) is dependent on the precession direction produced by the phase of the periodic noise; in equilibrium, the error signal and the noise will be equal in magnitude but 180° out of phase. No measurable disturbance of the sight-line results from the motion (see figure 43). It should be noted that only those noise frequencies which are within the harmonic system of the scan frequency are effective in causing the AN/DAN-3(XN-1) to lose the target. Therefore, the unit will respond to a signal-to-noise ratio of less than unity (1:1) with the apparent or amplifier noise.

If the over-all gain is so low that the noise signal cannot precess the gyro, tracking will cease before the maximum range is reached. It is evident then that a variable gain is necessary in order to permit tracking under various conditions of system and background noise. The AN/DAN-3(XN-1) units were modified in that respect. The operation of the gain control consisted of increasing the gain until the noise signal just caused a perceptible precession of the gyro.

(e) Methods of Verifying AN/DAN-3(XN-1) Tracking. - Because the AN/DAN(XN-1) is a null-seeking device, and because it tracks below the 1:1 signal-to-noise ratio (where the noise is the apparent or amplifier noise), it is relatively difficult to verify precisely the maximum tracking range. The several methods which are developed for verifying tracking are as follows:

1. Signal Detection. - It would be useful to be able to predict an expected maximum tracking range under the specific conditions of each flight. For such predictions, the AN/DAN-3(XN-1) was used occasionally as a detecting device. With the tracking gyro caged, the AN/DAN-3(XN-1) was moved across a target whose range was increasing while the signal was observed on an oscilloscope. The range at which this signal was no longer apparent was taken as the detectable range; in all cases, this range was less than the tracking range, since the entire amplifier noise appeared on the oscilloscope. The data resulting from such detection runs were used for predicting tracking ranges for subsequent runs of the same operation to permit more intelligent use of the tracking verification methods.

2. Recording of Error Voltage. - Using the test configuration described in Paragraph 7-c, the error voltage was taken from the AN/DAN-3(XN-1) preamplifier, amplified by both a Hewlett-Packard Model 400-C voltmeter and the radiometer-amplifier, and then recorded on a Brush recorder. In most cases, the final tracking was accomplished with a target

signal of a value less than the recorded noise level. During either day or night, when the signal from the original target was comparable with the noise, a condition of equilibrium was established with the error signal 180° out of phase with the noise signal, and some cancellation occurred. Consequently, when the target tracking ceased, the terminal position of the recorded signal increased in amplitude and the position of the target loss was easily observed. A typical recording which shows this effect is presented in figure 15.

It was noted that the amplitude change was more pronounced during the day when the noise was periodic in character than at night. The position of the gyro, recorded simultaneously with the error voltage, always showed an immediate shift of position at the same moment that the error voltage indicated a loss of target tracking.

3. Precession Current. - When the instrumentation equipment was not available to record the error voltage, the most effective method of verifying tracking consisted of interrupting the precession current. Such an interruption permitted the gyro to return under restoring forces to a balanced, normal position. Since the focal annulus then veered off center, a stronger signal passed through the preamplifier and was indicated on the oscilloscope. The evidence of a check for this effect was a Brush record of the gyro position showing a gradual shift terminated by a rapid return to the tracking position, as the precession circuit was again closed. This is illustrated in figures 16 and 17, together with a radar plot of the range taken simultaneously.

When the precession current and the gyro position were plotted simultaneously against timing pulses, the precession-current dips coincided with the gyro-position changes. Further changes in the gyro position when there were small or no dips in precession current were explained by the fact that the gyro position was recorded continuously while the precession current was recorded at intervals.

4. Other Methods. - Several other methods for verifying the tracking were also used. These additional methods may be classified as (a) an arbitrary precession-current method, (b) the course-change method, and (c) the noise method.

a. Arbitrary Precession-Current Method. - In this method, the voltage which is generated in the pickup coils and taken from the synchro transformer was fed into the amplifier in proper amplitude and phase in order to cause the gyro to deflect in some arbitrary direction after the target was lost, thus visually indicating the loss of tracking by the gyro-position indicator; this motion was also verified by the recording of the gyro position. The main disadvantage of this system was the range limitation imposed.

b. Course-Change Method. - The course-change method consisted of directing the target to fly a horizontal sinusoidal course of sufficient amplitude to cause the deflection of the gyro-position indicator. Loss of tracking was noted by the lack of deflection of the position indicator and Brush-recorder pen. The primary disadvantage of this method was that variation of target aspects presented a region of uncertainty with regard to loss time.

c. Noise Method. - The system noise, which is primarily the periodic voltage caused by magnetic induction, performs the same function as the applied current in the arbitrary precession method. This method is valid at night when tracking continues down to the system-noise level, but it is invalid in daytime.

(f) Search and Acquisition. - The search and acquisition functions of the infrared homing set are those in which the unit automatically searches a field of view, identifies an infrared target, terminates the search, locks on the target, and then commences automatic tracking. The principal features of a device of this type on which these functions are dependent may be given as follows: limits of search field, uniformity of entire field sensitivity, type of search, target recognition, rate of search, and maximum useful range.

Acquisition ability of the unit will be defined as the ability of the system to identify a target which enters the field of view, lock on the target, and then commence automatic tracking. The three types of acquisition which apply to a homing device are as follows: (1) acquisition by automatic search, (2) controlled search, and (3) physical positioning of the entire homing unit with the tracking gyro caged. The two latter types of acquisition make it necessary for the operator to identify the target by observing the oscilloscope display and then releasing the scanning head so that the automatic tracking may begin. The signal level necessary for acquisition following an automatic or manual search, together with the range established by this level, is important in evaluating such systems.

As mentioned in Paragraph 2-a, one of the contractual requirements specified that modification be made on the AN/DAN-3(XN-1) control unit in order to include an automatic search and acquisition system. After investigation of the problem preliminary models were built, from which evolved an automatic spiral-search unit.

The limits of field viewed in this spiral search unit are restricted by either the size of the refractive optical system or by the necessary stops to gyro motion. In the unmodified-type AN/DAN-3(XN-1), the limits are ± 15° around the center, and in that with the modified gyro, the limits are ± 23°.

Target identification is accomplished by a differential amplifier, which acts as a gate against noise but permits a signal peak to be transmitted through the main acquisition amplifier for actuating a relay to turn off the spiral scan. The amplitude of the actuating target signal and, consequently, the necessary target-signal-to-noise ratio to automatically acquire a target are variable. However, the signal-to-noise ratio employed must be such that a signal voltage greater than the noise peaks could be passed. If this condition is not true, then the acquisition amplifier may be triggered by a noise peak. It is thus apparent that the effective maximum tracking range is somewhat greater than the automatic search and acquisition range.

(2) MAXIMUM TRACKING-RANGE CHARACTERISTICS OF AN/DAN-3(XN-1).

(a) Description of Tests. - The test setup used for determining the maximum tracking range and the method of verifying tracking depended, to a large extent, on the type of instrumentation facilities available and on the operating conditions. Thus, no recordings of error voltage were made in actual flight. Some of the general verification methods used in flight included recording of the precession current, visual checks of an arbitrary precession current, and recorded course of the target. Absolute verification of a tracking range, during flight, was accepted only if the results of two or more methods of verification were available, whereas absolute verification of the ground-to-air ranges was accepted from error-voltage recordings alone, since they indicated clearly a definite point of break-off.

A brief statistical summary of the entire flight schedule is presented in Table 1. This summary is treated in more detail in Appendix A, which briefly describes each operation. A description of all ground operations is given in Appendix B.

Table 1. Statistical Summary of Flight Operations

Time Night or Day	Target	Number of Operations	Number of Runs	Number of Successful Operations
N	F-80	17	74	13
D	F-80	11	51	8
N	2F-80	3	26	3
D	2F-80	1	4	1
N	PB4Y-2	2	18	2
Operations for other purposes		9	—	9
TOTAL		43	173	36

Altitude: 10,000 to 22,000 feet.

Weather Extremes: Humidity - less than 10%; Temperature - -31°C; Pressure - 320 mm.
Humidity - 78%; Temperature - +9.9°C; Pressure - 689 mm.

In order to establish the tracking-range performance of the AN/DAN-3(XN-1), a total of 92 runs extending over 21 flights were made on various targets. The results of these runs are given in figures 18, 19, 20, and 26. Since the tracking range depends on the background and target conditions, it was necessary to separate the data obtained in the air-borne operations into six general classifications of night and day flights for each of the three types of targets employed. The ranges obtained in ground operations were divided into two classifications, night and day, using an F-80 target.

(b) Test Data. - Data on the night tracking ranges obtained in the air-borne operations are presented graphically in figure 18, in which the PB4Y-target range and single- and double-target F-80 ranges are treated together. This graph presents the range data obtained on each operation, together with an average curve for the data obtained on each flight-test day; a total of 27 single-jet target runs extending over 10 flight operations are represented.

Fifty-two runs were made to obtain the ranges presented in figure 18; results from many of the runs had to be discarded, since equipment failure and instrumentation trouble, such as radar losing track, targets running low on fuel, etc., would have resulted in misrepresentative data. However, the tracking ranges included a composite representation typifying the range variation under conditions of changing target aspect, jet performance, atmospheric humidity conditions, etc., and have not been subjected to any selection with regard to maximum range under ideal conditions. In fact, not all the tracking ranges presented are obtained on range performance tests alone; the results of runs made for other test purposes are also included, if these runs were not broken off prematurely. All the tracking-range data were obtained from various regions of the tail aspect of the target aircraft.

During the first part of August, equipment facilities were made available at NAMTC for more exact testing and classifying of the lead sulfide cells. The tests permitted the determination of the relative sensitivities of the cells and the selection of proper voltage and load resistance for optimum performance of each type of cell. Improvement in the tracking range after 13 August was shown by the increase in maximum ranges, which resulted from this investigation; the values can be accepted as typical of the AN/DAN-3(XN-1) range performance and are so used throughout this report.

The tracking-range data, shown in figure 18, pertaining to a dual target were obtained as a result of investigations on target resolution. Also indicated in this figure are the tracking ranges of the PB4Y multi-engine target airplanes which were flown under normal cruise conditions. All the PB4Y ranges are those taken from the tail aspect; it was found that there were greater variations in tracking ranges with small changes in aspect of such an aircraft than existed in jet aircraft.

Figure 19 presents a summary of all the night ground-to-air tracking ranges resulting from the ground-test setup described in Paragraph 7-c. In this figure, all ranges from each operation are shown, together with the average curve. The original purpose of these ground tests was to correlate the tracking ranges with the air-borne tests so that a control would be established by which large variations in air-borne ranges could be detected. A great improvement in maximum tracking ranges was noted from these tests by mid-August, when AN/DAN-3(XN-1) improvements were made. The ranges obtained from night ground-to-air tests were usually smaller than the night air-borne ranges, as expected.

An idea of the consistent range performance of the AN/DAN-3(XN-1) can be gained from the number of runs on each date presented on these graphs. The fuel capacity of jet targets was limited and, hence, the number of possible runs which could be made in a single operation. Approximately 6 to 8 runs might be expected from a single target on a night operation, depending on the performance of the pilot and other factors. It will be seen that usually the number of points of data plotted (the sum of points on both graphs) is equal to the total number of runs made during each flight, indicating that all of these runs were successful in the achievement of lock-on and tracking to the ultimate range.

In figure 20, daytime tracking ranges obtained in flight for single F-80 targets are presented. Decreased positive contrast and the presence of background noise reduced the daytime ranges. These daytime ranges, however, were increased by the judicious selection of optical filters, based on results of spectral measurements of target and background radiations.

The general spectral character of the target radiation is shown in figure 21. The larger part of the effective radiation incident on the lead sulfide cell is within 1.9- to 2.5-micron wavelength range. The spectral character of the interfering sky radiation is shown in figure 22. Four pronounced energy peaks lie between the 1.0- and 2.5-micron region, but from 75 to 90% of this radiation may be eliminated by using a filter, which cuts off the radiation below 1.9-micron wavelengths. A filter with transmission characteristics such as that of germanium crystal illustrated in figure 23 accomplishes this cutoff; filters of this type only became available near the conclusion of the flight-test program. More efficient filters are also possible, but they were unavailable before the conclusion of the program. The daytime tracking range depends considerably on the portion of the sky in which the observation is made, since the magnitude of the interfering background radiation varies throughout the sky, as illustrated in figures 24 and 25. The tracking-range increase obtained in flight operations was not as great as in ground operations, since the parent airplane always tracked the target in an attitude directed to or near the horizontal where the steep horizon gradient resulting from haze and smog was most severe. Moreover, air-to-air operations ceased before the best filter results were obtained.

A graph of ranges obtained in daytime ground-to-air tests is shown in figure 26. The graph is divided into two portions, showing tracking ranges peculiar to two filter arrangements, the Polaroid C2 and 4010 combination and the germanium filter. Until spectral measurements were made and germanium filters obtained, the Polaroid C2 and 4010 combination appeared better than all other combinations, as noted from results of practical tests. This graph also shows an increase in range as a result of improvements made on AN/DAN-3(XN-1) in mid-August. An average daytime tracking range before the improvements were made was about 1.25 miles; following the modification of the unit, this range was increased to approximately 2.75 miles. When the germanium filters became available, the range was further increased to approximately 3.5 miles.

It must be remembered that the range values given above are averages obtained with various sky-background conditions. In conducting both ground-to-air and air-to-air daytime operations, the tracking ranges were obtained in that half of the sky which was away from the sun. The target was usually acquired in a section of the sky where the interfering radiation was too low to permit a clear identification of the lock-on signal, but the target was tracked in the sections of the sky where the interfering radiation was of greater magnitude. Accordingly, the ranges were not true maxima but represented many conditions of sky background over the section of the sky mentioned. Cloudy sky backgrounds were not included in these daytime ground-to-air tests.

(3) ERROR SIGNAL VS TRACKING RANGE. - Better understanding of the tracking performance of the AN/DAN-3(XN-1) at all ranges is gained through a knowledge of the magnitude of the error-signal voltage at all target ranges and aspects. In order to determine these voltages the ground-test configuration previously described was modified so that the error-signal voltage could be recorded and radar tracking and plotting of the target position could be utilized. Values of the error signal vs tracking range were obtained under all daytime and nighttime conditions, at 70, 40, and 20' mirror-tilt angles, and with and without filters. The primary purpose of these tests was to compare the effects of changes in test configurations under similar conditions, with simultaneous recording of the cell signal at various tracking ranges.

Two average cell-signal voltages vs tracking-range curves plotted from the data obtained during night operations using a 20 and 40' mirror tilt are shown in figure 27; in this case, the 40' mirror arrangement yielded a maximum range of 7 miles. The large difference in ranges between the two configurations was probably due to the performance of the particular detector or the AN/DAN-3(XN-1) unit used at the time. A true comparison could only be obtained by changing the mirror tilt in the same unit. In figure 28, Curve No. 1 is a comparable graph of a daytime tracking range obtained by using the same 40' mirror tilt and a germanium filter. The signal level shown in the graph is lower than that obtained at night, as expected.

The remaining group of curves of daytime signal vs tracking range characteristics of several AN/DAN-3(XN-1) configurations illustrated in figure 28 are, with the exception of one, the average of a number of curves of representative conditions. Curve No. 2, a plot of signal using no filter, is the only exception; this curve averages higher than all other curves except No. 4 and probably would have been higher than the latter, had background conditions not varied from day to day and hour to hour. It will be noted that the daytime tracking range without filter is very short. The validity of some points on the lower portion of Curve No. 2 is somewhat doubtful. The other curves are generally representative, since they are averages of a number of runs under similar conditions within which any deviation from the average is not large. It will be noted that the germanium filter, because of the decreased radiation attenuation, produces higher signal levels than does the Polaroid C2 and 4010 filter combination.

Using the test setup described in Paragraph 77c, a PB4Y-2 target was set up on the ground at night in order to determine the signal vs tracking range relation, the resolution, and jitter effects. The results of these tests, comprising the signals at short ranges and at various aspects, are shown in figure 29.

If the signal level vs tracking range relation were plotted on log-log graph paper, it would be expected that, since the signal level is proportional to the total radiation energy, the signal would vary inversely as the square of the range and that the curve thus obtained would have a slope of -2 at ranges beyond which the major effects of absorption are experienced. Actual data do not conform to these curves, since these curves are drawn for the tracking-error signal. As previously explained, the target image is centered between the lobes of the reception beam pattern at short ranges, but as the signal intensity decreases the image moves toward the lobe peak, thus effectively increasing the sensitivity of the AN/DAN-3(XN-1).

It is anticipated that the inverse square law would apply at intermediate ranges beyond which the principal effect of the absorption has occurred; this law also applies to shorter ranges than the range at which the images ride up on the lobe of the scan pattern. The curve shown in figure 30 substantiates these views for the range between 0.1 and 1 mile. The data from which the curves are plotted were gathered from a ground operation in the tracking of a jet target under conditions specified in figure 30.

(4) TARGET SIGNAL VS ASPECT ANGLES. - As described in Appendix C, to determine the variation of intensity with respect to viewing aspect, the radiation from various targets was measured on the ground. The maximum effective tracking range of an AN/DAN-3(XN-1) type of homing set was found to be a function of the aspect angle presented by the target largely because of the variation in the projected area of the target.

To verify the maximum tracking range at any particular aspect angle was difficult, since a target airplane could not be flown in such a manner as to present the desired aspect continuously. The technique used in air-borne tests of maximum aspect ranges involved predetermined flight paths of the jet targets; these targets started in the normal, straight path and, at a suitable range, altered this course rapidly to present the desired aspect of the jet. This method was unsatisfactory, since it was difficult to control the path of two airplanes at the desired ranges. Tests of aspect signals were far more satisfactory in the ground-to-air operations, since the ground radar plotted the target course concurrently with the AN/DAN-3(XN-1) tracking. The data on various ranges and aspects obtained from these tests were reduced and graphs plotted; a typical curve of the target signal vs tracking range is shown in figure 31. The aspect angles are indicated at the various plotted points.

Utilizing the expected variation of range with target-aspect angle, a group of curves of maximum ranges vs target-aspect angles was plotted. Each curve of this group represents a signal level which could be expected at the corresponding range and aspect for some particular value of the target-radiation intensity, tailpipe temperature, or the AN/DAN-3(XN-1) performance. The actual data of range vs aspect were then applied to these curves as shown in figure 32. Although there is some dispersion of points about the expected curves, the results are generally in agreement with theoretical computations. Using a 600-microvolt signal as a basis, the group of equal expected signals was appropriately valued; it was then possible to predict from the curve an approximate maximum range corresponding to each aspect angle.

(5) SEARCH AND ACQUISITION CHARACTERISTICS OF AN/DAN-3(XN-1).

(a) Description of Tests. - The test setups used for verifying search and acquisition characteristics were already described under Paragraph 7-a. For determining the search characteristics of the AN/DAN-3(XN-1), the target plane was flown ahead of the parent plane at a fixed range, and the automatic search mechanism was operated with the acquisition amplifier gain set at a predetermined level. The AN/DAN-3(XN-1) was then permitted to search until an automatic lock-on was achieved. In the initial orientation stages some difficulty was encountered in predicting the desirable acquisition signal level. In addition, there existed some regions of the field which were not scanned; thus it was necessary to repeat the scan until lock-on was achieved.

(b) Test Data. - For the reasons stated above, the determination of the maximum search and acquisition range was difficult. However, it can be shown that a scale factor can be used to determine the maximum automatic search and acquisition range from the known maximum tracking range. This scale factor represents the ratio between the highest noise peaks, which affect the acquisition amplifier and the effective system noise.

The ability of the search and acquisition system to acquire the target under various operating conditions was verified. The maximum tracking range at which the signal was sufficiently strong to permit acquisition following manual search varied with atmospheric conditions, since the latter affected not only the attenuation of the signal from the target but the maximum gain setting of the AN/DAN-3(XN-1) which, in turn, was determined by the background radiation. Some of the values obtained are shown in Table 2.

Table 2. Examples of Acquisition Ranges Obtained Under Various Atmospheric Conditions

Date	Operation No.	Relative Humidity %	Temperature °F	Tracking Range miles
8-13-51	9	34	39.7	3-1/4
8-14-51	35	51	7.9	7+
8-14-51	35	51	7.9	4
8-30-51	70	16	9.8	6-1/2*
9-4-51	10	12	18.5	5+*
9-4-51	10	12	18.5	5-1/4*

*Two adjacent targets.

The tracking ranges are necessarily approximate, since most of them are in excess of the operating range of the radar for this type of target.

(6) MINIMUM TRACKING-RANGE CHARACTERISTICS. - The minimum tracking-range characteristics that were investigated are jitter, the effects of saturation signals on the detector cell, and the ability of the AN/DAN-3(XN-1) to track at close range. Jitter is considered as a rapid and erratic change of tracking-gyro axis with respect to the AN/DAN-3(XN-1) or missile centerline; its existence will decrease the effectiveness of the guidance system. The problem of jitter is treated in detail in Paragraph 9-b(2)(c).

The ability of the AN/DAN-3(XN-1) to track an F-80 target at a short range was established both in the air and on the ground, and the minimum tracking range was only limited by safety considerations. The minimum tracking range in the air was, at times, less than 100 feet; figure 33 is a reproduction of the Brush oscillograph recordings of such a flight. The only position fluctuations shown on the recordings are due to the relative shifts of the target and the parent airplane.

The procedure used with the equipment for simulated flight tests was a much better method for checking jitter and the tracking ability of the unit at a short range, since one random motion, that of the target airplane, was eliminated, and another, the motion of the AN/DAN-3(XN-1), was minimized. A reproduction of the Brush oscillograph recordings made by the use of this configuration is shown in figure 34. The data show no jitter at ranges down to 120 feet when viewing the jet target from astern and 30 feet for a 90° aspect; these ranges are limited by safety considerations.

A graph showing averages of data on cell signals vs tracking ranges gathered from the different ground tests conducted at night is presented in figure 35. Tail- and side-aspect runs were included in these tests, during which no filters were used but various mirror-tilt angles and cell sizes were employed.

Since the quantity of radiant energy received by the detector cell is dependent on the distance from the radiation source, a saturation signal could be expected at some short range. Such a signal having a saturation level of 8 millivolts was obtained from a jet target with a tail-pipe temperature of 500°C at a range of 350 yards. Saturation effect is of no consequence to tracking accuracy.

With relation to the tracking rate, however, the saturation effect is most important. At extended ranges, where tracking rates are necessarily low, the cell signal has likewise low amplitude. At shorter ranges, where the tracking rates must be increased if the infrared homing set is to remain locked on the target, the cell signal will increase so that increased tracking rates are possible. Although a saturated cell signal prevents any further increase in the tracking rate, the maximum rate attained below the saturation point should be sufficient for any presently considered tactical use of the AN/DAN-3(XN-1).

b. TARGET-TRACKING CHARACTERISTICS OF AN/DAN-3(XN-1).

(1) GENERAL DISCUSSION.

(a) Functions of a Homing Head. - The basic functions of a homing head are to track and indicate continuously, in two co-ordinates, the angular difference between the missile centerline and the missile-to-target sightline. This angular difference will be referred to as the heading error.

(b) Significant Characteristics of AN/DAN-3(XN-1). - Among the performance factors which determine the workability of the AN/DAN-3(XN-1) are the tracking characteristics, resolution, response to multiple-target situations, tracking accuracy, angle noise, and general ability of the tracking head to remain locked-on during evasion action.

The tracking characteristics were investigated for two distinct types of targets and the results compared with the performance data from the laboratory investigations. Owing to instrumentation restrictions and an insufficient number of runs, extraneous errors could not be minimized, and insufficient quantitative results were recorded. Thus, the majority of the results were qualitative and were substantiated, where possible, by quantitative data.

Instrumentation difficulties primarily consisted of determining the target position with sufficient accuracy independent of the AN/DAN-3(XN-1). The only available means that could be considered sufficiently accurate were the recordings from the nose cameras, but these were restricted in range and could not be used at night. Correlation of the films from various cameras could not be made with any certainty. Some position data could be obtained with the radar camera, but its accuracy was restricted to approximately ±1.5° at the desired ranges. As a result, even the parent-aircraft maneuvers could not be eliminated entirely from the data recorded.

These difficulties in part were due to the lack of necessary instrumentation equipment and in part to limited time schedules, which excluded the possibility of developing suitable apparatus and methods. Although the results were not primarily quantitative, the recorded data for the AN/DAN-3(XN-1) did prove that its performance is satisfactory within the limits of instrumentation, and established significant orders of magnitude to substantiate the laboratory and analytical results.

(c) Importance of Target Characteristics. - Although a knowledge of target radiation characteristics is important, to determine them completely for all classes of targets was beyond the scope of this program. However, two classes of targets, the single-jet engine and multi-engine reciprocating types, were selected as representative. The radiation characteristics of such targets were determined, and then these targets were used throughout the performance tests; the target characteristics are given in Appendix C.

(2) TEST RESULTS.

(a) Angular Resolution. - Angular resolution is defined as the angle between two targets at which one target has primary control over the tracking system. The target sightline may be perturbed by the presence of a second target, but the latter will not be followed as it moves away from the field of view. Although this factor has no significance when dealing with a single-engine target, the image of which is small with respect to the cell, it is important when dealing with large or multi-engine targets or multiple single-engine targets.

1. Discussion. - Resolution will depend on whether a target is entering or leaving the field of view, the target angular rates, the instantaneous field of view, and the separation of the lobes in the scan pattern. If a single target is being tracked at the center of the symmetrical scan pattern, the resolution angle cannot be greater than one half the total scan field, since an approaching target must occur within this angle in order to be seen in the field of view. If, however, the angular separation of the two targets is initially zero, the resolution angle can be no greater than the peak-to-peak separation of the scan field. The exact angle of resolution for any two targets and the amount of perturbation of the sightline then depend on the intensity of the targets and the shape of the scan field.

The exact angle of resolution and the response of the homing head during this interval can be determined analytically for known target configurations and shapes of scanning patterns.

2. Multiple Targets.

a. Expected Results. - In general, if two F-80 targets flying close together subtend an angular distance much smaller than the effective cell angular view, they will appear as one target. If they separate at equal angular rates, the AN/DAN-3(XN-1) will point to the weighted heat centroid of this combination. For sources of equal intensity and size, this centroid will be the geometrical center of the thermal configuration of the source. As the separation angle increases, the AN/DAN-3(XN-1) will follow the centroid as weighted by the scan pattern until, in the case of equal intensity targets, both targets are located on the peaks of the scan pattern. When separation increases beyond this point, the AN/DAN-3(XN-1) will follow the more intense target or, if the target intensities are equal, the target with the least angular rate of motion relative to the spin axis of the tracking gyro. The shift from the centroid to a single target will be gradual, resulting in final centering on the target selected when the second target is completely removed from the field of view.

For multi-engine targets the same general results can be expected. However, depending on the engine configuration, changing target aspect could conceivably cause random transient shifts, although this possibility appears to be small.

b. Laboratory Tests. - Simulated tests were made in order to determine the response to two individual targets. The general results are summarized as follows:

When the system is unperturbed by other targets and is tracking a point target, the tracking head is directed within 0.1° of the point source. If a target is being tracked and a second target enters the field of view, the tracking head is perturbed, depending on the intensity, rate of motion, and the path across the field of view of the interfering target.

The laboratory experiments indicated that the system is unaffected by a second point-target until such a target is within an angle of 110' of the initial target for a 70' mirror. For targets of equal intensity, the second target must approach within an angle of 90' before it can dominate the tracking control. The maximum angle for perturbation would then be 45'. These values were smaller for smaller scanning mirror-tilt angles.

When two point targets of equal intensity were separated, resolution initially occurred at a separation angle of 90'. The perturbing effect of the second target diminished to zero at a maximum separation angle of 150'.

c. Flight Tests. - In order to verify these results against those of actual targets under flight conditions, air-to-air and ground-to-ground tests were made using PB4Y-2 and F-80 targets.

(1) F-80 Jet-Engine Targets. - The air-to-air tests using two single-engine jet targets were not completely conclusive. The exact angle of resolution between the two distinct targets could not be determined because of the limitation of the instrument accuracy, as explained in a previous section. However, these limited tests did indicate the validity of the analytical and laboratory test results. Four flights consisting of 30 runs were made. Four general types of maneuvers were performed in an attempt to cover all possible situations. These maneuvers were as follows:

(a) Both targets at equal tailpipe temperatures, aircraft flying wing-to-wing, wing aircraft separating gradually.

(b) Lead plane with high tailpipe temperature, wing-to-wing, with wing aircraft separating gradually.

(c) Lead plane with lower tailpipe temperature, wing-to-wing, with wing plane separating gradually.

(d) Lead plane being tracked, wing plane cutting diagonally and crossing the sightline between parent aircraft and the initial target.

Two mirror-tilt angles, 70 and 40', were used. Typical results are shown in figures 36 through 38. Figure 36 is a plot of the results of the crossover flight pattern; the upper curve shows the target positions relative to the P2V-2N, as indicated by the AN/DAN-3(XN-1). The lower curve shows the relative target positions as indicated by the radar. Low-frequency variation of the path of the target being tracked indicates the relative lateral motion of the parent aircraft. The targets could not be photographed with the boresighted cameras, and no adequate means of eliminating motion of the parent plane was available. The inaccuracy of the radar, of course, precluded the use of radar photographs for this purpose. It will be noted from the figures that the AN/DAN-3(XN-1) has begun to track the centroid, during the tests, after the wing aircraft had crossed the line of sight but then it has returned immediately to the aircraft tracked. The amplitude of the angular perturbation of the AN/DAN-3(XN-1) on separation of the two targets is physically impossible and is attributed to a variation of the parent-aircraft path which could not be determined.

Figure 37 shows typical results of two targets of equal tailpipe temperatures, the targets separating slowly. The low-frequency and small-amplitude variation of the relative target path indicated by the AN/DAN-3(XN-1) is probably caused by variations of the parent-aircraft aspect. It may appear that the position indicated by the homing set at Frame No. 51 might show a deviation from the initial target position. However, since this angle is only approximately one third of the indicated radar separation, this explanation does not appear plausible. This divergence appears to be a part of the deviation caused by variation in the parent-aircraft aspect. However, possible existence of a small deflection cannot be excluded. Nevertheless, the actual response to this situation verifies the prediction that perturbations which may exist are extremely small.

Figure 38 shows results from maneuvers of two airplanes separating, with different tailpipe temperatures. From this figure, it cannot be determined whether the AN/DAN-3(XN-1) indication at Frame No. 87 is caused by a shift in the centroid or is merely due to the parent-aircraft maneuver. However, as in the preceding case, these data do show that any deviation which occurs must be extremely small.

In an attempt to determine the angle of separation to a closer degree, estimates were obtained from the pilots on the target separation distance as a function of time. Independent estimates by two pilots agreed within 50 feet. An additional source of possible error was due to the time difference in recording the estimated distances. However, the results were significant in verifying the orders of magnitude. The test results are given in Table 3.

Table 3. Tracking Range with Respect to Average Target Separation

Range miles	Average Separation ft	AN/DAN-3(XN-1) Sightline
1.75	100	Tracking centroid
1.25	200	Tracking centroid
1.25	300	Lock on one target with no perturbation

The accuracy of the test results given in Table 3 is probably not better than approximately one-half degree. The AN/DAN-3(XN-1) averaged, or followed directly, the centroid to a separation angle of somewhat less than 1.5° and completely locked on one target at an angle of approximately 2.2°. The resolution angle is then in the range between 1.5° and 2.2°. Since these values correspond reasonably well with the computed and laboratory results, they are acceptable. The tests were made using a 40' mirror angle; it is evident that the resolution angle can be reduced considerably by reducing the mirror angle and the field of view.

In order to determine the response of the AN/DAN-3(XN-1), the recorded servo outputs for all the runs were analyzed in considerable detail. In general, no sudden shift was indicated when the AN/DAN-3(XN-1) actually resolved two targets. On two runs out of a total of 30, a few random shifts between targets were noted. It appeared from the data, however, that the shifts were probably caused by the variation of the separation between the two targets, particularly since such shifts were not periodic. Such a condition is not expected to exist in normal tactical situations where the separation angle is essentially fixed and resolution occurs by an extremely rapid change in the range of the missile carrying the homing head.

Several AN/DAN-3(XN-1) units were used during the test, and in some runs a low-frequency oscillation and an increase in servo noise were apparent. After further analysis of the data, it was found that these conditions existed for one AN/DAN-3(XN-1) only, and that they varied in an erratic manner throughout the runs. Using the other two AN/DAN-3(XN-1) units, the results were consistent and showed normal response without jitter or oscillation throughout the region of resolution.

(2) PB4Y-2 Multi-engine Targets. - Fourteen test runs were made during two flights, using two AN/DAN-3(XN-1) units. These runs were made at ranges from 1/4 to 1 mile. The target aspects were

not restricted to the tail of the PB4Y-2 but were varied to the limits of 15° possible in flight. Six test runs were made with the first AN/DAN-3(XN-1), and on all six runs the recorded position outputs of this unit were very similar. No hunting or increase in noise was present. The oscillograph traces were quite smooth and showed no sudden shift in position. It was not possible to determine the exact target center or the point of resolution, since the flights were at night, and no boresighted camera data were available. During one run, an initial acquisition transient of an oscillatory nature was noted at a range of 3/4 mile, but this transient disappeared within several seconds. The cause of this transient was not known, but it was similar to the response which could have occurred during acquisition, if the operating speed were below the normal operating range.

On eight runs, using a second AN/DAN-3(XN-1), erratic and indeterminate results were obtained. This response was found to be a malfunction characteristic rather than a proper operation characteristic. During testing of this unit, it was found that the tracking-gyro bearing was faulty. With this faulty bearing, the unit displayed the same general characteristics as when operating against a single target in laboratory tests.

The character of the response to such a target was determined by the flight tests, but detailed knowledge of the effective target center and the resolution capability of the system was not established. In order to obtain these data, static ground tests were performed; the nature of the tests and procedures were discussed in an earlier section.

d. Ground Tests.

(1) F-80 Jet-Engine Target. - Ground tests were made to determine the effective target center of the F-80. Test results on closing ranges from target aspects varying within 90° from the tail indicated that the AN/DAN-3(XN-1) always tracked the tailpipe.

(2) PB4Y-2 Targets. - Two different scanning patterns (i.e., mirror-tilt angles) were used during these runs and the resolution was determined for each run. The angular position of the tracking head was plotted as a function of the tracking range. The positions of the PB4Y-2 engines and the peak sensitivities of the scan cone were also plotted. The results are shown in figures 39 and 40. The 70' tilt angle resulted in a scan-cone angle of 90' between sensitivity peaks. Three runs were made with this setup. The result of each run showed an indicated random variation of left-right heading of approximately 1° at a minimum period of about 6 seconds, during which time the truck, on which the AN/DAN-3(XN-1) was mounted, advanced approximately 80 feet along a line toward the target. It was reasonably certain that the variation in heading was due to the course taken by the truck.

To confirm that the erratic course of the truck was the cause of the variation of heading, similar runs were made with the tracking loop open. Any change in the position output would then be caused by a slow gyro drift or by variations of truck heading. All results showed the same variation in heading, indicating that the AN/DAN-3(XN-1) field of view was not wandering about the target. As final proof, the vertical indications showed no change except at one region of the runway where a depression in the ground existed.

At a range of approximately 90 feet the truck was stopped, and the heading error was reduced to zero by rotating the AN/DAN-3(XN-1) housing. A flashlight aligned with the AN/DAN-3(XN-1) centerline was used to determine the exact target center.

The average of three runs, using the 70' mirror angle, is plotted in figure 39. The plots of all three runs show that the AN/DAN-3(XN-1) selected the starboard side of the extreme starboard engine, although no difference in the operating characteristics between the engines could be noted. This target point was an exhaust stack which apparently was at a higher temperature than those of other targets. This stack can be seen in figure 8. To a range of 0.30 mile all four of the reciprocating engines appeared as one to the AN/DAN-3(XN-1). At 0.21 mile range, the starboard engines were resolved from the port engines and the AN/DAN-3(XN-1) began to shift to the starboard engines. At a range of approximately 0.16 mile, the port engines were completely out of the field of view of the AN/DAN-3(XN-1) and the unit tracked the centroid of the starboard engines, resolving the inboard engine at 0.10 mile and excluding it completely at about 0.07 mile. The angular separation of the starboard engines at this range was approximately 1.6°.

The laboratory tests indicated that when the angular separation between two targets was such that the targets would occur within a cone angle of slightly less than 90' for a 70' mirror and 50' for a 40' mirror, the AN/DAN-3(XN-1) tracked the heat centroid as weighted by the detecting element. The tests further indicated that at target separations greater than 2.5°, with 70' mirror tilt, and 1.5° with 40' mirror tilt, the AN/DAN-3(XN-1) would track only one target. From the data of the air-borne operations, the separation at which the AN/DAN-3(XN-1) locked on one target exclusively was 2.2°. Since the distances between the two target airplanes were determined by visual estimates only, this could account for the flight test results differing somewhat from the laboratory test results.

Figure 40 shows the results of tests using a 40' mirror angle. The range at which the AN/DAN-3(XN-1) began to deviate from the centroid of all the four engines of the PB4Y-2 was not clearly defined. Resolution of the starboard engines from the port engines appeared to occur at a range of 0.33 mile. At a range of 0.26 mile the port engines were out of the field of view, and the AN/DAN-3(XN-1) tracked the centroid of the starboard engines; the starboard engines were separated by approximately 1° at 0.20 mile range when the outboard engine began to dominate. At 0.16 mile the unit centered on the outboard engine. All the other engines were out of the field completely.

e. Summary of Results. - Generally, the expected results were obtained in laboratory tests and verified by flight and ground tests conducted under this program.

The angular resolution was determined most often using a 40' mirror-tilt angle in the AN/DAN-3(XN-1), since it was believed that this configuration would be most desirable because the longer ranges are obtained more precisely with the 40' mirror-tilt rather than the 70' angle, and that such information would be more appropriate.

Tests using reciprocating-engine type targets (PB4Y-2) indicated only slight shifts of the effective target center at various ranges between 1/4 and 1 mile. Although the flight tests indicated the character of response that could be expected, it was decided that more specific information could be obtained from ground tests.

There were no measurements made of temperatures at the exhaust stacks, although cylinder head temperatures were within 10°C of each other at approximately 205°C. Consequently, the cooling effects of the wind were not obtained.

The reason for the shift of the AN/DAN-3(XN-1) tracking from the four-engine centroid to the two-engine centroid and finally to the starboard outboard-engine is evident from figure 40. The AN/DAN-3(XN-1) was displaced slightly to the right from being dead astern to the PB4Y-2 so that the port-engine exhaust stacks would be removed from the field of view first. The outboard-engine exhaust stack on the starboard side was at such an aspect that a larger area was presented to the infrared homing set and, consequently, weighted heavier by the detector cell, accounting for the final shift to the one target. The 70' mirror-tilt angle data appearing in figure 39 give evidence of characteristics similar to those shown in figure 40.

In general the flight and ground tests verified the laboratory investigations which, in turn, substantiated the expected results.

(b) Tracking Accuracy.

1. General. - In a tracking head, the accuracy is dependent on the signal strength, angular crossing rate of the target, scan rate, and noise. The effects of these parameters on gyro-position accuracy are fully covered in Reference a, Paragraph 5.

Additional factors, such as refraction by the atmosphere, shock waves, or aerodynamic windows, may also cause errors. These effects will not be considered at this time, since the subject is beyond the scope of this report.

2. Results on Tracking Accuracy. - The only reliable means of determining the over-all error of the indicated sightline, as well as its relationship to various physical variables, is to compare continuously the indicated sightline with the known target positions, or at close intervals, with the target moving at various angular rates relative to the AN/DAN-3(XN-1).

During the flight tests, the true direction of the sightline relative to the attitude of the P2V-2N parent plane could be obtained from two sources, the nose cameras and the radar. The nose cameras gave an exact indication of the heading error, and the photographic films could be read to a fraction of one degree in both azimuth and elevation. Unfortunately, there was no satisfactory system for positive correlation of the films from these cameras with other instrument records, so that in the few instances where a target did appear in the developed film it contributed no information. The position information obtained by radar did not have the accuracy required.

The method of checking the tracking accuracy consisted of comparing the relative direction of the sightline, as indicated by both the radar and the AN/DAN-3(XN-1), at each indicated point during the run.

The relative direction of the sightline indicated by the radar was obtained directly in azimuth by projecting the photographic film image on a polar plot paper. Although the radar scope was equipped with a lubber mark, indicating the P2V-2N centerline, this was not sufficiently visible on the film to be usable. Therefore, it was necessary to project two successive frames simultaneously, using the line between the sector centers as the reference mark. The azimuthal displacement of the target from this line was then read directly in degrees and plotted against time, using the numbers on the frame counter as the abcissa reference.

The radar film was usable in over half of the flights. However, it was impossible to read the radar film with sufficient preciseness to establish positively the accuracy of the AN/DAN-3(XN-1). The target spot on the PPI scope was of a constant size, so that as the range decreased the target occupied a larger angle; at 1 mile this angle was approximately 5°. Since the edges of this spot were not clearly defined, it was difficult to locate its center with any reasonable precision.

