VOLUME 2

SECTION I

FR-3022-V01
FR-3022-V01-II

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Washington, D. C.

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Declassification authority: NAVY DECLASS GUIDE / NAVY DECLASS MANUAL, 11 DEC 2012, 03 SERIES

A Joint Report
on the Developement of

GUN FIRE CONTROL SYSTEM MARK 61 MOD. 0-2

By

Charles H. Shaw
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The Johns Hopkins University

and

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Equipment Research Section
Radio Division III
Naval Research Laboratory

DECLASSIFIED: By authority of: 5000A January 1958
Delivered by: E. Bliss Code 2027

NRL Report No. R-3022
APL/JHU Mon. No. 135
Copy No. [redacted]

April, 1947

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VOLUME II

(This volume contains the appendices referred to as footnotes in Vol. I)

Contents

Appendix A. "Report on Power Driven Gun Director Mark 61." P. J. Larsen (Nov. 28, 1944)

Appendix B. "Automatic Radar Tracking." E. P. Ney, E. W. Smith, J. L. Young Univ. of Virginia (Feb. 5, 1945)
"Automatic Tracking with the Mark 61 Director." E. P. Ney, E. W. Smith, J. L. Young Univ. of Virginia (Feb. 5, 1945)

Appendix C. "Vibration Test of Mark 61 Turret." C. M. Antoni, JHU-APL/TM-1592 (Apr. 16, 1945)
"Fire Control - Gun Director Mk. 61 Mod 0. Fire Control Section Interim Report on Problem 0-143T-C. Preliminary Comment on Results of Vibration Test." NRL Letter to Chief, BuOrd (C-S71-3(395B)

Appendix D. "Reports from Bureau of Ordnance Test Unit, Anti-Aircraft Training and Test Center, Dam Neck, Virginia. (R. L. Jones)

"Gun Director Mk. 61 Mod. 0A Ser. No. 2 - Installation Report of." (Apr. 18, 1945)
"Gun Director Mk. 61 Mod. 0 Ser. No. 2 - Interim Report of Tests of."(Apr. 30,1945)
"Gun Director Mk. 61 Mod. 0 Serial No. 2 - Interim Report of Test of." (May 15, 1945)
"Gun Director Mk. 61 Mod. 0 Ser. 2 - Power Drive Performance, Results of Test of. (June 7, 1945)

Appendix E. "List of Specifications for the Gun Fire Control System, Mk. 61 Mod. 2."
"Specifications and Drawings for the Components of Mk. 61 Mod. 2."

DECLASSIFIED

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Appendix F. "Evaluation Report on Task B, Gun Fire Control Systems, (Contract NOrd 7386) APL/JHU/TP-28."
P. J. Larsen
(June 14, 1946)

Appendix G. Mk. 61 Gun Director: "Method of Determining Proper Damping Setting of Gyros for Stabilizer Mark 1."

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"Calibration of Gun Fire Control Systems Mark 57 and Mark 61", by R. Kogge, issued separately as APL/JHU Technical Monograph No. 134.

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A P P E N D I X A

November 28, 1944

REPORT
ON
POWER DRIVEN
GUN DIRECTOR, MK 61

by Paul J. Larsen

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DECLASSIFIED

APPENDIX A

INDEX OF CONTENTS

GENERAL	PAGE
Formation of Group	1
Objective	1
Prior Devices & Test Observations	1
Adoption of Hydraulic Drive	2
Specification	3
Design Tasks	3
1. STABILIZATION SYSTEM FOR GUN DIRECTOR	4
Type of Power System	4
Type of Gyro	4
1st Roll Table Tests	5
Vickers 16801 Pump	5
Amplifier	5
Arma Control Motor Gear Ratio 130 : 1	5
Damping Generator	5
Arma Control Motor Gear Ratio 5 : 1	5
Theoretical Results	6
First Derivative Error Signal	6
Army M^2 Hydraulic Control	6
Accelerometer--First Derivative Error Signal	6
R.C. Network--First Derivative Error Signal	6
University of Virginia Tests	6
2nd Roll Table Tests	6
Rate Gyro	7
1st Servo Control Arma Gear Ratio 5 : 1	7
Latest Experimental Stabilization Circuit	8
D.C. Stroke Generator	8
A.C. Stroke Generator	8
Bibliography	8
2. J.H.U. ORIGINAL DIRECTOR AND NORGE DESIGN #1	8
Plans and Drawings	8
Basket Components	9
1/4 Scale Mock-up	9
Norge Conference	9
OSRD-Norge Development Contract	10
Full Scale Director Fabrication	10
Central Lower Bearing	10
Norge Modified Design of J.H.U. Director	10
Full Scale Wood Mock-up	10

DECLASSIFIED

APPENDIX A

INDEX OF CONTENTS

	PAGE
Formation of Group	1
Objective	1
Prior Devices A Test Observations	1
Adoption of Hydraulic Drive	2
Specification	3
Design Tasks	3
1. STABILIZATION SYSTEM FOR GUN DIRECTOR	4
Type of Power System	4
Type of Gyro	4
Test Roll Table Tests	5
Vickers 1560I Pump	5
Amplifier	5
Arma Control Motor Gear Ratio 150 : 1	5
Damping Generator	5
Arma Control Motor Gear Ratio 5 : 1	5
Theoretical Results	6
First Derivative Error Signal	6
Amp'r Hydraulic Control	6
Accelerometer--First Derivative Error Signal	6
T.O. Network--First Derivative Error Signal	6
Solvers Ltd. of Virginia Tests	6
Test Roll Table Tests	6
Tests Gyro	7
Test Servo Control Arma Gear Ratio 5 : 1	7
Latest Experimental Stabilization Circuit	8
T.O. Stroke Generator	8
A.O. Stroke Generator	8
Bibliography	8
2. I.U.D.- OPTICAL DIRECTOR AND SONAR DESIGN #1	8
Plans and Drawings	8
Basket Components	9
1/4 Scale Mock-Up	9
Norge Conference	9
CEMD-Norge Development Contract	10
Full Scale Director Fabrication	10
Central Lower Bearing	10
Norge Modified Design of I.U.D. Director	10
Full Scale Wood Mock-Up	10

DECLASSIFIED

DECLASSIFIED

Preliminary Production Design Drawings 10
Norge Design #1 10
Second Operator 10
Optical Sight 10
Roll & Pitch Platform 11
Hydraulic Lift Platform 11
J.H.U. Original Director completed 11

3. LOWER OPTICAL SIGHT 11

Combining Optical Sight With T & E 11
MK 60 Prism Sight 11
Fixed Sight 12
OSRD-Farrand Development Contract 12
Optical Design Adopted 12
Complete Sight 12
Delivery 12
Improvement Contemplated for Production 12

4. PRODUCTION DESIGN CHANGE, MARCH 24, 1944 13

Decision As To Two Operators 13
1/8 Scale Mock-up, Norge Designs 1,2,3,4,5 13
Maxson Proposed Director 13
1/4 Scale Mock-up Norge Design #5, Basket 13
Section T-BuOrd Conference March 24, 1944 13
Norge Design #5 Adopted 13
Worm Driven Radar 13

5. MK 61 DIRECTOR 13

Design Started March 24, 1944 13
Delegating Design Between Norge & J.H.U. 14
Mechanical Calculations 14
Stress Analysis 14
Gear Transmission Design 14
Electrical Equipment Design 14
Navy Specification 14
Electrical Components 14
Dial Indicating Panel 15
Servo Mechanism Amplifiers 16
Open Sight 16
Assembly in Basket 16
Cable Twist 16
Train Travel Limited to ± 360° 17
Cable Diagram 17
Manual Operation of Servo Valve 17
Hydraulic Limit Stop Protection 17
Permanent Mechanical Limit Stops 17
Serial #1 Director Completed November 3, 1944 17

DECLASSIFIED

DECLASSIFIED

Tests at Factory 17
MK 28 Radar 17
Mechanical Lock Positions for Access 18
Interlocking Power Switch 18
Shipped to University of Virginia 19
Hour-glass Worm Drive for Radar 19
1/4 Scale Mock-up of Director 19
Preliminary General Information Booklet 19
Mechanical and Electrical Test Data Book 19
Blue Prints 19
Tests at University of Virginia 19
Delivery of Serial #2 Director 20
MK 29 Radar 20
Delivery of Serial #3 Director 20
MK 39 Radar 20

INDEX OF FIGURES 20-21-22

DECLASSIFIED

DECLASSIFIED

APPENDIX A

REPORT ON POWER DRIVEN GUN DIRECTOR, MK 61

by Paul J. Larsen

In September, 1943, Section T, OSRD, was requested by the Bureau of Ordnance of the United States Navy Department to develop a power driven gun director for use with 40 mm and 5" gun mounts. The designs to have two main objectives in mind, namely, (1) capable of blind tracking within a ± 2 mil tracking error on a rolling ship, necessitating a stabilized line of sight, and (2) operation by semi-skilled personnel requiring simplicity of control and all components to be readily accessible, and to be so designed as to keep to a minimum maintenance and service.

With these main objectives in mind, group SPP was formed on October 1, 1943, consisting of seven people. For the first two months, that is October and November, 1943, all available data and information was obtained relating to power driven gun directors and gun mounts. Many visits were made to proving grounds and industrial and scientific laboratories, for the purpose of obtaining data and information relating to (1) ways and means to stabilize a director, (2) construction of gun directors and mounts, and (3) type of power drive systems employed or contemplated for future use. Many conferences were held with representatives of the Bureau of Ordnance, RE Group, the Bureau of Aeronautics, and the Bureau of Ships of the U.S. Navy, obtaining their viewpoints and field experiences in respect to requirements and operational performances of gun directors and mounts in use.

Based upon the data and information obtained from all of these sources, samples of some of these directors and gun mounts were obtained for laboratory study and analysis. Laboratory tests were conducted on the following types of directors and mounts:

1. MK 49 Gun Director as manufactured by the Ford Instrument Company:

   This employed an electric motor drive with friction clutches for train and elevation, controlled from gyro output contacts. Stabilization employed a free gyro processed mechanically by joystick for tracking rates.

2. MK 23 50 calibre Submachine Gun Turret as manufactured by the Borg-Warner Corporation:

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Power drive system consisted of a hydraulic pump valved through a handle bar control for train and elevation.

3. Martin Model 250SH2 Aircraft Gun Turret:

Non-stabilized, power driven through use of a hydraulic pump valved through a handle bar control for train and elevation.

4. Field Tests:

a. Field tests were observed on 1 and 2 above and on a MK 50 gun director as manufactured by Arma Corporation. These tests were conducted at the Naval A nti-Aircraft Test Center, Dam Neck, Virginia. The MK 50 gun director was cross level stabilized, employing a free vertical gyro. This gun director was powered by an amplidyne type of control system, Ward Leonard Circuit.

b. Field tests were also observed at M.I.T. on an SCR-584 Army automatic tracking radar director, non-stabilized, powered by an amplidyne electric drive system manufactured by the General Electric Company and the Westinghouse Electric Manufacturing Company.

c. Laboratory and field tests were observed on a model CXBL automatic tracking radar at M.I.T., stabilized by use of a free gyro having magnetic vane takeoffs, powder driven by a dual Vickers type 16801 hydraulic pump and motor unit valved by a special servo mechanism developed by M.I.T.

d. Laboratory and field tests were observed at Westinghouse Electric Manufacturing Company at Springfield, Mass., of a restrained gyro stabilizer system used for stabilization of gun turrets in Army medium tanks M-3 and M-4. Gyros were electrically driven procession actuating silverstat contactors controlling electric motor.

After the above study of tests and of the servicing and maintenance problems encountered by the Navy on gun directors and gun mounts using either amplidyne electric or hydraulic power drive systems, the hydraulic power drive system was adopted as the power drive system for the director. This decision was based on the following:

1. Compactness.

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2. Ease of Servicing.

3. Maximum speed range.

4. Large torque outputs at slow speeds.

5. Most satisfactory performance and least maintenance aboard ship as no commutators are used and control circuits are simple.

6. Navy approved hydraulic components available whereas Navy approved amplidynes of size required, approximately 1 H.P. or less, are not available. Navy approved amplidyne system could not be designed and fabricated by General Electric Company or Westinghouse Electric Manufacturing Company in less than 16 to 18 months.

The following general specification was adopted by Group SPP as a basis for designing the power driven director:

Range, 6000 yards.
Director train limited to 720° so as to use cable twist in place of contactor rings.
Director elevation, - 20° to +90°.
Tracking in train and elevation between rates of 1 ⅛ (0.06°) and 20° per second.

Slowing in train or elevation up to 45° or 50 per second.
Acceleration 30° to 50° per second.
Stabilization of line of sight to 2 to 4 ⅛ with roll and pitch as follows:
Roll, 25°
Period of roll, 9 seconds
Pitch, 5°
Period of pitch, 5 seconds.
Tracking error to be within one half circle of 2 ⅛.
Weight less than 4000 lbs. above deck, plus below deck radar and computing elements.

To undertake the above program of designing a power driven director, specific design tasks were assigned to two project sections of Group SPP, The assignments were as follows:

Project Section SPP-1:

Design and fabrication of laboratory test model director employing the hydraulic power drive system.

Project Section SPP-2:

Design of a stabilization system to be employed in the

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above laboratory model director, including the design of electric control system and servo valve mechanism for use with the hydraulic power drive system.

For purposes of chronological report as to the activities of Group SPP this report is divided into specific sections relating to the various phases leading up to the final design of the MK 61 gun director. These sections include the work in design and fabrication undertaken by the Norge Division of the Borg-Warner Corporation, and are as follows:

1. Stabilization System for Gun Director.
2. J.H.U. Original Director and Norge Design #1.
3. Lower Optical Sight.
4. Production Design Change, March 24, 1944.
5. MK 61 Director

1. STABILIZATION SYSTEM FOR GUN DIRECTOR

In connection with the development of a power turret, one of the first considerations was the choice of the type of power to be used for controlling the turret for stabilization and tracking. Since the decision had already been made when the group started on the problem to develop as simple a turret consistent with satisfactory performance as possible, the turret design chosen was that of train and elevation motion without cross level correction.

Two alternatives for the drive presented themselves: (a) A free gyro, and (b) two rate gyros -- one for train and one for elevation. The latter method was initially chosen for several reasons, which follow:

1. Rate gyros with electrical pickoffs were in production while no usable free gyros were available.
2. It looked like the rate gyro sys tem might be the simpler.
3. A hydraulic drive system fits in well with the rate gyro while the free gyro is best used with an electric motor drive.
4. Hydraulic systems are in wide usage on shipboard and have given excellent service. Electrical systems of

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the amplidyne type have given commutation troubles probably due to the large short circuit currents.

The system first set up was a very simple one. A rolling table was constructed to simulate a rolling deck. The amplitude was adjustable from ± 5° to ± 20° with period 15 seconds. On top, with axis parallel to roll axis, was placed another rolling platform upon which was mounted the MK 15 rate gyro, with its input axis parallel to the roll axis. The pickoff output was led to a power amplifier of gain 3000 (See notebook of C.H.Shaw #439 page 43), and thence to an Arma #6 two-phase drag cup A.C. motor. The shaft of this motor was connected to a gear reducing system (170 : 1) to the gyro platform. After adjustments had been made, this system stabilized a 10° roll with a residual roll of ± 1.5 ⁄ (December 16, 1943).

Thus encouraged, we proceeded with the installation of the variable displacement hydraulic pump (Vickers 16801) and hydraulic motor. In this arrangement the Arma Motor was made to operate the hydraulic servo valve through a gear reduction of 130 : 1, while the hydraulic motor was geared to the gyro-platform with a ratio of 800 : 1. Figs. 1 and 2 show the general arrangement of the first roll table setup. On January 5, 1944, this system was tried out and was found to "hunt" badly -- a result which we later realized was to be expected. The Arma anti-hunt network was tried in the amplifier circuit to eliminate the hunting but performed rather badly because it was not possible to include enough series resistance and retain the required sensitivity. Figs. 3 and 4 illustrate the Vickers 16801 pump which was equipped with the rotary servo valve. Fig. 5 shows the amplifier developed for this sytem, while Fig. 6 shows one of the 130 : 1 control boxes.

The next step was the addition of a damping generator to the stroke control gear train. The A.C. induction generator output was fed back into the amplifier with phase difference of 180° from that of gyro putput. Hunting was eliminated and the following performance was obtained with this arrangement:

Table roll of ± 10°

Period 7-15 seconds

Residual roll ± 14 ⁄

Tracking tests on a stationary platform showed that one could track a target to a half circle of 1 ⁄. On a rolling platform, however, about 5 ⁄ was the best possible. Better stabilization was obviously required. A block diagram of the complete arrangement is shown in Fig. 17 (Lower Figure page 46 of Shaw's Notebook #439). Two gear ratios were tried to the hydraulic valve, the first of 130 : 1 and the second of 5 : 1.

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This last was constructed after results at the University of Virginia had indicated an improvement with a low gear ratio.

The drive gear box was rebuilt with much more rugged construction and the stroke gear train was rebuilt, using gear sizes and ratios to reduce the effective moment of inertia on the stroke motor shaft to a minimum. The circuit was examined in detail for components which might be introducing delay into the system and therefore making it unstable at the higher sensitivities. A theoretical investigation was made by Mindlin, Sigley, and company and by Cook. Many measurements of circuit constants were made. The theoretical results showed that if the components behaved in practice as set up in the equations, the circuit should stabilize to about ± 2 mil on a 10° roll. However, it is certain that the equations did not represent the physical system accurately. For example, the following assumptions were made which are known to be not true: No backlash in gear trains, no Coulomb friction, no dead space in the hydraulic control, zero time response for the hydraulic system, strict linear response in all circuit components. The effect of introducing the above factors is to require greater damping than would otherwise be necessary. This introduces acceleration errors and accounts for the poor stabilization. It was concluded that proportional damping was inadequate to produce the required degree of stabilization. A correction for the acceleration errors could be introduced by applying a first derivative error signal. Fig. 7 shows one of the gear boxes so modified that either proportional damping in the form of a Ford magnetic damper or a D.C. Elinco generator (see Below) could be used.

An Army M2 hydraulic drive for 90 mm gun was obtained from Frankford Arsenal. The stroke control assembly was connected to the hydraulic valve of the Vickers 16801. This unit uses a D.C. stroke generator with resistance-capacitance networks to produce a delayed damping signal. Stabilization was not improved.

The next improvement came from the University of Virginia, where stabilization systems have been studied since the Spring of 1944. They introduced an approximate first derivative error signal by means of a rather crude accelerometer attached to the rolling table and found considerable improvement in stabilization and tracking. Their results were checked here, where the degree of stabilization was improved to about ± 7 mil on a ± 10° roll. They subsequently worked out a simple RC network to give damping and first derivation error control and added a considerable dither to the hydraulic control valve. With these additions they were able to stabilize to 1 mil total roll on a ± 15° roll. Results at APL were not quite so good (2 mil total roll on ± 10°) but allowed tracking to a half circle

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of 1 ⁄. Figs. 8 and 8a show the Vickers 20400 pump which was adopted as soon as available because greater speed range was allowed thereby. Fig. 9 shows the hydraulic motors used. Figs. 10, 11, 12, 13 show the laboratory table model upon which the development work was done. The symbols employed on Figs. 10, 11, 12, and 13 are as follows:

A-MK 15 gyro mounted on platform to be stabilized.
B-Rolling deck
C-Deck drive
D-Electric motor drive for hydraulic pump
E-Hydraulic pump
F-Stroke control mechanism
G-Drive gear transmission
H-Sump pump
J-Reservoir
K-Amplifier
L-Hydraulic motor
M-Restoring generator
N-Prony brack cylinder for testing performance with Coulomb friction
O-Steel disc to simulate turret moment of inertia in train
P-Motor and gear train to rotate deck at constant rate for tests
Q-Tracking joystick
R-Rotatable transformer
S-Power for rotatable transformer

Fig. 14 is a close-up view of the rate gyro, in which the symbol A is the pickoff magnet; B the output gimbal axis; C the thermostat, and D the gyro wheel.

Figs. 15 and 16 show some of the elements of the servo control box. The symbols employed on Figs. 15 and 16 are as follows:

T-Stroke motor
U-Stroke generator
V-Dither motor
W-Limit stop worm
X-Manual tracking control
Y-Hydraulic servo valve and lever
Z-Dither mechanism.

Fig. 18 is the latest experimental circuit for possible installation in future MK 61 directors.

With this general design drawings were made for a production control unit using the higher gear ratios which is under construction at this time at Apex Machine Mfg. Company, N.Y.C. Meanwhile, two stroke control assemblies have been made

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up at APL and three more are under construction to take care of the Norge Turrets until the Apex controls are ready. Tests are now under way at University of Virginia on the first Norge Turret.

The D.C. stroke generator is a potential source of trouble, since a dirty commutator will upset the action of the circuit. A circuit has been developed at Naval Gun Factory, using an A.C. stroke generator and work has been started to try to apply the circuit to the stabilization system.

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	9-23-44	(Memo CHS to PJL) Stabilization & Tracking with M2 Control
	10-6 -44	(Memo CHS to PJL) Effect of Friction on Stabilization
	11- -44	Operating Manual for MK 61 Director

2. J.H.U. ORIGINAL DIRECTOR AND NORGE DESIGN #1

For the purpose of studying the various director designs considered, a drawing "Outline of MK 61 Director Designs" is included at the rear of this report and reference thereto will be made from time to time.

By the middle of December, 1945, detailed plans and drawings had been prepared for the laboratory test model director, which hereafter will be referred to as the "J.H.U. Original Director" as shown in View #1 on the drawing "Outline of MK 61 Director Designs".

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This design made use of the MK 23 fifty calibre sub-machine gun turret gear ring and ring roller bearing structure. A basket suspended to this ring roller bearing structure was constructed for carrying the tracker in train. The basket housing the following components:

a. MK 17 computor

b. Cradle for supporting a gyro stabilizer box of a design to be determined.

c. Two Vickers Hydraulic Pump Motor Units Type 16801 with double ended electric drive motor.

d. Prism type optical sight Bendix type 80400A with control panel below sight incorporating a main switch, a telephone outlet, train and elevation indicating dials and a T & E scope.

e. A mplifier rack assembly with amplifiers for servo valve mechanism control.

f. Controller for remote control operation and protection of electric motor on hydraulic pump.

g. Train gear transmission box including train synchros.

h. Elevation gear transmission box and elevation synchros

i. Upper structure for support of MK 28 (45" dish) radar.

j. Two servo valve mechanisms for control of hydraulic valves.

k. 440/110 volt power transformer.

l. Open sight for tracker.

A 1/4 scale mock-up of this director was completed on December 4, 1943. Figs. 19 and 20 show two views of this mock-up. At a conference held on December 10 between Section T and Bureau of Ordnance Officials, this general design was accepted as meeting the requirements. The Bureau of Ordnance recommended the Norge Division of the Borg-Warner Corporation as a possible pilot manufacturer to assist in the production design and fabrication of a number of pilot production directors for field and fleet test.

A conference with the officials of the Norge Division in respect to accepting a development contract was held in Detroit on December 14, 1943, and the Norge Division agreed

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to accept a development contract to design and manufacture six sample gun directors of a design similar to the "J.H.U. Original Director". An OSRD development contract with the Norge Division, Contract #OEMsr-1264, symbol T-92, was entered into effective December 1, 1943, dated March [illegible], 1944.

Fabrication of a full scale "J.H.U. Original Director" in accordance with J.H.U. plans and designs proceeded at J.H.U. for purposes of testing various stabilization systems. Tests of torque and friction were made on various types of bearing structures. After many tests, the bearing structure for the basket was changed to a lower central bearing for supporting the mass weight and shook leads of the basket. The upper annular gear ring, in addition to the use of the gear for train drive, was utilized only as a radial bearing, carrying no vertical load as heretofore. Friction, by use of the lower central bearing, was reduced by at least one third. The Norge Division also agreed with the advantage of this type of bearing structure and proceeded with the design using this method of bearing structure. View #2, "Norge Modification of J.H.U. Director" on the drawing "Outline of MK 61 Director Designs" shows the central lower bearing and the tracker shifted forward to axis of director.

For purposes of aiding production design the Norge Division made a full scale wooden mock-up of the basket structure upon which mock-ups of the components were assembled. This assisted in determining accessibility of components and the structural supports required to secure the components in the basket. Figs. 21 and 22 are photographs of full scale basket mock-up. Figs. 23, 24, and 25 show full scale mock-up of components assembled on basket. In early February the Norge Division had completed preliminary production design drawings of the proposed MK 61 director, incorporating additions and improvements made by J.H.U. and modifications for production and manufacturing purposes.

Norge Design #1 as shown in View #3 of "Outline of MK 61 Director Designs" was the design adopted at Norge and drawings detailing components were partly completed by the end of February, 1944, for fabrication of six complete gun directors according to this design. In view of a request from the Bureau of Ordnance in the early part of February, provisions were made for carrying a second man in the director. This second man, or control officer, was desired in the power director for spotting and directing the tracker to new targets. A one quarter scale mock-up of this director was constructed and is shown in Figs. 26 and 27.

The lower optical sight contemplated for use in the final gun director as shown in View #2 and in Figs. 26 and 27, con-

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sists of a fixed sight employing a driven prism within the sight for elevation. This sight is described later under Section 3 of this report.

For purposes of testing different stabilization systems of the director, a special roll and pitch platform and constructed to simulate ship roll and pitch. Surveys of different testing platforms in use at Dam Neck, Virginia, M.I.T., Sperry Corporation and General Electric Company were made and a design for a platform that could be constructed in a minimum time, using standard material and accessories was completed. Hydraulic pistons were employed, the pumps were controlled by a motor driven valve control so as to obtain varying rolls and pitches at different periods. Due to leakage past the pistons, platform drifted "off-center". Differntial gears were installed to couple the platform motion with the valve control mechanism to automatically correct and adjust the valve driving action so that the angle of roll or pitch could be maintained symmetrical around the normal horizontal position of platform. A rigid guide frame and arm was installed to restrain the platform from a torsional displacement and to produce a smooth oscillatory motion. A small building with a removable canvas top was constructed around the platform for necessary enclosure to work during inclement weather. In addition, a hydraulic lift platform was constructed for handling the director, to be mounted on the platform and other heavy apparatus incidental to the project.

The construction of the "J.H.U. Original Director" continued at J.H.U. and during the middle part of April, 1944, this laboratory director was completed. Figs. 28 and 29 show the "J.H.U. Original Director" as fabricated by J.H.U., installed on the roll and pitch platform. A standard MK 60 lower optical sight was employed. Tracking tests were made under different rolls and pitches to determine the operability of different stabilization systems, servo mechanisms and electrical control circuits developed, using the laboratory roll and stabilization table previously described.

3. LOWER OPTICAL SIGHT

During the early consideration of the design of a power driven gun director, various representatives of the Bureau of Ordnance recommended that we adopt a fixed lower optical sight, that is, a sight which does not elevate in respect to the tracker, necessitating the tracker's head to follow the optical sight in elevation. The sight recommended by the Bureau of Ordnance was the MK 60 prism type sight in which the elevation is accomplished by rotating a prism. In view of stabilizing

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the line of sight, this type of optical system only requires the prism to be actuated from the stabilization drive system and therefore stabilization of the prism system is made without the tracker being conscious of stabilization action over which he has no control.

For blind tracking, the tracker of necessity is required to view a T & E scope in which a spot representing the image has to be tracked in respect to a fixed cross hair. The Bureau of Ordnance generally agreed that it would be an improvement to combine this T & E scope as part of the optical system so as to make it possible for the tracker to view either the visual target or the T & E spot from the same eyepiece.

An OSRD development contract with the Farrand Optical Company, Contract #OEMsr 1250 was entered into on January 27, 1944, dated February 19, 1944, to design, develop and fabricate five combination optical sights in which the T & E scope spot would be visible through the same optical path used by the tracker for viewing a visible object. After laboratory tests an optical design was adopted as shown on Fig. 30, which is self-explanatory. Fabrication of five complete optical sights in accordance with this design was started on May 25, 1944. The first sight was delivered on September 21, 1944, and is now installed on the MK 61 Director. Serial #1, at the University of Virginia. Figs. 31 and 32 show different views of this lower optical sight or telescope. The balance are scheduled for delivery on December 15, 1944, January 6, 1945, January 25, 1945, and February 15, 1945.

An improved design of this combined telescope has been completed in which it is possible to view the visual target as well as the T & E spot simultaneously without reducing the brightness from the direct viewing path. The present design necessitates manual operation of a filter into the direct viewing path in order to make the T & E spot visible. The brightness of the T & E spot undoubtedly is extremely low and the normal brightness level of the direct viewing path such as obtained from a blue sky or reflections from clouds is of such magnitude as to make the T & E spot invisible. The use of filters is therefore necessary to view the T & E spot under such brightness conditions. The improved proposed design makes this manual introduction of a filter unnecessary as the visual object and the T & E spot are viewed on different portions of the objective lens. The lens being a wide angle lens of the order of 70°, has a portion of the lens not required for the direct viewing path blocked out and this blocked out portion is used for the T & E optical path. This improved design can be readily incorporated into the production design when decision to produce the director in quantity is made.

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4. PRODUCTION DESIGN CHANGE, MARCH 24, 1944.

Numerous meetings were held during the month of March, 1944, between Section T and the Bureau of Ordnance in respect to a final determination as to the best director design to adopt, in view of the Bureau of Ordnance's decision that the director must be adapted for two men, one a tracker and one an officer observer.

The Norge Division was requested on March 3, 1944, to submit various designs incorporating two operators. On March 20 the Norge Division submitted a one eighth scale mockup of their designs numbers 1 to 5 inclusive, shown in Views 3, 4, 5, 6, 7, and 8 on drawing "Outline of MK 61 Director Designs." Figs. 33, 34, 3 5, 36, and 37 are photographs showing these mockups respectively. Fig. 35 is a modified version of design #3 as shown in View #6 of the drawing, to reduce the maximum operating diameter from 110" to 82".

The Maxson Corporation of New York submitted a 1/8 scale mockup of a proposed director as diagramatically shown in Fig. 38 and in photograph, Fig. 39.

J.H.U. constructed a 1/4 scale mockup of the basket structure for Norge design #5 for purposes of ascertaining whether or not the components contemplated for installation in the basket structure would fit the design recommended by Norge. Fig. 40 shows this mockup of the Norge design #5 basket structure.

On March 24, 1944, at a conference at J.H.U. between officials of the Bureau of Ordnance and Section T the various mockups of the designs proposed were shown and after long discussions as to the merit and demerits of the different designs it was unanimously agreed that Norge design #5 seemed to be the most practical. The Norge Division was accordingly advised to stop all work in connection with the Norge design #1 and to proceed with the design and fabrication of a gun director similar to the Norge design #5. One objectionable feature raised at this meeting to Norge design #5 was the blocking of the view in the rear of the director by the upright structure supporting the radar. The structure then contemplated consisted of driving the radar dish and transmitter box through use of a pantograph drive system. In view of this objection the design was changed to a worm drive which eliminated the wide pedestal structure shown on Norge design #5, and the structure for supporting the radar dish and transmitter box was changed to a pipe construction, permitting visibility through the structure.

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5. MK 61 DIRECTOR

In accordance with the decision arrived at on March 24,

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1944, the redesign of the MK 61 Director proceeded at J.H.U. and at Norge. In order to expedite this design and the fabrication of the miscellaneous components entering into the director, designs for particular components were divided between J.H.U. and Norge. All main mechanical components, including basket and turret structure, were delegated to Norge and the electrical components and servo mechanism units were delegated to J.H.U.

In respect to the mechanical design of the director, Norge made calculations in respect to the maximum tolerances that could be allowed in the gear train systems to meet tracking requirements and still keep backlash to a minimum, as backlash would effect the servo mechanism control system. The basic mechanical structure, the shell, basket, supports for components in basket, and radar supporting structure, were calculated to withstand the shock loads encountered aboard ship. These calculations were carried out jointly by Dr. Bruce Johnston of J.H.U. and engineers of the Norge Division. The gear transmissions for train and elevation, including the worm drive system for the radar, were designed and calculated by Mr. Floss, the gear specialist of the Norge Division, to withstand the torque requirements, wind loads and gun blast forces encountered aboard ship.

The electrical components designed by J.H.U. were designed in accordance with U.S. Navy specifications to withstand shocks, water-proof test, and electrical insulation requirements set forth in these specifications. It was soon found that no standard Navy approved equipment was available, even including such simple items as step-down transformers, controller motor starter, electric motor used for driving the hydraulic pumps, and other such components. Designs and fabrication of such units therefore became necessary.

The majority of equipment available was designed for aircraft purposes and was therefore not strong enough to withstand the shock of blast loads encountered aboard ship. The electric motor for driving the hydraulic pumps had to be designed for operation from the 440 volt 3 phase 60 cycle standard ship power supply, and its frame construction, to conform with Navy specifications, had to be of steel. Motors available for these hydraulic pumps were standard aircraft motors having aluminum frames, and operated on 24 volt D.C. standard aircraft power supply.

Some of the electrical components designed by J.H.U. for use in the MK 61 director are shown on Figs. 41, 42, 43, and 44. The components on these figures are indicated by the following symbols:

A-Main fuze distribution box, encasing low voltage

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step-down transformers and spare fuzes.

B-Original 440 volt 3 phase 1 1/2 H.P. electric drive motors for hydraulic pumps, aluminum construction not complying with U.S. Navy specification.

C-Navy approved constructed 440 volt 3 phase 1 1/2 H.P. electric drive motor of steel construction.

D-Controller motor starter for protection of electric motor and remotely operated from control panel start-stop switch.

E-Computer power and telephone terminating cabinet.

F-Service receptacle outlet and switch.

G-Computer and director control terminating cabinet.

H-Radar power terminating cabinet.

I-Fire control circuit terminating cabinet.

J-Synchro generator terminating cabinet.

K-Synchro power junction box.

L-T & E scope and radar co-axial cable terminating cabinet.

M-Main 440 volt power disconnect switch with interlock.

N-Synchro and phased A.C. main power disconnect switches.

O-Observer's telephone outlet receptacles, mounted on control panel.

P-Tracker's telephone receptacle and sight wiper control switch, mounted on control panel.

Q-Dial indicating panel, including dials for train and elevation and a manual range control unit for manually setting in observed range to the computer mounted on control panel.

R-Main power control panel, consisting of cease-firing switch and indicator, start-stop push button for controller motor starter and on-off switch for all electric circuits, mounted on control panel.

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S-Sight wiper receptacle.

T-Electrical servo cabinet encasing aided tracking units and anti-hunt units for train and elevation servo systems.

U-Servo supply unit encasing electrical power supply for servo system.

V-T & E scope mounted below optical sight. Figs. 43 & 44 show views of this scope, including the train and elevation warning indicator lucite rods for giving notice to the tracker when he approaches the end of travel in train and elevation.

For operating the servo mechanism electrically, special servo amplifiers and power supplies were also designed and fabricated to meet U.S. Navy specifications. Fig. 45 is a view of one of the amplifiers and power supplies designed to be used with the first servo mechanism control valve employing the Arma Servo motor. This design was later changed and combined amplifier and power packs are now under construction for use with the second type of servo mechanism control valve in which a Diehl servo motor is employed.

Other components designed and fabricated by J.H.U. are as follows:

1. 440 V/115 V 1 1/2 KW step-down power transformer.
2. Open sight for tracker and observer.
3. Two types of servo mechanism control units for control of hydraulic valve on pump.

Design and fabrication of all the mechanical parts at Norge and the electrical components at J.H.U. progressed rapidly and assembly of components on basket structure was started during the middle part of September, 1944. Fig. 46 shows three views of some of these components assembled on the basket, including partial wiring.

The electrical connections from the basket proper were brought out by employing a cable twist through the center of the bottom central bearing. This method of bringing electrical connections out had been tested during the early experimental period at J.H.U. and consisted of positioning the multiconductor cables and coaxial cables symmetrically around the axis of the director on a maximum diameter of not exceeding 6". The cables are supported where they enter the cable twist at the top and then are loosely suspended through the lower center bearing. A spacer ring rotating on a rod from the top support,

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and located in the base of the bearing retains their circumferential arrangement. The cables were then looped in a fan-shape to fastenings provided on the bearing pipe structure. The total loose cable length between the top fastening and the deck fastening is approximately 54". Tests conducted, twisting the basket ± 360° in respect to the normal cable position, showed no wire or cable failures after 200,000 twists. A cable twist for bringing the electrical circuits out from the basket to the stationary deck was adopted as it eliminated the necessity of using contactor rings, which in service had given serious trouble. The cable twist does, however, limit the travel in train and for this reason, travel of the director in train was limited to ± 360° or a total of 720°.

The cable connections in the MK 61 Director between the components in the basket structure and in the cable twist are shown in cable diagram, Fig. 62. It will be noted from this cable diagram that a total of 27 multi-conductor cables and coaxial cables extend through the cable twist. Tests conducted on the completed MK 61 Director indicate that these cables do not materially increase the torque required to move the basket in train.

The servo mechanism control boxes for the MK 61 Director were designed to make it possible to operate the hydraulic valve, either through the electro servo control system, stabilized or non-stabilized, or by direct manual control of the valve action from the joystick control handle. This mechanical control was incorporated so that the director could be operated in event the electro-servo system failed. A protective limit stop control was incorporated in the servo mechanism valve control box operated by being connected to the gear drive system in elevation or train. The limit stop starts functioning at -15° and + 75° on elevation and at ± 345° on train. The purpose of the limit stop is to actuate the valve control mechanically so as to restore the hydraulic system to zero position before the basket or elevation components reach the permanent mechanical limit stops provided in the structure.

On November 3, the first MK 61 Director, Mod 0, Serial #1, was completed at Muskegon. Preliminary tests of operation without stabilization were conducted at Muskegon to insure normal operation of all components of the director. Tests were made on the electrical performance of each component, torque loads of director, moment of inertia and alignment. The results of these tests are as follows:

1. Total weight of director, 5,731 lbs.

2. Weight of basket assembly, including radar support, MK 28 radar and lower optical sight, 3,609 lbs.

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3. Center of gravity of basket assembly on counterline of basket from front to back end and 3" to the rear of basket center.

4. Moment of inertia 11,000 lb.ft.^{2} slug ft.^{2}.

5. Alignment between all pads and perpendicularity of trunnion axis of radar, computer and stabilizer were less than .06 m/m with permissable tolerances ranging from .3 m/m to 1.0 m/m.

6. Torque required to overcome static friction and to keep the basket moving in train, 0.31 ft. lbs. applied to the input shaft of the train gear box.

7. Torque required to overcome static friction and to keep the elevation components moving in elevation, 0.28 ft. lbs. applied to the input shaft of the elevation gear train.

A permanent mechanical lock is provided for locking the basket structure in train in any one of twelve positions so as to have access to the components assembled on the basket structure. An interlocking power switch is connected with the lock so that when the lock engages the shell locking the basket the electric power to the hydraulic motor is disconnected. All other electric power in the director is not effected by the operation of this switch, permitting servicing. Figs. 47, 48, 49, 50, 51, 52, and 53 are views of the basket structure of the director through the door of the outer shell in the following lock positions:

Fig. 47: Lock position #4, access to permanent train limit stop.

Fig. 48: Lock position #5, access to joystick control box and electrical servo control unit and firing switch.

Fig. 49: Lock position #6, access to amplifiers, firing switch, and gear drive system to optical sight and open sight.

Fig. 50: Lock position #7, access to servo supply power unit and gear drive system to train and elevation indicator dials.

Fig. 51: Lock position #8, access to train servo mechanism valve control box and gearing system for manual operation of train and elevation servo valve mechanism.

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Fig. 52: Lock position #9, access to electric power motor and hydraulic pump assembly, clutch linkage system for manual operation, train synchro box and elevation synchro box.

Fig. 53: Lock position #11, access to train and elevation transmission boxes, synchro power junction box, hydraulic motors, lubrication pump and radar worm drive torque tube.

The complete MK 61 director, Mod 0, Serial #1, as shipped to the University of Virginia on November 4, 1944, is shown on Figs. 54 and 55. The radar worm drive system on the director as delivered, and as shown on Fig. 55, employed a conventional worm and worm gear drive. Preliminary factory test indicated excessive backlash of this worm drive system and an hour-glass worm gear drive system had been designed and was under fabrication. Since the delivery of the director to the University of Virginia this hour-glass worm gear drive system has been completed, and is now installed on the director.

As a guide and to assist in the design of this MK 61 director a 1/4 scale mockup was started when the basic design was agreed on, and all component designs and changes were checked in this mockup for accessibility and positioning to insure design would fit in director. Figs. 56, 57, 58, 59, 60, and 61 show views of this mockup.

The following data was sent with the MK 61 director to the University of Virginia:

1. Preliminary General Information Booklet enclosing simplified schematics of control system and diagrams of all electrical components in director.

2. A mechanical and electrical Test Data Booklet covering test data on all components used in this MK 61 director.

3. A complete set of blue prints of the director and detailed parts thereof.

Tracking and stabilization tests are now being conducted at the University of Virginia on this director on a roll and pitch platform. It is expected that some improvements will be made to the control system o f the director during tests and these improvements will be incorporated into future models.

The second director which will be known as MK 61, Mod 0-A, Serial #2, is now being assembled at Norge, incorporating the MK 29 radar instead of the MK 28. It is hoped that the third director produced will be equipped with the MK 39 radar which

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will replace the MK 29. Some improvements to the mechanical drive systems are now being designed for incorporation into the third director.

Director Serial #2 is scheduled for delivery on or about December 20, subject however to delivery of the MK 29 radar components and the fabrication of the parts required for adapting the director to this radar. Serial #3 is scheduled for delivery on or about February 15 and this delivery date is likewise subject to change dependent upon the delivery of the MK 39 radar equipment and incorporation of changes necessary to accommodate it.

INDEX OF FIGURES

1. First Roll Table for Test of Stabilization, December, 1943

2. View of Hydraulic & Gyro Stabilized Table on First Roll Table

3. Vickers Type 16801 Hydraulic Pump & Motor

4. Vickers Type 16801 Hydraulic Pump showing rotary Control Valve

5. Amplifier-Power Pack Unit for Arma Control Motor System, April, 1944

6. Stroke Control Unit, Arma #5 Motor, Gear Ratio 130 : 1

7. Experimental Model Stroke Control Assembly for use with M-2 Amplifier and Derivative Error Control.

8. Vickers Type 20400 Hydraulic Pump with Piston Control Valve, First Sample April, 1944. Separate Hydraulic Motor Needed.

8a. Production Vickers Type 20400 Hydraulic Pump with Mounting Bosses added to housing July, 1944. Adopted as Hydraulic Pump Unit on MK 61 Director.

9. Vickers 30 degree and 15 degree Hydraulic Motors used with 20400 Pump on MK 61 Directors. 30 degree motor has better speed characteristics at low speeds.

10. Second Roll Table for test of Stabilization, August, 1944, with first Production Servo Mechanism using Arma Motor and low gear ratio, 9 : 1.

11. Second Roll Table, Rear View.

DECLASSIFIED

DECLASSIFIED

12. Second Roll Table, Right Front View.

13. Second Roll Table, Left Rear View

14. MK 17 Computer Gyro (MK 15 Original) on Stablized Platform of Roll Table.

15. First Production Servo Mechanism Control with Arma Motor, low gear ratio 9 : 1, rear view, November, 1944.

16. First Production Servo Mechanism Control, Front View showing Manual Clutch Jaws for engaging mechanism for manual operation of piston valve.

17. Schematic of "Proportional Damping Stablization System".

18. Schematic of "Latest Experimental Stablization System"

19. 1/4 Scale Mock-up "J.H.U. Original Director"

20. 1/4 Scale Mock-up "J.H.U. Original Director"

21. Full Scale Mock-up "J.H.U. Original Director" Basket at Norge

22. Full Scale Mock-up "J.H.U. Original Director" Basket at Norge

23. Full Scale Mock-up of Components, Norge Design #1.

24. Full Scale Mock-up of Components, Norge Design #1.

25. Full Scale Mock-up of Components, Norge Design #1.

26. 1/4 Scale Mock-up, Norge Design #1

27. 1/4 Scale Mock-up, Norge Design #1

28. "J.H.U. Original Director" on Roll and Pitch Platform

29. "J.H.U. Original Director" on Roll and Pitch Platform

30. Schematic Drawing of Lower Optical Sight Optical Paths.

31. Farrand Telescope (Combined Optical T & E Paths)

32. Farrand Telescope (Combined Optical T & E Paths)

33. 1/8 Scale Mock-up of Norge Design #1

34. 1/8 Scale Mock-up of Norge Design #2

DECLASSIFIED

APPENDIX A

DECLASSIFIED

35. 1/8 Scale Mock-up of Norge Design #3
36. 1/8 Scale Mock-up of Norge Design #4
37. 1/8 Scale Mock-up of Norge Design #5
38. Drawing of Maxson Proposed Director
39. 1/8 Scale Mock-up of Maxson Proposed Director
40. 1/4 Scale Mock-up of Norge Design #5 Basket Structure
41. Electrical Components Closed.
42. Electrical Components Open
43. T & E Scope
44. T & E Scope
45. Amplifier and Power Supply
46. Assembly of Components on Basket
47. Director in Lock Position #4
48. Director in Lock Position #5
49. Director in Lock Position #6
50. Director in Lock Position #7
51. Director in Lock Position #8
52. Director in Lock Position #9
53. Director in Lock Position #11
54. MK 61 Director Serial #1, Front View
55. MK 61 Director Serial #1, Right Side View
56. 1/4 Scale Mock-up of MK 61 Director, Front View
57. 1/4 Scale Mock-up of MK 61 Director, Right Side View
58. 1/4 Scale Mock-up of MK 61 Director, Left Rear View
59. 1/4 Scale Mock-up of MK 61 Director, Right Rear View
60. 1/4 Scale Mock-up of MK 61 Director, Right View
61. 1/4 Scale Mock-up of MK 61 Director, Control Panel View
62. Cable Diagram for MK 61 Mod 0 Serial #1 Gun Director

DECLASSIFIED

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FIGURE 1

The first rolling table with hydraulic drive, G-Rolling deck; F-Stabilized platform; E-Gyro; A-Arma stroke motor; E-Stroke gear train; J-Stroke generator; C-Hydraulic pump and motor (16801); D-Drive gear transmission; H-Tracking potentiometer

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FIG. 1

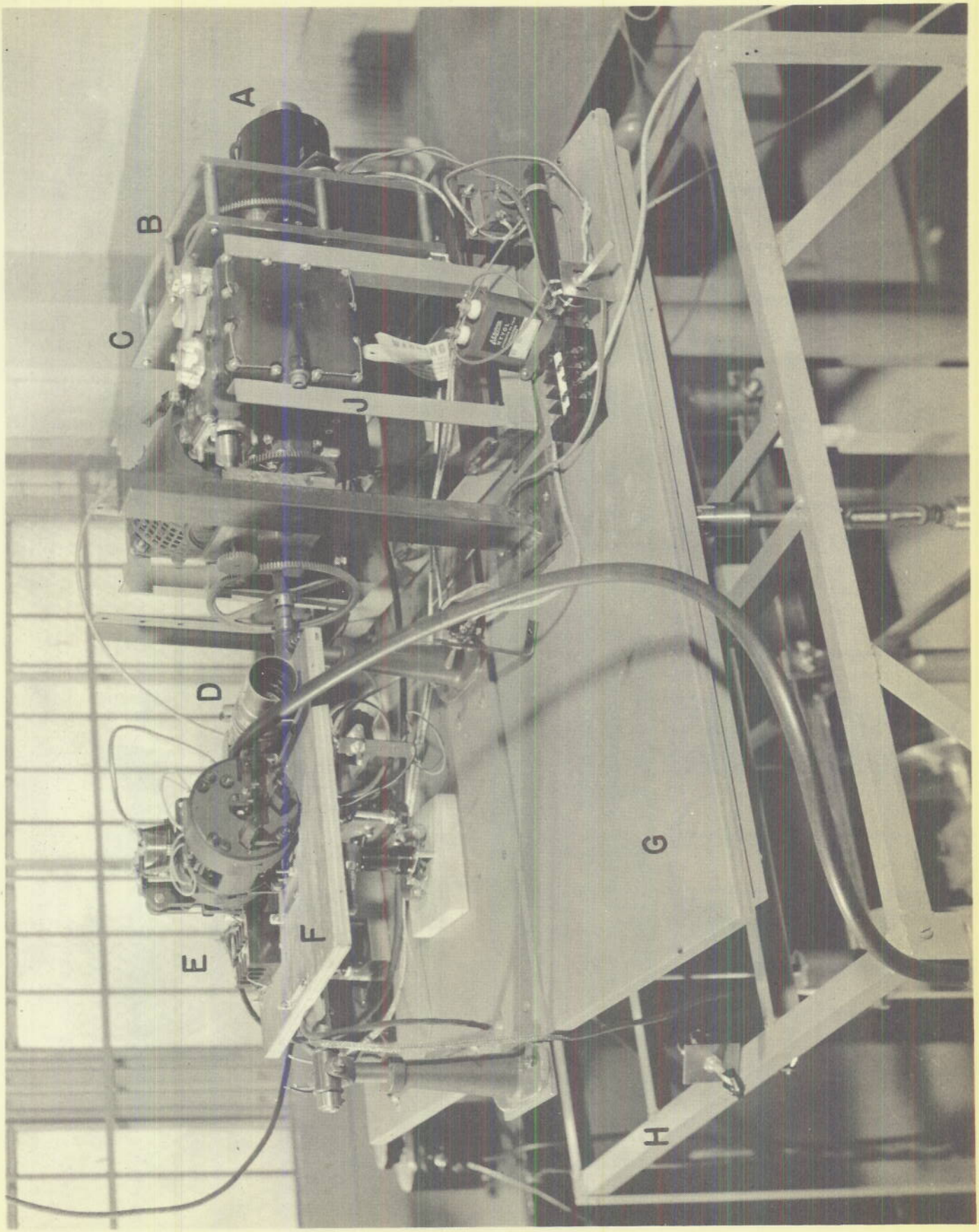

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FIG. 2

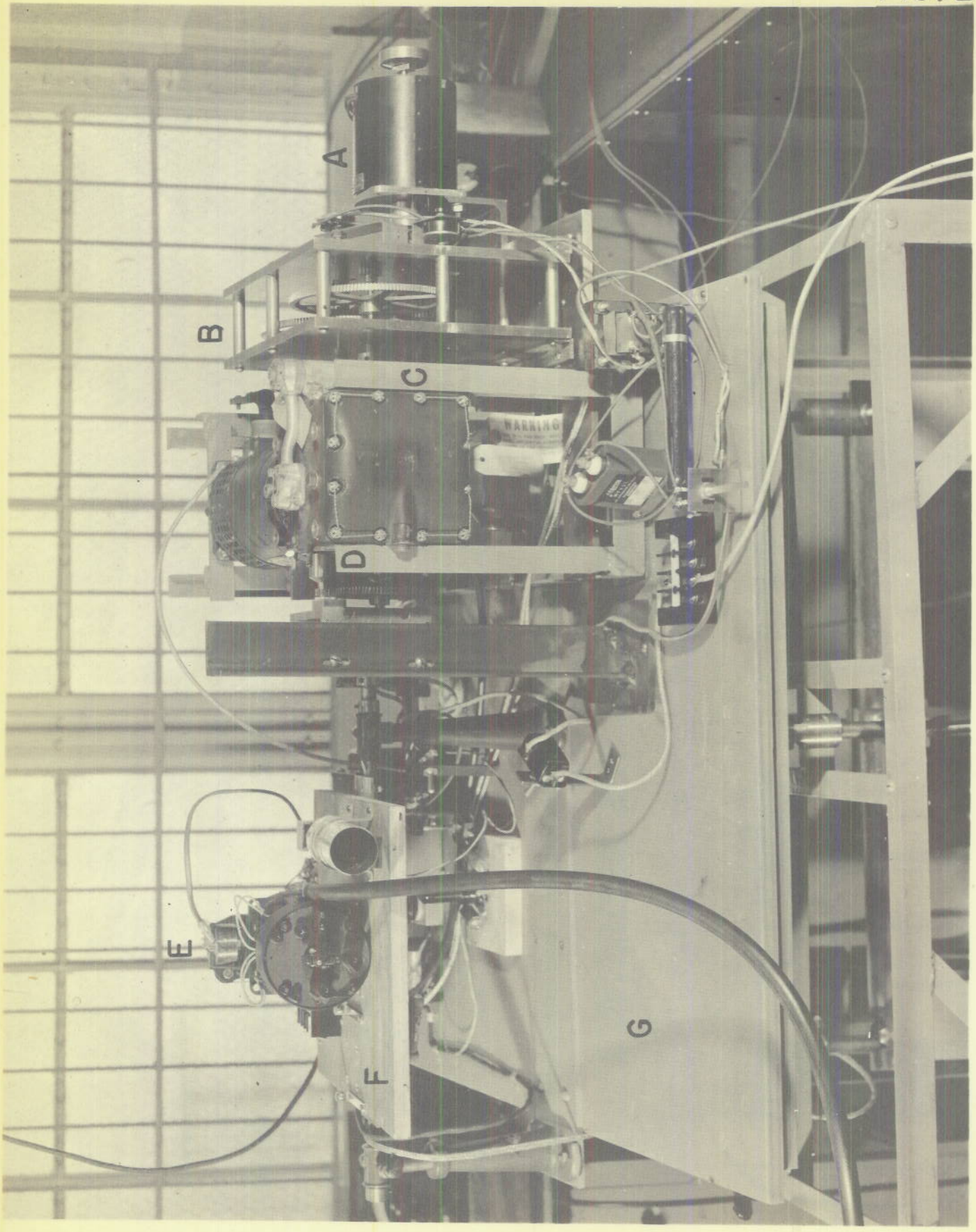

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FIG. 3

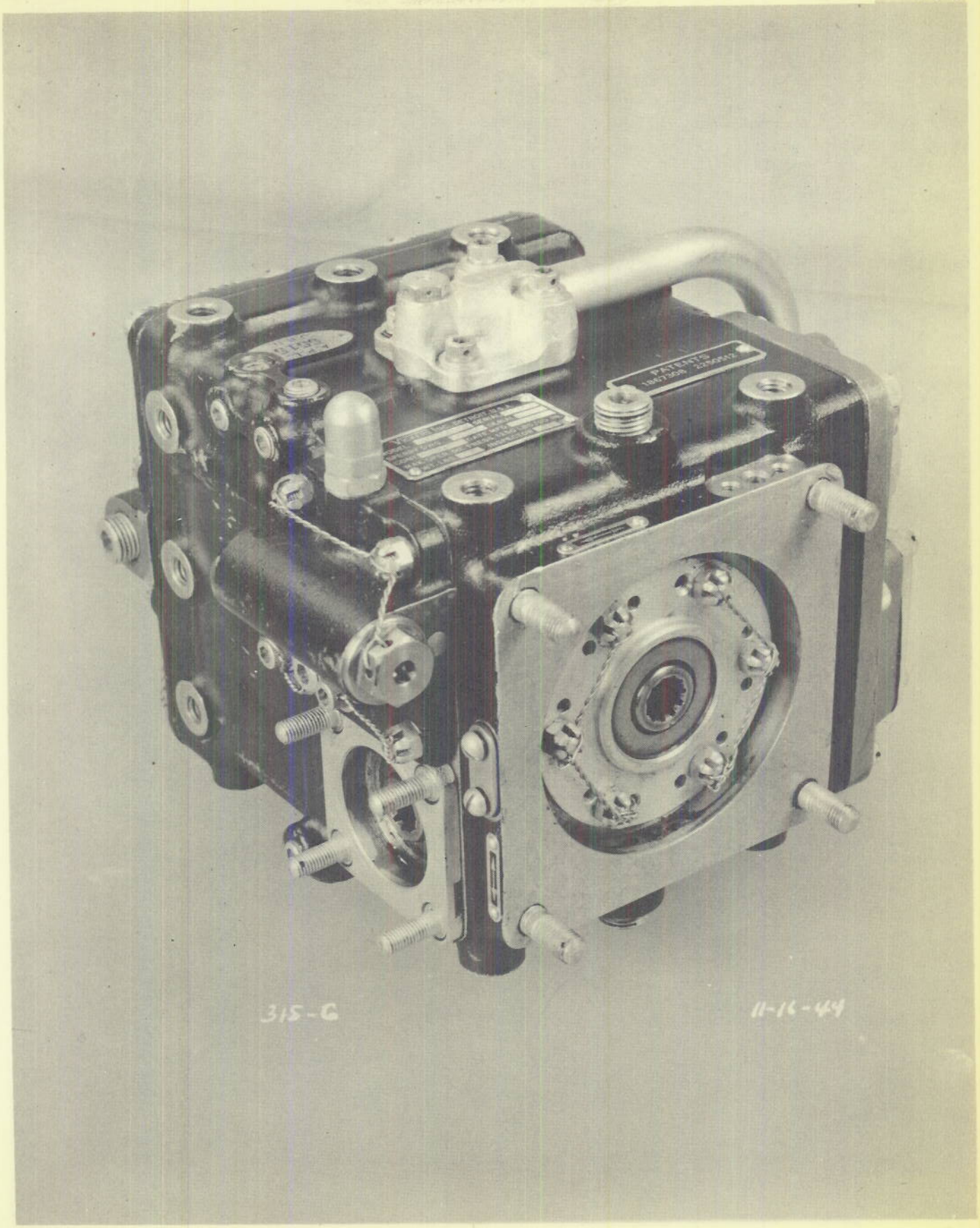

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FIG. 4

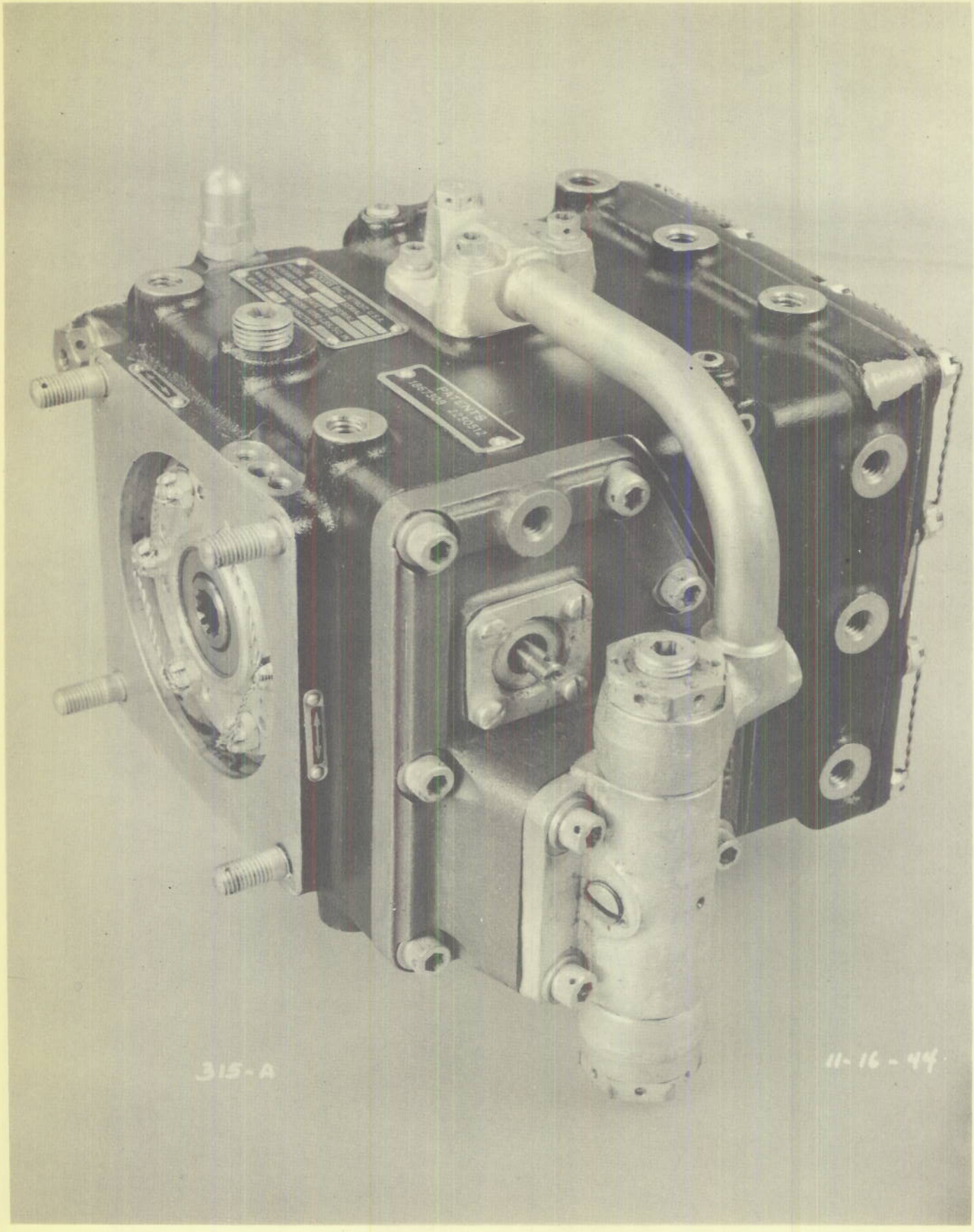

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FIG. 5

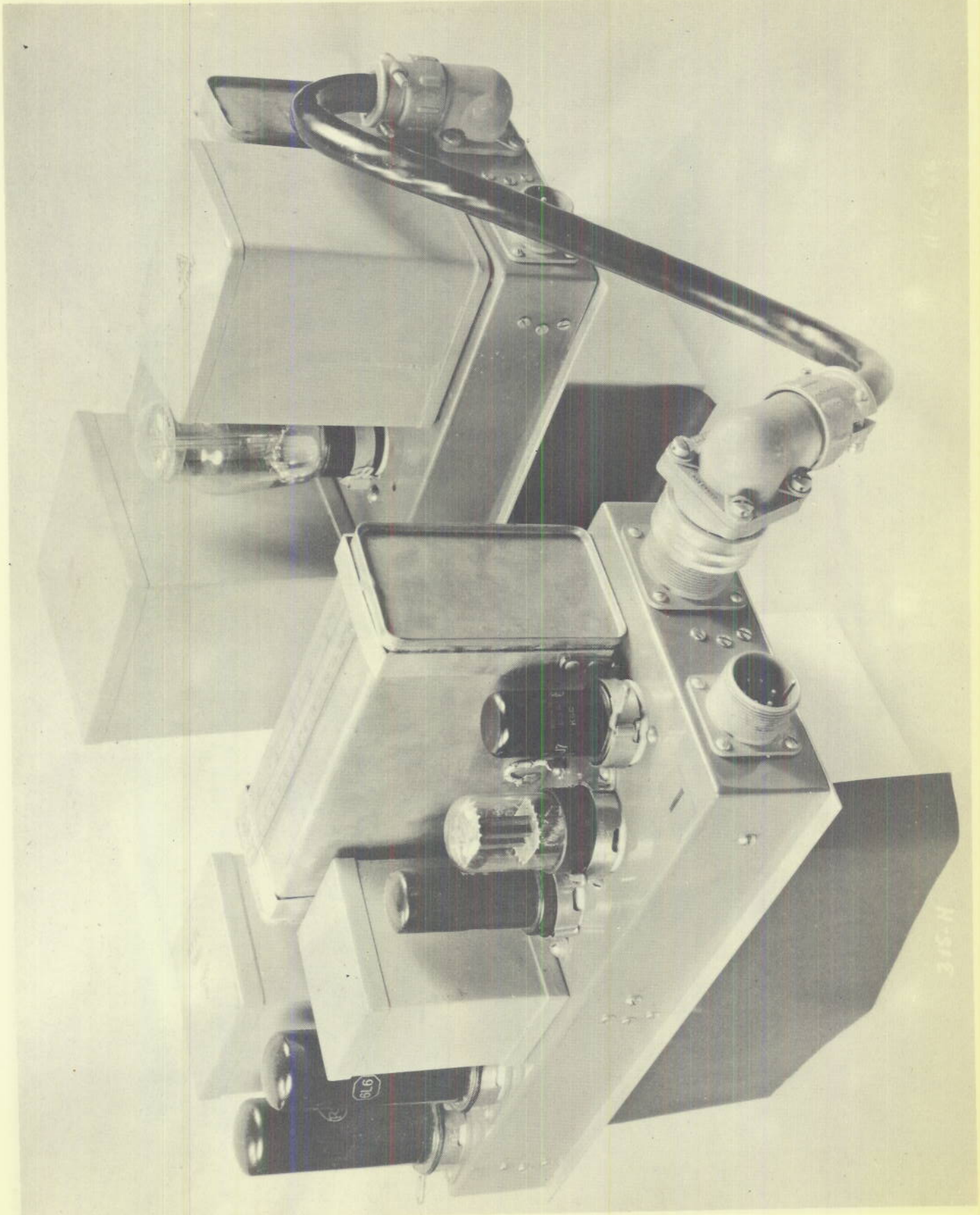

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FIG. 6

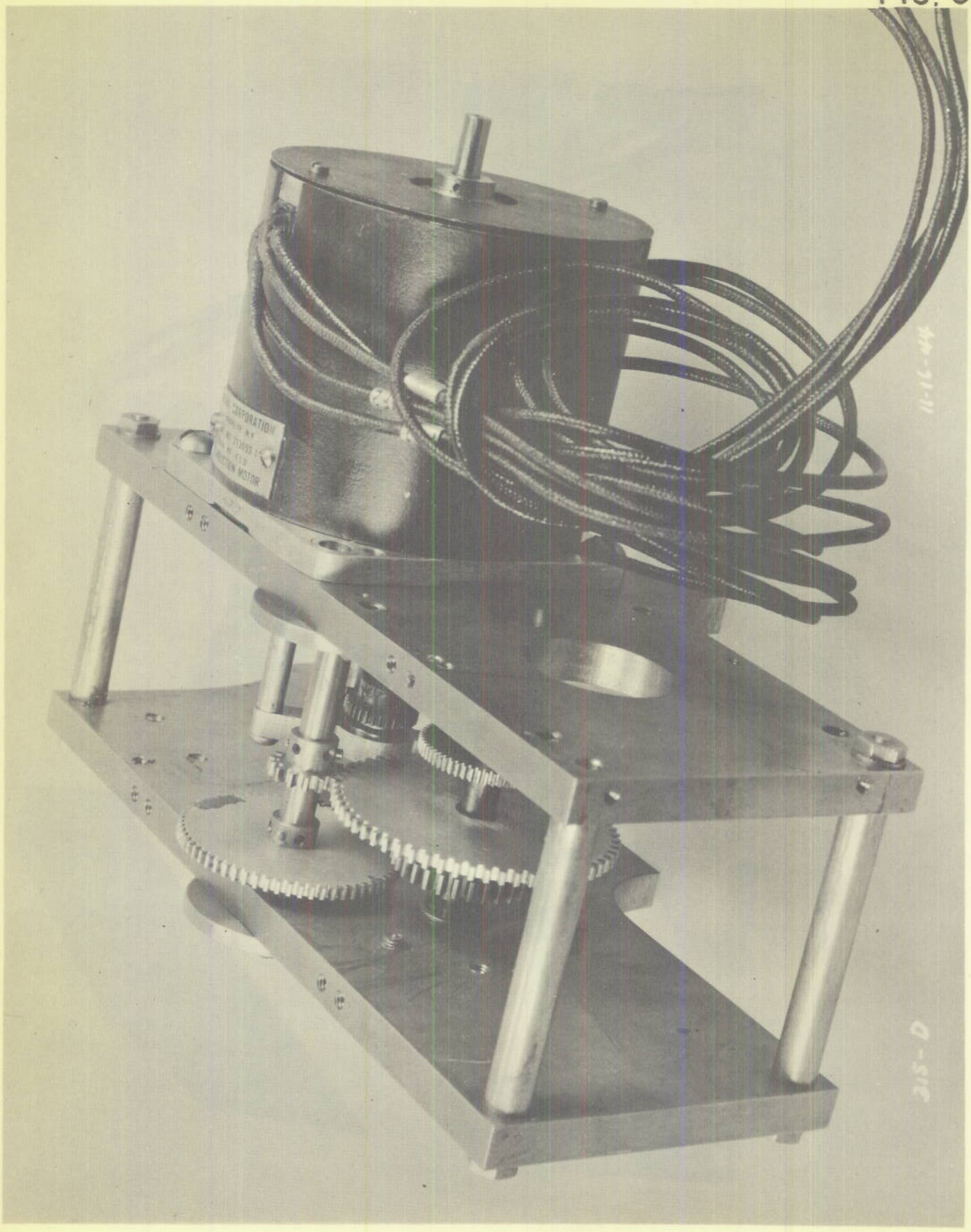

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FIG. 7

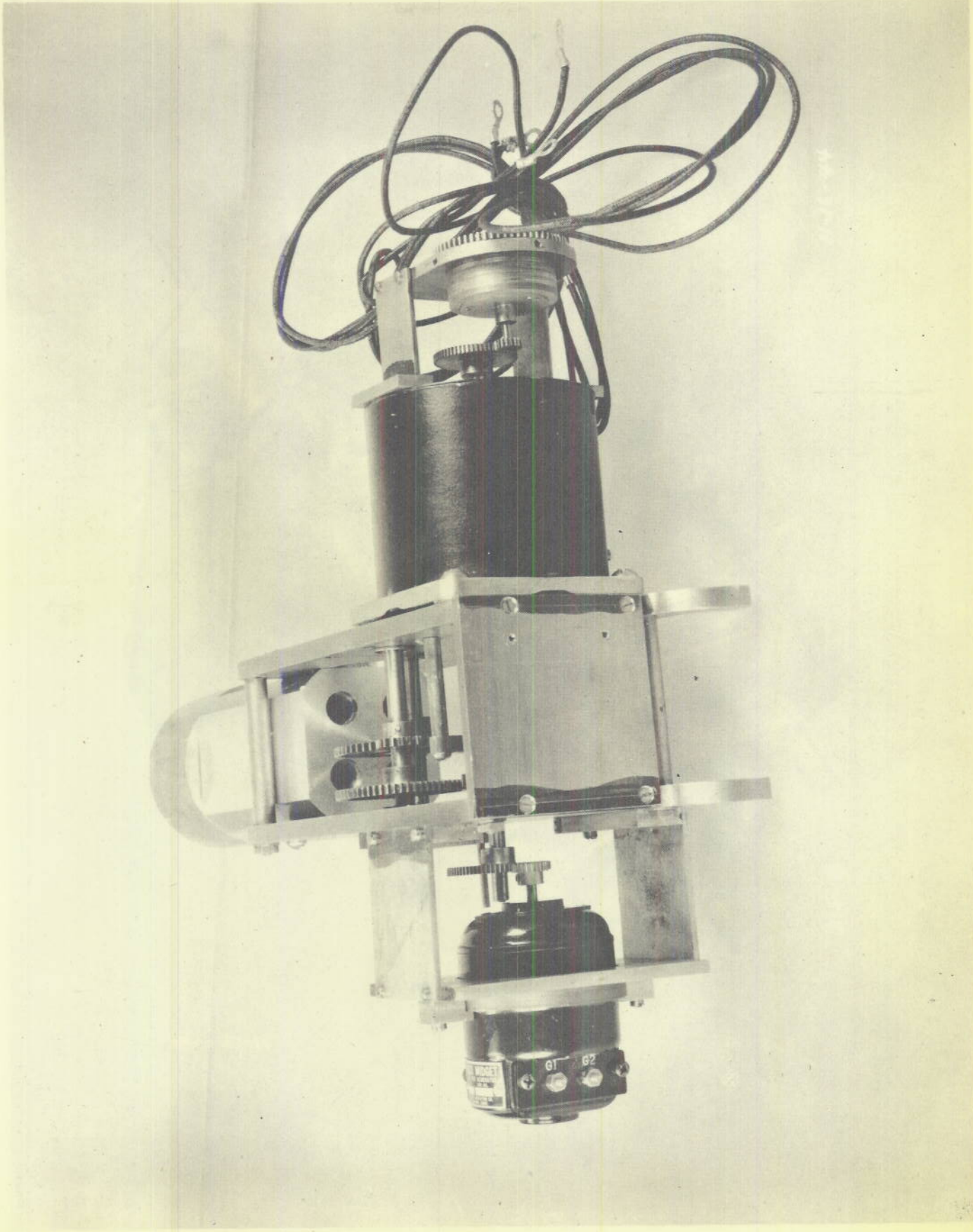

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FIG. 8

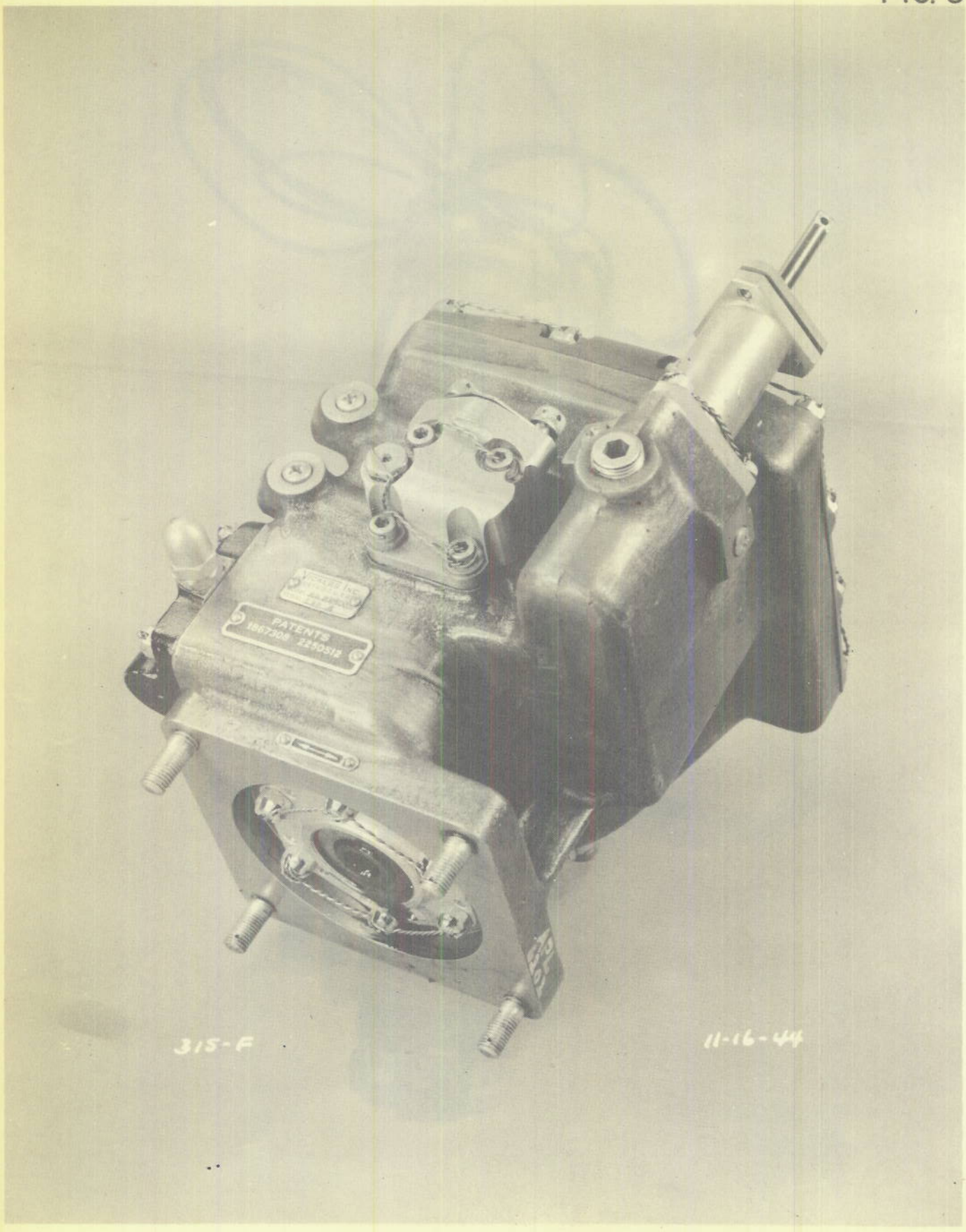

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FIG. 8a

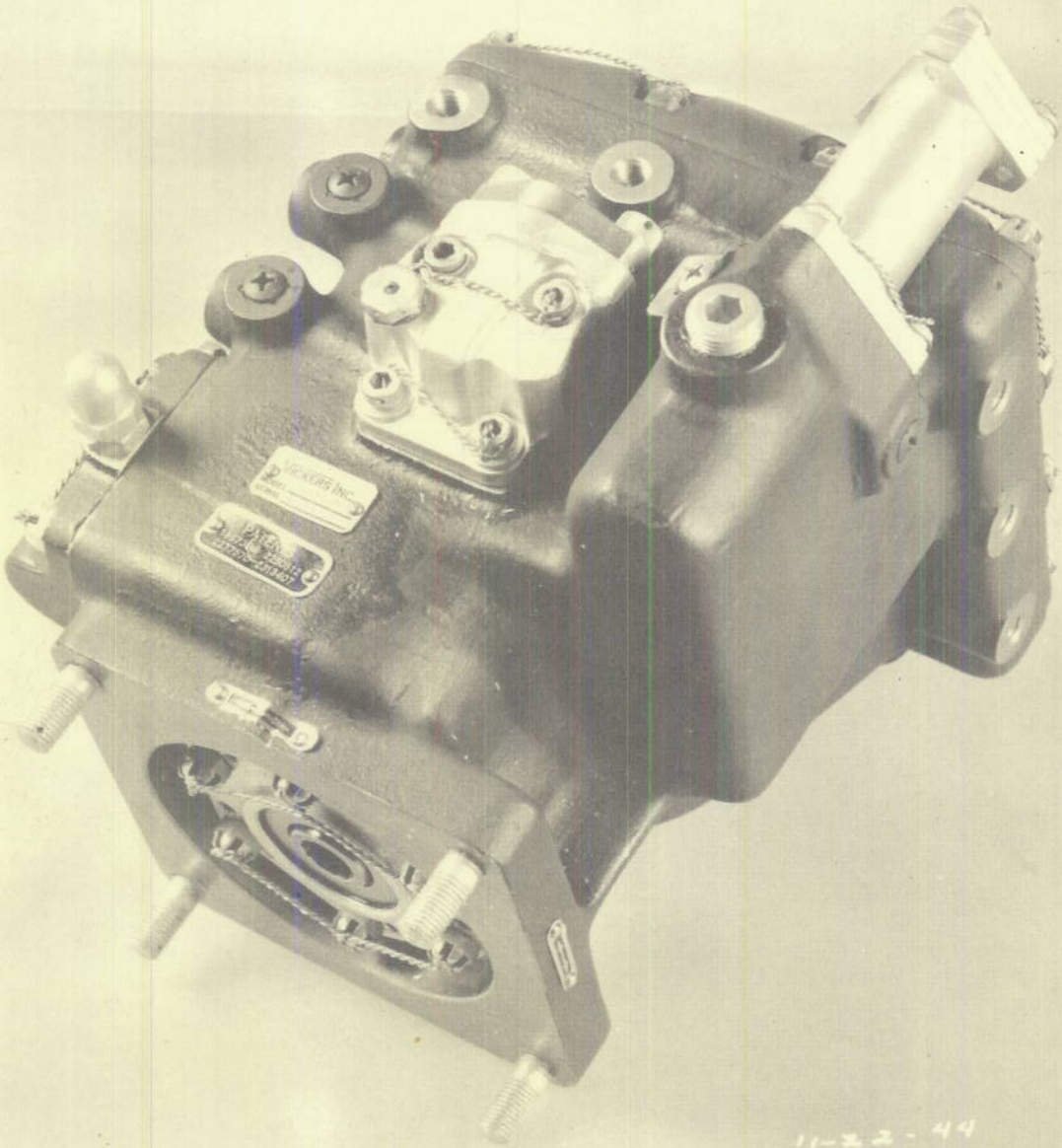

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FIG. 9

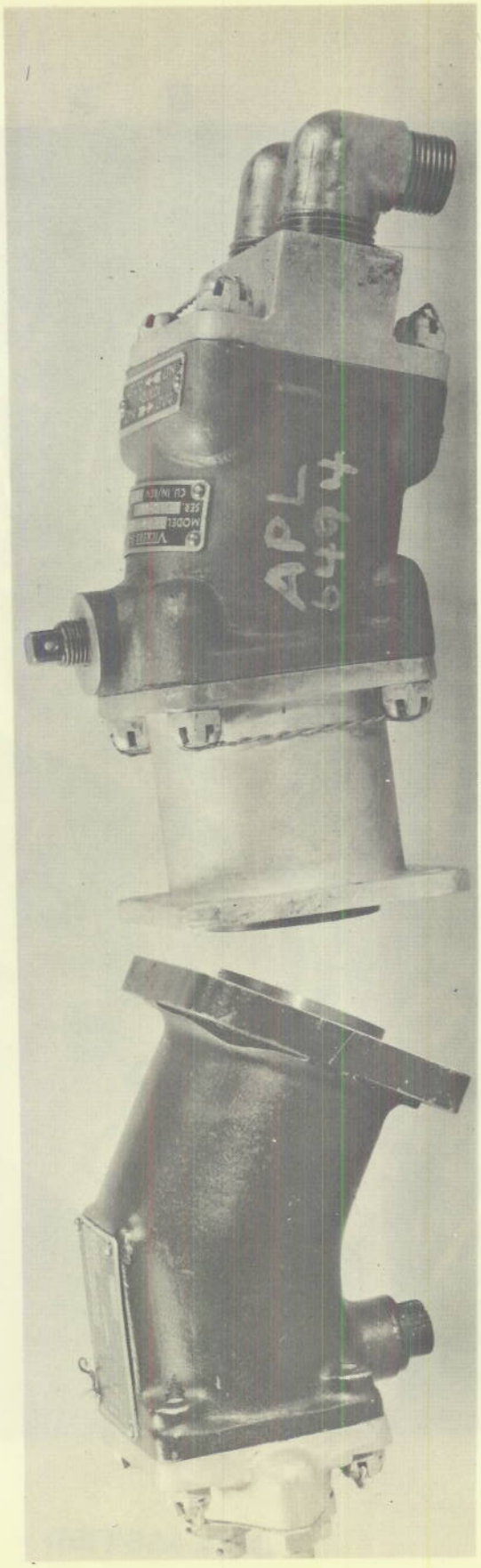

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FIG. 10

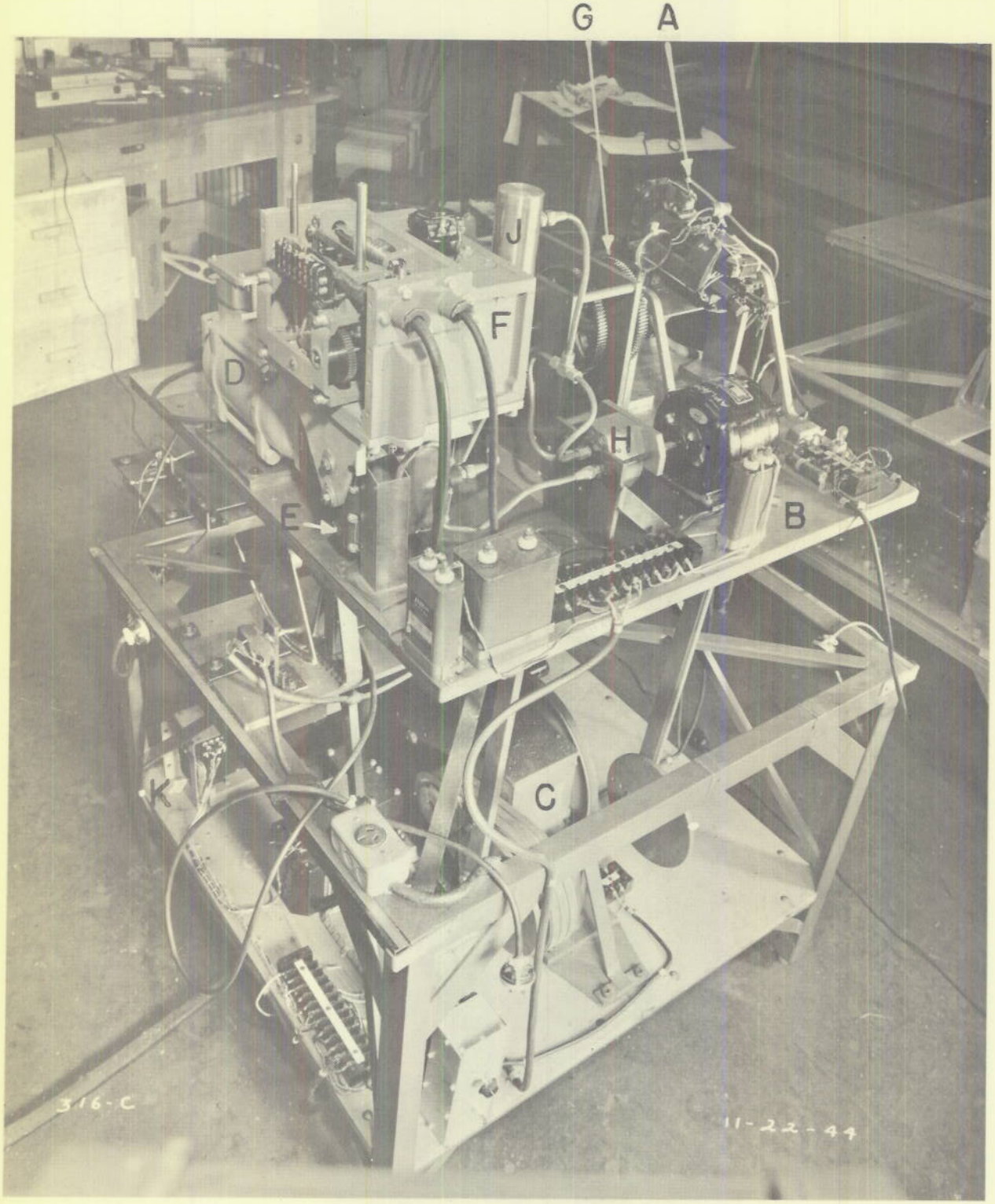

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FIG. 11

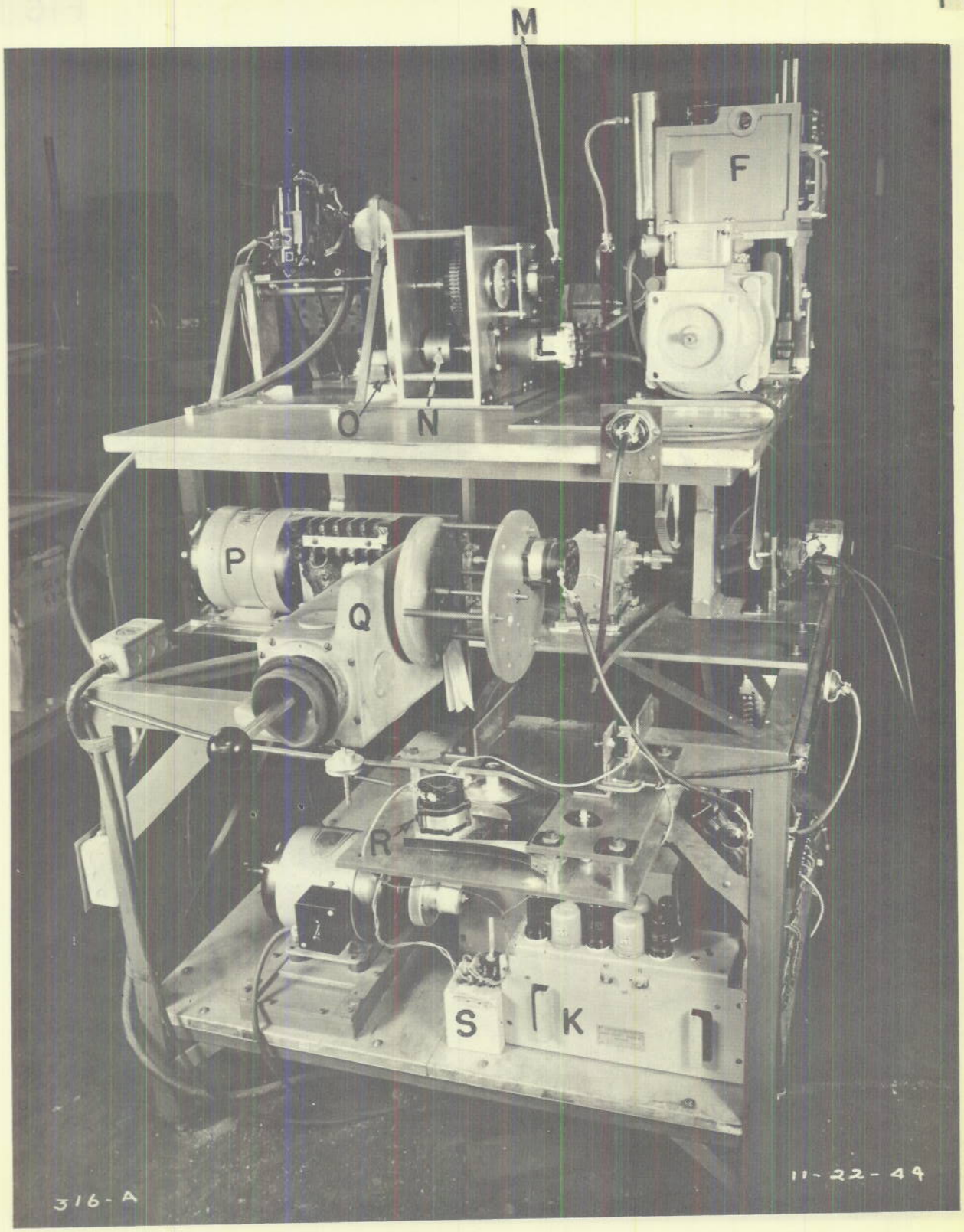

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FIG. 12

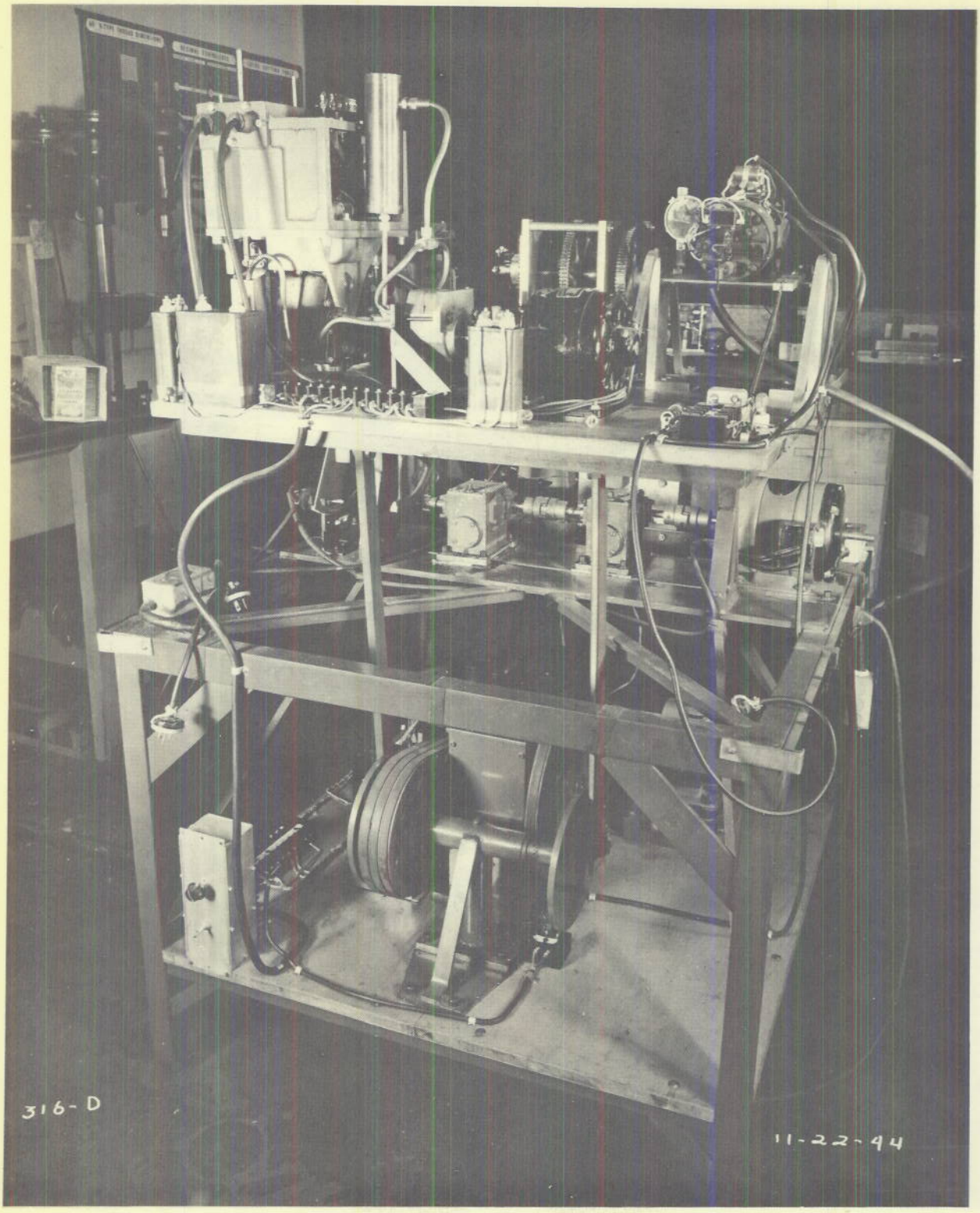

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FIG. 13

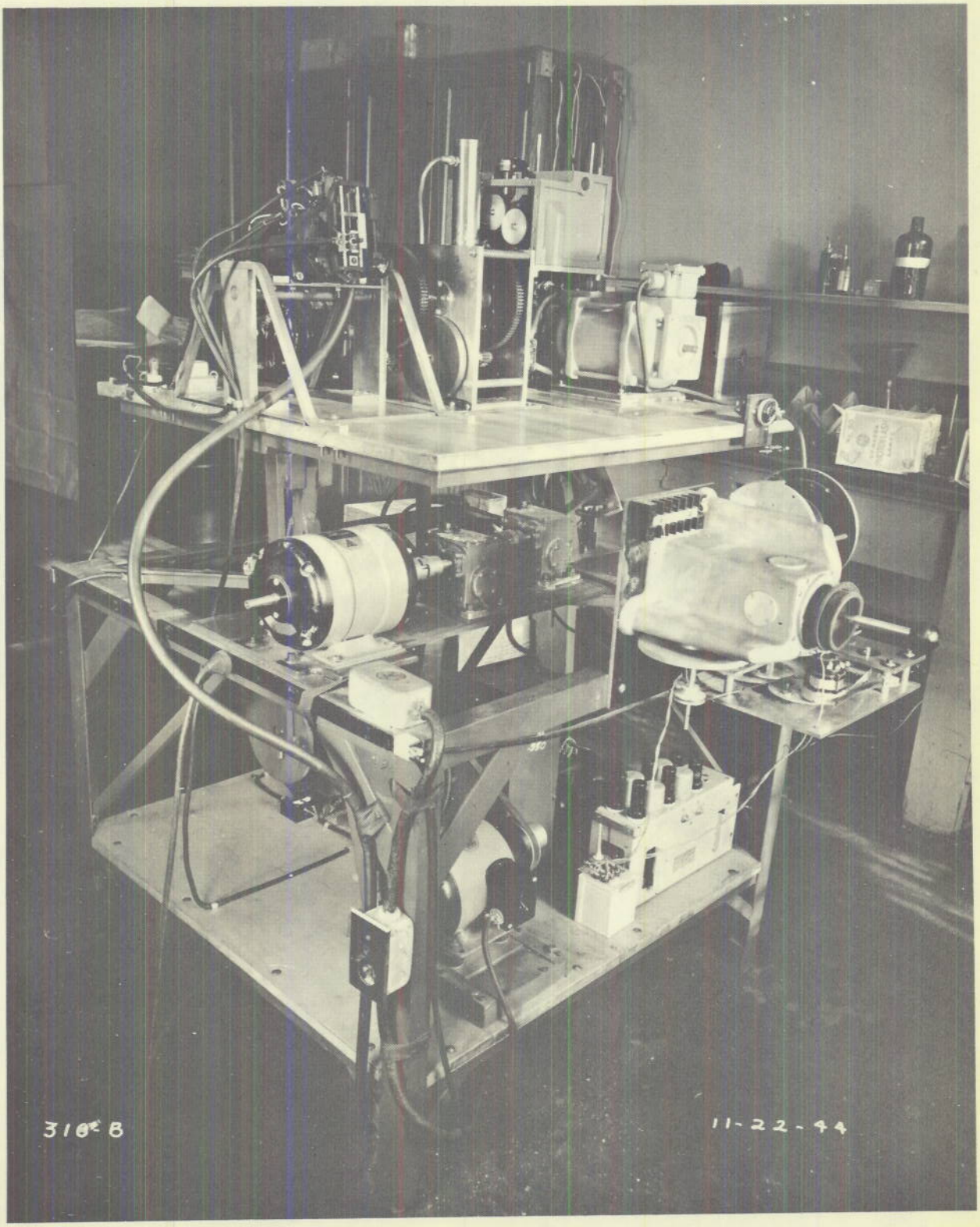

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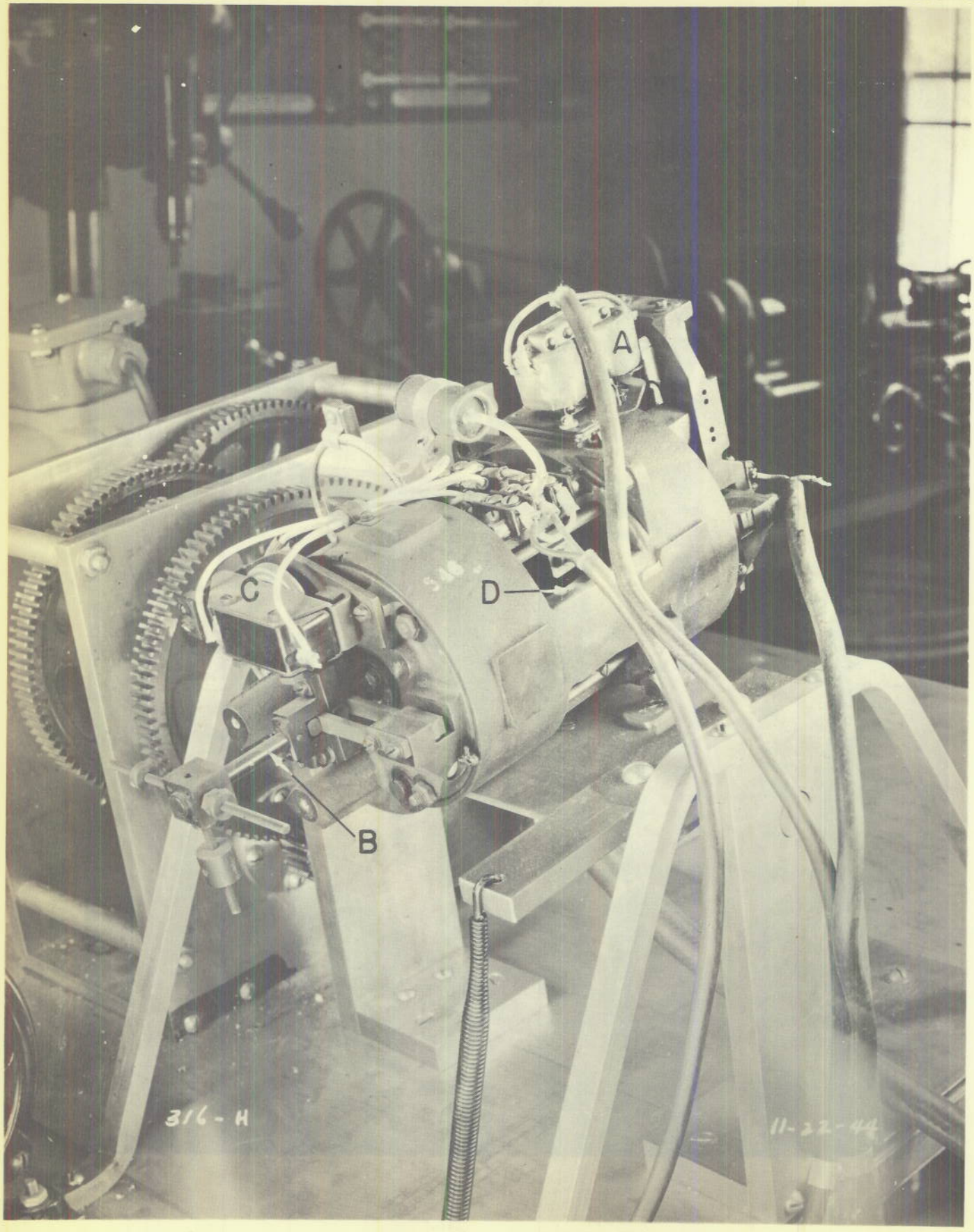
FIG. 14



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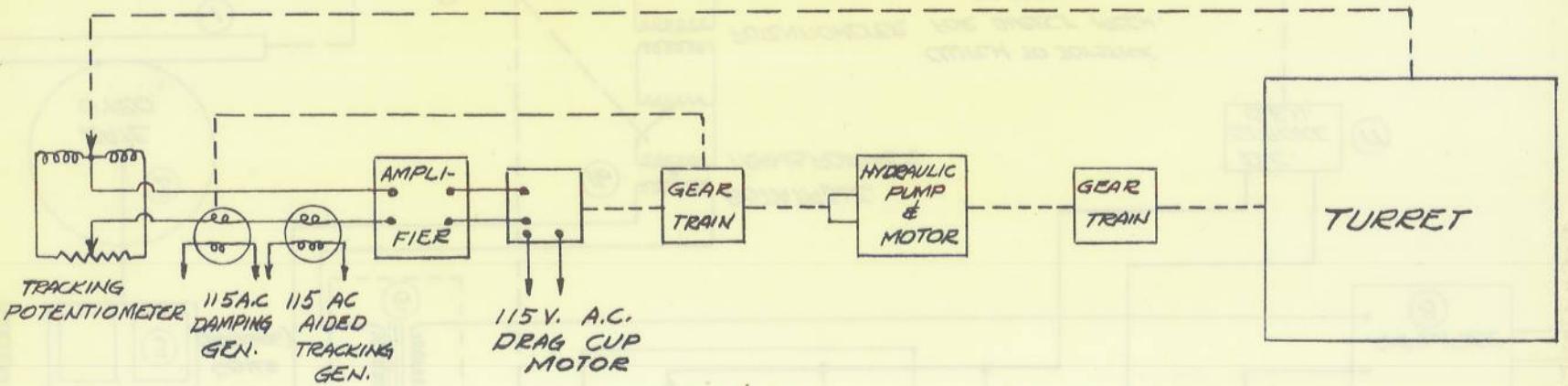

PROPORTIONAL DAMPING STABILIZATION SYSTEM

FIG. 17

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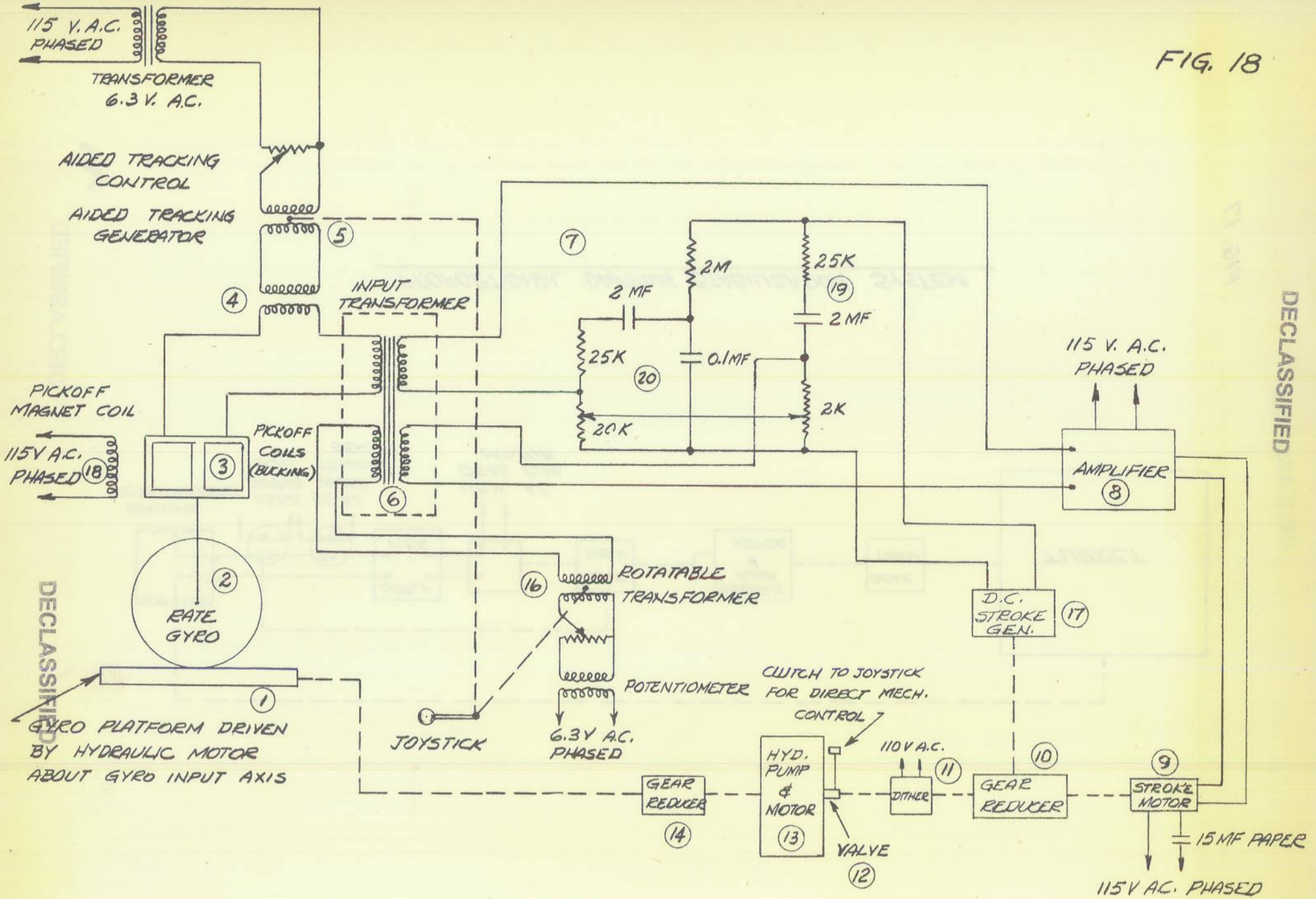
DECLASSIFIED