Synchronizing pulses on another channel of the recorder permitted the determination of the time at which the cameras were tripped; thus, the indicated gyro position could be obtained for each radar camera frame. These positions were read in millimeters of displacement of the recorder-pen trace. It was necessary to convert the displacements into the value of the voltage fed to the d-c amplifier. The actual gyro displacement in degrees was obtained from this voltage value, in conjunction with a servo-calibration chart of the AN/DAN-3(XN-1). The servo of the AN/DAN-3(XN-1) was calibrated each time the unit was in the laboratory, prior to its return to NAMTC.

The indicated gyro positions, in azimuth only, were then plotted simultaneously with the radar plots mentioned in the preceding paragraphs. Several examples of such graphs are shown in figures 41 and 42.

The difference between the two graphs was then plotted against a parallel time axis, to show the indicated error. In this graph, the indicated sightline obtained from the AN/DAN-3(XN-1) obviously was the more accurate of the two and was chosen to represent the reference direction.

The resulting indicated-error graphs showed maximum errors approximately as great as the known probable error in the instrumentation. Therefore, it was impossible to definitely establish the tracking accuracy of the AN/DAN-3(XN-1) from these tests. However, this accuracy was obtained from laboratory tests, where better instrumentation was available. The tests do indicate, however, an upper limit to a possible error as defined by the instrumentation error.

An additional source of error arose from the fact that the radar camera shutter was open for an entire scan during exposure of each frame. This period was approximately 1.5 seconds. The other three cameras were operated instantaneously at the start of each scan and, hence, this starting time reference was chosen as the point for reading the Brush traces indicating the gyro position. However, this could be in error by a maximum of 1.5-second time interval; during this time the P2V-2N could have changed attitude or the target could have moved. Observed changes in indicated heading error in an interval of three seconds were as great as 7°.

(c) Angle Noise, or Jitter.

1. General. - One of the most important factors affecting the performance of the tracking system is the presence of any false signals and their character. These signals are usually due to the fluctuations of the apparent sightline to the target, when in reality no sightline deviation exists. Such false signals, are defined as angle noise, or jitter.

Photographs of the oscillograph records of the servo-output voltages at various ranges are included in this report, since they best illustrate the presence or absence of angle noise, or jitter.

Although there were occasional indications of increased servo noise, these were found to be caused by faulty gyro bearings. The illustrative traces presented in this report show the normal output: These traces show no evidence of jitter. The recording system responds up to 100 cycles. It is not known if any jitter occurred at frequencies above 100 cps, but jitter at high frequency would not be expected to have any detrimental effect on missile operation.

The presence of jitter below 100 cps will decrease the effectiveness of the guidance system concerned. Therefore, the investigation of this problem is of particular importance in evaluating any guidance or tracking system.

2. Discussion of Expected Results. - The two main causes of jitter are (1) the instantaneous change of effective target center caused by a change in the relative target aspect, and (2) changes in the tracking-head position caused by a rapid fluctuation of target signal intensity, known as scintillation.

The significance of the problem of variation in effective target center resides in the distinction between an active and a passive system. In the case of the AN/DAN-3(XN-1), which is a passive system, this factor does not pose a problem. Since the target radiates the energy which actuates the AN/DAN-3(XN-1) and the sources of radiation are relatively small and unvarying, the basic cause for a shift in target sightline does not exist. The problem of effective target-center variation might exist in daylight operation if negative contrast is used or if reflected sunlight produces an appreciable portion of the total signal. Since the AN/DAN-3(XN-1) at present operates only on positive contrast, no shift in target center would be perceptible. Just to what extent the reflected sunlight will contribute to this effect is not known at the present time. Under nighttime conditions, no shift in effective center would be expected.

In a system such as the AN/DAN-3(XN-1), the signal source covers only a very small area if the target is the tailpipe of a typical, single-engine jet plane. Therefore, fluctuations in intensity can cause no apparent motion of the target. The finer resolution possible with this type of device, compared with a radar, can minimize such effects from multi-engine planes by resolving these engines at a considerable range. The jitter in the AN/DAN-3(XN-1) is considered as an increase in basic servo-output noise.

Figure 33 illustrates a tracing of the servo-output condition at short range, and figure 43 at intermediate and long ranges.

Those causes which are considered inherent to the system are, in turn, divided into three groups: those that have the greatest effect at short, intermediate, and long ranges.

a. Short Range. - At ranges which give an image diameter equal to or greater than the cell diameter, jitter may occur because there is not a small null position. If the target is a TO-2 jet, this condition may occur at a range of approximately 20 yards.

b. Intermediate Range. - At an intermediate range, which gives an image annulus of internal diameter greater than the cell diameter, but in which the signal is sufficiently strong to override any noise effects, small gyro motion is possible before error is detected.

c. Long Range. - This is the range at which the noise signal is of the same order of magnitude as the signal and will vary with background and humidity conditions. This situation may give rise to the motion of the gyro which will normally be quite random but extremely small.

In investigating any jitter effects, the region of importance is at relatively short ranges.

Scintillation has already been defined as a rapid fluctuation of the intensity of target radiation at the homing head. It may arise from true fluctuations of the target-radiation intensity, as by pulsation of hot exhaust gases and variation of effective target temperature, or by random reflections of sun rays. Since, in most targets, the primary sources of radiation are metallic parts, the thermal time constant would be large, and any significant fluctuation of radiation intensity would be slow. Signal variation caused by the reflection of sunlight could conceivably be of a rapid nature.

Scintillation might also arise from density variations in the transmitting media produced by convection currents. These fluctuations could in general be most extreme at low altitude, decreasing with increase in altitude.

3. Air-borne Tests. - Throughout the air-borne tests, runs were made at very short ranges which, at times, were less than 100 feet. The servo-output noise levels were then compared with the output at long ranges and also when the target was lost. No increase or change in this noise level was noted. Although the noise spectrum could not be obtained in flight, the recorded trace of the Brush oscillograph would indicate any increase in the noise content. As in all other tests, it was not possible to exclude low-frequency variations caused by changes in parent-aircraft aspect.

The procedure used with the flight-simulator test setup was a much better method for checking jitter, since one motion, that of the target airplane, was eliminated, and another, the motion of the AN/DAN-3(XN-1), was minimized. Therefore, any recorded motion of the gyro position could be attributed to jitter with no regard to the relative motions of the target and the AN/DAN-3(XN-1).

These tests were made with F-80 and PB4Y-2 targets. A reproduction of the oscillograph recordings made by the use of this configuration appears in figure 34. The data show complete absence of jitter at ranges down to 120 feet, with the jet target viewed astern and 90 feet for a 90° aspect. As previously explained, these were the closest ranges possible.

4. Summary of Results. - It was stated that any jitter which occurred at frequencies above 100 cps which could not be recorded with the Brush recorder would have no adverse effect on missile operation. Therefore, the investigation of the AN/DAN-3(XN-1) jitter was limited to that existing below 100 cps, with particular reference to low-frequency variations and short-range operations.

Jitter of this character was best investigated in the ground tests using the flight-simulator test setup, since one haphazard motion, that of the target, was eliminated. Complete absence of jitter was recorded at ranges down to 120 feet at a tail aspect, and to 90 feet at a 90° aspect.

The absence of jitter at these minimum ranges of which tests were conducted is indicative of the noteworthy operating characteristic of the AN/DAN-3(XN-1).

(d) Tracking Ability. - The tracking ability cannot be discussed quantitatively, since it is integrally related to all the tests previously mentioned. For the purpose of this discussion, tracking ability will be defined as the ability of the AN/DAN-3(XN-1) to remain locked on a selected target under all conditions and to indicate any conditions under which the unit will lose target. The following conditions were imposed to determine these characteristics:

1. Aspect change
2. Multiple-source targets
3. Multiple targets
4. Extremely short-range tracking
5. Parent-aircraft oscillation and maneuver
6. Target maneuver
7. Target evasive action
8. High angular rates of motion

9. Background effects

   a. Clouds

   b. Horizon

   c. Clear sky

10. Jamming sources, or false targets in addition to the above conditions

11. Simulated tactical runs

(e) Results. - In 32 flights consisting of 188 runs and many ground-to-air operations no loss of tracking was found except that due to the following causes:

1. Sightline exceeding orientation limits of gyro

2. Equipment failure

3. Reduction of signal below minimum tracking level, by increasing range or aspect

It was not possible to determine the effectiveness of jamming by the use of false targets or flares, because no suitable sources were available. No background sources were found at night which could disrupt tracking. Although the moon presents a legitimate target when filters are not used, operations were not affected by its presence or by reflections from clouds which existed during many runs.

Although the equipment was designed for night operation only, its use in daylight could be hindered by intense gradients such as cloud edges and the horizon. Even though these discontinuities existed within the tracking field of view of the AN/DAN-3(XN-1), they did not affect its ability to remain locked on the selected target. In relatively clear skies or hazy skies no loss of target occurred. The effect of such conditions was twofold: reduced contrast and, hence, signal level, and increased total noise level of the system, which reduced the maximum range.

The noise caused by sky backgrounds was roughly equivalent to the internal noise except in the very close proximity to the sun (see figure 44). With the exception of the above-mentioned regions, the loss of tracking did not occur, and the only effect was the previously mentioned reduction of maximum range. In a tracking condition without a target in the field of view, no motion occurred toward either the horizon or the sun unless these were within the field of view.

Attempts were made to determine the ability of the AN/DAN-3(XN-1) to remain locked on the targets crossing at high tracking rates. Target information obtained from the night flight of 13 September 1951 presented definite crossing rates at which targets could be tracked. Although the crossing rates were far below the tracking ability of the AN/DAN-3(XN-1), as measured in the laboratory, the target velocities necessarily limited these rates. Of the 11 runs of a jet plane crossing in front of the parent airplane, tracking rates varied from 2° 40' to 6° 20' per second. An additional feature of these particular tests was the fact that the maximum radiated signal from the target was not always apparent to the AN/DAN-3(XN-1), since the target aspects varied from 30 to 85° from a completely astern view. The crossing rates given in this report represent the rates of the target at the time it entered the cone of vision and tracking commenced.

In flight, the F-80 could not maneuver to a position where tracking could be evaded by changing attitude. No loss of tracking occurred because of multiple targets or multi-engine sources, even on the runs where one of the AN/DAN-3(XN-1) units was not operating normally. In flight, ranges estimated at 20 yards were flown with no loss of target even though the parent aircraft buffeted violently in the jet stream. Through all simulated maneuvers no loss of tracking occurred.

In the course of the night operation of 10 August 1951, flights were made over simulated guidance paths. In Run No. 4 of these flights, the AN/DAN-3(XN-1) was used to guide the pilot of the P2V-2N in a pursuit course. The jet-engine target airplane, with a tailpipe temperature of 575°C, maneuvered a course consisting of a 360° turn at a range of 1 mile from the parent plane. The maximum rate of turn was 1.5° per second. The pilot of the P2V-2N maintained a range of 1 mile from the target and followed it around in a circle with no difficulty, using the left-right and up-down crosspointer indicator for his guidance.

Run No. 8 of this operation included a pursuit course in which the target plane was flown at the discretion of the target-plane pilot. The parent airplane was flown in accordance with the direction indications from the crosspointer indicator, while the target plane veered sharply to the left and right and changed altitude. The pilot of the P2V-2N, an experienced night fighter-plane pilot, confirmed the fact that the AN/DAN-3(XN-1) provided sufficient guidance data to enable him to pursue the target. These flights indicated that an AN/DAN-3(XN-1) type equipment would be a valuable addition to the existing night fighter-plane radar sets, which do not perform very favorably in the ranges between 1 and 2.5 miles.

The night flight of 16 August gave further evidence of the AN/DAN-3(XN-1) tracking ability, since information from it was used to guide the parent airplane through a wide 180° turn in pursuit of the jet-target airplane. The starting range was 4 miles for this turn, and the parent airplane closed on to a range of 2 miles upon completion of the 180° turn. This maneuver was similar to an interception type of course taken by a missile during tracking of a target.

A simulated guidance run was made on a PB4Y-2 airplane, which was used as a target for the night operation of 7 September. The PB4Y-2 made continuous 15° bank turns and changed course 45° to the left and right at a range of 0.75 mile. The P2V-2N, guided by the servo-output signal information presented by the crosspointer indicator, was able to follow the target maneuvers with no difficulty.

With a change in either the course or the altitude of the target, varying angular aspects in both the horizontal and the vertical planes were presented which were checks on the ability of the homing set to track with a high, apparent change of radiation intensity. Angular rates of tracking were also tested simultaneously with target maneuvers and changes of source intensity. Because all the above-mentioned conditions, together with other conditions (included under various headings of this report), were imposed on the AN/DAN-3(XN-1) without loss of tracking, it is apparent that the tracking ability of the AN/DAN-3(XN-1) was confirmed.

SECTION D: CONCLUSIONS

9. CONCLUSIONS.

The following conclusions were drawn as a result of the flight-test program:

a. TRACKING-RANGE CHARACTERISTICS. - The sensitivity of the AN/DAN-3 (XN-1) may be explained qualitatively by stating that the unit is capable of tracking an F-80 target to an average maximum range of 8 nautical miles at night, and 3.5 miles in daytime. Both night and day ranges are dependent on angular aspect; long ranges are obtainable from the rear quadrant. Limiting ranges of 1 mile in the forward quadrant of the aircraft are possible. Average ranges obtained by means of the unit operating on the ground are approximately 20% less than those at 20,000 feet altitude.

The effect of various background conditions disturbing the system was investigated. It was found that it is possible to track a target at long ranges at night under extremes of humidity conditions; the only source of a spurious target was the radiation from the moon, but its radiation reflections did not interfere with the system operation. Tracking below the apparent system-noise limit was easily possible.

In daytime, background noise had little effect on tracking over any portion of a blue sky, with the exception of a cone of approximately 40° surrounding the sun. Within this cone, noise due to sky radiation would increase, thereby decreasing maximum range rapidly. Anticipated difficulty with horizon gradients and with clouds was experienced. Two effects of day backgrounds consisted of a decrease in contrast and the introduction of background noise. It was possible to increase target contrast by proper filtering.

Attenuation by ground haze is an additional problem which may be severe under certain circumstances. Reflected sunlight from the ground interfered with operation but no problem was encountered at night.

Measurements of the intensities of the radiations from various types of targets were made; this information, together with similar data on target backgrounds, was developed to the point where it is possible to predict fairly accurately the expected tracking ranges for various targets at given angular aspects and under different background conditions. Correlation of this information with known performance characteristics of the AN/DAN-3(XN-1) will permit engineering improvements.

b. TRACKING CHARACTERISTICS. - The ability of the AN/DAN-3(XN-1) to acquire a target, to remain locked on this target, and to track it to its extreme range was verified by laboratory tests and proved over a total of 80 flight operations. The suitability of the AN/DAN-3(XN-1) as a homing device, capable of tracking a jet engine type of aircraft or a reciprocating-engine type plane was indicated; there is definite possibility of extending this tracking range on both types of targets. In general, shorter tracking ranges were obtained on the reciprocating-engine type of aircraft than jet aircraft, as expected. The tracking error could not be determined accurately in flight.

Unlike radar, no trouble with angle noise, or jitter, was experienced. The problems of tracking at a minimum range apparently did not exist. Resolution in the AN/DAN-3(XN-1), which is dependent on scan-cone angle, occurs at an angle of approximately 50'. The effective target center of a jet engine was found to be the center of the tailpipe, and for a reciprocating engine the exhaust stack or the manifold. Although tracking ranges below the system noise were possible, the acquisition of targets can only be achieved at ranges above this noise level, at the present time.

PART II

RECOMMENDATIONS

10. RECOMMENDATIONS.

The following general recommendations are made with regard to future programs:

a. It is recommended that additional information on the radiation characteristics of military targets be gathered; this should include spectral distribution and aspect-angle information.

b. The data in Item 1 should be evaluated for determining whether future aircraft design can permit a reduction in the effective radiation of American aircraft, and whether present models can be modified for reducing their radiation.

c. Studies of target-background radiation, optical contrast, and methods of target discrimination should be made.

d. A broad investigation of the general daytime problem of increasing contrast, including the effects of absorption and scattering, should be made; such an investigation should lead to results which, coupled with measurements of target characteristics, could be used to predict all-weather range probabilities.

e. Further development and testing of homing devices should be continued. The work on testing should include the present AN/DAN-3(XN-1) and improved models engineered from knowledge of radiation contrast characteristics. The tests can be conducted economically on a ground-to-air basis; they afford a continuous verification of laboratory test results.

f. Test procedure should be standardized, particularly with regard to tracking sensitivity, target resolution, and tracking accuracy; pertinent terminology should be standardized. A cognizant agency should correlate all results by defining such terms and recommending standard means of measurement.

g. The feasibility of infrared systems for tail warning and automatic search has been quite generally proved by the present and other infrared programs. Developmental work should be initiated on these phases of infrared detection.

h. The suitability of infrared detection to air- and ground-fire control appears promising, and an early investigation of such possibilities is deemed important.

i. A general over-all study of the radiation characteristic of all military targets, such as ships, tanks, locomotives, trucks, etc., would be of value to several phases of the program.

j. A work program should be undertaken for incorporating engineering modifications of the AN/DAN-3(XN-1) into an over-all missile.

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PART III

SUPPLEMENTARY DATA

APPENDIX A

FLIGHT-TEST DATA

CONFIDENTIAL

APPENDIX E

FLIGHT-TEST DATA

NO.	OP	DATE	D/N	TARGET	ALTITUDE (ft)	WEATHER	PURPOSE	COMMENTS
AA-1	—	6-13-51	D	—	—	—	First flight checkout	—
AA-2	—	6-18-51	D	—	—	—	Radar delivered to San Diego repair depot	—
AA-3	—	6-20-51	D	—	—	—	To fly to Inyokern to arrange fuel for jets	—
AA-4	6	6-26-51	D	J	15,000	Clear, haze on horizon	Orientation and checkout	—
AA-5	49	6-27-51	D	J	15,000	Clear above, overcast below	Orientation and checkout	—
AA-6	2	7-2-51	D	J	20,000	Clear above, clouds to 3000 ft, horizon haze	Orientation and checkout	—
AA-7	30	7-5-51	N	J	20,000	Clear	Orientation and checkout	—
AA-8	86	7-6-51	D	J	10,000	Clear, horizon haze	Range measurements	Radar failed; ranges could not be confirmed
AA-9	30	7-10-51	N	J	10,000	Clear at altitude, haze below	Night ranges	Not confirmed
AA-10	46	7-11-51	D	J	10,000	Clear at altitude, haze to 10° elevation	Day ranges	2- to 3-mile ranges confirmed
AA-11	71	7-12-51	N	J	10,000	Clear at altitude, haze to 10° elevation	Night ranges and minimum range response	Equipment malfunctioned; jet out of fuel when repairs completed
AA-12	6	7-16-51	N	J	10,000	Clouds at 9000 and 13,000 ft, haze at operating altitude	Maximum range measurements	Tracking ranges to 4 to 5 miles obtained
AA-13	32	7-17-51	N	J	11,000	Clear	Maximum range measurements	Tracking ranges to 3 miles obtained
AA-14	48	7-18-51	N	J	10,000	Clouds, scattered rain	Maximum range measurements	Tracking ranges to 4 miles obtained
AA-15	32	7-24-51	N	J	10,000	Clear, scattered high clouds	Maximum tracking-range measurements	Ranges to 5-1/2 miles obtained
AA-16	51	7-25-51	D	J	10,000	Scattered cumulus clouds overhead, usual haze	Day ranges with selected filters	Ranges to over 1 mile
AA-17	54	7-25-51	N	J	11,000	Clear	Range, autoacquisition; short range response, 40-minute mirror tilt	No jitter; ranges to 5 miles acquired
AA-18	65	7-26-51	D	J	10,000	Extreme haze	Range measurements, selected filter	Ranges of 1/2 to 3/4 mile
AA-19	68	7-26-51	N	J	11,000	Clear with distant cumulus clouds	Maximum range, autoacquisition	Ranges to 3-1/2 miles
AA-20	85	7-27-51	D	J	20,000	High thunderheads, usual haze	Day ranges	Ranges from 3/4 to 1 mile
AA-21	108	7-28-51	N	J	—	—	Effects of humidity, background and target radiations	AN/SAN-3(XN-1) not operated
AA-22	29	7-31-51	D	J	11,000	Clear, with low scattered clouds	Range, background effects	Maximum range 1/4 mile
AA-23	48	8-2-51	D	J	—	Clear, normal haze	Ranges, maneuvers, aspect shots	Ranges to 3 miles, maximum
AA-24	91	8-3-51	N	J	12,000	Clouds at 10,000 and 15,000 ft	Range, acquisition, and background measurements	An attempt to measure target radiation intensity
AA-25	4	8-6-51	N	J	15,000	Clear above, low overcast	Range, aspects effects	Ranges to 4 miles
AA-26	27	8-7-51	N	J	12,000	Clear, relative humidity below 40%	Pursuit, range aspects	Ranges to 4-1/2 miles

NO.	OP	DATE	D/N
AA-27	69	8-9-51	D
AA-28	72	8-9-51	N
AA-29	90	8-10-51	N
AA-30	9	8-13-51	N
AA-31	35	8-14-51	N
AA-32	55	8-15-51	N
AA-33	72	8-16-51	N
AA-34	70	8-30-51	N
AA-35	86	8-31-51	D
AA-36	88	8-31-51	N
AA-37	10	9-4-51	N
AA-38	26	9-5-51	D
AA-39	51	9-6-51	N
AA-40	66	9-7-51	N
AA-41	66	9-13-51	D
AA-42	68	9-13-51	N
AA-43	85	9-14-51	D

ABBREVIAT

AA -
NO -
OP -
D/N -
TARG -
ALT -
D -
N -
J -
2J -

1

APPENDIX A

FLIGHT-TEST DATA

	PURPOSE	COMMENTS
	First flight checkout	—
	Radar delivered to San Diego repair depot	—
	To fly to Inyokern to arrange fuel for jets	—
on horizon	Orientation and checkout	—
, overcast	Orientation and checkout	—
, clouds to ison haze	Orientation and checkout	—
	Orientation and checkout	—
om haze	Range measurements	Radar failed; ranges could not be confirmed
itude,	Night ranges	Not confirmed
itude, elevation	Day ranges	2- to 3-mile ranges confirmed
itude, elevation	Night ranges and minimum range response	Equipment malfunctioned; jet out of fuel when repairs completed
00 and aze at titude	Maximum range measurements	Tracking ranges to 4 to 5 miles obtained
	Maximum range measurements	Tracking ranges to 3 miles obtained
tered rain	Maximum range measurements	Tracking ranges to 4 miles obtained
ered high	Maximum tracking-range measurements	Ranges to 5-1/2 miles obtained
mulus ead,	Day ranges with selected filters	Ranges to over 1 mile
	Range, autoacquisition; short range response, 40-minute mirror tilt	No jitter; ranges to 5 miles acquired
)	Range measurements, selected filter	Ranges of 1/2 to 3/4 mile
istant ds	Maximum range, autoacquisition	Ranges to 3-1/2 miles
heads,	Day ranges	Ranges from 3/4 to 1 mile
	Effects of humidity, background and target radiations	AN/DAN-3(XN-1) not operated
low ouds	Range, background effects	Maximum range 1/4 mile
n haze	Ranges, maneuvers, aspect shots	Ranges to 3 miles, maximum
,000 and	Range, acquisition, and background measurements	An attempt to measure target radiation intensity
low	Range, aspects effects	Ranges to 4 miles
ive ow 10	Pursuit, range aspects	Ranges to 4-1/2 miles

NO.	OP	DATE	D/N	TARGET	ALTITUDE (ft)	WEATHER	PURPOSE	COMMENTS
AA-27	69	8-9-51	D	—	—	Usual haze	Performance at maximum altitude	Target failed to take off
AA-28	72	8-9-51	N	—	—	—	—	Target failed to take off
AA-29	90	8-10-51	N	J	10,000	Ground haze, otherwise clear	Aspect effects, maximum range	Maximum range 4-1/2 miles, 30° sharpest effective aspect
AA-30	9	8-13-51	N	J	12,000	Clear	Aspect effects, maximum range	Maximum range 4-1/2 miles (terminated by jet trouble, greater range possible).
AA-31	35	8-14-51	N	J	20,000	Clouds 12,000 to 15,000 ft	Range with increased cell volts, selected cell and aspects	Range to 12 miles
AA-32	55	8-15-51	N	J	20,000	Clouds (reflecting bright moonlight)	Range with increased cell volts, selected cell and aspects	Range to 10 miles
AA-33	72	8-16-51	N	J	20,000	Clear	Range and pursuit course	Range to 10 miles; lock-on at 3 miles, followed easily in maneuvers
AA-34	70	8-30-51	N	2J	20,000	Clear	Resolution, 2 targets	15-mile range
AA-35	86	8-31-51	D	2J	20,000	Usual haze, scattered clouds	Dual-target performance	See Paragraph 9, b, (2).
AA-36	88	8-31-51	N	PBAY	12,000	Clear	General performance with reciprocating-engine target	Ranges to 2 miles
AA-37	10	9-4-51	N	2J	20,000	Clear	Dual-target performance	Ranges to 14 miles
AA-38	26	9-5-51	D	J	16,000	Extreme haze	Guidance course	No runs, excessive haze
AA-39	51	9-6-51	N	J	20,000	Ground fog, otherwise clear	Range, acquisition	Batteries low
AA-40	66	9-7-51	N	PBAY	11,000	Clear	Performance, reciprocating-engine target	Ranges to 2-1/2 miles
AA-41	66	9-13-51	D	J	20,000	Clouds, to 10,000 ft, much haze	Metcalf committee demonstration	Ranges to 2 miles
AA-42	68	9-13-51	N	2J	20,000	Clear	Dual-target response, Metcalf demonstration	Range to 18 miles at high crossing speeds
AA-43	85	9-14-51	D	J	22,000	Extreme haze	Range and pursuit, Metcalf demonstration	1 mile

ABBREVIATIONS AND SYMBOLS

AA - Air-to-Air Test
NO - Flight Number
OP - Operation (Pt. Mugu Official Designation; number started at one each week).
D/N - Day or Night
TARG - Target
ALT - Altitude
D - Day
N - Night
J - Single-Target Jet Fighter (F-80, TO-1, or TO-2)
2J - Two Targets (F-80, TO-1, or TO-2)

2

APPENDIX B

GROUND-TEST DATA

APPENDIX B

GROUND-TEST DATA

DATE	TIME	PLACE	INSTRUMENTS	CP.	TARG.	PURPOSE	RESULTS
7-23-51	0955 to 1005	East end of landing strip	AN/DAN-3(XN-1) power supply control box, air supply, oscilloscope, radar-range tachometer	—	TO-1	To determine feasibility of ground-to-air operations for (1) reference and control of airborne operations, (2) checking optical filter performance in improving range, and (3) determining nature of sky-background problem	Ground operations appeared feasible. For this purpose improvement of range was obtained by use of the best filter; 1200 yd maximum combination.
7-25-51	1400 to 1515	East end of landing strip	AN/DAN-3(XN-1) power supply control box, air supply, oscilloscope, radar-range tachometer	11	TO-1	(1) Determine best filter thickness for maximum range (2) Test under different background conditions	Maximum range of 1500 yd achieved.
7-26-51	1430 to 1545	East end of landing strip	AN/DAN-3(XN-1) power supply control box, air supply, oscilloscope, radar-range tachometer	33	TO-1	To check filters	Maximum range 1500 yd
7-27-51	2130 to 2245	East end of landing strip	AN/DAN-3(XN-1) power supply control box, air supply, oscilloscope, radar-range tachometer	39	TO-1	To determine signal strength from jet on ground	High reflection from landing strip and background observed. Jet signal was noted beyond 200 yd.
7-30-51	1040 to 1137	East end of landing strip	AN/DAN-3(XN-1) power supply control box, air supply, oscilloscope, radar-range tachometer	8	TO-1	To determine increase in range with increase in altitude as horizon effect decreased	Large increase in range determined
7-31-51	1100 to 1210	Laguna Peak	As before, but no radar; stopwatch and jet velocity used to determine range	22	TO-1	To determine feasibility of operating on mountain peak to obtain more constant background condition	Poor tracking because of instrument difficulties, but excellent background condition
8-1-51	1120 to 1225	Laguna Peak	As before, but no radar; stopwatch and jet velocity used to determine range	43	TO-1	To determine range when detecting and the ratio detection; filter tracking performance	Good results
8-1-51	1550 to 1638	Laguna Peak	As before, but no radar; stopwatch and jet velocity used to determine range	49	TO-1	Filter performance by checking consistent results	Good results; operation cut short by communication trouble
8-2-51	1025 to 1135	Laguna Peak	As before, but no radar; stopwatch and jet velocity used to determine range	63	TO-2	To check polarization of sky; to verify filters	Good results
8-2-51	1430	Landing field	Radiometer	70	—	Radiation-aspects and tail	Good
8-6-51	1315 to 1400	Laguna Peak	Radiometer	100	TO-2	To check range ratio; best filter combination vs [illegible]	Good results; large increase in range noted
8-13-51	2115 to 2152	Laguna Peak	Radiometer	9	TO-2	Use as a control operation for air tests	Ground operations appeared to be excellent for simulating air operations.
8-14-51	2130 to 2330	Laguna Peak	Radiometer	35	TO-2	Use as a control operation for air tests	Good ranges
8-15-51	1445 to 1530	Laguna Peak	Radiometer	50	TO-2	To determine best filter thickness	Very poor; could not lock AN/DAN-3(XN-1) on target consistently
8-15-51	2150 to 2205	Laguna Peak	Radiometer	55	TO-2	Air-to-air control	Good range
8-20-51	2000 to 2100	West end of Pt. Mugu landing strip	As before, plus radiometer and amplifier	13	TO-2	To determine radiation intensity at various aspects with and without filters	Excellent results
8-21-51	2230 to 0130	West end of Pt. Mugu landing strip	AN/DAN-3(XN-1) plus Perkin-Elmer monochromator with a lead sulfide detector and Brush recorder	31	TO-2	To determine spectral distribution of energy from tailpipe and from hot gases; to determine length of hot gases to which AN/DAN-3(XN-1) will respond	Excellent results
8-23-51	2230 to 0015	West end of Pt. Mugu landing strip	AN/DAN-3(XN-1) and Perkin-Elmer monochromator with a lead sulfide detector and Brush recorder	69	TO-2	Same as above, and aspect	Excellent results
8-24-51	2230 to 0132	West end of Pt. Mugu landing strip	AN/DAN-3(XN-1) and Perkin-Elmer monochromator with a lead sulfide detector and Brush recorder	86	TO-2	To check tail aspect	Confirms 8-21-51 results

DATE	TIME	PLACE	INSTRUMENTS
8-24-51	1500	West end of Pt. Mugu landing strip	AN/DAN-3(XN-1) and Perkin-Elmer monochromator with a lead sulfide detector and Brush recorder
8-24-51	2117 to 2140	Laguna Peak	Same as 7-23-51
8-27-51	1305 to 1420	Laguna Peak	Same as 7-23-51
8-27-51	2120 to 2300	Laguna Peak	Same as 7-23-51 using modified AN/DAN-3(XN-1)
8-29-51	2130 to 0100	West end of Pt. Mugu landing strip	Same as 7-23-51 using modified AN/DAN-3(XN-1)
9-5-51	2200 to 0130	West end of Pt. Mugu landing strip	Radiometer and Amplifier ([illegible])
9-13-51	1340 to 1358	Laguna Peak	Same as 7-23-51, using modified AN/DAN-3(XN-1)
9-14-51	1330 to 1420	Laguna Peak	Same as 7-23-51, using modified AN/DAN-3(XN-1)
9-14-51	2040 to 2120	Laguna Peak	Same as 7-23-51, using modified AN/DAN-3(XN-1)
9-17-51	2007 to 2130	Laguna Peak	Same as 7-23-51, using modified AN/DAN-3(XN-1)
9-18-51	Day	Laguna Peak	Same as 7-23-51, using modified AN/DAN-3(XN-1)
9-20-51	2100	Pt. Mugu runway	Perkin-Elmer monochromator
9-21-51	1430 to 1675	Laguna Peak	AN/DAN-3(XN-1)
10-2-51	2100	Pt. Mugu runway	Radiometer, AN-DAN-3(XN-1) and Brush recorder
10-3-51		Laguna Peak	AN/DAN-3(XN-1), Radar and tachometer, pre-amplifier, radiometer and radar amplifier
10-4-51	1330 to 1530	Laguna Peak	AN/DAN-3(XN-1), Radar and tachometer, pre-amplifier, radiometer and radar amplifier
10-9-51	2055	Laguna Peak	AN/DAN-3(XN-1), Radar and tachometer, pre-amplifier, radiometer and radar amplifier
10-10-51	2050	Pt. Mugu strip	AN/DAN-3(XN-1), Radar and tachometer, pre-amplifier, radiometer and radar amplifier
10-11-51	2050	Laguna Peak	AN/DAN-3(XN-1), Radar and tachometer, pre-amplifier, radiometer and radar amplifier
10-15-51	1410 to 1610	Laguna Peak	AN/DAN-3(XN-1), Radar and tachometer, pre-amplifier, radiometer and radar amplifier
10-15-51	1940 to 0020	Pt. Mugu strip	AN/DAN-3(XN-1), Radar and tachometer, pre-amplifier, radiometer and radar amplifier
10-16-51	2030 to 2100	Laguna Peak	AN/DAN-3(XN-1), Radar and tachometer, pre-amplifier, radiometer and radar amplifier

APPENDIX B

GROUND-TEST DATA

INSTRUMENTS	CT.	TARG.	PURPOSE	RESULTS
-3(XN-1) power control box, air oscilloscope, range tachometer	—	TO-1	To determine feasibility of ground-to-air operations for (1) reference and control of airborne operations, (2) checking optical filter performance in improving range, and (3) determining nature of sky-background problems	Ground operations appeared feasible. For this purpose improvement of range was obtained by use of the best filter; 1200 yd maximum combination.
-3(XN-1) power control box, air oscilloscope, range tachometer	11	TO-1	(1) Determine best filter thickness for maximum range (2) Test under different background conditions	Maximum range of 1500 yd achieved.
-3(XN-1) power control box, air oscilloscope, range tachometer	33	TO-1	To check filters	Maximum range 1500 yd
-3(XN-1) power control box, air oscilloscope, range tachometer	39	TO-1	To determine signal strength from jet on ground	High reflection from landing strip and background observed. Jet signal was noted beyond 200 yd.
-3(XN-1) power control box, air oscilloscope, range tachometer	2	TO-1	To determine increase in range with increase in altitude as horizon effect decreased	Large increase in range determined
re, but no stopwatch and locity used to ine range	22	TO-1	To determine feasibility of operating on mountain peak to obtain more constant background condition	Poor tracking because of instrument difficulties, but excellent background condition
re, but no stopwatch and locity used to ine range	43	TO-1	To determine range when detecting and the ratio detection; filter tracking performance	Good results
re, but no stopwatch and locity used to ine range	49	TO-1	Filter performance by checking consistent results	Good results; operation cut short by communication trouble
re, but no stopwatch and locity used to ine range	63	TO-2	To check polarization of sky; to verify filters	Good results
ter	70	—	Radiation-aspects and tail	Good
ter	100	TO-2	To check range ratio; best filter combination vs [illegible]	Good results; large increase in range noted
ter	9	TO-2	Use as a control operation for air tests	Ground operations appeared to be excellent for simulating air operations.
ter	35	TO-2	Use as a control operation for air tests	Good ranges
ter	90	TO-2	To determine best filter thickness	Very poor; could not lock AN/DAN-3(XN-1) on target consistently
ter	55	TO-2	Air-to-air control	Good range
ters, plus radiom- and amplifier	13	TO-2	To determine radiation intensity at various aspects with and without filters	Excellent results
-3(XN-1) plus -Elmer mono- ter with a lead detector and recorder	31	TO-2	To determine spectral distribution of energy from tailpipe and from hot gases to determine length of hot gases to which AN/DAN-3(XN-1) will respond	Excellent results
-3(XN-1) and -Elmer mono- ter with a lead detector and recorder	69	TO-2	Same as above, and aspect	Excellent results
-3(XN-1) and -Elmer mono- ter with a lead detector and recorder	86	TO-2	To check tail aspect	Confirms 8-21-51 results

DATE	TIME	PLACE	INSTRUMENTS	CT.	TARG.	PURPOSE	RESULTS
8-24-51	1500	West end of Pt. Mugu landing strip	AN/DAN-3(XN-1) and Perkin-Elmer monochromator with a lead sulfide detector and Brush recorder	—	TO-2	Spectral energy distribution mapping of day sky	Excellent results
8-24-51	2117 to 2140	Laguna Peak	Same as 7-23-51	69	TO-2	Air-to-air control	Good results
8-27-51	1305 to 1420	Laguna Peak	Same as 7-23-51	11	TO-2	To determine maximum range by flying target high, to lose target above high horizon background	Range increased as plane flew higher, but inability to see plane limited elevation
8-27-51	2120 to 2300	Laguna Peak	Same as 7-23-51 using modified AN/DAN-3(XN-1)	14	TO-2	To determine maximum range	Range increased very appreciably
8-29-51	2130 to 0100	West end of Pt. Mugu landing strip	Same as 7-23-51 using modified AN/DAN-3(XN-1)	50	F84F	To determine AN/DAN-3(XN-1) behavior against F84F	Good results
9-5-51	2200 to 0130	West end of Pt. Mugu landing strip	Radiometer and Amplifier (60)	26	F84F	To check energy sources and level at various aspects; demonstration for British Group	Good results
9-13-51	1340 to 1352	Laguna Peak	Same as 7-23-51, using modified AN/DAN-3(XN-1)	46	TO-2	To check range using germanium filter	Fair results
9-14-51	1330 to 1420	Laguna Peak	Same as 7-23-51, using modified AN/DAN-3(XN-1)	65	TO-2	To check range using germanium filter	Expected increase in range not obtained
9-14-51	2040 to 2120	Laguna Peak	Same as 7-23-51, using modified AN/DAN-3(XN-1)	88	TO-2	Air-to-air control range	Results not recorded
9-17-51	2007 to 2130	Laguna Peak	Same as 7-23-51, using modified AN/DAN-3(XN-1)	9	TO-2	To demonstrate AN/DAN-3(XN-1) performance for Metcalf committee	Good
9-18-51	Day	Laguna Peak	Same as 7-23-51, using modified AN/DAN-3(XN-1)	29	TO-2	Demonstration for Metcalf committee	Fair
9-20-51	2100	Pt. Mugu runway	Perkin-Elmer monochromator	71	F-94	To check spectral intensity	Good
9-21-51	1430 to 1675	Laguna Peak	AN/DAN-3(XN-1)	—	F-94	To check range	Good
10-2-51	2100	Pt. Mugu runway	Radiometer, AN/DAN-3(XN-1) and Brush recorder	30	F-80	To check target signal, AN/DAN-3(XN-1) boresighted with radiometer	Poor
10-3-51		Laguna Peak	AN/DAN-3(XN-1), Packard tachometer, preamplifier, radiometer and radar amplifier	—	F-80	Range to compare CF and [illegible] filters vs germanium	Good
10-4-51	1330 to 1530	Laguna Peak	AN/DAN-3(XN-1), Packard tachometer, preamplifier, radiometer and radar amplifier	70	F-80	To verify range at which target is lost	Good
10-9-51	2055	Laguna Peak	AN/DAN-3(XN-1), Packard tachometer, preamplifier, radiometer and radar amplifier	31	TO-2	To verify strength when target lost	Good
10-10-51	2050	Pt. Mugu strip	AN/DAN-3(XN-1), Packard tachometer, preamplifier, radiometer and radar amplifier	35	TO-2	—	Poor
10-11-51	2050	Laguna Peak	AN/DAN-3(XN-1), Packard tachometer, preamplifier, radiometer and radar amplifier	78	F84F	Aspect range and scintillation	Good
10-15-51	1410 to 1610	Laguna Peak	AN/DAN-3(XN-1), Packard tachometer, preamplifier, radiometer and radar amplifier	2	TO-2	Tracking and detecting	Good
10-15-51	1940 to 0020	Pt. Mugu strip	AN/DAN-3(XN-1), Packard tachometer, preamplifier, radiometer and radar amplifier	6	TO-2	Tail and side aspects	Good
10-16-51	2030 to 2100	Laguna Peak	AN/DAN-3(XN-1), Packard tachometer, preamplifier, radiometer and radar amplifier	36	TO-2	Tracking and aspect	Good

APPENDIX C

TARGET AND BACKGROUND RADIATION CHARACTERISTICS

TARGET AND BACKGROUND
RADIATION CHARACTERISTICS

1. DISCUSSION.

It has been explained in previous sections of this report that owing to lack of sufficiently detailed information it became necessary, as the work progressed, to determine the radiation characteristics of the military targets under test. A knowledge of the intensity of the radiation emitted by the target in that wavelength region which is effective in energizing a lead sulfide cell permitted a theoretical verification of the maximum night ranges obtained and a check on the performance of the AN/DAN-3(XN-1). Additional data on the magnitude and spectral distribution of the target radiation, together with information on the background characteristics, permitted improvement of the spectral contrast and gave rise to a simple procedure whereby day ranges could be improved. In order to obtain this information, tests were conducted to determine the following factors:

a. The total radiation energy emitted by various target planes in the 1- to 3-micron region, at aspects from nose to tail.

b. The spectral distribution of the radiation energy.

c. The total energy radiated by typical sky background, including clear sky, haze, cloud, and horizon effects, and the spatial distribution of total energy. From such indirect measurements, sky-background energy gradients were obtained.

d. By scanning methods, sky-background energy gradients were obtained directly.

e. The spectral distribution of the sky-background energy.

f. The best filter selection to increase optical contrast between the target and the background.