FIG. 18



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DECLASSIFIED

FIG. 19

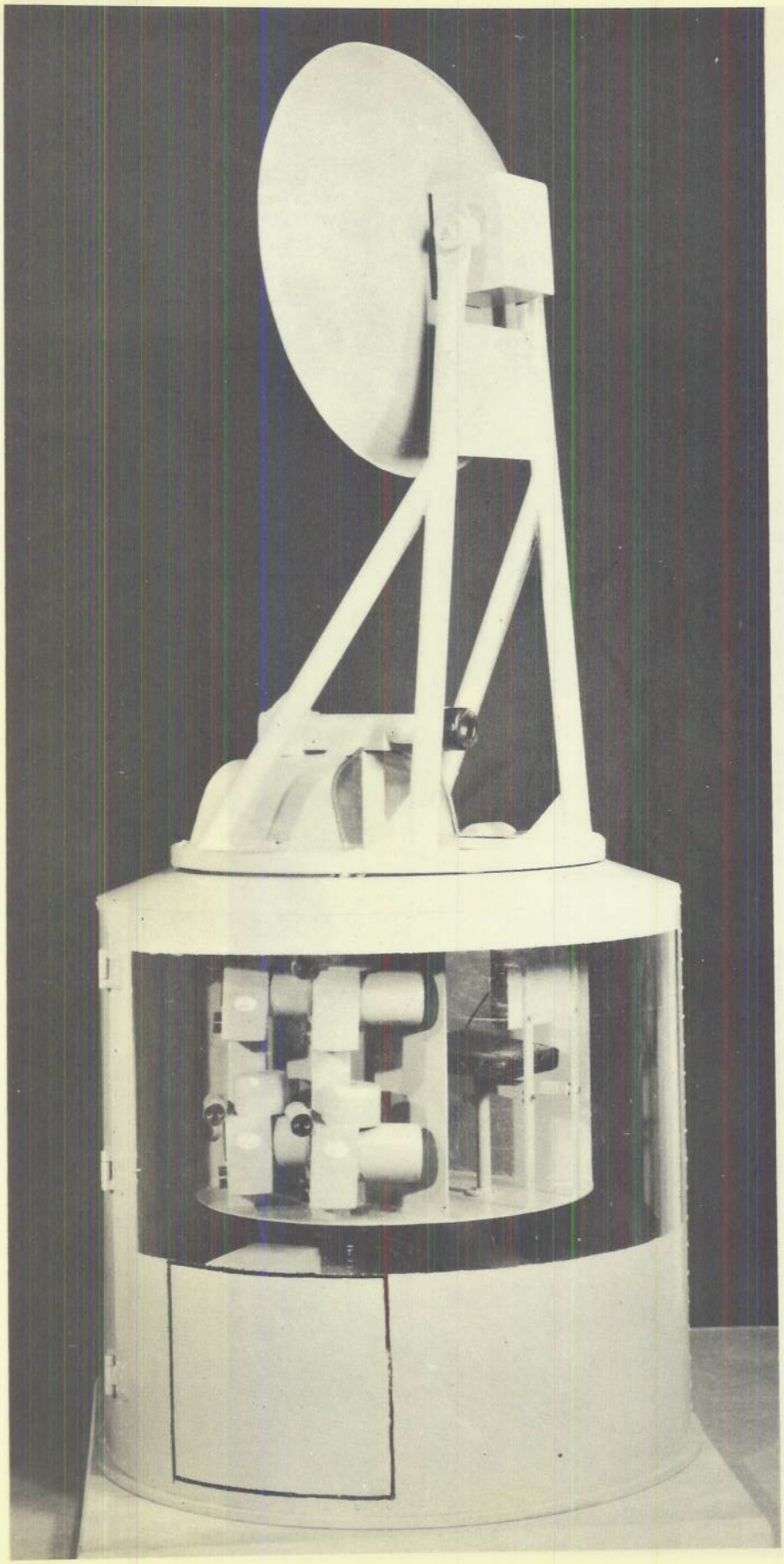

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FIG. 20

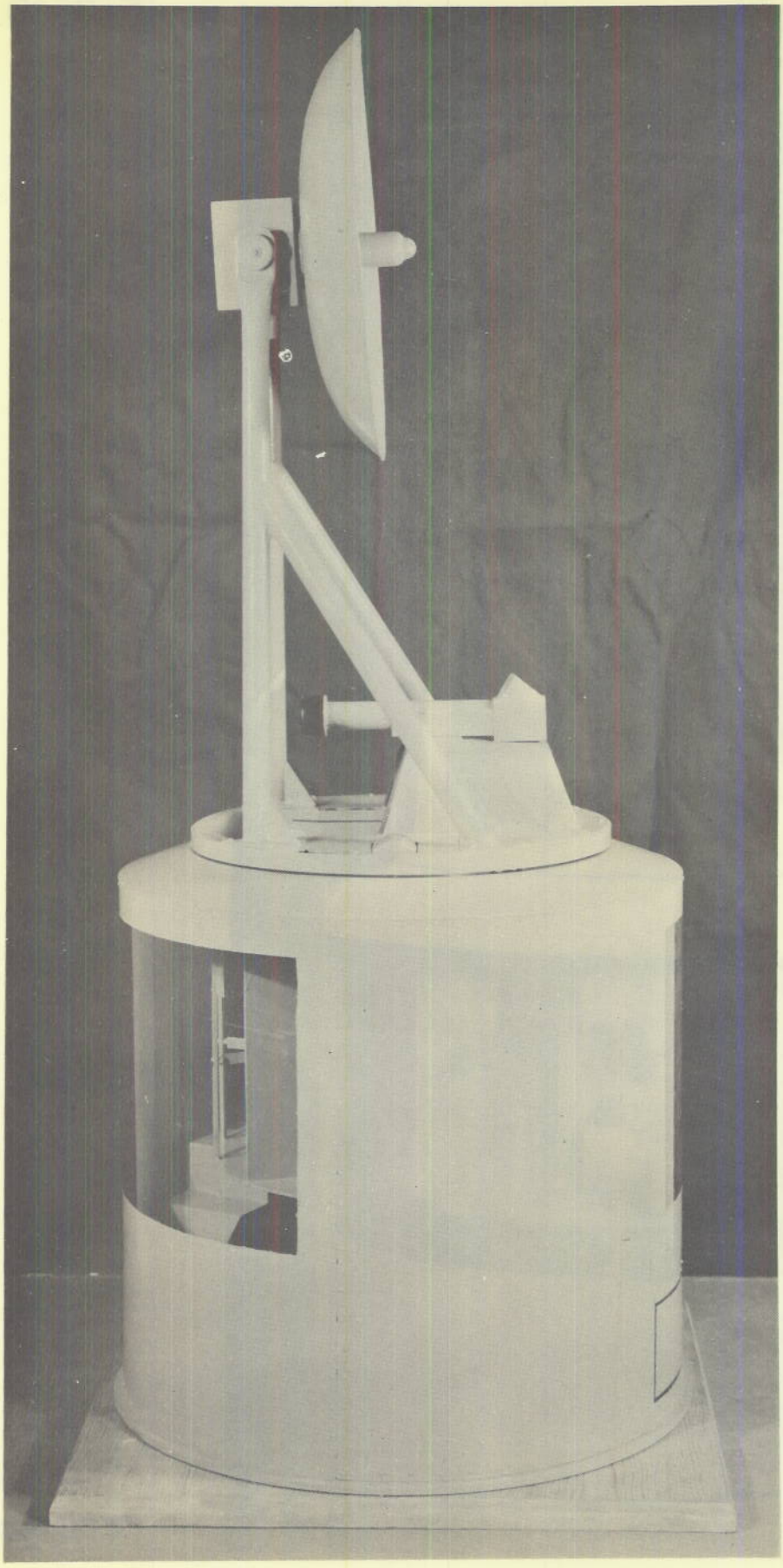

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FIG. 21

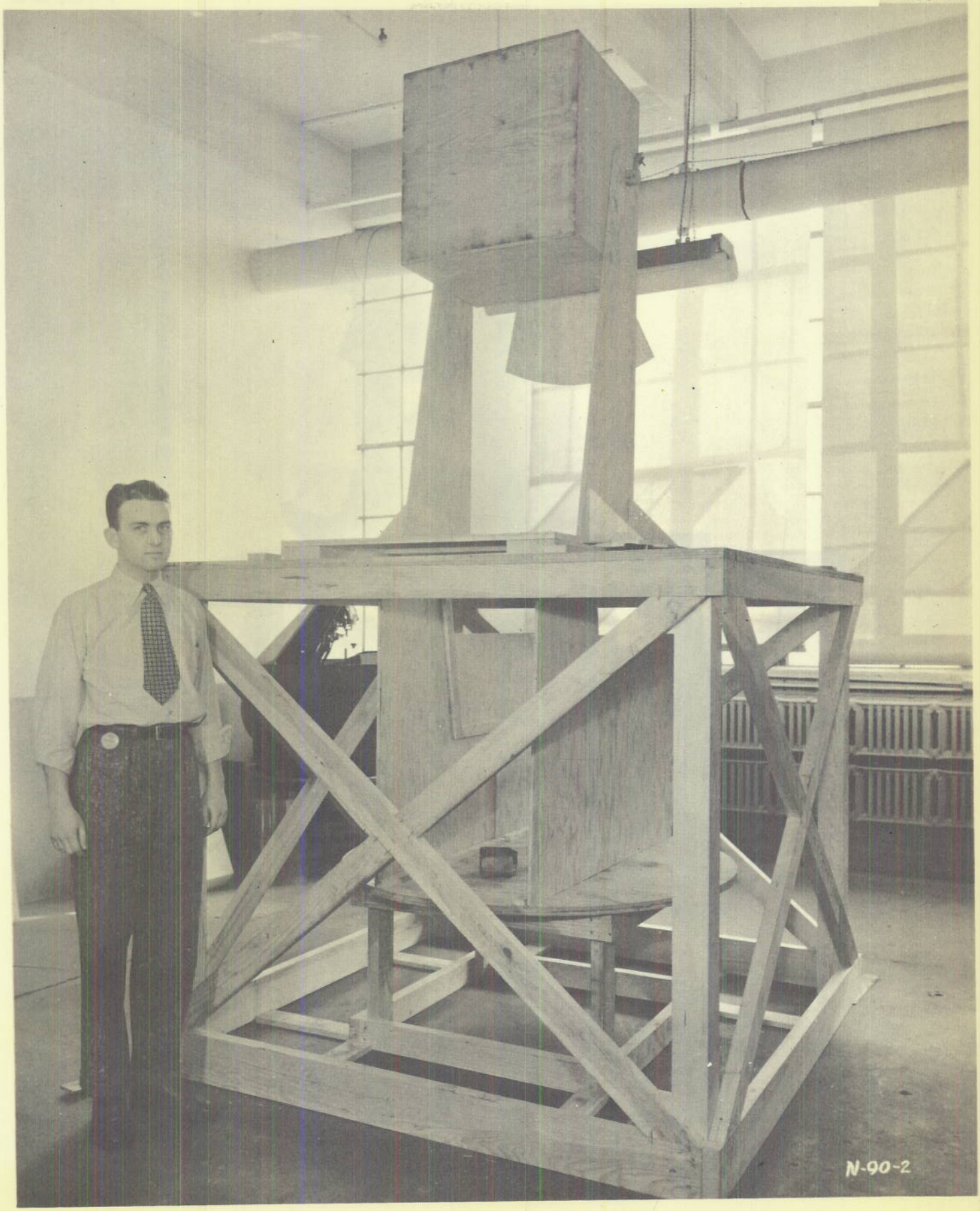

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FIG. 22

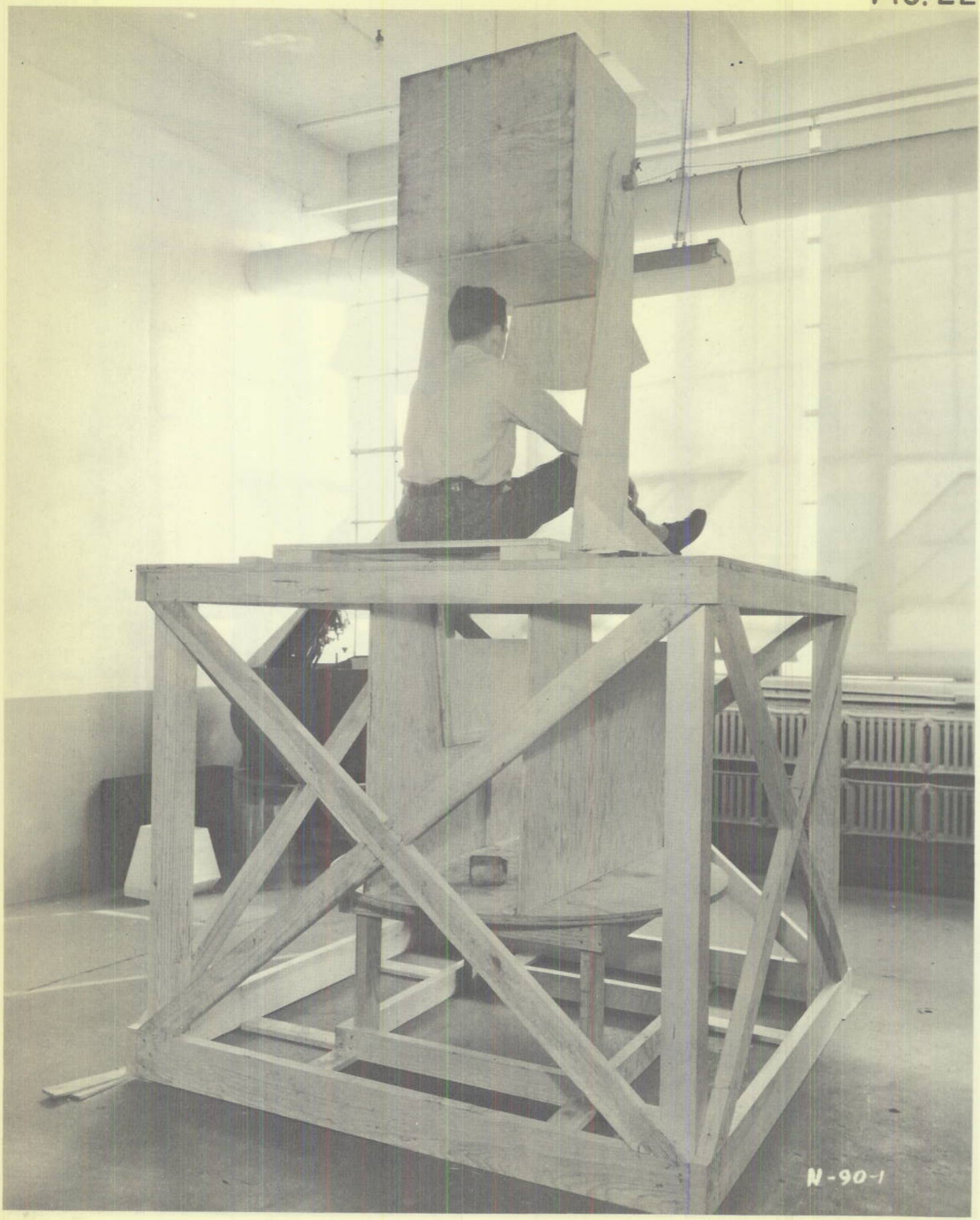

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FIG. 23

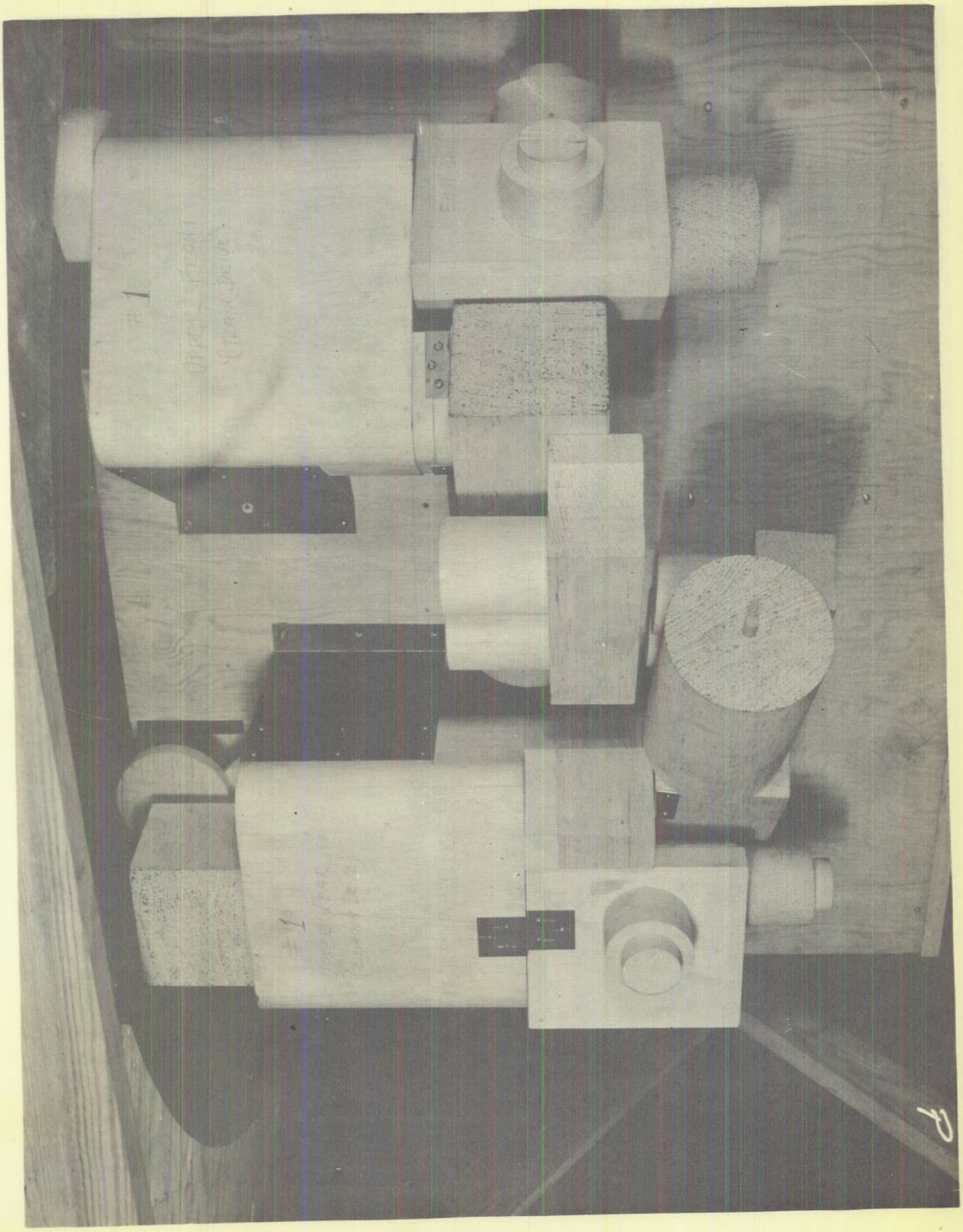

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FIG. 24

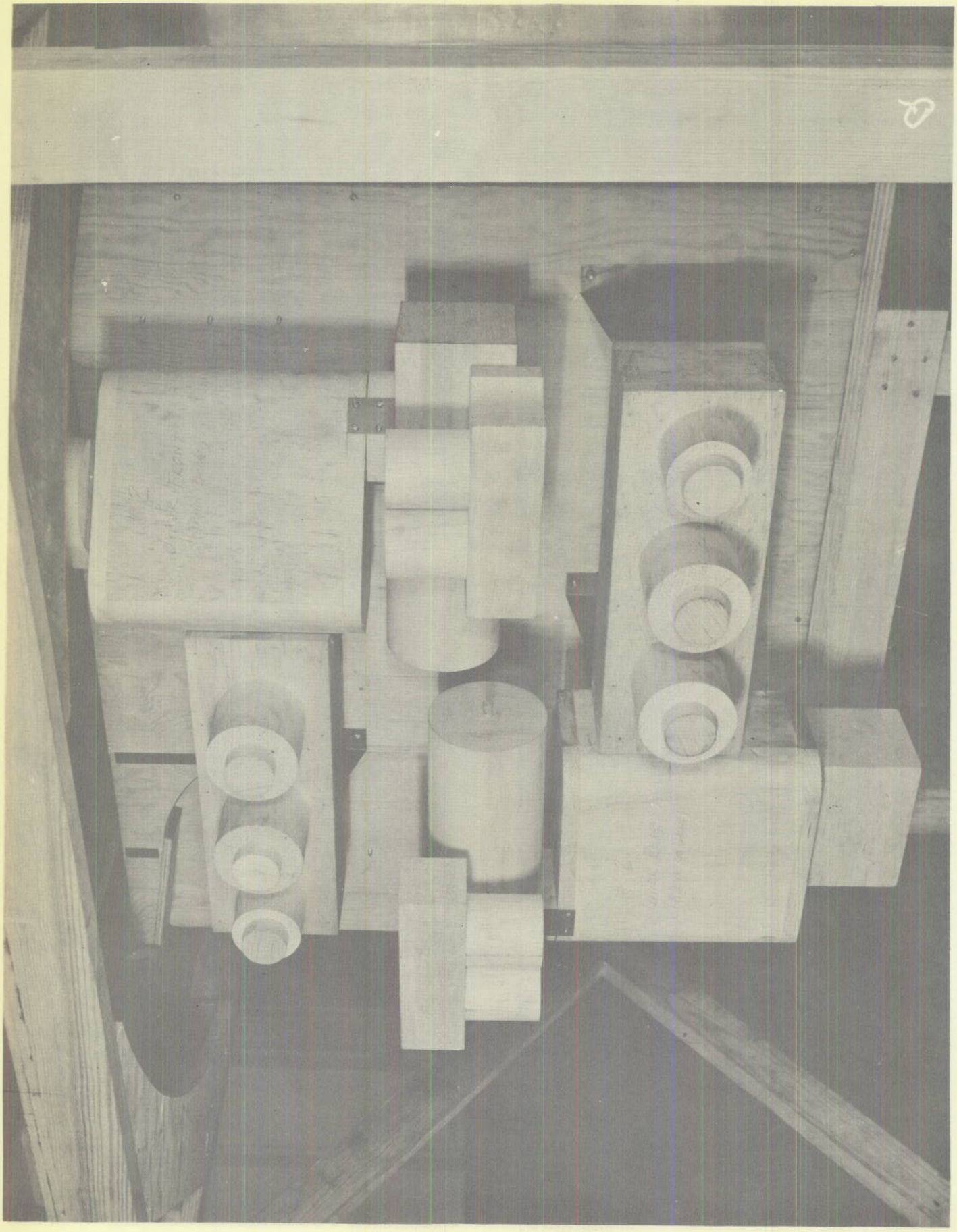

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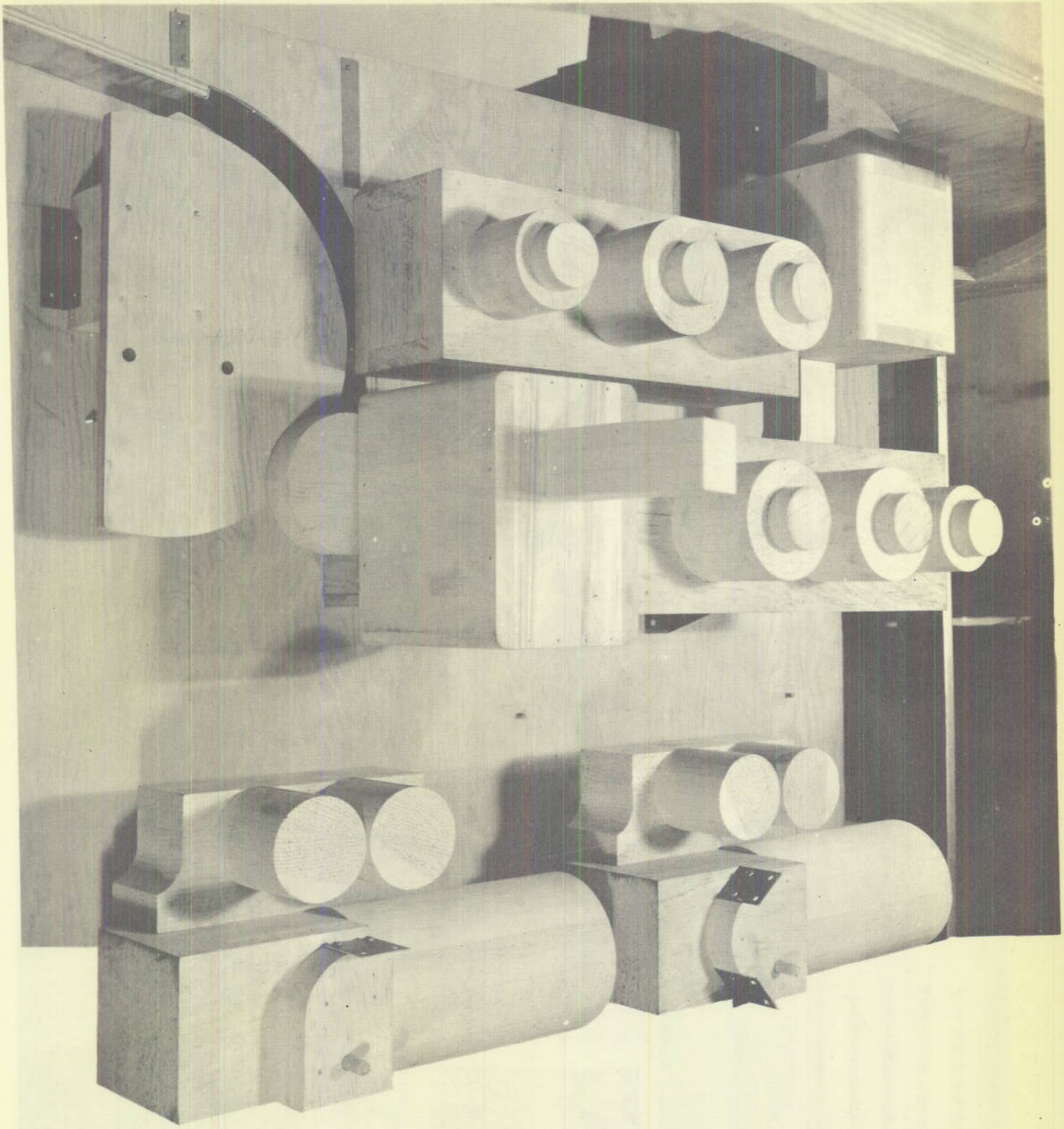
FIG. 25



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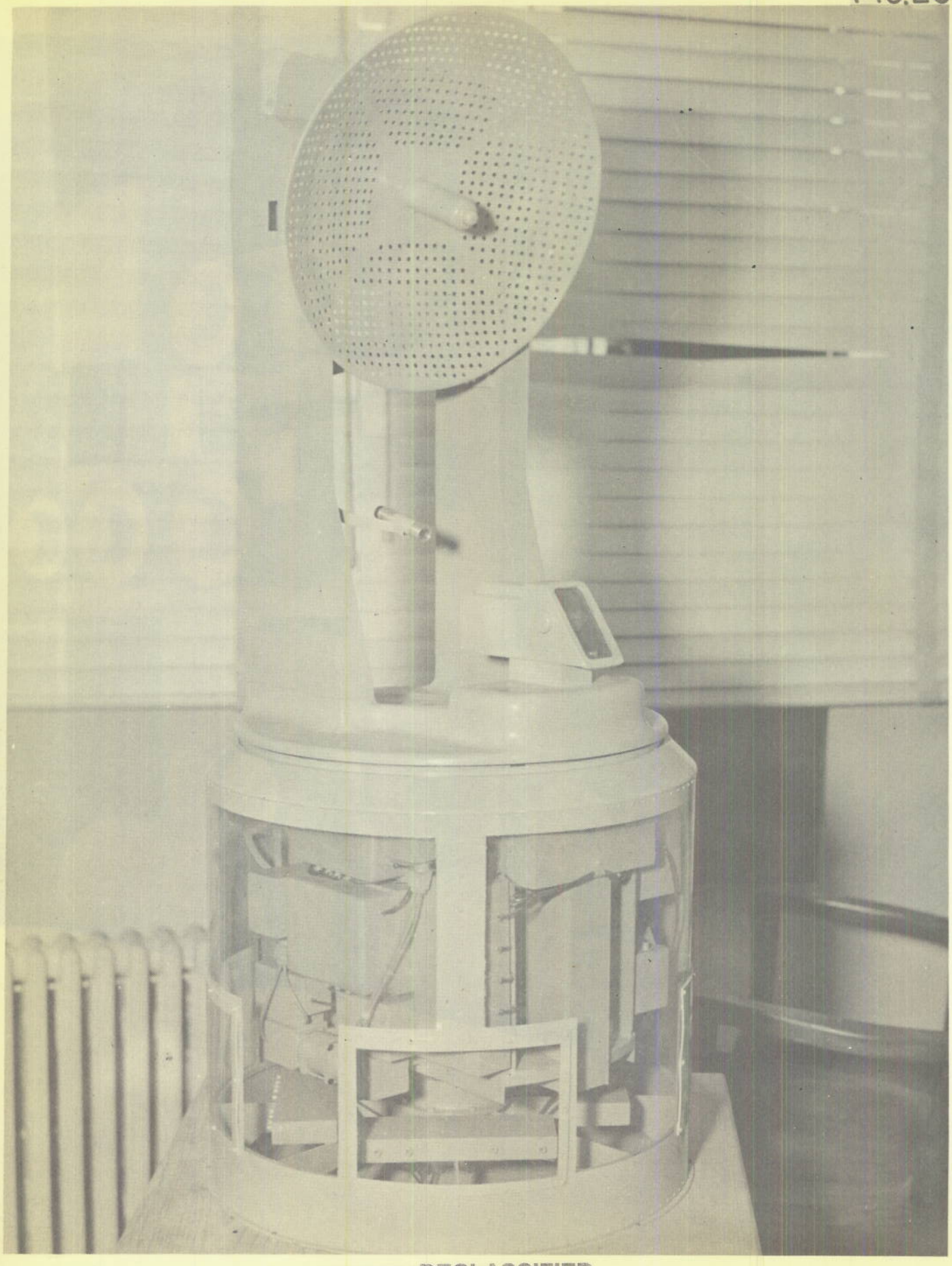
DECLASSIFIED

FIG. 26



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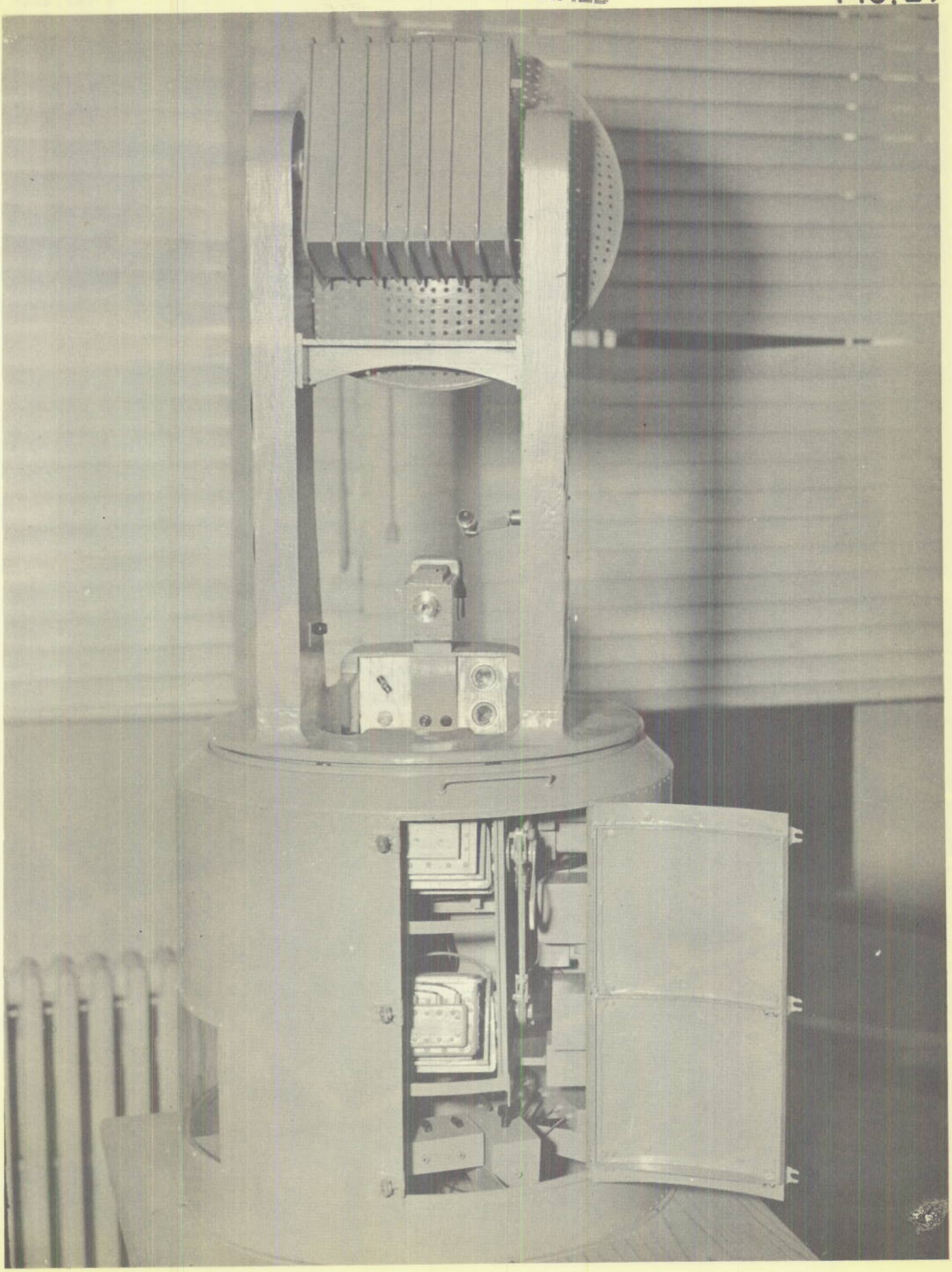
DECLASSIFIED

FIG. 27



DECLASSIFIED

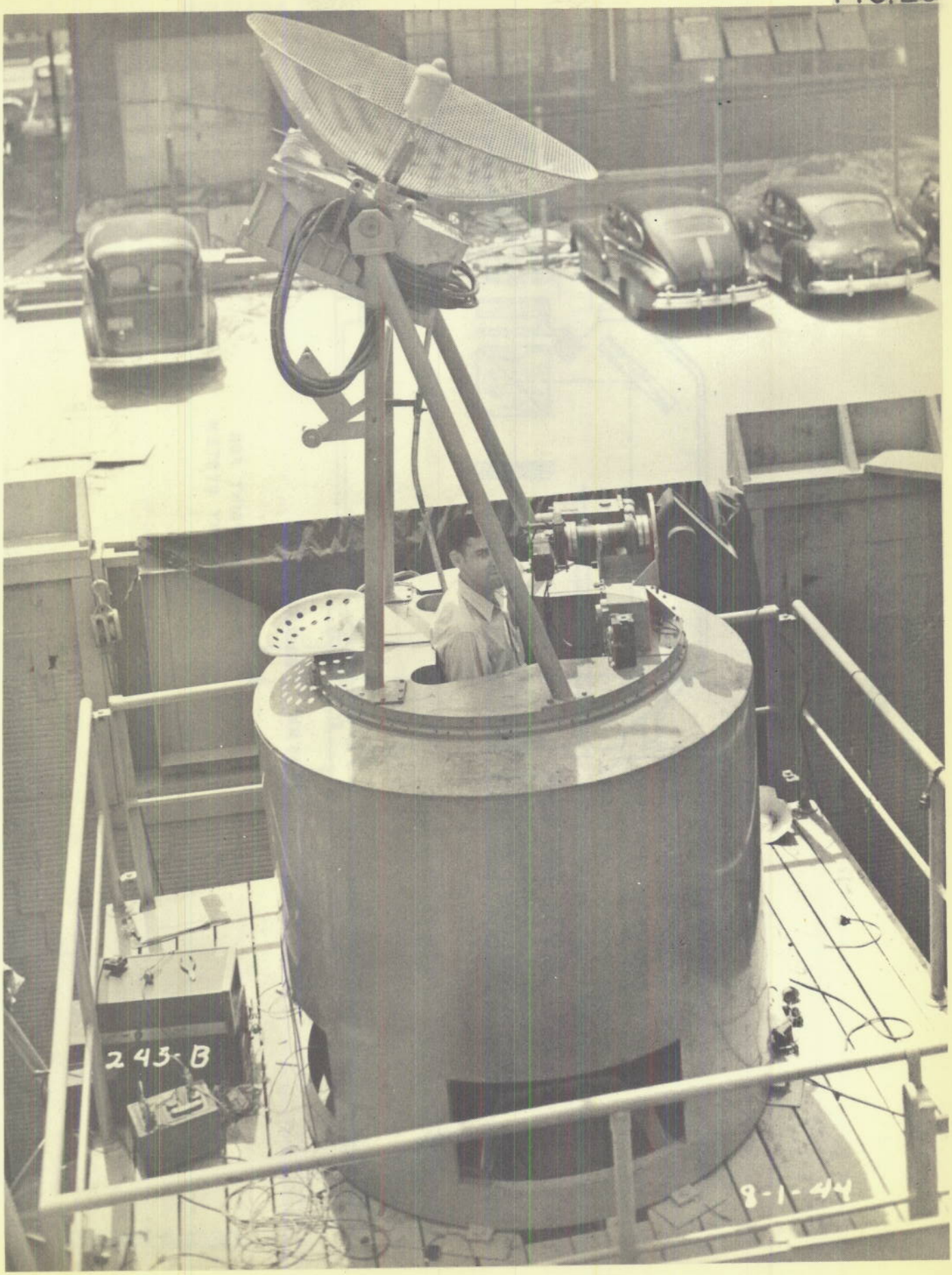
DECLASSIFIED

FIG. 28

DECLASSIFIED

DECLASSIFIED

FIG. 29



DECLASSIFIED

FIG. 30

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OPTICAL ARRANGEMENT
TELESCOPE O.S.R.D.

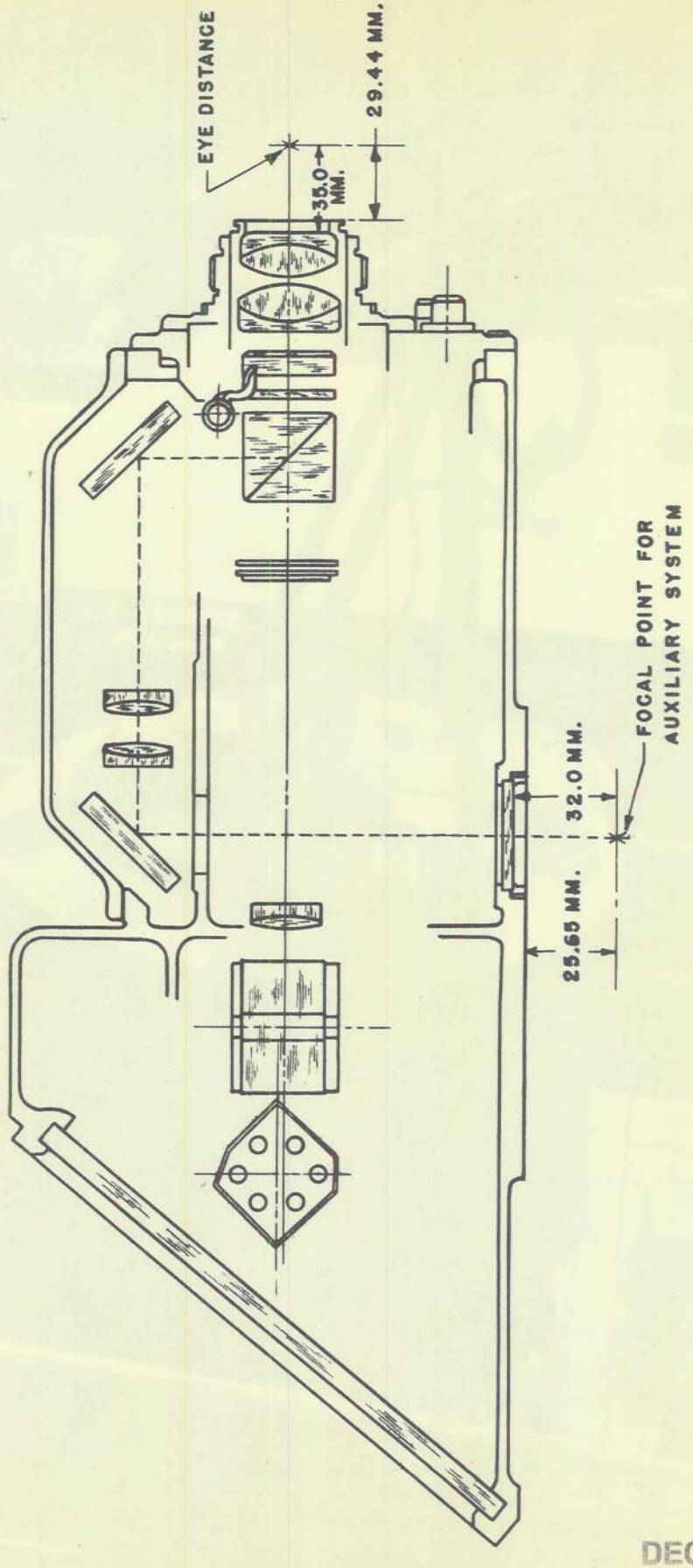

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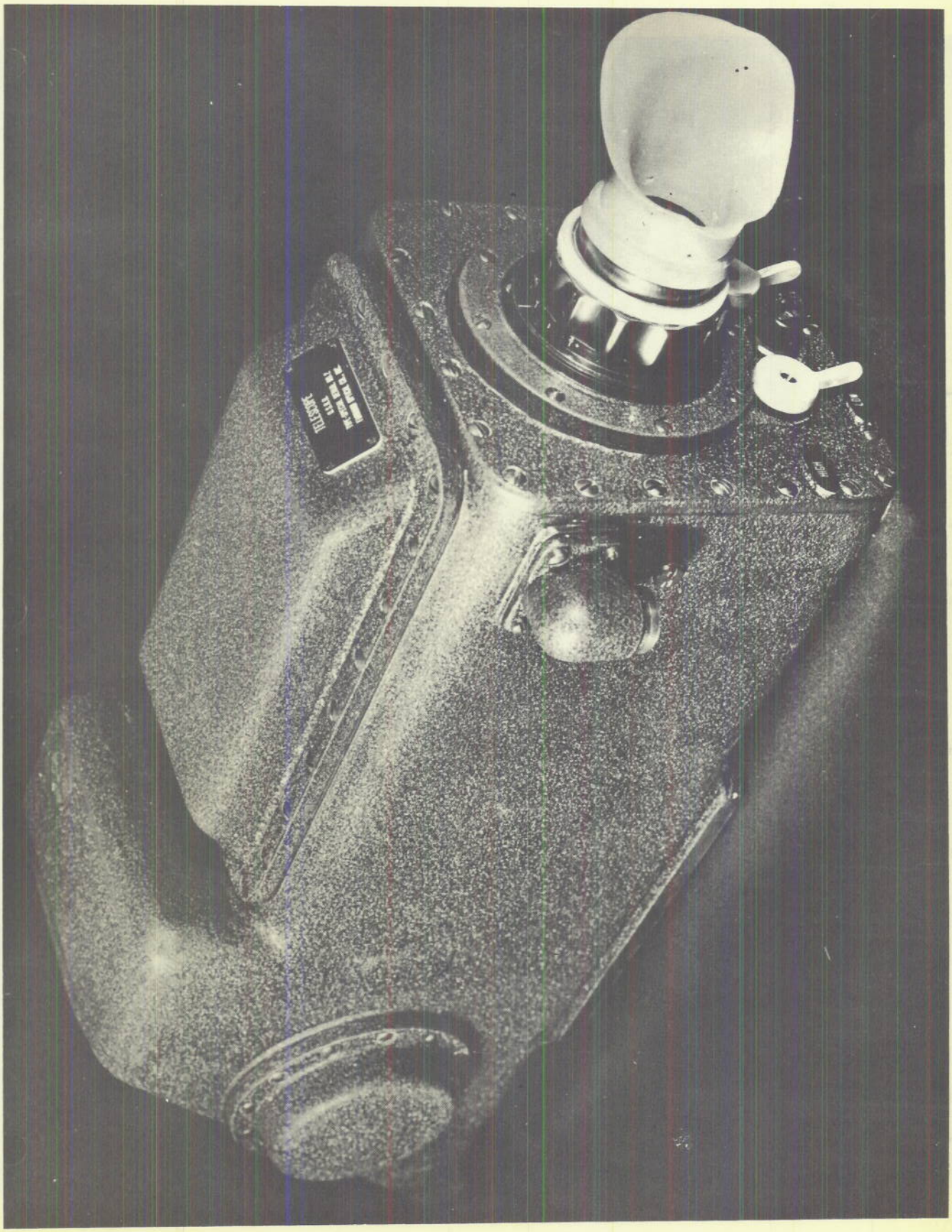
FIG. 31



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DECLASSIFIED

FIG.32

DECLASSIFIED

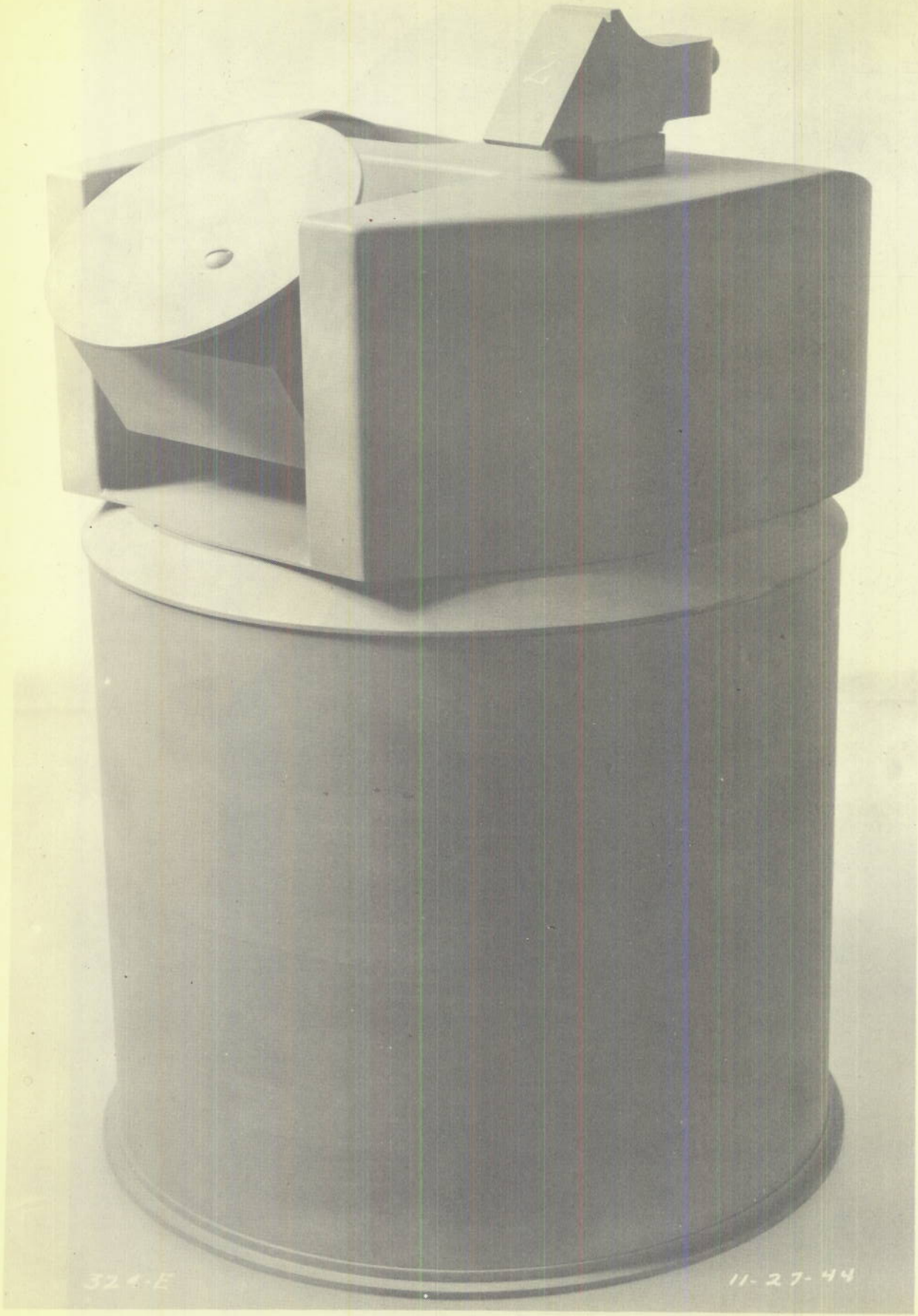
DECLASSIFIED

FIG. 33

DECLASSIFIED

DECLASSIFIED

FIG. 34



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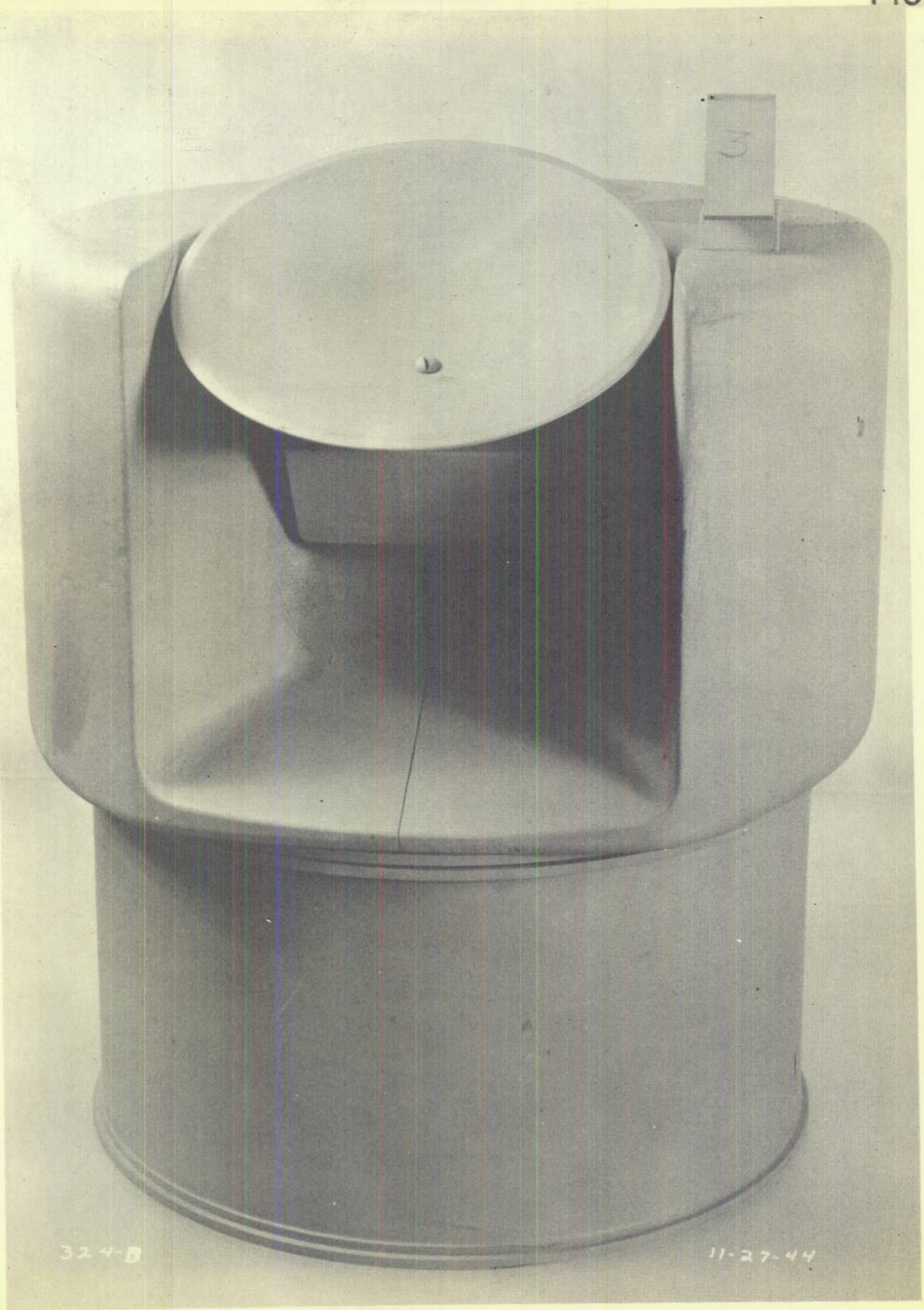
DECLASSIFIED

FIG.35



DECLASSIFIED

DECLASSIFIED

FIG.36

DECLASSIFIED

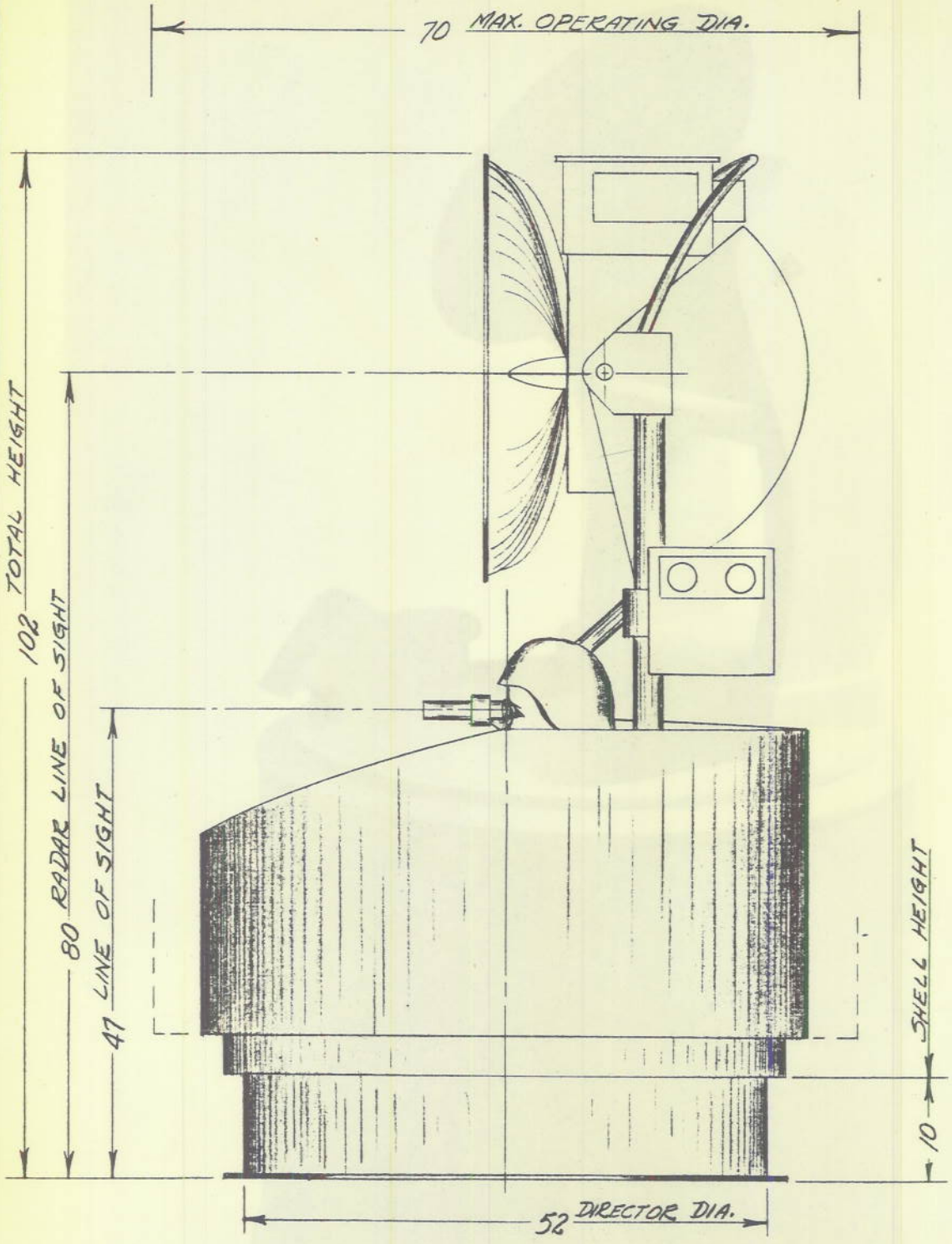
DECLASSIFIED

FIG. 37

DECLASSIFIED

DECLASSIFIED

FIG. 38



DESIGN OF PROPOSED
MAXSON DIRECTOR
FEBRUARY 1944

DECLASSIFIED

PEP
11-15-44

A-D548-0

"ALBANENE" No. 1951 K&E CO., N.Y.
REG. U.S. PAT. OFF.
40024

DECLASSIFIED

FIG. 39

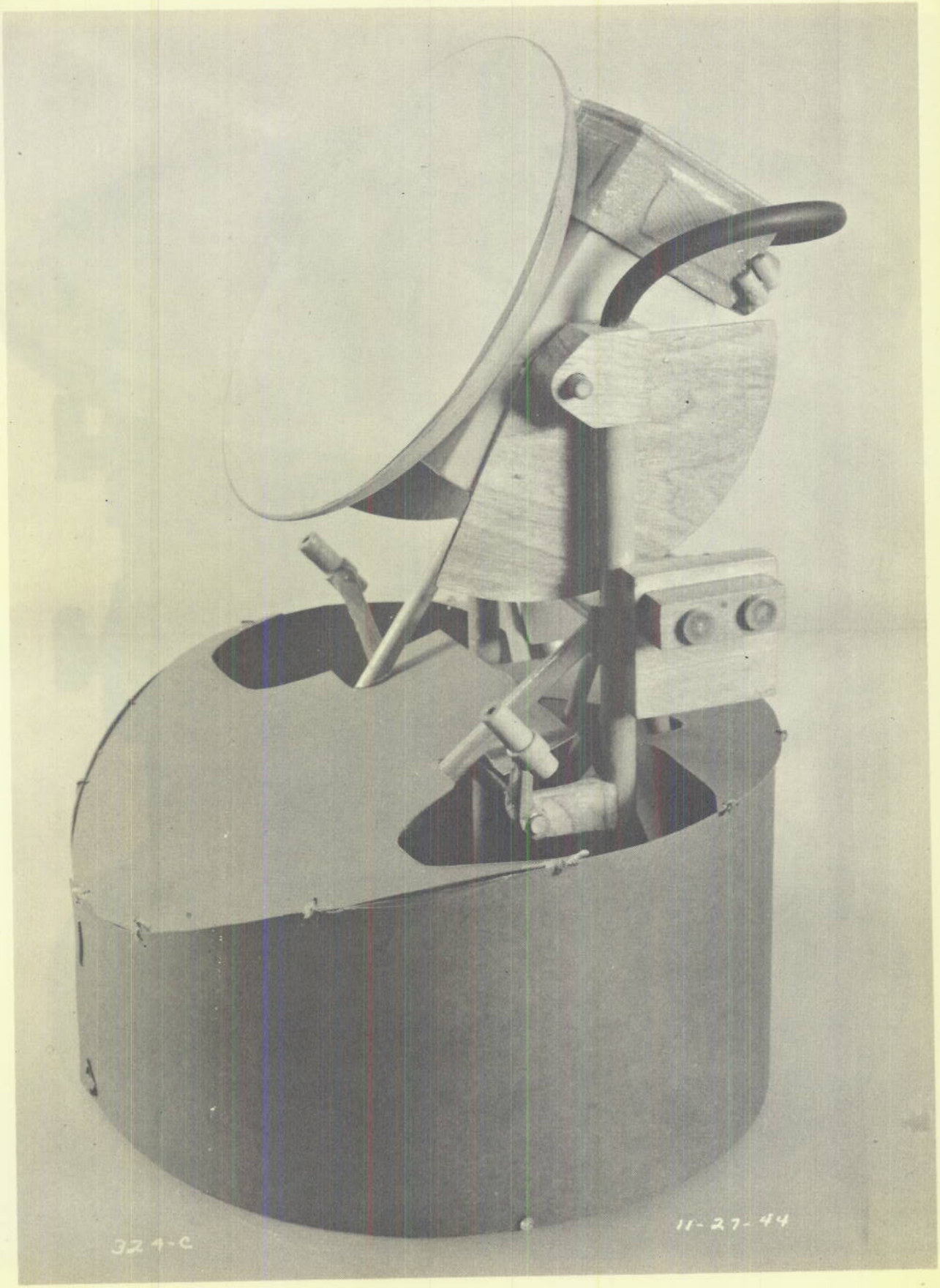


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FIG.40

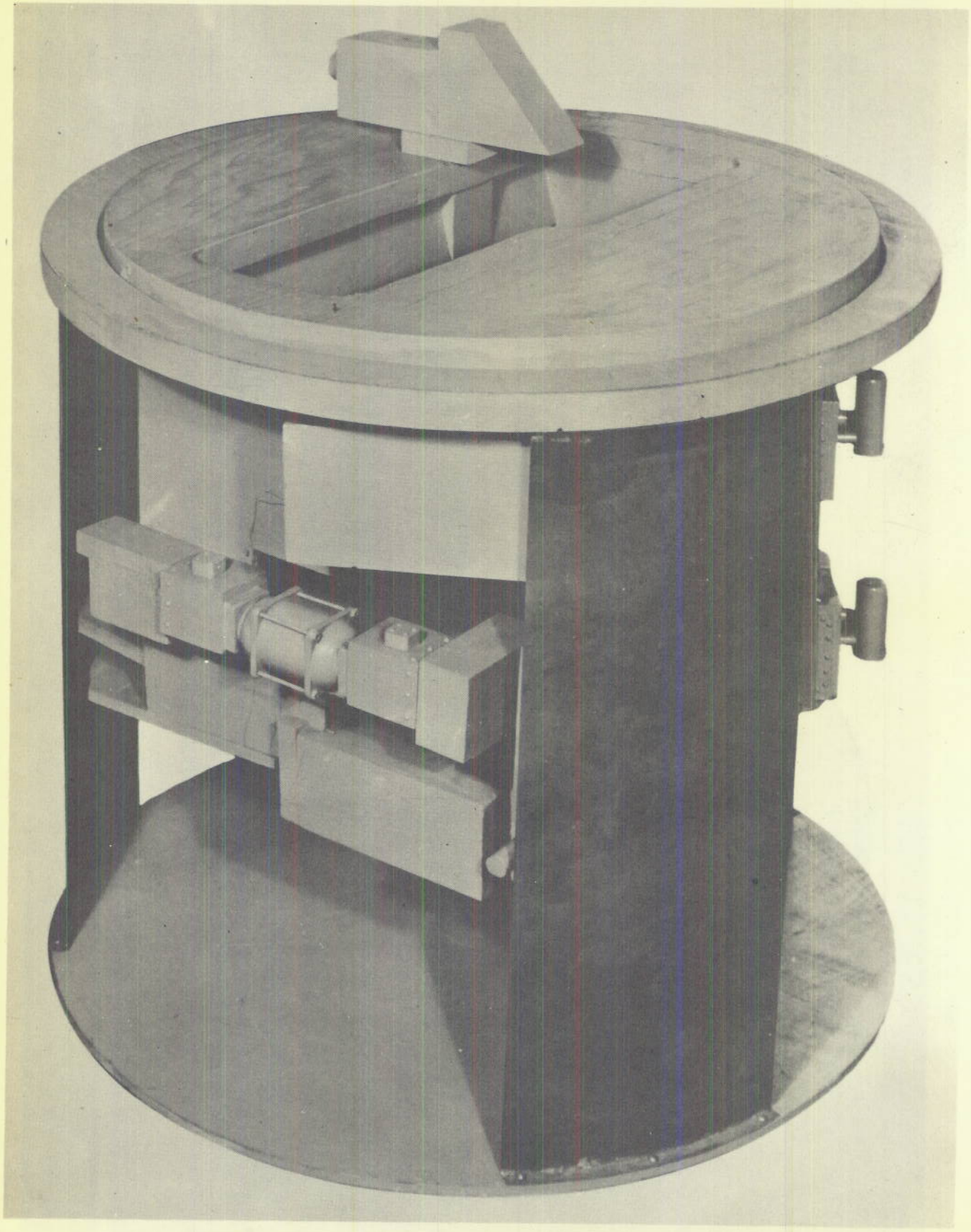

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FIG. 41

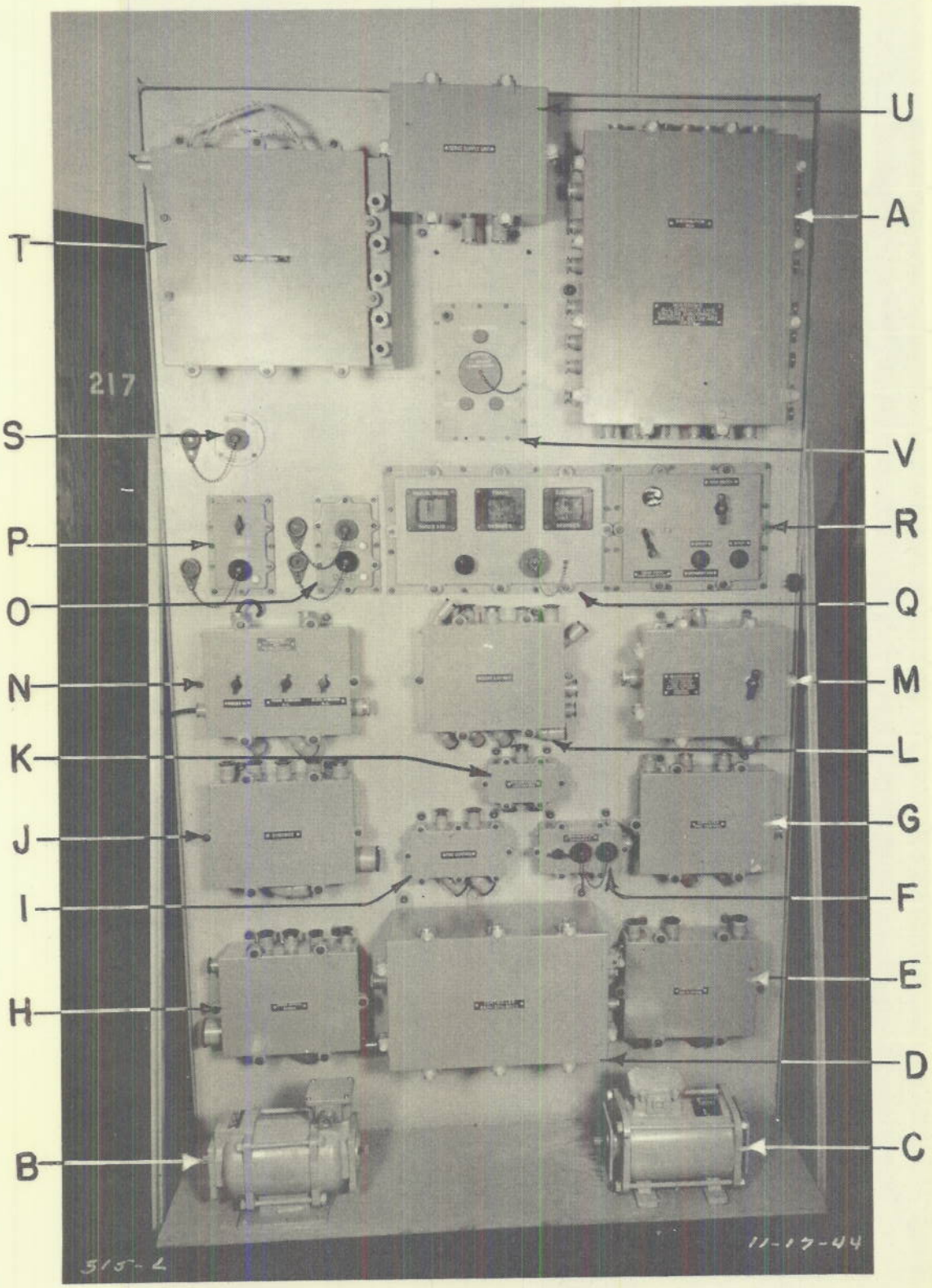

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FIG. 42

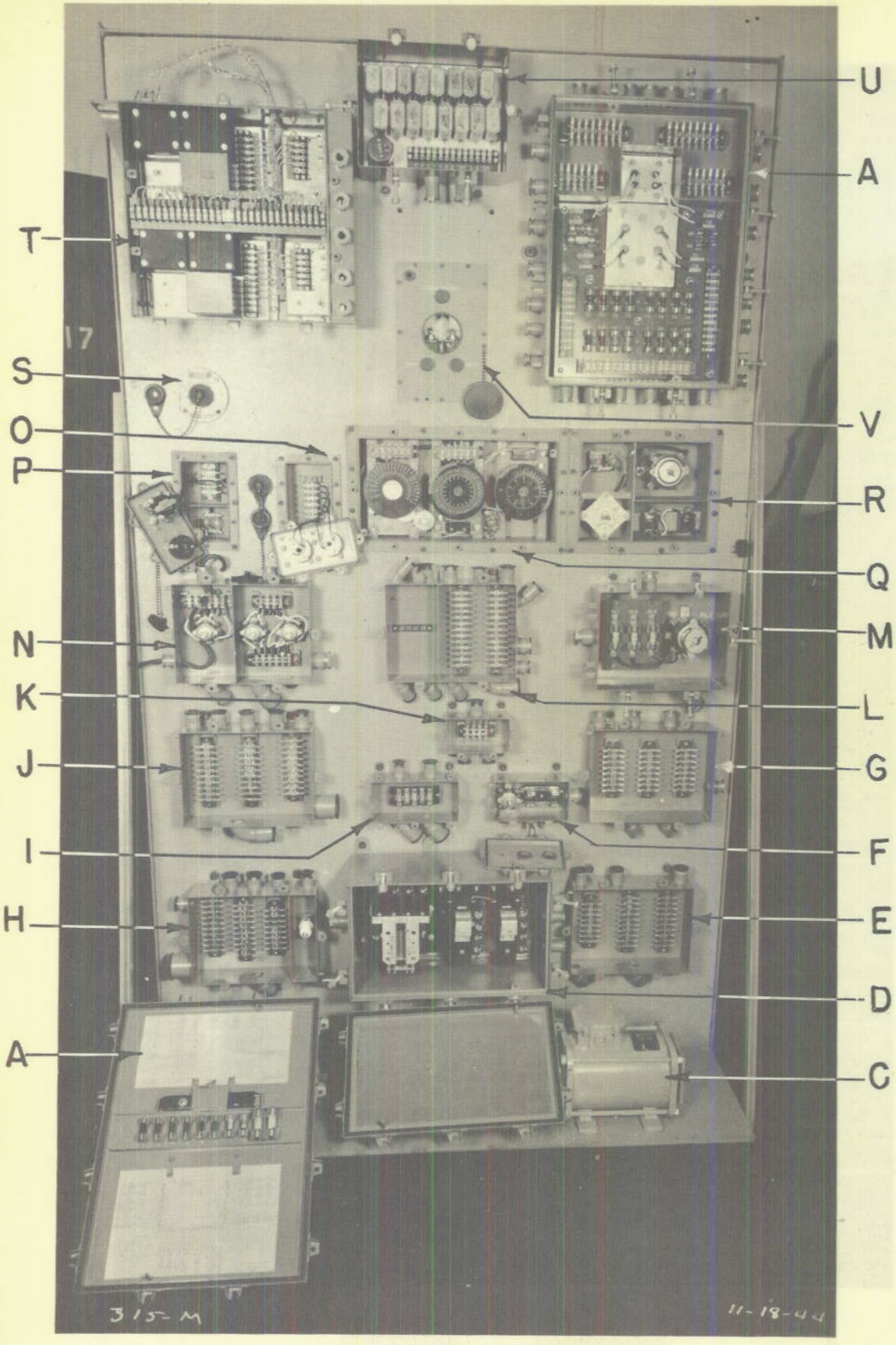

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FIG. 43

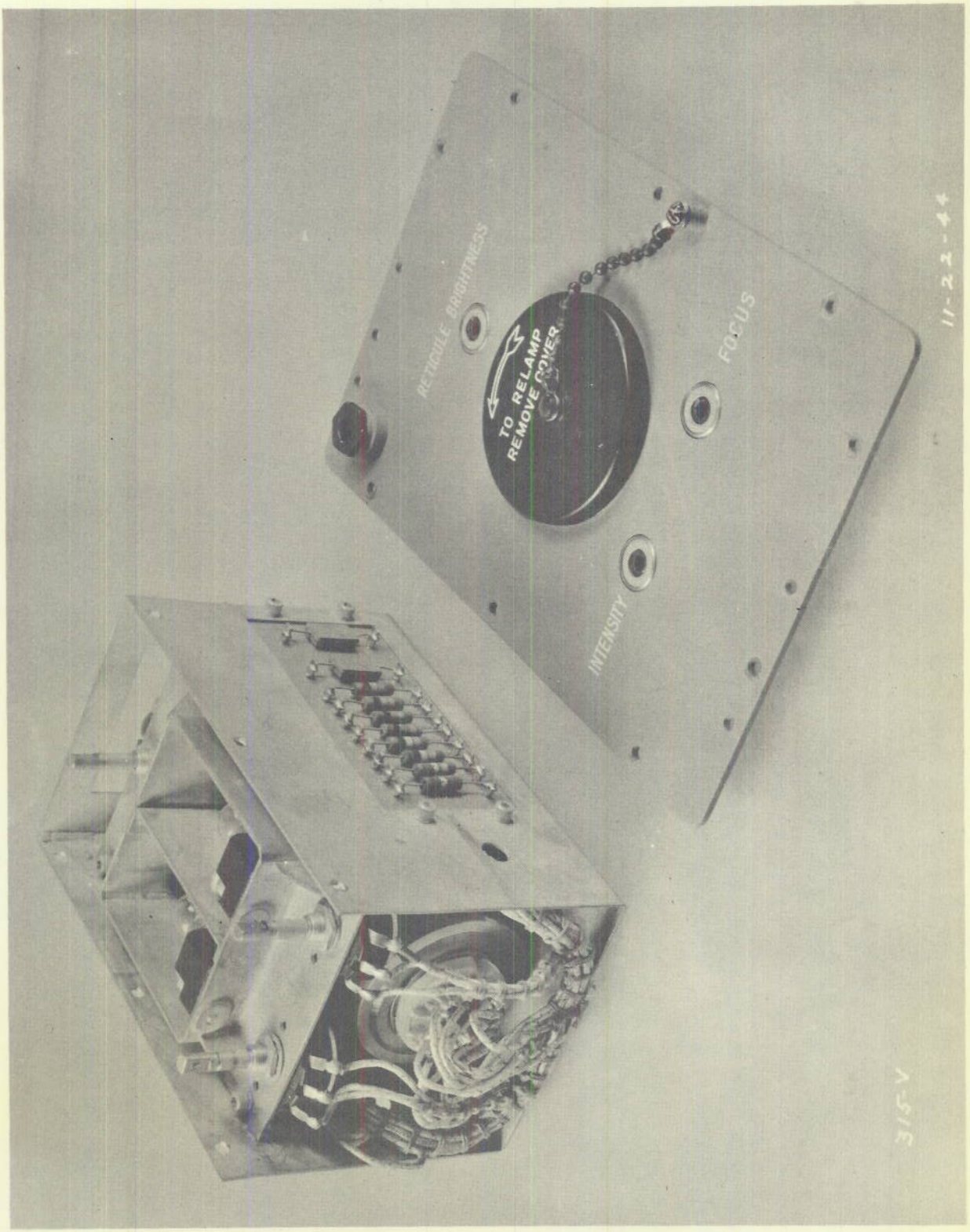

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FIG. 44

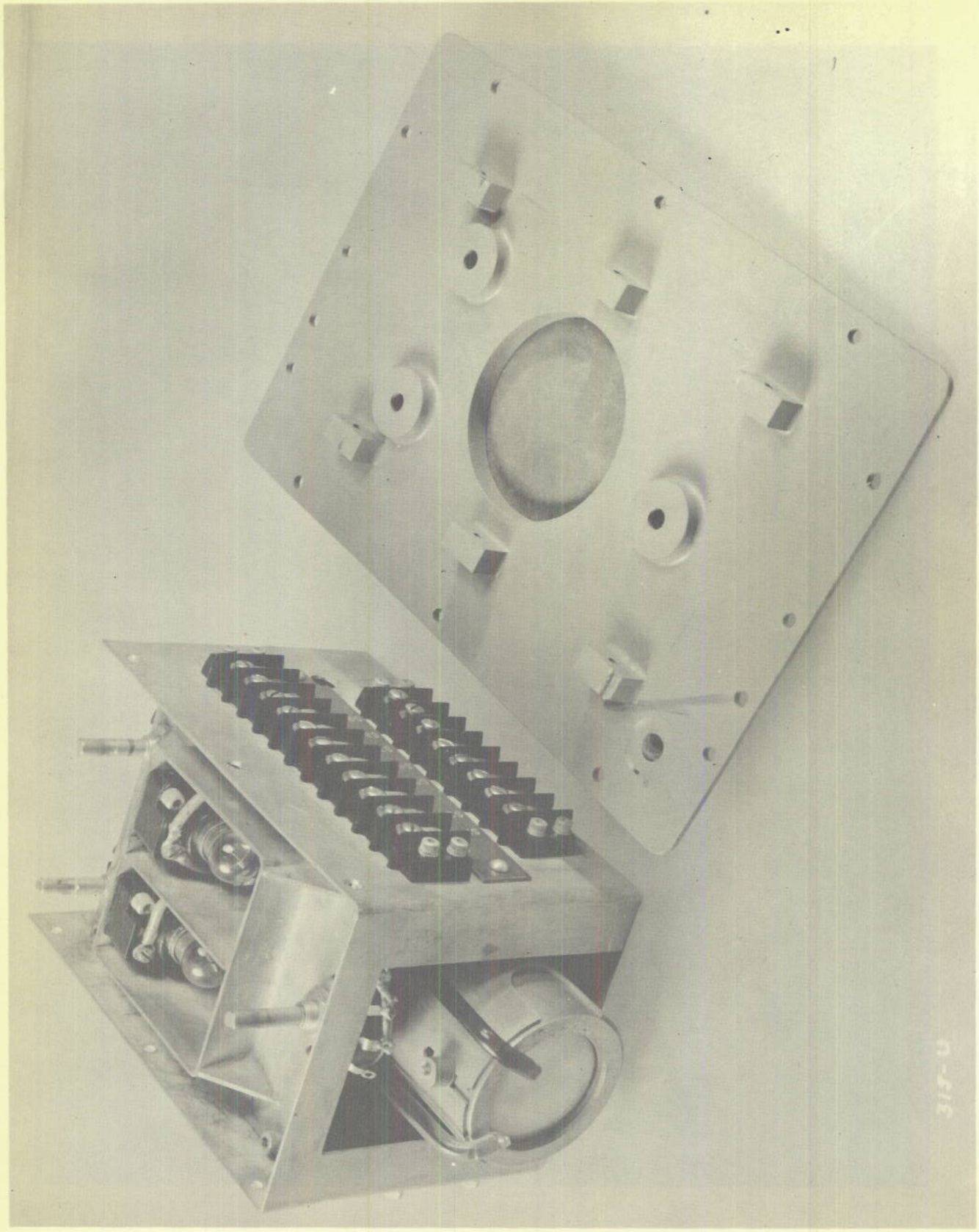

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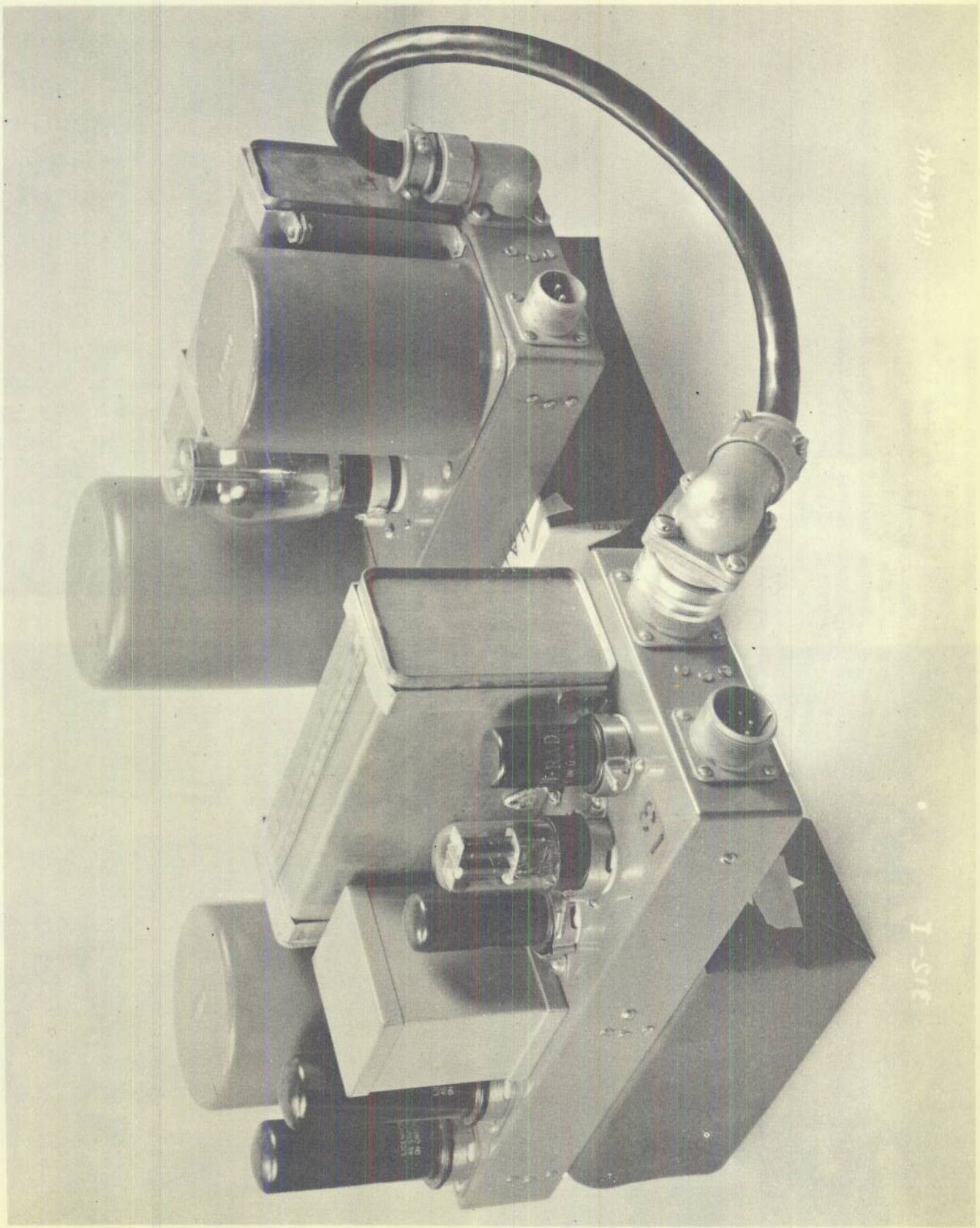
FIG. 45