2. EQUIPMENT.

In order to conduct the tests listed above, a calibrated radiometer using a lead sulfide cell receiver was employed to measure the total radiant energy incident on the cell, and an infrared monochromator using a lead sulfide receiver was used to determine the spectral distribution of this energy. A radiometer suitable for this purpose was constructed by Aerojet; the monochromator was a Perkin-Elmer Universal type and was modified by joint efforts of Aerojet and NAMTC engineers. An amplifier applicable to either instrument was employed, with its output being recorded on a Brush recorder. The details of the equipment are described as follows:

a. THE RADIOMETER. - The design features of the radiometer are shown in figure 45. The radiometer consists principally of a collecting lens of a type similar to that used in the AN/DAN-3(XN-1), a 1/8-inch-square Eastman lead sulfide cell mounted at the focal point of the lens, a filter disc positioned by means of an indexed dial on the back of the radiometer chassis, and a 210-cps chopper driven by a motor. Various filters could be inserted in front of the cell for selective reception of radiation by the cell.

b. THE MONOCHROMATOR. - A Perkin-Elmer Universal Monochromator was adapted for the spectral distribution determination work by making the following modification: A collecting mirror of appropriate aperture was installed in an off-axis Herschellian system to receive sufficient radiation from jet-engine targets. The position of the mirror was adjustable so that the radiation could be focused on the entrance slit. A chopper disc, driven at 210 cps was installed in front of the entrance slit, and a lead sulfide cell was mounted at the exit slit. The wavelength drive was rotated by a small motor in order to scan automatically the entire spectrum of a desired spectral region. A diagram of the equipment is shown in figure 14.

c. THE RADIOMETER AMPLIFIER. - This amplifier consisted of two sections, one section providing an a-c amplification of the chopped radiation and the other section providing a d-c amplification of the rectified signal. The frequency-response characteristics of the instrument are shown in figure 46; when desired, a band-pass filter can be switched into the circuit of the amplifier, giving the characteristics shown in figure 47.

d. EQUIPMENT TO MEASURE ENERGY GRADIENTS. - The AN/DAN-3(XN-1) test unit, consisting of the infrared homing set, Du Mont oscilloscope Model 241, General Radio 35-mm oscilloscope recording camera, and power supply, was used to investigate the waveshape of the signal from the target and from background energy gradients. The signal was fed into the oscilloscope from the preamplifier of the AN/DAN-3(XN-1) subsequent to two stages of amplification and was recorded on the General Radio recording camera. In addition, the energy gradient was determined from mapping the background intensity over the sky by means of the radiometer. The correlation between the two measurements was then investigated.

3. PROCEDURE.

Subsequent to the construction of the radiometer and its amplifier, the entire unit was calibrated against the total radiation from a black body at a temperature of 600°C.

This calibration was performed at NAMTC, on 7 August, and again on 26 September 1951.

The filters employed are designated for the first test by subscript "1" and for the second by subscript "2" and were as follows:

Test and Filter Designations

Test - 7 August 1951		Test - 26 September 1951	
Position	Filter	Position	Filter
1_1	None	1_2	Polaroid C2 and Germanium
2_1	None	2_2	Germanium
3_1	None	3_2	4010
4_1	Polaroid C2	4_2	Polaroid C2
5_1	E.K. Silver Chloride	5_2	None
6_1	Polaroid C2 and 4010	6_2	Polaroid C2 and 4010

Average Results of the Two Tests Given Above

Filter No.	Radiometer Amplifier Gain	Output Signals D-C Volts	Input From Amplifier Calibration Curve (Microvolts)
1_1 and 5_2	10^3	33.0	31.8×10^3
3_1 and 3_2	10^3	16.0	15.7×10^3
4_1 and 4_2	10^3	5.4	6.7×10^3
6_1 and 6_2	10^3	3.3	4.2×10^3
5_1	10^4	24.3	2.4×10^3
1_2	10^3	4.4	5.1×10^3
2_2	10^3	10.0	10.4×10^3

From this table, the calibration may be made as follows:

Data

Distance, radiometer to black body - 915 cm

Black-body aperture - 1/4-inch diameter

Black-body area - 0.3165 cm^2

Black-body emissivity - 1

Lead sulfide spectral sensitivity range - 0.9 to 3.2 microns

From Planck's law, the total energy radiated in 2π steradians from a black body 1 cm^2 in area at 600°C is 3.3 watts/cm^2. The amount of radiant energy in the wavelengths between 0.9 and 3.2 microns is 22.6%; thus the energy to which the cell is sensitive is 0.741 watts/cm^2. In the absence of absorption, the energy W in the beam per unit area at a distance r is

$$W = \frac{W_o}{\pi r^2}$$

where the factor π enters because the emitting surface is considered to obey Lambert's law. After the application of effective-area and other corrections, a calibration of 1 millivolt per 2.8×10^{-9} watt/cm^2 was obtained for the radiometer amplifier.

The spectral sensitivity of the Eastman Kodak lead sulfide cells used in the tests was determined by Dr. Edgar Kutzscher and Curt Foster of NAMTC; a typical sensitivity curve is shown in figure 48. The group of curves in this figure are also applicable to the wavelength sensitivity of the lead sulfide cells used in the AN/DAN-3(XN-1) during the flight tests.

The transmission characteristics of various filters were measured by means of a Baird spectrophotometer. Curves for various applicable filters are shown in figures 23, 49, and 50.

4. MEASUREMENT OF TARGET INTENSITY.

The radiation intensity of the F-80 (TO-2 type) target plane was measured by viewing this target at various ranges and various aspects. Curves showing typical observed results are shown in figures 51 and 52. The radiation appears to be similar to that from a black body at the appropriate tailpipe temperature, and to have a cosine distribution which is modified at 90° aspect because of the protrusion of 3 inches of the tailpipe through the skin of the plane, as is visible in the photograph of figure 53. An approximate, effective emissivity of 0.8 can be calculated from these data. Similar curves for an F-94 type plane are shown in figure 54.

5. SPECTRAL DISTRIBUTION OF TARGET RADIATION.

The spectral distribution of the target radiation was measured with the monochromator at three points:

a. The hot exhaust gas issuing 4 feet behind the tailpipe and observed at 90° aspect.

b. The 3-inch protrusion of tailpipe at 90° aspect.

c. The hot exhaust gas and tailpipe observed from the rear of the tailpipe, i.e., at 0-degree aspect.

Figure 21 illustrates the target spectrum for an F-80 jet at 500°C, with no filter, and tail aspect at 187.5 feet with respect to the monochromator. The spectrum has a black-body character, and the peak emission is between 2.2- and 2.4-micron wavelengths, with a small peak at 1.71 microns, cutting off sharply at 2.6 microns.

Figure 55 shows the spectrum of an F-80 jet tailpipe protrusion observed at a 90° aspect from a distance of 50 feet. This spectrum also is black-body type.

Figure 56 shows the hot exhaust-gas spectrum of an F-80 target, and figure 57 shows a similar spectrum for the exhaust from an F-94.

6. SKY BACKGROUND.

a. SKY-BACKGROUND INTENSITY. - The sky-background intensity contours are shown in figures 24 and 25. The blue-sky map shows a peak intensity around the sun, with an area of minimum intensity at a position at right angles to the sun and the energy gradient increasing slowly around this area. This follows a distribution originally determined by Lord Rayleigh, who advanced a theory of scattering in an atmosphere of uniform pollution; this distribution is considerably modified by impurities existing in the atmosphere when observed from a low altitude.

The overcast-sky map shows a higher radiation level, with erratic gradients caused by clouds above the haze. The intensity gradient across the cloud edges is not shown in the figures. In the area marked "patches of blue sky, erratic" very steep energy gradients were noted, and no over-all contour could be made.

Figure 58 is an intensity gradient on a meridian through the sun, and shows the variation from the sun to the area of minimum energy.

b. SKY-BACKGROUND ENERGY GRADIENTS. - In the test configuration used, the AN/DAN-3(XN-1) has an instantaneous field of view of 1° and scans a cone of 2° 20' solid angle.

In order to compare various filters, the background was measured on a blue-sky day, and the filter contrast improvement was checked in an area of the sky of low intensity, so that the background energy gradient would not change appreciably while the filters were being changed.

Tests were conducted to observe the energy gradient on a meridian from the horizon to the zenith, at 15° increments of elevation. The amplitude of the signal was taken as a measure of the energy gradient for an integrated area (1° field) of the sky, scanned in a 2° 20' cone. The general plot for these measurements conforms to the radiation intensity contour map, with high energy gradient across the horizon, reaching a minimum at right angles to the sun and increasing again at the zenith, as the view of observation approaches the sun.

7. SPECTRAL DISTRIBUTION OF SKY BACKGROUND.

Figure 22 shows the background spectra of various sky conditions, at various elevations and constant azimuth angle with respect to the sun. These curves show the same spectral peaks with various magnitudes, depending on the angle of observation.

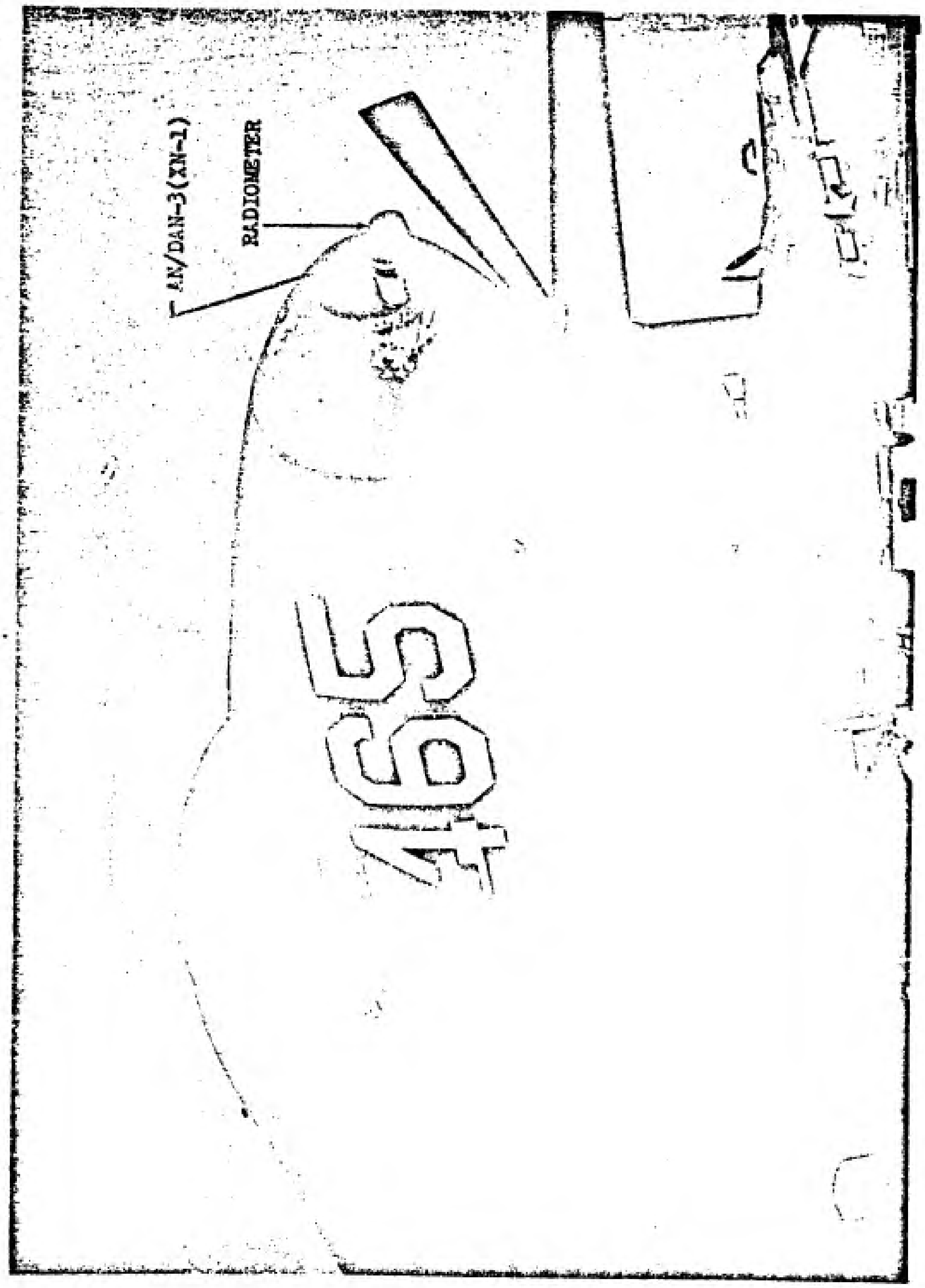
8. CONTRAST IMPROVEMENT.

The F-80 target spectrum (figure 56) shows an emission between 2.2' to 2.4-micron wavelengths. The background shows a peak energy at shorter wavelengths in water-vapor absorption windows, with a small energy in the 2.2 to 2.4-micron band.

A comparison of the curves given in figures 55 to 57 shows that a filter which cuts off sharply at 2 microns and has a high transmission at wavelengths above 2 microns would materially reduce the background without appreciably attenuating the target signal. Germanium appears to be the best filter material obtainable at the present time. Figure 3 shows the transmission of the uncoated material

APPENDIX D

ILLUSTRATIONS



Nose Section of P2V-2N, Showing AN/DAN-3(XN-1) and Radiometer

Figure 1
Appendix D
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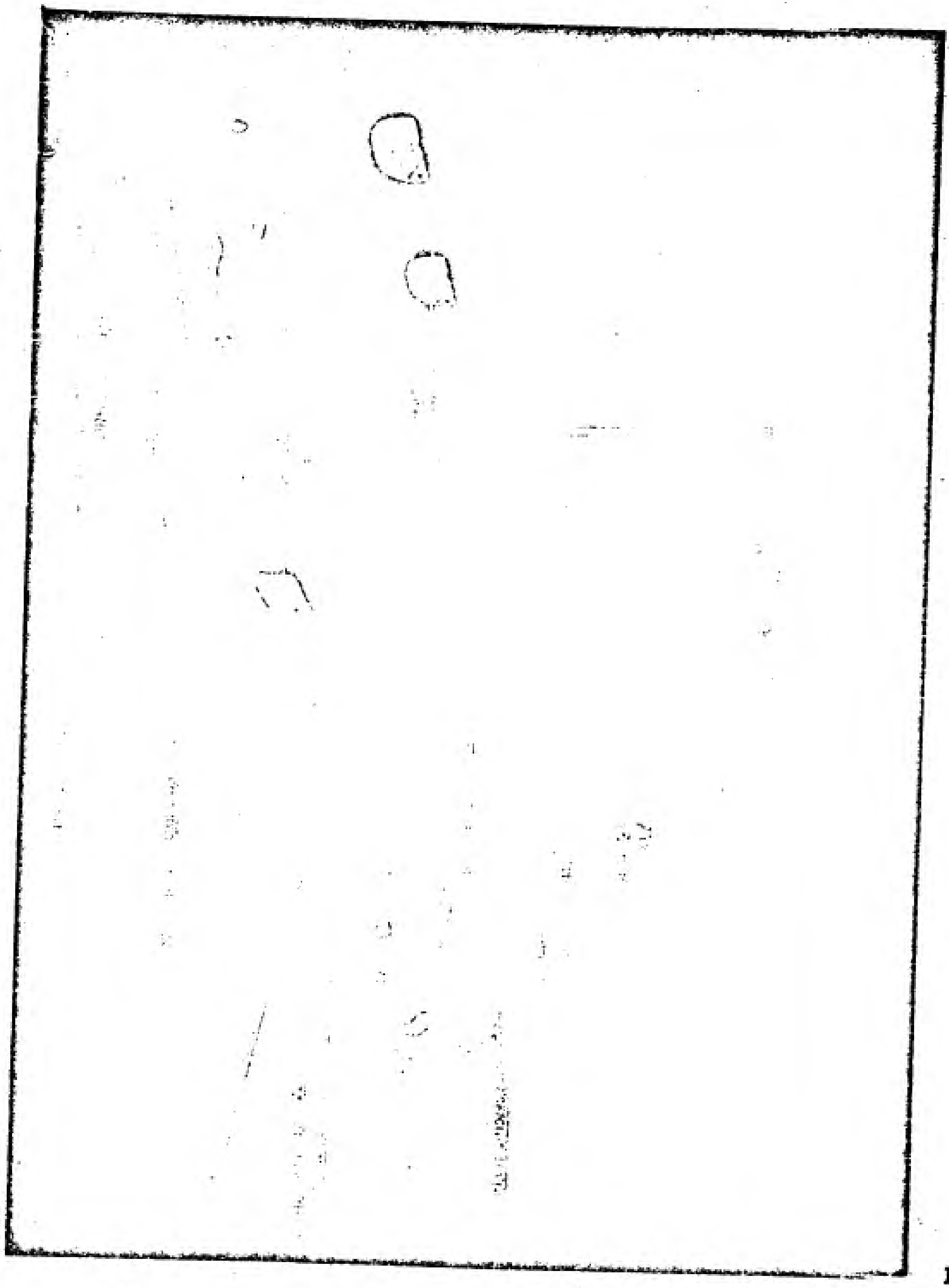
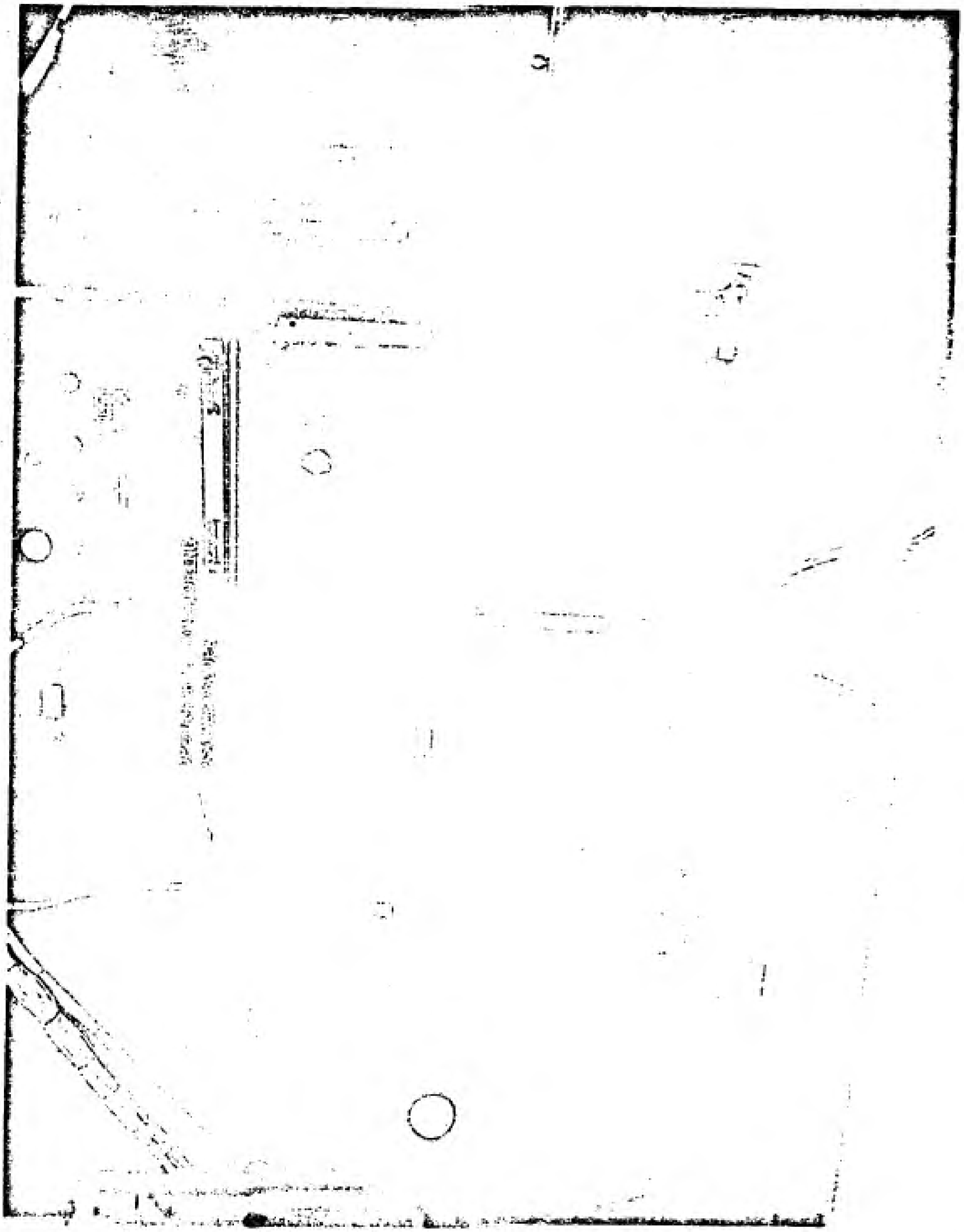


Interior View of Nose Section of P2V-2N,
Showing Equipment Mounting and Control Racks

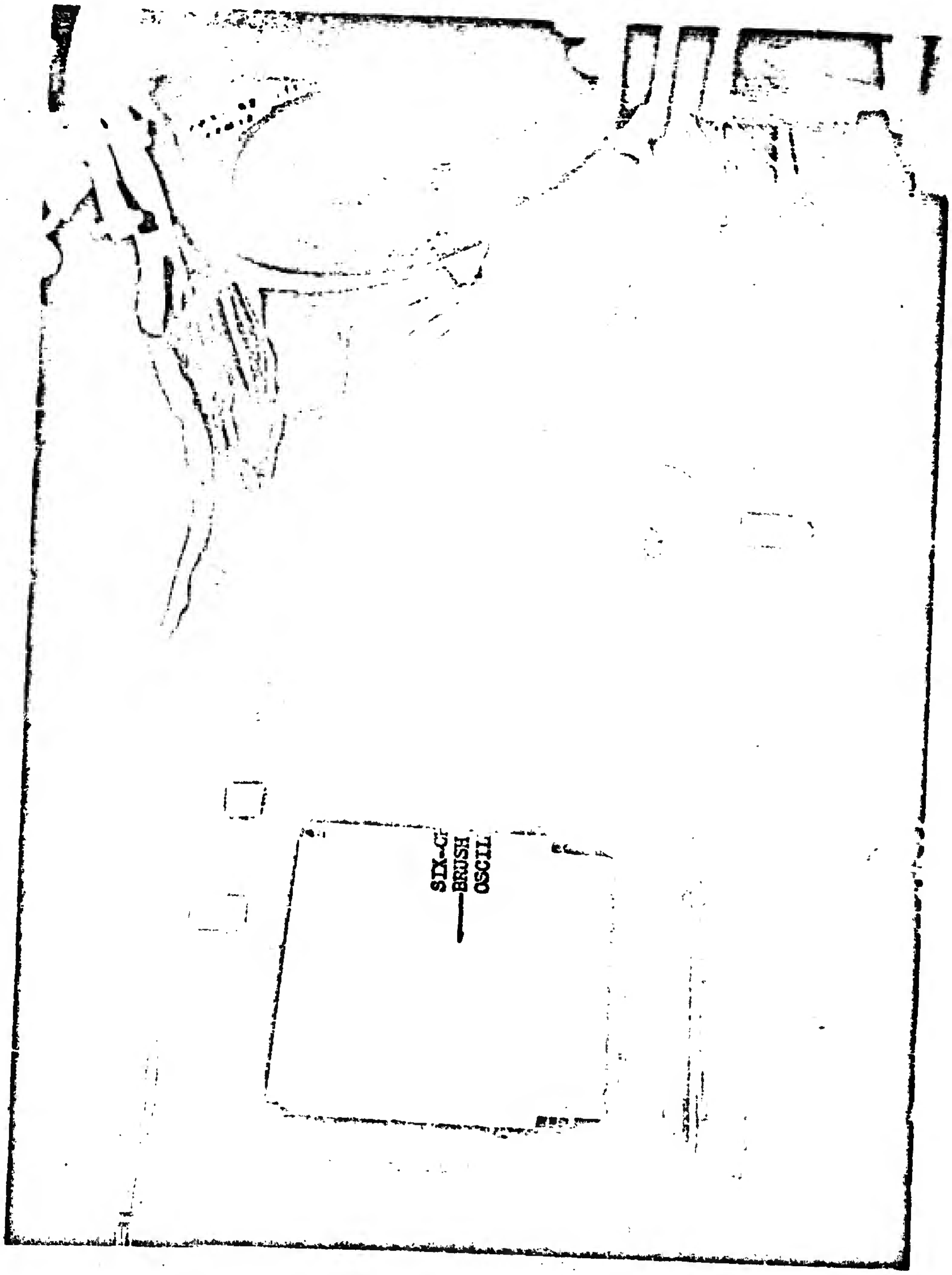
Figure 2



Section of Instrumentation Compartment Aboard P2V-2N, Showing APS-38 Radar

Figure 3
Appendix D

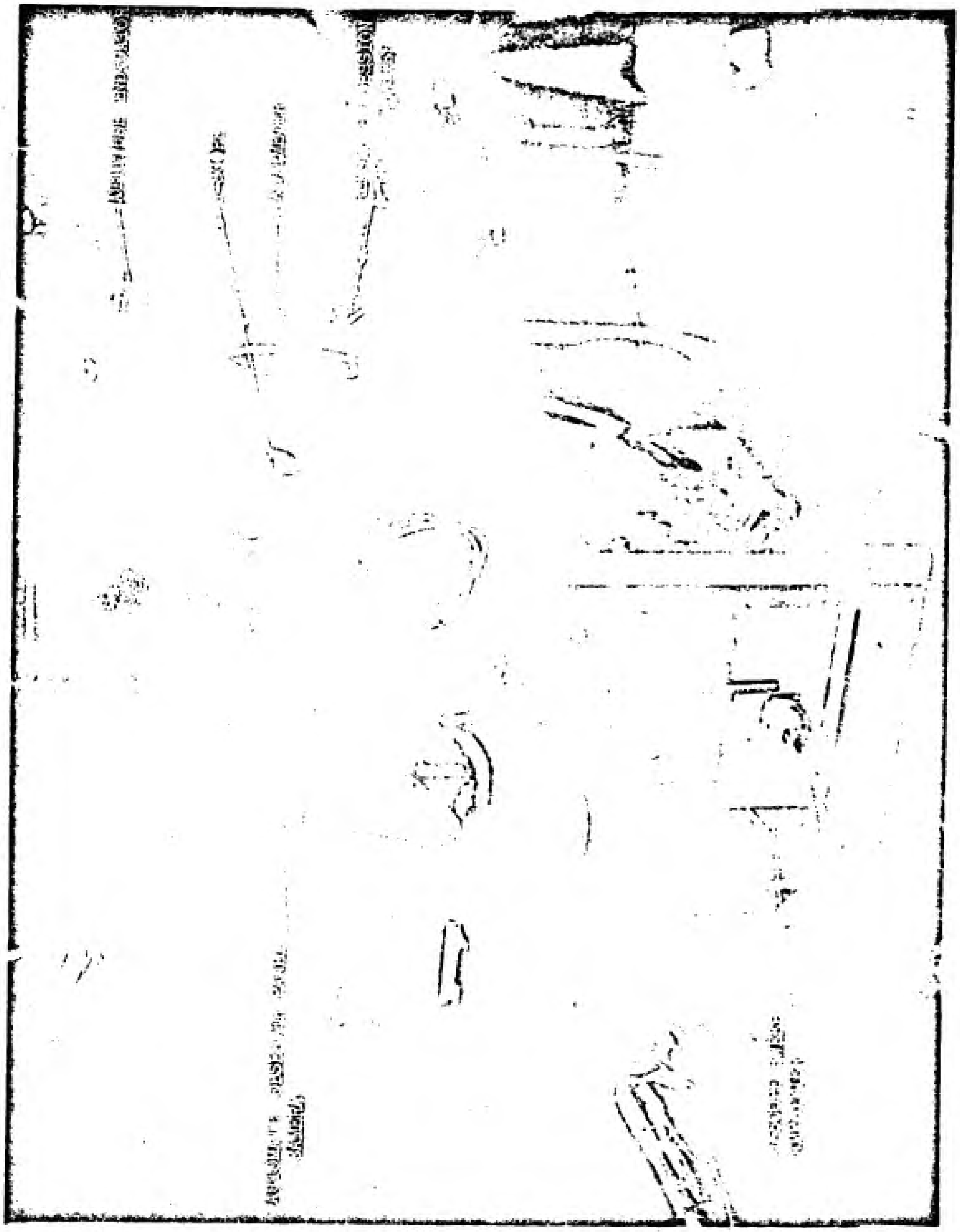
CONFIDENTIAL



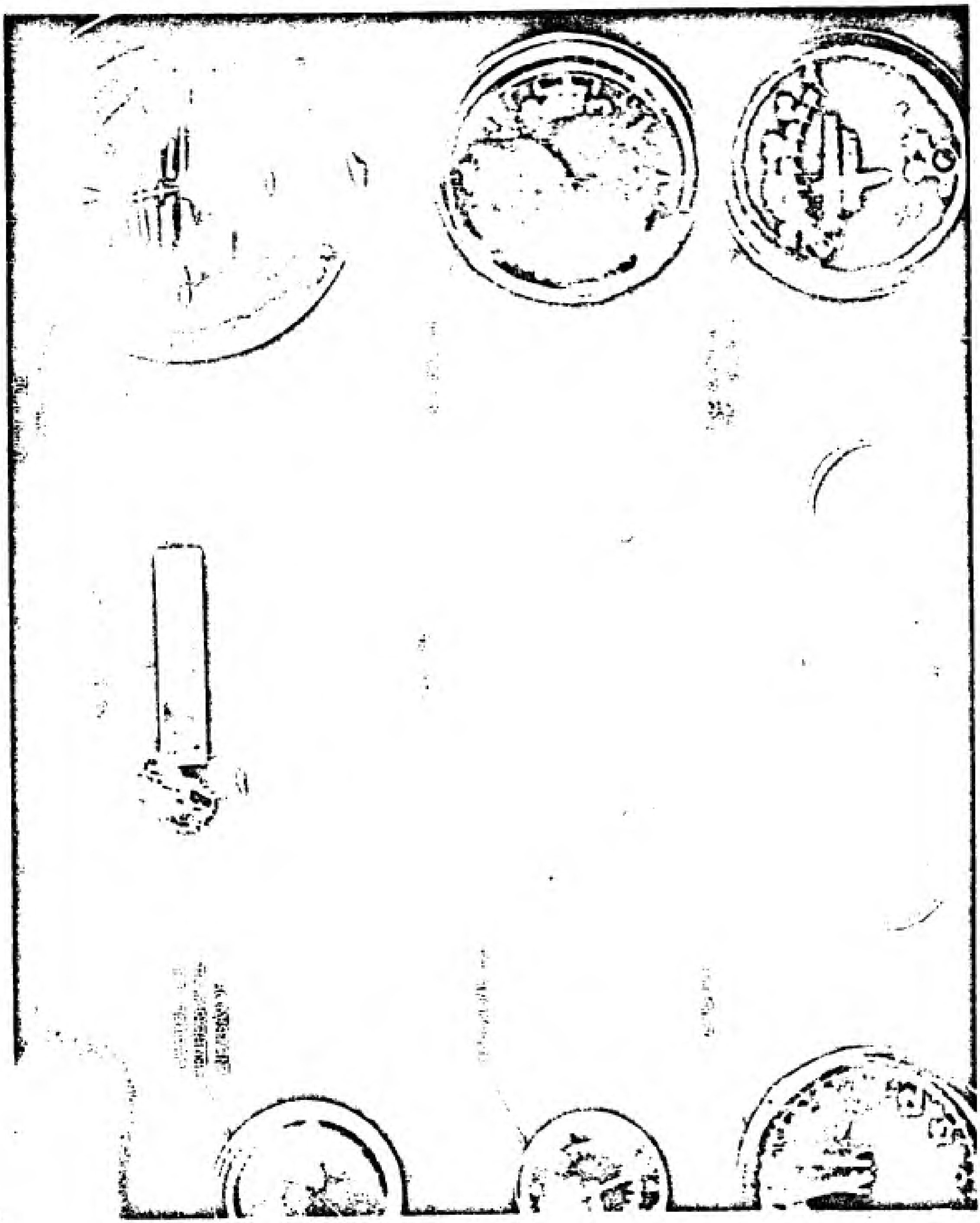
Navigator's Compartment Aboard P2V-2N, Showing 6-Channel Oscillograph

Figure 4
Appendix D

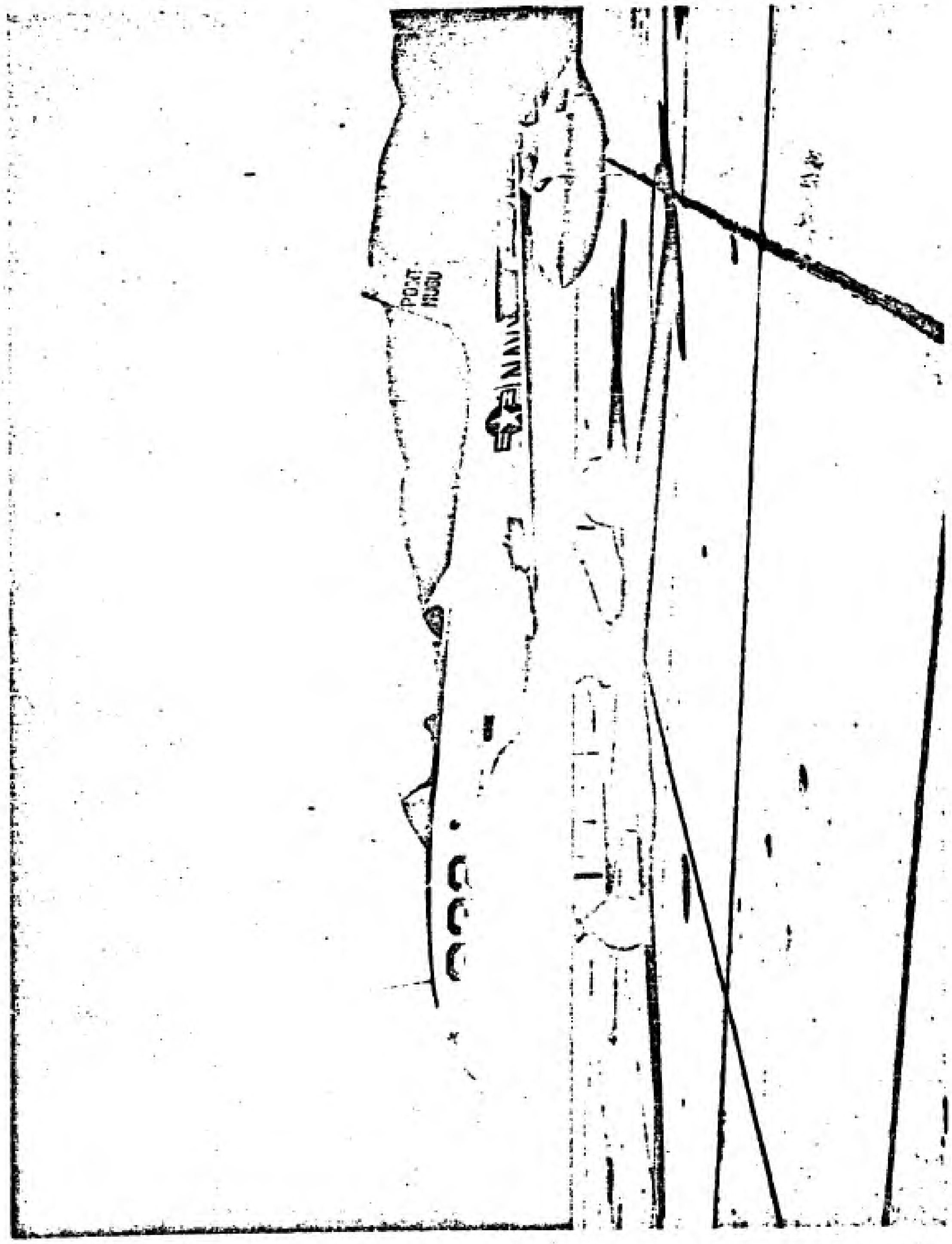
CONFIDENTIAL



Instrumentation Rack Containing Automatic Observer Panel

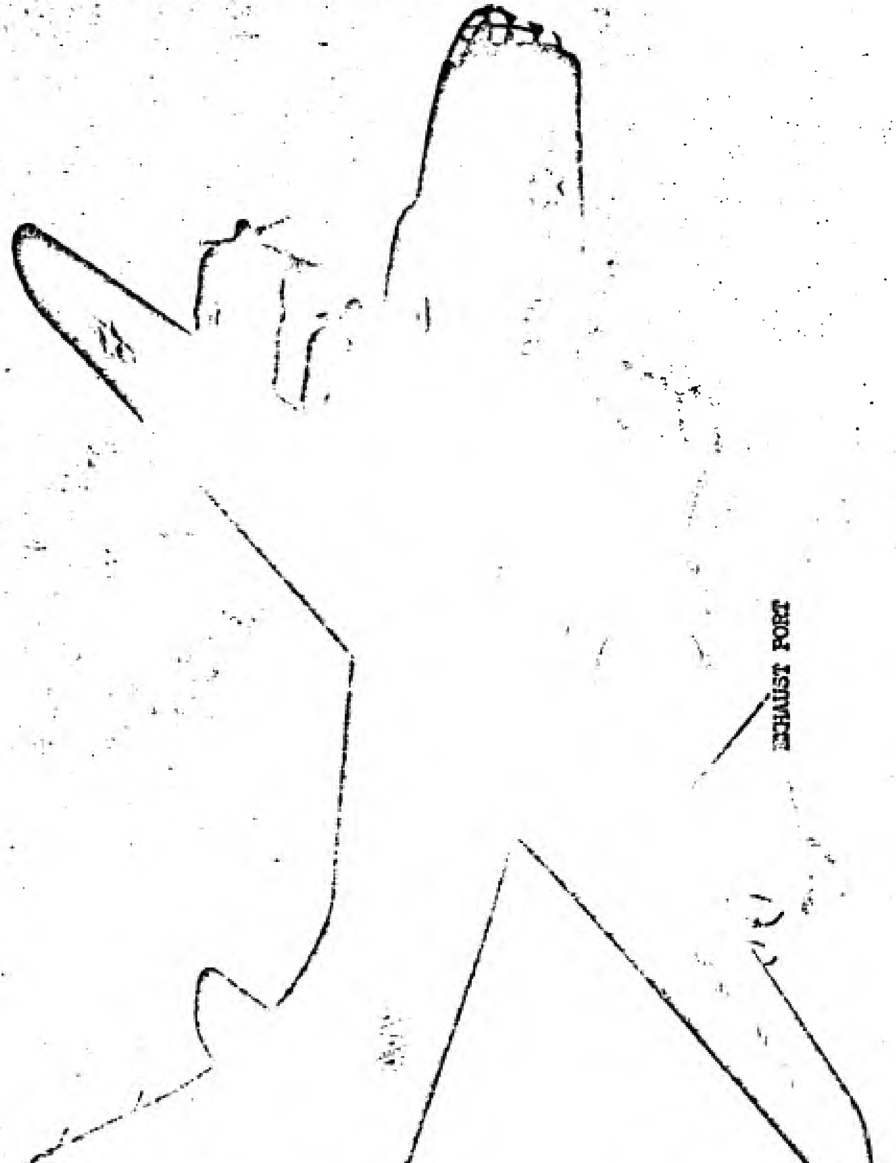


Film Data, Automatic-Observer Panel



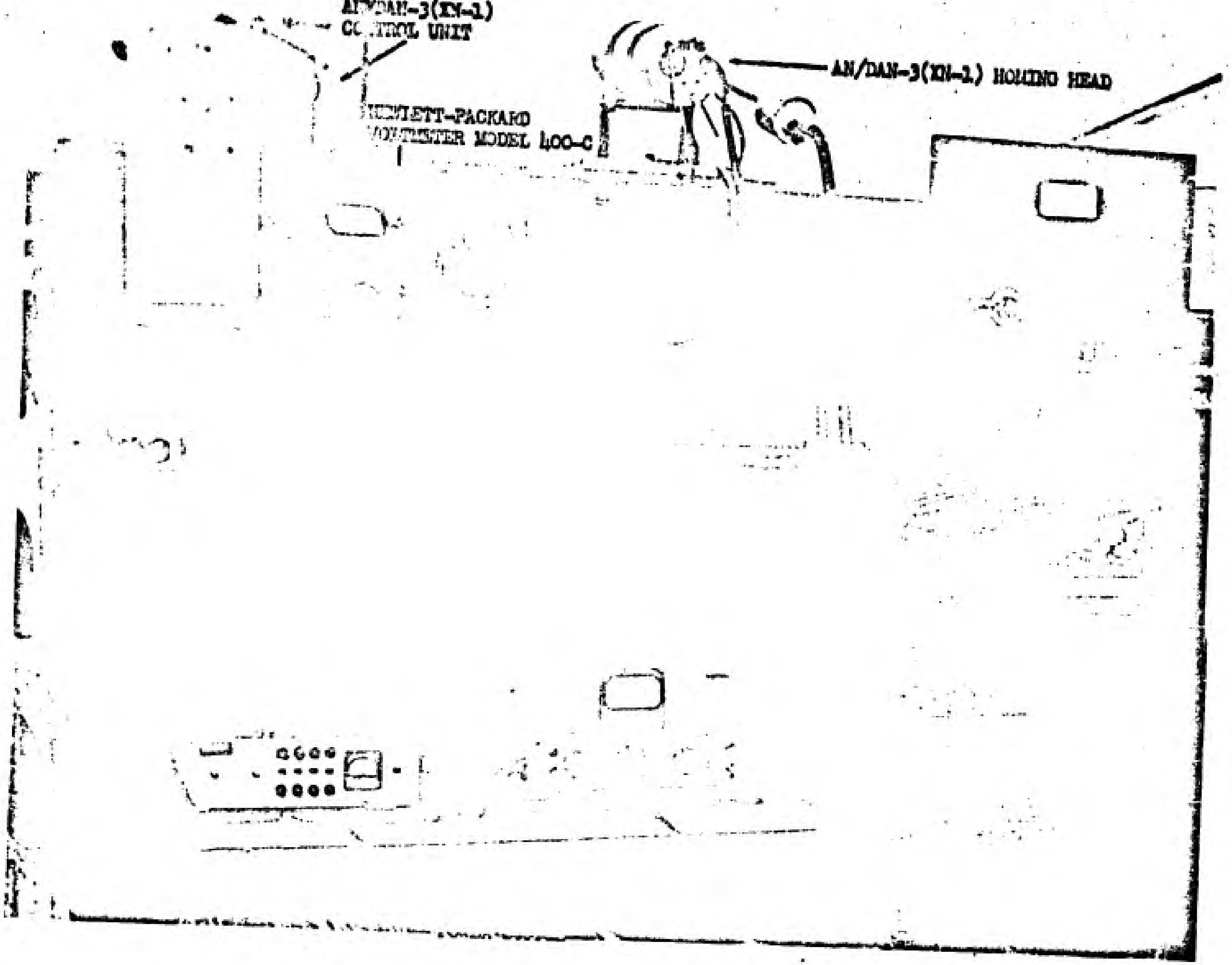
Target Plane TO-2 (Jet-Engine Type)

Figure 7



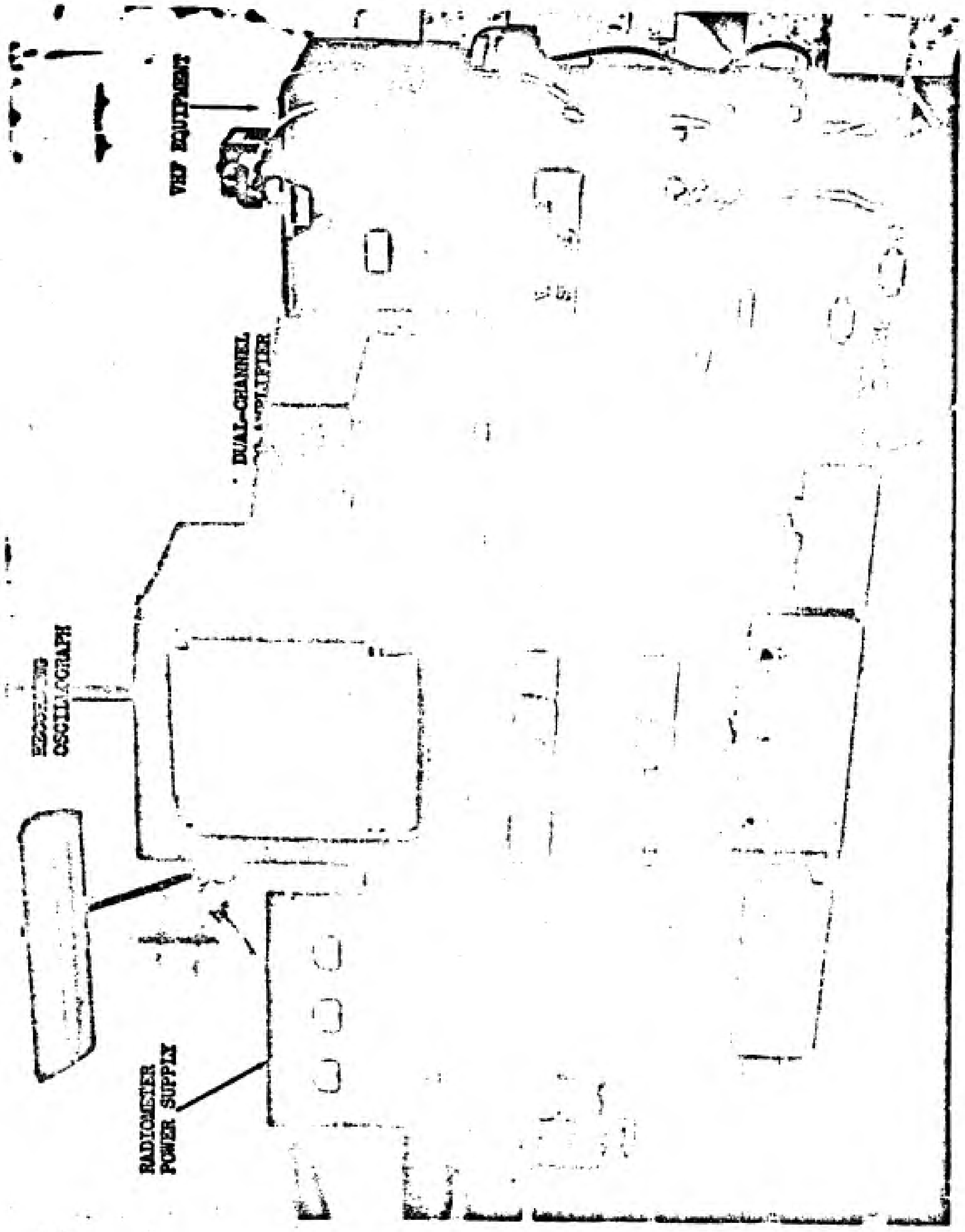
Target Plane PB4Y-2 (Reciprocating-Engine Type)

Figure 8
Appendix D
Page 68



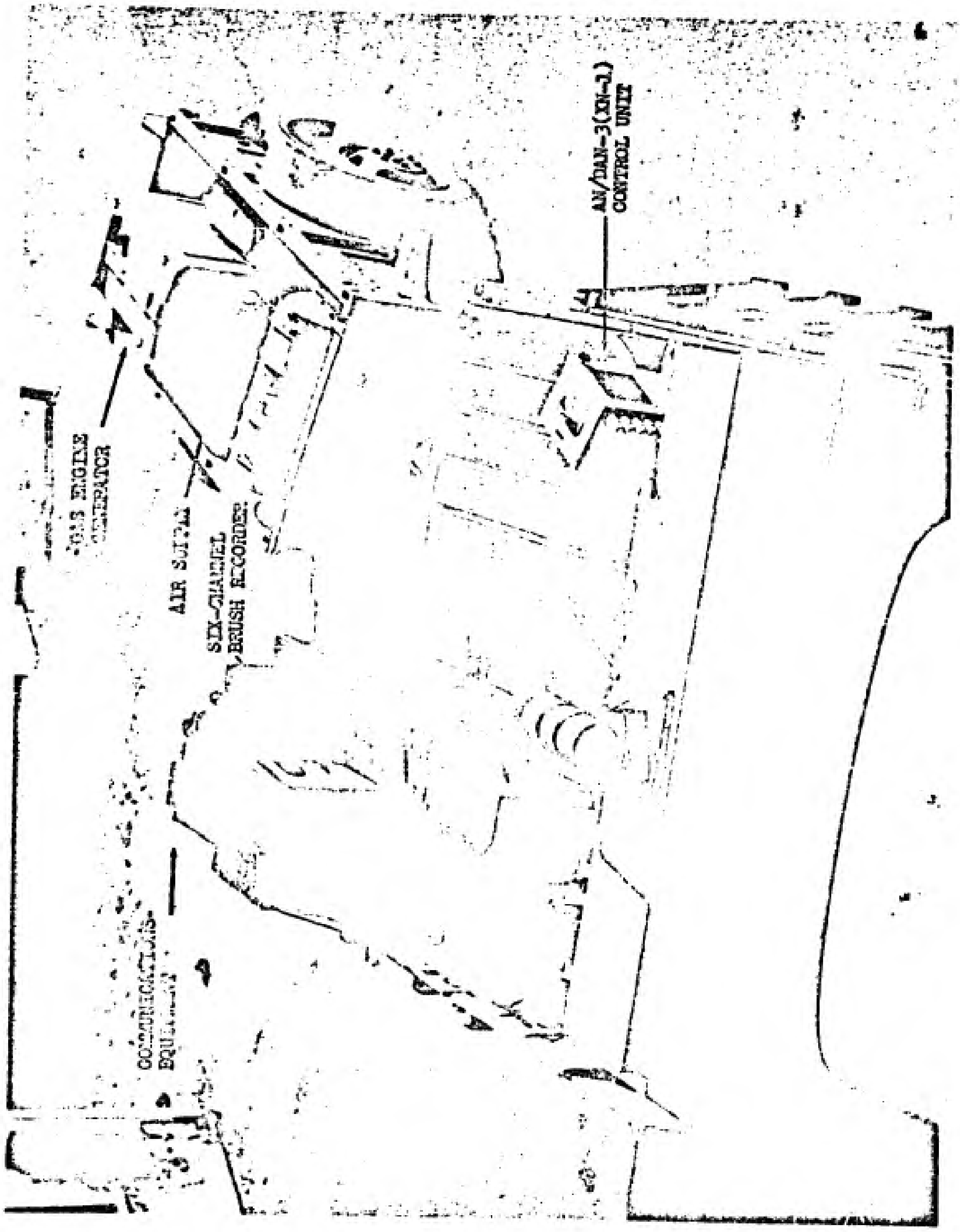
Instrumentation Setup on Front Rack of Truck
Used for Ground-to-Ground Tests

Figure 9
Appendix D



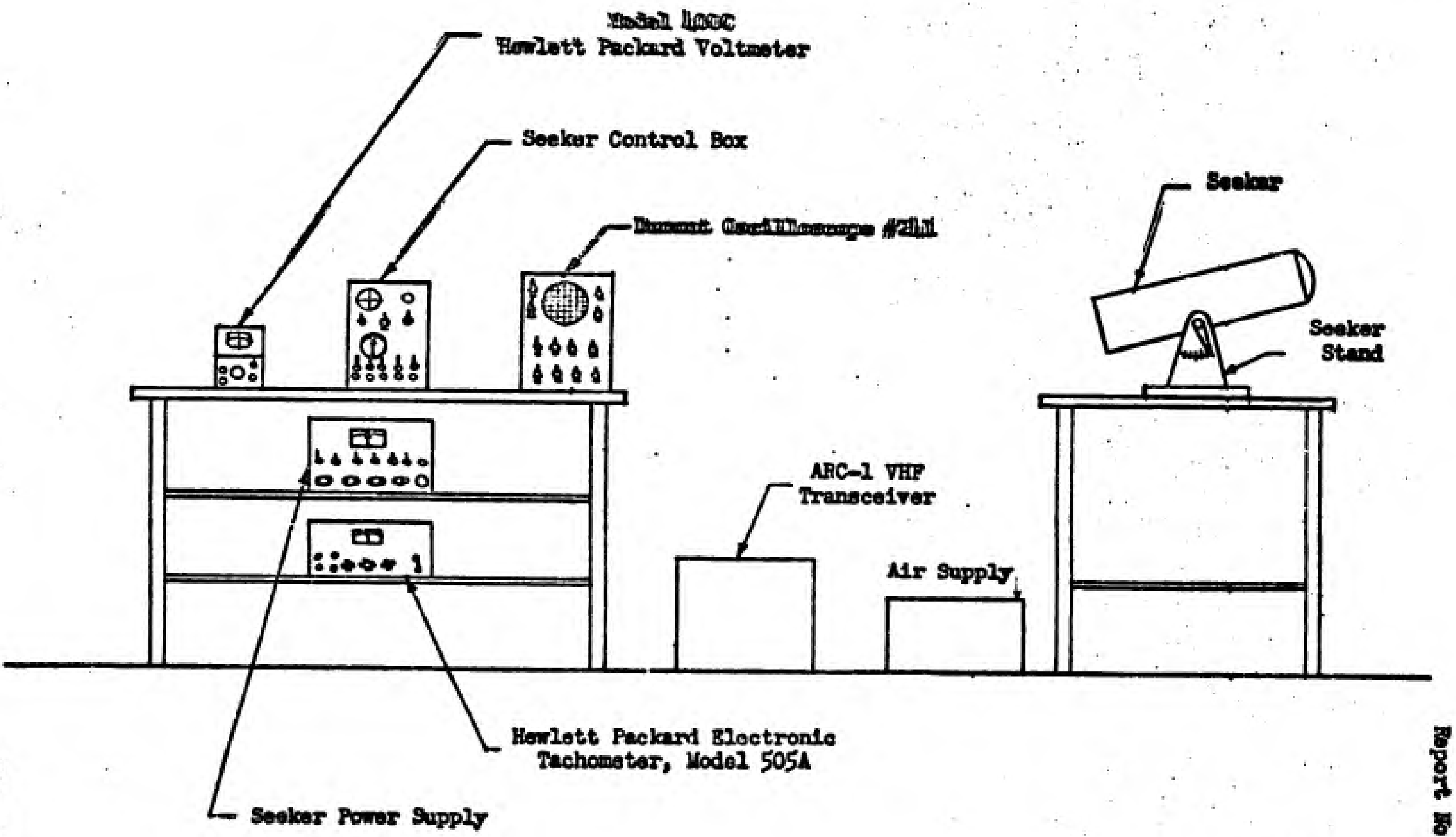
Instrumentation Setup on Side Bench of Truck Used for Ground-to-Ground Tests

Figure 10
Appendix D

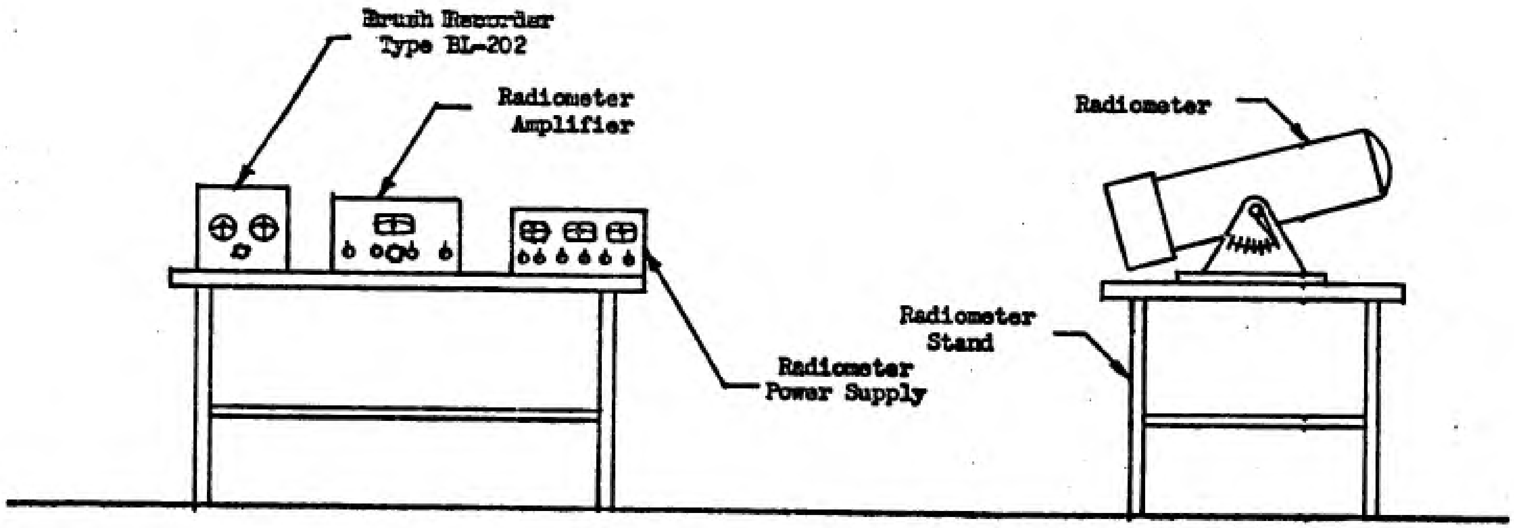


Truck and Trailer Assembly Used for Ground-to-Ground Tests

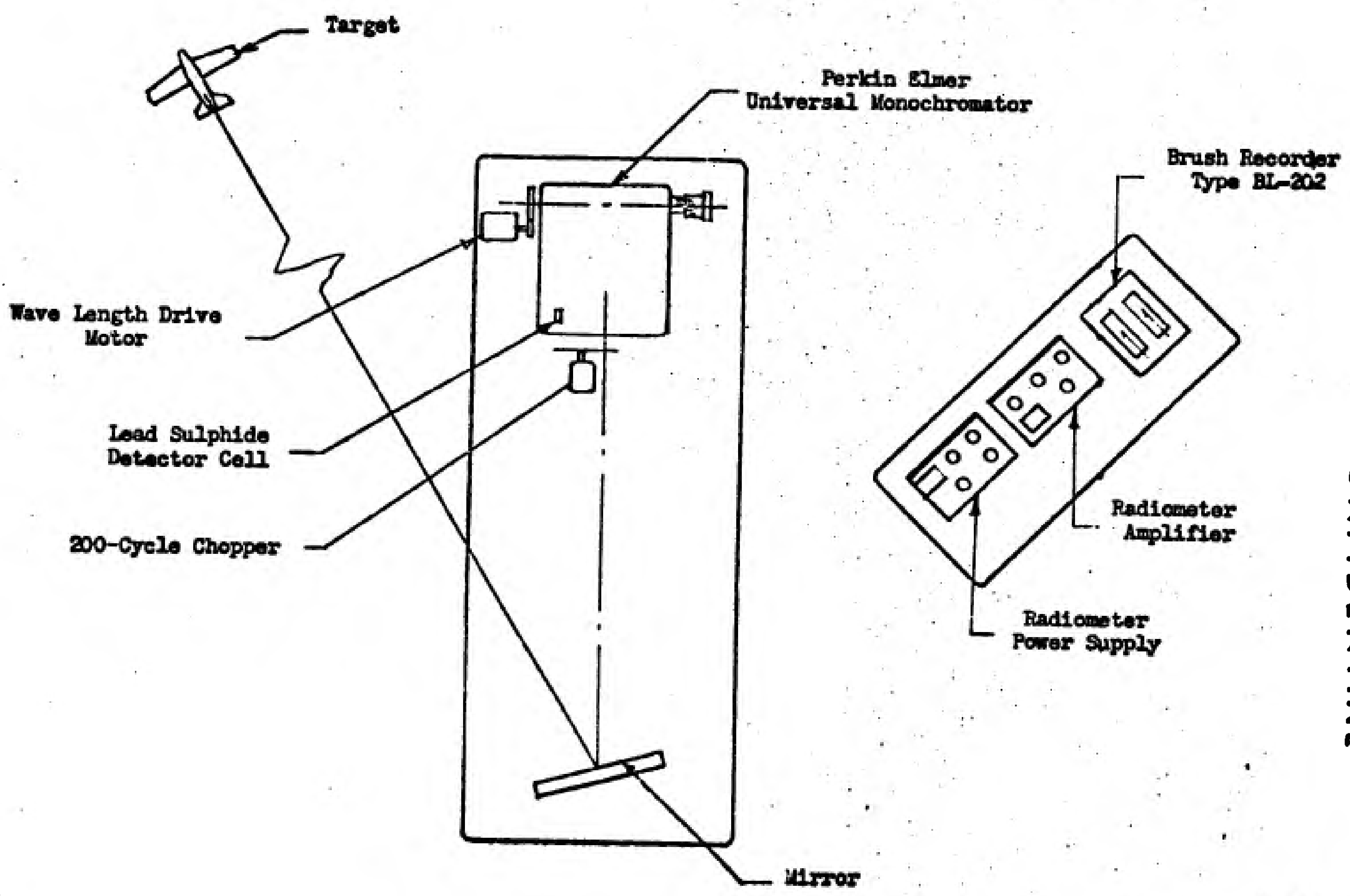
Figure 11



The AN/DAN-3(XN-1) and Instrumentation Setup for Ground Tests

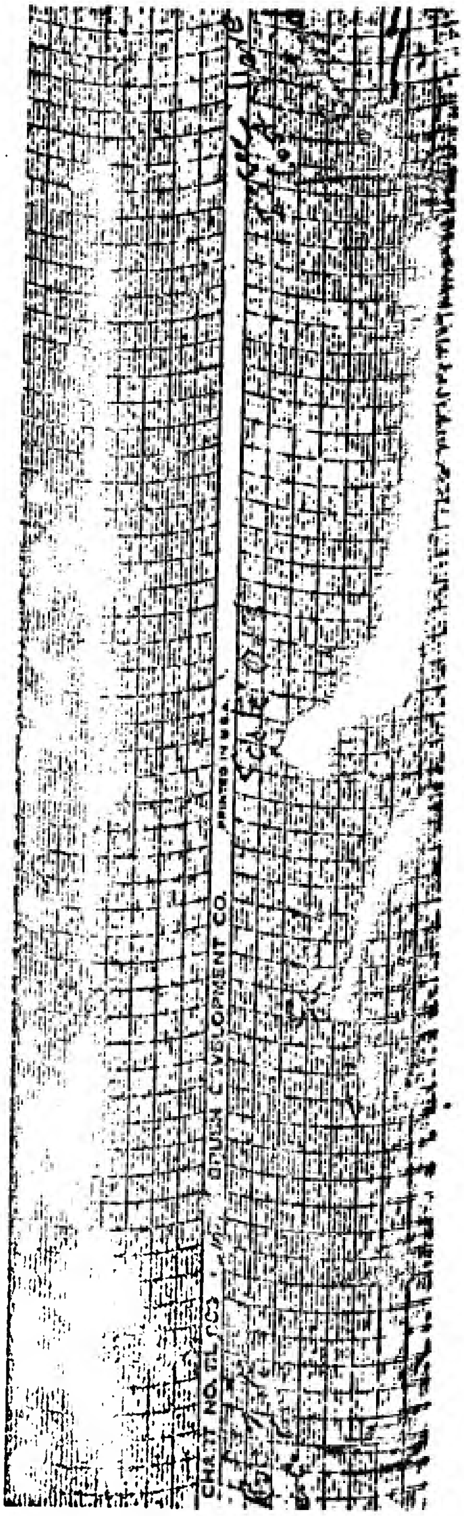


The Radiometer Test Assembly for Ground Tests



Monochromator Test Assembly for Ground Tests

Figure 14
Appendix D



Typical Brush Recording of Error-Signal Voltage Obtained in Ground Tests

Figure 15

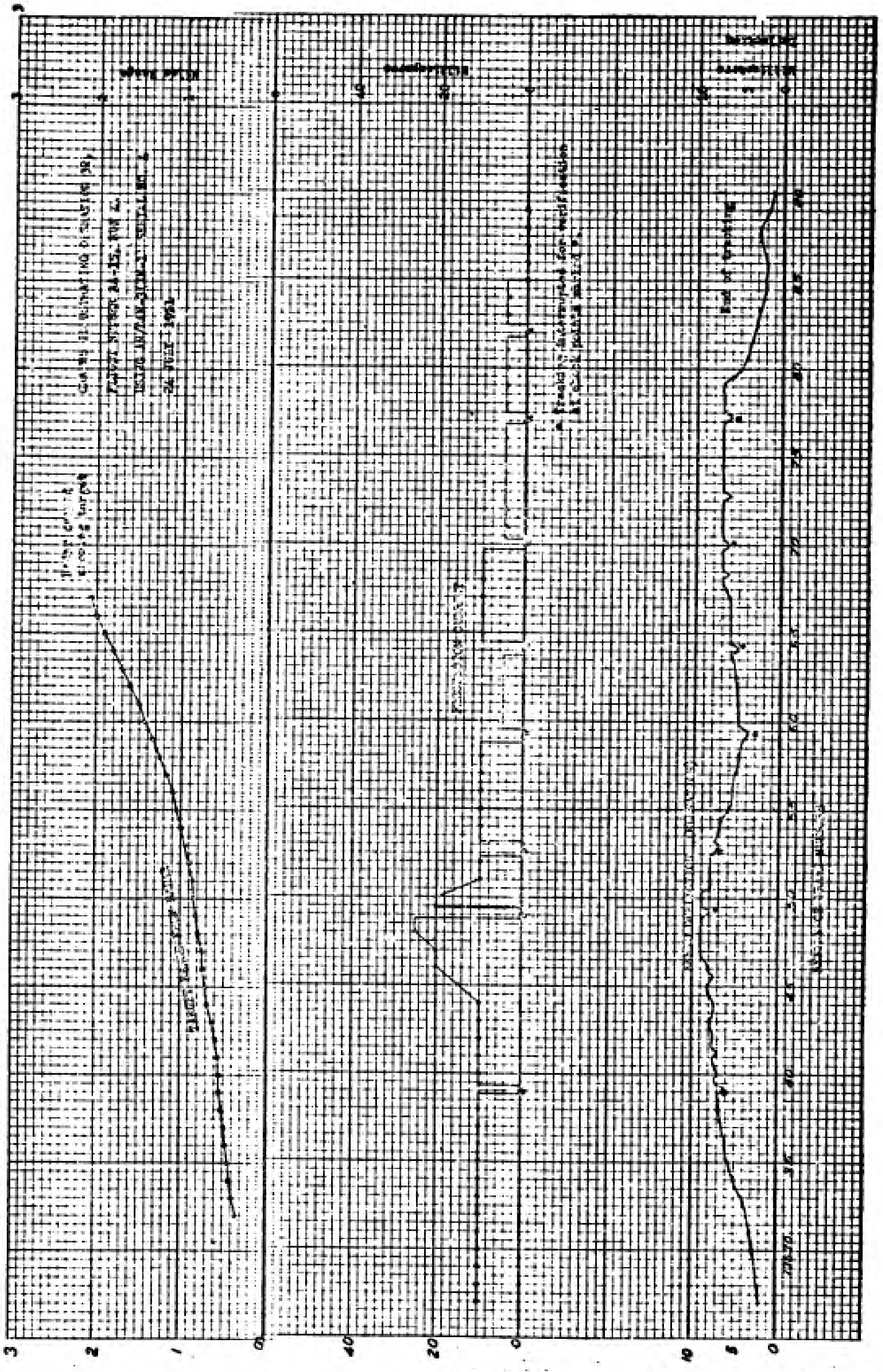

24 JULY 1951
End of tracking
* Tracking interrupted for verification at check points marked *.
0
1
2
3
0
20
40
0
5
10
35
40
45
50
55
60
65
70
75
80
85
90