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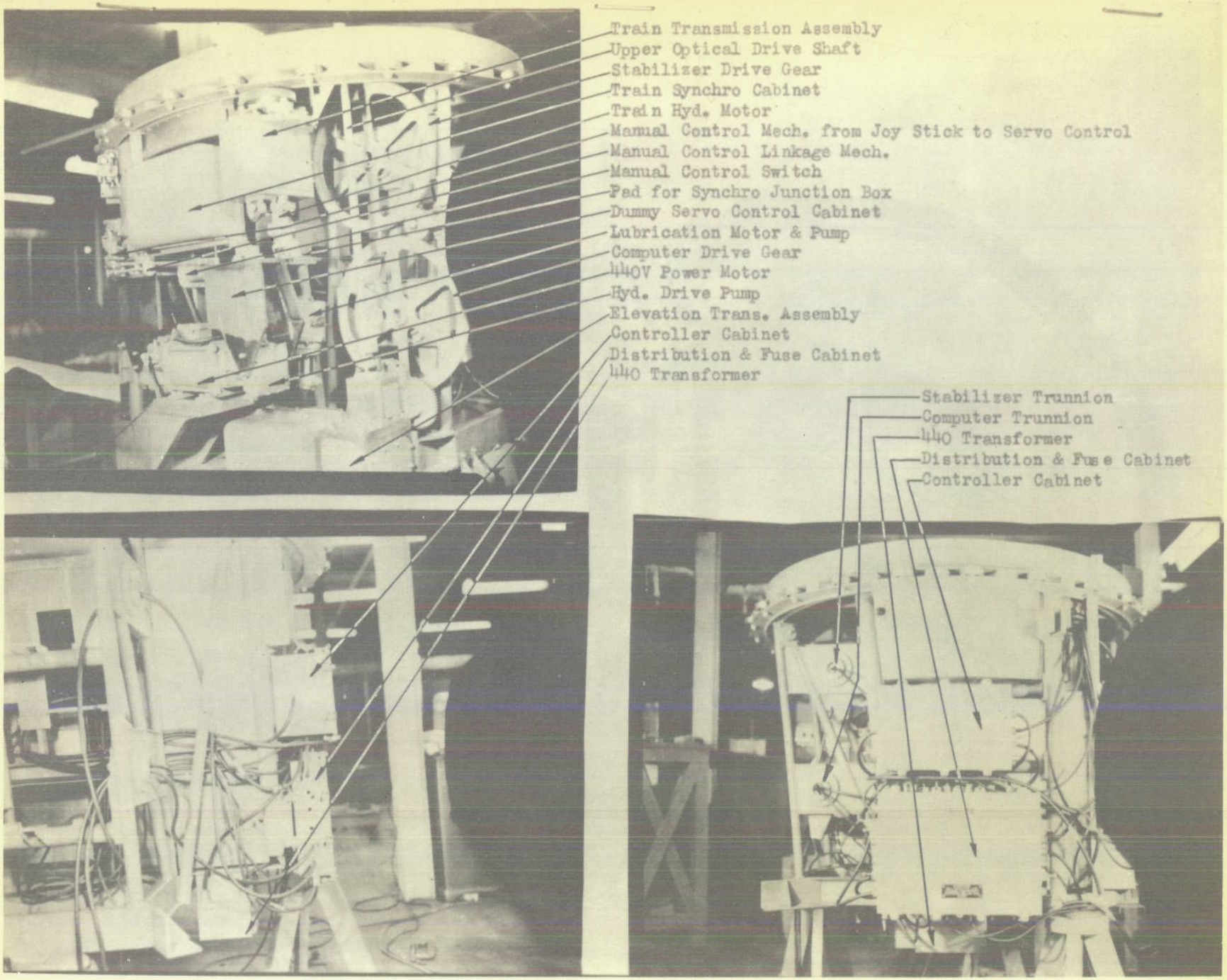

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FIG. 46

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FIG. 47

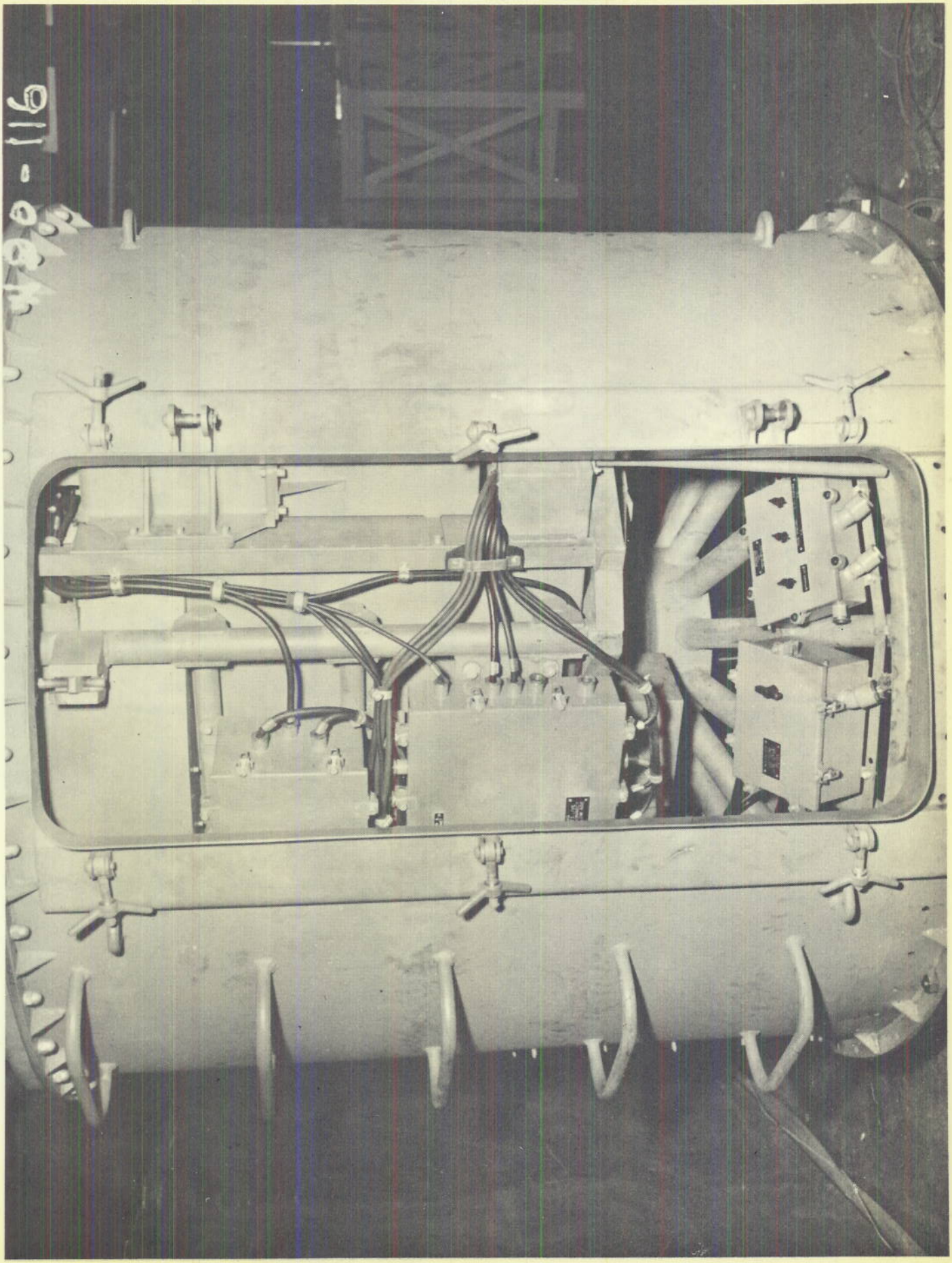

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FIG. 48

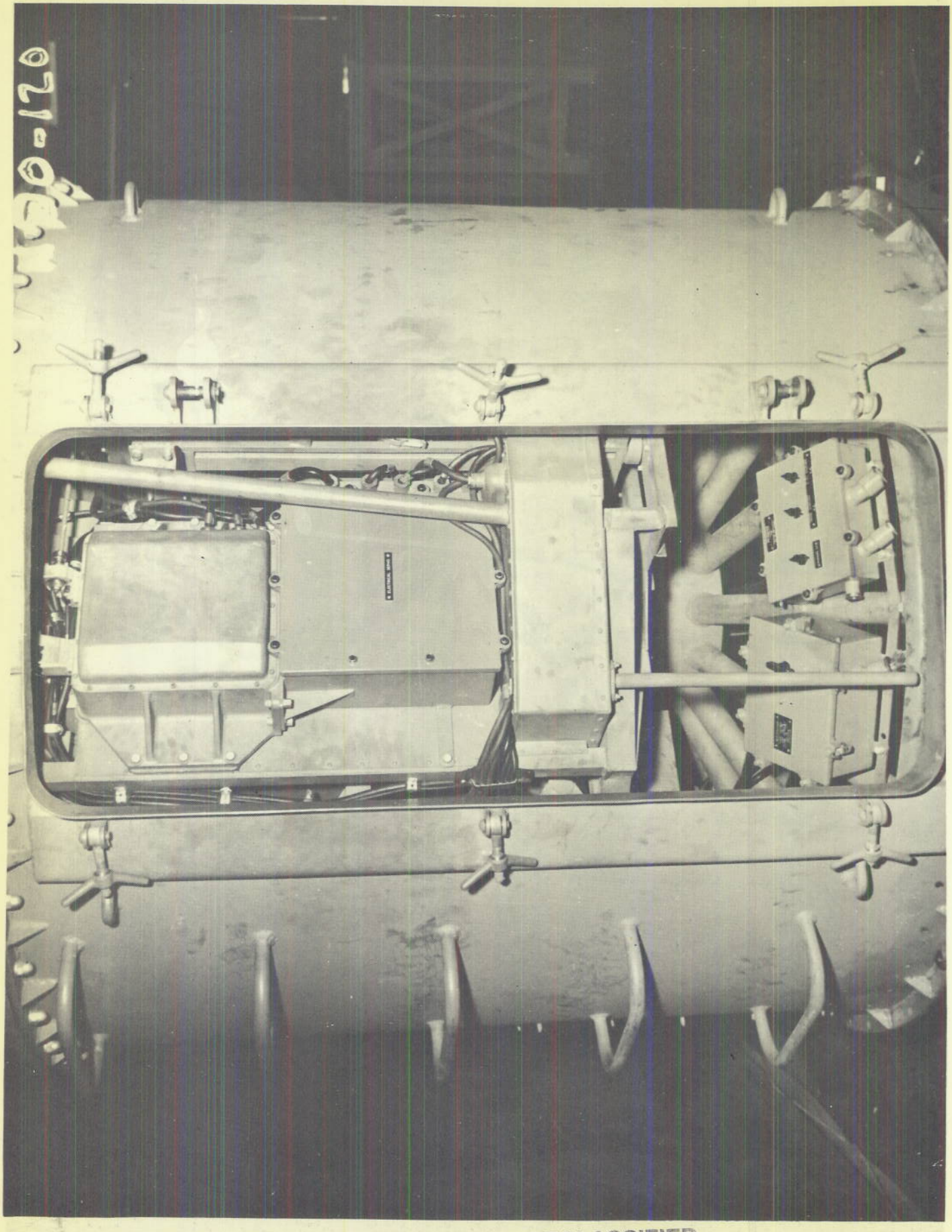

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FIG. 49

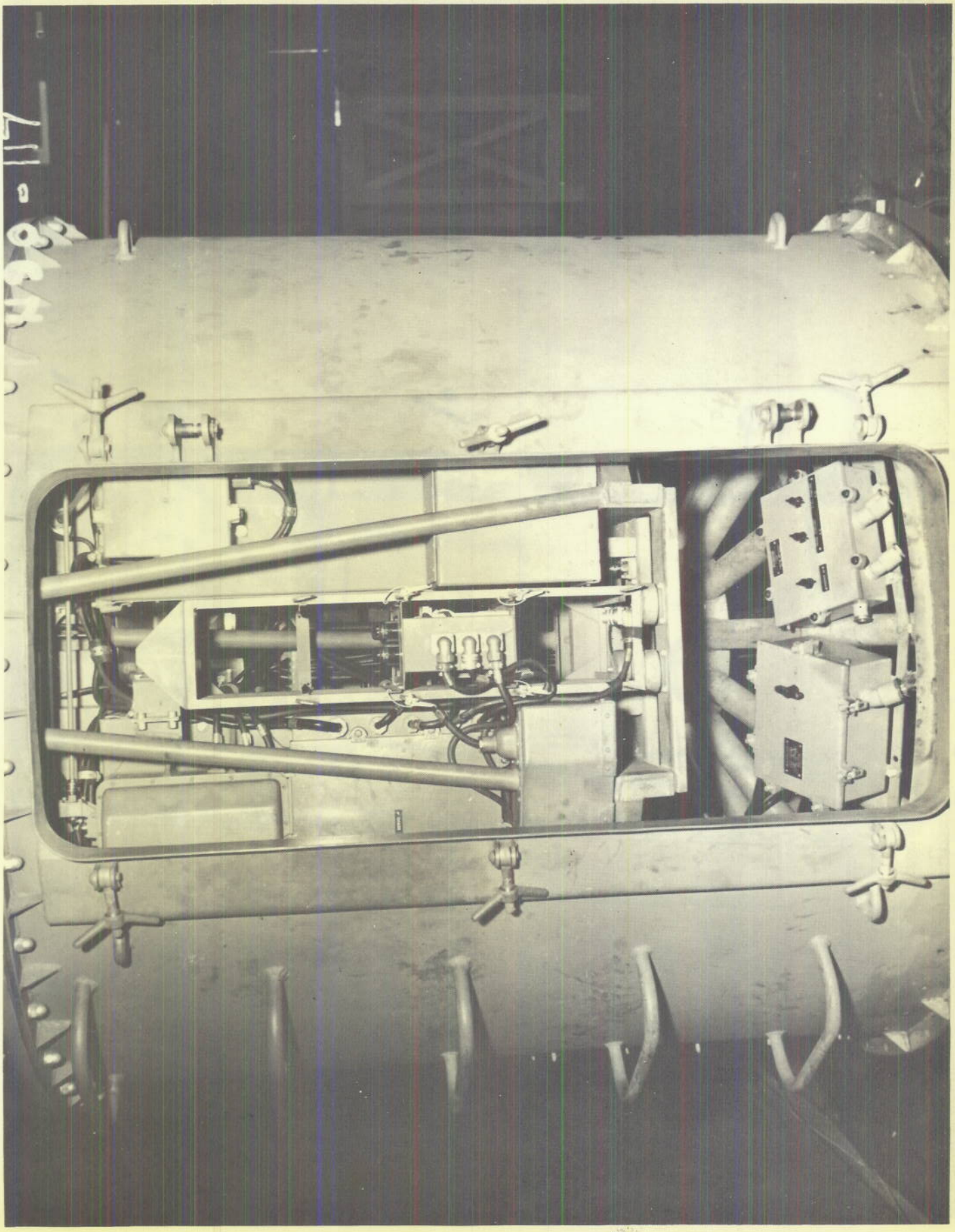

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FIG. 50

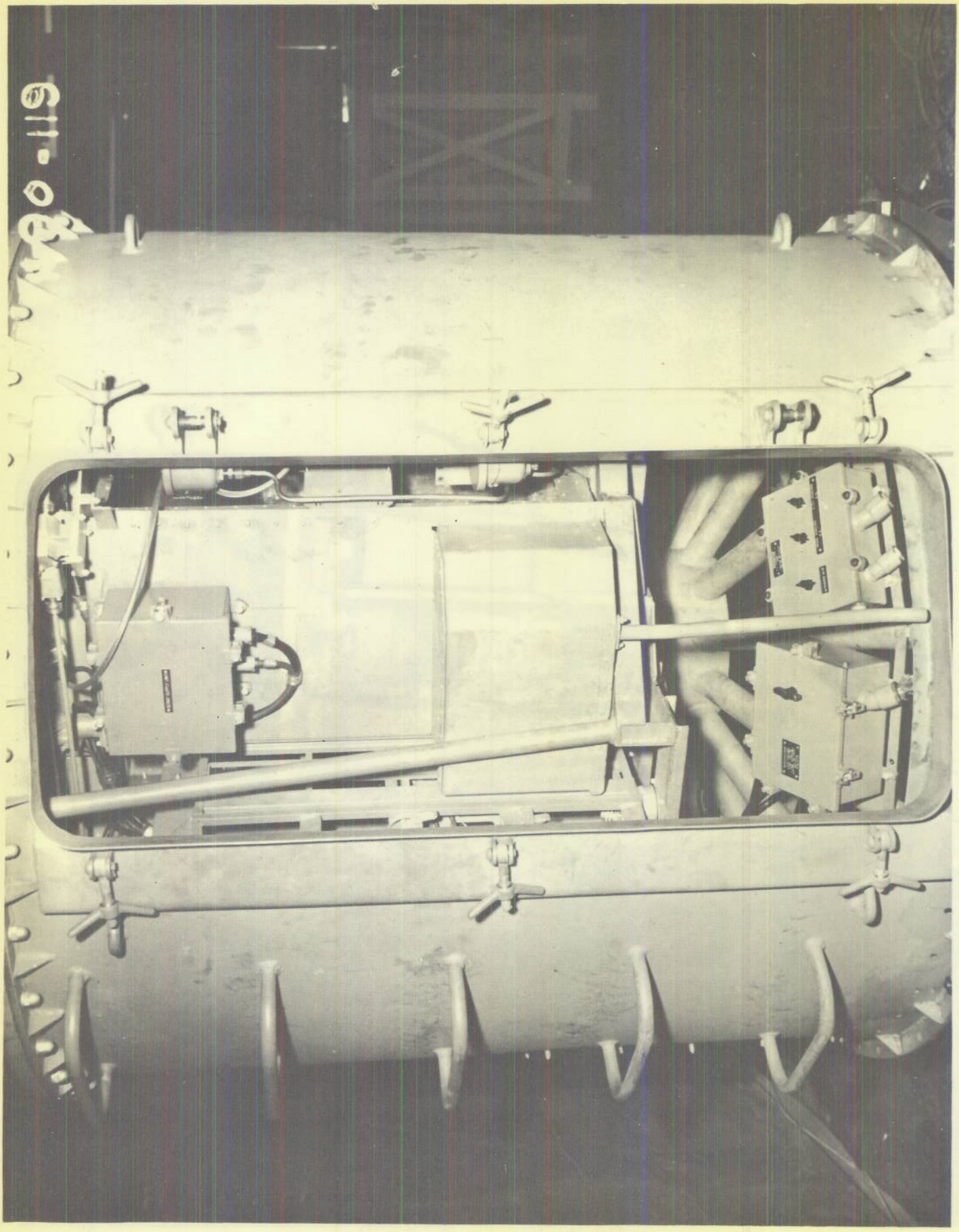

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FIG. 51

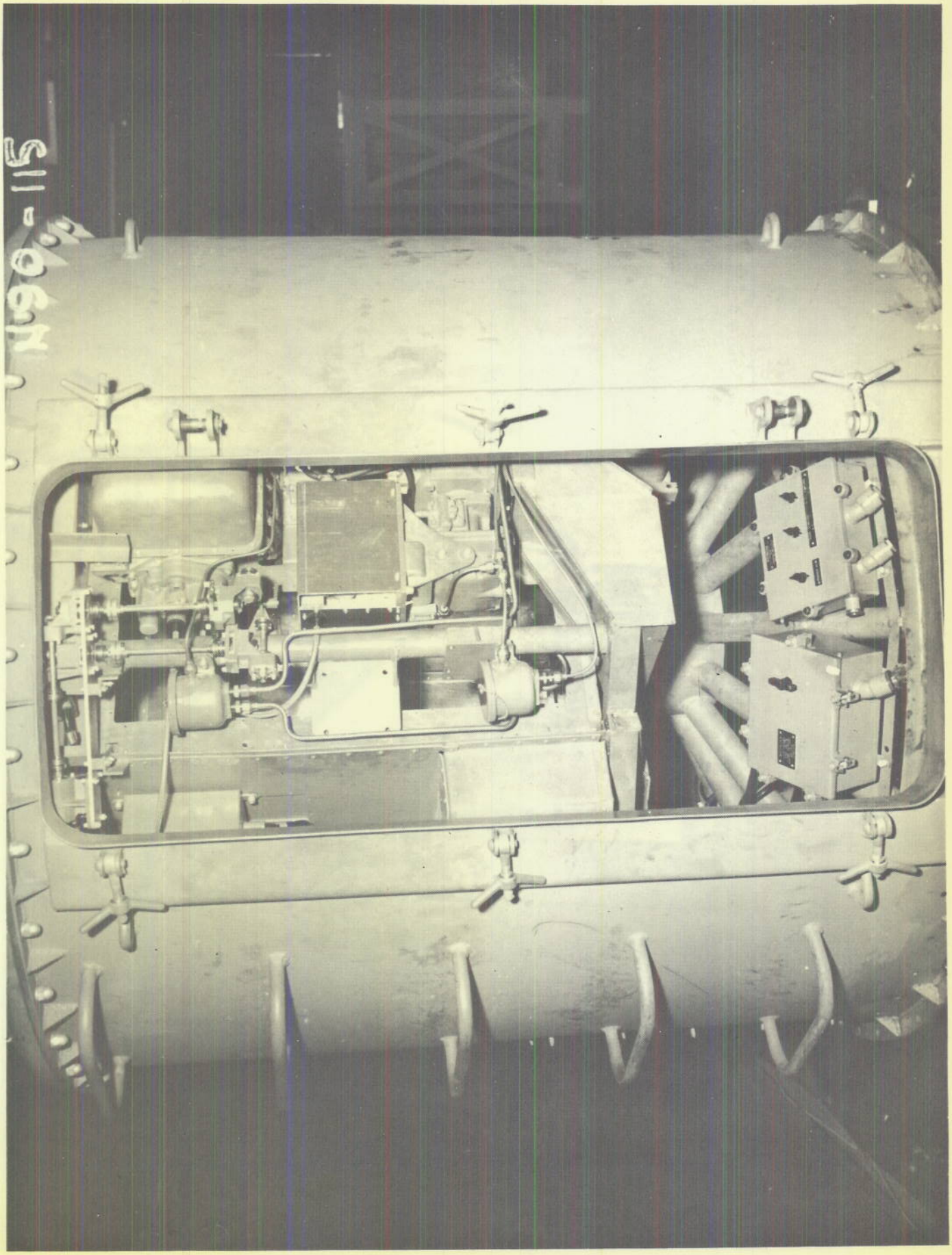

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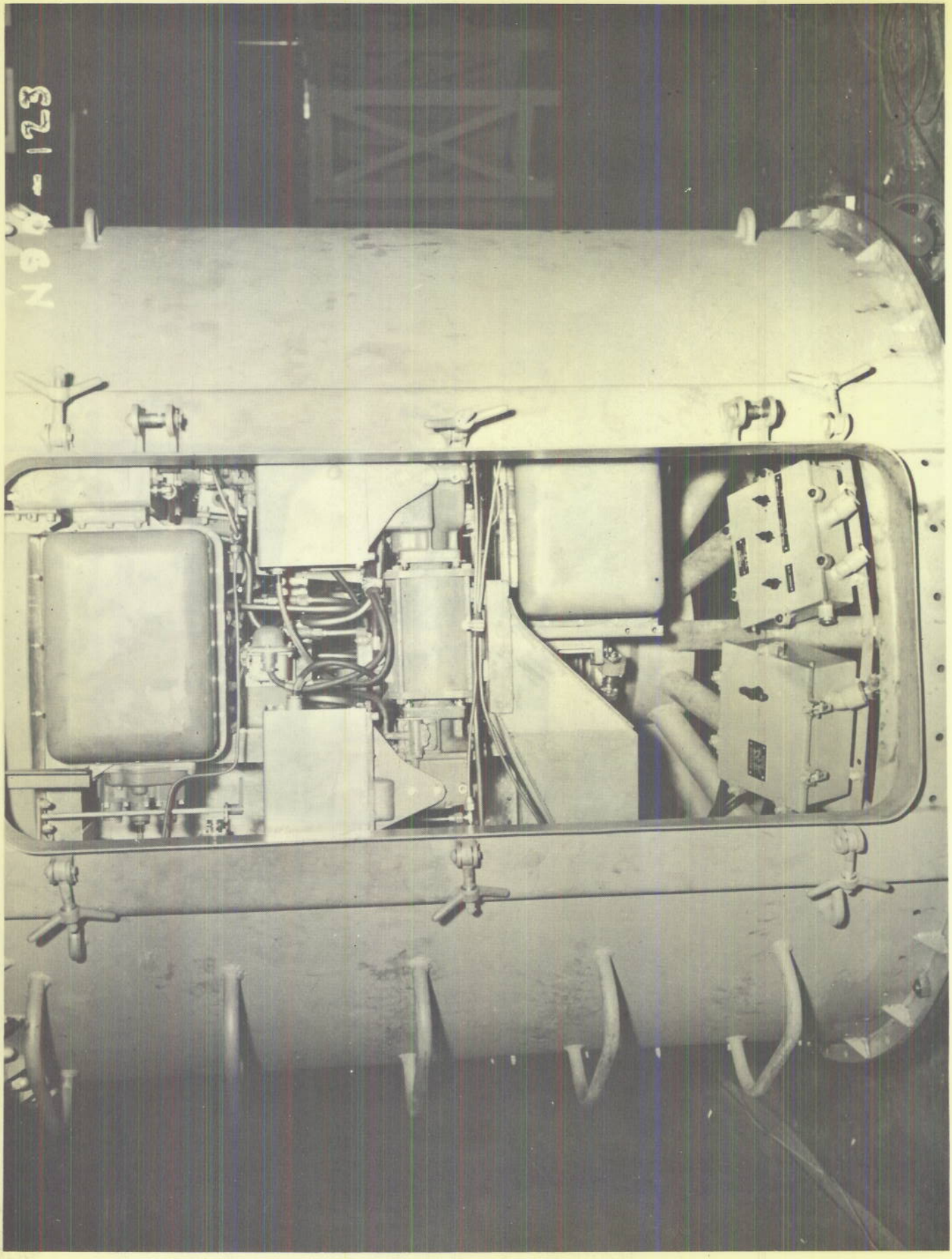
FIG. 52



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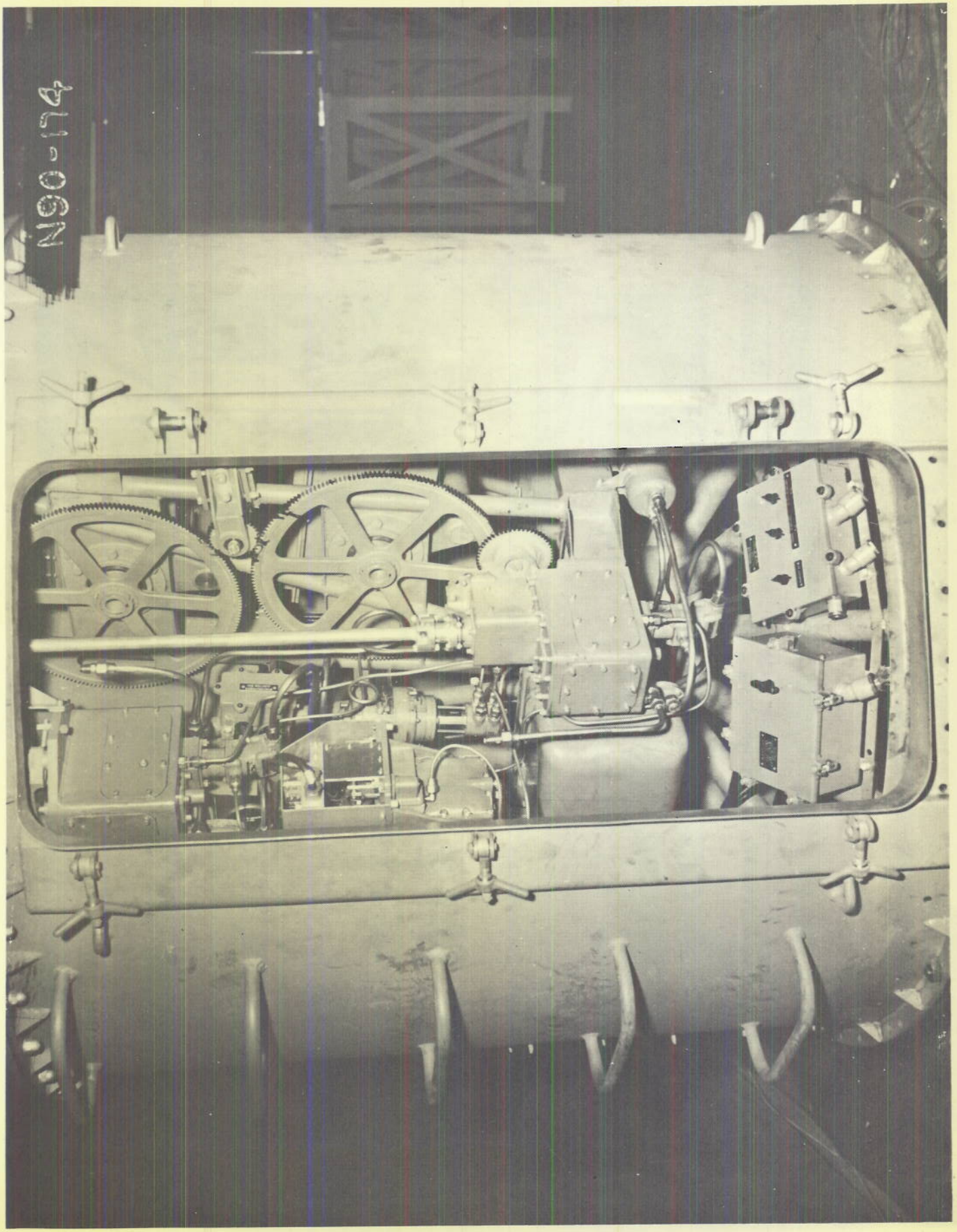
DECLASSIFIED

FIG. 53



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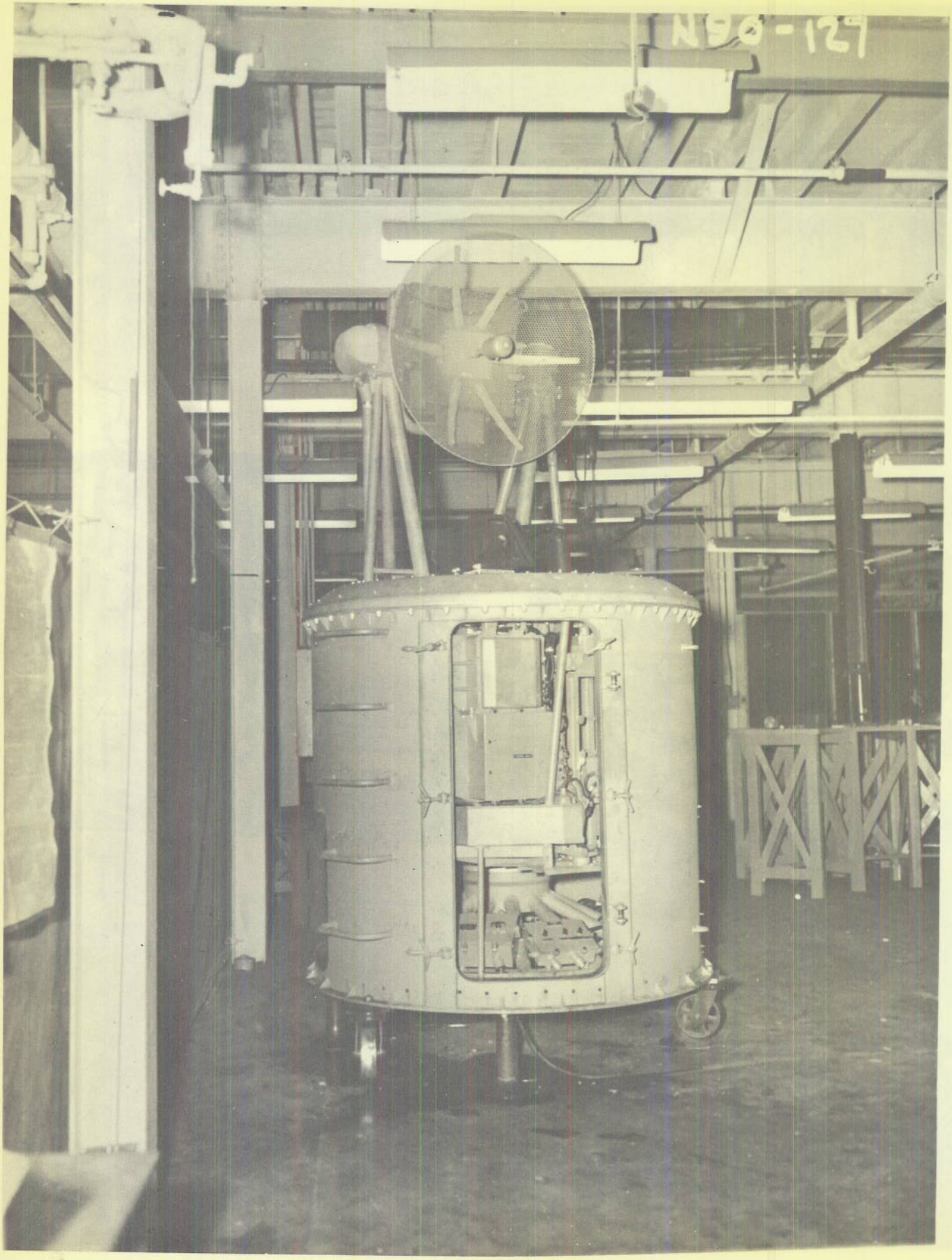
DECLASSIFIED

FIG. 54



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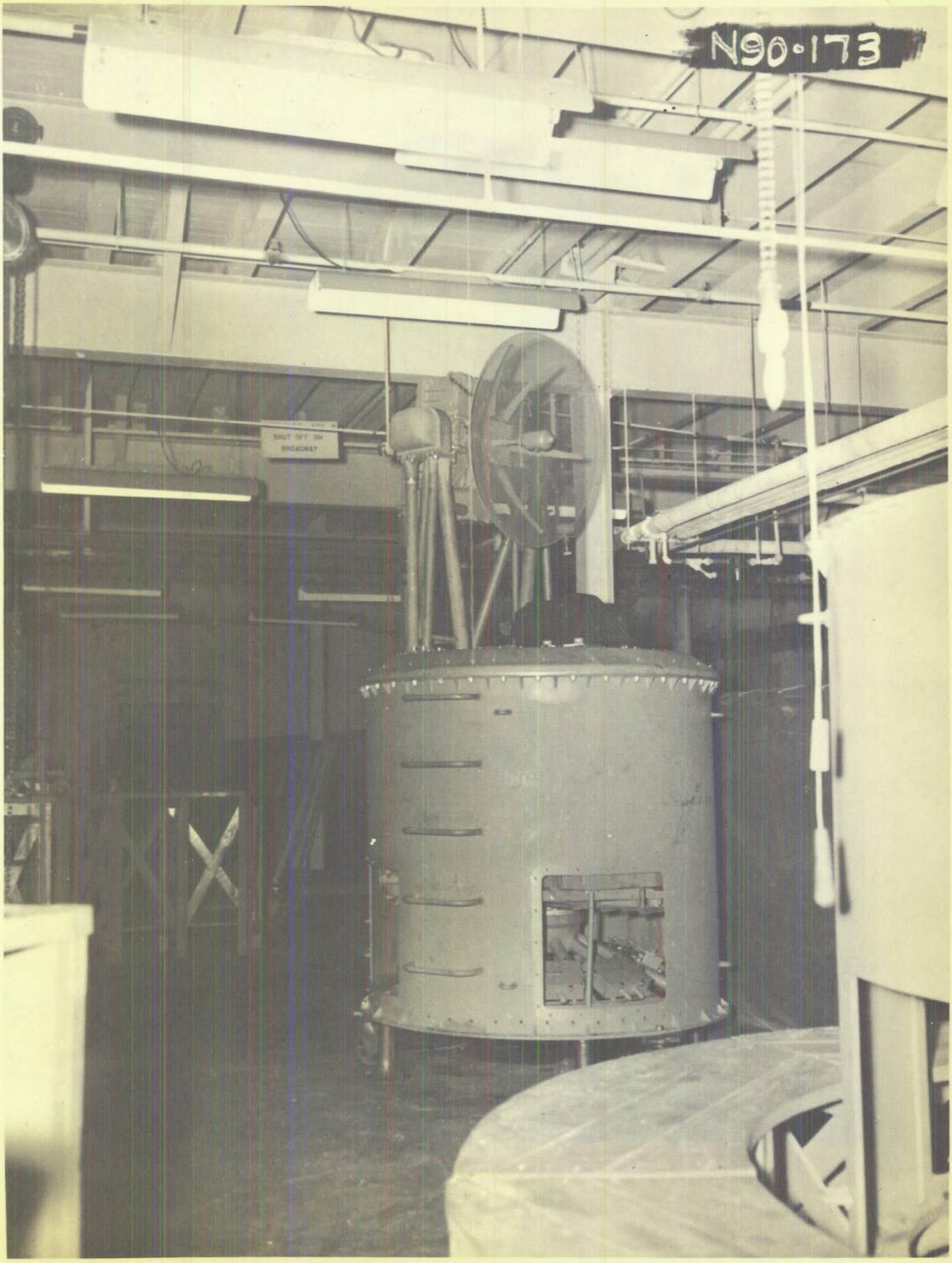
DECLASSIFIED

FIG. 55



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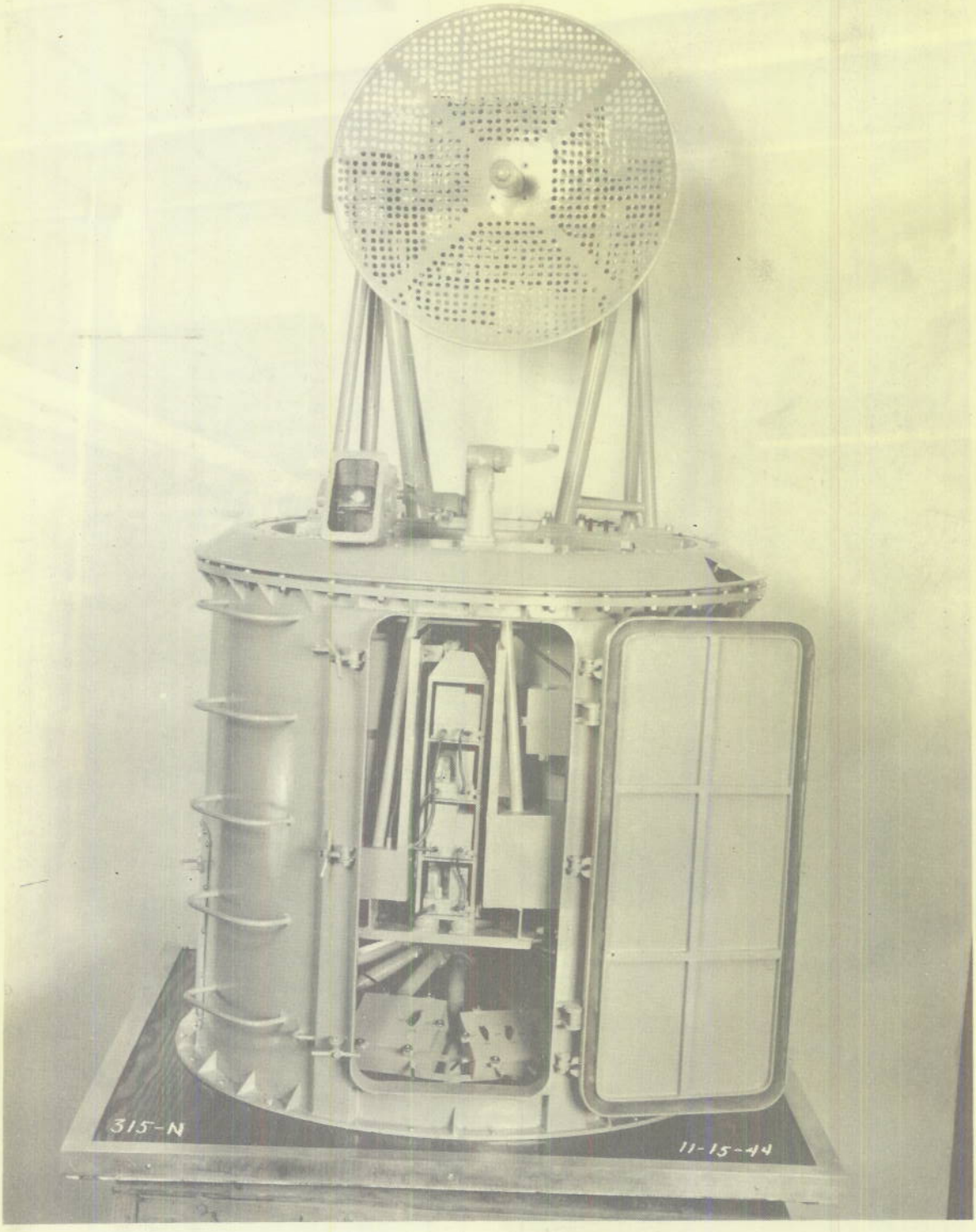
DECLASSIFIED

FIG. 56



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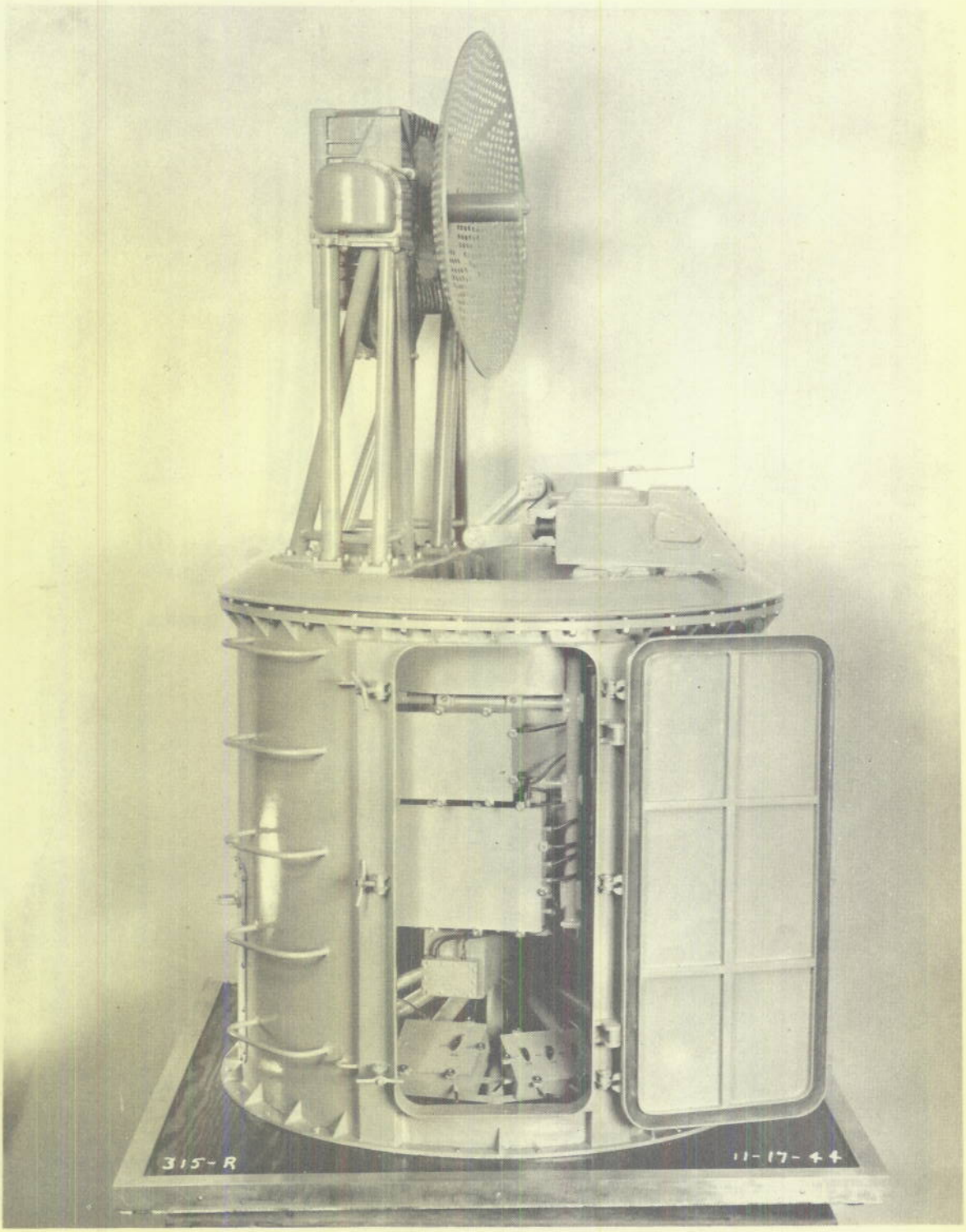
DECLASSIFIED

FIG. 57



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DECLASSIFIED

FIG. 58

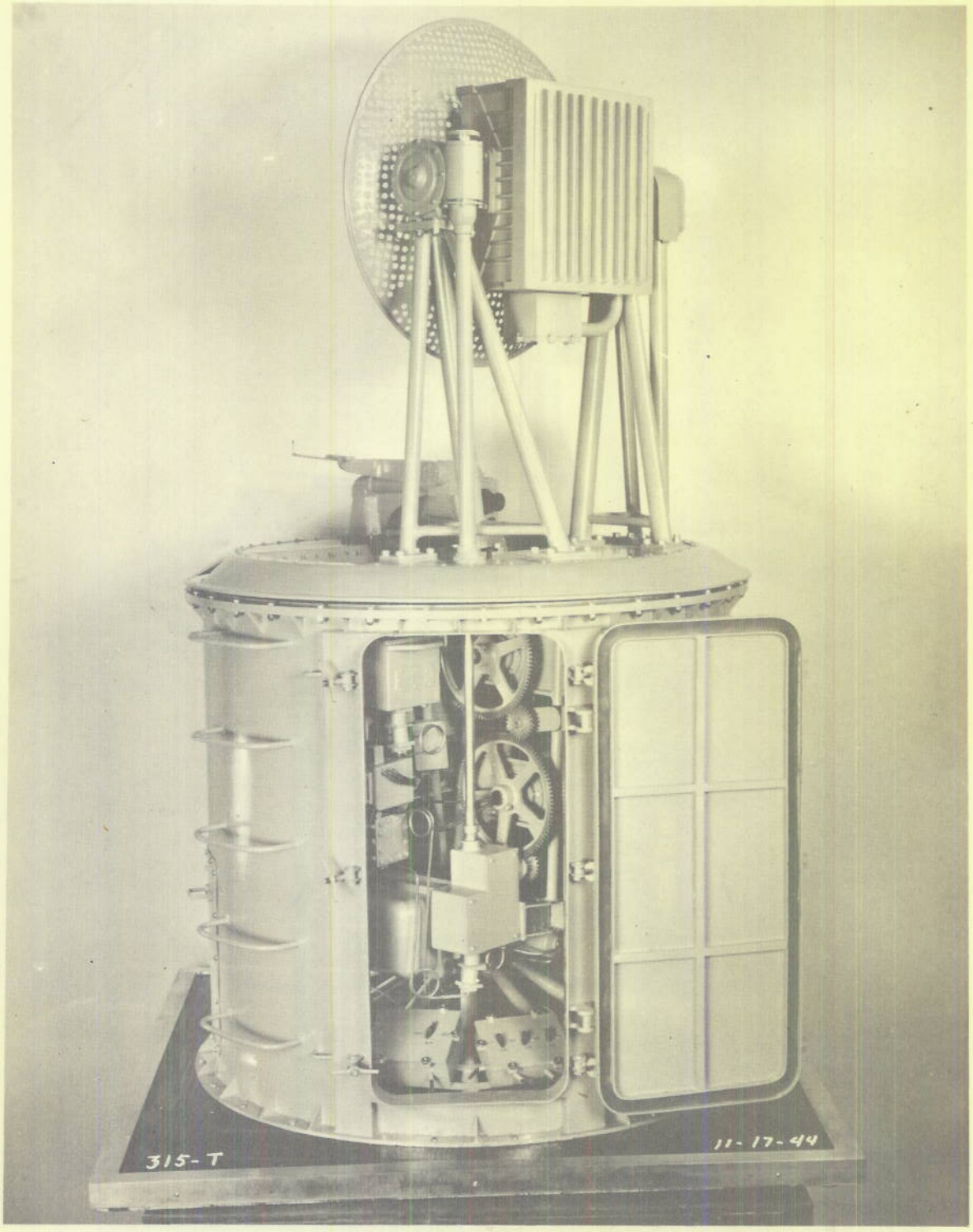

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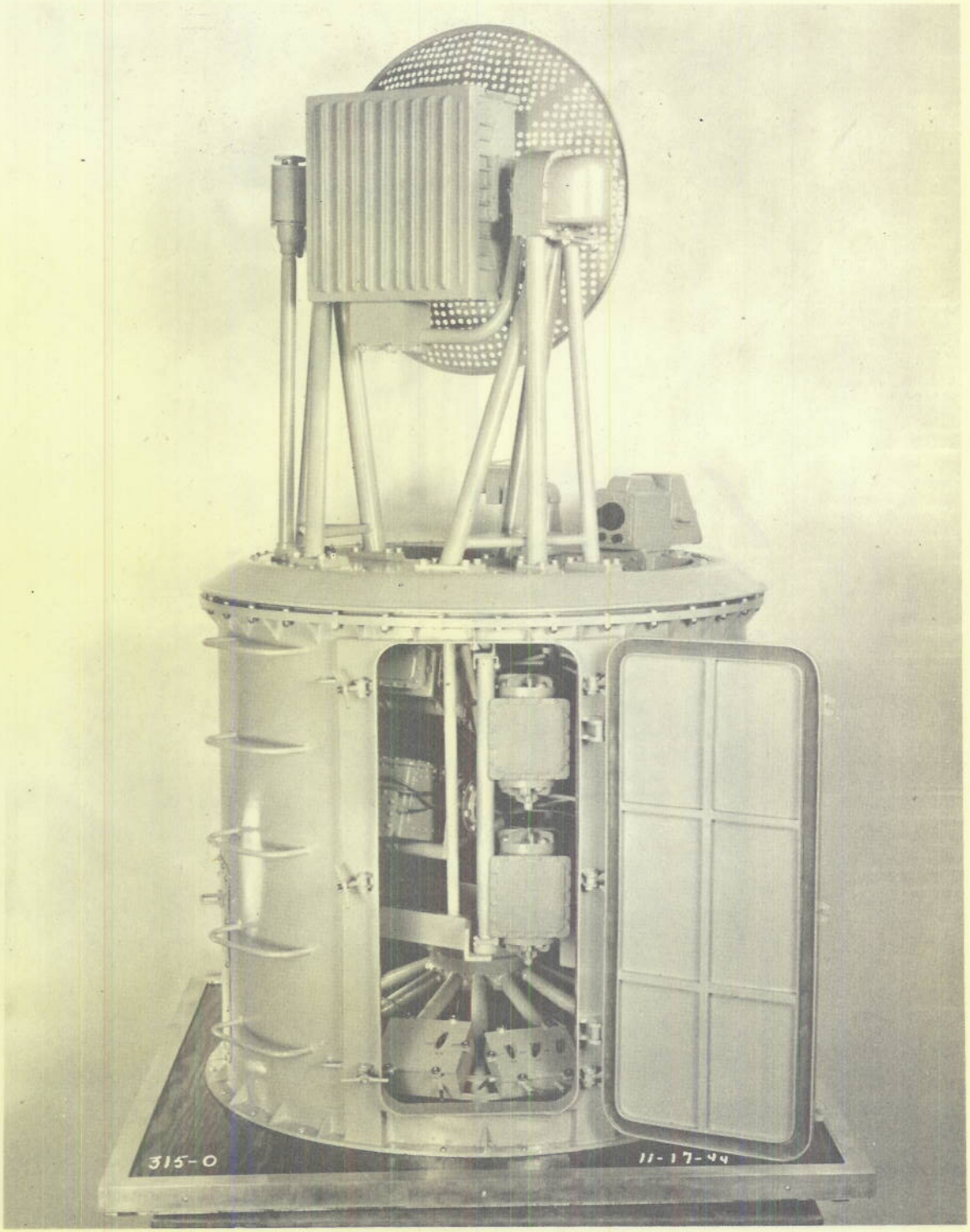
FIG. 59



DECLASSIFIED

DECLASSIFIED

FIG. 60

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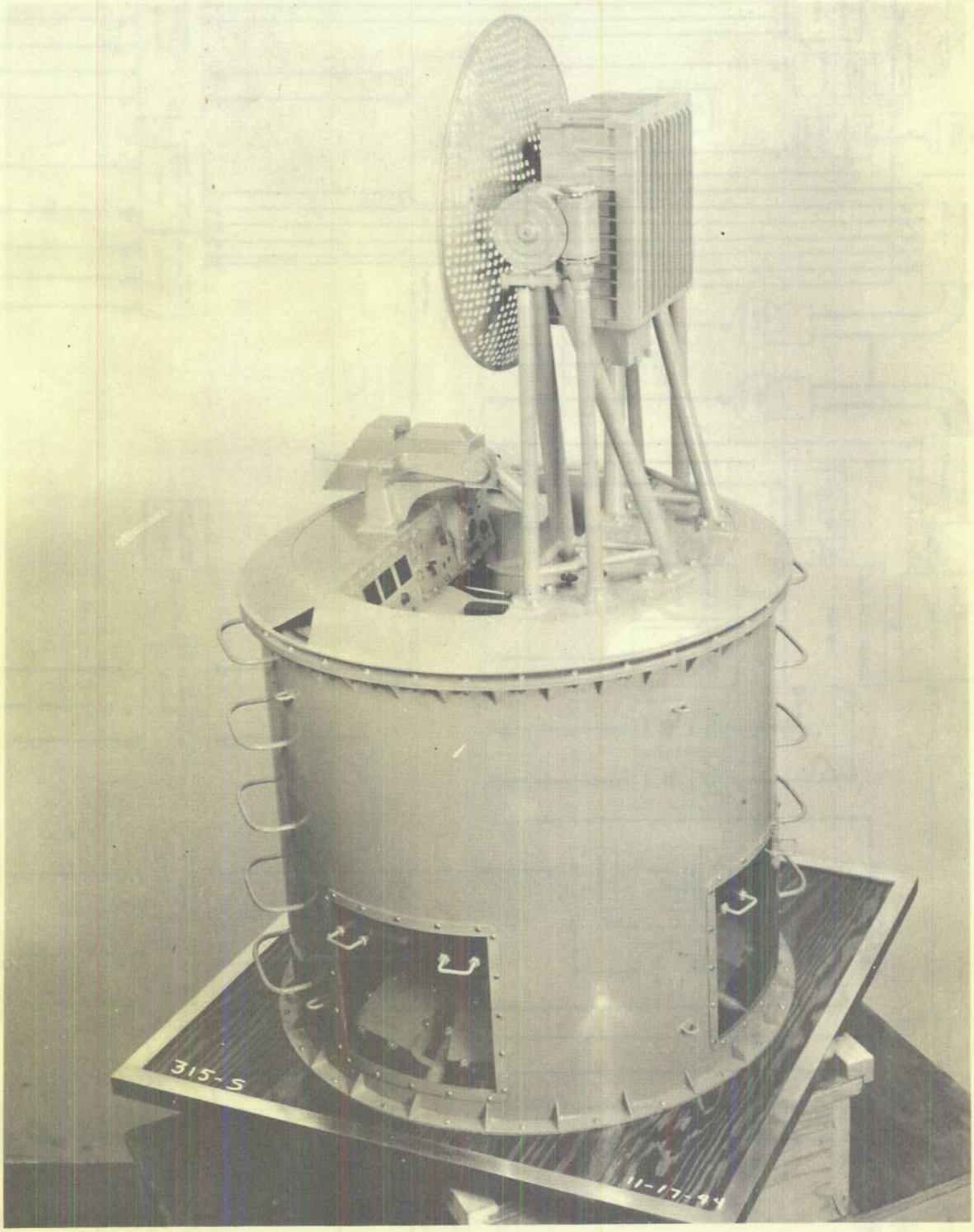
DECLASSIFIED