Figure 16

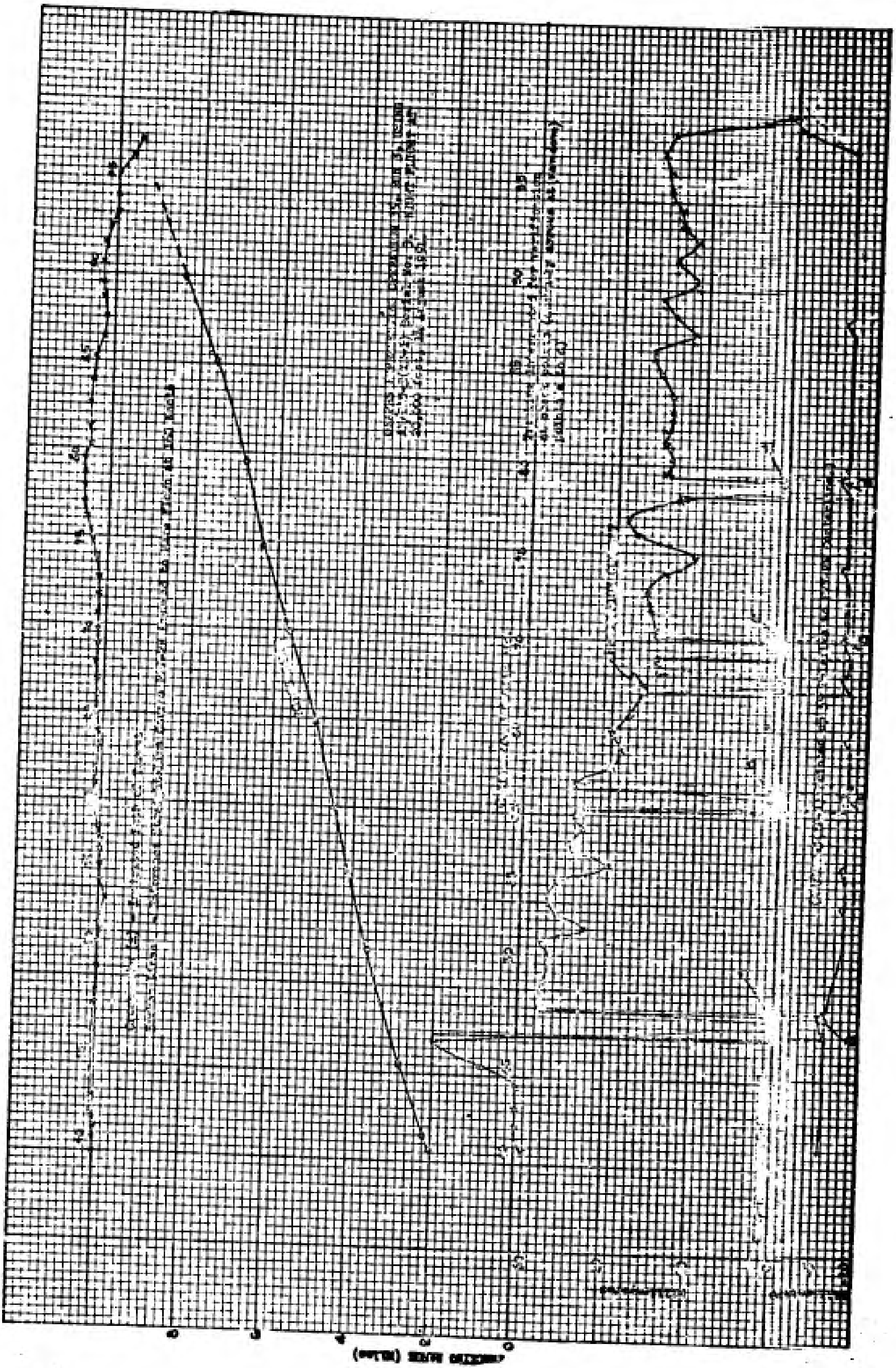


Figure 17
Appendix D

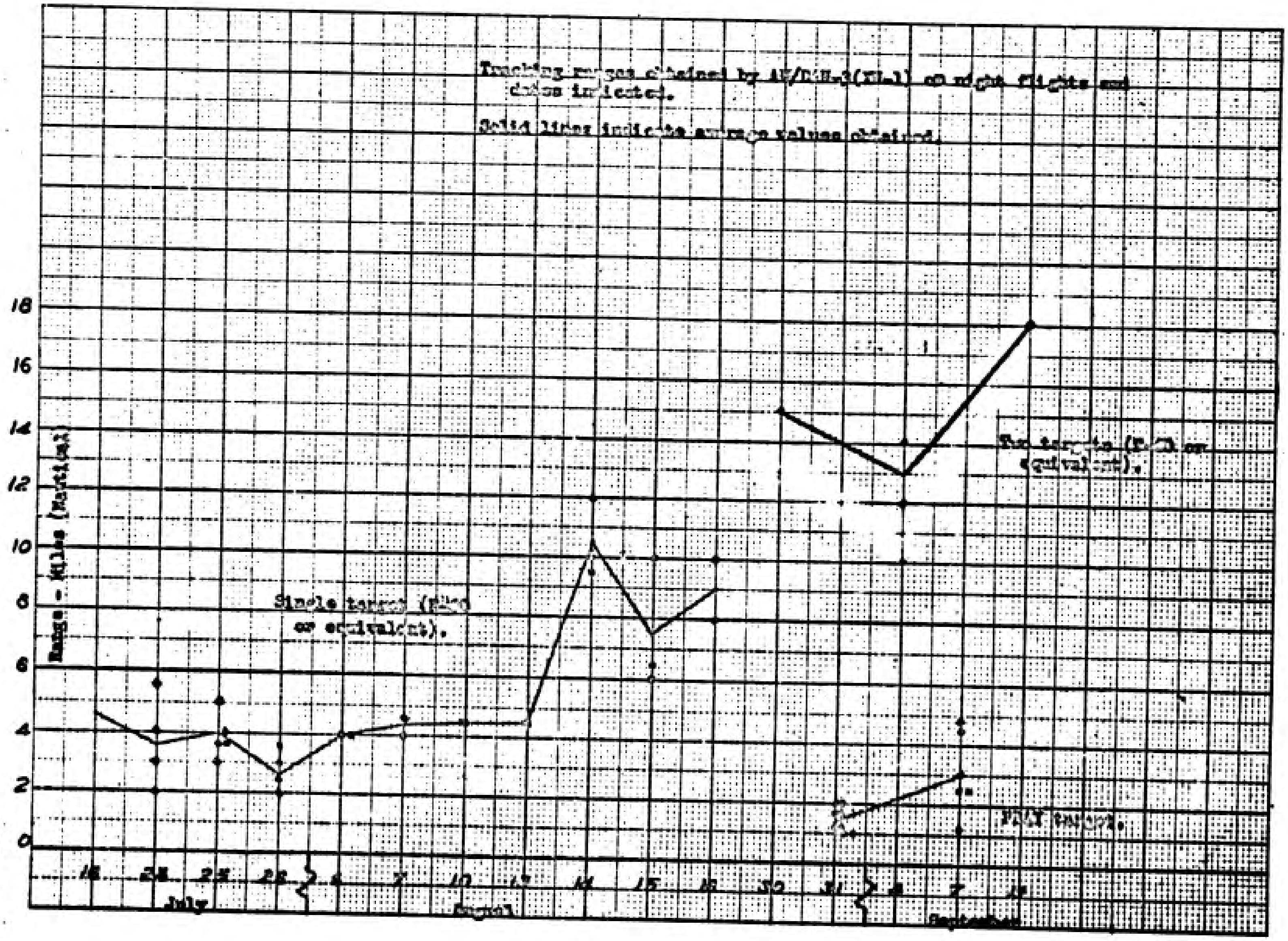


Figure 18
Appendix D

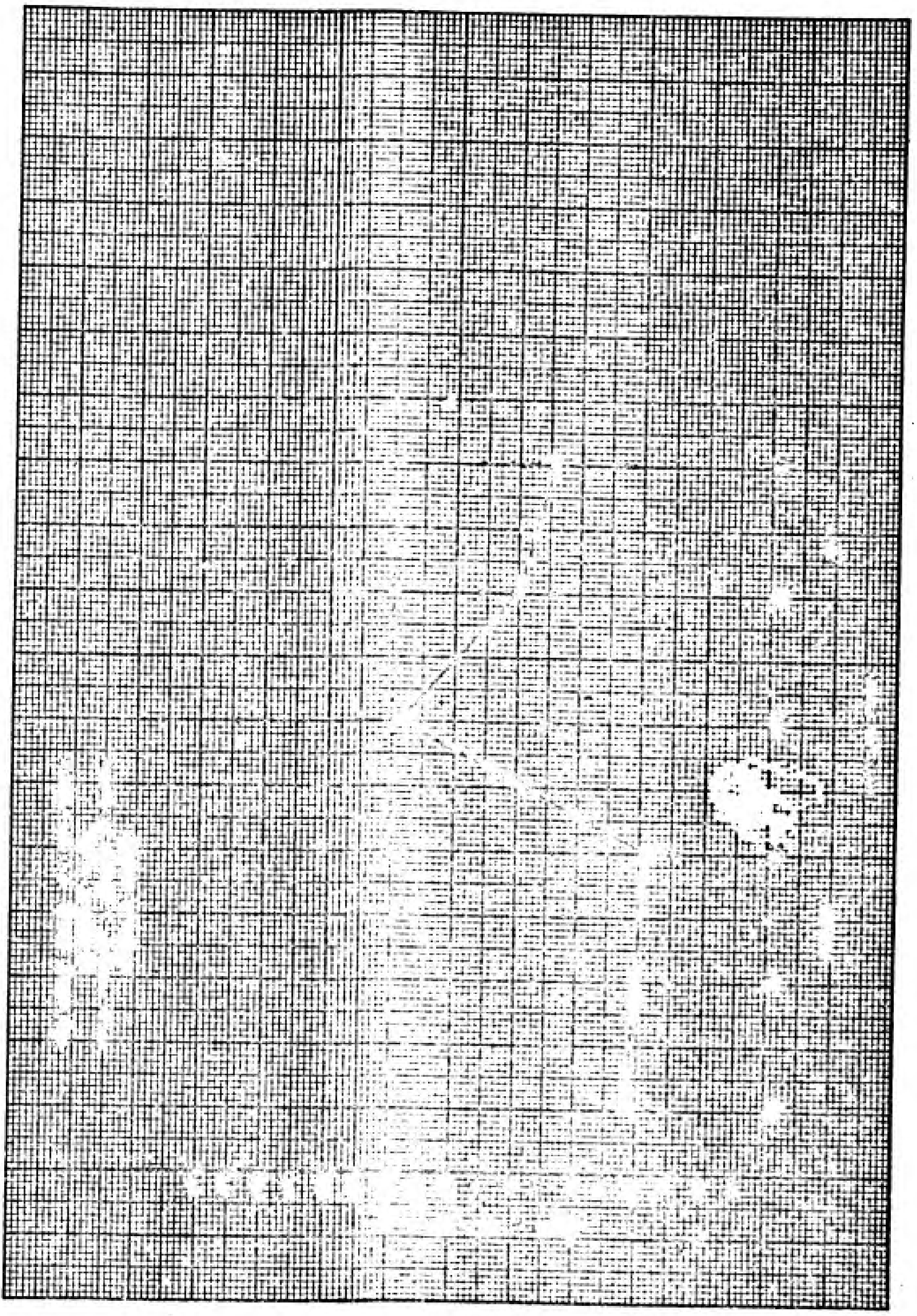


Figure 19

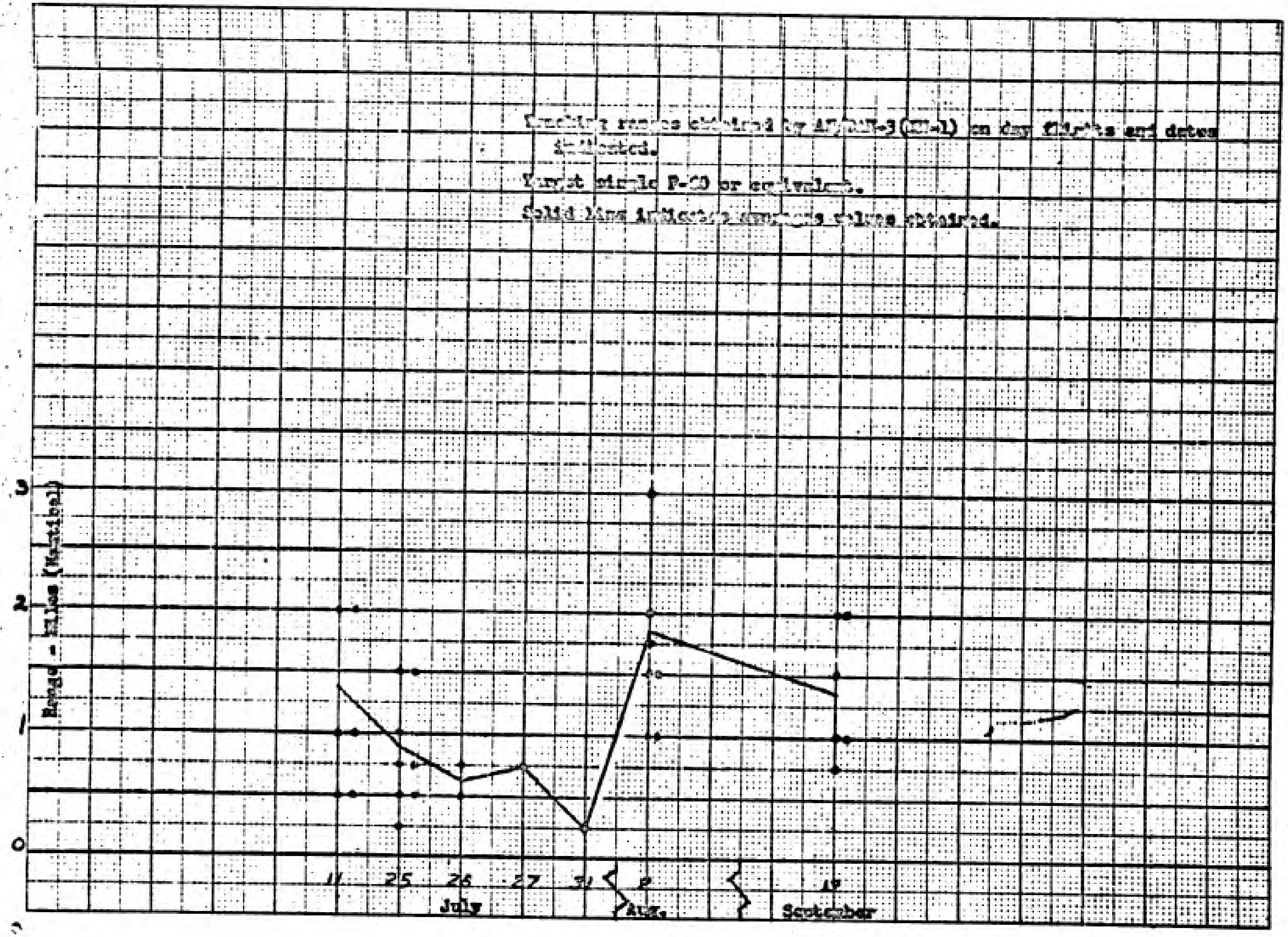


Figure 20
Appendix D

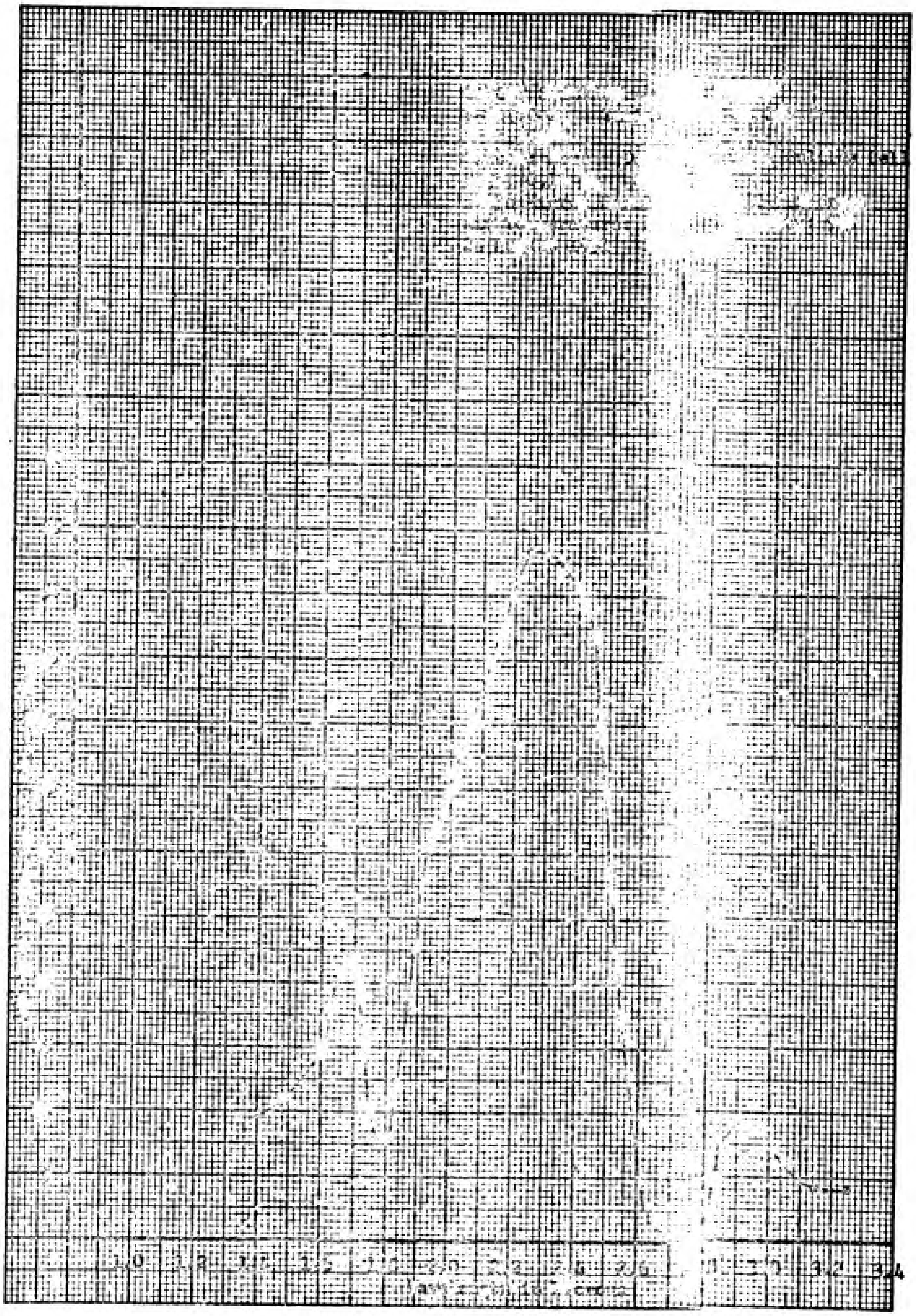


Figure 21

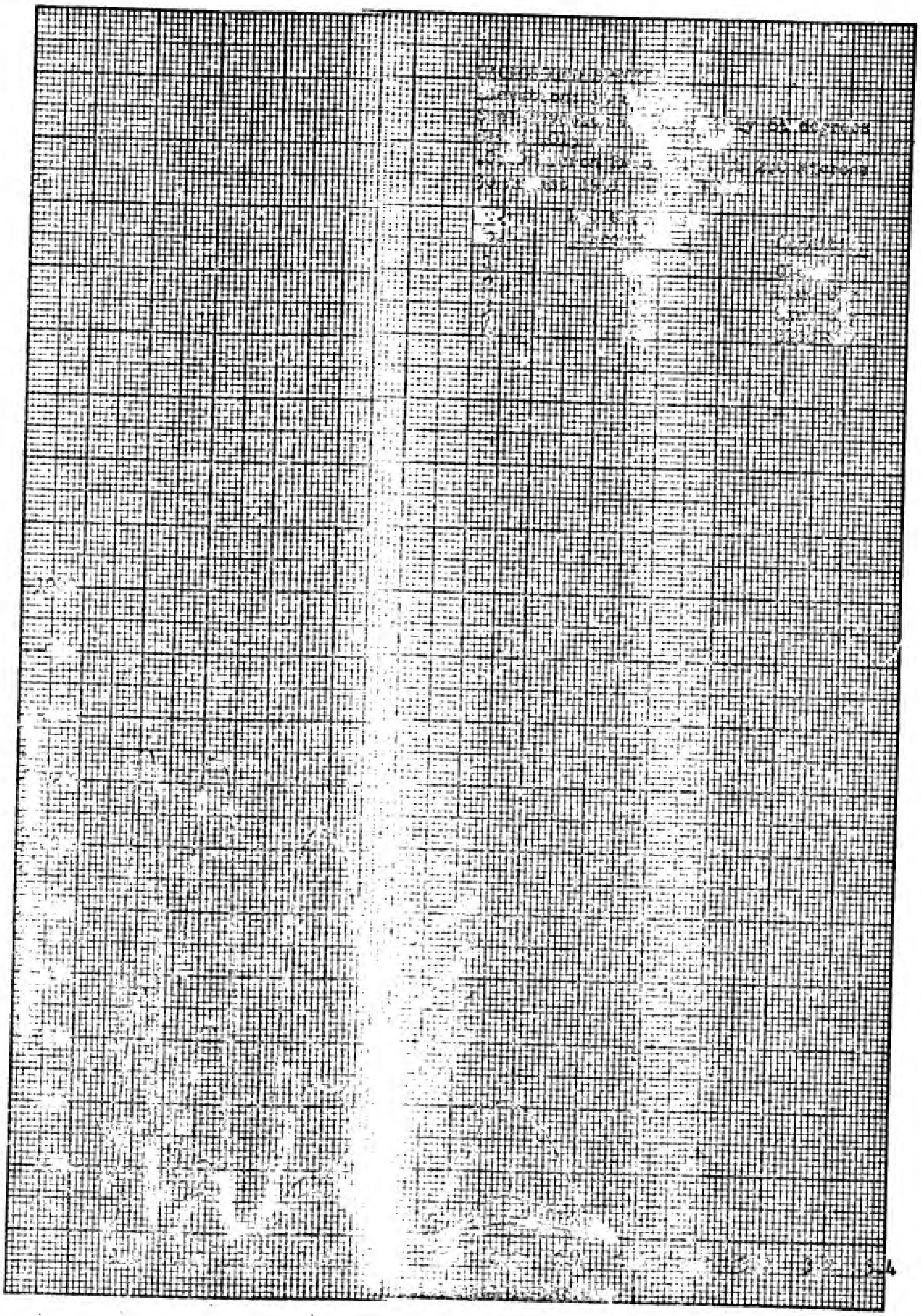


Figure 22
Appendix D

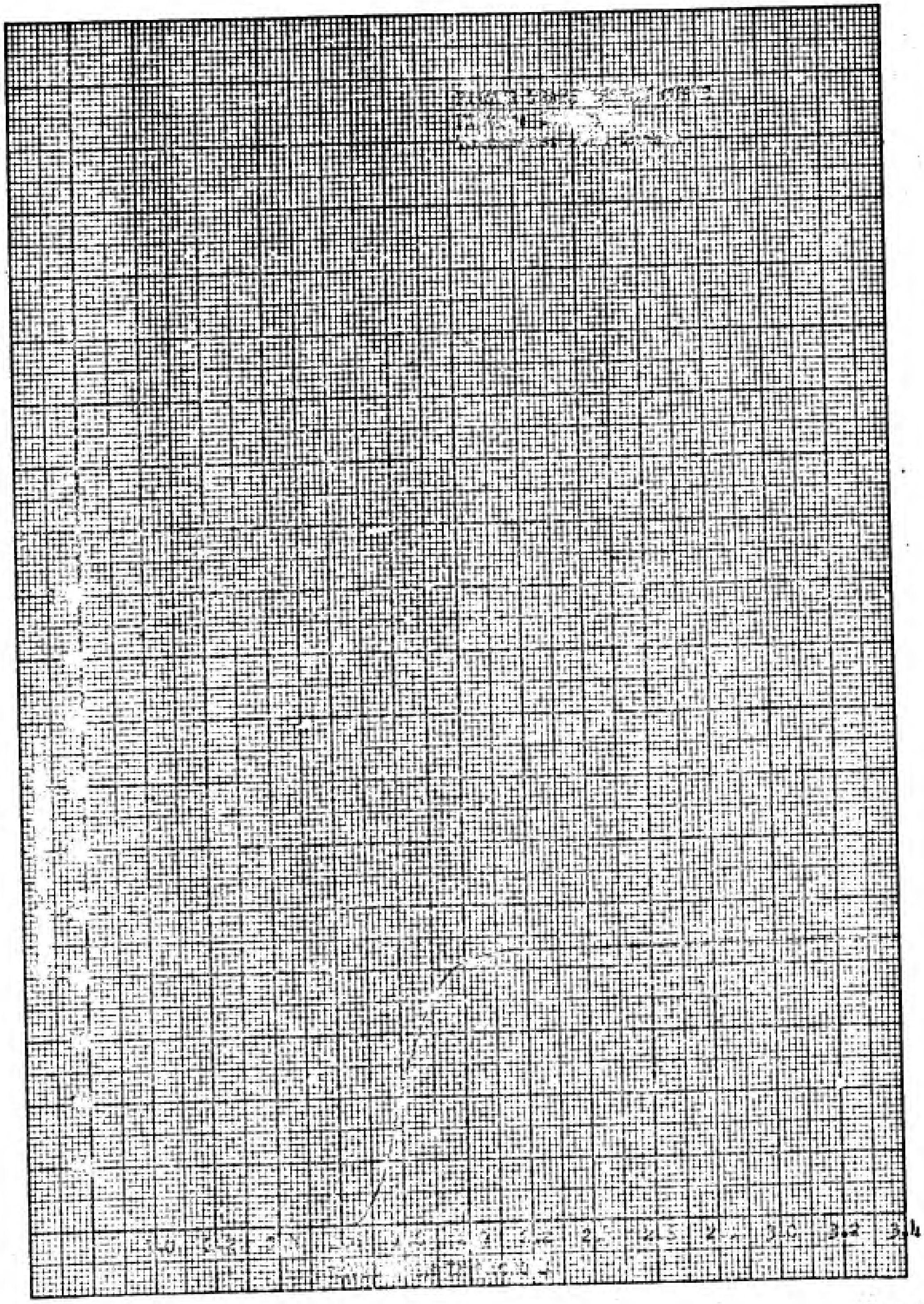
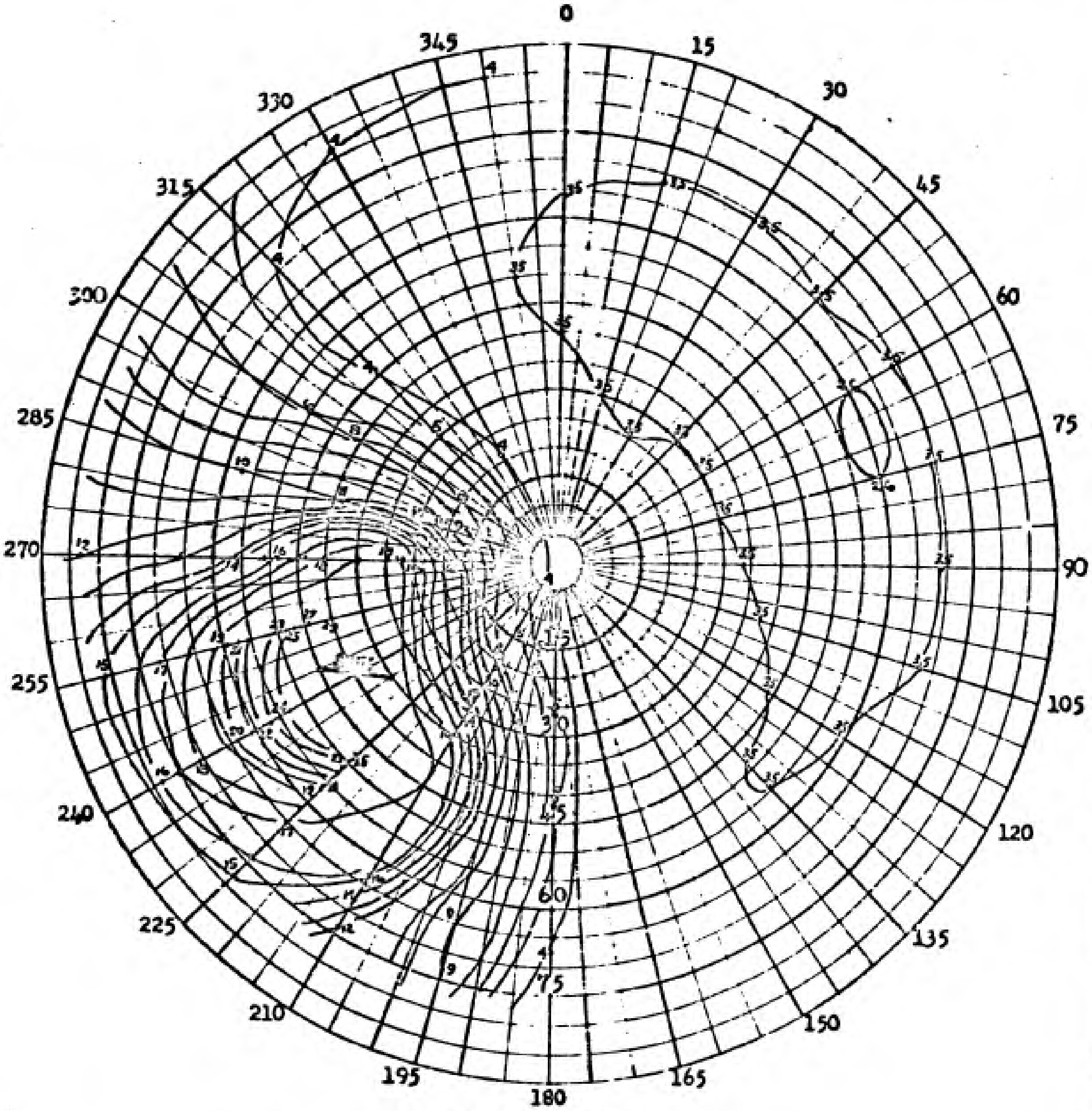


Figure 23

BLUE SKY MAP
INTENSITY CONTOURS

Report No. 546



RADIOMETER TESTS

TEST # 2 DATE 20 May 1951

TEMP. 25.5°C GAIN 10^3

CELL EASTMAN KODAK PbS

C . SIZE 1/8" SQUARE

FILTER # 7380 & # 4060

WEATHER LIGHT SMOG TO 2000'

PURPOSE DETERMINE SKY RADIATION INTENSITY

TIME: Start 1430 Finish 1630

SUN ANGLE: Start - Elev. 35° Azimuth 235°

Finish - Elev. 45° Azimuth 245°

NOTES READINGS ARE PEAK VOLTS x 10^{-3}

Figure 24

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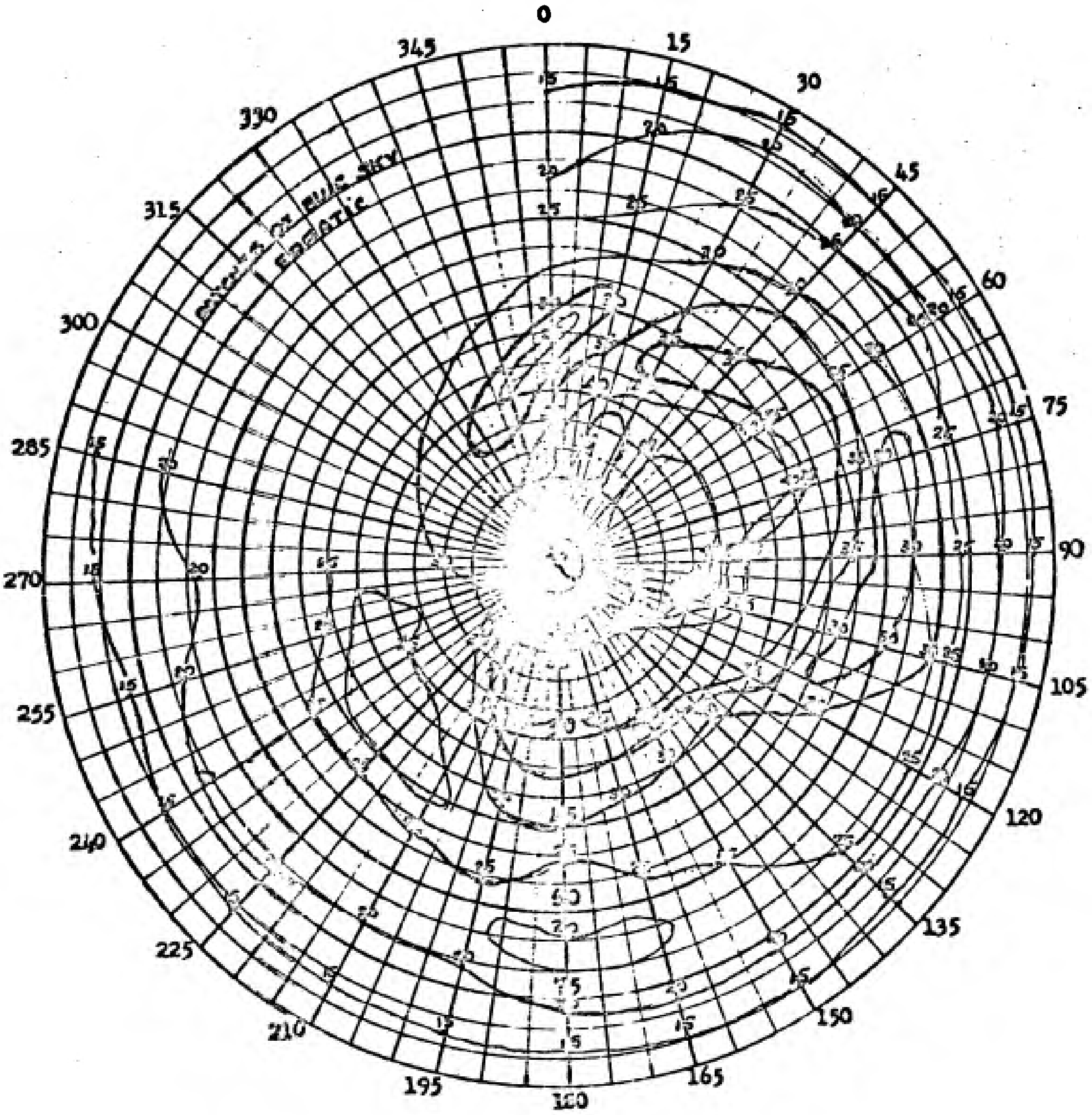
Report No. 546

OVERCAST SKY MAP
INTENSITY CONTOURS



RADIOMETER TESTS

TEST # 4 DATE 22 May 1951

TEMP. 22°C GAIN 10^2

CELL Eastman Kodak PbS

C. SIZE 1/8" Square

FILTER #7380 and #4060

WEATHER Overcast - cloud patches

PURPOSE Test Overcast Skies

TIME: Start 1027 Finish 1148

SUN ANGLE: Start - Elev. 32 Azimuth 95

Finish - Elev. 22 Azimuth 105

NOTES Readings are peak volts x 10^{-2}

Minor variations ± 2 volts over sky

Figure 25
Appendix D

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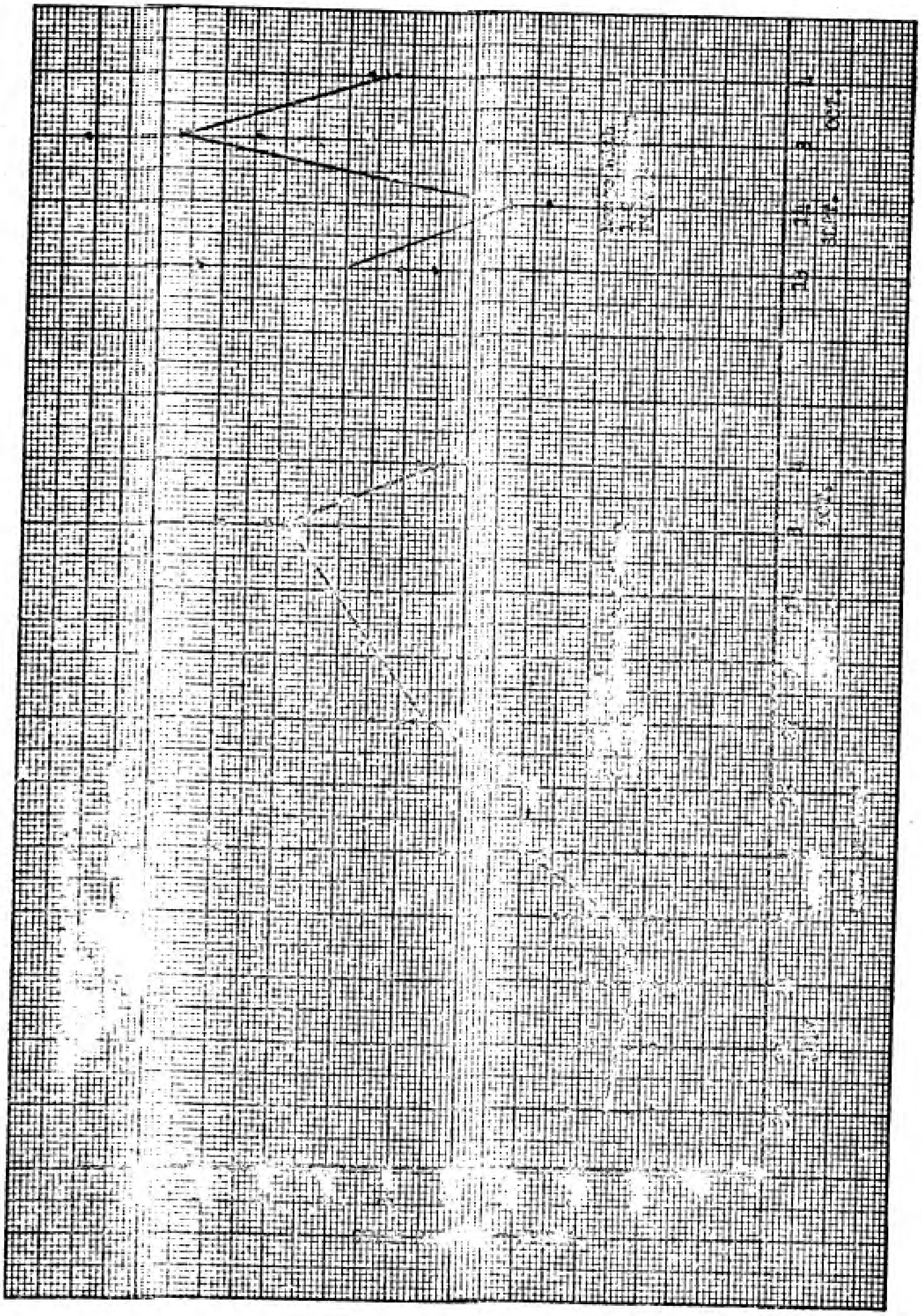


Figure 26
Appendix D
Page 86

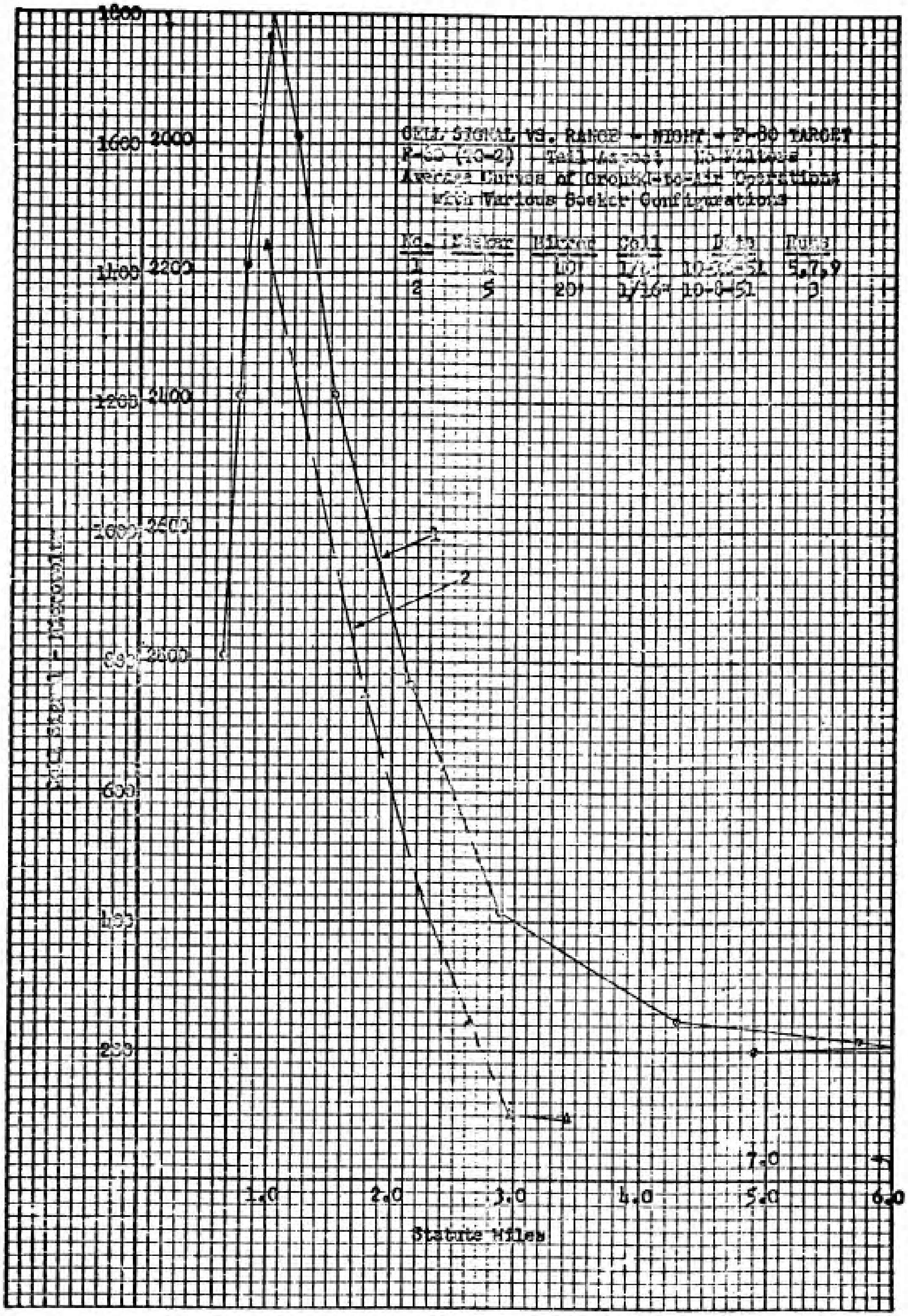
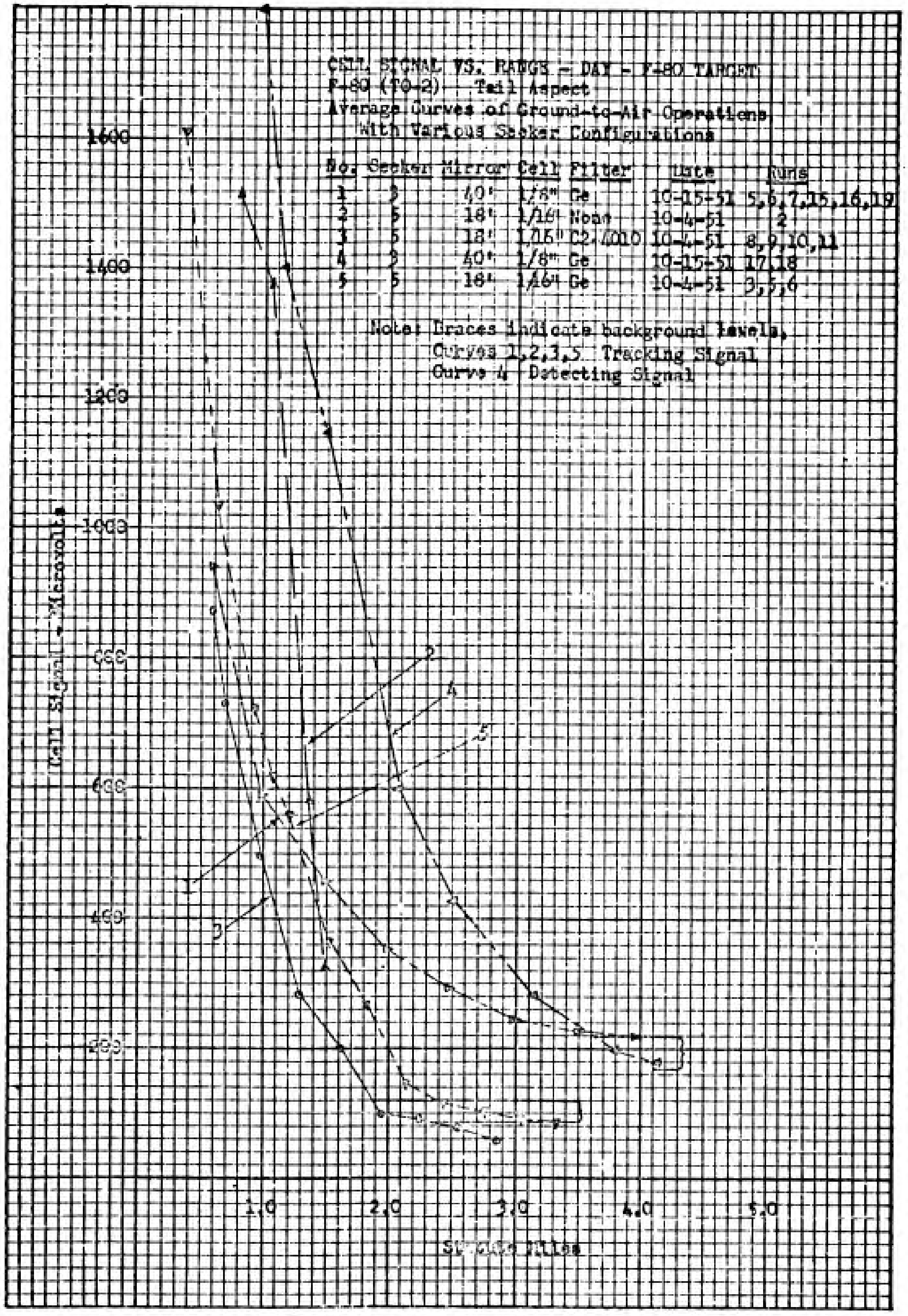


Figure 27
Appendix D



CELL SIGNAL VS. RANGE - DAY - F-80 TARGET
F-80 (TO-2) Tail Aspect
Average Curves of Ground-to-Air Operations
With Various Seeker Configurations

No.	Seeker	Mirror	Cell	Filter	Date	Runs
1	3	40"	1/8"	Ge	10-15-51	5,6,7,15,16,19
2	5	18"	1/16"	None	10-4-51	2
3	5	18"	1/16"	C2 4010	10-4-51	8,9,10,11
4	3	40"	1/8"	Ge	10-15-51	17,18
5	5	18"	1/16"	Ge	10-4-51	3,5,6

Note: Braces indicate background levels,
Curves 1,2,3,5 Tracking Signal
Curve 4 Detecting Signal

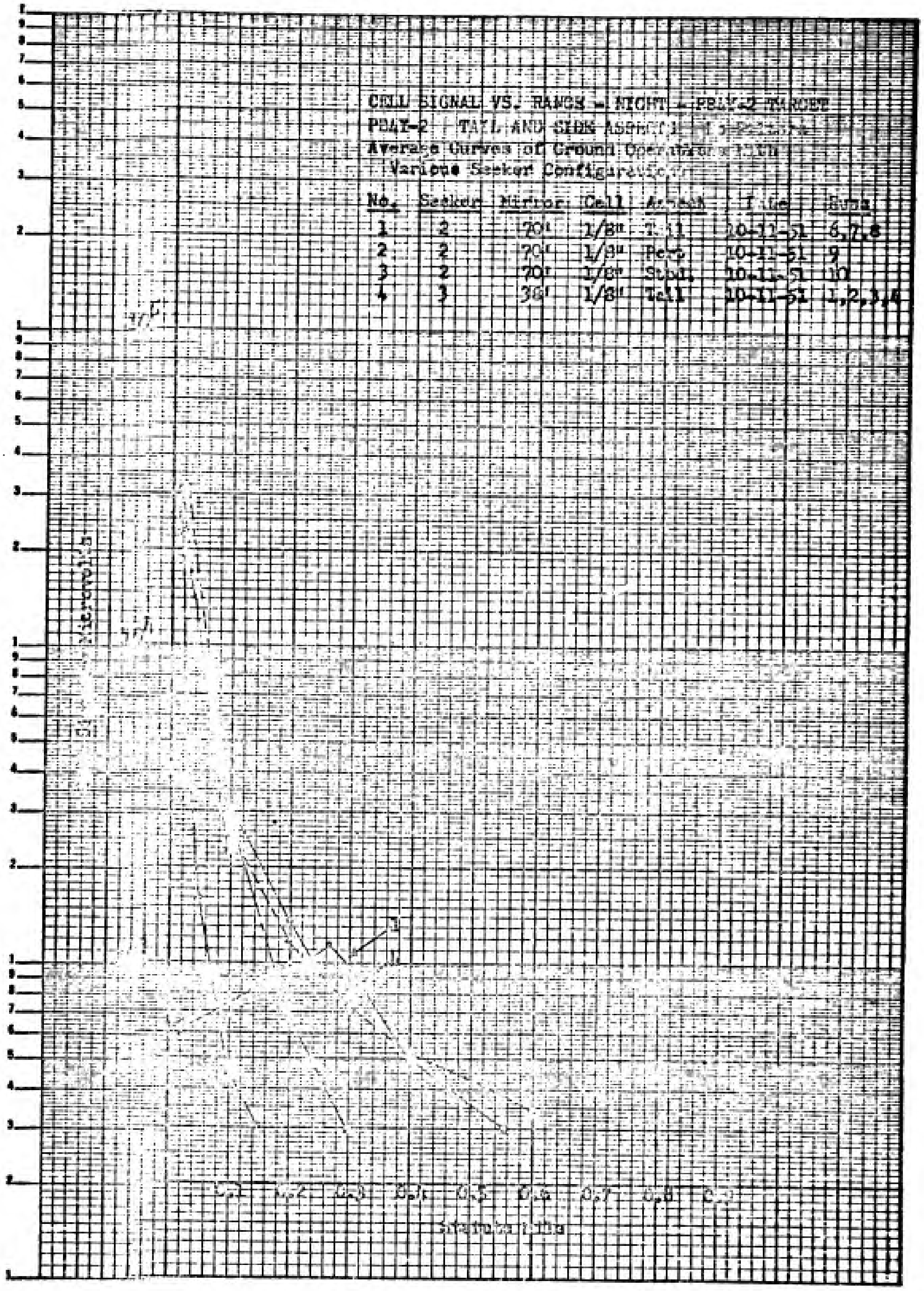


Figure 29
Appendix D

CELL SIGNAL VS. RANGE - NIGHT - F-80 TARGET
F-80 (TC-2) Tail and Side Aspects No Filters
Average Curves of Ground Operations With Various
Seeker Configurations

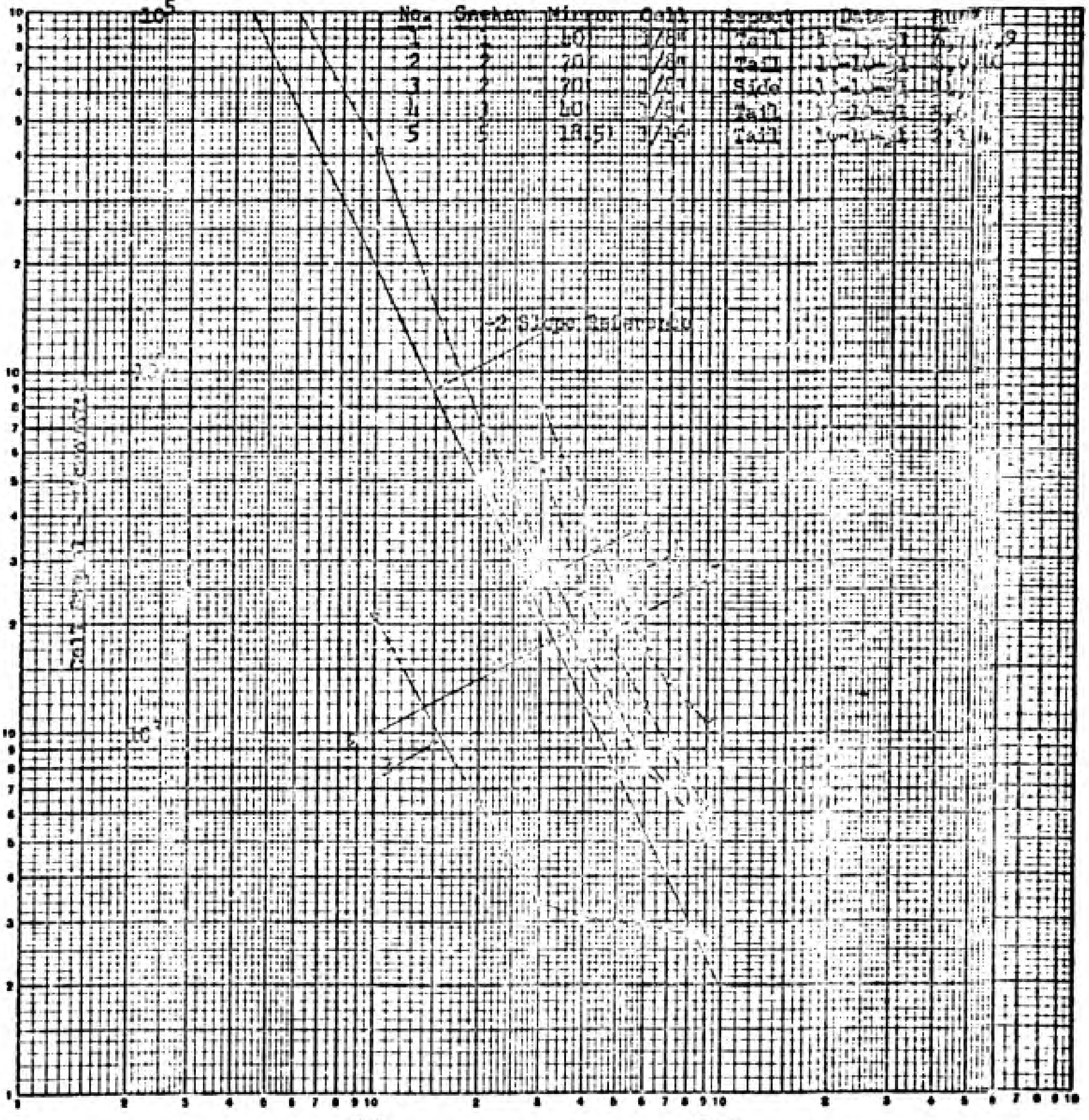
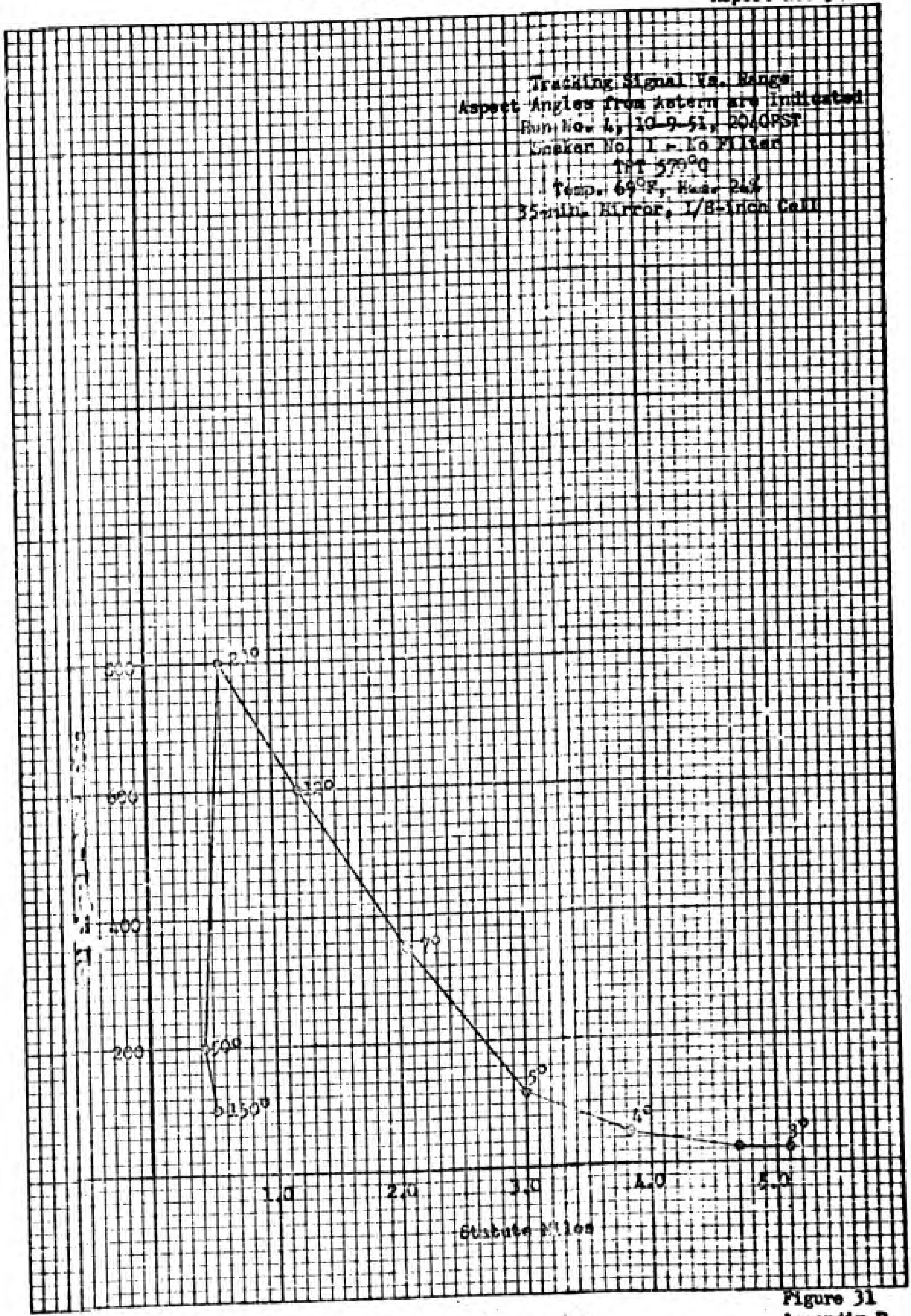
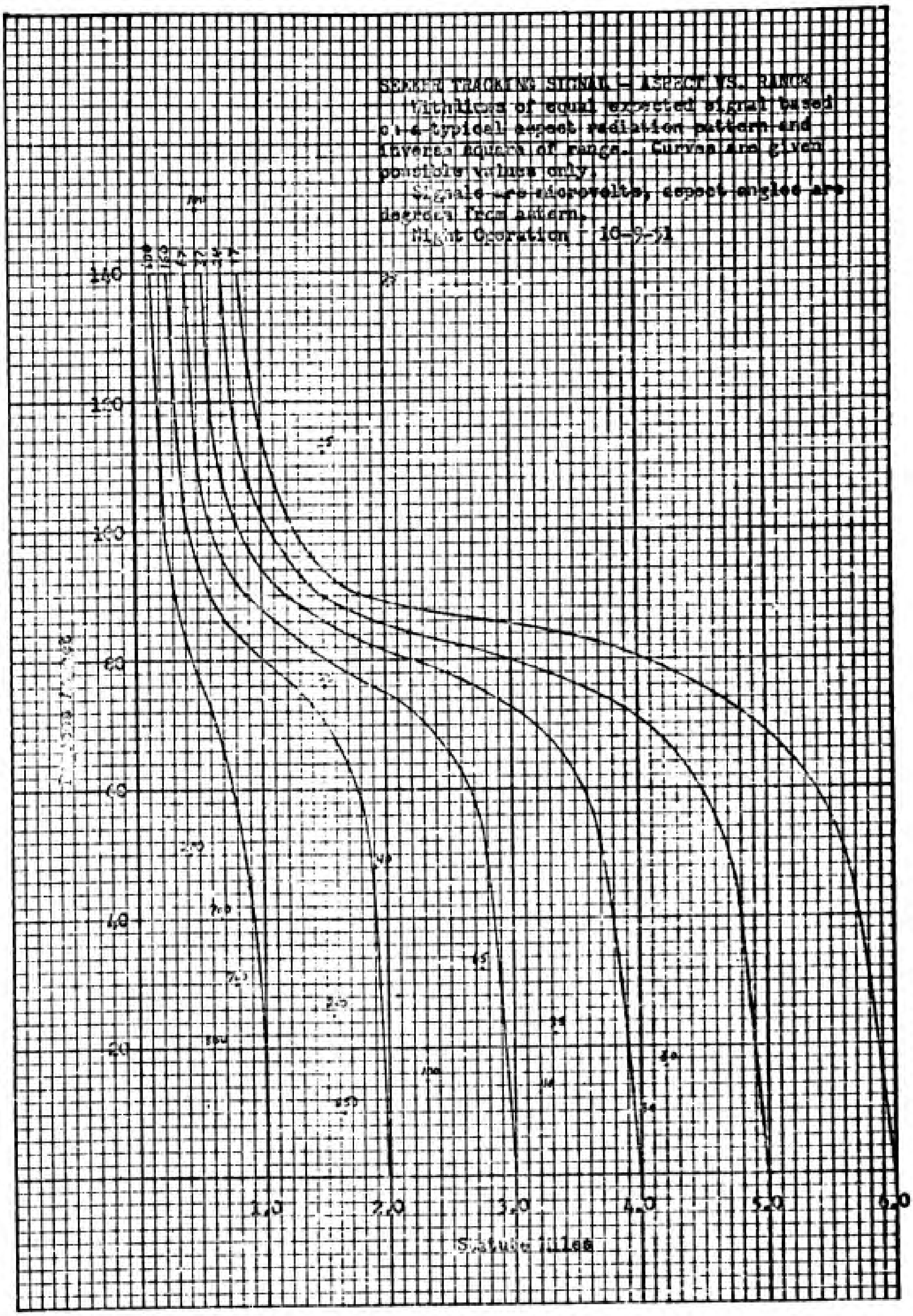


Figure 30
Appendix D
Page 90


Tracking Signal Vs. Range
Aspect Angles from Astern are Indicated
Run No. 4, 10-9-51, 2040PST
Snaker No. 1 - No Filter
TPT 579°C
Temp. 64°F, Hum. 24%
35-min. Mirror, 1/8-inch Cell
800
600
400
200
21°
12°
7°
5°
4°
3°
50°
150°
1.0
2.0
3.0
4.0
5.0
Statute Miles



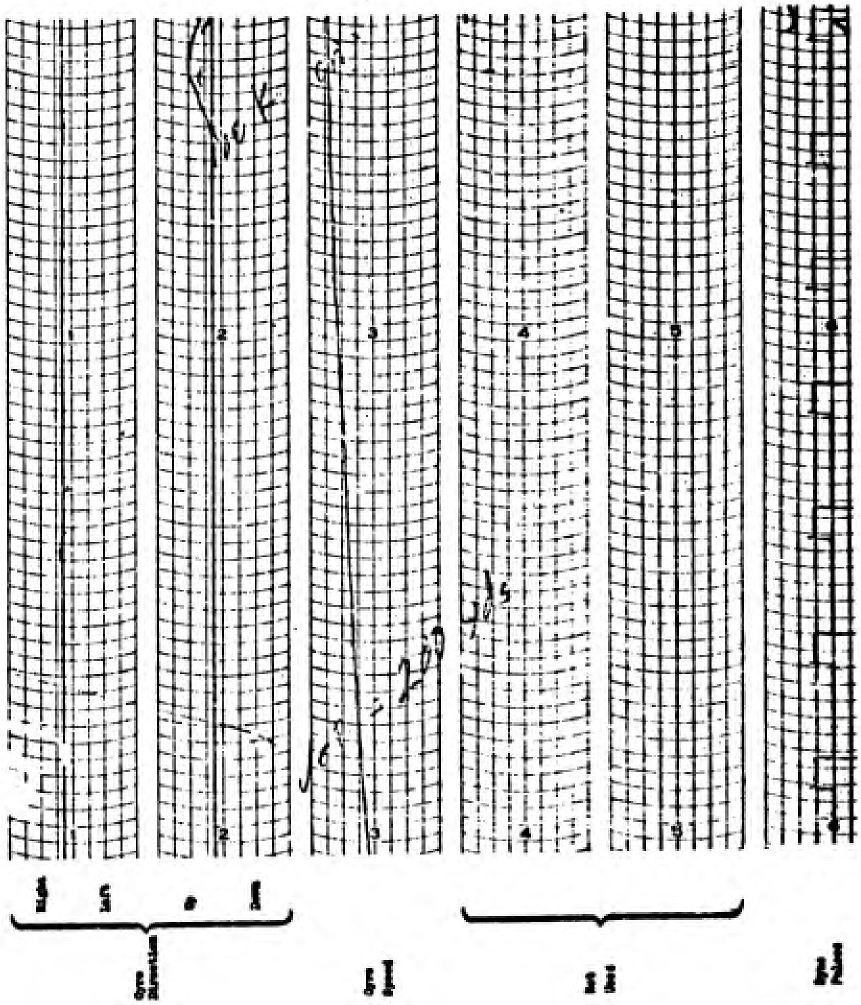
SEEKER TRACKING SIGNAL - ASPECT VS. RANGE

[illegible] of equal expected signal based on a typical aspect radiation pattern and inverse square of range. Curves are given possible values only.

Signals are microvolts, aspect angles are degrees from astern.

Night Operation - 10-9-51

Figure 32
Appendix D



Brush Recording of Minimum Tracking Range Flight, Showing Relative Shifts of Target with Respect to Parent Airplane

Figure 33
Appendix D

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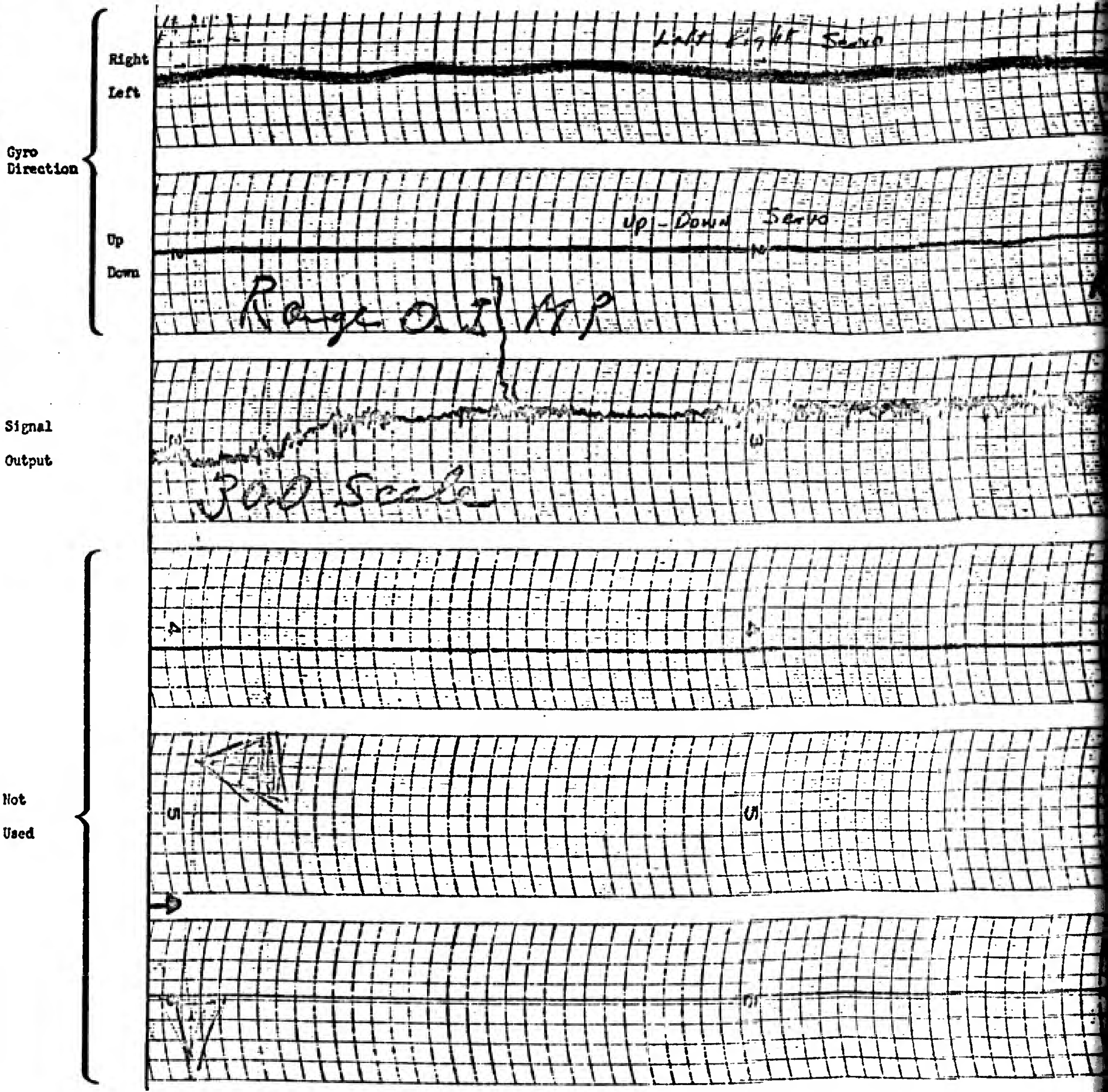
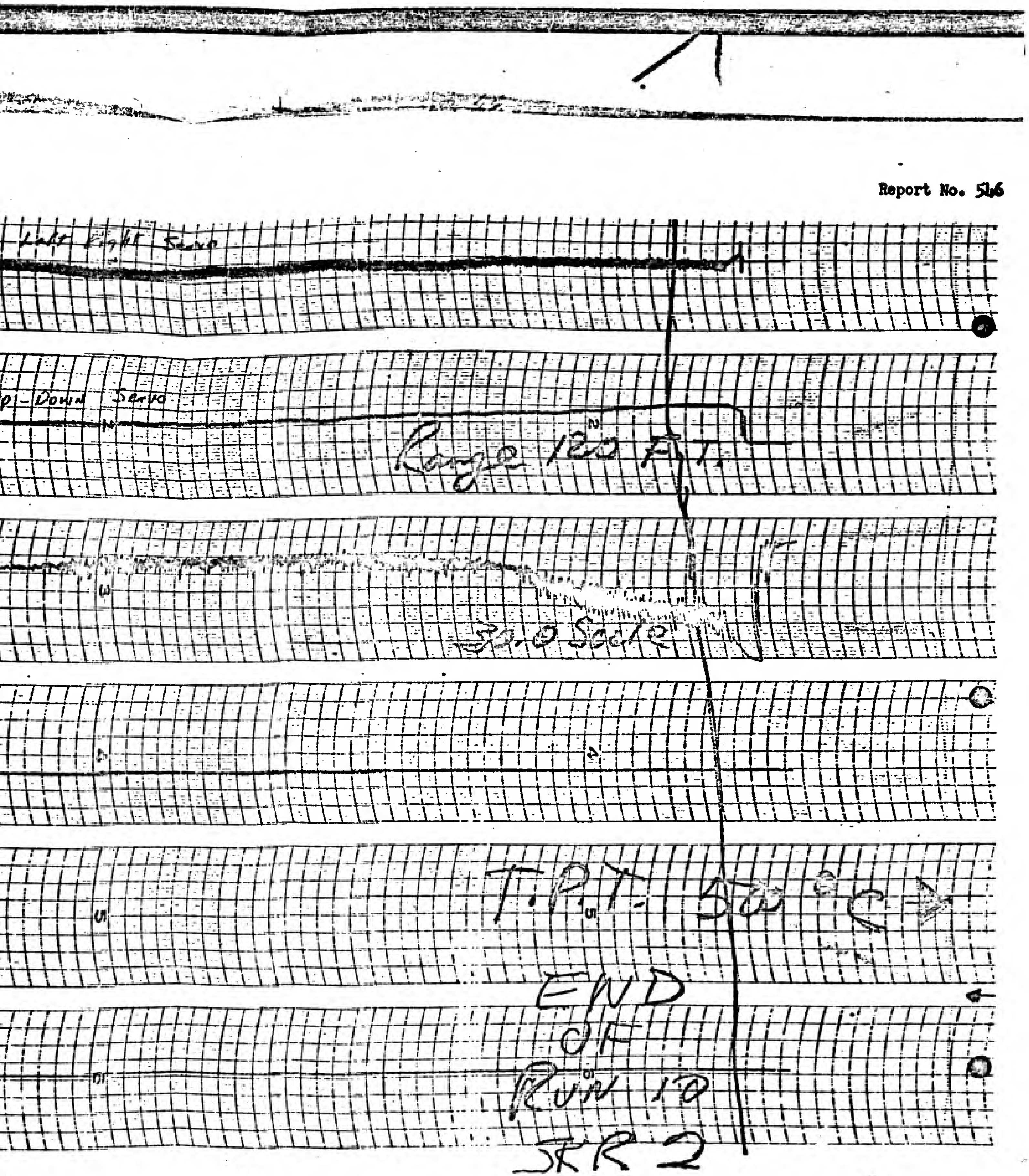


Brush O

①



Brush Oscillograph Record Obtained from Flight Simulator
Configuration at Minimum Range

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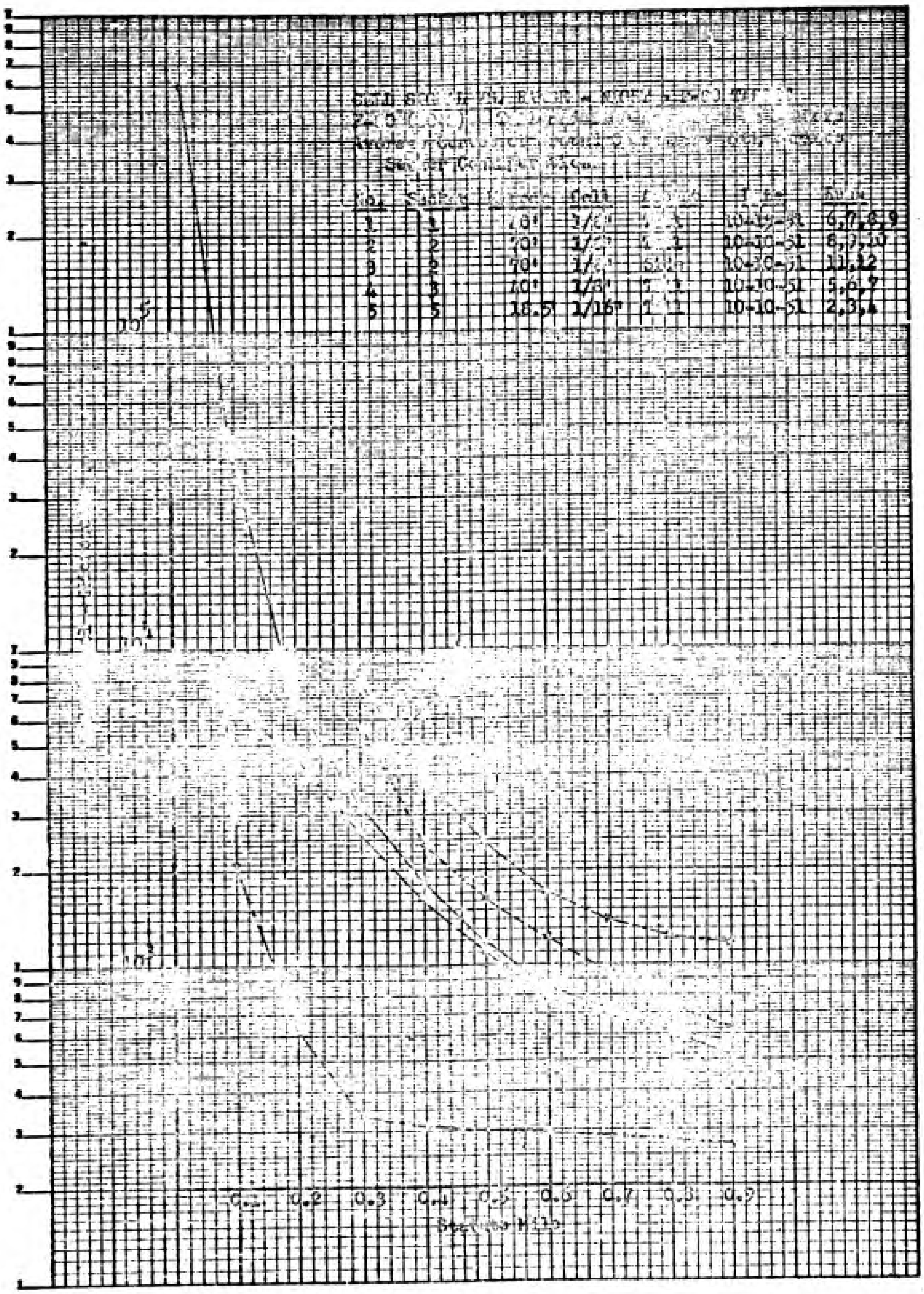
10^5
10^4
10^3
1
2
3
4
5
6
7
8
9
No.
1 1 70' 10-10-51 6,7,8,9
2 2 70' 10-10-51 8,9,10
3 2 70' 10-10-51 11,12
4 3 70' 1/8" 10-10-51 5,6,7
5 5 18.5' 1/16" 10-10-51 2,3,4
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