FIG. 61



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DECLASSIFIED

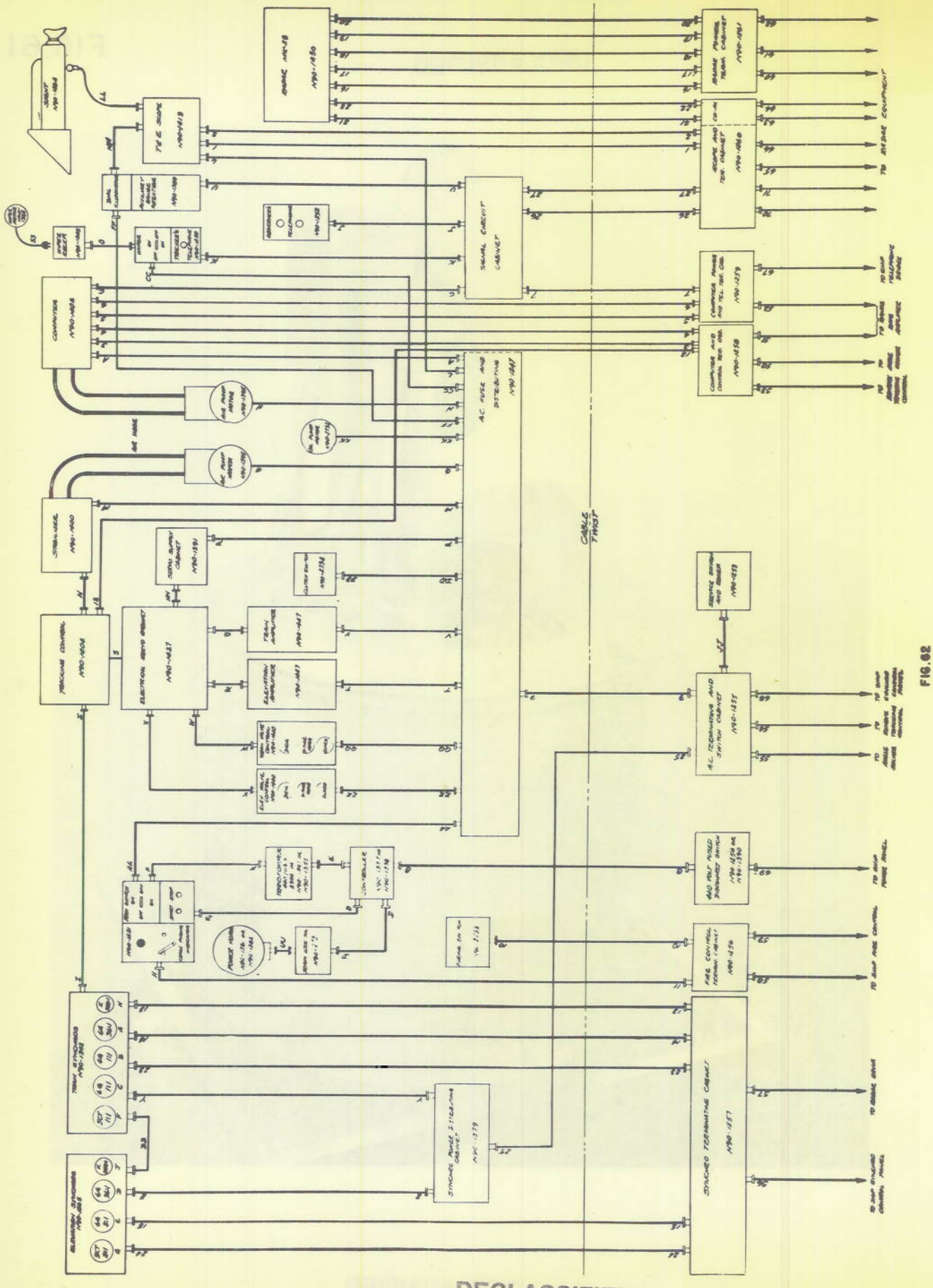
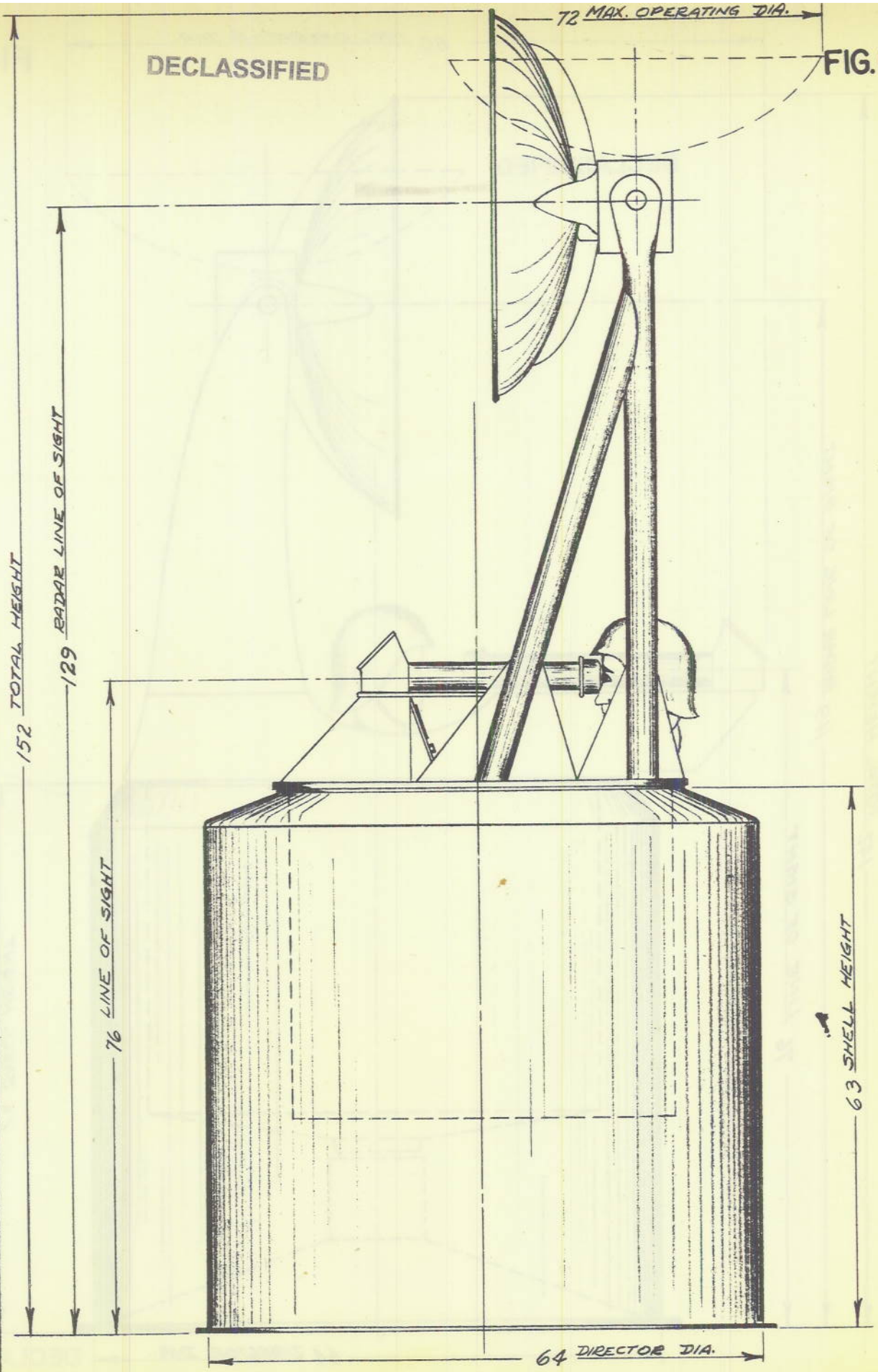


FIG. 62

DECLASSIFIED

DECLASSIFIED

FIG. 63a

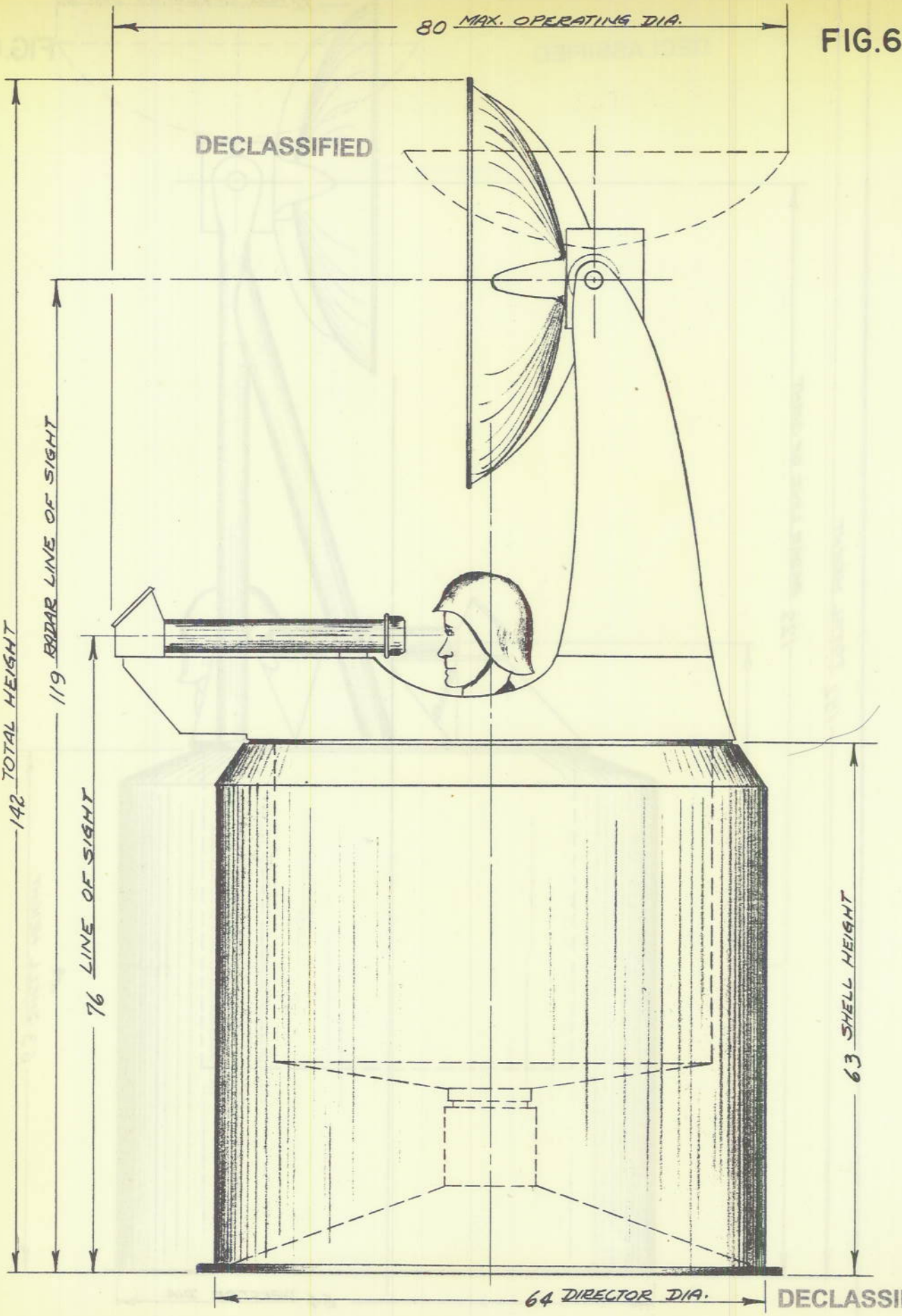


DECLASSIFIED

J.H.U. ORIGINAL DIRECTOR

DECEMBER 1943

FIG.63b



DECLASSIFIED

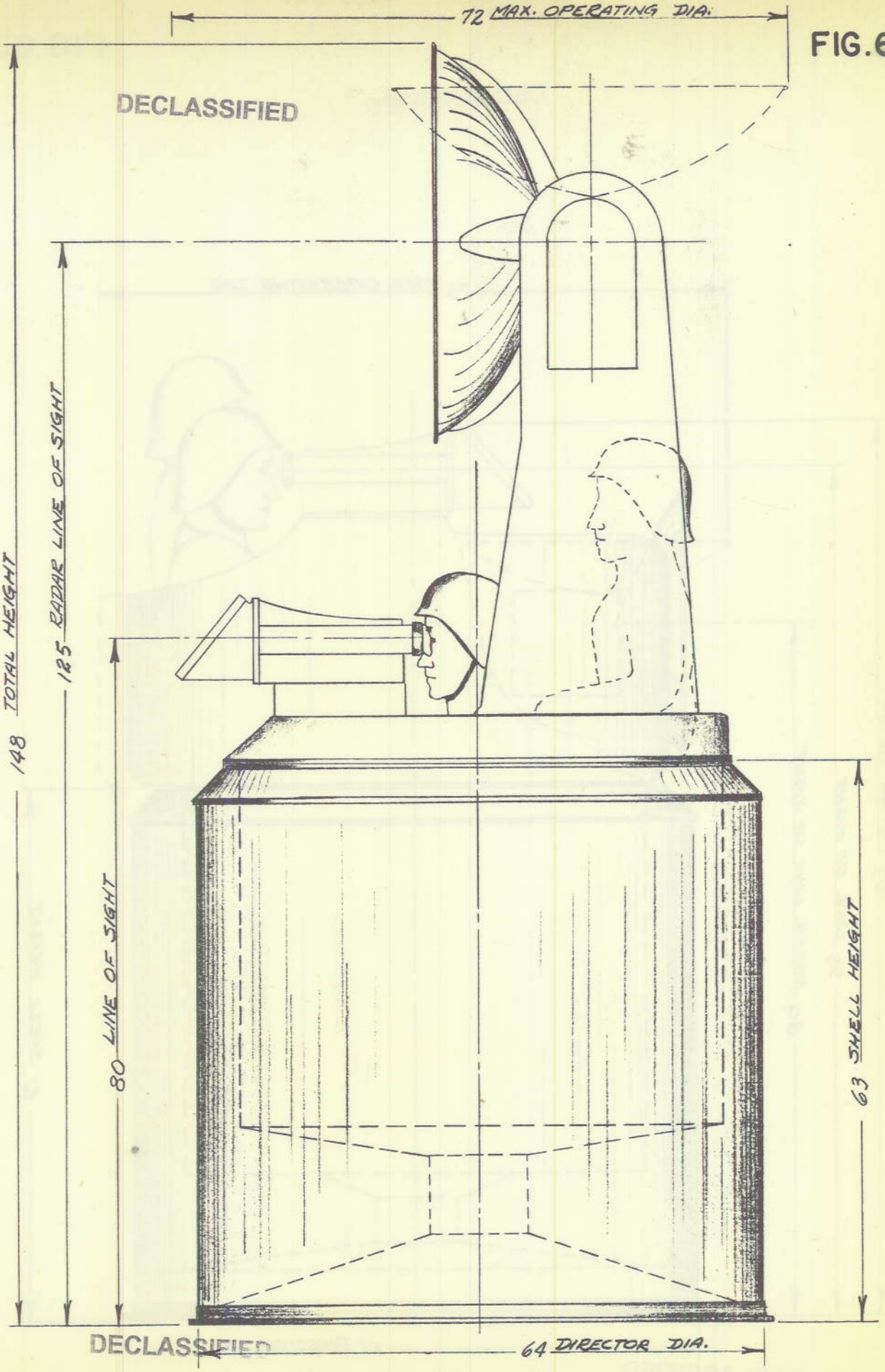
DECLASSIFIED

NORGE MODIFICATION OF J.H.U DIRECTOR

JANUARY 1944

FIG. 63c

DECLASSIFIED



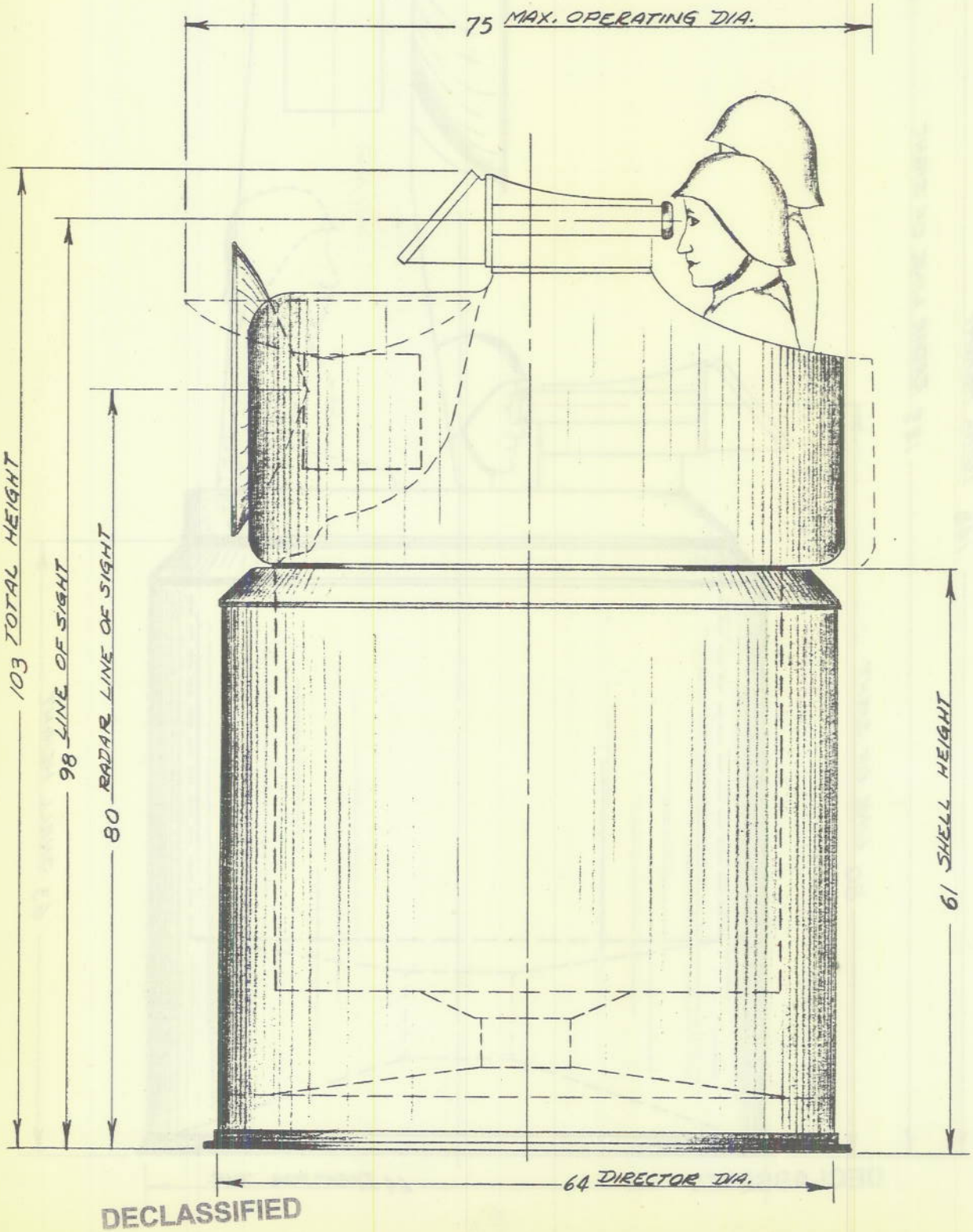
DECLASSIFIED

NORGE DESIGN #1

FEBRUARY 1944

FIG.63d

DECLASSIFIED

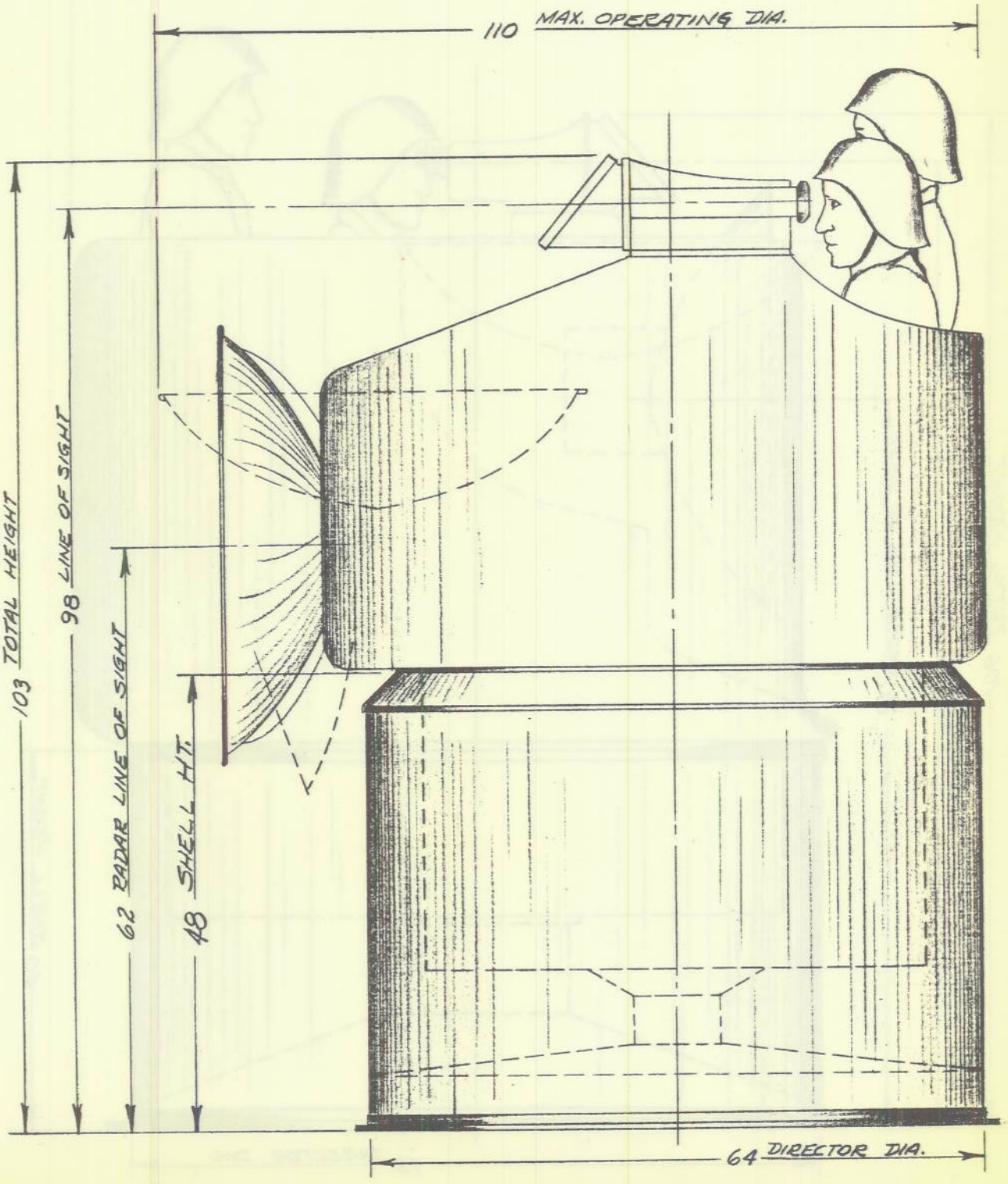


DECLASSIFIED

NORGE DESIGN #2

FEBRUARY 1944

DECLASSIFIED

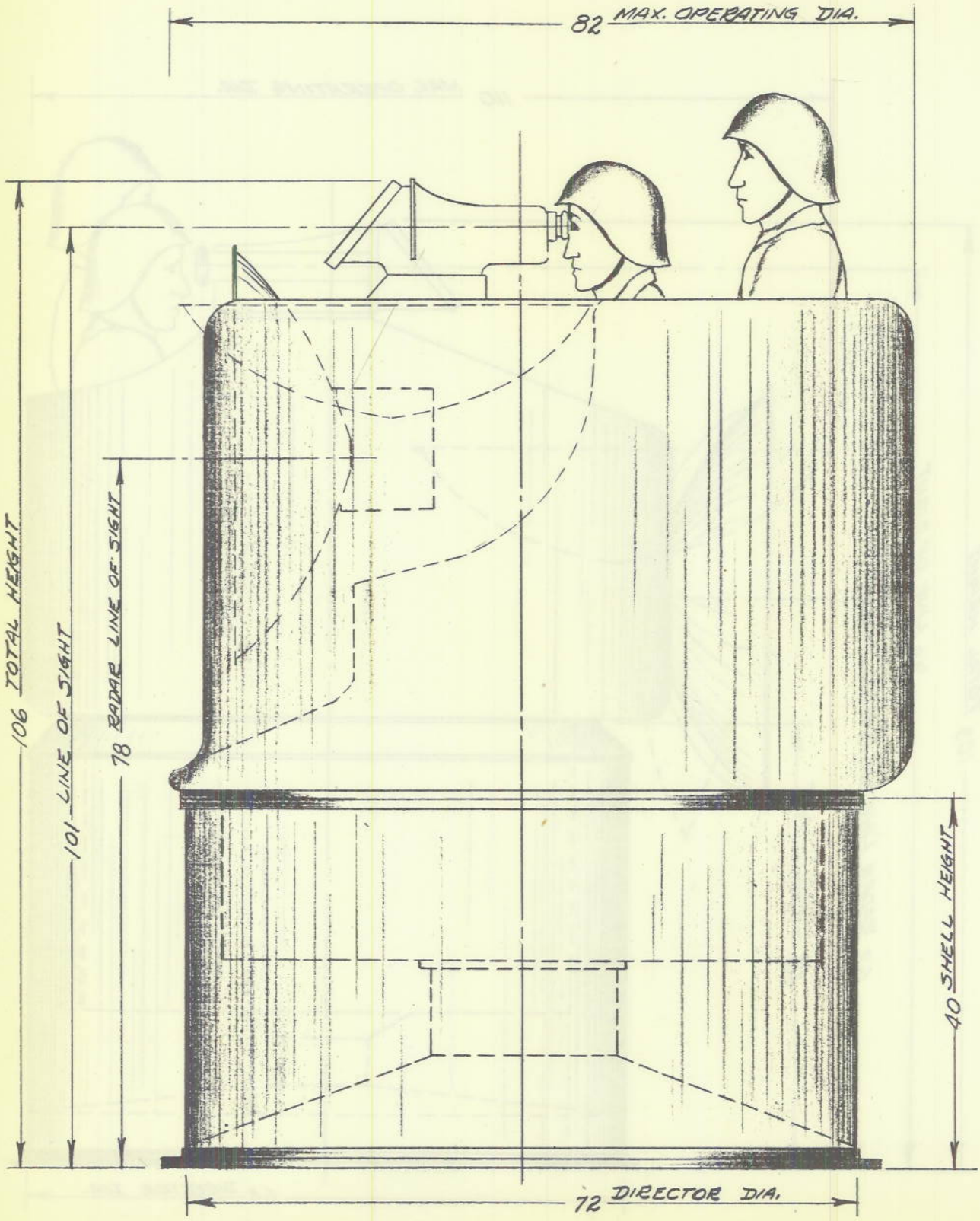


DECLASSIFIED

NORGE DESIGN #3
FEBRUARY 1944

FIG.63f

DECLASSIFIED



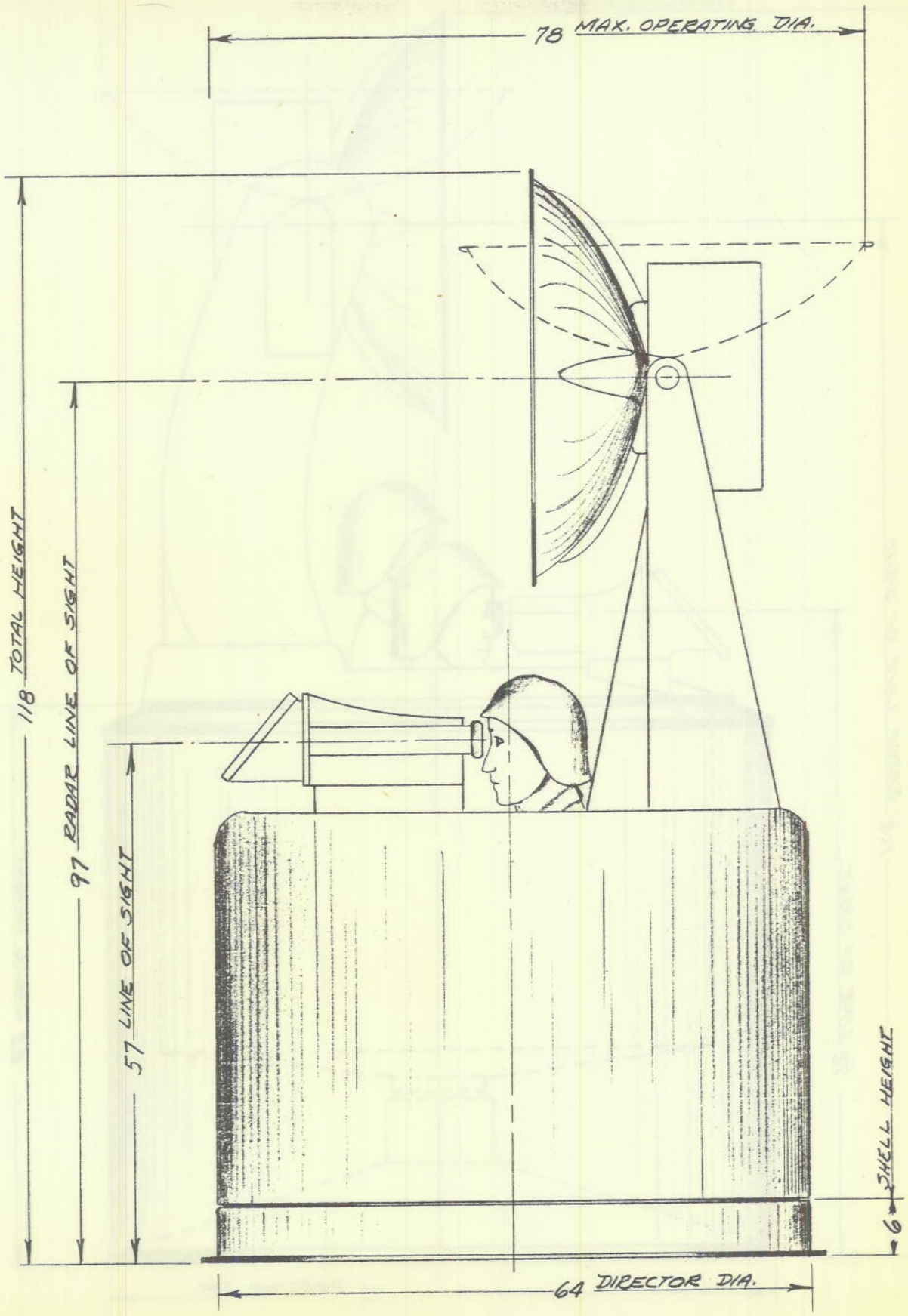
DECLASSIFIED

MODIFIED NORGE DESIGN #3

MARCH 1944

DECLASSIFIED

FIG. 63g

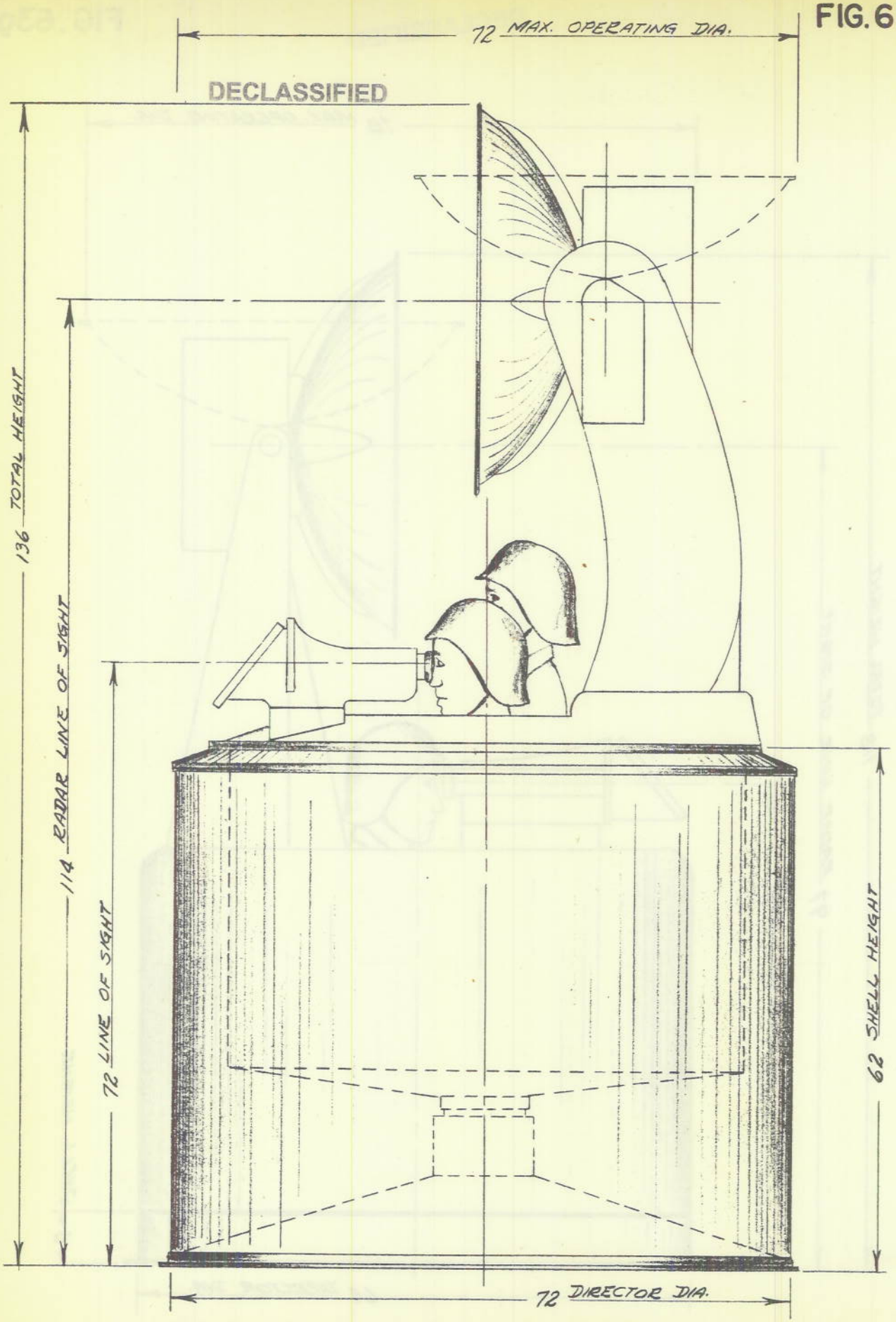


DECLASSIFIED

NORGE DESIGN #4

FEBRUARY 1944

FIG. 63h

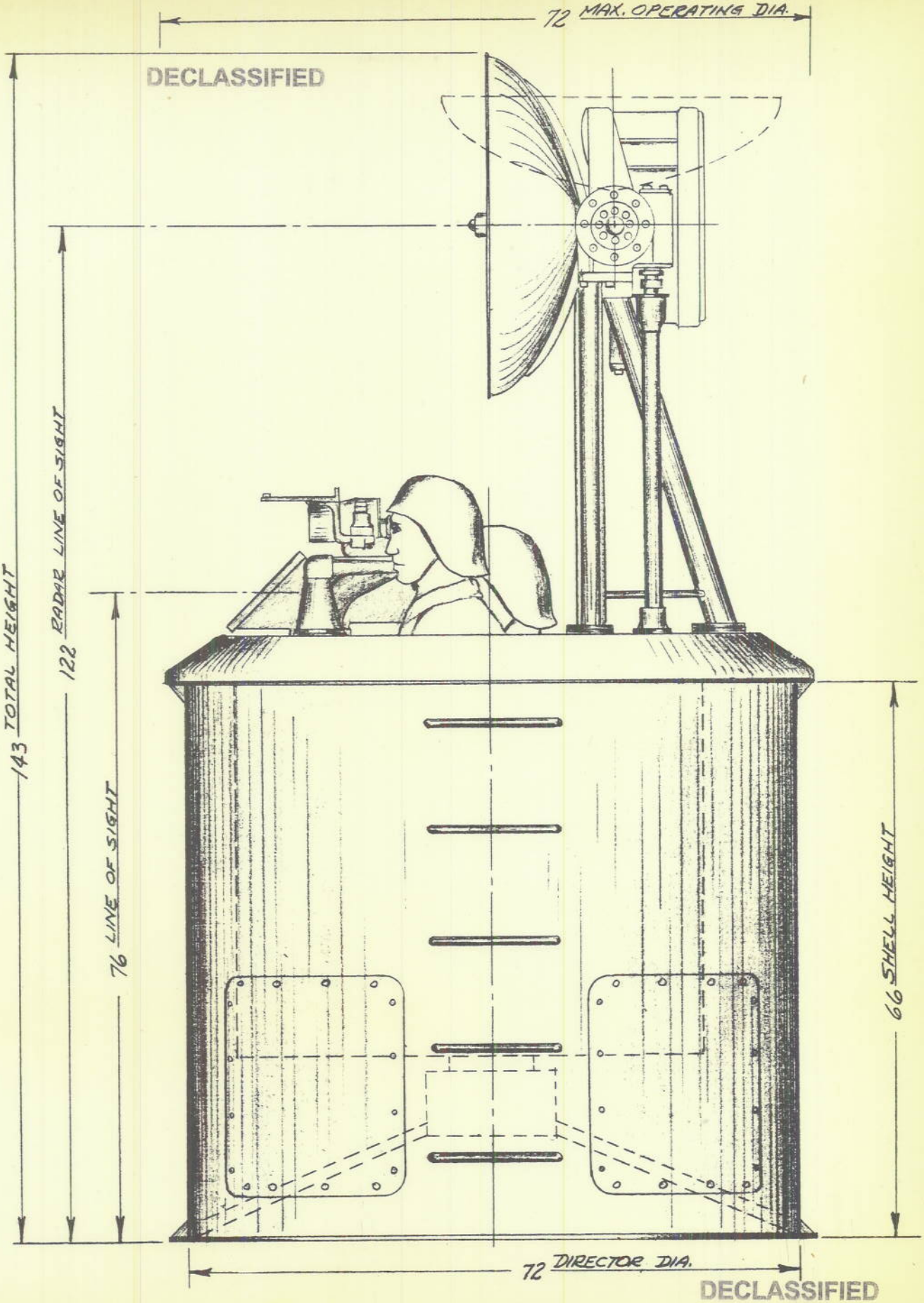


DECLASSIFIED

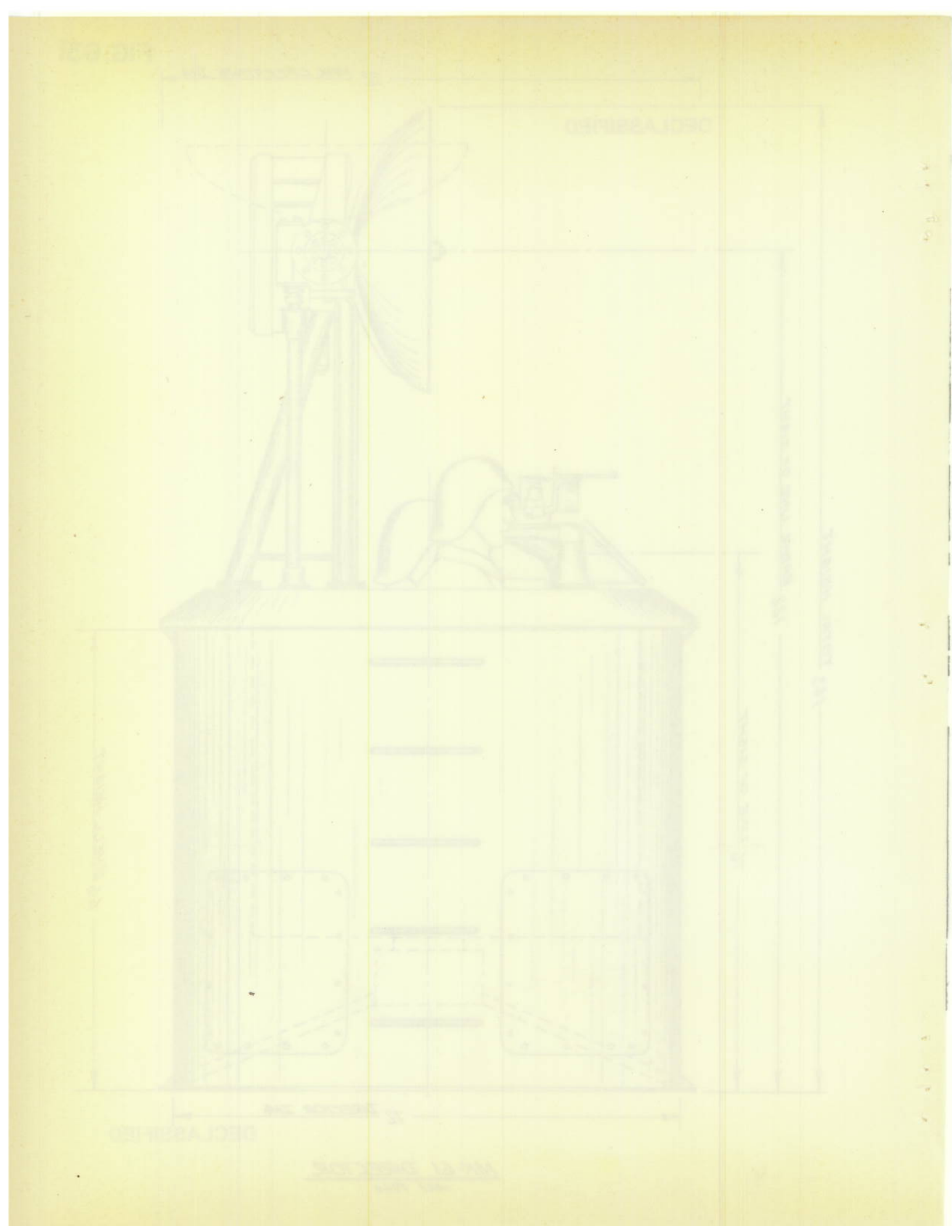
DECLASSIFIED

NORGE DESIGN #5
FEBRUARY 1944

FIG. 631



MK-61 DIRECTOR
MAY 1944



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APPENDIX B

REPORT XIII

FEBRUARY 5, 1945

AUTOMATIC RADAR TRACKING

CONTRACT OEMsr-1082

UNIVERSITY OF VIRGINIA

REPORT TO DR. M. A. TUVE, CHAIRMAN, SECTION, OSRD

This work was carried out principally by the following co-workers:

E.P. Ney
E.W. Smith
J.L. Young

Approved by: J.W.Beams
Prof. of Physics

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APPENDIX B

AUTOMATIC RADAR TRACKING

A method of automatic radar tracking has been developed using the MK. 28 Radar and MK 62 gun director.

Voltages from the train and elevation oscilloscope plates were applied to the grids of the cathode followers.

A fraction of the follower voltage is picked off the ganged potentiometers R_1R_2, and passes through a filter which reduces the effect of rapid fluctuations in plate voltages. The resultant D. C. voltages are applied to the grids of a 6SN7. The plates of this tube are connected through the potentiometer, R_3, and the two primaries of the transformer, TR-1, to the same source of 110 volt A. C. that energize the rotatable transformers in the joystick. The output of the transformer, TR , is connected through the double pole switch, SWI, to the input of the tracking amplifiers. The circuit described thus far will be referred to as the "A" channel.

The output of the tracking amplifiers (and hence the tracking rate of the turret) will then be proportional to the voltage difference between the plates of the oscilloscope. This means there will always be an error (the director will lag behind the target) proportional to the angular velocity of the line of sight.

Attempts were made to reduce this error to negligible values by increasing the gain of the electrical circuit and introducing anti-hunt devices, but so far this has not been successful.

An alternate method of eliminating the constant error was devised which involves the use of an amplifier similar to the one used in the Army M-2 director system, and a 2 phase motor with gear train. With this arrangement (shown in the accompanying drawing) the error voltage from the cathode followers is also fed into the Army amplifier and the gear train turns the balance potentiometer R_3. This system is heavily damped and cannot respond fast enough to cause hunting, but can respond to reasonable changes in the angular velocity of the line of sight. This circuit will be referred to as the "S" channel. As long as there is an error voltage, the 2-phase motor will continue to move the balance potentiometer R_3. This will unbalance the circuit so that it maintains a constant output with zero input. When a point is reached at which this output is just sufficient to maintain the proper tracking rate, the motor will stop and the turret will continue to track at the proper rate with zero error. If an error voltage develops, the "A" channel will act quickly to

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AUTOMATIC RADAR TRACKING

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bring the director back to the proper position. If the "A" channel cannot completely eliminate the error in a short time, it is because a new rate has been established and the "B" channel will respond to the error voltage, moving R_3 to a new position corresponding to the new rate.

During manual operation, large error voltages will be applied to both "A" and "B" channels, with the result that when SWI is thrown to "automatic" R_3 will usually be in a position of extreme unbalance. To avoid this, the switch SW2 is provided, which applies the output of TR_1 to the input of the "B" channel in the proper phase to cause R_3 to move to a position which gives zero output from TR_1. SWI and SW2 are operated together so that when changing to automatic, R3 will be in approximately the right position to start tracking smoothly.

At the conclusion of the experiments, MK 62 director was tracking automatically from a table having a $\pm$ 15°, 20 second roll and a $\pm$ 5°, 7.5 second pitch with an average error of between 3 and 4 mils.

E. P. Ney
W. W. Smith
J. L. Young

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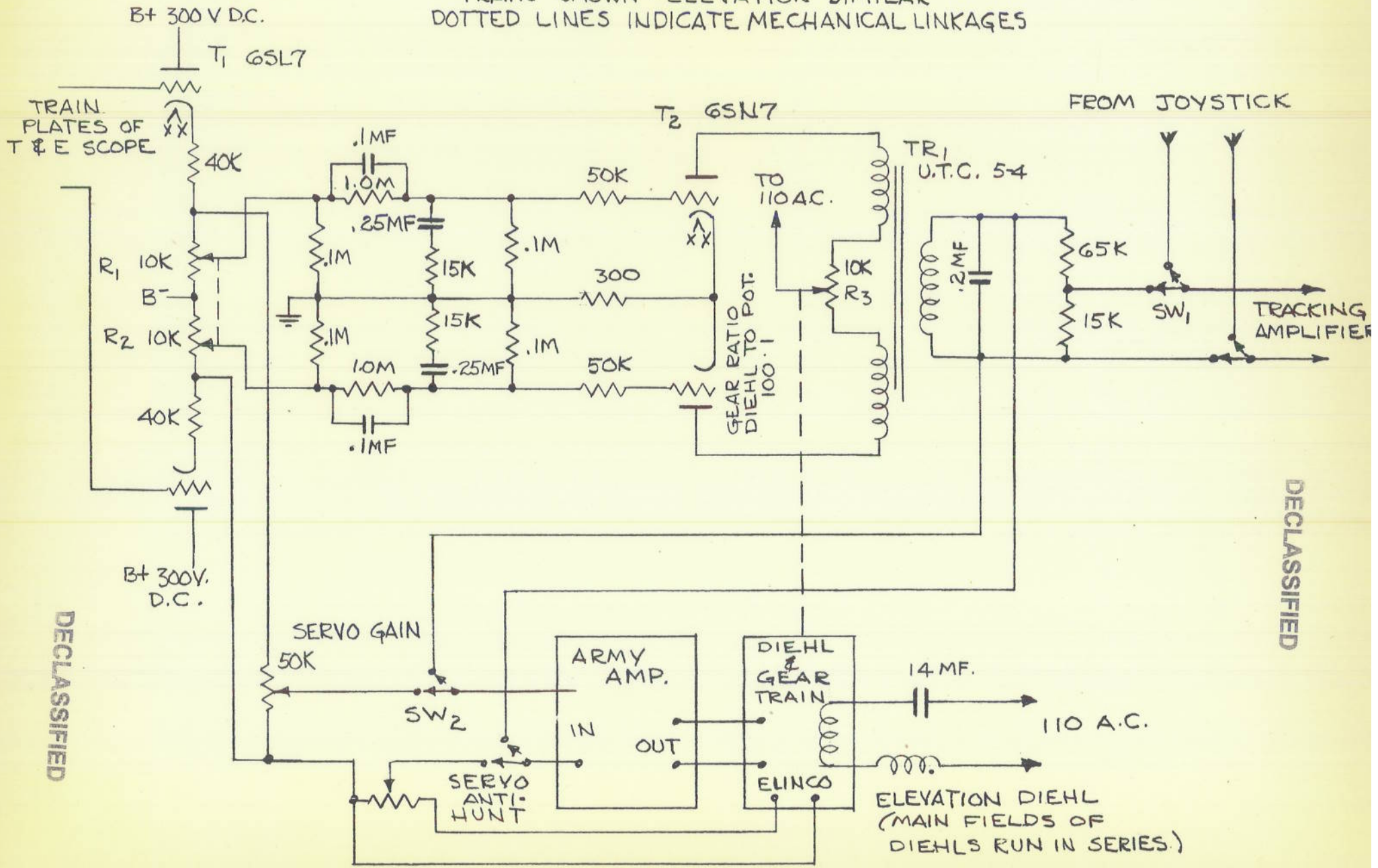
AUTOMATIC TRACKING CIRCUIT

TRAIN SHOWN - ELEVATION SIMILAR
DOTTED LINES INDICATE MECHANICAL LINKAGES



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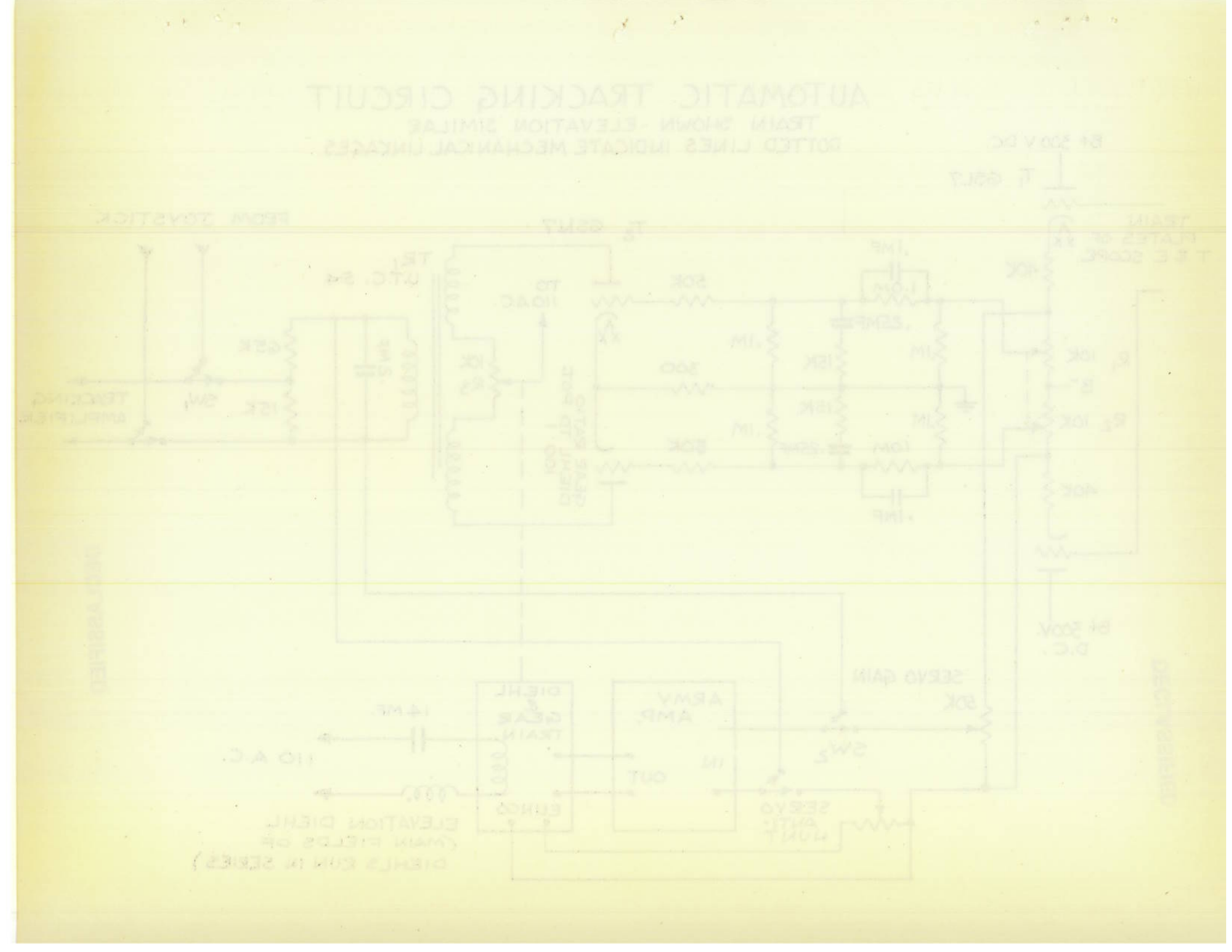

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AUTOMATIC TRACKING WITH THE MARK 61 DIRECTOR

The automatic tracking circuit previously described* has been applied to the Mark 61 gun director. Better results were obtained than with the Mark 62.

Data were taken as before on various courses. All of the data taken have been reproduced in Table I. Data were taken with both the Mark 28 radar and the Mark 29 radar and with slow and fast rolls as indicated. Some manual radar data are included for comparison.

TABLE I

Roll** Amp.	Period	Type of Tracking	Course	Range Yds.	Dispersion in gun mils	Radar
± 15°	20 sec.	Automatic	20° crossing	4250-1450	1.5 ✓	Mk 28
± 15°	20 sec.	"	20° "	4200-1400	1.9 ✓	Mk 28
± 15°	20 sec.	"	20° "	3500-1350	1.4 ✓	Mk 28
± 15°	20 sec.	"	20° "	4250-1600	1.7 ✓	Mk 28
± 15°	18 sec.	"	Perpendicular	3000	1.3 ✓	Mk 28
± 15°	18 sec.	"	"	3000	1.4 ✓	Mk 28
± 15°	18 sec.	"	"	3000	1.4 ✓	Mk 28
± 15°	12 sec.	"	20° crossing	4150-1400	1.2 ✓	Mk 28
± 15°	12 sec.	"	20° "	3950-1350	1.6 ✓	Mk 28
		Ave. Automatic			1.5 ✓	Mk 28
± 15°	18 sec.	Manual	20° "	4300-1500	3.6 ✓	Mk 28
± 15°	18 sec.	"	20° "	3600-2800	3.5 ✓	Mk 28
± 15°	18 sec.	"	Perpendicular	3000	3.0 ✓	Mk 28
± 15°	20 sec.	Automatic	20° crossing	4400-1500	1.1 ✓	Mk 29
± 15°	20 sec.	"	20° "	4450-1500	1.0 ✓	Mk 29
± 15°	20 sec.	"	20° "	4850-3900	1.0 ✓	Mk 29
± 15°	20 sec.	"	20° "	7350-6450	1.0 ✓	Mk 29
± 15°	20 sec.	"	20° "	7400-6300	1.1 ✓	Mk 29
		" Average			1.0 ✓	Mk 29

* Automatic Radar Tracking E. P. Ney; E. W. Smith; J. L. Young

** The pitch was constant in all runs ± 5°; 7-1/2 sec. period.

It was found that the system would track with zero velocity error up to rates of 16 degrees a second. In many experiments the system tracked planes circling overhead at elevation angles of from 80 to 85° with negligible error. In this case the train rate is about 16° per second. The automatic tracking circuit will hold the director on the target as long as there is a target indication on the range scope. Several planes were tracked out to 18,000 yards.

A complete drawing of the circuit as used on the Mark 61 director is included. (Fig. 1)

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AUTOMATIC TRACKING WITH THE MARK 61 DIRECTOR

The automatic tracking circuit previously described has been applied to the Mark 61 gun director. Better results were obtained than with the Mark 62.

Data were taken as before on various courses. All of the data taken have been reproduced in Table I. Data were taken with both the Mark 28 radar and the Mark 29 radar and with slow and fast rolls as indicated. Some manual radar data are included for comparison.

TABLE I

Amp.	Period	Type of Tracking	Course	Range Yds.	Diaper-sion in mils	Radar
± 15°	20 sec.	Automatic	20° crossing	4650-1450	1.5	Mk 28
± 15°	20 sec.	"	20° "	4600-1400	1.3	Mk 28
± 15°	20 sec.	"	20° "	3800-1350	1.4	Mk 28
± 15°	20 sec.	"	20° "	4650-1600	1.7	Mk 28
± 15°	18 sec.	"	Perpendicular	3000	1.3	Mk 28
± 15°	18 sec.	"	"	3000	1.4	Mk 28
± 15°	18 sec.	"	"	3000	1.4	Mk 28
± 15°	12 sec.	"	20° crossing	4150-1400	1.2	Mk 28
± 15°	12 sec.	"	20° "	3950-1350	1.6	Mk 28
Ave. Automatic					1.5	Mk 28
± 15°	15 sec.	Manual	20° "	4300-1500	3.6	Mk 28
± 15°	18 sec.	"	20° "	3000-2800	3.8	Mk 28
± 15°	18 sec.	"	Perpendicular	3000	3.0	Mk 28
± 15°	20 sec.	Automatic	20° crossing	4400-1500	1.1	Mk 29
± 15°	20 sec.	"	20° "	4650-1500	1.0	Mk 29
± 15°	20 sec.	"	20° "	4850-3900	1.0	Mk 29
± 15°	20 sec.	"	20° "	7350-6450	1.0	Mk 29
± 15°	20 sec.	"	20° "	7400-6500	1.1	Mk 29
Average					1.0	Mk 29

* Automatic Radar Tracking E. F. Key; E. W. Smith; L. L. Young

** The pitch was constant in all runs ± 5°; 7-1/2 sec. period.

It was found that the system would track with zero velocity error up to rates of 16 degrees a second. In many experiments the system tracked planes circling overhead at elevation angles of from 80 to 85° with negligible error. In this case the train rate is about 160° per second. The automatic tracking circuit will hold the director on the target as long as there is a target indication on the range scope. Several planes were tracked out to 18,000 yards.

A complete drawing of the circuit as used on the Mark 61 director is included. (Fig. 1)

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Circuit Constants for Figure 1

R_1 = 40 K ohms	R_{36} = 10 K	C_1 = .1 mf
R_2 = 10 K	R_{37} = 100 K	C_2 = .1 mf
R_3 = 40 K	R_{38} = 360	C_3 = .25 mf
R_4 = 10 K	R_{39} = 100 K	C_4 = .25 mf
R_5 = 25 K	R_{40} = 1500	C_5 = .03 mf
R_6 = 1 meg	R_{41} = 40 K	C_6 = .15 mf
R_7 = 1 meg	R_{42} = 10 K	C_7 = 8 mf
R_8 = 100 K	R_{43} = 40 K	C_8 = 8 mf
R_9 = 100 K	R_{44} = 10 K	C_9 = .05 mf
R_{10} = 75 K	R_{45} = 10 K	C_{10} = .05 mf
R_{11} = 250	R_{46} = 25 K	C_{11} = 14 mf
R_{12} = 75 K	R_{47} = 25 K	C_{12} = .03 mf
R_{13} = 10 K	R_{48} = 1 meg	C_{13} = .15 mf
R_{14} = 20 K	R_{49} = 1 meg	C_{14} = .1 mf
R_{15} = 100 K	R_{50} = 100 K	C_{15} = .1 mf
R_{16} = 100 K	R_{51} = 100 K	C_{16} = .25 mf
R_{17} = 20 K	R_{52} = 75 K	C_{17} = .25 mf
R_{18} = 250	R_{53} = 250	C_{18} = .25 mf
R_{19} = 20 K	R_{54} = 75 K	C_{19} = .25 mf
R_{20} = 10 K	R_{55} = 10 K	V_1 = 6SL7
R_{21} = 100 K	R_{56} = 1500	V_2 = 6SN7
R_{22} = 360	TR_1 = Interstage	V_3 = 6SC7
R_{23} = 100 K	TR_2 = "	V_4 = 6N7
R_{24} = 10K	TR_3 = "	V_5 = 6N7
R_{25} = 30 K	TR_4 = Output	V_6 = 5Z3

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Circuit Constants for Figure 1

R_1 = 40 K ohms	R_{36} = 10 K	C_1 = .1 mf
R_2 = 10 K	R_{37} = 100 K	C_2 = .1 mf
R_3 = 40 K	R_{38} = 560	C_3 = .25 mf
R_4 = 10 K	R_{39} = 100 K	C_4 = .25 mf
R_5 = 25 K	R_{40} = 1500	C_5 = .05 mf
R_6 = 1 meg	R_{41} = 40 K	C_6 = .15 mf
R_7 = 1 meg	R_{42} = 10 K	C_7 = 8 mf
R_8 = 100 K	R_{43} = 40 K	C_8 = 8 mf
R_9 = 100 K	R_{44} = 10 K	C_9 = .05 mf
R_{10} = 75 K	R_{45} = 10 K	C_{10} = .05 mf
R_{11} = 250	R_{46} = 25 K	C_{11} = .14 mf
R_{12} = 75 K	R_{47} = 25 K	C_{12} = .05 mf
R_{13} = 10 K	R_{48} = 1 meg	C_{13} = .15 mf
R_{14} = 20 K	R_{49} = 1 meg	C_{14} = .1 mf
R_{15} = 100 K	R_{50} = 500 K	C_{15} = .1 mf
R_{16} = 100 K	R_{51} = 100 K	C_{16} = .25 mf
R_{17} = 20 K	R_{52} = 75 K	C_{17} = .25 mf
R_{18} = 250	R_{53} = 250	C_{18} = .25 mf
R_{19} = 20 K	R_{54} = 75 K	C_{19} = .25 mf
R_{20} = 10 K	R_{55} = 10 K	V_1 = 6SL7
R_{21} = 100 K	R_{56} = 1500	V_2 = 6SN7
R_{22} = 560	TR_1 = Interstage	V_3 = 6SC7
R_{23} = 100 K	TR_2 = "	V_4 = 6BY7
R_{24} = 10K	TR_3 = "	V_5 = 6BY7
R_{25} = 20 K	TR_4 = Output	V_6 = 5Z3

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Circuit Constants for Fig. 1 (cont'd.)