Figure 35

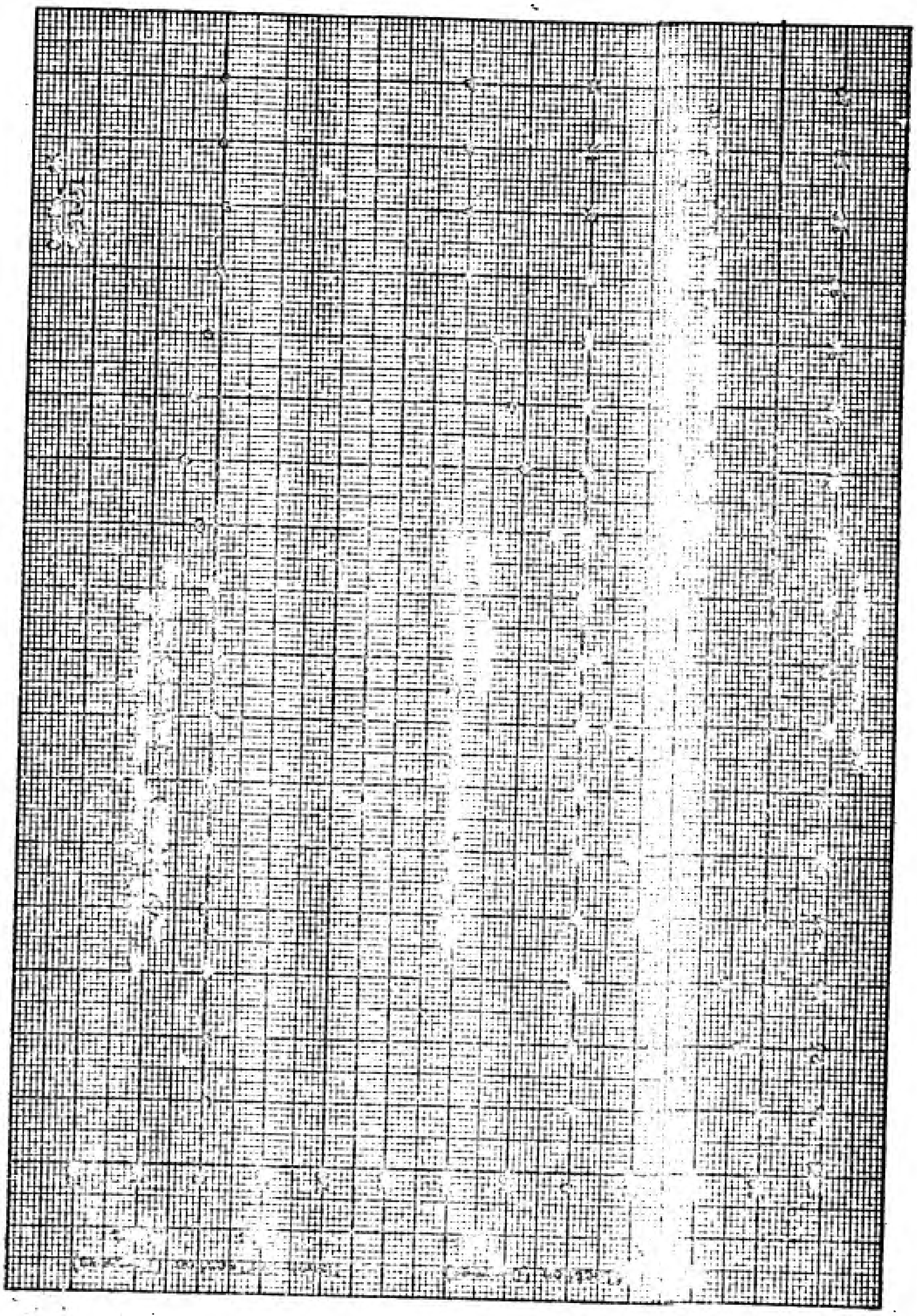

Figure 36
Appendix D

CONFIDENTIAL

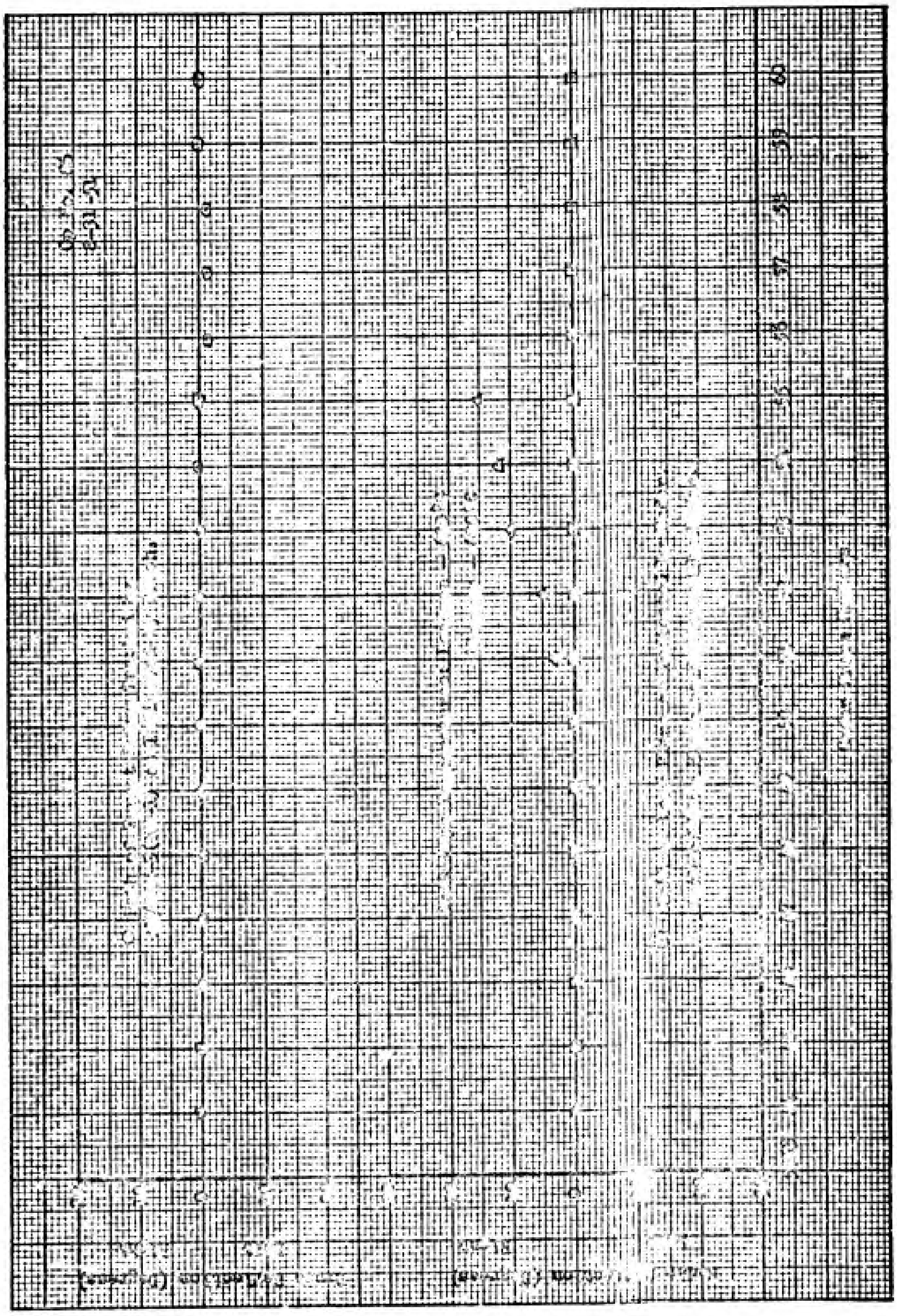

Figure 37
Appendix D

CONFIDENTIAL

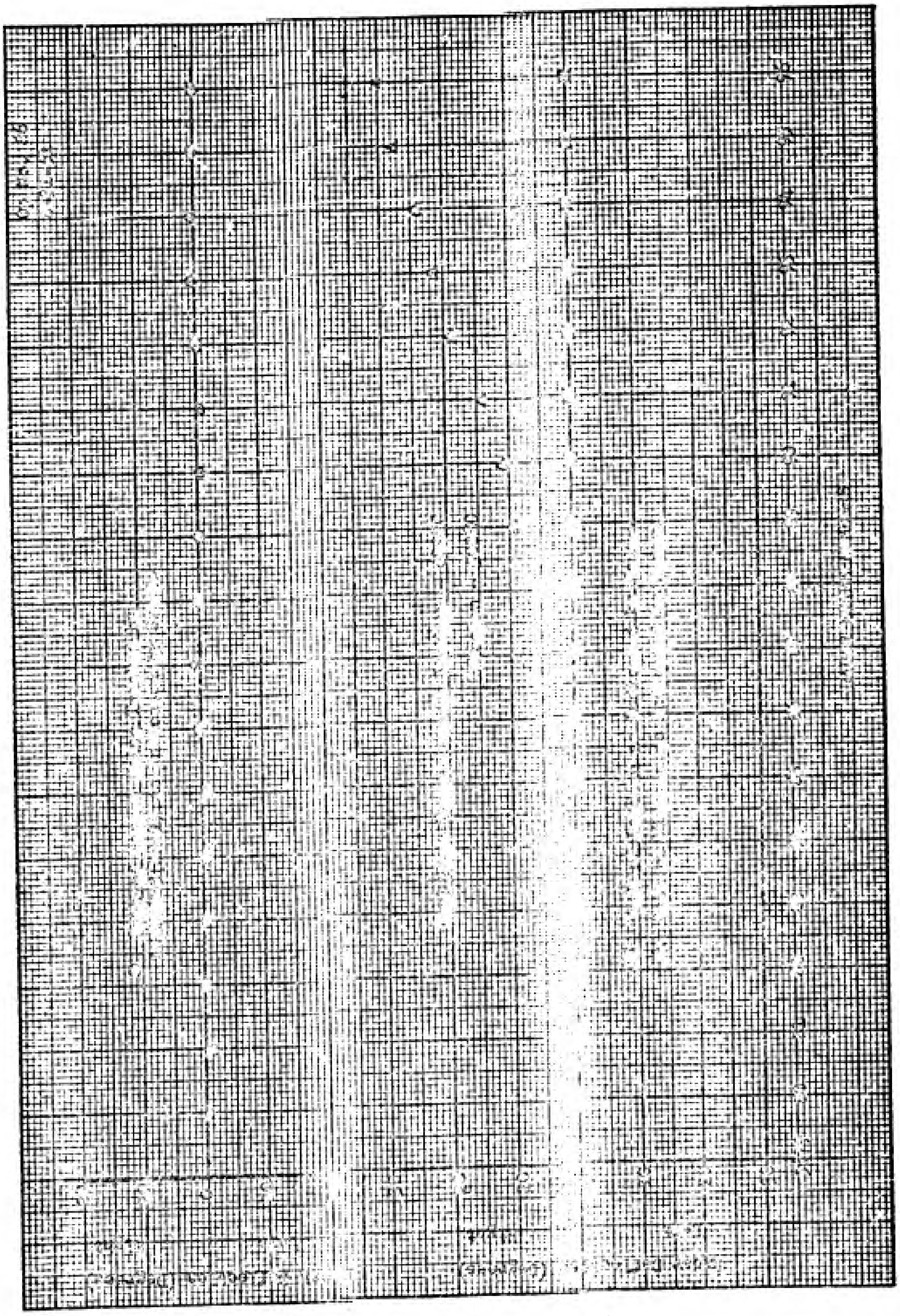

Figure 38
Appendix D

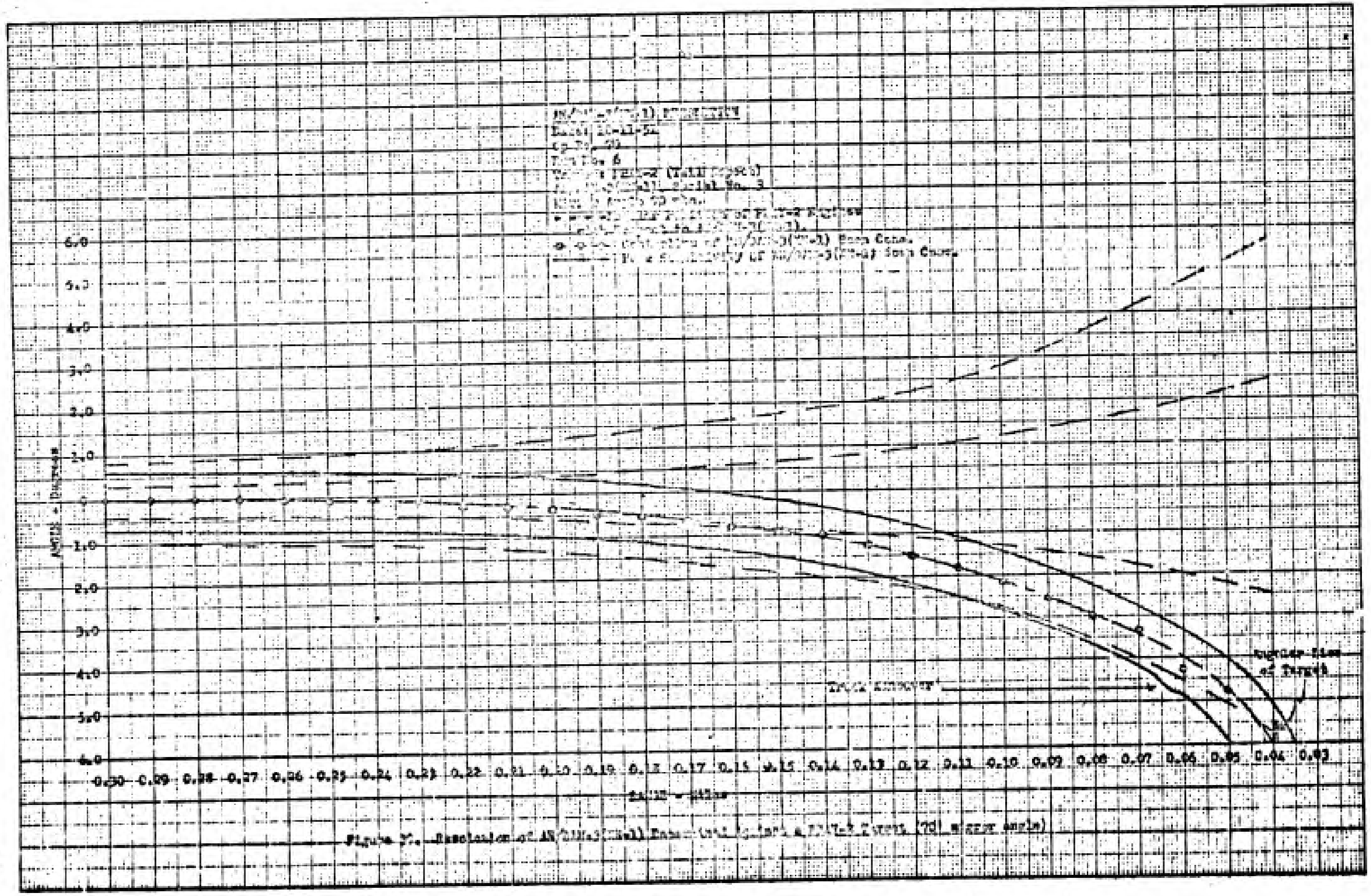

Figure 39
Appendix D

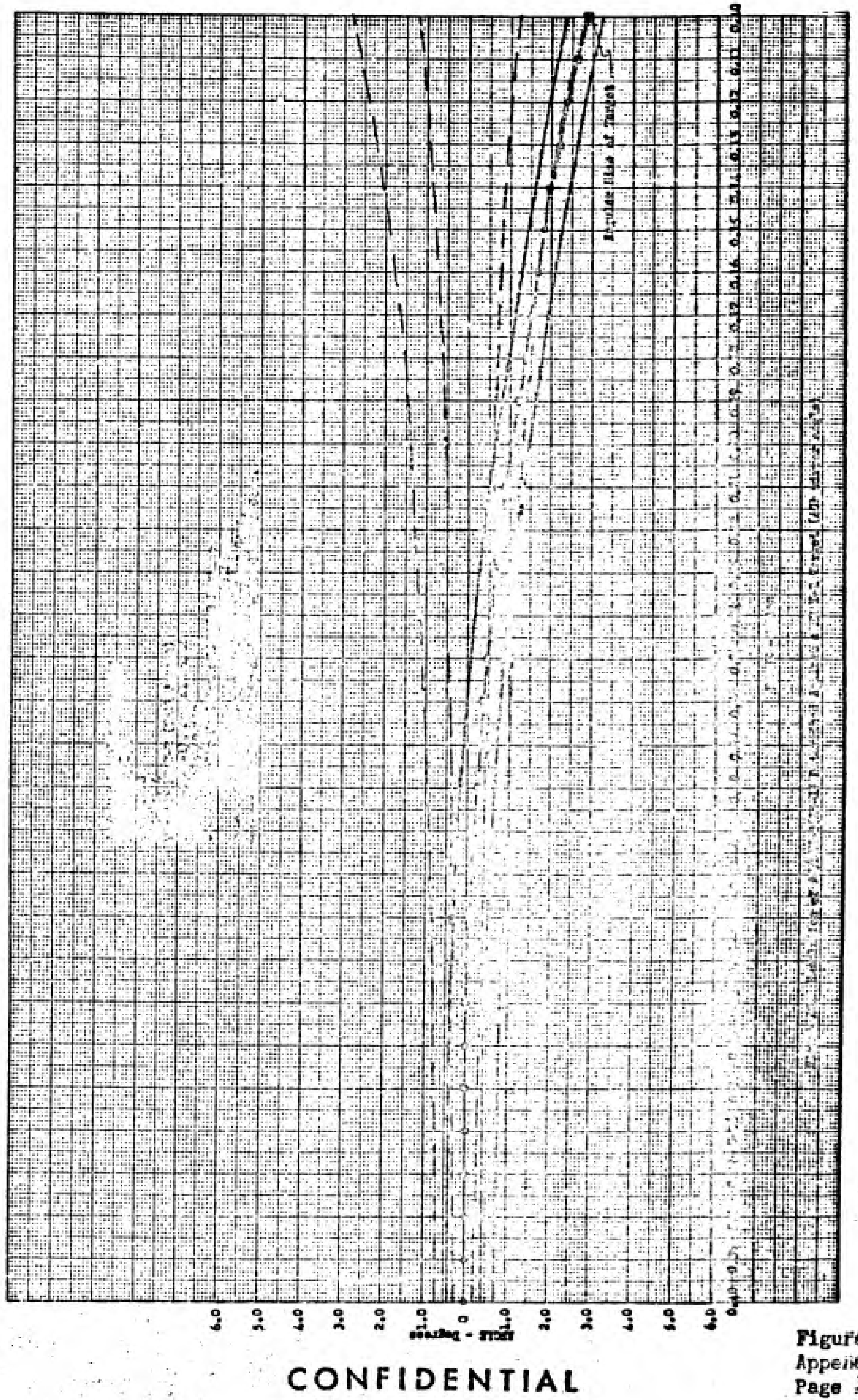

Figure 40
Appendix D

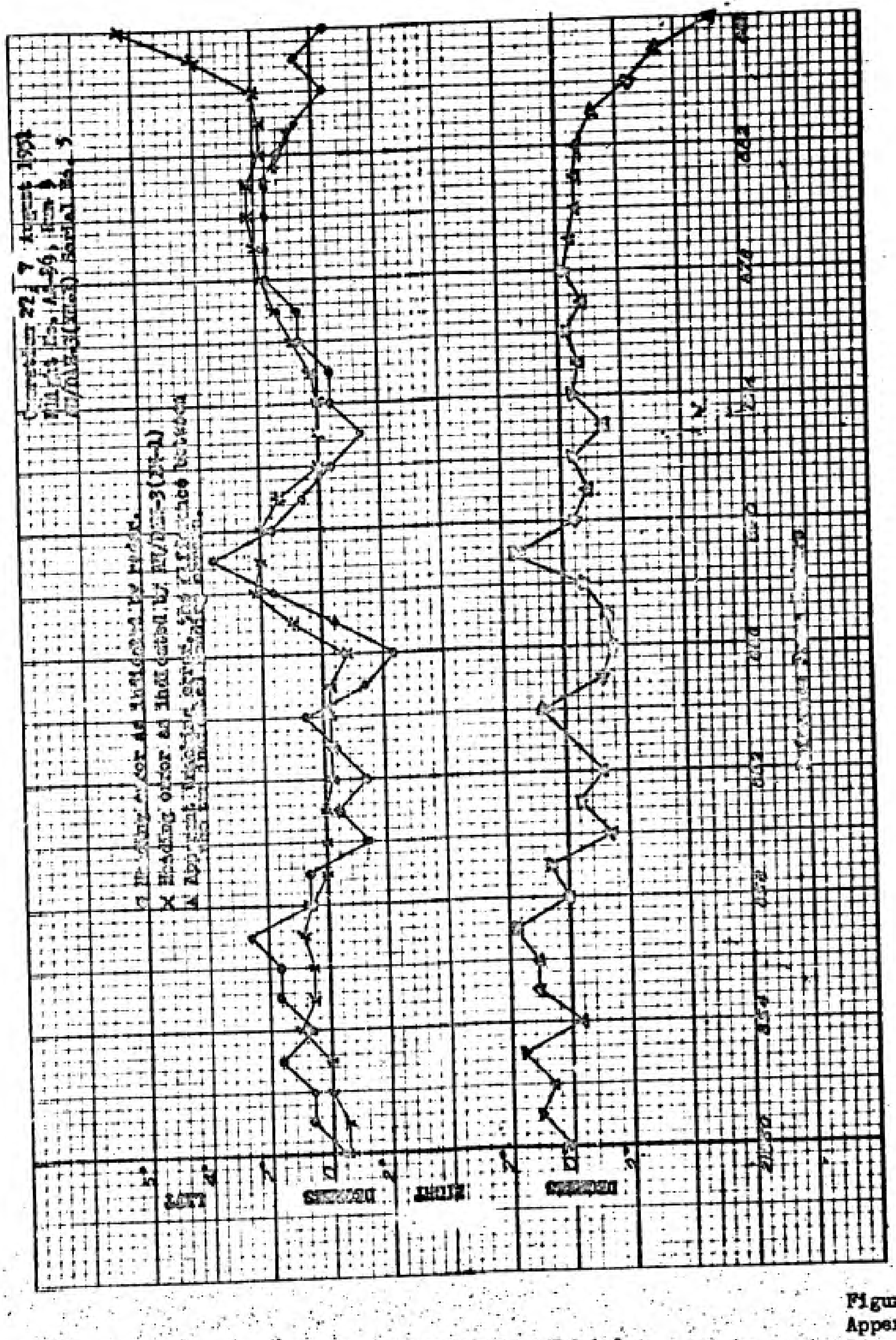

Figure 41
Appendix D

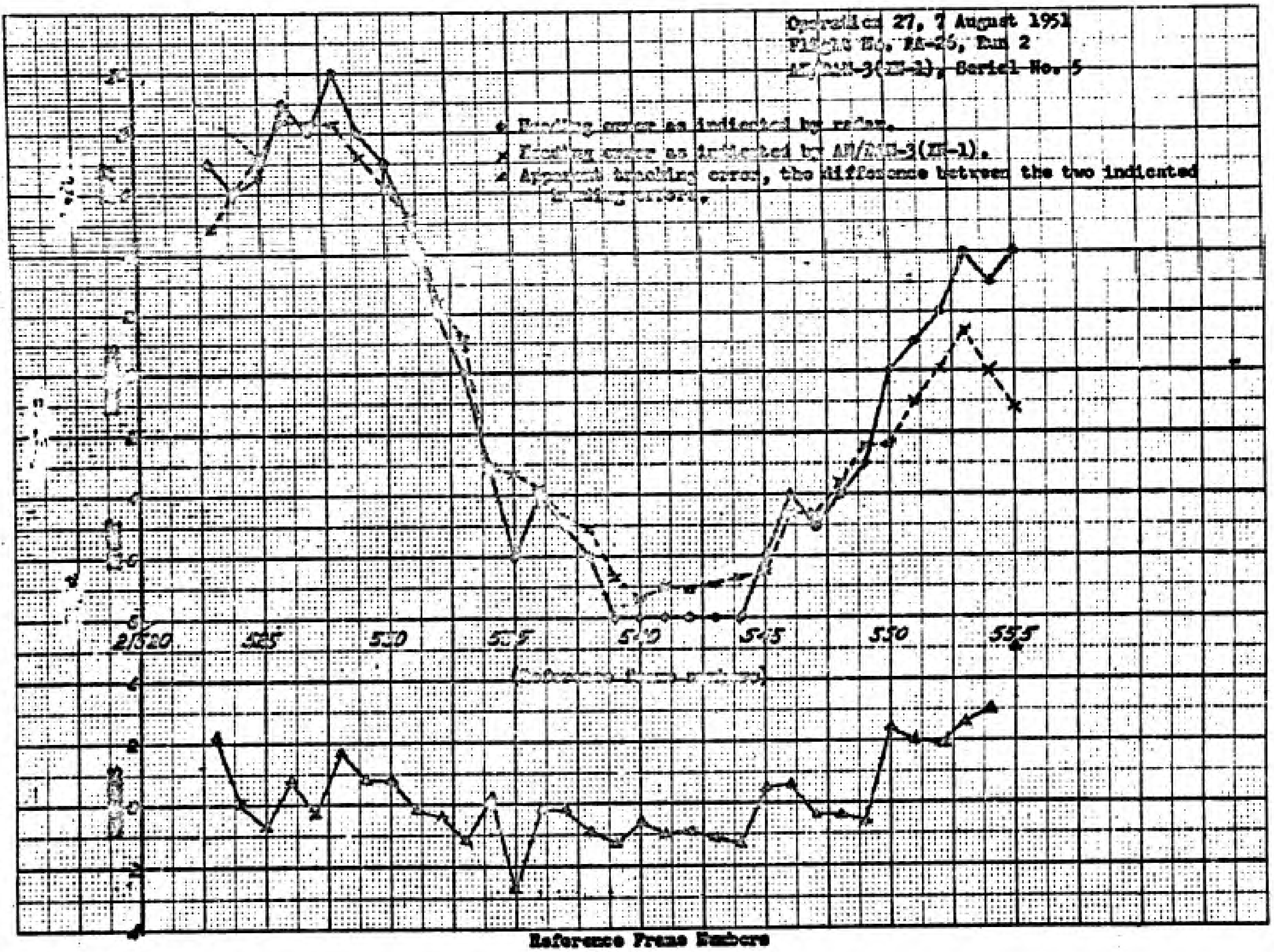

Figure 42
Appendix D

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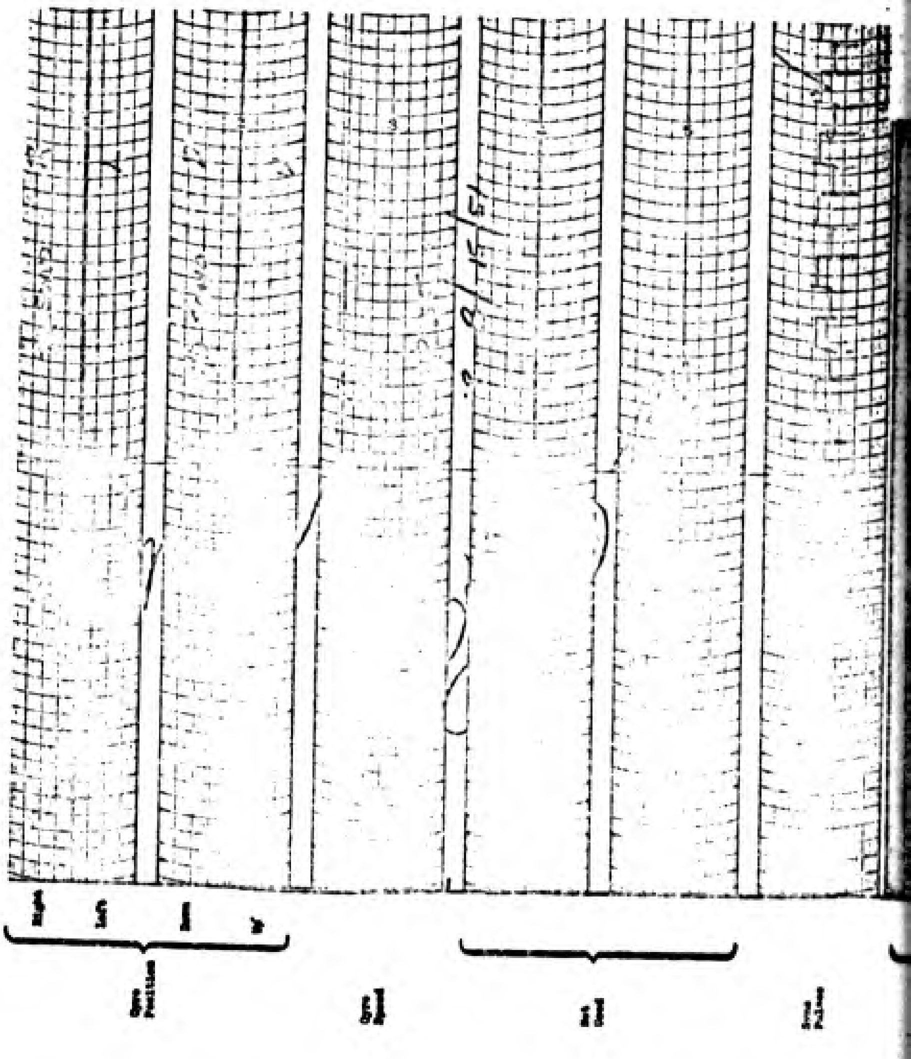
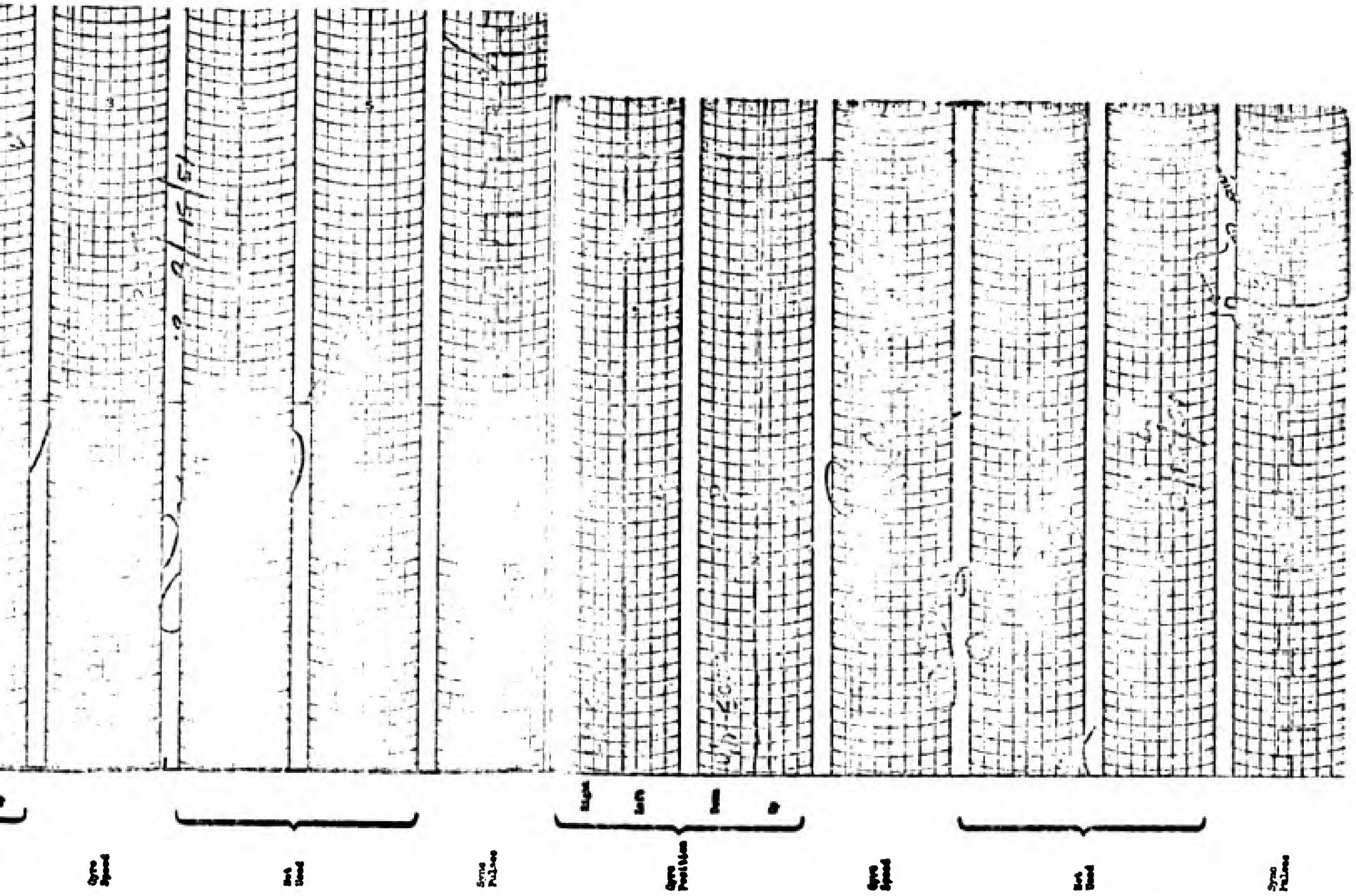


Brush Recording of

①



Brush Recording of Typical Servo Output (Jitter) at Intermediate Range

Figure 43
Appendix D

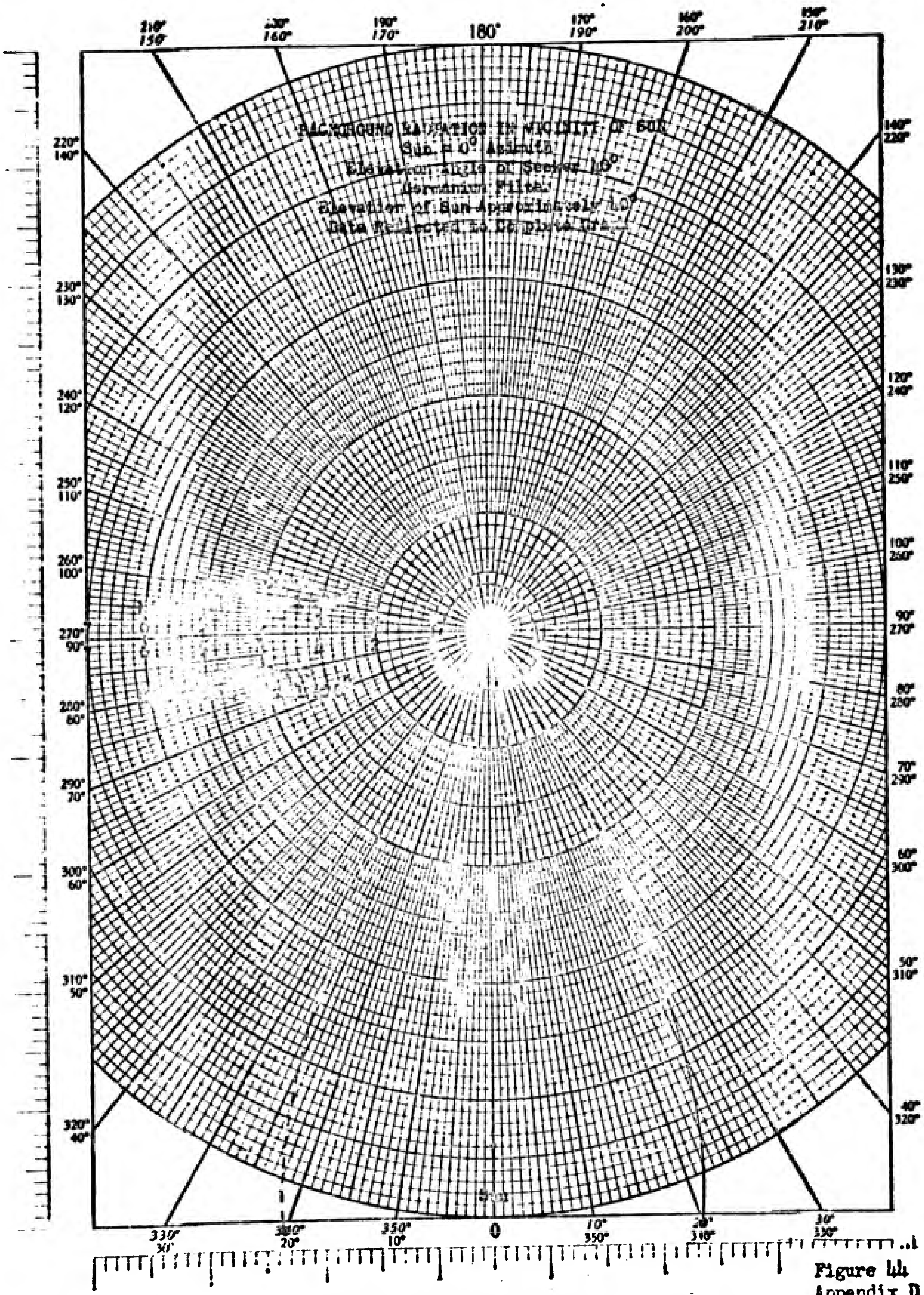
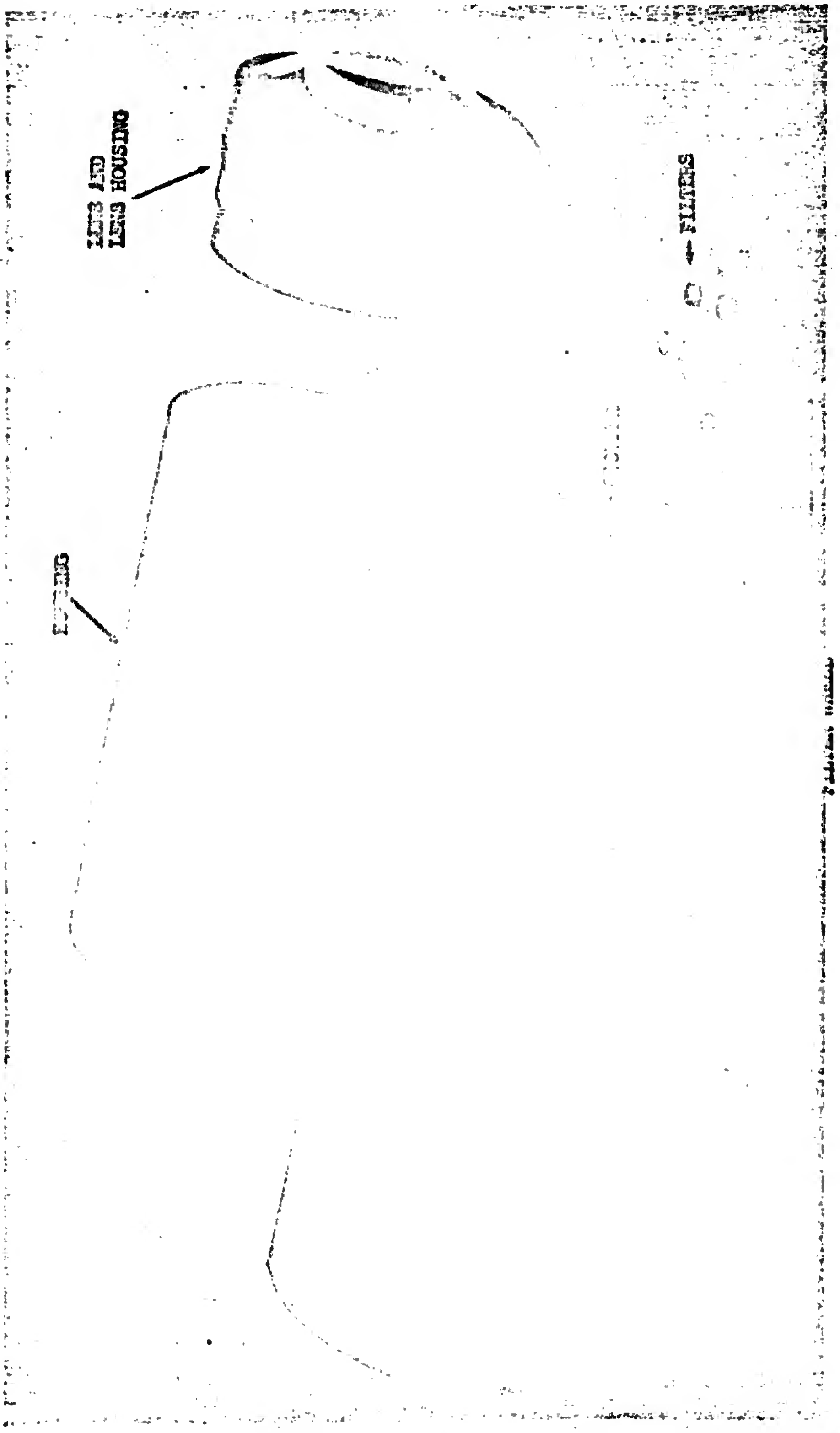

BACKGROUND RADIATION IN VICINITY OF SUN
Sun = 0° Azimuth
Elevation Angle of Scanner 10°
Germanium Filter
Elevation of Sun Approximately 10°
Data Reflected to Complete Gra
180°
210° 150°
200° 160°
190° 170°
170° 190°
160° 200°
150° 210°
140° 220°
130° 230°
120° 240°
110° 250°
100° 260°
90° 270°
80° 280°
70° 290°
60° 300°
50° 310°
40° 320°
220° 140°
230° 130°
240° 120°
250° 110°
260° 100°
270° 90°
280° 80°
290° 70°
300° 60°
310° 50°
320° 40°
330° 30°
340° 20°
350° 10°
0
10° 350°
20° 340°
30° 330°

Figure 44



General View of Radiometer, Disassembled

Figure 45
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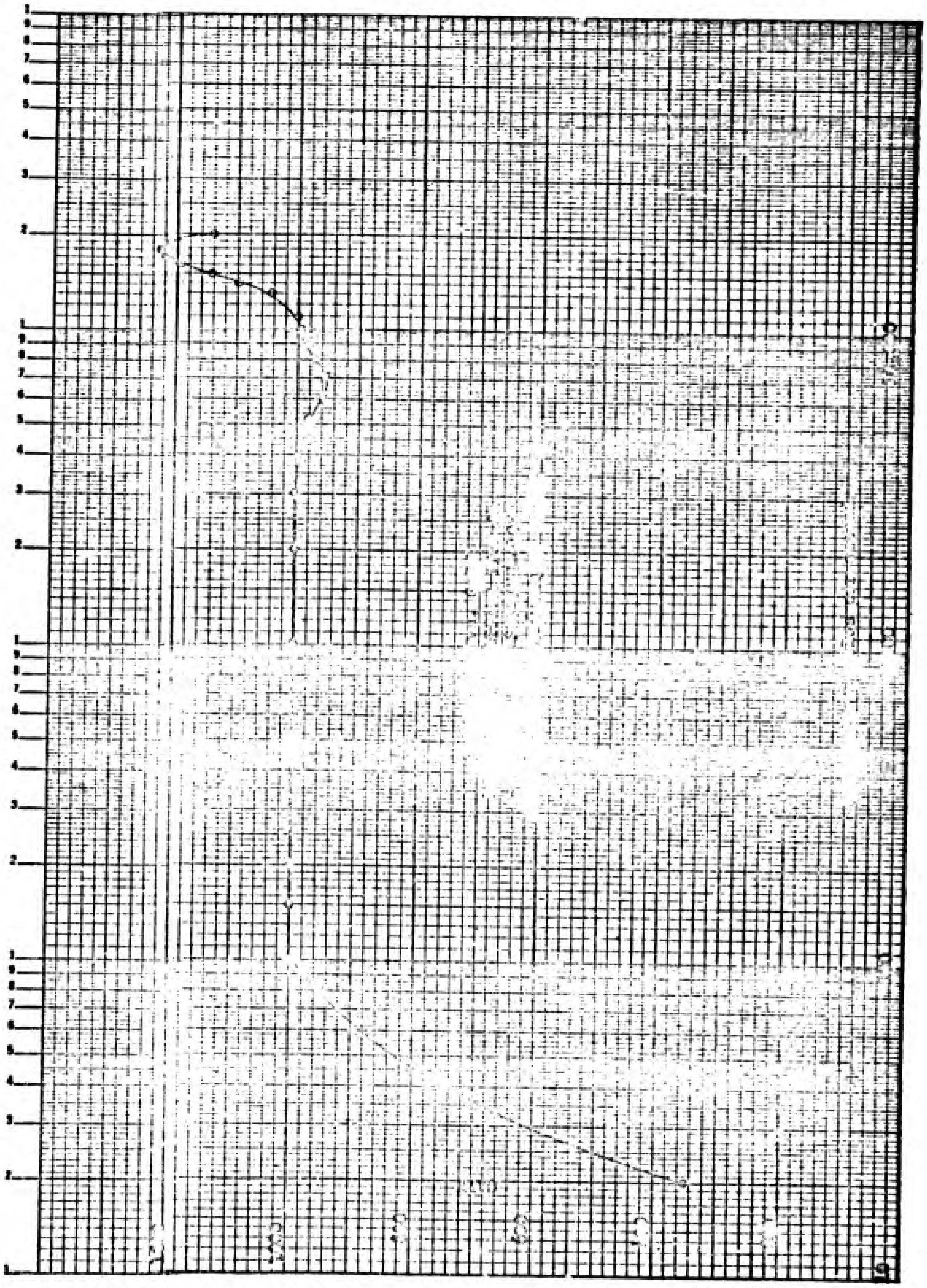

Figure 46
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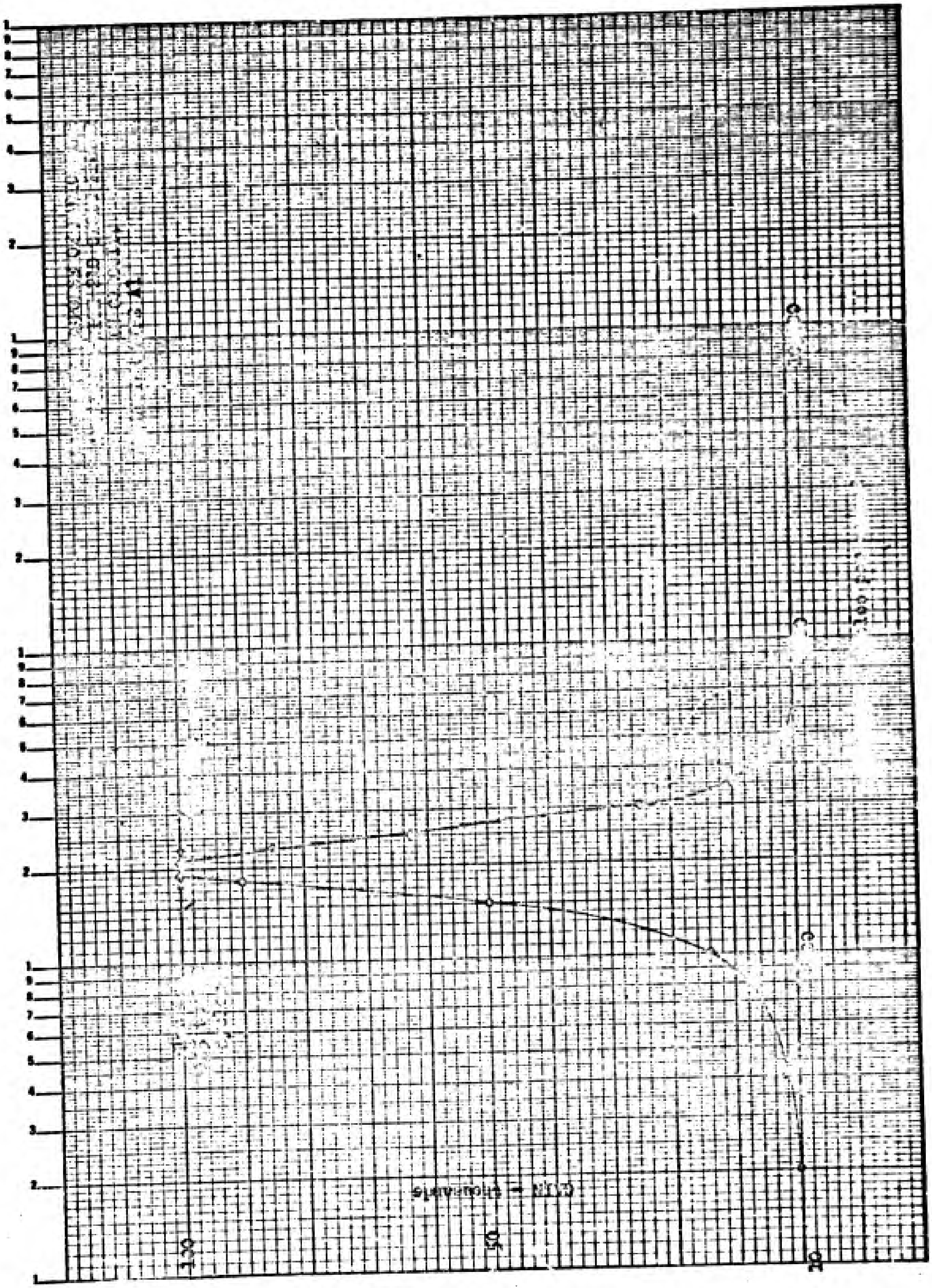

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Figure 47
Appendix D

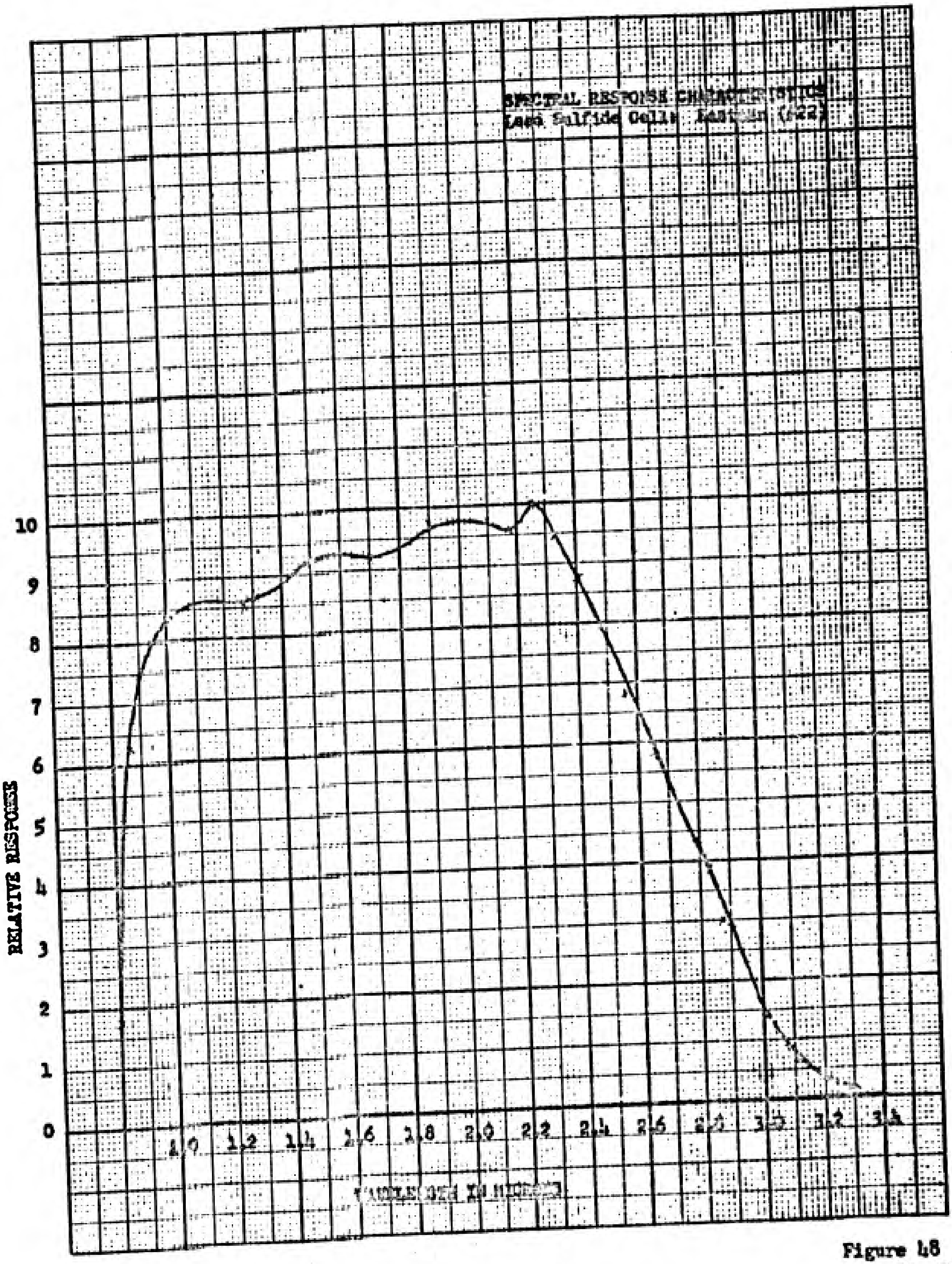

SPECTRAL RESPONSE CHARACTERISTICS
Lead Sulfide Cell: Eastman (622)
RELATIVE RESPONSE
0
1
2
3
4
5
6
7
8
9
10
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
WAVELENGTH IN MICRONS