R_{26} = 30 K
R_{27} = 200
R_{28} = 5 K
R_{29} = 5 K
R_{30} = 20 K
R_{31} = 100 K
R_{32} = 100 K
R_{33} = 20 K
R_{34} = 250
R_{35} = 20 K

TR_5 = Power
TR_6 = Choke
TR_7 = Power
TR_8 = Interstage
TR_9 = "
TR_{10} = Power
TR_{11} = Interstage

V_7 = 5V4G
V_8 = 6SC7
V_9 = 6N7
V_{10} = 6N7
V_{11} = 6SL7
V_{12} = 6SN7

E. W. Smith

E. P. Ney

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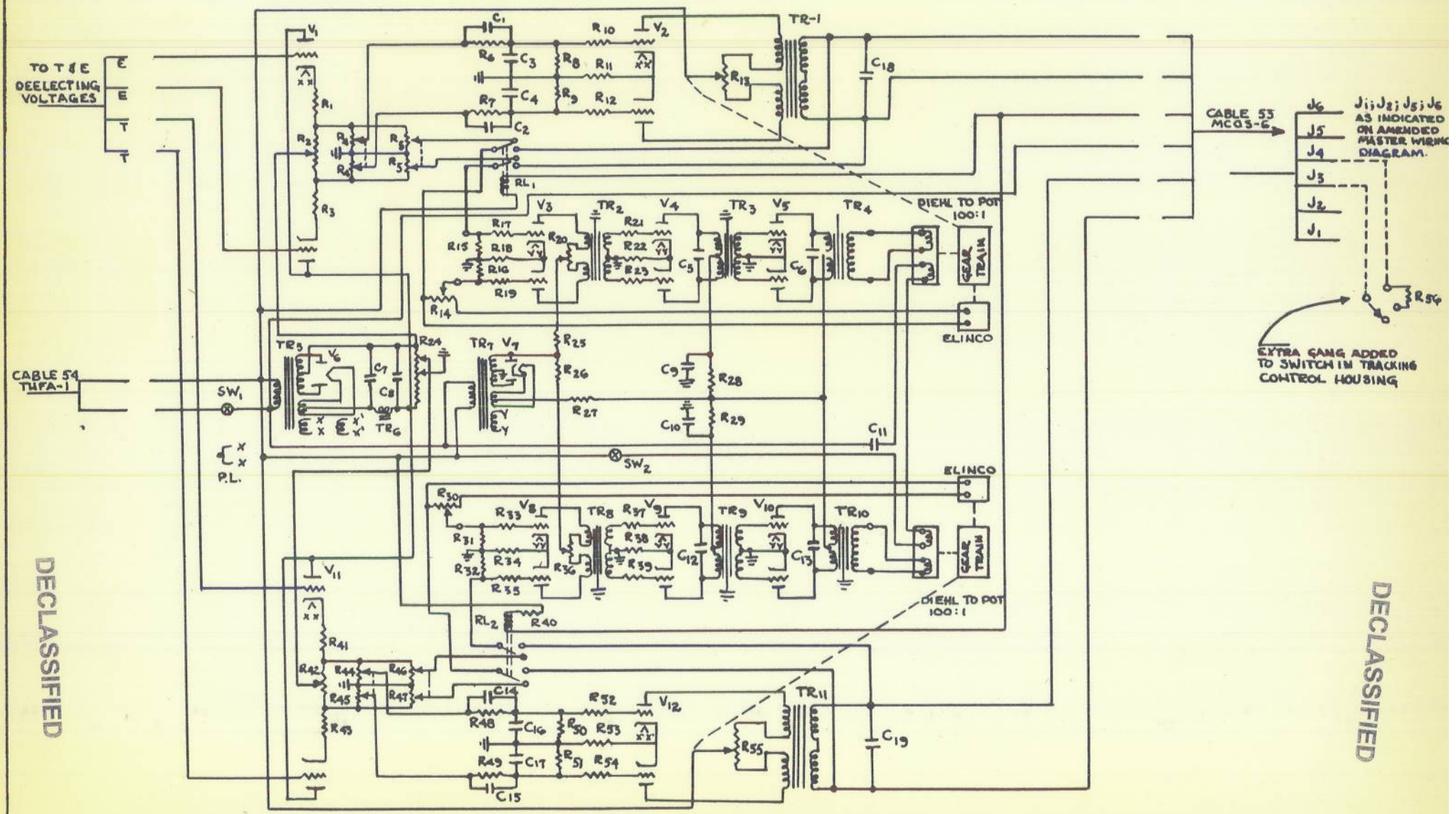
AUTOMATIC TRACKING CIRCUIT



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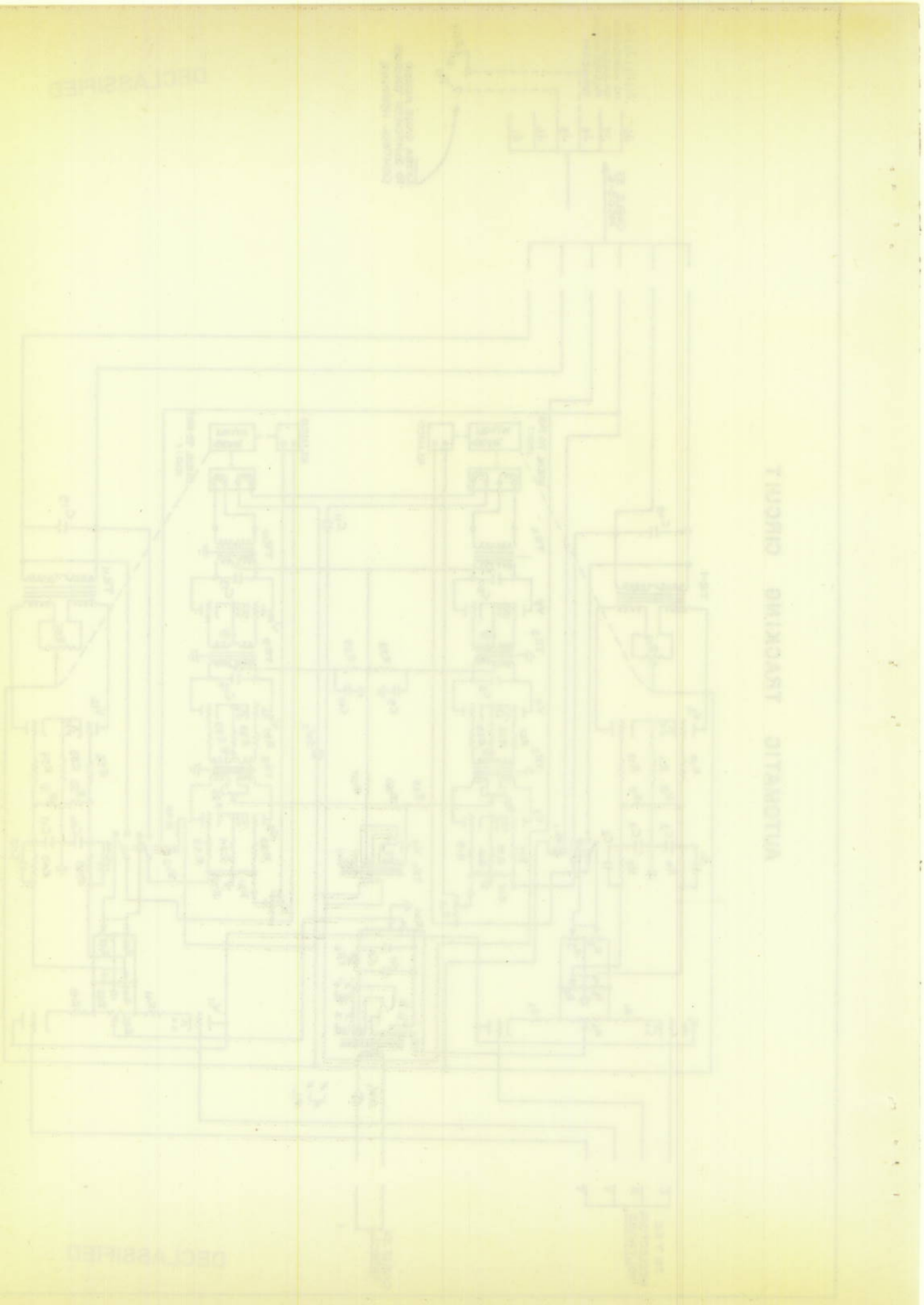

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APPENDIX C

JHU-APL/TM-1592
Copy No. 22 Extra
April 16, 1945

To: R. Zaborowski

From: C. M. Antoni

Subject: Vibration Test of Mark 61 Turret

Abstract:

1. Included in this report are the results of a vibration study made on the JHU vibration table of the Mark 61 Turret. Failures and resonances during the test are noted, particular emphasis being placed on the upper structure. The results of a static test to determine the natural frequency of this upper structure are also appended.

Conclusions:

2. An apparent resonance of the upper structure or tripod developed at 15 cps in the 0°, 90°, and 180° positions. (0° and 180° are with axis of nutation parallel to longitudinal axis of table. 90° position is at right angles to these two.) From a consideration of curves of amplitude of vibration of the structure thru various frequencies (Figs. 2, 3, 4) from the natural freq uency of this part of the turret determined in a static deflection test (Fig. 5) and from a consideration of the flexure due to resonance of the vibrating table because of the large mass of the turret, this apparent resonance at 0° and 180° is accounted for by flexture in the table. For the 90° position, the results are not clear.

3. As a unit, the Mk 61 turret withstood the test exceptionally well with no serious resonances or failures noted. It was vibrated thru a range of frequencies from 400 cpm to 2000 for a period of 9½ hours.

Resonances Noted:

4. The pump mounting resonated laterally at 7-8 cps with interference with the supporting structure. A vertical resonance was noted at 17 cps.

5. The computer and stabilizer showed a vertical resonance at 21-23 cps with an amplification of approximately 3.6 times.

6. The small oil lines resonated at from 30 to 35 cps.

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7. Manual drive rods resonated at 31 cps.

8. Various resonances of the T.R. box on its shock mounts were noted. These mounts had been changed at the start of the test from Barry C-2045 to C-2080. A horizontal resonance occurred at 20 cps. A rotational resonance was noted at 22 cps.

Failures:

9. One manual drive rod came loose.

10. The intermediate wave receiver in the T.R. box stripped its holding screws and came loose, tearing off the wave guide at its entrance to the T.R. box. When repaired with steel screws, no further trouble was encountered.

11. The worm o f the radar elevation drive developed and play due to the prolonged vibration, causing jitter in later operation. The end bearing was replaced and trouble was corrected There was no damage to worm or worm gear.

Recommendations:

12. More clearance should be allowed for lateral movement of the air pump support.

13. Removal of the T.R. box from the rotating part of the upper structure as planned. It is felt that this change will resolve the resonance at 90° by supplying a positive tie between the two tripods.

C. M. Antoni

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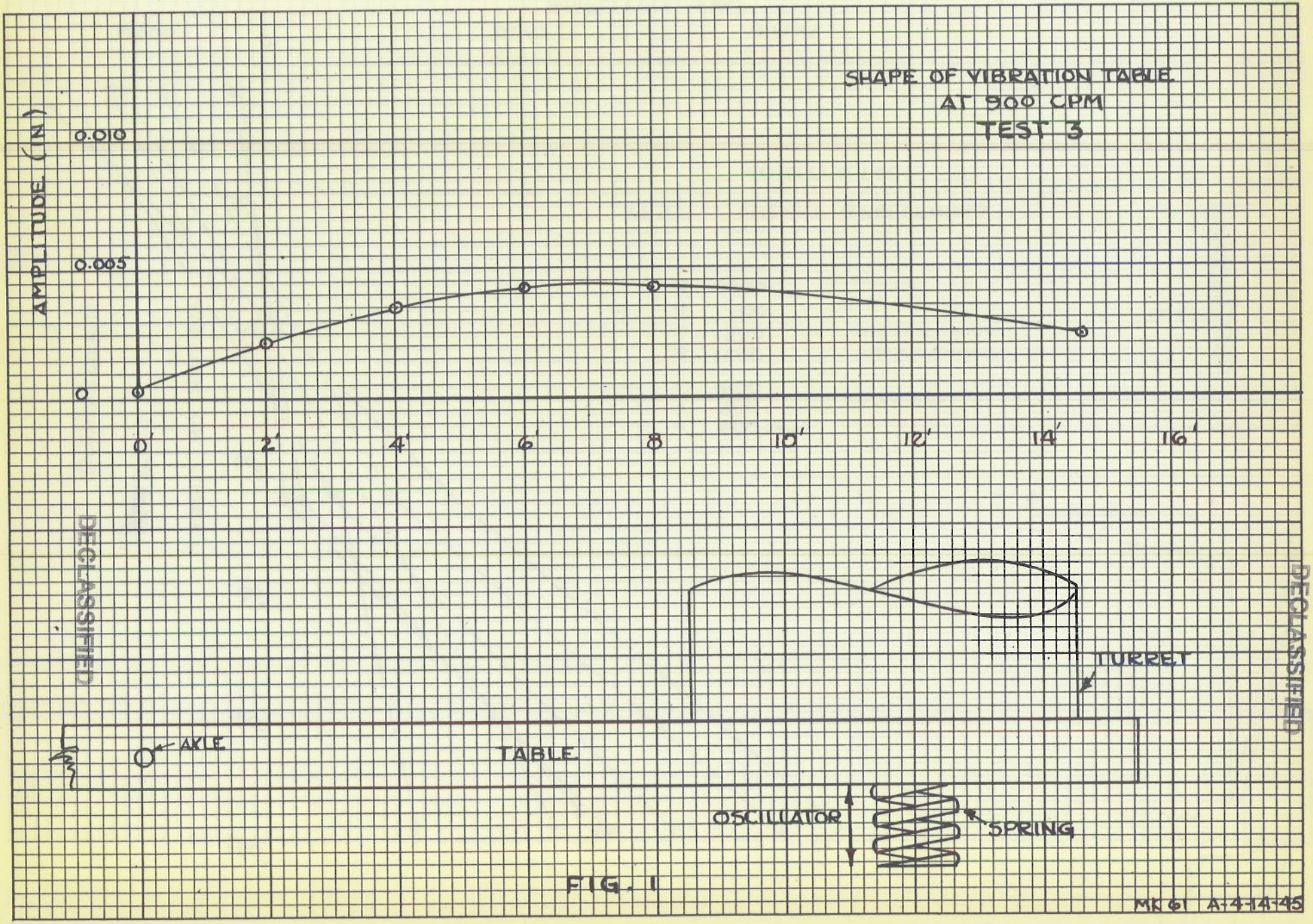

FIG. 1

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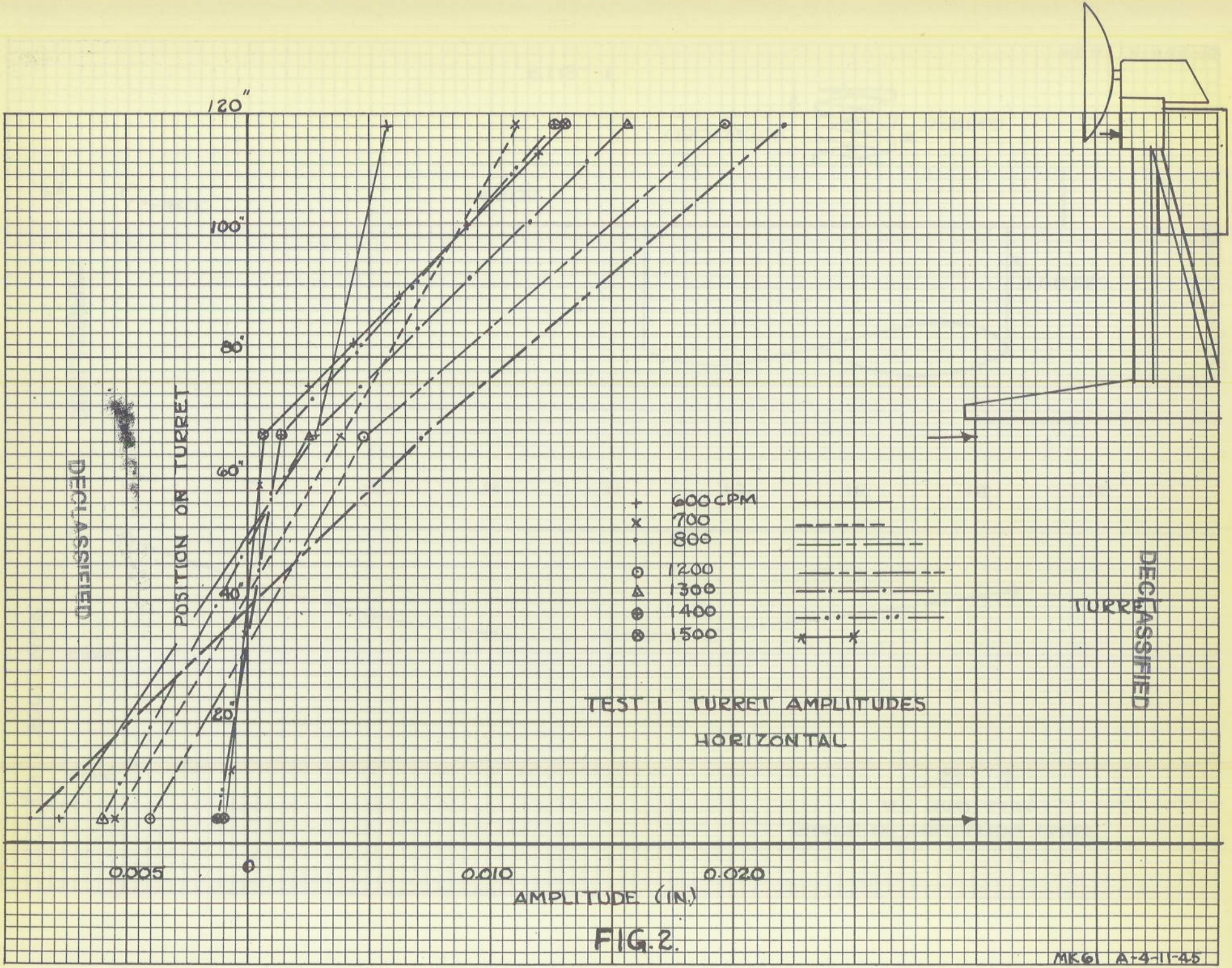
120"
100"
80"
60"
40"
20"
0
POSITION ON TURRET
0.005
0.010
0.020
AMPLITUDE (IN.)
600 CPM
700
800
1200
1300
1400
1500
TEST I TURRET AMPLITUDES
HORIZONTAL
TURRET
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DECLASSIFIED
MK61 A-4-11-45

FIG. 2.

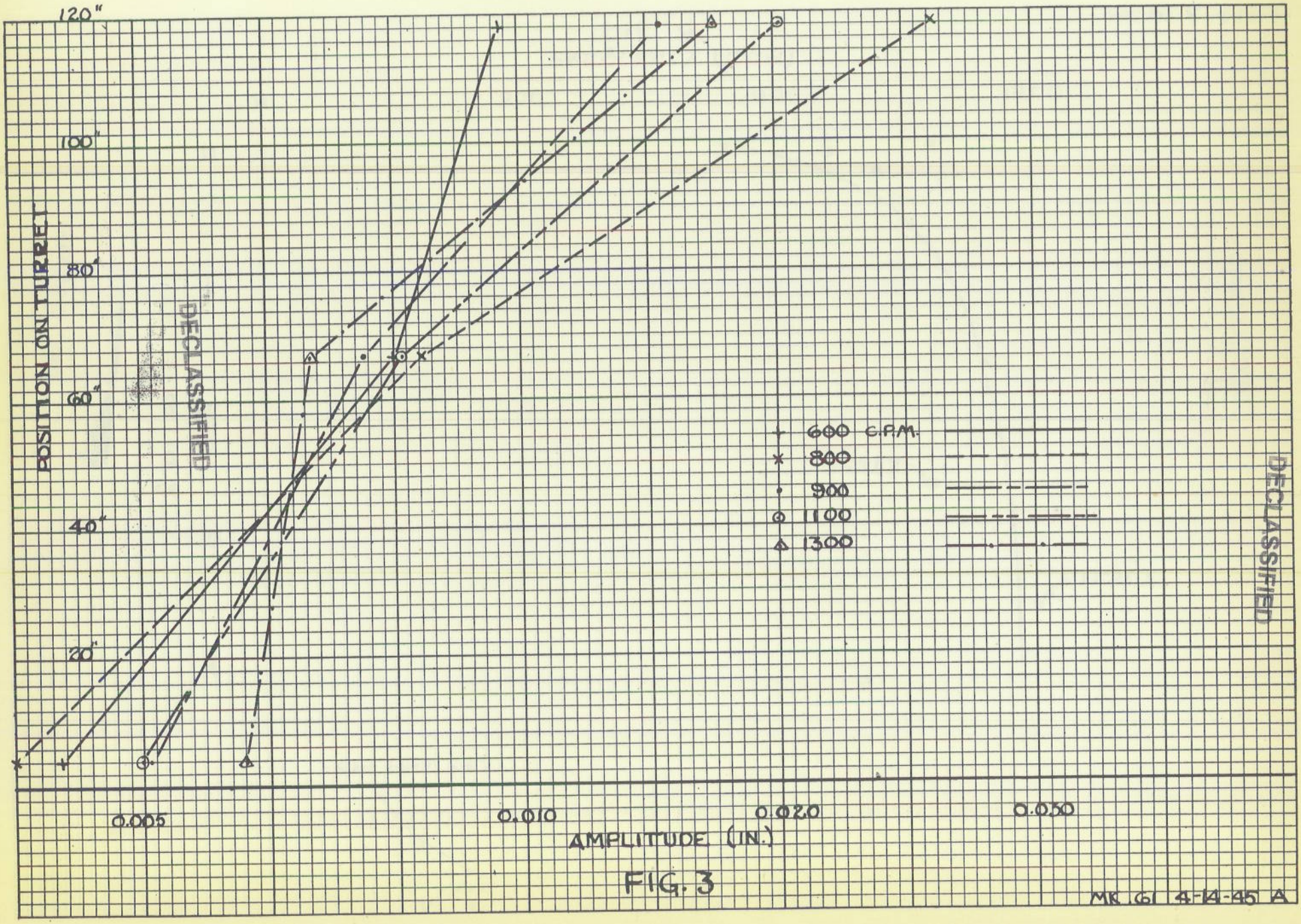

FIG. 3

MR 61 4-14-45 A

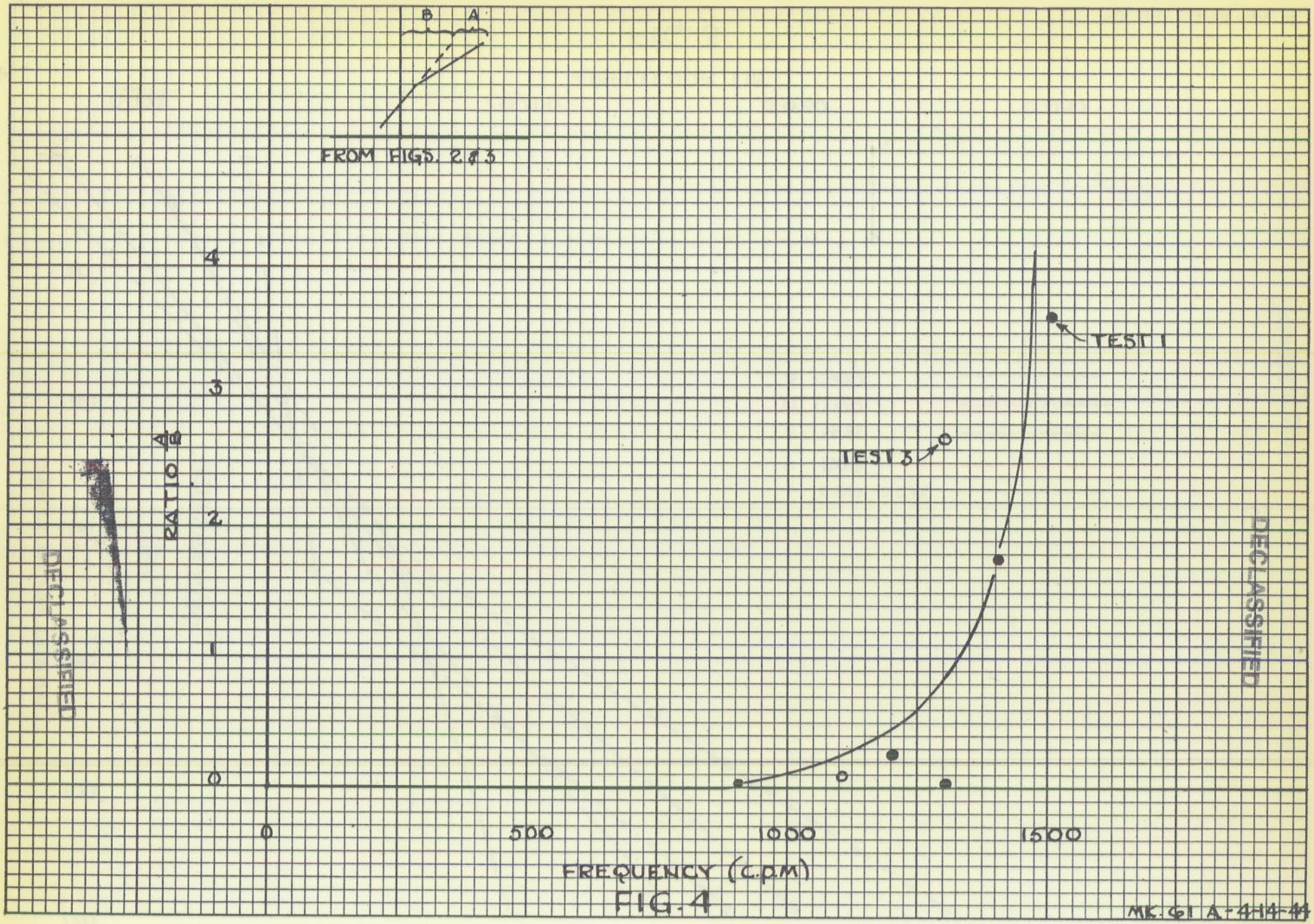

FIG. 4

MK. 61 A-4-14-44

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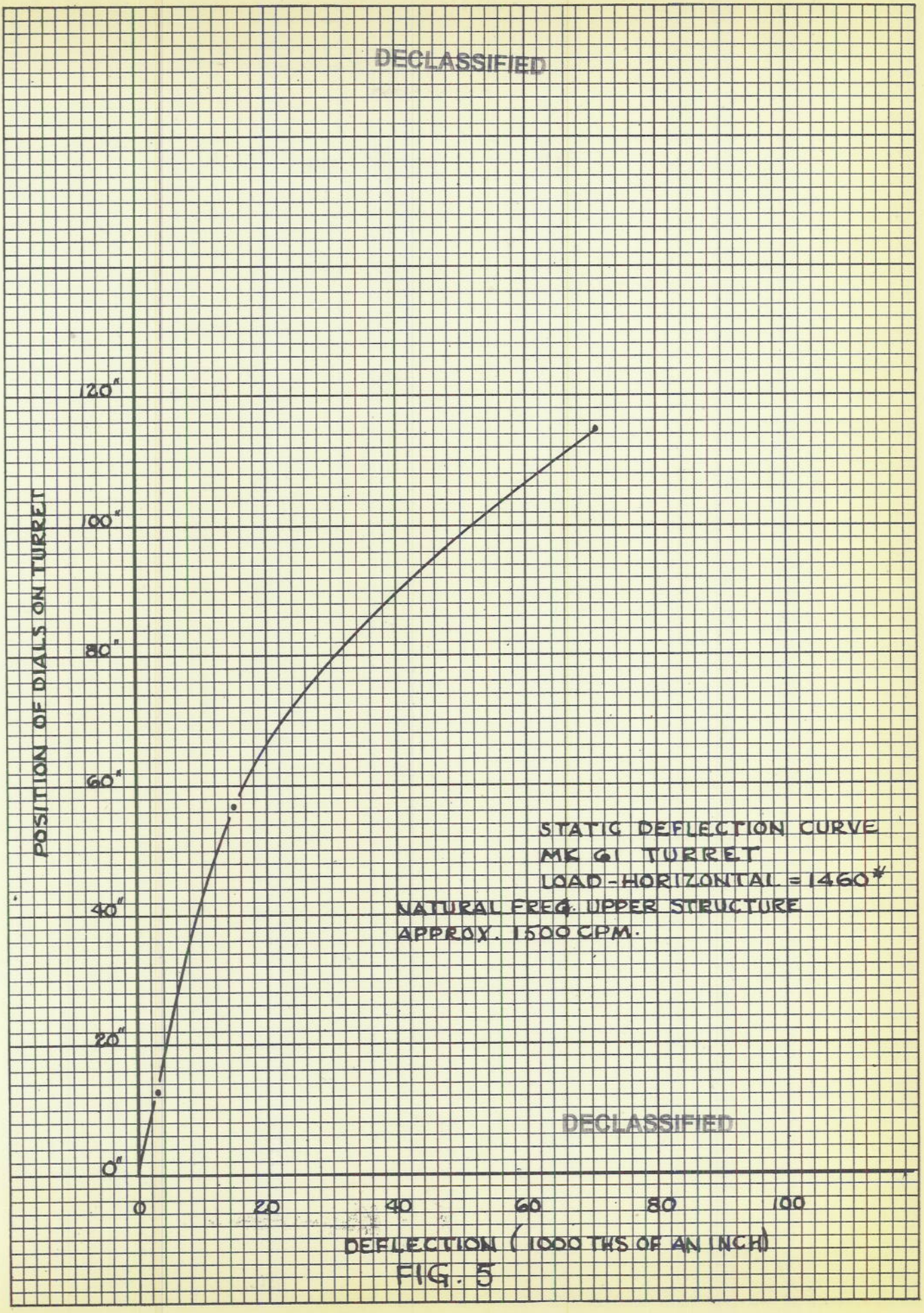

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FIG. 5

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APPENDIX C

NAVAL RESEARCH LABORATORY

WASHINGTON 20, D. C.

To: The Chief of the Bureau of Ordnance
Attn: Re4c, Re4f

Subj: Fire Control - Gun Director Mk 61 Mod 0. Fire Control Section Interim Report on Problem O-143T-C; Preliminary Comment on Results of Vibration Test.

Ref: (a) Johns Hopkins University conf report JHU-APL/TM 1215, "Vibration Tests of the Mk 57 Stand", dated 25 January 1945.

(b) NRL conf ltr C-S71-3(395B) to BuOrd, "Vibration Tests of Gun Director Mk 57 Stand", dated about 5 April 1945.

(c) BuShips NAVSHIPS (917-930D) RE 9284B, "Inclination, Shock and Vibration Test Specifications", dated 1 August 1944.

Abstract

1. The present report is a very preliminary discussion. With one serious exception that will require some modification, the subject gun director performed well.

Discussion

2. The Gun Director Mk 61 Mod 0 was subjected to a vibration test at the Applied Physics Laboratory of Johns Hopkins University on 27, 28, and 29 March 1945. Personnel from this Laboratory witnessed the tests and co-operated with APL Engineers in planning the procedure of the test. A report will be forwarded by APL to the Bureau of Ordnance after the data are analyzed, and this Laboratory will write a letter of commentary on the APL report.

3. There are no test facilities available for vibrating equipment of this weight (5800 pounds for the subject director) at the amplitudes specified in reference (c), nor for tilting the director during vibration. However, the full frequency range of 5 to over 33 cycles per second was explored, and the amplitudes measured at the deck were on the order of half the amplitudes specified in reference (c) (0.024 in. from 5 to 23 cps and 0.003 in. from 23 to 33 cps are specified). The equipment was vibrated for a total of about 15 hours.

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APPENDIX C

NAVAL RESEARCH LABORATORY

WASHINGTON 20, D. C.

To: The Chief of the Bureau of Ordnance
Attn: Code, Re4f

Subj: Fire Control - Gun Director Mk 61 Mod 0. Fire Control System Interim Report on Problem C-1437-C.
Preliminary Comment on Results of Vibration Test.

Ref: (a) Johns Hopkins University conf report JHU-APL/TM 1215, "Vibration Tests of the Mk 57 Stand", dated 25 January 1965.

(b) NRL conf ltr C-371-35(39GB) to BuOrd, "Vibration Tests of Gun Director Mk 57 Stand", dated about 5 April 1965.

(c) BuShips NAVSHIPS (917-0300) RE 92G4B, "Installation, Shock and Vibration Test Specifications", dated 1 August 1964.

Abstract

1. The present report is a very preliminary discussion. With one serious exception there will require some modification, the subject gun director performed well.

Discussion

2. The Gun Director Mk 61 Mod 0 was subjected to a vibration test at the Applied Physics Laboratory of Johns Hopkins University on 27, 28, and 29 March 1965. Personnel from this Laboratory witnessed the tests and co-operated with APL Engineers in planning the procedure of the test. A report will be forwarded by APL to the Bureau of Ordnance after the data are analyzed, and this Laboratory will write a letter of commentary on the APL report.

3. There are no test facilities available for vibrating equipment of this weight (3600 pounds for the subject director) at the amplitudes specified in reference (c), nor for tilting the director during vibration. However, the full frequency range of 5 to over 55 cycles per second was explored, and the amplitudes measured at the deck were on the order of half the amplitudes specified in reference (c) (0.024 in. from 5 to 25 cps and 0.003 in. from 25 to 55 cps are specified). The equipment was vibrated for a total of about 30 hours.

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4. The Computer Mk 16 and Radar Mk 29 Mod 2 below-decks units were electrically connected to the director for observation but were not vibrated. There was no appreciable jitter in the dials of the Computer Mk 16 resulting from vibration of the director.

5. Damages. At this writing checks have not been completed on the alignment of the optics and of the radar, nor of the Computer Mk 17. The only damages observed immediately during the tests were as follows:

(a) The screws holding the receiver unit in the radar transmitter-receiver box sheared, and the wave-guide was broken as a result. This occurred on the second day of test during the resonance of the antenna supporting structure of the director between about 15 and 18 cps.

(b) A shaft came loose in the manual control mechanism running between the mountings above the servos. This damage was trivial. The Ford couplings simply unlocked because of temporary lack of proper spacing springs.

(c) The solenoid actuating the radar high-voltage cut-off came apart, but was operating successfully after repair.

(d) At some frequencies the hydraulic lines vibrated strongly, and should be secured. However, no damage was observed.

6. Resonances. A serious resonant condition prevailed in the antenna supporting structure during tests at frequencies of 15 to 18 cps. There is a possibility that an appreciable portion of the motion might have resulted from flexing of the vibration table. However, visual observations showed that at about 16 cps the antenna supporting structure vibrated with lateral excursions estimated at ± 0.080 inch, whereas the excursions of the main structure of the director were much smaller, and were moderately uniform from the turntable down to the base. It is to be noted that no thrust is provided by the right-hand trunnion bearing, so that for vibrations along the trunnion axis, no stiffness is realized from the right-hand support. At about 17 cps there was a torsional vibration of the elevation shaft for the radar antenna. This undoubtedly resulted because the center of gravity of rotating units was about six inches below the trunnions, the bracket having been originally designed for the Radar Mk 28. This latter mode of vibration could be corrected by some alteration of the bracket. However, it is considered that this resonance should be ignored as such, and the entire transmitter-receiver unit moved from the trunnions to a mounting position at the base of the present supporting pipes.

7. The above considerations are simply a first estimate. The part played by flexing of the table is possibly exaggerating the trunnion motion in the spectrum of 15 to 18 cps may be

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clarified when a detailed anaylsis is available for the vibration amplitude measurements made at numerous points along the table and over the entire director. In addition a check can be made of the fundamental resonance to be expected for the antenna supporting structure. With this in view, a deflection vs. load characteristic was taken by means of a block and chain, with Ames dials measuring the displacement of the trunnion bearings relative to the base of the antenna support structure.

8. The two air compressor units on their common shock mounting structure have a lateral vibration resonance in the low frequency range, and a vertical resonance in the middle frequency range. It is possible for a lateral motion of these units to result in collision with an adjacent structure. Although it is understood that the vibration from these pumps has a deleterious effect on the Computer Mk 17, it is desirable that additional efforts be made to premit stiffening these shock mountings. There was no damage to these units during the sustained vibration of this test.

Conclusions

9. First observations of this director have led to a tentative conclusion that the general mechanical design is very good, that with one major exception the unit stands up very well under vibration, and that the components are arranged well for accessibility.

Recommendations

10. (a) The transmitter-receiver unit should be removed from the trunnions and placed at the base of the antenna support structure.

(b) Since it is not likely that (a) above will sufficiently raise the resonant frequency of the structure, consideration should be given to additional structural members connecting the present supporting pipes. It might be desirable to make a small sacrifice in side visibility in order to attach additional struts to the director just left of the control officer and just right of the pointer-trainer.

(c) Shipboard installations should be provided with ventilation because of excessive heating of the hydraulic system. (This will be further investigated in type tests.) It is suggested that air be circulated from below decks into the base of the director, with a return by an external pipe from a hole located in the wall of the director.

(d) Seat pads should be provided for the pointer-trainer and control officer to reduce the effect of vibration on the operators and to make it easy to prevent any lurching on a rolling ship.

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APPENDIX D

BUREAU OF ORDNANCE TEST UNIT
ANTI-AIRCRAFT TRAINING AND TEST CENTER
DAM NECK, VIRGINIA

Serial No. (059)

18 April 1945

From: The Officer-in-Charge.
To: The Chief of the Bureau of Ordnance.

Subject: Gun Director Mk. 61 Mod. OA Ser. No. 2 - Installation Report of.

Reference: (a) Telcon between Lt. Lock Section (Re_{4c}) BuOrd and the Officer-in-Charge, BOTU of 1 April 1945.
(b) BOSO No. 172342 of 20 March 1945.
(c) BOSO No. 173726 of 2 0 March 1945.

1. The subject director and Radar Mk. 29 was received at this activity from the Applied Physics Lab., John Hopkins University April 4, 1945 on verbal instructions from the Bureau of Ordnance. The below deck computing units were received in accordance with reference (a) and (b) 1 April 1945.

2. The subject director was mounted on a Mk. 1 roll platform. The below deck components were installed in the fire control room using a cable run of approximately 130 feet.

3. The casualties and troubles encountered during installation are as follows:

(a) The roll correction torque motors burned out. The cause of this casualty is not definitely known. A new Mk. 17 computer was installed.
(b) Excessive back lash occurred in the elevation worm drive assembly to the radar transmitter unit at an elevation of from 40 to 45 degrees. A new elevation worm drive assembly was installed which corrected this trouble.
(c) The elevation stabilizing gyro did not return the armature of the pick-off to a zero position, necessitating the installation of a new stabilizing unit.
(d) The audio output transformer Type T-OD-8083 in the D.S. booster amplifier burned out. This was caused by a short circuit between the primary and secondary winding. The transformer was replaced.
(e) There was an excessive binding of the elevation gear train in the slew sight. This assembly was removed and returned to the Applied Physics Lab., John Hopkins University.
(f) The output shaft of the joy stick to the train rotating transformer was bent causing binding in the gear train and a slow train rate being introduced at the zero position of the joy stick. The damaged shaft was replaced.

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APPENDIX D

Serial No. (059)

Subject: Gun Director Mk. 61 Mod. 0A Ser. No. 2 - Installation Report of.

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(g) The train synchro leads in the computer Mk. 16 were reversed.

4. The installation of the subject director and its component parts as to mounting and the electrical wiring of the system required five days (approximately 105 man hours). However nine additional days have been required to correct the casualties and troubles listed in paragraph 3.

5. On April 13, optical and full automatic radar controlled firing runs were conducted from both a stationary and rolling platform for observation of the over all performance of the subject director system. However the defective stabilizer unit had not been detected and was in the system during this firing resulting in very erratic gun elevation orders.

6. Firing runs were conducted on April 17 and April 18, However, the slew sight and the director operators' open sight are constructed as a single unit and the removal of the defective slew sight, which in turn removed the operators' open sight, made it extremely difficult to find the target with the telescope. It is considered necessary to provide an independent open sight.

7. The casualties and troubles that were encountered during installation have been corrected. Final adjustments are being made to obtain the optimum setting for satisfactory performance of the s ubject director system. Further reports will be submitted as the test progresses.

R. L. Jones.

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APPENDIX D

BUREAU OF ORDNANCE TEST UNIT
ANTI-AIRCRAFT TRAINING AND TEST CENTER
DAN NECK, VIRGINIA

Serial No. 068

30 April 1945

FROM: The Officer-in-charge.

TO: The Chief of the Bureau of Ordnance.

SUBJECT: Gun Director Mk.61 Mod. 0 Ser. 2 - Interim report of tests of.

REFERENCE: (a) OTU Conf. ltr. dated 18 April 1945.

1. Reference (a) and a preliminary report covering the installation of, and the necessary modifications to the subject director to place it in operating condition.

2. The tests to date have included firing and tracking tests from the rolling platform using optical, T&K radar, and automatic radar tracking. Both sleeve and TBO-8 drone targets were used for the firing tests, and type SBD, F6N, F4N aircraft have been used to obtain high tracking rates. The results of these tests have indicated a few points in the design of the subject director which need correction before optimum performance can be obtained.

3. Preliminary Results of Firing Tests:

(a) Approach runs at 4500 ft. altitude - Stationary Platform.

Mode of Tracking	No. of Runs	No. of Rounds	Firing (Mils) X	Firing (Mils) X	Firing (Mils) h	Tracking (Mils)	Tracking (Mils)
Optical	2	26	-1.3	6.8	6.9	3.6	1.4
T & E	2	41	-2.9	6.1	7.1	3.5	1.8
Automatic	1	17	1.2	3.1	3.3	6.3	2.3
(b) Approach runs on bow, roll 12o, 5o/10", Alt.4500ft.							
Optical	11	171	1.2	3.2	5.7	9.7	2.1
T & E	2	37	1.2	5.8	6.4	12.2	2.7
Automatic	4	88	1.7	0.3	4.0	12.8	2.9

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APPENDIX A

Serial No. 068

Subject: Gun Director Mk. 61 Mod. 0 Ser. 2 - Interim report of tests. of.

Mode of Tracking	No. of Runs	No. of Rounds	Firing (Mils) X	X	h	Tracking (Mils)	(Mils)
*(a) Passing runs ahead or astern, roll 12o/9" Pitch 5o/10" Alt. 3000 ft.							
Optical	11	192	3.2	4.1	3.6	9.4	3.9
T & E	2	40	4.2	3.2	5.3	11.5	3.4
A utomatic	4	55	0.4	0.8	4.2	11.3	3.3

*NOTE: This type of run was used to obtain maximum amplitude of cross roll.

4. Preliminary Conclusions:

From the results of the tests to date it is concluded that:

(a) The performance of the subject director is very good in so far as accuracy of fire on straight flying targets is concerned. However, the results of the firing runs listed in the preceding paragraph are not considered representative of the capabilities of this director when certain improvements have been incorporated.

(b) The major deficiency of the subject director is its' lack of any form of radar target acquisition system.

(c) The slowing sight control originally furnished with the director is of an unsatisfactory design and must be replaced with a control of very much sturdier construction.

(d) The automatic radar tracking system furnished with the subject director has given promising results, but tends to lag excessively on High speed targets at short ranges. This activity is further investigating the characteristics of this system and a detailed report of the results of such investigation will be forwarded at a later date.

(e) The general design of the subject director from point of view of structural strength and ease of maintenance is considered excellent. Most of the components included in the stabilizing and power-drive systems are accessible, and are packaged in such a form as to permit their replacement, when necessary, with only a minimum of delay.

(f) Aside from the lack of an adequate target acquisition system the major deficiency of the subject director is in the design of the joystick. The present joy stick should be replaced with one having much stiffer viscous damping, a non-linear rate response, and a suitable aided tracking ratio.

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The backlash which exists in the present damping system should be eliminated.

(g) The solution time of the computer Mk. 17 is too long. With the improvement in the tracking to be expected from a stabilized system a shorter solution time may be used. In view of the type of aircraft tactics and target speeds currently be encountered by the fleet, solution time must be held to the minimum possible value. It is to be noted that, in its present form, the subject director has a solution time which is twice that of the gun fire control system Mk. 65.

5. Tests Against Manuevering Drone Targets.

A few runs were fired against a TDD-2 drone flying diving courses. These runs, although at present too few in number to establish the performance of this system on diving targets, definitely showed the effects of the relatively long solution time of this system.

6. Tracing Test Against High Speed Diving Aircraft.

Preliminary tracking runs were made against types F4U and F6F aircraft flying diving pass runs at a speed of approximately 345 knots and at an angle of dive from 40o to 70o, simulating suicide attacks. No difficulty was experienced in tracking such a target using optical or T & E radar tracking. The automatic radar tracking circuit, however, proved unable to handle the combination of high angular velocity, and angular accelerations in excess of 1.5 degrees per second per second. The precision analysis of the gun orders computed by the subject system on such targets, will be completed as soon as possible. The results of these tests will be made the subject of a further report.

7. Optical Acquisition of Dive Bombers.

Tests were conducted on a type SB0 aircraft in dives to determine the time required for the director operator to establish tracking. The target commenced a dive from an altitude of from 7000 to 8000 feet. These dives were at diving angles varying from 40o to 70o, at speeds of approximately 270 m.p.h; and on various target angles. The average time required for an experienced director operator to slew, from 30o to 90o, on the target and start tracking, after the commencement of the dive, was from 5" to 6". The target was gated by the rad operator about one second later. This test was necessarily conducted without the aid of the slewing sight. It is expected that the installation of the slewing sight, and an open sight for the director operator will reduce these times.

8. Tests are being continued on the subject director.

R. L. Jones

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APPENDIX D

BUREAU OF ORDNANCE TEST UNIT
ANTI-AIRCRAFT TRAINING AND TEST CENTER
DAM NECK, VIRGINIA

Serial No. (073)

15 May 1945

From: The Officer-in-Charge.
To: The Chief of the Bureau of Ordnance.

Subject: Gun Director Mk. 61 Mod. 0 Serial No. 2 - Interim report of Test of.

Reference: (a) BOTU Conf. ltr. NC113-1/S71(Mk. 61) (20-45) Ser. 059, dated 18 A pril 1945.
(b) BOTU Conf. ltr. NC113-1/S71(Mk. 61) (20-45) Ser. 068, dated 30 April 1945.

1. Reference (a) was a preliminary report covering the installation of and certain necessary modifications to the subject director. Reference (b) was a preliminary report of the performance on tracking and firing runs of the subject director. In addition to the tracking and firing runs reported in reference (b), the tests to date have included firing against a type TDD-2 target drone (modifiedto give greater manueverability and higher speed), flying simulated suicide attacks.

2. Results of Test.

Detailed results of the tests to date are contained in enclosures (A) and (B). The tracking error records taken during the firing runs were synchronized with the firing. The results of the firing at the TDD-2 drones flying maneuvering courses are shown graphically in enclosure (A). Enclosure (B) contains the remainder of the results of s tandard firing tests against towed sleeve targets. These data show that while the subject system computes accurately when the target is flying a straight line course, the s olution time is too long to permit effective fire against high speed maneuvering targets. While it is probably out of the question to predict accurately the future position of a high speed target flying a curving course, it is considered essential that the shortest possible solution time be used to provide a hitting answer as soon as the target straightens out to press home an attack.

3. Conclusions:

From the results of the tests to date, it is concluded that the following improvements should be incorporated in the gun director Mk. 61 before its delivery for service use.

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APPENDIX D

Serial No. (073)

Subject: Gun Director Mk. 61 Mod. 0 Serial No. 2 - Interim Report of Test of.

- -

(a) The overall solution time of the associated computers Mk. 17 and Mk. 16 should be reduced to at least half the present value, and if possible, to an even lower value.

(b) The director should be fitted with adequate target acquisition controls both for optical control and for radar control. The BTL target acquisition unit previously tested at this activity as a part of the gun fire control system Mk. 63, may be readily adapted to the gun director Mk. 61.

(c) The joy stick tracking control must be further improved in its mechanical design, and, if possible, simplified to facilitate greater ease of maintenance. This unit is inaccessible in its present location.

(d) The switching from the 40mm to the 5"/38 ballistics should be so arranged as to permit the changeover by throwing a single switch in a convenient location.

4. Further tests in progress.

(a) A new joy stick assembly, furnished by the Applied Physics Laboratory, Johns Hopkins University, has been installed. This assembly has considerably greater viscous damping than the joy stick used during the test covered in this report. Some improvement in tracking is expected, but the new joy stick is not satisfactory in that it contains an excessive amount of coulomb friction. This friction, measured at the outer end of the joy stick amounts to 6 to 8 ounces in elevation, and 18 to 25 ounces in traverse. It is recommended that the coulomb friction component be reduced to less than 2.5 ounces measured at outer end of the joy stick. Since the limitation on tracking accuracy imposed by the action of the joy stick is serious, it is recommended that the present assembly be removed from the director and reworked to reduce the friction to an acceptable value.

(b) This activity has recently received the necessary information from A.P.L. to reduce the solution time of the computing system associated with the subject director to one half its present value. This change is currently being accomplished. It is believed that the combination of an improved joy stick assembly, and a shorter solution time will result in material improvement in the effectiveness of fire against maneuvering targets.

(c) It should be noted that the present maximum range tracking rate for the Mk. 2 9 radar is approximately 395 knots.

R. L. Jones.

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MK. 61 DIRECTOR

Firing on a Maneuvering Target *

Target - Drone T.D.D. - 2
Roll - 12°-9 Seconds
Pitch - 5°-10 Seconds

Run No.	Mode of Tracking	Range (Yds) Open	Range (Yds) Close	No. of Rounds	Firing MPI (Mils) $\bar{X}$	Firing MPI (Mils) $\bar{Y}$	Firing MPI (Mils) h	Firing S (Mils)	Tracking S (Mils)
113	Optical	1850	1950	19	+11.5	+7.0	13.5	23.1	3.8
114		1850	1500	32	+ 8.2	-1.2	8.3	21.3	4.4
115		1600	1650	18	+ 3.7	+11.5	12.1	18.7	4.4
116		1500	1500	23	- 4.1	+0.2	4.1	16.5	2.8
120		1800	1100	24	+ 1.8	-8.7	8.9	19.2	3.4
121		1650	1300	16	+ 4.5	+3.7	5.8	18.6	2.6
122		1400	1100	17	+ 3.9	+4.8	6.2	15.3	3.6
			Average					19.0	3.6
117	T&E(Exp.Oper)	1250	1100	19	- 1.4	-4.0	4.2	18.6	3.4
123	T&E(Inexp.	1400	950	16	+24.1	-0.4	24.1	32.3	11.4
124	Operator)	1400	1000	18	- 3.9	+1.1	4.1	25.5	10.2
125		1300	900	15	+ 1.0	+8.0	8.1	15.1	5.7
			Average					24.3	9.1

NOTE: Approximate speed of drone on straight-line flight, 100 m.p.h.

* Target was making miscellaneous dives and turns.

MK. 61 DIRECTOR SYSTEM

Approach Runs at Altitude of 4500 Ft.

Course	Roll	Pitch	Mode of Tracking	No. of Runs	No. of Rounds	Firing MPI(Mils) $\bar{X}$	Firing MPI(Mils) $\bar{Y}$	Firing MPI(Mils) h	Firing S (Mils)	Tracking S (Mils)
	0	0	Optical	4	71	-1.7	+7.2	7.5	4.1	1.4
	0	0	T&E(Exp.Oper.)	2	41	-2.9	+6.1	7.1	5.5	1.8
	0	0	T&E(Inexp.Oper)	2	39	+6.6	-0.2	8.4	8.9	3.1
	0	0	Automatic	1	17	+1.2	+3.1	3.3	6.8	2.3
Ahead or Astern	12°-9"	0	Optical	3	47	-2.9	+8.2	10.5	10.4	1.8
	12°-9"	0	T&E(Exp.Oper.)	2	28	-3.1	+5.5	6.3	10.8	2.6
	12°-9"	0	T&E(Inexp.Oper.)	2	32	-1.2	+1.9	2.4	12.4	4.2
	12°-9"	0	Automatic	2	32	+6.0	-1.4	6.2	11.9	3.3
Ahead or Astern	12°-9"	5°-10"	Optical	11	171	-1.2	+5.2	5.7	9.7	2.8
	12°-9"	5°-10"	T&E(Exp.Oper.)	2	37	+1.9	+5.8	6.4	12.2	2.7
	12°-9"	5°-10"	T&E(Inexp.Oper.)	3	47	-2.1	+5.1	5.8	18.0	5.4
	12°-9"	5°-10"	Automatic	4	58	+1.7	-0.3	4.0	12.8	2.8
Abeam	12°-9"	5°-10"	Optical	4	79	-2.4	+10.8	11.3	6.8	2.4
	12°-9"	5°-10"	T&E(Exp.Oper.)	3	37	-0.6	+7.6	7.9	7.3	3.4
	12°-9"	5°-10"	T&E(Inexp.Oper.)	2	34	-1.5	+8.3	8.6	16.1	6.3
	12°-9"	5°-10"	Automatic	4	69	+0.4	+4.6	5.2	8.8	2.7

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MK. 61 DIRECTOR SYSTEM

Altitude of Plane 3000 Ft.

Course	Roll	Pitch	Mode of Tracking	No. of Runs	No. of Rounds	Firing MPI (Mils) $\bar{X}$	Firing MPI (Mils) $\bar{Y}$	Firing MPI (Mils) h	Firing S (Mils)	Tracking S (Mils)
Approach	0	0	Optical	4	66	- 2.0	+ 5.0	6.1	4.4	1.4
	0	0	Automatic	2	28	+ 2.3	- 6.1	6.6	12.0	3.9
Approach	12°-9"	5°-10"	Optical	1	15	+ 0.4	+ 1.9	1.9	10.4	2.6
Ahead or Astern	12°-9"	5°-10"	T&E(Inexp. Oper.)	1	14	+ 4.7	- 6.2	7.8	14.5	5.0
Approach Abeam	12°-9"	5°-10"	Optical	5	88	- 2.9	+ 5.6	6.7	6.6	2.7
	12°-9"	5°-10"	Automatic	5	93	- 0.8	+ 1.1	2.7	9.6	3.3
Passing	0	0	Optical	2	39	- 5.0	+ 3.2	6.0	5.0	1.7
	0	0	T&E(Exp.Oper)	3	47	- 2.9	+ 2.3	4.0	6.0	2.8
	0	0	T&E(Inexp.Oper)	2	38	- 3.4	+ 2.9	5.0	10.6	4.2
	0	0	Automatic	2	41	- 6.1	+ 4.0	7.4	9.0	3.0
Passing Ahead or Astern	12°-9"	5°-10"	Optical	11	192	- 3.2	+ 4.1	5.6	9.4	2.8
	12°-9"	5°-10"	T&E(Exp.Oper)	2	40	- 4.2	+ 3.2	5.3	11.5	3.4
	12°-9"	5°-10"	T&E(Inexp.Oper)	2	39	- 3.7	+ 2.0	4.3	14.4	4.4
	12°-9"	5°-10"	Automatic	5	69	- 1.1	+ 1.4	4.6	10.9	3.1
Passing Abeam	12°-9"	5°-10"	Optical	3	43	+ 1.0	+ 7.5	9.0	8.8	2.6

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MK. 61 GUN DIRECTOR SYSTEM

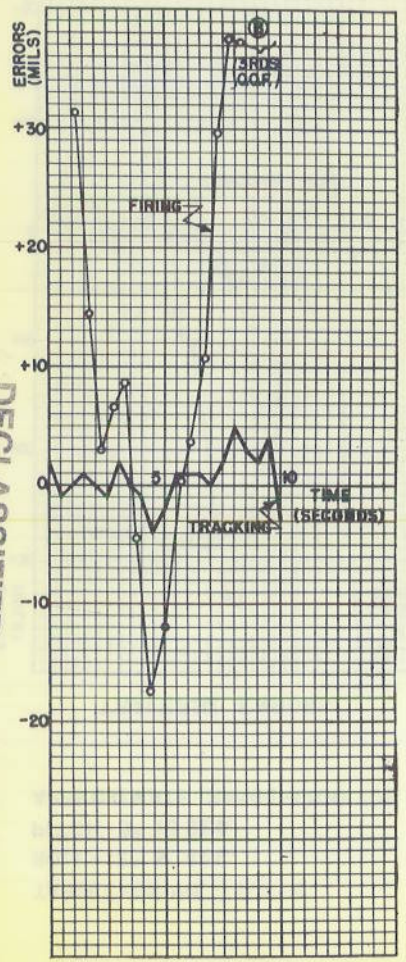
OPTICAL 40MM FIRING ON A MANEUVERING TARGET

TARGET - DRONE T.D.D. - 2
ROLL - 12° 9 SEC.
PITCH - 5° 10 SEC.
APPROXIMATE RANGE - 1700 YDS.

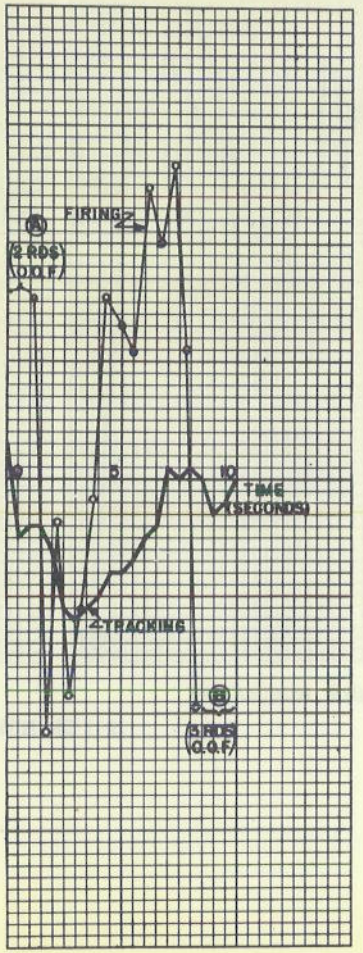
DATE - 4 - 26 - 45
TEST NO. 20 - 45
B.O.T.U. DAM NECK, VA.

RUN NO. 113

TRAVERSE ERRORS



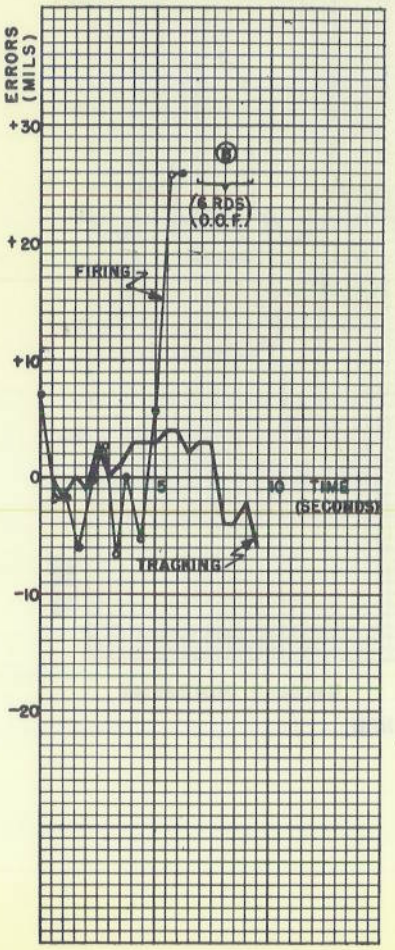
ELEVATION ERRORS



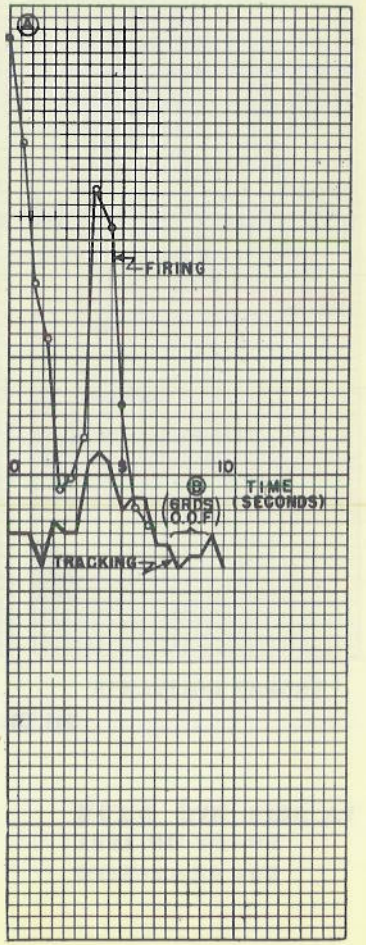
A - TARGET STARTED DIVE.
B - TARGET LEVELED OFF & TURNED TO THE LEFT.

RUN NO. 115

TRAVERSE ERRORS



ELEVATION ERRORS



O.O.F - OUT OF THE CAMERA FIELD.

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MK. 61 GUN DIRECTOR SYSTEM

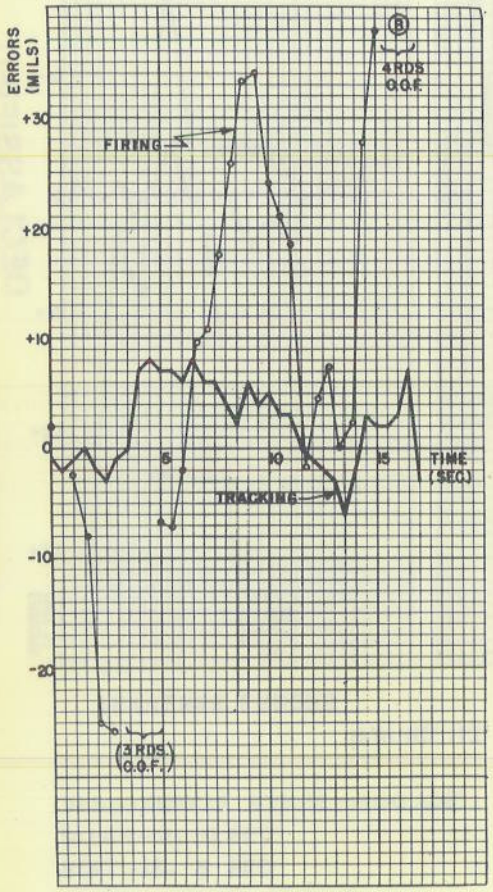
OPTICAL 40MM FIRING ON A MANEUVERING TARGET

TARGET - DRONE T.D.D - 2
ROLL - 12° 9 SEC.
PITCH - 5° 10 SEC.
APPROXIMATE RANGE - 1700 YDS.

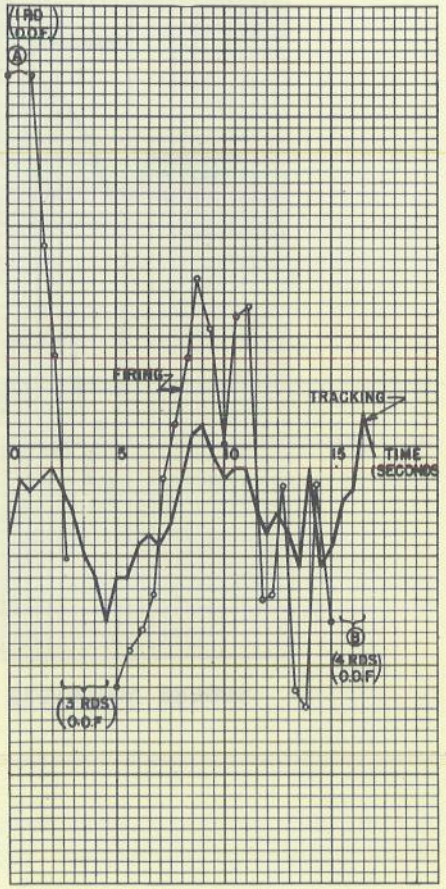
DATE - 4 - 26 - 45
TEST NO. 20 - 45
B.O.T.U. DAM NECK, VA.

RUN NO. 114

TRAVERSE ERRORS



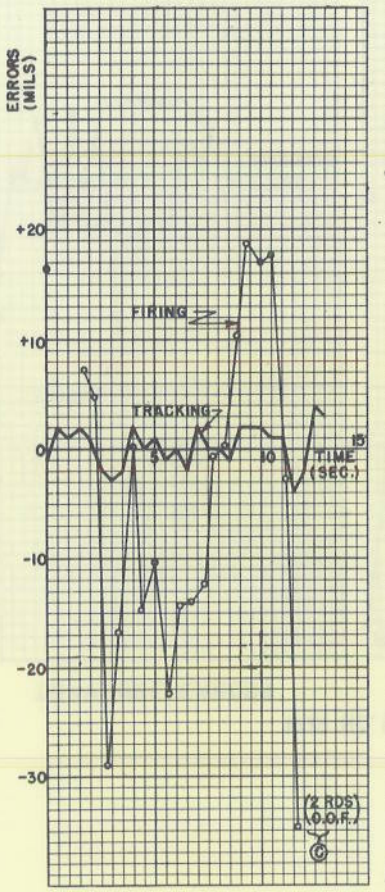
ELEVATION ERRORS



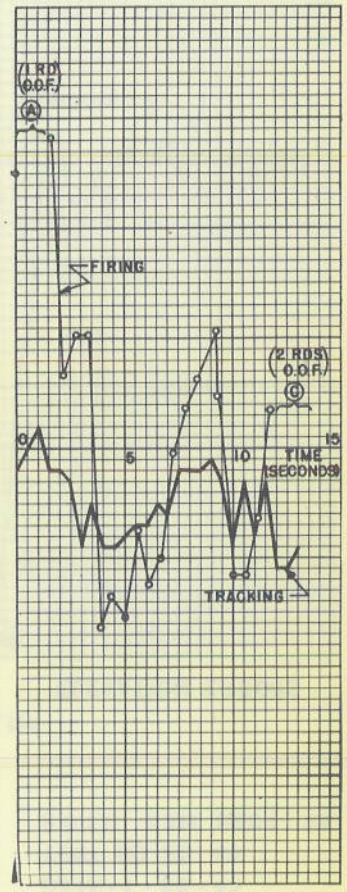
A - TARGET STARTED DIVE.
B - TARGET LEVELED OFF & TURNED TO THE LEFT.

RUN NO. 116

TRAVERSE ERRORS



ELEVATION ERRORS



C - TARGET LEVELED OFF & TURNED TO THE RIGHT.
O.O.F - OUT OF THE CAMERA FIELD.

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BUREAU OF ORDNANCE TEST UNIT
ANTI-AIRCRAFT TRAINING AND TEST CENTER
DAM NECK, VIRGINIA

Serial No. (080) 7 June 1945

From: The Officer-in-Charge.
To: The Chief of the Bureau of Ordnance.

Subject: Gun Director Mk. 61, Mod. 0, Ser. 2 - Power Drive Performance, Results of Test of.

Reference: (a) BOTU conf. ltr. NC 113-1/S71)Mk. 61)(20-45), Ser. 059, dated 18 April 1945.
(b) BOTU report NC113-1/S71(Mk. 61)(20-45) Ser.068, dated 30 April 1945.
(c) BOTU conf. ltr. NC115-1/S71(Mk. 61)(20-45) Ser. 073, dated 15 May 1945.

Enclosure: (a) Fig. 1. A block diagram of the system tested.
Fig. 2. The frequency response of the power drive in train.
Fig. 3. The frequency response of the power drive in elevation.
Fig. 4. One cycle of director response.

1. Reference (a) was a preliminary report covering the installation of, and necessary modifications to, the subject director to place it in operating condition. Reference (b) was an interim report which included the results of firing and tracking tests from a rolling platform using optical, T&E radar, and automatic radar tracking. Reference (c) described tracking and firing tests using maneuvering targets. This report covers the results of tests on the subject director to determine its response in train and elevation to sinusoidal rate signals from the joy stick.

2. Method of Test:

In effect, the joy stick was given a sinusoidal horizontal or vertical motion of constant amplitude. For each frequency, the amplitude of the director, and the phase angle between the director position and the joy stick position were recorded. A dummy director signal was used in place of the joy stick signal to avoid mechanical difficulties. (Note: Fig. 1).

3. Results of Test:

(a) Figures 2 and 3 plot the response of the system in

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Serial No. (080)

train and elevation respectively. The data are not to be construed as precise, because of certain difficulties encountered in making the measurements. The difficulties themselves are significant data, and will be enumerated later in the report. As seen from the plots, the transfer locus approaches the minus ninety degree axis, indicating that the director speed is proportional to the magnitude of the input (joystick) signal at low signal frequencies.

(b) The principal point of interest is the frequency at which the position of the director and the position of the joy stick are 180° degrees out of phase with each other. In most servo mechanism designs, this frequency is the limiting factor in the system's performance. In the subject system the higher this value, the more accurately the director can track evasive targets. This critical point occured at slightly over two cycles per second in train, and at about three cycles per second in elevation, both of which are low, considering the relatively light load imposed by the director on the power drives. These measurements show, however, that there is less lag in the elevation than in the train servo mechanism. Consequently the system's performance in elevation should be superior to that in train when the power drive becomes part of a closed cycle system. There is also a more rapid change in gain, when the frequency in the elevation unit is changed. This further indicates that the elevation unit has better possibilities for the design of a complete servo comprised of an automatic tracking unit and a director power drive.

4. Comments:

(a) The difficulties encountered in making the measurements and the subsequent analysis were largely the result of undesirable characteristics of the system. One of these, drift, caused the director during the test of the system, to have superposed on its sinusoidal motion an unidirectional velocity. This shifted the zero point about which oscillations in train or elevation were taking place. With no sinusoidal input signal and the joy stick voltage disconnected, the drift could easily be eliminated by introducing a bias voltage of proper magnitude at the input. When a sinusoidal signal was superposed, however, the drift changed continuously throughout the test, necessitating an ever varying bias signal to keep it minimized. This type of non-linearity is undesirable in the operation of the system since it results in a varying sensitivity and a shifting null.

(b) Another type of non-linearity present which adversely affects the performance of the system is the presence of a dead zone - that is, a certain minimum voltage is required before the director begins to move. This effect is very serious when the

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director is on a rolling deck where very small dead space regions are distressing to the tracker. The magnitude of the dead zone was measured in train and found to correspond to about 6% of full director speed, or more than 0.8 degrees per second.

(c) An even more serious non-linearity exists, however, which causes the response of the director to differ markedly from sinusoidal motion despite the fact that a mine wave is applied to the input terminals. The most notable feature of the response is a decided lurch or jerky motion so that the speed of the director for a very low frequency of joy stick oscillation is as shown in figure 4. When tracking very low rates in elevation, the director lopes. These characteristics are most undesirable, either for manual or automatic tracking.

5. Recommendations:

(a) An effective means of improving the director performance would be to speed up the stroking system. This requires a lower coulomb, or breakaway friction load upon the stroke motor, and a reduced gear ratio between the motor and the pilot piston. With the low stroking force required on the hydraulic unit, the gear ratio may be reduced many times over. The substitution of a a-c drag cup generator or a low inertia, low friction, d-c generator for the present stroke generator would be a major improvement. This would reduce the breakaway torque of the gear train and the reflected inertia of the stroke generator. The limit stops on the present design seem unnecessarily complex. Simple stops may be easily designed which will be effective and yet not contain the scissors type release mechanism. In addition a higher overall system gain should be provided. The present amplifier does not drive the stroke motor hard enough, despite the fact that the gain control is set at maximum.

(b) A definite improvement in performance should result from the removal of the radar transmitter unit from below the dish so that the unbalanced loan on the elevation worm drive is eliminated. It is understood that such a change in the location of the transmitter on the "A" frame is already in progress.

(c) The voltage from the joy stick should be non-linearized for positions bordering the null. Experience with the MK. 50 director has indicated that a rate voltage proportional to the square of the joy stick position is satisfactory. While this will not affect the system in automatic tracking, it will materially aid the tracker when the unit is manually operated. This recommendation has been previously made in reference (b).

R. L. Jones

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MK 61 DIRECTOR POWER DRIVE

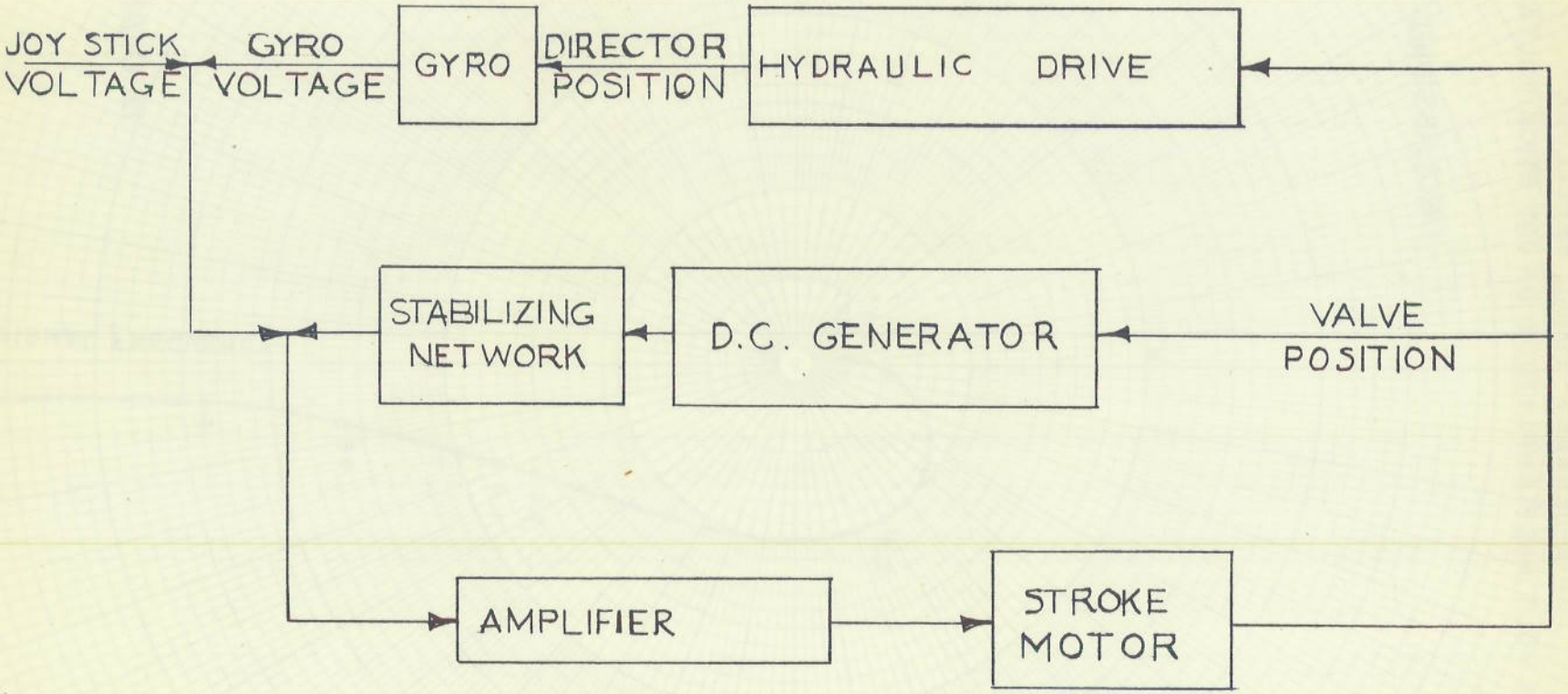

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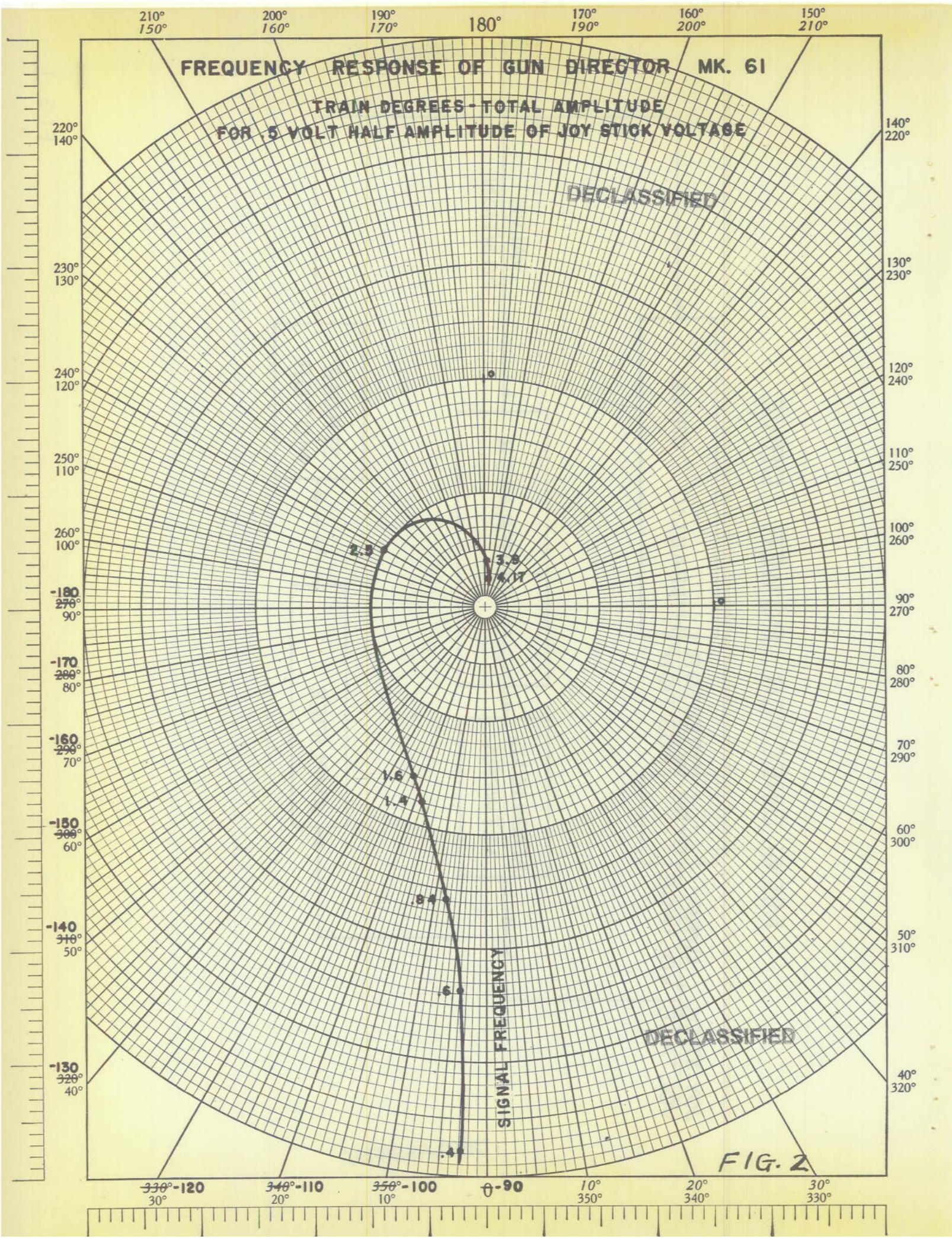
FIG. 1


FREQUENCY RESPONSE OF GUN DIRECTOR MK. 61
TRAIN DEGREES - TOTAL AMPLITUDE
FOR .5 VOLT HALF AMPLITUDE OF JOY STICK VOLTAGE
DECLASSIFIED
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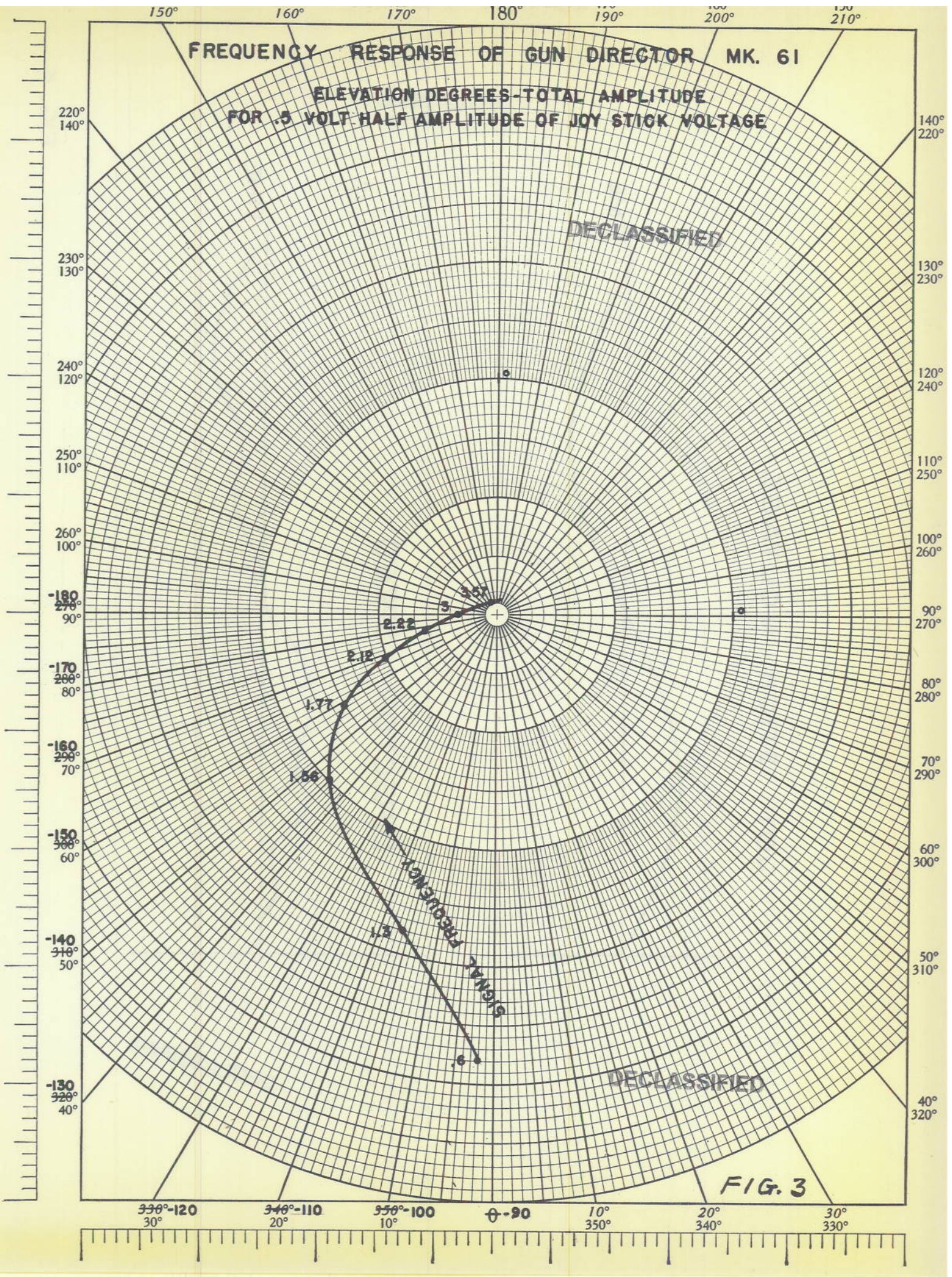
SIGNAL FREQUENCY
2.5
3.8
4.17
1.6
1.4
.8
.6
.4
210° 150°
200° 160°
190° 170°
180°
170° 190°
160° 200°
150° 210°
220° 140°
230° 130°
240° 120°
250° 110°
260° 100°
-180 270° 90°
-170 280° 80°
-160 290° 70°
-150 300° 60°
-140 310° 50°
-130 320° 40°
140° 220°
130° 230°
120° 240°
110° 250°
100° 260°
90° 270°
80° 280°
70° 290°
60° 300°
50° 310°
40° 320°
330°-120 30°
340°-110 20°
350°-100 10°
θ-90
10° 350°
20° 340°
30° 330°

FIG. 2


FREQUENCY RESPONSE OF GUN DIRECTOR MK. 61
ELEVATION DEGREES-TOTAL AMPLITUDE
FOR .5 VOLT HALF AMPLITUDE OF JOY STICK VOLTAGE
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SIGNAL FREQUENCY
3.57
3
2.22
2.12
1.77
1.56
1.3
.6
θ-90
FIG. 3

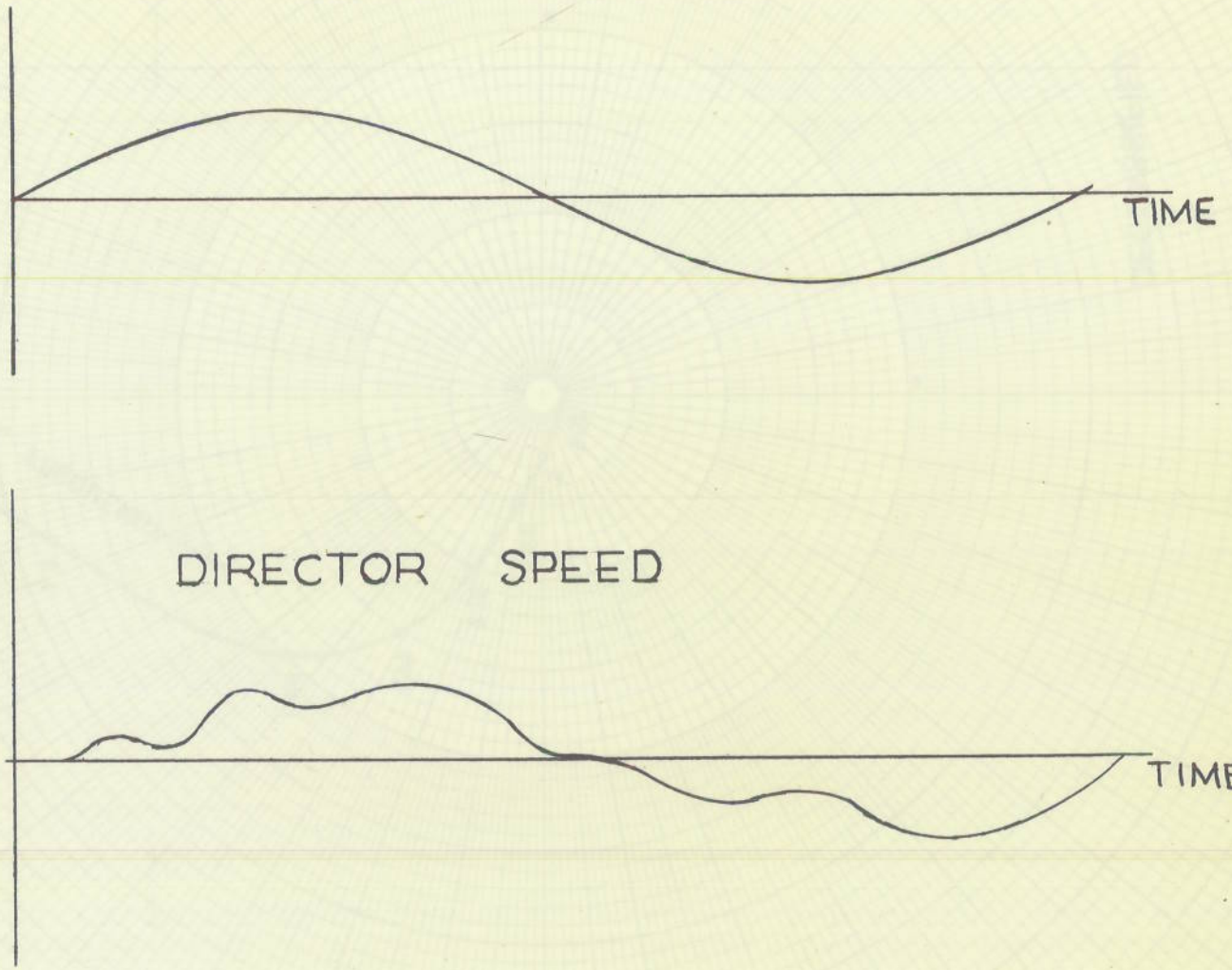

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FIG. 4

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LIST OF SPECIFICATIONS

for the

GUN FIRE CONTROL SYSTEM

Mk 61 Mod.2

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APPENDIX E

O.S.	Title
3916	Procurement Spec. Test Unit Mk 27 Mod 0 and Test Units Mk 25 Mods 0&1
3917	Procurement Spec. Test Unit Mk 26 Mod 0 (Hydraulic Test Stand)
3922	Test Spec. for Train and Elevation Power Drive for Gun Director Mk 61
3923	Test Spec. Kollsman Generators
3924	Test Spec. Stabilizer Unit Mk 1 Mod 1
3925	Procurement Spec. Test Unit Mk 28 Mod 0 (Roll Table)
3926	Test Spec. Horizon Indicator Mk 4 Mod 0
3927	Test Spec. T & E Scope
3928	Test Spec. Tracking Amplifier
3929	Test Spec. Misc. Electrical Components
3930	Test Spec. Mechanical Units
3931	Test Spec. Control Unit (Manual Rate) Mk 31 Mod 0 (Pointer's Control Unit)
3932	Test Spec. for Optical Alignment of Gun Director Mk 61
3933	Test Spec. for Gun Director Mk 61
3971	Test Spec. Gun Fire Control System Mk 61
3974	Procurement Spec. for Telescope Mk 92 Mod 2
4654	Manufacturer's Spec. for Watertight Motor (Howell)
5301	Procurement Spec. Test Unit Mk 29 Mod 0 (Kollsman)
5303	Test Spec. Slewing Sight Mk 6 Mod 0
5302	Procurement Spec. Slewing Sight Mk 7 Mod 0

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APPENDIX E

List of Specifications
November 25, 1946

O.S.	Title
1700	Procurement Spec. Dynamic Tester (for Director Mk 61) Mk 34 Mod 0
1701	Procurement Spec. Director Synchro Dial Box Mk 35 Mod 0
1702	Procurement Spec. Gun Order Synchro Dial Box Mk 36 Mod 0
3403	Procurement Spec. Computer Mk 17 Mods 0-3
3658	Procurement Spec. Wind Transmitter Mk 4 Mods 4-5
3689	Procurement Spec. Stabilizer Unit Mk 1 Mods 0 & 1
3814	Procurement Spec. Computer Mk 16 Mod 2
3815	Procurement Spec. Computer Mk 33 Mods 0-6
3825	Procurement Spec. Gun Director Mk 61 Mods 0-3
3860	Procurement Spec. Train Parallax Corrector Mk 5 Mods 0 & 1
3861	Procurement Spec. T&E Hydraulic Power Drive Mk 1 Mod 0
3869	Procurement Spec. Gun Order Corrector Mk 3 Mods 0 & 1
3888	Test Spec. Computer Mk 16 Mod 2
3889	Procurement Spec. Test Unit Mk 21 Mod 0 (For Computer Mk 16)
3901	Test Spec. Computer Mk 33 Mods 0-6
3903	Procurement Spec. Test Unit Mk 24 Mod 0
3915	Procurement Spec. Gun Fire Control System Mk 61 Mods 0-9

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APPENDIX E

SPECIFICATIONS AND DRAWINGS

for the

COMPONENTS OF

MK 61 MOD 2

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APPENDIX E

Component - Gun Fire Control System

Mark 61 Mod 0-9

Proc. Spec. O.S. 3915
Test Spec. O.S. 3971

Wiring Diagram (Below decks)	Dwg. No. 907750
Wiring Diagram (Interconnections)	Dwg. No. 908498
Cable Diagram	Dwg. No. 903349

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APPENDIX E

Component - Gun Director

Mark 61 Mod 0-3

Proc. Spec. O.S.3825
Test Spec. O.S.3932 (Optical Alignment)
Test Spec. O.S.3933 (Complete Director)

Parts List Reference	Sk. No. 168000
Assembly	Dwg.No. 904000
Circuit Diagram	Dwg.No. 904102
Cable Diagram	Dwg.No. 903349
Gear Diagram	Dwg.No. 907500
Chart of Basic Components	Dwg.No. 908500
Lubrication Chart	Dwg.No. 907200
Mounting and Clearance	Dwg.No. 903172

Components - Miscellaneous Electrical Equipment

Proc. Spec. O.S.3929

Components - Miscellaneous Mechanical Equipment

Proc. Spec. O.S.3920

Test Equipment Used on Above

Dynamic Tester for Director Mark 61

Mark 34 - Mod 0 Test Spec. O.S.1700

Synchro Dial Box

Mark 35 - Mod 0 Test Spec. O.S.1701

Gun Order Synchro Dial Box

Mark 36 - Mod 0 Test Spec. O.S.1702

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APPENDIX E

Component - T. & E. Hydraulic Power Drive for Gun Director Mk 61

Mark 1 - Mod 0

Proc. Spec. O.S.3861
Test Spec. O.S.3922

Parts List	Sk. No. 124582,3
Assembly	Dwg.No. 904500
Circuit Diagram	Dwg.No. 903256
Installation	Dwg.No. 168096
Hydraulic Motor	Dwg.No. 901397
By-pass valves	Dwg.No. 903060
Hydraulic Pump	Dwg.No. 903254
Servo valve control	Dwg.No. 903255
Return pump	Dwg.No. 903258
Pump and Servo	Dwg.No. 904600
Oil Filter Tank	Dwg.No. 904650
1½ hp motor	Dwg.No. 901382
Installation	Dwg.No. 908700

Test Equipment Used on Above

Hydraulic Test Stand

Mark 26 - Mod 0

Proc. Spec. O.S.3917

Parts List	Sk. No. 168243
Assembly	Dwg.No. 902510
Circuit Diagram	Dwg.No. 907984

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APPENDIX E

Component - Watertight A.C. Motor for Mk 61 Hydraulic System

Proc. Spec. O.S. 4654

Parts List	Sk. No.904515
Assembly	Dwg.No.901382
Electrical Specs.	Dwg.No.904519
Stator Winding Data	Dwg.No.903282

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APPENDIX E

Component - Kollsman Generator

Test Spec. O.S.3923

Assembly	Dwg.No. 257468-5
Assembly	Dwg.No. 257468-6

Test Equipment Used on Above

Test Unit

Mark 29 - Mod 0 - Proc. Spec. O.S. 5301

Parts List	Sk. No. 168244
Assembly	Dwg.No. 902503
Circuit Diagram	Dwg.No. 907959

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Component - Computer (Load Angle)

Mark 17 - Mod 0-3 Proc. Spec. 3403

Parts List	Sk. No. 172214
Assembly	Dwg.No. 493727
Circuit Diagram	Dwg.No. 904099
Assembly	Dwg.No. 493728
Assembly	Dwg.No. 493729
Assembly	Dwg.No. 493737
Assembly	Dwg.No. 493741

Test Equipment Used on Above

Gyro Test Table

Mark 27 - Mod 0 Proc. Spec. 3916

Parts List	Sk. No. 168242
Assembly	Dwg.No. 902500
Circuit Diagram	Dwg.No. 907996

Gyro Test Unit for Traverse and Elevation

Mark 25 - Mod 0, 1 Proc. Spec. 3916

Parts List	Sk. No. 168240 (Mod 0)
	Sk. No. 168241 (Mod 1)
Assembly	Dwg.No. 902501 (Mod 0)
Circuit Diagram	Dwg.No. 907988 (Mod 0)
Assembly	Dwg.No. 902502 (Mod 1)
Circuit Diagram	Dwg.No. 907997 (Mod 1)

Roll Table Test Unit

Mark 28 - Mod 0 Proc. Spec. 3925

Parts List	Sk. No. 168246
Assembly	Dwg.No. 902506

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Component - Stabilizer Unit

Mark 1 - Mod 1

Proc. Spec. O.S.3689
Test Spec. O.S.3924

Parts List	Sk. No.136793 (Mod 1)
Assembly	Dwg.No.494218 (Mod 1)
Circuit Diagram	Dwg.No.903262 (Mod 1)
Assembly	Dwg.No.494219 (Mod 1)
Assembly	Dwg.No.494220 (Mod 1)
Assembly	Dwg.No.494221 (Mod 1)
Assembly	Dwg.No.494222 (Mod 1)

Test Equipment Used on Above

Gyro Test Unit

Mark 27 - Mod 0 Proc. Spec. O.S. 3916

Parts List	Sk. No. 168242
Assembly	Dwg.No. 902500
Circuit Diagram	Dwg.No. 907996

Gyro Test Unit

Mark 25 - Mod 0.1 Proc. Spec. O.S. 3916

Parts List	Sk. No. 168240 (Mod 0)
Parts List	Sk. No. 168241 (Mod 1)
Assembly	Dwg.No. 902501 (Mod 0)
Circuit Diagram	Dwg.No. 907988 (Mod 0)
Assembly	Dwg.No. 902502 (Mod 1)
Circuit Diagram	Dwg.No. 907997 (Mod 1)

Roll Table Test Unit

Mark 28 - Mod 0 Proc. Spec. O.S. 3925

Parts List	Sk. No. 168246
Assembly	Dwg.No. 902506

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APPENDIX E

Component - Tracking Amplifier

Test Spec. O.S. 3928

Parts List	Sk. No. 168087
Assembly	Dwg.No. 903259 Tracking Ampl.
Circuit Diagram	Dwg.No. 903260 " "
Wiring Diagram	Dwg.No. 902448
Assembly	Dwg.No. 903184 Parallel T
Assembly	Dwg.No. 903427 Input Transp.
Assembly	Dwg.No. 904087 Output Transp.
Assembly	Dwg.No. 901368 Filament "

Test Equipment Used on Above

Filter Network Test Unit

Parts List	Sk. No. 168249
Assembly	Dwg.No. 908452
Circuit Diagram	Dwg.No. 908457
Test Schematic Diagram	Dwg.No. 909321

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APPENDIX E

Component - Horizon Indicator

Mark 4 - Mod 0 Test Spec. O.S. 3926

Parts List	Sk. No. 168056
Assembly	Dwg.No. 907001
Circuit Diagram	Dwg.No. 903211

Test Equipment Used on Above

Roll Table Test Unit

Mark 28 - Mod 0 Proc. Spec. O.S. 3925

Parts List	Sk. No. 168246
Assembly	Dwg.No. 902506

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APPENDIX E

Component - Control Unit (Manual Rate) (Pointer's Control Unit)

Mark 31 - Mod 0 Test Spec. O.S. 3931

Parts List	Sk. No. 168085
Parts List	Sk. No. 904076
Circuit Diagram	Dwg.No. 904077
Circuit Diagram (Control Sub-Accel)	Dwg.No. 903292
Circuit Diagram (Control Chassis)	Dwg.No. 903294
Ins tallation	Dwg.No. 908261

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Component - Slewing Sight

Mark 6 - Mod 0

Prec. Spec. O.S. 5302
Test Spec. O.S. 5303

Parts List	Sk. No. 168090
Assembly	Dwg.No. 903310
Circuit Diagram	Dwg.No. 903311
Circuit Diagram (Control Chassis)	Dwg.No. 903249

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APPENDIX E

Component - Telescope

Mark 92 - Mod 2 Proc. Spec. O.S. 3974

Parts List Sk. No. 167919
Assembly Dwg.No. 909997

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Component - Computer (Angle Solver)

Mark 16 - Mod 2

Proc. Spec. O.S. 3814
Test Spec. O.S. 3888

Parts List	Sk. No. 146064
Circuit Diagram	Dwg.No. 562320

Test Equipment Used on Above

Overall Test

Mark 21 - Mod 0 Proc. Spec. 3889

Parts List	Sk. No. 168250
Assembly	Dwg.No. 909322
Wiring Diagram	Dwg.No. 909323

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APPENDIX E

Component - Computer

Mark 33 - Mod 1-8

Prec. Spec. O.S. 3815
Test Spec. O.S. 3901

Parts List	Sk. No. 145667
Circuit Diagram	Dwg.No. 562299

Test Equipment Used on Above

Mark 24 - Mod 0 Proc. Spec. O.S. 3903

Parts List	Sk. No. 168251
Assembly	Dwg.No. 909324
Wiring Diagram	Dwg.No. 909325

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Component - T. & E. Scope

Test Spec. O.S. 3927

Parts List	Sk. No. 168083
Assembly	Dwg.No. 903320
Circuit Diagram	Dwg.No. 903324
Wiring Diagram	Dwg.No. 903428

Test Equipment Used on Above

T. & E. Power Supply Test Equipment

Parts List	Sk. No. 168245
Assembly	Dwg.No. 902504
Circuit Diagram	Dwg.No. 907949

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APPENDIX E

Component - Wind Transmitter

Mark 4 - Mod 4 Proc. Spec. O.S. 3658

Parts List	Sk. No. 146415 (Mod 5)
Circuit Diagram	Dwg.No. 664346
Wiring Diagram	Dwg.No. 563056 (Mod 5)

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APPENDIX E

Component - Train Parallax Corrector

Mark 5 - Mod 0,1 Proc. Spec. O.S. 3860

Circuit Diagram (Mod 0) Dwg.No. 606513

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APPENDIX E

Component - Gun Order Corrector

Mark 3 - Mod 0, 1 Proc. Spec. O.S. 3869

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The Johns Hopkins University

Applied Physics
Laboratory

8621 Georgia Avenue
Silver Spring, Md.

Technical Paper No. 28

Part I

Contract NOrd 7386
Evaluation Report - Task B
Gun Fire Control Systems

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TABLE OF CONTENTS

PART I

Chapter		Title	Page
I		Summation of Report	1
II		Contract Objective	2
III		Summary of Developments	5
	A	Gun Director Mk 57	5
	B	Gun Director Mk 61	5
	C	Gun Director Mk 62	8
IV		Division of Technical Direction	9
	A	At APL/JHU	9
	B	By Bureau of Ordnance, Section Re4c	11
	C	By Bureau of Ordnance, Section Re4f	
V		Proposed Alternative Progress	14
	1	APL/JHU Short Range Program	14
	2	Kollox Corp. Short Range Program	15
	3	Submarine Signal Co. Short Range Program	15
	4	APL/JHU Long Range Program	16
	5	Submarine Signal Co. Long Range Program	17
VI		Contract Recommendations	19
	A	A PL/JHU Short & Long Range Programs	19
	B	APL/JHU Long Range Program Only. Kollex Corp. Short Range	19
	C	Submarine Signal Co. Short & Limited Long Range Programs	20
	D	Bureau of Ordnance Recommendation	20
VII		Short Range Program	21
	A	Time Scale	21
	B	Personnel	22
	C	Work Outline	23
	C1	Gun Director Mark 61	23
	C2	Radar System Mark 47	27
	63	Computers Mark 16 & Mark 33	30
	C4	W ind Transmitter Mark 4	31
	C5	Parallax Corrector Mark 5 etc.	32
	C6	Instruction Books	32
	C7	Procurement and Test Specifications	33

DECLASSIFIED

DECLASSIFIED

TABLE OF CONTENTS

PART I

Chapter	Title	Page
I	Summation of Report	1
II	Contract Objective	2
III	Summary of Developments	5
	A Gun Director Mk 57	5
	B Gun Director Mk 61	5
	C Gun Director Mk 62	8
IV	Division of Technical Direction	9
	A At APL/JHU	9
	B By Bureau of Ordnance, Section Navy	11
	C By Bureau of Ordnance, Section Navy	
V	Proposed Alternative Programs	16
	1 APL/JHU Short Range Program	16
	2 Kollsman Corp. Short Range Program	18
	3 Submarine Signal Co. Short Range Program	18
	4 APL/JHU Long Range Program	18
	5 Submarine Signal Co. Long Range Program	17
VI	Contract Recommendations	19
	A APL/JHU Short & Long Range Programs	19
	B APL/JHU Long Range Program Only.	
	Kollsman Corp. Short Range	19
	C Submarine Signal Co. Short & Limited Long Range Programs	20
	D Bureau of Ordnance Recommendation	20
VII	Short Range Program	21
	A Time Scale	21
	B Personnel	22
	C Work Outline	23
	C1 Gun Director Mark 61	25
	C2 Radar System Mark 17	27
	85 Computers Mark 16 & Mark 33	30
	C4 X and Transmitter Mark 4	31
	C5 Parallax Corrector Mark 5 etc.	32
	C6 Instruction Books	32
	C7 Procurement and Test Specifications	33

DECLASSIFIED

DECLASSIFIED

Chapter		Title	Page
VII Cont.			
	C8	Test Equipment	34
	C9	Amplidyne Drive	35
	C10	Gun Fire Control System Tests. Laboratory & Shore Base	35
	a	Laboratory	35
	b	Chesapeake Beach Annex	35
	c	Comparison Test with Gun Fire Control System Mk 56	36
	d	Firing Tests (Dam Neck Proving Ground)	36
	e	Estimated Time and Personnel	36
	C11	Shipboard Installation and Tests	37
	C12	Evaluation of Test Data	37
	C13	Additional Production Contract Design Revisions	38
	a	Train and Elevation Synchros	38
	b	Sholl Assembly	39
	C	Hydraulic Power Drive System	39
	d	Gyro Computer and Gyro Stabilizer	39
	e	Other Components of Gun Fire Control System Mark 61	40
VIII		Long Range Program	42
	A	Time Scale	42
	B	Personnel	42
	C	Work Outline	42
	1	Improvement on present Gun Fire Control System Mark 61	42
	2	Future Research	44

EXHIBITS

Exhibit	Title	Referred to Article
1	Fire Control System Mk 57 O.P.1323C	III-A
2	Gun Director Mk 61 (30" Dish)	III-B
3	Gun Fire Control System Mk 61	III-B
4	Progress Chart, Gun Director Mk 61	VII-A
5	Personnel Chart	VII-B

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INDEX
PART 2

APPENDIX	TITLE	REFERRED TO IN PART 1 ARTICLE
A	List of Basic Components in Gun Director Mk 61	IIIB
B	FLOW DIAGRAM: Gun Fire Control System Mk 61	IIIB
C	CABLE DIAGRAM: Gun Director Mk 61 (#903349)	
D	CABLE DIAGRAM: Below Deck Gun Fire Control System Mk 61 (907750)	IIIB
E	GEAR SYSTEM DIAGRAM: Gun Director Mk 61 (907500)	IIIB
F	CONTROL PANELS: Gun Director Mk 61 (907900)	IIIB
G	TELESCOPE Mk 92 MOD 2. (909997) 2 sheets	IVA
H	TELESCOPE Mk 92 MOD 2 Photograph	IVA
I	MOTOR CONTROLLER-906425 Photograph	IVA
J-1	MAIN SWITCH & START-STOP PANEL 903237	IVA
J-2	MAIN SWITCH & START-STOP PANEL 903237	IVA
J-3	CEASE FIRING SWITCH PANEL 903235	IVA
J-4	CEASE FIRING SWITCH PANEL 903235	IVA
J-5	POINTERS TELEPHONE PANEL 903314	IVA
J-6	POINTERS TELEPHONE PANEL 903314	IVA
J-7	CONTROL OFFICERS TELEPHONE PANEL 903318	IVA
J-8	CONTROL OFFICERS TELEPHONE PANEL 903318	IVA
J-9	Main Fuse Cabinet 903308	IVA
J-10	Main Fuse Cabinet 903308	IVA
J-11	Transformer & Relay Fuse Cabinet 903312	IVA
J-12	Transformer & Relay Fuse Cabinet 903312	IVA
J-13	440 VOLT FUSE CABINET 903241	IVA
J-14	440 VOLT FUSE CABINET 903241	IVA
J-15	Water Pump Switch 903570	IVA
J-16	Water Pump Switch 903570	IVA
J-17	Service Outlet 903327	IVA
J-18	Service Outlet 903327	IVA
J-19	Train Lock Switch 902743	IVA
J-20	Train Lock Switch 902743	IVA
J-21	440V-270V Disconnect Switch 903323	IVA
J-22	440V-270V Disconnect Switch 903323	IVA
J-23	A.C. Terminating & Switch Cabinet 903325	IVA
J-24	A.C. Terminating & Switch Cabinet 903325	IVA
J-25	Water Pump Fuse Cabinet 903334	IVA
J-26	Water Pump Fuse Cabinet 903334	IVA
J-27	Synchro Terminating Cabinet 903322	IVA
J-28	Synchro Terminating Cabinet 903 322	IVA
J-29	Synchro Power Junction Box 901379	IVA
J-30	Synchro Power Junction Box 901379	IVA
J-31	Radar Terminating Cabinet 903330	IVA
J-32	Radar Terminating Cabinet 903330	IVA

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APPENDIX	TITLE	REFERRED TO IN PART 1 ARTICLE
J-33	Fire Control Terminating Cabinet 901256	IVA
J-34	Fire Control Terminating Cabinet 901256	IVA
J-35	Computer Power & Telephone Terminating Cabinet 903333	IVA
J-36	Computer Power & Telephone Terminating Cabinet 903333	IVA
J-37	Computer & Control Terminating Cabinet 903267	IVA
J-38	Computer & Control Terminating Cabinet 903267	IVA
J-39	Spare Cable Terminating Cabinet 903204	IVA
J-40	Spare Cable Terminating Cabinet 903204	IVA
K	Open Sight 904101	IVA
L	Computer Mark 16 Mod 2	IVB
M	Computer Mark 33 Mod 1	IVB
N	Computer Mark 17 Mod 3	IVB
O	Stabiliz er Unit Mark 1 Mod 1	IVB
P	Wind Transmitter Mark 4 Mod 5.	IVB
Q	270 V.D.C. Motor Generator 292366	IVB
R	Parallax Computer Mark 5 Mod 0	IVB
S	Gun Ordor Corrector Mark 3	IVB
T	Amplifier Mark 10 Mod 0	IVB
V	Radar Console Mark 3 Mod 2 (Mod 1 shown)	IVC

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I

SUMMATION OF REPORT

This report submits broadly the present status and future activity contemplated on Task B of Bureau of Ordnance Contract NOrd 7386.

The contractural relationship between the Bureau of Ordnance and APL/JHU is recommended to be maintained as at present to complete the Short Range Program as set forth in Proposal V1. This recommendation is submitted as the preferred arrangement by the Bureau of Ordnance as set forth in Chapter VI-d. Future activity by APL/JHU after March 1947 on this basis is limited to engineering cooperation and supervision of Shipboard tests of Gun Fire Control System Mark 61 by a select few technically qualified staff members from present group. Future gun fire control system developments and improvements thereafter will be handled bythe Bureau of Ordnance through contractural arrangements with the Submarine Signal Co. as set forth in Proposal V-3.

On the basis of only completing the Work Outline on Present Gun Fire Control System Mk 61 as set forth in Chapter VII the present size staff now assigned by APL/JHU to Task B should be retained intact until March 1947. Reduction thereafter should be made to meet staff requirements for shipboard tests and continuation of coordination of design and production.

Present space at Forest Grove Station and facilities assigned should be retainedintact until July 1947.

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II

CONTRACT OBJECTIVE

The statement of purpose and scope of activity contemplated under this task as given in the APL/JHU - BuOrd, Contract NOrd 7386 reads as follows:

> "Objective of this task is the development of 'intermediate' blind firing directors of a type suitable for defense against multiple night attacks. This work shall include design, experimental production and testing of such directors, their component parts and supplementary equipment used in carrying out this work. This shall also include any necessary cooperation with, and assistance to, the armed forces and others relative to the use, development, production and testing of directors and investigation when necessary, of the characteristics of weapons with which they are used. It shall also include cooperation through consultation and otherwise, as may be practicable with other agencies concerned with the development or use of devices and methods with which this task is concerned."

The above scope resulted in the development by APL/JHU of various Gun Fire Control Systems, which hereafter under "Summary of Developments" (Art. II) are more specifically set forth. As an introduction to the subject matter of this report, it is believed necessary to outline briefly what a "Gun Fire Control System" is and what basic features such a system must possess.

1. A Gun Fire Control System is basically a system for acquiring a target either by optical or radar means, computing a solution from electrical devices which will establish the future position of the target, that is, the position at which the target will be, taking into consideration the elapsed time of projectile travel and other factors. The system transmits this computed future position by electrical information to the Gun Mounts employed directing their

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II

CONTRACT OBJECTIVE

The statement of purpose and scope of activity contemplated under this task as given in the AFL/UDU - Navy, Contract Nord 7586 reads as follows:

"Objective of this task is the development of 'intermediate' Gun Fire Control Systems, which hereafter under "Summary of Developments" (Art. II) are more specifically set forth. As an introduction to the subject matter of this report, it is believed necessary to outline briefly what a "Gun Fire Control System" is and what basic features such a system must possess.

1. A Gun Fire Control System is basically a system for acquiring a target either by optical or radar means, computing a solution from electrical devices which will establish the future position of the target, that is, the position at which the target will be, taking into consideration the elapsed time of projectile travel and other factors. The system transmits this computed future position by electrical information to the Gun Mounts employed directing their

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positioning automatically.

2. The problems in such a system are numerous and very complex. The system must be capable of coping with all types of targets including high velocity targets such as the kamikaze suicide bombs and missiles such as the V-1 bombs. To obtain accurate solution of gun orders corrections for the following factors are necessary. a) ballistics of projectile, b) own ships course, c) own ships speed, d) drift due to wind, e) roll and pitch of ship, f) parallax due to different positioning of director and gun mount on ship etc. Evasive tactics of targets further complicate the solution. The solution time must be short to be effective and for this reason computation should be automatic.

3. The development, design and construction of such a system requires a basic knowledge of the strenuous specifications to which the system is subjected and under which it must operate. To be an effective system it must be able to operate, a) under all conditions of visibility: sunlight, fog, smoke and at night, b) under wide range of temperature $-20^{\circ}C$ to $+ 65^{\circ}C$, c) under all conditions of humidity and d) unaffected by winds, gun blasts and shocks. These operational factors require that each and every component and assembly be individually designed to meet rigid Navy specifications established by the Bureau of Ordnance from field experiences. Each and every component, assembly and the completed system must be so designed that

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accessibility and serviceability of any part can readily be accomplished. All parts must be standardized so that replacement parts can be kept to a minimum and readily replaced in the field. Special materials and finishes are required to meet rigid tests to insure withstanding conditions encountered on shipboard and salt water reaction. All units and assemblies require shock and vibration tests and most components are subjected to life tests. All of these factors must be kept in mind in developing and designing a Gun Fire Control System and at the same time reducing the overall weight of the system to a minimum without sacrificing safety factors and overall performance.

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III

SUMMARY OF DEVELOPMENT

The status of designs and development of models evolved for blind firing gun directors developed under this task may be briefly summarized as follows:

III-A GUN DIRECTOR MK 57

The manually controlled Gun Director Mark 57, including associated radar, gyro computer and electronic computer equipments, started in the April of 1943, were rushed through development as a "crash program" and were produced for the Navy's emergency needs by the latter part of 1944. Following completion of the development activities including field testing and service operations on installations in the fleet, technical direction was turned over to the Bureau of Ordnance Section Re4, on November 1, 1945, to supervise the production contracts, service and maintenance problems. A total of 450 Gun Directors Mark 57 were contracted for and the majority of these were installed in the fleet. A set of sketches as furnished in the operating instruction book O.P. 1323C is attached in PART I as Exhibit 1, for purposes of illustrating the make-up of the Gun Fire Control System Mark 57.

III-B GUN DIRECTOR MK 61

The power operated Gun Director Mark 61, started in November of 1943, was next proven in by an APL/JHU laboratory built model, in the spring of 1944, followed by Norge production prototypes in November 1944. The Gun Director Mark 61 was

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originally designed to be used with the computer equipments originally developed for the Gun Fire Control System Mark 57 and all preliminary field tests were made using such equipment.

The fundamental difference between the Gun Director Mark 57 and Gun Director Mark 61 is that the latter is power operated instead of manually operated in train and elevation. A power operated gun director has numerous advantages over a manually operated gun director in that additional features can be added that are not possible on a manual gun director, some of these are:

1. Stabilization for roll and pitch of ship. In the Gun Director Mk 61 gyro stabilization is employed to stabilize the line-of-sight. This stabilization automatically retains line-of-sight on target without roll and pitch compensation by the Pointer (Tracking Operator).
2. Power operation permits control of Gun Director from below deck by Radar Search Operator.
3. Power operation permits automatic Radar Tracking of target from Radar without manual limitations.

The development work and fabrication of the Gun Director Mark 61 was originally under the technical direction of APL/JHU. In March 1945 the technical direction and coordination of this project was diverted to the Bureau of Ordnance under the technical direction of Mr. Paul J. Larsen, assigned as Bureau of Ordnance Representative Re43. Three production models of Gun Director Mark 61 Mod 0, used to prove in the design, were fabricated by

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the Norge Division, Borg-Warner Corporation, Muskegon Heights, Michigan, under OSRD Contract OEMsr 1264. A total of 23 Gun Directors Mark 61 are now in production under contracts; 13 at Norge on Contract NOrd 8686; and 10 at The U. S. Naval Gun Factory, Washington, D.C., under Project E4790. Deliveries from Norge are expected to begin in July, 1946, and from the U. S. Naval Gun Factory in January, 1947. Completion of these Gun Directors is expected within the next 12 months. A more detailed account of the present status and future work outline on Gun Director Mark 61 and the associated equipment required for the complete Gun Fire Control System Mark 61 is given under Short Range and Long Range Programs Chapters VII and VIII.

A photograph of Gun Director Mark 61 is attached in PART I as Exhibit 2, for purposes of illustrating production design of director using a 30" Radar Dish.

A Photograph of the Gun Fire Control System Mark 61 is attached in PART I as Exhibit 3, for purposes of illustrating the make-up of complete system.

The following drawings are attached in PART 2 as Appendices:

A: List of Basic Components in Gun Director Mk 61.

B: FLOW DIAGRAM Gun Fire Control System Mk 61.

C: CABLE DIAGRAM Gun Director Mk 61 (BuOrd Drg. #903349)

D: CABLE DIAGRAM Below Deck Gun Fire Control System Mk 61 (BuOrd Drg. #907750)

E: GEAR SYSTEM DIAGRAM Gun Director Mk 61 (BuOrd Drg. #907500)

F: CONTROL PANELS Gun Director Mk 61 (BuOrd Drg. #907900)

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III-C GUN DIRECTOR MK 62

As a parallel development to Gun Director Mark 61 the power driven Gun Director, Mark 62 was undertaken by Endev Corporation under APL/JHU technical direction on OSRD Contract OEMsr 1246, and BuOrd Contract NOrd 7786. An experimental model was tested at University of Virginia in February of 1945. This development was terminated on June 15, 1945 after evaluation and decision by the Bureau of Ordnance to accept the design of Gun Director Mark 61. Two experimental models of the Gun Director Mark 62 were made by Endev Corporation in Chicago, one of which has been scrapped and the other shipped to the Naval Ordnance Museum at Montauk Point, Long Island, N.Y.

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IV

DIVISION OF TECHNICAL DIRECTION

Complete technical direction of the Gun Fire Control System Mark 61 is under the cognizance of Section Re4 of the Bureau of Ordnance. The reference to APL/JHU herein is solely to point out which portion of the technical work is being carried out at APL/JHU Laboratories, even though the technical direction of such work is by the Bureau of Ordnance or its representative.

IV-A AT APL/JHU

Present APL/JHU Group DEB staff at the Forest Grove Station operates under the technical direction of the Bureau of Ordnance Representative Re43, (Paul J. Larsen). Mr. Larsen has direct supervision of all technical developments and production designs for Gun Director Mark 61 and technical coordination control over the production in progress at Norge and at the U. S. Naval Gun Factory. On specific requests of the Bureau of Ordnance, APL staff members have assisted in consultation with other contractors and cooperated in coordinating designs of the other components required for the complete Gun Fire Control System Mark 61 to insure attainment of the end-results and characteristics desired.

In addition to the specific Gun Director design activities it has also been necessary for the APL/JHU staff to design and construct experimental models of other components of the System, such as; (1) Target Acquisition consoles including

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IV

DIVISION OF TECHNICAL DIRECTION

Complete technical direction of the Gun Fire Control System Mark 61 is under the cognizance of Section R64 of the Bureau of Ordnance. The reference to APL/JHU herein is solely to point out which portion of the technical work is being carried out at APL/JHU laboratories, even though the technical direction of such work is by the Bureau of Ordnance or its representative.

IV-A AT APL/JHU

Present APL/JHU Group R64 staff at the Forest Grove Station operates under the technical direction of the Bureau of Ordnance Representative R64, (Paul D. Larsen). Mr. Larsen has direct supervision of all technical developments and production designs for Gun Director Mark 61 and technical coordination control over the production in progress at Norge and at the U. S. Naval Gun Factory. On specific requests of the Bureau of Ordnance, APL staff members have assisted in consultation with other contractors and cooperated in coordinating designs of the other components required for the complete Gun Fire Control System Mark 61 to insure attainment of the end-results and characteristics desired.

In addition to the specific Gun Director design activities it has also been necessary for the APL/JHU staff to design and construct experimental models of other components of the system, such as: (1) Target Acquisition consoles including

Radar automatic tracking amplifiers and components thereof, such as the Pointers Control Units (Joy Stick); and (2) production test equipment for basic components used in the Gun Director. Close supervision and engineering assistance between APL/JHU staff and contractors in addition to Norge, required on the following components forming part of the Gun Director:

ITEM	CONTRACTOR
Gun Director Mk 61 Mods 1 & 2	
Complete Assembly	Norge Division
Basket Sub-assembly	Peters-Dalton, Incorporated
Shell Assembly	Detroit Michigan Stove Co.
Gun Director Mk 61 Mod 3	
Complete Assembly	U. S. Naval Gun Factory
Basket Sub-Assembly	Peters-Dalton Inc.
Shell Structure	Detroit Michigan Stove Co.
Slew Sight Mk 6 Mod 0 (Based on APL/JHU-Norge Design)	U. S. Naval Gun Factory Washington, D. C.
Optical Sight Mk 92 Mod 2 (Based on APL/JHU Farrand Optical Co. redesign of Mark 60 Telescope)	U. S. Naval Gun Factory Washington, D. C.
See Blueprint Telescope Mk. 92 Mod. 2 (BuOrd Dwg. No. 909997) Appendix "G" Part 2. (2 sheets). See Photograph Appendix "H", Part 2.	
Hydraulic Drive System (Based on APL/JHU-Vickers Design)	Vickers Incorporated, Detroit, Michigan
Pointers Control Unit for Target Acquisition Unit	Submarine Signal Company, Boston
Amplifier (Tracking) etc.	Electronic Tube Corporation, Phila., Pa.

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Motor Controller	Cutler Hammer Company Milwaukee, Wisconsin

See Photograph Appendix "I", Part 2.

Electrical Control Cabinets, etc.	Sight Light Corporation, Deep River, Conn.

See Photographs Appendix "J-1 to J-40", Part 2.