Figure 48

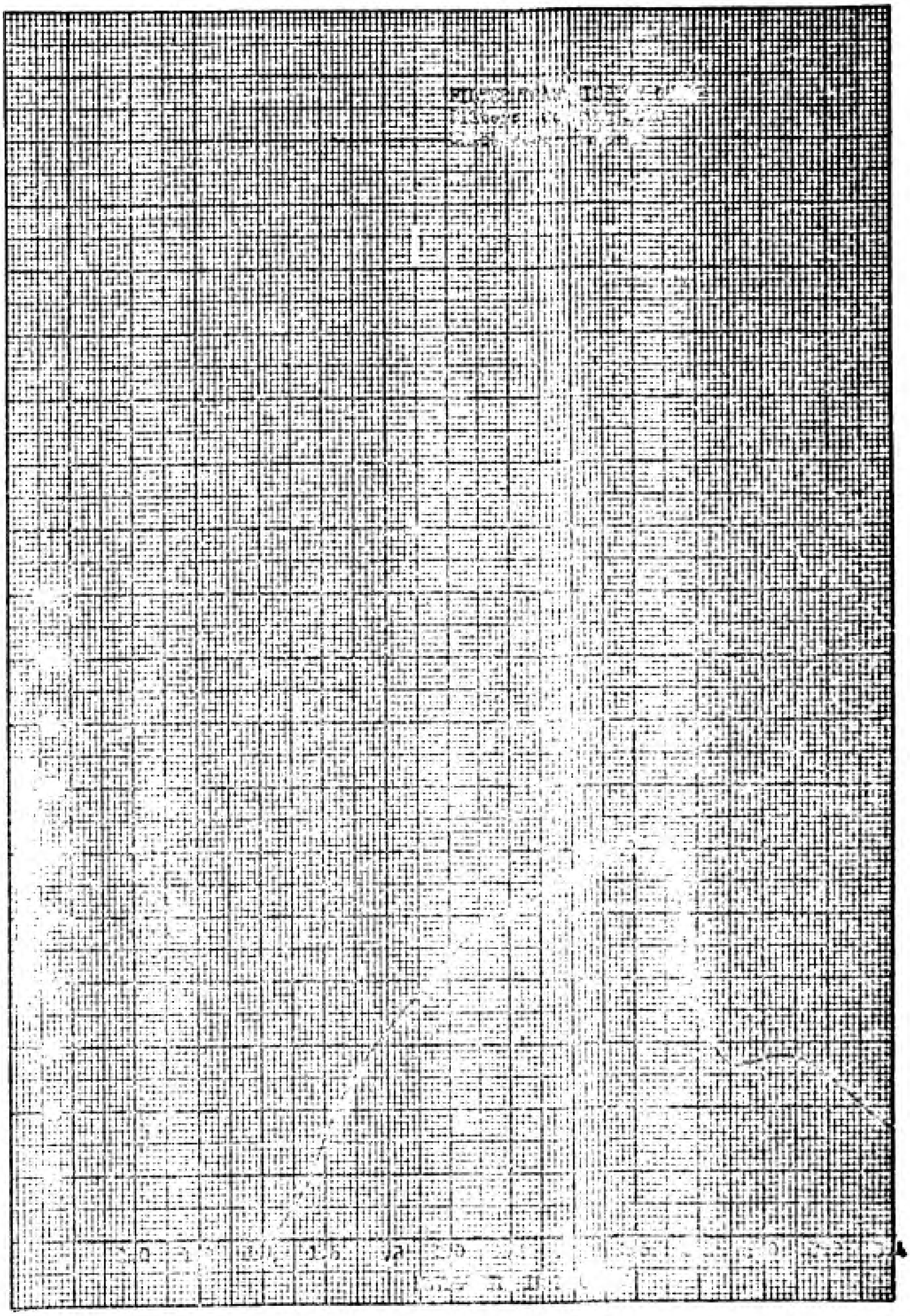


Figure 49
Appendix D

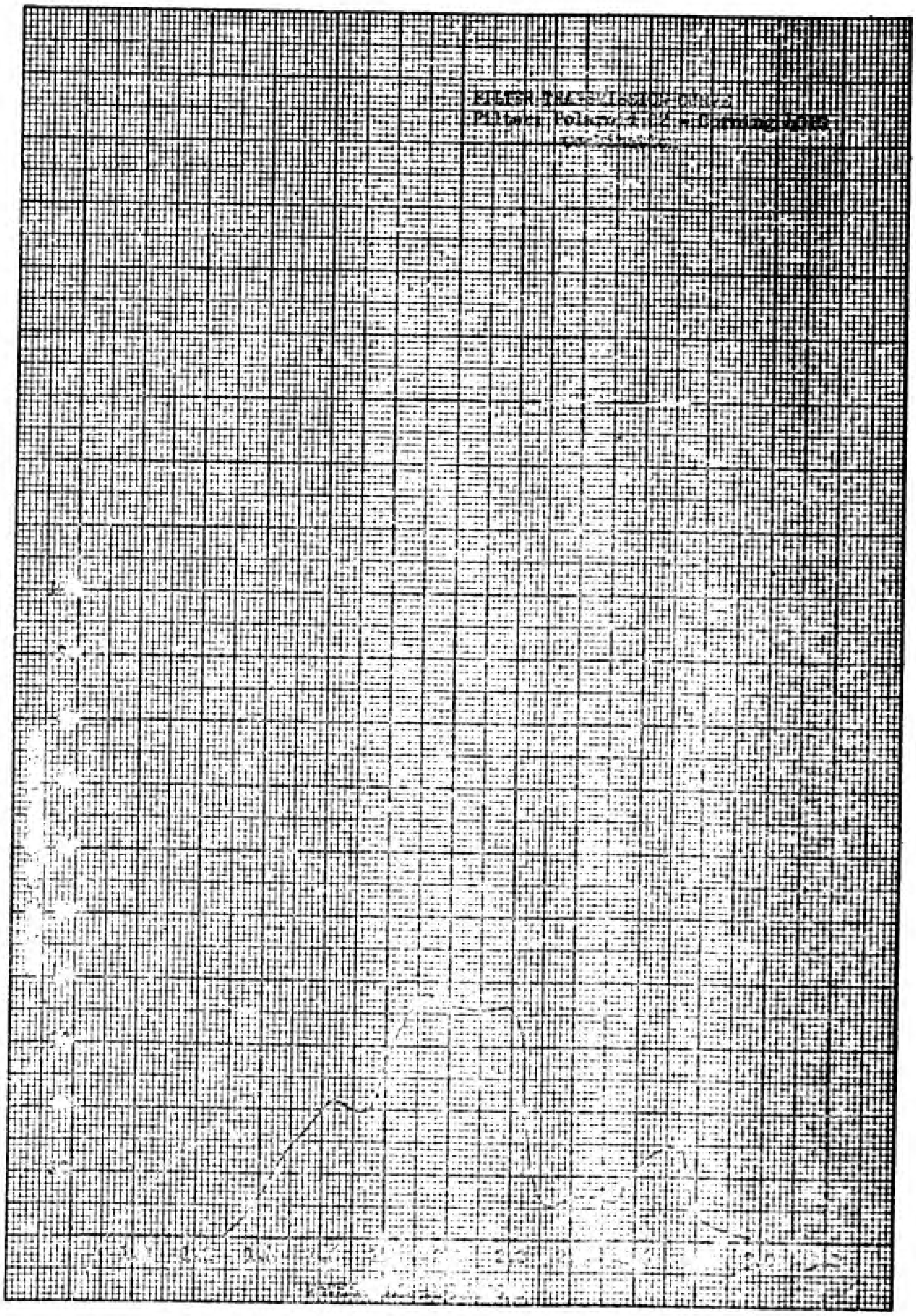


Figure 50

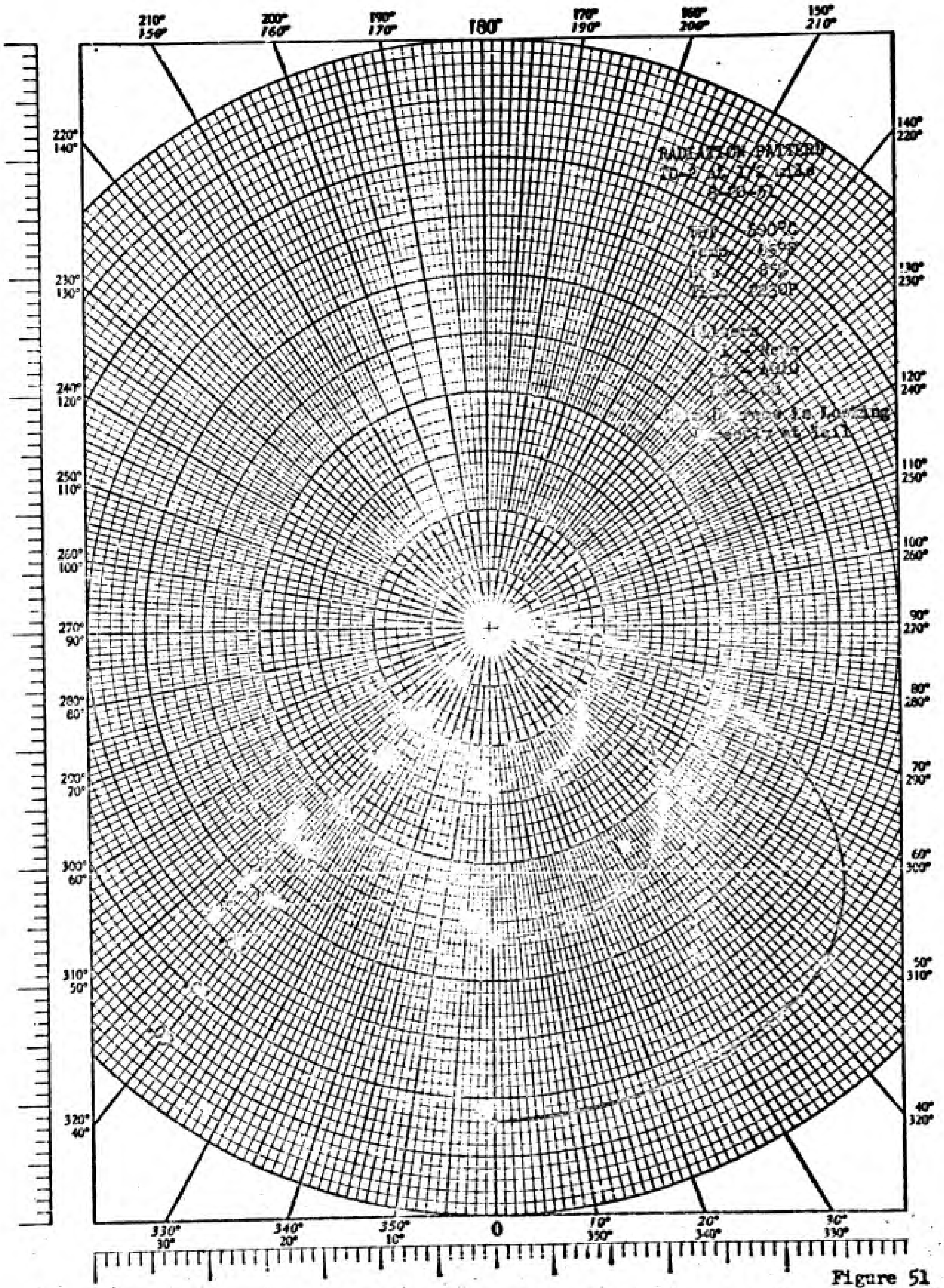

RADIATION PATTERN
590KC
Loading
180°
210° 150°
200° 160°
190° 170°
170° 190°
160° 200°
150° 210°
220° 140°
140° 220°
230° 130°
130° 230°
240° 120°
120° 240°
250° 110°
110° 250°
260° 100°
100° 260°
270° 90°
90° 270°
280° 80°
80° 280°
290° 70°
70° 290°
300° 60°
60° 300°
310° 50°
50° 310°
320° 40°
40° 320°
330° 30°
340° 20°
350° 10°
0
10° 350°
20° 340°
30° 330°

Figure 51

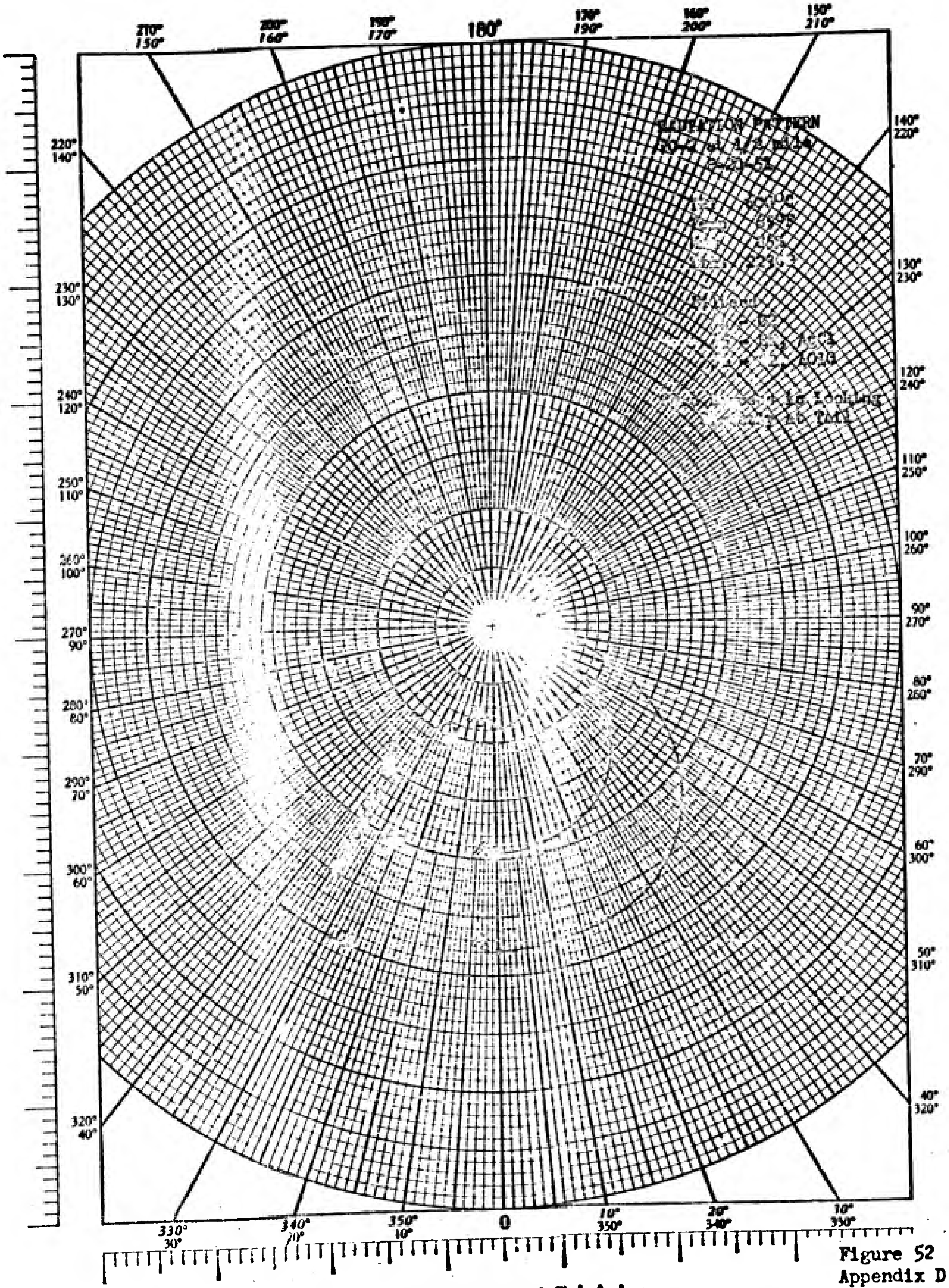
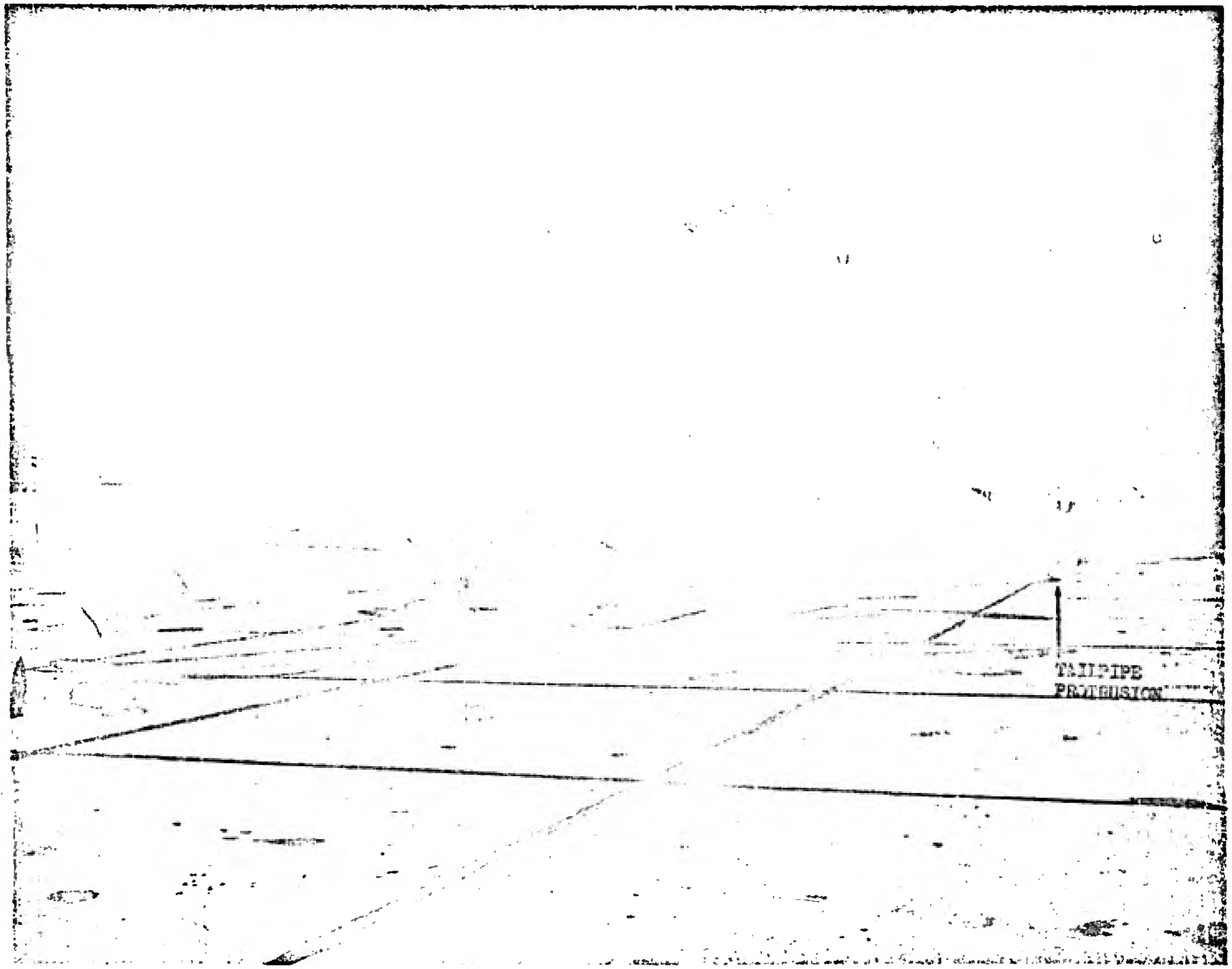

180°
170° 190°
160° 200°
150° 210°
140° 220°
130° 230°
120° 240°
110° 250°
100° 260°
90° 270°
80° 280°
70° 290°
60° 300°
50° 310°
40° 320°
10° 350°
20° 340°
10° 350°
0
350° 10°
340° 20°
330° 30°
320° 40°
310° 50°
300° 60°
290° 70°
280° 80°
270° 90°
260° 100°
250° 110°
240° 120°
230° 130°
220° 140°
210° 150°
200° 160°
190° 170°
PATTERN
Looking
Tail

Figure 52



TO-2 Jet Fighter Aircraft, 3/4 Left Rear View

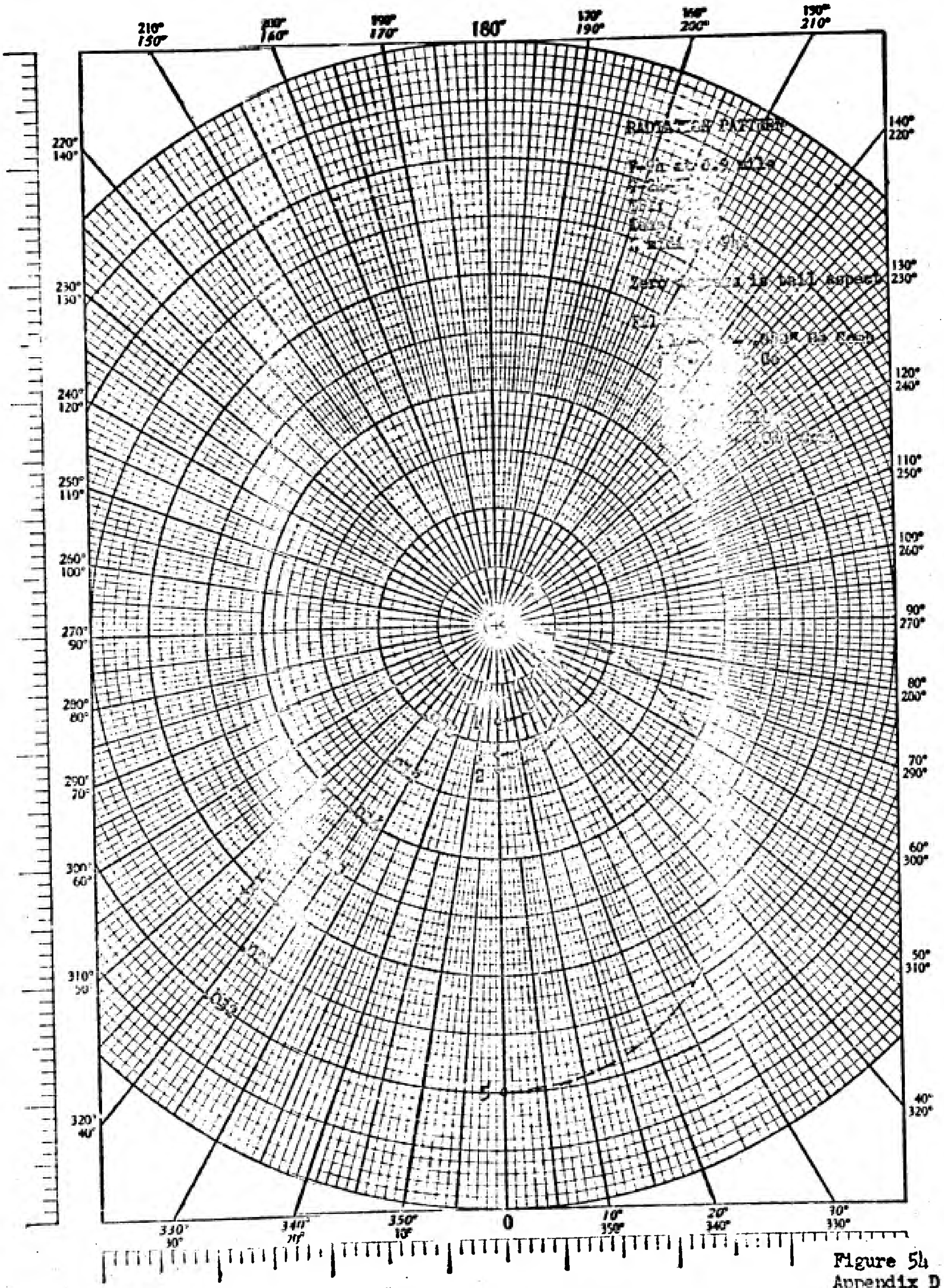


Figure 54
Appendix D

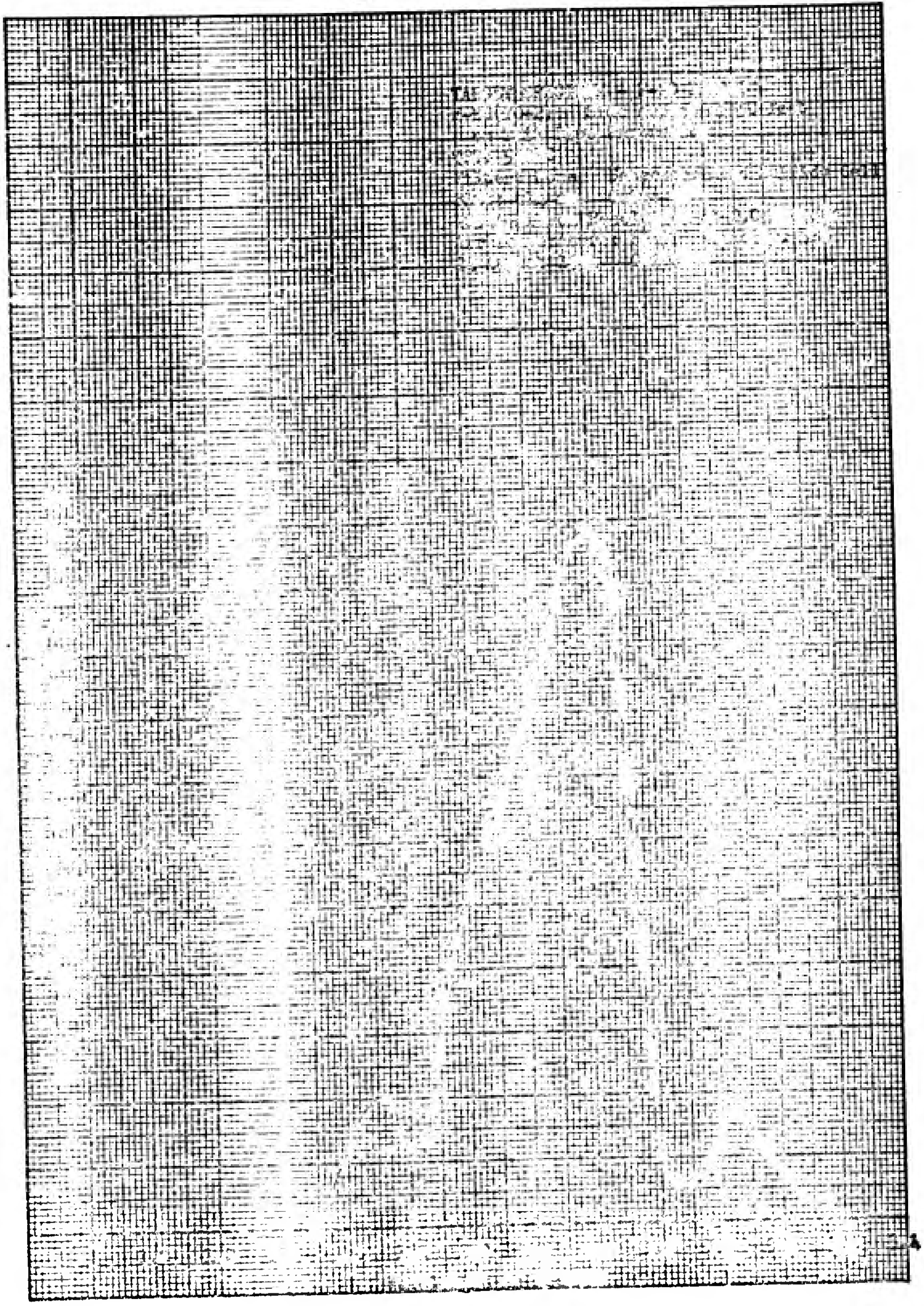


Figure 55

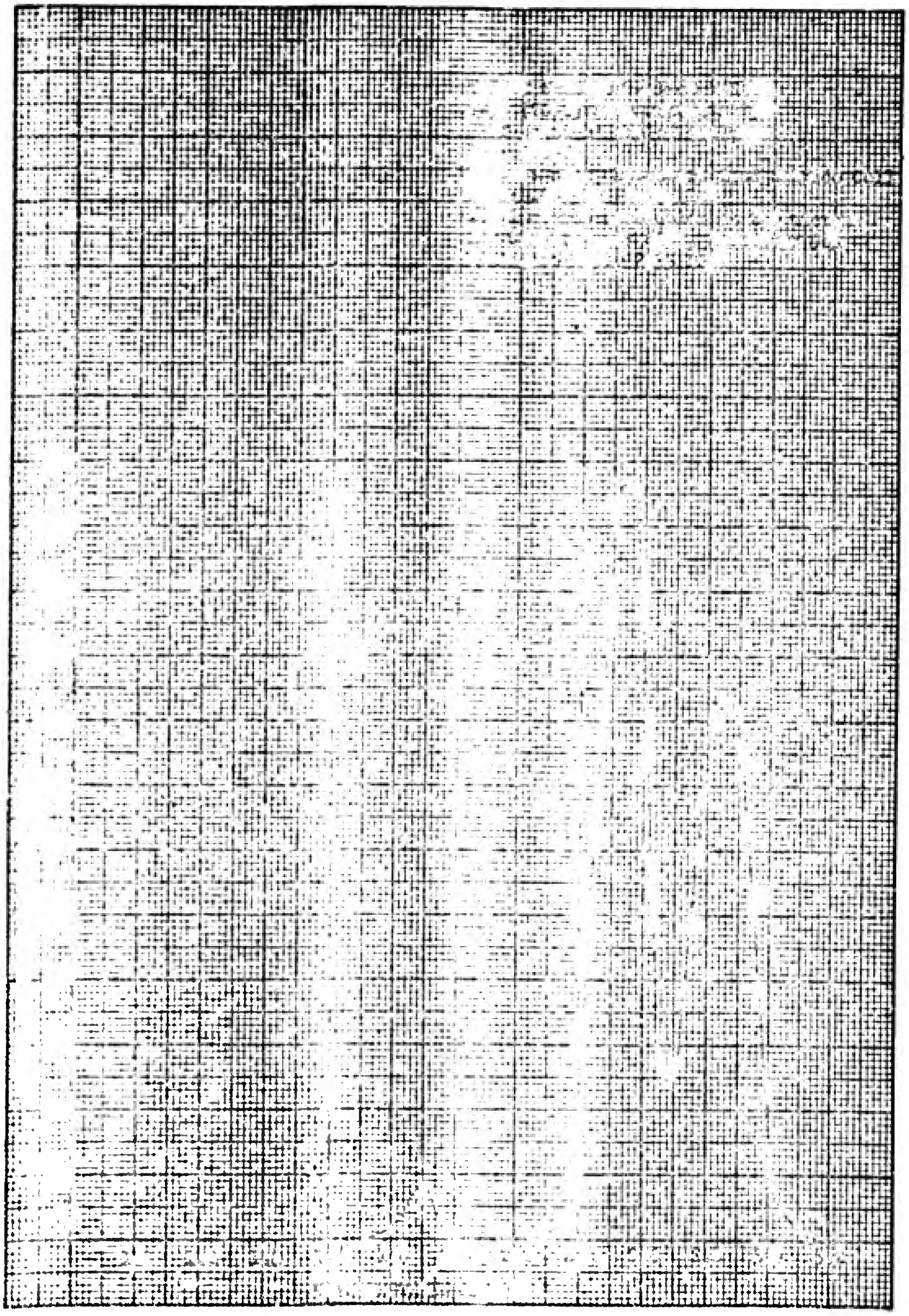


Figure 56
Appendix D

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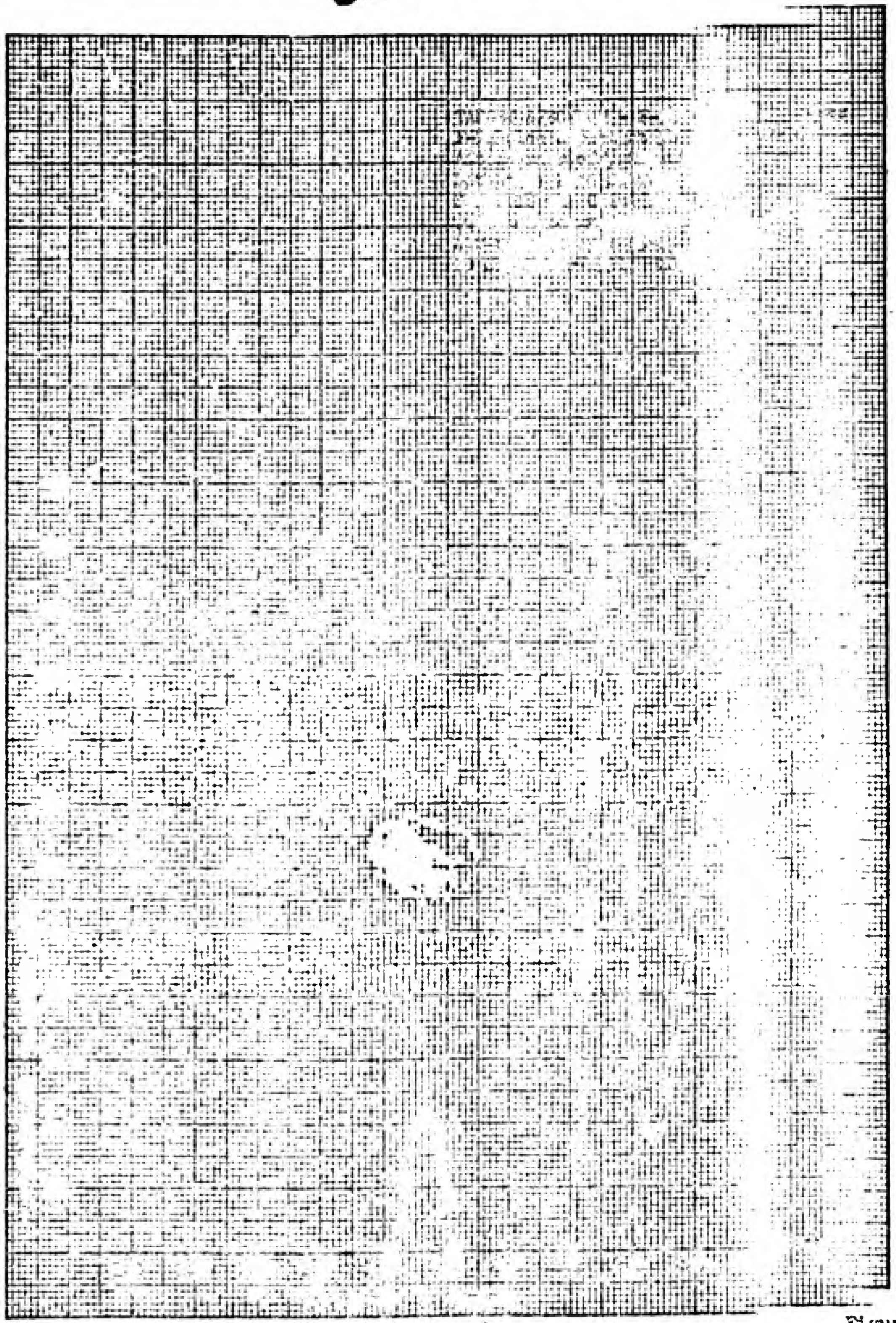

Figure 57
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Pag

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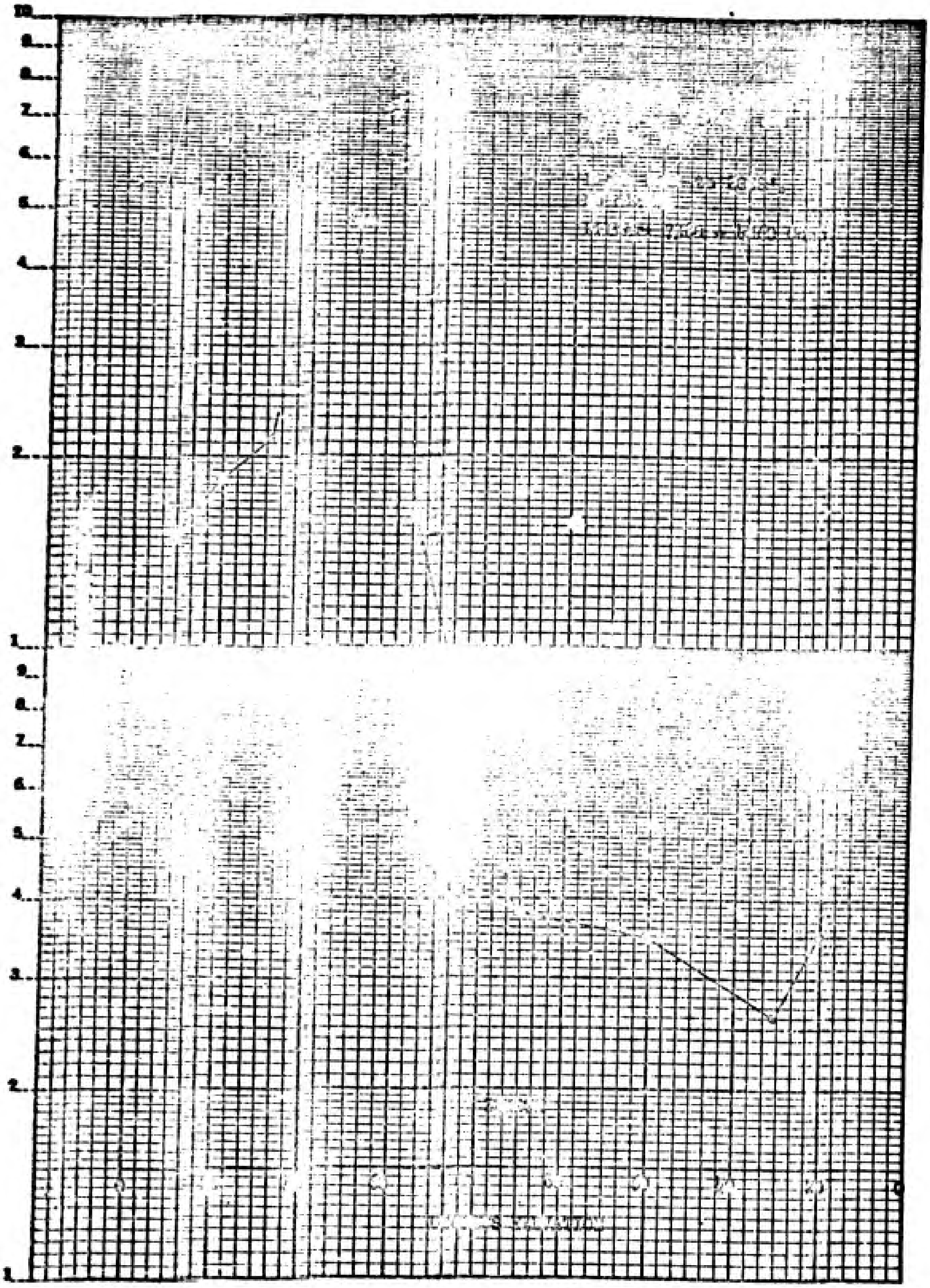

Figure 58

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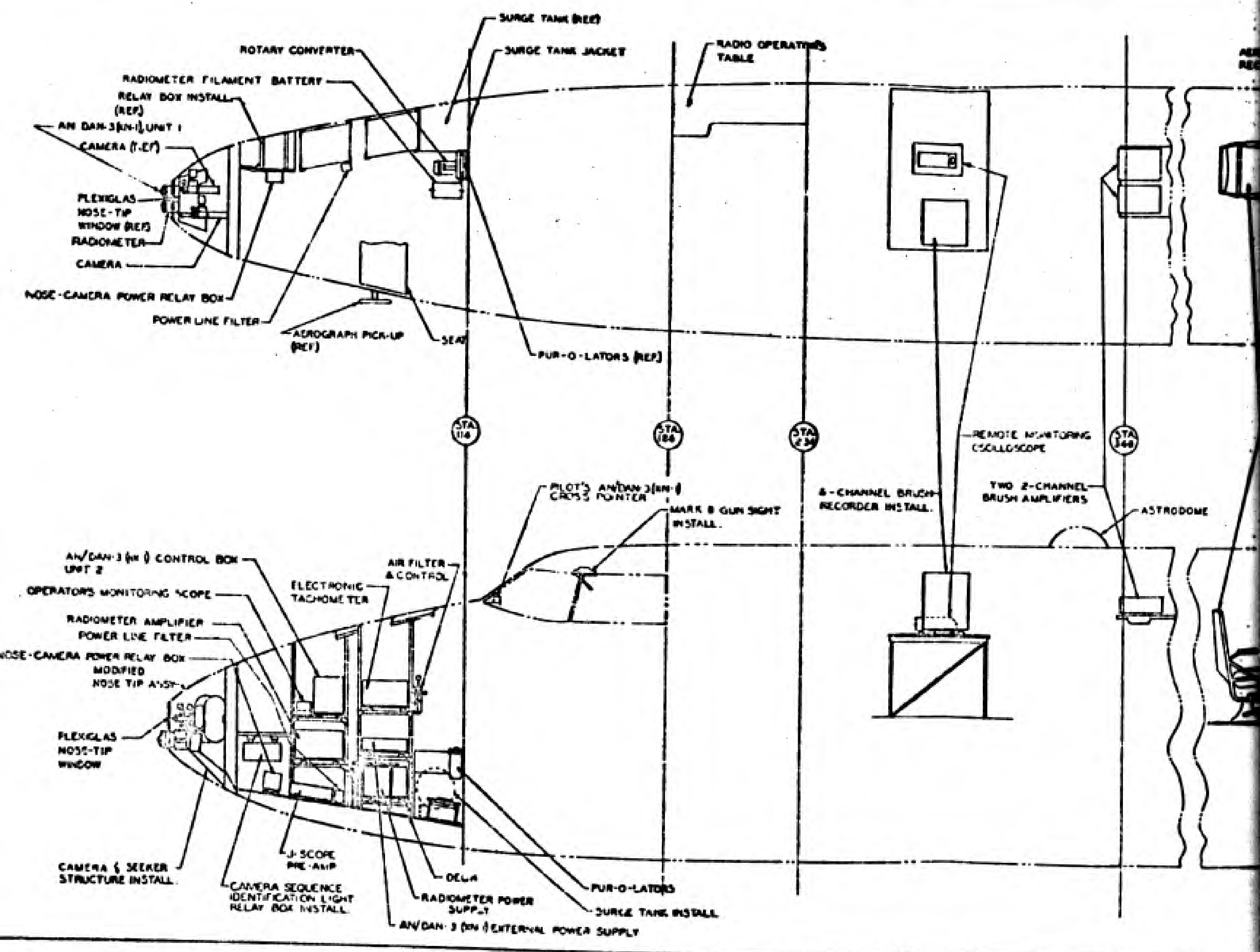

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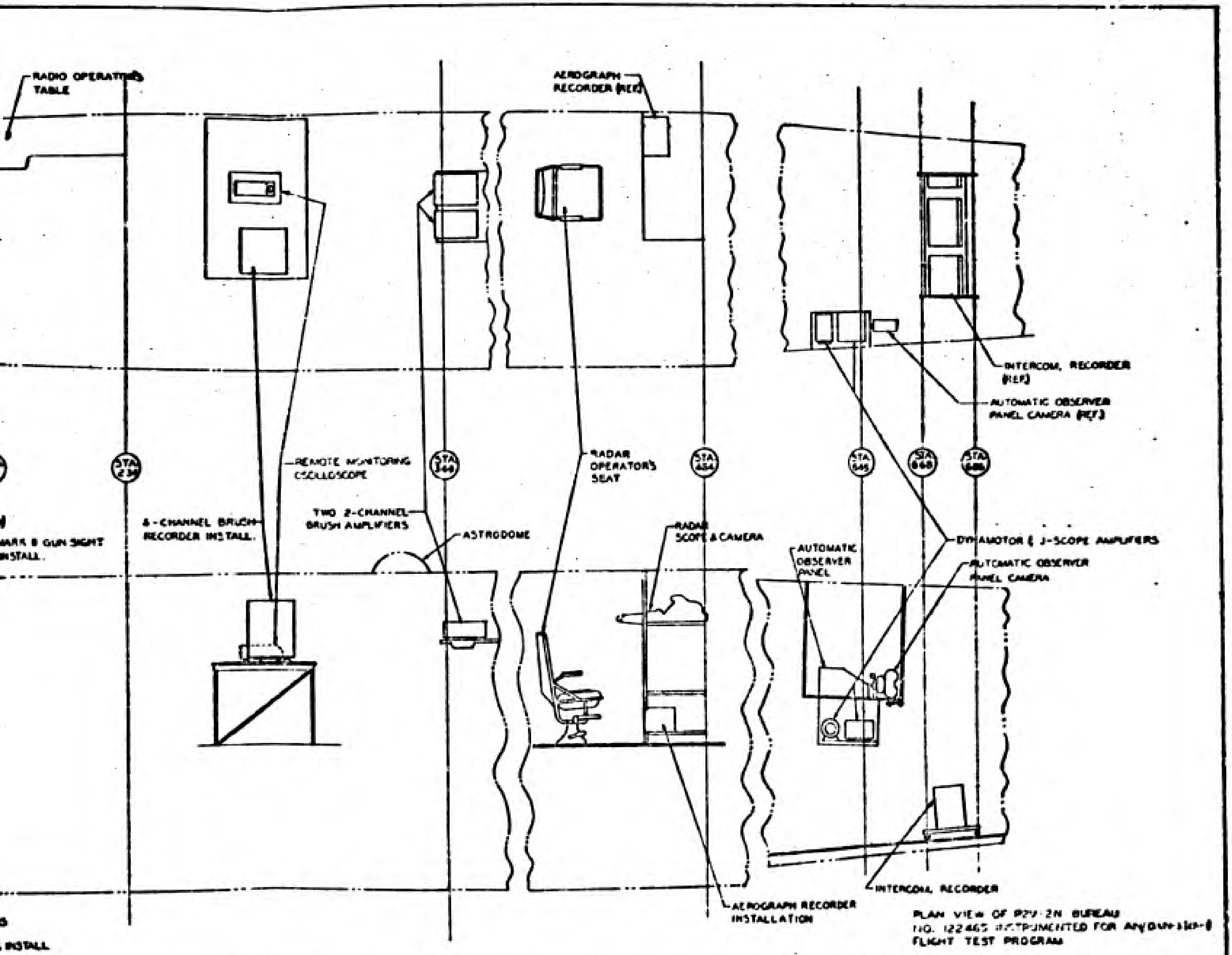

Inboard Profile Installation of the Infrared Homing Set

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