D. C. Filter	Raytheon Manufacturing Co., Waltham, Mass.
Radar Worm Transmission	Michigan Tool Corporation, Michigan
T. & E. Scope	Electronic Tube Corporation, Phila., Pa.
Open Sight	U. S. Naval Gun Factory, Washington, D. C.

See Photograph Appendix "K", Part 2.

In all, approximately 18 contractors and 14 sub-contractors are at present involved in fabricating components for the Gun Director Mark 61, excluding those directly under Bureau of Ordnance Contract on other components of the Gun Fire Control System Mark 61.

IV-B By Bureau of Ordnance, Section Re-4c

Upon termination of technical direction by APL/JHU of the Gun Fire Control System Mark 57, Section Re4c, of the Bureau of Ordnance assumed technical direction thereof. This is now under the guidance of Comdr. Lloyd Mustin and Mr. David Gold. Technical responsibility of the design and operational characteristics of the computer components of

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Gun Fire Control System Mark 61 is likewise under the technical of Section Re4c. The computer components and the companies producing same, are as follows:

COMPONENTS	COMPANY
Computer Mark 16 Mod 2	Submarine Signal Company
See Photograph Appendix "L", Part 2.	
Computer Mark 33 Mod 1	Submarine Signal Company
See Photograph Appendix "M" Part 2.	
Computer Mark 17 Mod 3	Eastman Kodak Company
See Photograph Appendix "N" Part 2.	
Stabilizer Unit Mark 1 Mod 1	Eastman Kodak Company
See Photograph Appendix "O" Part 2.	
Wind Transmitter Mark 4 Mod 5	Sperry Corporation
See Photograph Appendix "P" Part 2.	
Motor Generator Set	Louis-Allis Company
See Photograph Appendix "Q" Part 2.	
Motor Controller	Cutler Hammer Company
Parallax Computer Mark 5 Mod 0	Ely-Reeves, New York City
See Photograph Appendix "R" Part 2.	
Gun Order Corrector Mark 3	Ely-Reeves, New York City
See Photograph Appendix "S" Part 2.	
Amplifier Mark 10 Mod 0	Ely-Reeves, New York City
See Photograph Appendix "S" Part 2.	
Relay Transmitter Mark 13	Ely-Reeves, New York City

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Close association and cooperation is maintained between Re4c and APL/JHU staff to insure coordinated system, design and performance.

IV-C By Bureau of Ordnance, Section Re-4f.

Upon termination of technical direction by APL/JHU of the Radar System Mark 39, Section Re4f of the Bureau of Ordnance assumed technical direction thereof, this is now under the guidance of Mr. James Bridges and Lt. J. A. Rexroth. Technical direction of design and operational characteristics of the Radar Equipment Mark 47 for the Gun Fire Control System Mark 61 is likewise under the cognizance of Re4f. The components of Radar System Mark 47 produced by the Submarine Signal Company are as follows:

Radar Console Mark 3 Mod 2
See Photograph Appendix "U" Part 2.
View shown is Mark 3 Mod 1, lower panel is moved to top for Mod 2.

Radar Console Mark 6 Mod 0 housing

Target Acquisition Unit Mark 4 Mod 0

Automatic Tracking Unit Mark 5 Mod 0

Antenna Mark 5 Mod 1

Transmitter Receiver Mark 4 Mod 0

Voltage Regulating Transformer

Wave Guide System
Close coordination and cooperation exists between Section Re4f, Submarine Signal Co. and APL/JHU staff to insure a coordinated system.

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V

PROPOSED ALTERNATIVE PROGRAMS

In view of post-war transitions being made in the manufacturing and research organizations which have been associated with this task, including the APL/JHU Laboratory, considerations must be given at this time to the most effective organizational set-up necessary in the future to continue coordination of the inter-related developments and carry through to completion the present Gun Fire Control System Mark 61 as well as promotion of future research, developments, and improvements of gun fire control systems in general. If it is the intention of APL/JHU to divest itself of all applied engineering developments except fundamental basic research, the problem is to determine how the present "Gun Fire Conrol" activity can be most effectively continued for the benefit of the Bureau of Ordnance. The following alternative programs are submitted as suggestions for both Short Range and Long Range Programs: (See Chapters VII and VIII for interpretation of these programs.)

Proposal 1. APL/JHU SHORT RANGE PROGRAM.

Continue present contract for the short range program with present APL/JHU staff under direct technical supervision of Re43. Experience over the past year has proven this arrangement extremely effective in the development of models and designs for production, as well as to effectively coordinate production activities among several contractors including the U. S. Naval Gun Factory. This has been largely due to the fact that the group under Re43 has been able to function to advantage as a semi-independent agency under the

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"Section T Pattern" of APL/JHU, in addition to having an official status as part of the Bureau of Ordnance. A comparatively high degree of specialization in gun fire control technique has been achieved by this group in its extremely close association with the Bureau of Ordnance, the Naval Research Laboratory and the U. S. Naval Gun Factory.

Proposal 2. KELLEX CORPORATION: SHORT RANGE PROGRAM

Transfer present task and present personnel of APL/JHU, Group DEB to Kellex Corporation, on same basis to continue the present short range program under the technical direction of the Bureau of Ordnance Representative Re43 as heretofore. Assuming that contracturally this is possible and that the present facilities at Forest Grove Station are maintained and that the present personnel is transferred, this proposal should be as effective as Proposal 1 above for completion of the short range program within the same time period.

Proposal 3. SUBMARINE SIGNAL COMPANY, SHORT RANGE PROGRAM

Transfer task and necessary technically qualified personnel to Submarine Signal Company in Boston, upon completion of present design, laboratory tests and shore base field tests of the Gun Fire Control System Mark 61, but before the System has been initially proven by shipboard tests. (Approximately January 1947) Submarine Signal Company has agreed to accept from the Bureau of Ordnance, a contract to assume responsibility of the overall Gun Fire Control System Mark 61 except for the mechanical design of the Gun Director Mark 61 per se. This obligation by

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"Section 7 Potter" of APL/JHU, in addition to having an official status as part of the Bureau of Ordnance. A comparatively high degree of specialization in Gun Fire Control technique has been achieved by this group in its extremely close association with the Bureau of Ordnance, the Naval Research Laboratory and the U. S. Naval Gun Factory.

Proposal 2. KOLLSMAN CORPORATION: SHORT RANGE PROGRAM

Transfer present task and present personnel of APL/JHU, Group D23 to Kollsman Corporation, on same basis to continue the present short range program under the technical direction of the Bureau of Ordnance Representative Dets as heretofore. Assuming that contractually this is possible and that the present facilities at Forest Grove Station are maintained and that the present personnel is transferred, this proposal should be as effective as Proposal 1 above for completion of the short range program within the same time period.

Proposal 3. SUBMARINE SIGNAL COMPANY, SHORT RANGE PROGRAM

Transfer task and necessary technically qualified personnel to Submarine Signal Company in Boston, upon completion of present design, laboratory tests and shore base field tests of the Gun Fire Control System Mark 81, but before the System has been initially proven by shipboard tests. (Approximately January 1947) Submarine Signal Company has agreed to accept from the Bureau of Ordnance, a contract to assume responsibility of the overall Gun Fire Control System Mark 81 except for the mechanical design of the Gun Director Mark 81 per se. This obligation by

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Submarine Signal Company entails training and furnishing of personnel for installation, maintenance and service as required to insure operability of such systems installed in the fleet, make such improvements as changing military requirements demand, prepare Ordalts and modify equipment. The Submarine Signal Company in agreeing to accept this responsibility has an interest in having as many of the present personnel from APL/JHU whom are technically qualified transferred to their organization. To affect such transfer of such qualified personnel and all necessary and essential facilities at Forest Grove Station to Submarine Signal Company without jeopardizing current work, such transfer should not be made before the early part of 1947.

Proposal 4. APL/JHU LONG RANGE PROGRAM

For the proposed long range program (Chapter VIII) continue present contractural arrangement between Bureau of Ordnance and APL/JHU, but reduce staff after completion of short range program to a basic group of approximately 2 physicists, 6 engineers and necessary technicians to act as consultants to the Bureau of Ordnance in coordinating, planning, and conducting research on fire control systems to meet future needs based on advanced design of weapons and missiles, and to apply advanced technological developments to this field.

Assuming the short range program is continued under Proposals 1, 2 or 3, a select group of the present APL/JHU staff carrying out the short range program should be retained as a part of the APL/JHU structure, to conduct the research and development of future Gun Fire

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Control Systems as specifically assigned by the Bureau of Ordnance. Coordination between this group with outside contractors or governmental plants who are to manufacture such future gun fire control systems should preferably be maintained through a similar technical direction authorization as now exists by Re43 of the Bureau of Ordnance. The advantage of a semi-independent and specialized research and engineering staff functioning as at present, cannot be too strongly advocated, since such a disinterested and technically competent, non-profit motivated, coordinating group can most effectively initiate and promote those advancements which will insure the highest degree of performance to meet the changing military requirements.

Proposal 5. SUBMARINE SIGNAL COMPANY LONG RANGE PROGRAM

For a limited long range program specific to improvements to Gun Fire Control System Mark 61 only (Chapter VIII-C-1-a to VIII-C-1-f inclusive only) contractural arrangements should be entered into between Bureau of Ordnance and Submarine Signal Company to undertake all improvements and modifications to Gun Fire Control System Mark 61 in the future. Personnel assigned or transferred to Submarine Signal Company under Proposal 3 above from APL/JHU in addition to others technically qualified specifically assigned by Submarine Signal Company from their organization to this task should insure the Bureau of Ordnance that improvements will be made for overall superior performance. Limitation to this long range program is the question whether the close liason, coordination and cooperation which will be required between the Submarine Signal Company, the U. S. Naval Gun Factory, the Naval

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Research Laboratory and others can be maintained without a disinterested semi-independent group with an official status as part of the Bureau of Ordnance, such as present group operating under a Bureau of Ordnance representative, having responsibility over technical direction and coordinated design.

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VI

CONTRACT RECOMMENDATIONS

A. APL/JHU Short and Long Range Programs

On the assumption that APL/JHU will continue to carry on Gun Fire Control System developments under contractural relationship with the Bureau of Ordnance on the short range program and research and development on a long range basis, it is recommended that Proposals 1 and 4 above, be adopted.

B. APL/JHU Long Range Program Only

On the assumption that APL/JHU only wishes to carry out fundamental basic research on Gun Fire Control Systems under contractural relationship with the Bureau of Ordnance on a long range program, according to Proposal 4, it is the writer's opinion that Proposal 2 would be the most beneficial short range program for the Bureau of Ordnance. This recommendation is based upon the fact that no change in present personnel or laboratory location will be required to complete the short range program and its technical completion would be assured at an earlier date with least organizational changes. This recommendation is also based on the closer coordination and cooperation which will exist between APL/JHU and Kellex, both being in Washington and in view of their other joint contractural relations with the Bureau of Ordnance.

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V

CONTRACT RECOMMENDATIONS

A. AFL/JHU Short and Long Range Programs

On the assumption that AFL/JHU will continue to carry on Gun Fire Control System developments under contractural relationship with the Bureau of Ordnance on the short range program and research and development on a long range basis, it is recommended that Proposals 1 and 4 above, be adopted.

B. AFL/JHU Long Range Program Only

On the assumption that AFL/JHU only wishes to carry out fundamental basic research on Gun Fire Control Systems under contractural relationship with the Bureau of Ordnance on a long range program, according to Proposal 4, it is the writer's opinion that Proposal 2 would be the most beneficial short range program for the Bureau of Ordnance. This recommendation is based upon the fact that no change in present personnel or laboratory location will be required to complete the short range program and its technical completion would be assured at an earlier date with least organizational changes. This recommendation is also based on the closer coordination and cooperation which will exist between AFL/JHU and Keller, both being in Washington and in view of their other joint contractural relations with the Bureau of Ordnance.

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C. Submarine Signal Co. Short and Limited Long Range Program

Assuming that APL/JHU does not wish to carry on further Gun Fire Control System development and research on either the short range or the long range basis under contractural relationship with the Bureau of Ordnance it is the writer's opinion, based on his interest in this project, his intimate knowledge of this task, the coordination of responsibilities, the cooperation and the organizational procedures established that the most effective contractural relationship would be adoption of Proposals 3 and 5 above.

D. Bureau of Ordnance Recommendation

The Bureau of Ordnance, Section Re4c has expressed preferance for continuation of Proposal 1 until March 1947 at which time Proposal 3 and 5 with Submarine Signal Co. should take effect on new contract now being negotiated. The Bureau of Ordnance has also expressed desire that APL/JHU at that time continue to retain a few of the present key people now on the project to assist in the shipboard tests and evaluate results for the Bureau of Ordnance for a period of at least 6 months. This Bureau of Ordnance recommendation is submitted herewith to assist APL/JHU in formulating their plan and policy.

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VII

SHORT RANGE PROGRAM

The Short Range Program entails the completion of all developments, designs, models, drawings, specifications, test equipment, laboratory tests, shore base field tests and shipboard tests of all components forming part of the Gun Fire Control System Mark 61, as well as cooperating in establishing a training program of Operators at the Fire Control School. The scope of this program is outlined in greater detail hereunder.

VII-A Time Scale - Approximately 12 to 14 months will be required to complete the present Gun Fire Control System Mark 61 now under development and manufacture as set forth in greater detail under Work Outline VII-C. This includes active coordination with interrelated contractors on Bureau of Ordnance research and production contracts and cooperation and coordination of the technical problems arising in connection therewith. Exhibit 4 attached hereto is a "Progress Chart" showing development of Gun Fire Control System Mark 61. The data thereon gives the progressive development stages of the system and shows the time factors involved in respect to delivery, laboratory tests, shore base field tests and shipboard tests based upon the latest delivery promises from contractors. This "Progress Chart" will be referred to numerous times hereafter.

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VII-B Personnel - Future Personnel requirements will be governed to a large extent by the time scale adopted, the extent of field testing and the location and accessibility of the test fields. The present APL/JHU group involved in laboratory activity only consists of the following:

		APL/JHU	Navy
(a)	Development and design, including Administrative and clerical	9	
(b)	Drafting and specifications	8	2
(c)	Model Shop and test equipment	16	1
(d)	Field Service (Laison and testing)	3	7
(e)	Part Time Condultants (A.S.Locke)	1	
	Totals	37	10

On the basis of the above estimated Time Scale VII-A, and the Work Outline below VII-C (Short range program), the present staff with the possible addition of two or three more engineers in the Field Service Classification should be adequate, this increase may be offset by a similar reduction in the Model Shop and Drafting classifications. Additional personnel will be required for field installation, testing and service, but these will be mostly Navy personnel assigned from time to time by the Bureau of Ordnance, the U. S. Naval Gun Factory and the Fire Control School. These men will ultimately supervise production system tests or actual installations and operate systems on vessels. However, concurrent therewith APL/JHU engineers

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VII-B Personnel - Future personnel requirements will be governed to a large extent by the time scale adopted, the extent of field testing and the location and accessibility of the test fields. The present AFL/UTU group involved in laboratory activity only consists of the following:

	AFL/UTU	Navy
(a) Development and design, including Administrative and clerical	9	
(b) Drafting and specifications	8	2
(c) Model Shop and test equipment	16	1
(d) Field Service (Delson and testing)	3	7
(e) Part Time Consultants (A.S.Locke)	1	
Totals	37	10

On the basis of the above estimated time Scale VII-A, and the Work Outline below VII-C (Short range program), the present staff with the possible addition of two or three more engineers in the Field Service Classification should be adequate, this increase may be offset by a similar reduction in the Model Shop and Drafting classifications. Additional personnel will be required for field installation, testing and service, but these will be mostly Navy personnel assigned from time to time by the Bureau of Ordnance, the U. S. Naval Gun Factory and the Fire Control School. These men will ultimately augment production system tests or actual installations and operate systems on vessels. However, assignment thereof with AFL/UTU engineers

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will be required to supervise installations and tests and evaluate the test results of the extensive field test program described in detail under Test Program VII-D, hereafter.

Exhibit 5 attached hereto is a "Personnel Chart" showing the peaks at APL/JHU of personnel employed on Gun Fire Control Systems Marks 57, 61 and 62. The trend of peaks are of interest in evaluating present personnel.

VII-C Work Outline

VII-C1 Gun Director Mark 61

VII-C1-a Complete present design of production Gun Directors Mark 61 including such modifications which are necessary to adapt associated system components, approve all designs, production drawings and design changes. Estimate completion by October 1946.

VII-C1-b Complete laboratory tests of 270 volt DC Filter Supply for complete system, design production unit and prepare production drawings and specification, arrange procurement. Estimate completion by September 1946.

VII-C1-c Coordinate changes with Vickers Incorporated to Hydraulic Power Drive and Servo system to improve operational characteristics and accessability for adjustment and servicing. Estimate completion by August 1946.

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VII-C1-d Redesign radar antenna structure of gun director to accommodate 48" Radar Dish. This redesign entails change to structure, drive shafting, cable housing and wave guide system. Redesign cannot be undertaken until 48" Radar dish and Antenna box design has been completed by Submarine Signal Company estimated by about September 1946, redesign should be completed by October 1946. This revision will not be incorporated on Norge Directors but structure etc, will be produced by the U. S. Naval Gun Factory for installation on Norge Directors on shipboard on or about March 1947.

VII-C1-e Conduct laboratory and field tests on Slew Sight Mark 6 Mod 0 when same is available. The U. S. Naval Gun Factory is manufacturing these Slew Sights from Norge - APL/JHU design. Tests are required to determine electrical sensitivity, operational characteristics and mechanical stability. First production unit expected by September 15, 1946, estimate completion of tests by November 1, 1946.

VII-C1-f Establish laboratory test procedure and test tolerances for Pointers Control Unit to ascertain optimum characteristics of electrical and viscous damping units of Control. First unit available from U. S. Naval Gun Factory from APL/JHU design,

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expected by September 15, 1946, estimate completion of tests by November 15, 1946.

VII-C1-g Conduct tests on Horizon Indicator Mark 4 Mod 0 to determine damping and allowable deviation from true horizon at different acceleration rates to ascertain accuracy and response characteristics. First Production unit from Norge expected August 15, 1946, estimate completion of tests by November 1, 1946 contingent upon completion of Test Unit Mark 28 Mod 0 being partially made by Norge.

VII-C1-h Design, prepare production drawings, and specifications for 60 cycle filter to reduce noise-to-signal ratio of servo system in gun director to improve tracking performance at long range, i.e. at low tracking rate. This work cannot be undertaken until complete gun director from Norge with all standard production units is received. Expect Gun Director Mark 61 Mod 1, Serial #4, from Norge about August 15 for preliminary roll and pitch tests at Forest Grove Station. Above design should be completed by September 15 and production filters available by November 1, 1946. See Exhibit 4 attached hereto.

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VII-C1-i Design, prepare production drawings and specification, and procure Heater System for Director required to maintain temperature of Shell Assembly, required to reduce condensation and retain control system, i.e., hydraulic etc., within temperature range for efficient and optimum performance. Design completion expected by September 1, 1946 and production units should be available by December 1, 1946 for installation on Norge Directors produced prior thereto.

VII-C1-j Coordinate design modifications and testing of directors with Norge, U. S. Naval Gun Factory, Naval Research Laboratory and other system component manufacturers to insure proper assembly and operation of overall system and interchangeability between Norge and U. S. Naval Gun Factory production components.

VII-C1-k Prepare such modifications to production design drawings, specifications and tests as may be found necessary after laboratory, shore base field and shipboard tests. Such tests using all standard production components in Director per se cannot be made until after December 1, 1946, and of complete production system, not until February 1, 1946 at the earliest. Estimate at least 4 months will be required after these dates to determine essential

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modifications, based upon evaluation of test results. See Exhibit 4 attached hereto.

VII-C2 Radar System Mark 47

VII-C2-a Radar System Mark 47 consists of two consoles (a) Radar Console Mark 3 Mod 0 housing the Radar Modulator, Range Unit Power supply etc., and (b) Radar Console Mark 6 Mod 0 housing the Target Acquisition Unit Mark 4 Mod 0, the Automatic Tracking Unit Mark 5 Mod 0, the below deck Director Pointers Control and Ships Search Synchros and servos. This Radar System is being manufactured by the Submarine Signal Company under two contracts. BuOrd Research Contract NOrd 9598, covers 4 systems, Mod 0, delivery of which is promised in November 1946. BuOrd Production Contract NORD 9576 for 20 Systems, Mod 1, are scheduled for delivery at 5 per month beginning January 1947. The delay in obtaining these systems has necessitated modifications of 3 Radar Consoles Mark 39 by APL/JHU to facilitate making overall gun fire control system tests with first production gun directors from Norge. The Radar System Mark 47 will incorporate the improvements which have been determined on tests conducted at Forest Grove Station and at Chesapeake Bay Annex, jointly between the Submarine Signal Company, the Naval Research Laboratory and APL/JHU.

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VII-C2-b Complete the design and construction of two Target Acquisition consoles incorporating automatic radar tracking to simulate Radar Console Mark 4 Mod 0 of Radar System Mark 47. These consoles will be used with the modified Radar Systems Mark 39 to facilitate laboratory tests at Forest Grove Station and shore base field tests at Chesapeake Bay Annex and at Dam Neck with production gun directors Serial #4 and #5 from Norge in August 1946, to ascertain overall system performance and determine modifications, if any, required to the Radar System Mark 47, manufactured by Submarine Signal Company. See Exhibit 4 attached hereto.

VII-C2-c Complete construction and test of below deck Director Pointer's Control Unit and coordinate and furnish design information and model to Submarine Signal Company for production design by them for use in Radar Console Mark 6 Mod 0.

VII-C2-d Coordinate and cooperate in the design of the Wave Guide System for the Gun Director with Submarine Signal Company, including the revisions required to accommodate the 48" Radar Dish. Design of Antenna and 48" Radar Dish is not expected from Submarine Signal Company until September 1946. Mock-up will be required for installation on gun director at Norge to determine clearances and installation accessability. Estimate completion of design by October 1946 at APL/JHU.

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VII-C2-e Modify 2 Radar Systems Mark 39 by incorporating therein the improvements made in the Radar System Mark 39 Console used at Forest Grove Station, on test of System. These modifications include such revisions as (a) new range rate pots, (b) new range rate indicator, (c) decreased range synchro speed 2:1 and changing 1F synchro to a 3G Synchro, (d) wiring revisions, (e) additional shielding etc. Estimate completion by September 1. These modified Radars Mk 39 will be used for the laboratory and preliminary field tests with the Target Acquisition consoles constructed by APL/JHU. (See VII-C2-b)

VII-C2-f Coordinate design with Submarine Signal Company of 48" Radar Antenna to insure adaptability of mounting on gun director.

VII-C2-g Conduct tests on modified Radar Systems Mark 39 and on Radar System Mark 47 Mod 0, and conduct comparison tests to determine operational characteristics. Tests will be conducted at Forest Grove Station and at Chesapeake Beach Annex jointly by APL/JHU, Naval Research Laboratory and Submarine Signal Company. Tests will establish response characteristic required from Automatic Tracking Unit after production gun director is available.

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VII C-3 Computers Mark 16 Mod 2 and Fuze Time Computer Mark 33 Mod 1.

VII C-3a. Submarine Signal Company has two contracts for designing & producing Computers Mark 16, Mod 2 and Mark 33, Mod 1 (a) BuOrd Research Contract NOrd 7923 covers 6 of each; these have all been delivered, two (2) to NRL and four (4) to APL/JHU. Three of each of these computers have been returned by APL/JHU to Submarine Signal Company for modification based upon tests which have been conducted at CBA and at APL/JHU. The fourth unit of each has been revised at APL/JHU to correct for phasing and other defects revealed on test. (b) BuOrd Production Contracts NOrd 9288, covers 20 Computers Mark 16 Mod 2 and NOrd 9289 covers 20 Fuse Time Computers Mark 33 Mod 1; these combined with the three above mentioned with corresponding computers will be used to complete the 23 Gun Fire Control Systems Mark 61, now being produced.

VII C-3b. Test first 3 production computers of each type at Forest Grove Station, with gun directors and radar system to ascertain that all improvements recommended in computers have been made in production.

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VII C-3c. Furnish the BuOrd and Submarine Signal Company theory, data and procedure for computation of new ballistic combinations for Computers & Radar and complete calculations for 3"/50 primary ballistics and 40 mm secondary ballistics. Estimate this will be completed by August 1, 1946. Submarine Signal Company will thereafter be responsible for future calculations.

VII C-3d. Coordinate and cooperate in preparing below deck interconnecting cable and wiring diagrams with Submarine Signal Company and the Bureau of Ships for complete Gun Fire Control System Mark 61.

VII C-4 Wind Transmitter Mark 4 Mod 5.

VII C-4a. For Gun Fire Control System Mark 61, 23 Wind Transmitters Mark 4 Mod 5 are required. Bureau of Ordnance Production Division Pr7c, has placed Contract NOrd 9396 with Sperry Corporation for 18 Wind Transmitters. Norge has placed contract with Sperry Corporation for the balance of 5 required. Delivery is expected by November 1, 1946. APL/JHU have submitted design revision to Mod 5, for addition of Synchro Capacitors to meet Bureau of Ships requirements. These modifications will be made

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by Sperry Corporation in above Wind Transmitters. Subsequent tests will be necessary at APL/JHU on initial production units to insure proper phasing and interconnection with associated equipment. Estimate completion of tests by November 15, 1946 based on above delivery.

VII C-5 Parallax Corrector Mark 5, Relay Transmitter Mark 13, Amplifier Mark 10, and Gun Order Corrector Mark 3.

VII C-5a. These units are being developed and produced by Ely-Reeves Company, under Bureau of Ordnance technical direction and contract. APL/JHU will be required to test first production unit of each in conjunction with Gun Fire Control System Mark 61 to insure proper interconnection, phasing and response characteristics. These tests cannot be conducted until complete Gun Fire Control System is installed at CBA or other test location established by the Bureau of Ordnance.

VII C-6 Instruction Books.

Assist in preparation of instruction service and operational manuals, charts and diagrams on Gun Fire Control System Mark 61. (This instruction manual may be broken down into several individual books, i.e. Gun Director Mark 61, Radar Equipment Mark 47 and Gun Fire Control System Mark 61, as decided by the Bureau of

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Ordnance.) Estimate completion of preliminary form by February 1, 1947.

VII C-7 Procurement and Test Specifications.

Inasmuch as the various components of the Gun Director Mark 61 and Gun Fire Control System Mark 61 are produced by different manufacturers, it is necessary that rigid procurement and test specifications be prepared so that all components of the gun director and of the system will perform at the precise functional level required when these components are assembled as a gun director and in a gun fire control system. To achieve that end, procurement and test specifications have been and are being written for the following units:

Unit	Procurement Spec.	Test Spec.
A. Train and Elevation Hydraulic Power Drive	O.S. 3861	O.S. 3922
B. Kollsman Voltage Generators		O.S. 3923
C. Stabilizer Unit Mark 1	O.S. 3689	O.S. 3924
D. Horizon Indicator Mark 4 Mod 0		O.S. 3926
E. Train and Elevation Cathode Ray Oscilloscope		O.S. 3927
F. Tracking Amplifier		O.S. 3928
G. Miscellaneous Electrical Units of Gun Director Mark 61		O.S. 3929
H. Mechanical Units of Gun Director Mark 61		O.S. 3930

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I. Pointers Control Unit		O.S. 3931
J. Alignment of Optical System of Gun Director Mark 61		O.S. 3932
K. Gun Director Mark 61	O.S. 3825	O.S. 3933
L. Gun Fire Control System Mark 61	O.S. 3915	none assigned
M. Electric Motor for Hydraulic Power Drive	O.S. 4654	

VII C-8 Test Equipment

In order to achieve the precise and coordinated performance required of the components of the gun director and the system, it has been necessary to design special test equipment and to supply this test equipment to the manufacturers, Naval Gun Fire Control School and assemblers of these components. Test equipment has been or is being designed and constructed to test the following items:

Item	Test Unit	Procurement Spec
A. Hydraulic Drive assembly	Mk 26 Mod 0	O.S. 3917
B. Gyro Units for Computers and Stabilizers	Mk 27 Mod 0	O.S. 3917
C. Stabilizer Unit Mark 1	Mk 28 Mod 0	O.S. 3925
D. Computer Mark 17	Mk 28 Mod 0	O.S. 3925
E. Horizon Indicator Mark 4 Mod 0	Mk 28 Mod 0	O.S. 3925
F. Kollsman Generators	Mk 29 Mod 0	O.S.
G. T & E Scope Power Supply	none assigned	
H. T Pad Anteruation Network	"	"
I. Test Unit for Gun Director Response Test	"	"

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VII-C-9 AMPLIDYNE DRIVE

The investigation of motor characteristics and adaptation of suitable motors to the drive systems in Gun Director Mark 61 has been started. This work is being continued to obtain comparative tests for evaluation of electric vs. hydraulic power drive, as requested by the Bureau of Ordnance. Estimate Completion by February 1, 1947.

VII-C-10 GUN FIRE CONTROL SYSTEM TESTS: LABORATORY & SHORE BASE

VII-C-10-a LABORATORY

Complete system test at Forest Grove Station on roll and pitch platform using the first production Gun Director Mark 61, delivery of which is expected in August 1946 from Norge with non-production Computer and Radar Systems to ascertain performance characteristics of System before shipment to CBA for laboratory field test. Estimate 2 months for completion.

VII-C-10-b CHESAPEAKE BEACH ANNEX OF NAVAL RESEARCH LABORATORY

Gun order analysis, both primary and secondary ballistics and fuze order analysis tests performed on roll and pitch platform at Chesapeake Bay Annex of NRL with system of VII-C-10-a above. Tests should bring out any errors which then can be analyzed to determine cause of error and steps taken to incorporate production changes as required to remedy.

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Gun order analysis, both primary and secondary ballistics and fuze order analysis tests performed on roll and pitch platform at Chesapeake Bay Annex of NRL with system of VII-C-10-a above. Tests should bring out any errors which then can be analyzed to determine cause of error and steps taken to incorporate production changes as required to remedy.

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VII-C-10-c COMPARISON TEST WITH GUN FIRE CONTROL SYSTEM MARK 56

If possible a Gun Fire Control System Mark 56 should be tested on the same Roll and Pitch platform and under same conditions at Chesapeake Beach Annex so that direct comparison between the two equipments may be made.

VII-C-10-d FIRING TESTS (DAM NECK PROVING GROUND)

These tests will simulate ship board operating conditions and will include actual firing results. Tests will be made with a typical Gun Fire Control System Mark 61, including all production components so that both optical and radar target acquisition tests may be conducted. The modified Radar Mark 39 with APL/JHU Target Acquisition Console may be used if the Radar Mark 47 is not available.

VII-C-10-e ESTIMATED TIME & PERSONNEL

These tests will require a minimum of four to six months starting not earlier than September 1946. In addition to personnel from Naval Research Laboratory and U.S. Naval Gun Factory, APL/JHU personnel of at least 4 engineers will be needed to supervise and assist in installation and training of operating fire control personnel. Some Navy Fire Control School personnel now being trained at APL will also be available. See Exhibit 4 attached hereto.

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VII-C-11 SHIPBOARD INSTALLATION AND TESTS

Tests of Gun Fire Control System Mark 61 on shipboard should next be conducted, using only standard production manufactured equipment throughout. Gun Director Mark 61 Mod 2, Serial #7 with Radar System Mark 47 and other computer systems, will not be available until January 1947, at least one month will be required at APL/JHU to test complete system prior to shipment to Proving Ground (Dam Neck) or direct to ship as determined by the Bureau of Ordnance and the OP. Dev. Force. Tests on ship will be made by the OP. Dev. Force in accordance with their procedures. These tests will require from three to five months minimum and a complete USN operating and installation crew will be needed to install, test, and to train regular ships fire control crew as required. In addition, at least two civilian engineers fromthe APL/JHU group should be present during installation and tests and such representatives of the contractors as may be required or desired. See Exhibit 4 attached hereto.

VII-C-12 EVALUATION OF TEST DATA

Results of tests above (VII-C-10 and 11 will be studied to determine what modifications, if any, are needed for ultimate end use in the fleet. Defects, improvements or modifications found necessary during tests will, if possible, be remedied to avoid future recurrance of casualties.

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VII-C-11 SHIPBOARD INSTALLATION AND TESTS

Tests of Gun Fire Control System Mark 63 on shipboard should next be conducted, using only standard production manufactured equipment throughout. Gun Director Mark 63 Mod 2, Serial 47 with Radar System Mark 47 and other computer systems, will not be available until January 1957, at least one month will be required at ADL/UNY to test complete system prior to shipment to Proving Ground (Dam Neck) or direct to ship as determined by the Bureau of Ordnance and the OP. Dev. Force. Tests on ship will be made by the OP. Dev. Force in accordance with their procedures. These tests will require from three to five months minimum and a complete UNY operating and installation crew will be needed to install, test, and to train regular ships fire control crew as required. In addition, at least two civilian engineers from the ADL/UNY group should be present during installation and tests and such representatives of the contractors as may be required or desired. See Exhibit 4 attached hereto.

VII-C-12 EVALUATION OF FIRM DATA

Results of tests above (VII-C-10 and 11 will be studied to determine what modifications, if any, are needed for ultimate end use in the Fleet. Defects, improvements or modifications found necessary during tests will, if possible, be remedied to avoid future recurrence of casualties.

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It is obvious that overlapping of tests will occur and therefore the demands on the trained engineers of the APL/JHU group will increase, it is expected however that at that time there will be an adequate number of Navy personnel trained and capable of carrying some of this load.

VII-C-13 ADDITIONAL PRODUCTION CONTRACT DESIGN REVISIONS

Additional production contracts for Gun Fire Control System Mark 61 components are planned for a total of 89 systems, plus vessel and shore base spares as required. Numerous revisions to the design of the Gun Director Mark 61, and the other components are contemplated for the additional production contract. These revisions are given in detail hereafter.

VII-C-13-a TRAIN AND ELEVATION SYNCHROS

Assemblies will be modified to the extent that both will be driven from separate gearing instead of from the power gear transmissions as in the present design. This change is recommended to facilitate installation of a micro-coupling on the input shaft of each for adjustment of all synchros simultaneously, exterior to the assembly. The design of these modifications to the synchro assemblies is completed, however the production drawings require checking. The new gear drive systems for this revision have to be designed and production drawings prepared. Estimated time - 3 months after July 1, 1946.

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VII-C-13-b SHELL ASSEMBLY

Change to base ring of shell assembly for accomodation of tapered annular leveling rings with external leveling screws. This design change requires modification of drawings and is in process at Norge. Estimated time - 3 weeks after July 1, 1946.

VII-C-13-c HYDRAULIC POWER DRIVE SYSTEM

On future production contracts the Bureau of Ordnance proposes to manufacture the Hydraulic Power Supply Units used in Gun Director Mk 61 at the U. S. Naval Gun Factory instead of on subcontract with Vickers Incorporated. This change of manufacturer will necessitate very close coordination between APL/JHU and the U. S. Naval Gun Factory in incorporating minor revisions in Vickers design to facilitate production on U. S. Naval Gun Factory facilities. Adequate test facilities for these units at U. S. Naval Gun Factory will require design and fabrication of test equipment necessary to insure that completed assembly will meet the operational characteristics of the completed system.

VII-C-13-d GYRO COMPUTER AND GYRO STABILIZER

The Eastman Kodak Company has officially advised the Bureau of Ordnance that they are not in a position to undertake further production of these units. The Bureau of Ordnance is contemplating having these units fabricated at the Naval Ordnance Plant, Indianapolis, Indiana. This change of manufacturer, of these important

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components of Gun Director Mark 61 and of the Gun Fire Control System Mark 61, will necessitate close coordination with the manufacturing organization at the Naval Ordnance Plant, Indianapolis, at least during the preliminary stages of the production, insuring that adequate test facilities are made available to test the components prior to assembly. This change in manufacturer of important components of Gun Director Mark 61 will necessitate fabrication at APL/JHU of additional test equipment for both the Naval Ordnance Plant and the U. S. Naval Gun Factory. Such design of test equipment and fabrication thereof is estimated to take approximately 5 months after September 1, 1946.

VII-C-13-e OTHER COMPONENTS OF GUN FIRE CONTROL SYSTEM MARK 61

The Bureau of Ordnance has also advised that on the future production contract, certain improvements to the Radar System and Computer System will be made to keep abreast of military requirements and service conditions. Some of these proposed changes are, (a) Automatic range, (b) increased target speed from 750 knots to 2,000 knots, (c) incorporation of windtransmitter as an integral part of Target Acquisition Unit Mk 4.

The above revisions will be made under the technical direction of the Bureau of Ordnance and incorporated by

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they
by other contractors;/will however require tests in the system under the supervision of engineers of APL/JHU, in coordination with representatives from the U. S. Naval Gun Factory, the Naval Research Laboratory and contractors. It is estimated that these modifications can not be embodied into the new production systems, even on a preproduction basis until May 1947. It is estimated that approximately 3 months will be required for testing these improvements after this date.

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VIII

LONG RANGE PROGRAM

VIII-A TIME SCALE

Any estimate of a time scale for this long range program would be indefinite, as such time scale will depend upon the scope of activities or problems which may be assigned by the Bureau of Ordnance from time to time. It is reasonable to say that such a program should be projected on a basis of three to five years to assure continuity of research and development problems.

VIII-B PERSONNEL

For a period of approximately 12 months during the present short range program, a selected group of about 2 physicists and 2 engineers should be obtained and be assigned to the short range program group to become acquainted with gun fire control problems in general and with shipboard installation and operational requirements. The eventual group to carry out the long range program should consist of approximately 3 physicists, 6 engineers, and necessary technicians, part of which should be from the present APL/JHU group to retain continuity of the technical military requirements.

VIII-C WORK OUTLINE

VIII-C-1 IMPROVEMENTS ON PRESENT GUN FIRE CONTROL SYSTEM MARK 61

VIII-C-1-a Increase range and range rates plus automatic features.

VIII-C-1-b Smaller director - possibly one man controlled

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VIII-C WORK OUTLINE

VIII-C-1 IMPROVEMENTS OF PRESENT GUN FIRE CONTROL SYSTEM MARK 61

VIII-C-1-a Increase range and range rates plus automatic features.

VIII-C-1-b Smaller director - possibly one man control

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or completely remote operated, reducing above deck weight without sacrificing performance.

VIII-C-1-c Possible redesign to "disturbed line of sight" in lieu of present "direct line of sight" to reduce below deck computer equipment.

VIII-C-1-d Development of electrically operated free gyro to replace present air operated rate gyros, this results in better response characteristics and reduces noise factor and eliminates Air Pumps. One of the present limitations of Gun Firector Mark 61 is the low signal to noise ratio and the low output level from the present air operated gyros used in the Computer Mark 17 and Stabilizer Mark 1. Considerable investigation on response characteristics has been carried on, which has revealed this limitation. Future development may overcome this limitation.

VIII-C-1-e Undertake more complete study of Target Acquisition principles and correlate requirements with other Radar Acquisition Systems aboard ship.

VIII-C-1-f Study changing of Servo system and signal control frequency to 400 cycles per second instead of 60 cycles per second. This will involve choice of adequate components and probably new design of some components to meet Bureau of Ordnance Specifications. This change to 400 cycle operation should materially reduce size and weight of below deck computer radar equipments and

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should result in Standardizing of Servo units in all equipment.

VIII-C-2 Future Research

VIII-C-2-a Coordinate gun director research and developments with others on interrelated devices and methods to meet changing military requirements.

VIII-C-2-b Undertake a basic study of fire control systems primarily for anti-aircraft and missile defense with the objective of developing a more simple yet adequate gun fire control system for automatic and blind firing operation at longer range, having shorter time constant to accomodate higher target speeds.

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FIG. 1

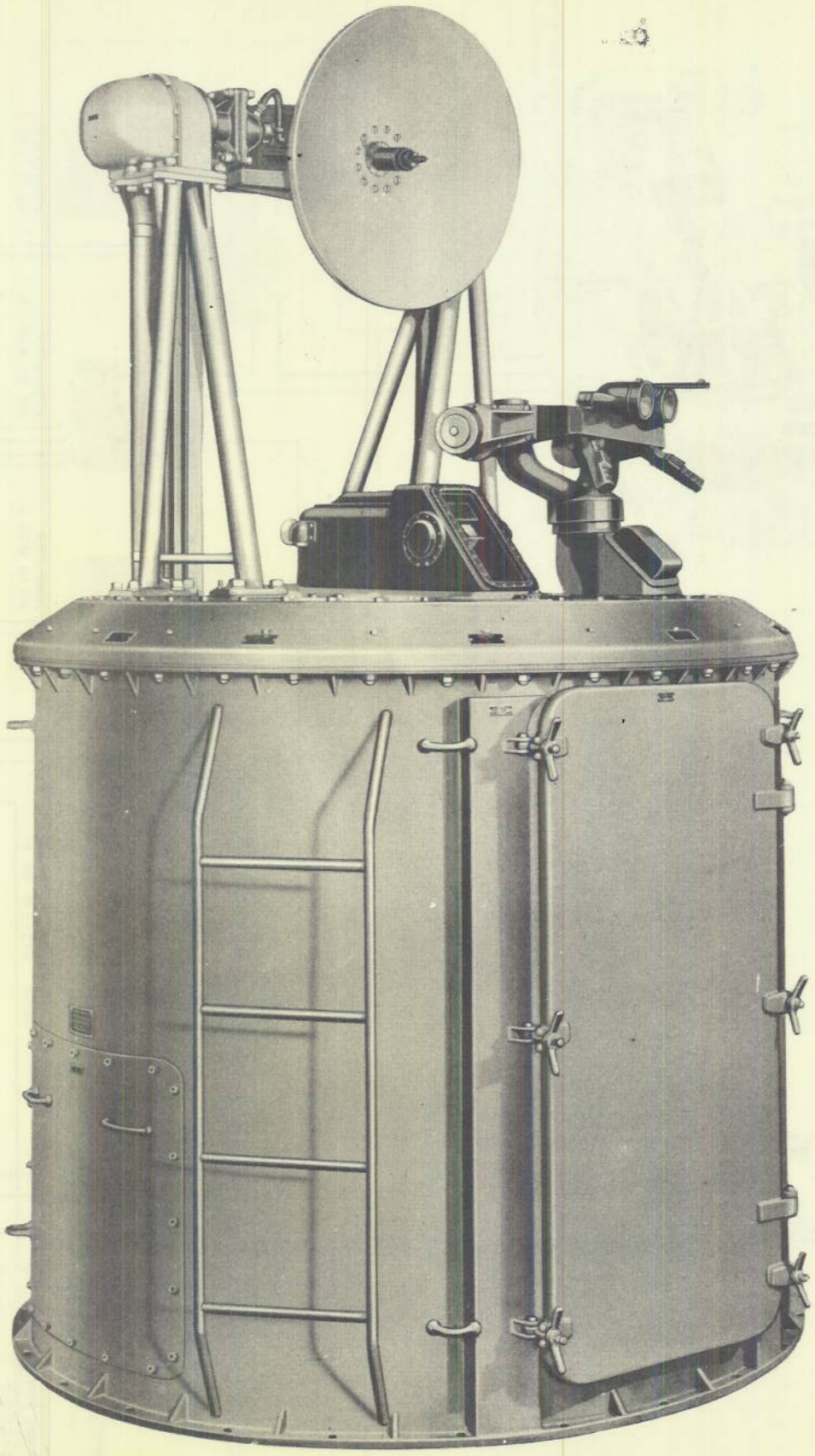

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FIG. 2

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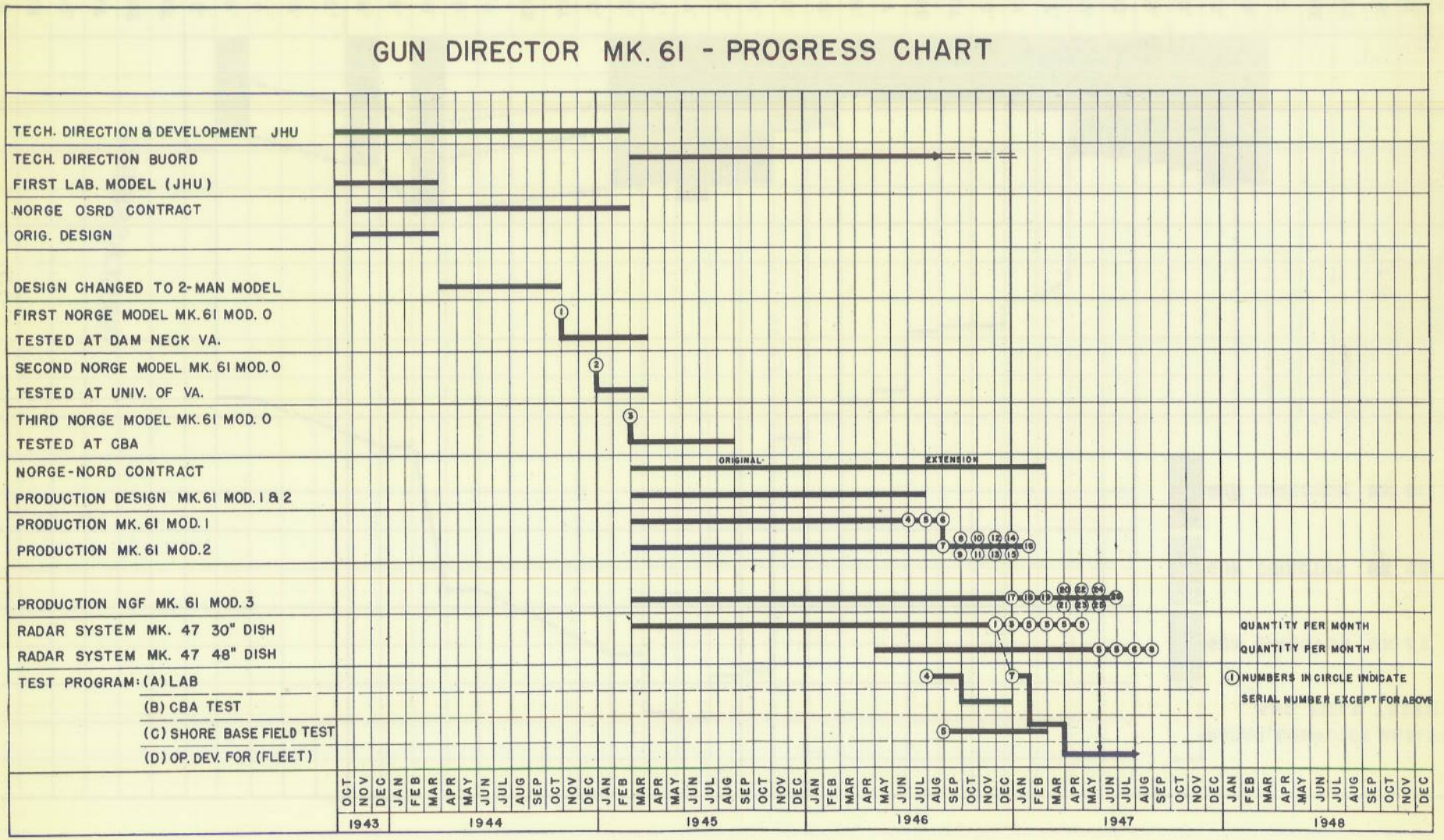
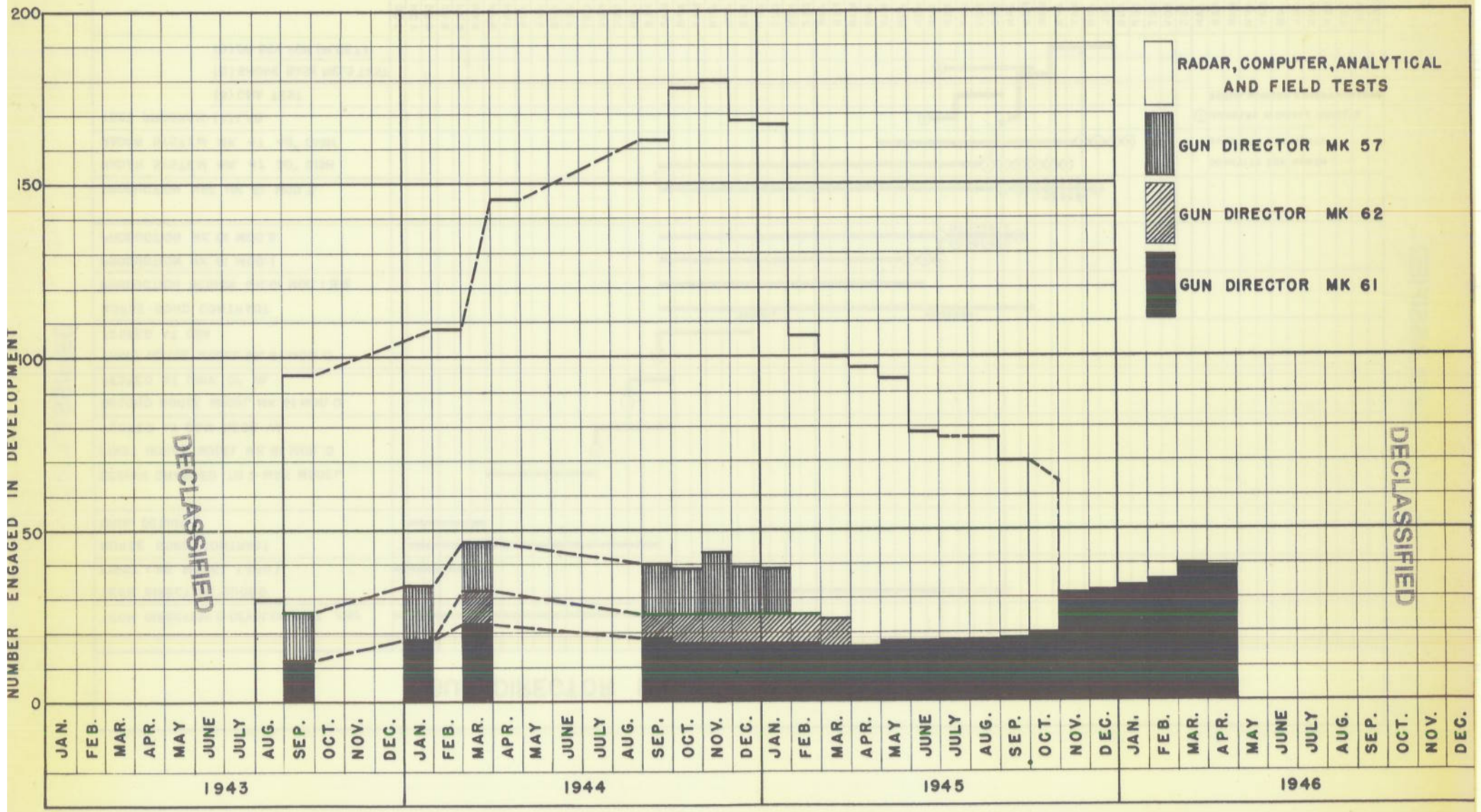
GUN DIRECTOR MK. 61 - PROGRESS CHART



CONTRACT NOrd 7386 TASK B
APL/JHU PERSONNEL-TIME CHART



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APPENDIX G

NAVAL RESEARCH LABORATORY

Report on

Mark 61 Gun Director

Method of Determining Proper Damping
Setting of Gyros for Stabilizer Mark 1

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Method of Determining Proper Damping
Setting of Gyros for Stabilizer Mark I

The Gyros must:

1. Produce a signal proportional to velocity about the gyro input axis (under static conditions)

2. Produce a signal whose amplitude increases with increase in frequency for a sinusoidal constant-amplitude input, such that the amplitude-frequency curve on a log-log plot is a straight line with a slope of plus one over as large a range as possible. This is equivalent to a rise of 6 db per octave; its purpose is to neutralize a 6db/octave drop present in the director servo, to net a flat frequency response signal under conditions of ship's motion.

A rate gyro is so designed as to produce the first of these two requirements, which is the primary purpose for which such gyros are usually employed. The second requirement may be attained only if the gyro constants are adjusted in certain definite relationships to each other. In the original design of the Mk 61 the necessary gyro adjustments were unspecified.

The correct setting of the gyro constants will here be determined, and suitable test procedure and equipment described which will enable the settings to be quickly and accurately made in production.

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GYRO EQUATIONS AND SOLUTION

The complete equation of performance for a rate gyro, as derived in "Theory of Mk 14 Gunsight" by Draper & Bentley is:

(1) $$I_g \frac{d^2\theta_g}{dt^2} + C_g \frac{d\theta_g}{dt} + K_g\theta_g = HW_i \cos\theta_g - HW_s \sin\theta_g - I_g \frac{dw_o}{dt} + M \text{ corr.} + M_i + M_u$$

where θ_g = gimbal angular displacement about gimbal (output) axis, with respect to the gyro case

I_g = moment of inertia of gimbal assembly about gimbal axis

C = viscous damping coefficient } gimbal with respect to case

k = spring constant }

w = angular velocity of gyro case:

w_i about input axis

w_s about secondary input axis

w_o about output axis

$H = I_{sp}\Omega$ = angular momentum of rotor

I_{sp} = moment in inertia of rotor

Ω = ang. velocity of rotor

M_{corr} = correction torque applied to output (gimbal) shaft as from unbalanced wts.

M_i = torque on output shaft due to the indicating system

M_u = torque on output shaft due to uncertainties (non-viscous, coulomb, etc.)

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Fig. 1 is a schematic diagram of the gyro.

Eq. 1 considers that the gimbal is suspended so that there is but one degree of freedom of the gimbal with respect to the case--viz., about the g axis.

We now make the following simplifications:

1. Let $\cos \theta_g = 1$

This is valid since θ_{gmax} for Mk 15 gyros is plus or minus 1.33° and $\cos 1.33^\circ = 0.9996$.

2. $W_s = W_o = 0$, and $\theta_i = \theta_{im} \sin w_f t$, where $W_i = \frac{d\theta i.}{dt}$

That is, consider a sinusoidal motion of displacement amplitude θ_{im} about the input axis only. These conditions may be fulfilled exactly in a test. Under service conditions, the term in eq. (1) involving W_s is small since $\sin \theta_g$ is small, and the motion W_o is unimportant.

3. $M_{corr} = M_i = M_u = 0$.

In the Mk 61 stabilizer, no M_{corr} is applied. M_i is due only to the induction coil pickoff magnetic drag and may be neglected. M_u is small and will be neglected here.

With these modifications, the gyro equation is:

$$(2)\quad I_g \frac{d^2\theta_g}{dt} + C_g \frac{d\theta_g}{dt} + K_g\theta_g = HW_i,$$

where

$$W_i = \frac{d\theta_i}{dt} = W_f\theta_{im} \cos W_f t$$

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Introducing dimensionless parameters;

$$\zeta = \frac{C_g}{2\sqrt{k_g I_g}} = \text{damping ratio} = \frac{\text{actual damping coefficient}}{\text{critical damping coefficient}}$$

$$W_n = \sqrt{\frac{k_g}{I_g}} = \text{undamped nat.frequency.} \qquad \text{and } \beta = \frac{W_f}{W_n} = \frac{\text{applied frequency}}{\text{und. nat. frequency}}$$

Equation (2) becomes:

$$(3)\quad \frac{d^2\theta_g}{dt^2} + 2\zeta W_n \frac{d\theta_g}{dt} + W_n{}^2\theta_g = \frac{H}{I_g} W_f \theta_{im} \cos W_f t$$

The steady-state part of the solution of this equation is:

$$(4)\quad \theta_{gss} = \frac{\frac{H}{K}\theta_{im} W_n \beta}{\sqrt{(1-\beta^2)^2 + (2\zeta\beta)^2}} \cos (W_f t - \varphi) \qquad \varphi = \tan^{-1} \frac{2\zeta\beta}{1-\beta^2}$$

$$(5)\quad \text{or } \theta_{gss} = \frac{HW_n}{k} \mu\beta \sin (W_f t + 90^\circ - \varphi)$$

where $\mu\beta = \dfrac{\beta}{\sqrt{(1-\beta^2)^2 + (2\zeta\beta)^2}}$ is the frequency - variant portion of the output: input amplitude ratio.

To fulfill the frequency response requirement, a log-log plot of $\mu\beta$ vs. β (amplitude ratio vs. frequency ratio) must have a slope of plus one. That value of ζ which most nearly gives this condition was found to be about.60 to.65, the plots being shown in the accompanying graph. (Fig. 2)

The phase angle φ is the angle of lag of output displacement (or voltage signal from the pickoff) behind input velocity. The phase angle as a function of frequency is shown in Fig. 24 of the main body of this report.

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SCHEMATIC DIAGRAM OF THE GYRO

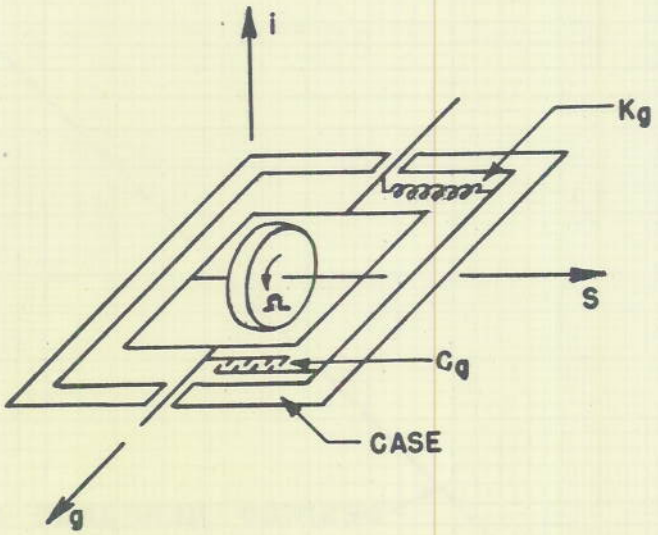

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FIG. 1

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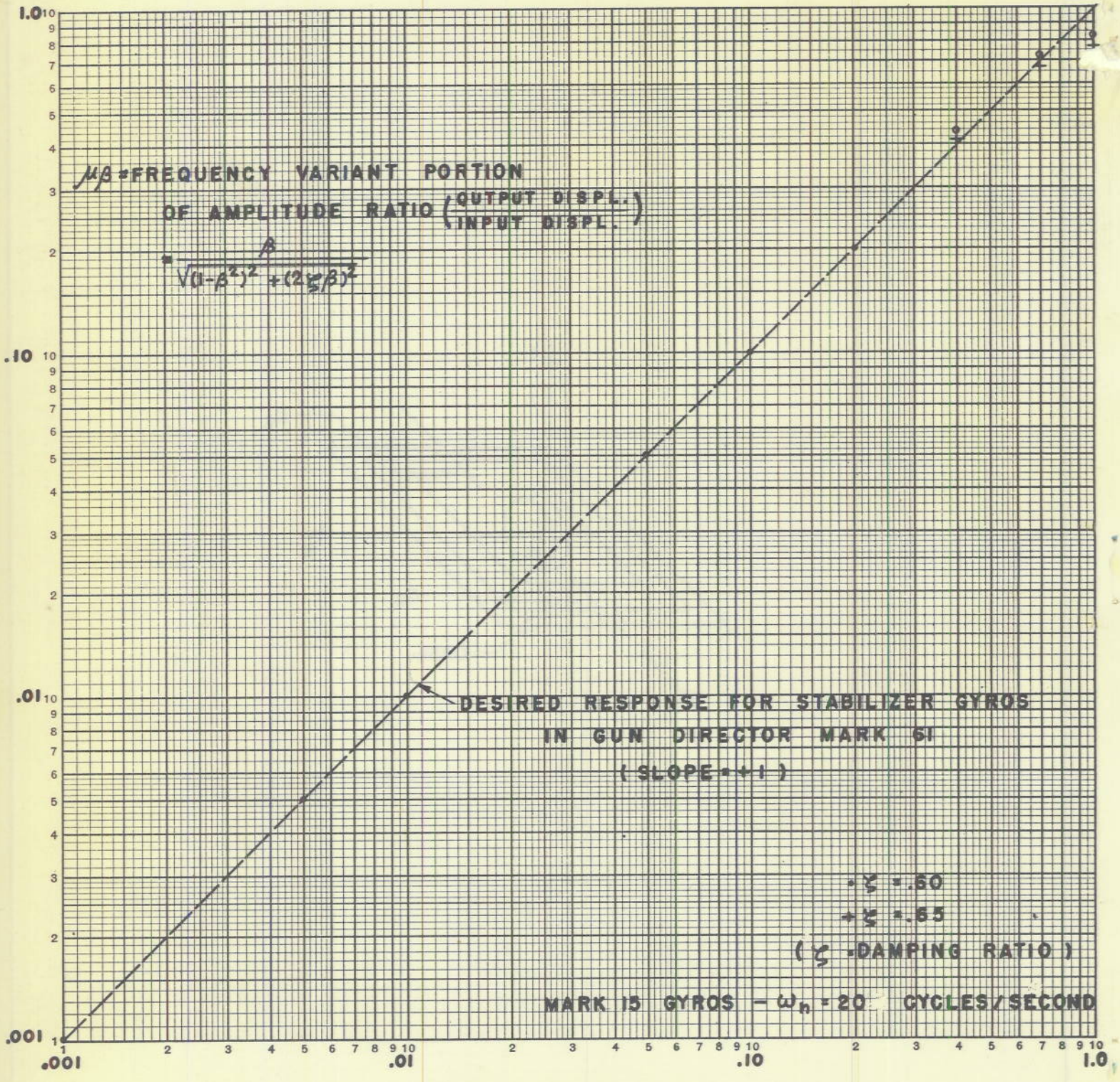
THEORETICAL FREQUENCY CHARACTERISTIC OF RATE GYRO



$$\beta = \frac{\omega_f}{\omega_n} = \frac{\text{FORCING FREQUENCY}}{\text{UNDAMPED NATURAL FREQ.}}$$

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FIG. 2