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TERMINATION REPORT
ON THE
DG6002 STABILIZATION REPEATER
FOR THE
ASTRA VERTICAL AND HEADING REFERENCE
SYSTEM
OF THE
CF-105 AVRO ARROW AIRCRAFT

CR-ED 1066 June 26, 1959

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Honeywell Controls
MILITARY PRODUCTS DOCUMENT CR-ED 1066

June 26, 1959

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FOREWORD

This represents one of four documents related to the Astra Vertical and Heading Reference System as prepared by Honeywell Controls Limited in accordance with the requirements of Section 2(a) of Contract CD/DRB 819009/0013/719-16-30-601, D.D.P. Serial Number 2-PP-8-13.

It is recommended that this report be read in conjunction with the following Honeywell Controls Documents:-

CR-ED 1041	Termination Report on the DG6000 Three Axis Repeater for the Astra Vertical and Heading Reference System of the CF-105 Avro Arrow Aircraft.
CR-ED 1065	Termination Report on the GG53 Miniature Stable Platform for the Astra Vertical and Heading Reference System of the CF-105 Avro Arrow Aircraft.
CR-ED 1067	Termination Report on the HG6000 Platform (Erection) Computer for the Astra Vertical and Heading Reference System of the CF-105 Avro Arrow Aircraft.

TERMINATION REPORT ON THE DG6002 STABILIZATION REPEATER FOR THE ASTRA VERTICAL AND HEADING REFERENCE SYSTEM OF THE CF-105 AVRO ARROW AIRCRAFT.

1 GENERAL

The Stabilization Repeater was a part of the D-YG709A-1 Level and Heading Reference System for the Avro Arrow Aircraft. The Stabilization Repeater consisted of two similar modular Servo Repeaters designated D-DG6002A-1 and D-DG6002A-2 respectively. Both units were mounted in the D-HG6000A-1 Platform Computer.

The function of the Stabilization Repeater was to repeat the angular position, velocity and acceleration of the platform axes to a specified accuracy. The output shaft of the azimuth repeater drove a control transformer, a coordinate resolver and a synchro transmitter. The output shaft of the elevation repeater drove a control transformer, a secant function potentiometer and a synchro transmitter.

2 BACKGROUND

Analytical studies for the Miniature Stable Platform revealed a need for azimuth resolution to provide the necessary transformation from Earth to Aircraft Coordinates. In addition, adequate control of the outer roll gimbal at high elevation angles could only be achieved by scheduling the gain of the gimbal drive servo. A suitable function was found to be the secant of the elevation angle. Although it was the design aim to drive the coordinate resolver and secant function potentiometer from the respective gimbals, it was thought advisable in the developmental stages to build two servo repeaters for this purpose, receiving their input signals from the platform synchro transmitters in parallel with other repeaters in the Astra System.

The dynamic performance requirements for the repeaters were severe, and it was originally thought that only a D.C. servo could give adequate response. Analysis showed that an A.C. servo was feasible and the design was commenced accordingly. The Stabilization Repeater was also known as the 2-Axis Repeater, and earlier as the Azimuth Axis Repeater. (Before the firm requirement for an elevation axis repeater was stated)

With conversion of the Stable Platform from accelerometer to mercury switch erection, as described in section 4.1.1 of Honeywell Controls Document CR-ED 1065, and the resulting redistribution of function, the role of the stabilization repeater was assumed by the DG6000 Three Axis Repeater (Honeywell Controls Document CR-ED 1041.) Work on the Stabilization Repeater was therefore terminated.

3 RELEVANT SPECIFICATIONS

Design was predicated upon the following specifications and the various Military Specifications as referenced therein.

MIL-E-7894A
White Rodgers Specification 500016 Rev. 2
Astra 1 Standards
Astra 1 Administrative Memo #18
R.C.A.F. Specification Air 7-6
R.C.A.F. Specification Inst. 92-5
T.D.S. 12269-06 Minneapolis-Honeywell Technical Design Specification for the DG6002 Stabilization Repeater

4 DESCRIPTION OF UNIT

4.1 General

The Stabilization Repeater consisted of two similar modular servo repeaters differing only in output device. Each servo repeater contained the following components:-

a) A 2-phase 400 cycle servo motor with integral tachometer generator.
b) A gear train for coupling the motor to the output device.
c) A control transformer for error sensing.
d) A synchro transmitter for instrumentation purposes.
e) A voltage amplifier.
f) A power amplifier
g) A D.C. power supply
h) An output device

In the case of the Elevation Axis Repeater the output device was a secant function potentiometer, and in the case of the Azimuth Repeater it was a coordinate resolver.

Each module measured approximately 7 3/4" x 7" x 2 1/2" and weighed 3 1/2 pounds. Electrical power and signal leads were taken to separate Bendix Pygmy PC06E type plugs.

4.2 Mechanical Design Details

The servo repeater consisted of a cast aluminum frame which formed the main supporting member. The size 15 servo motor was mounted in a precision bore beneath the frame. Immediately above was a rectangular enclosure which supported a casting carrying the control transformer and output devices. This second cover also carried two Bendix Pygmy type PC02A Boxmount receptacles and a dust cover. The form of the second casting and dust cover was that of a hollow triangular prism allowing free access to the synchro terminals and rear of the electrical connectors. The motor pinion meshed with a 120 tooth 96 pitch compound gear mounted on the control transformer shaft, giving a gear reduction of 8:1. The second gear of the compound gear meshed with 80 tooth 64 pitch scissor type antibacklash gears on the output device shafts. The remainder of the casting supported the electronic components, namely the pre-amplifier, power amplifier and power supply, and motor tuning and phasing capacitors.

4.3 Repeater Servo Design

Linear analysis showed that a size 15 servo motor would have ample power and response to meet the performance specifications. A gear ratio of 8:1 was chosen for optimum efficiency by a method analogous to impedance matching. Rate feedback was chosen as a stabilizing means.

It had originally been intended to use a Minneapolis-Honeywell EG129 transistorized magnetic amplifier, but analysis showed that its time constant of 11 milliseconds would lead to instability. A search was made for proprietary magnetic amplifiers with smaller time constants, but proved fruitless. The decision was then made to design a transistor power amplifier to be driven from a Minneapolis-Honeywell EG113C transistor amplifier.

Further linear anlaysis showed that marginal stability would be obtained if two equal time constants of four milliseconds were assumed to be present, one in the amplifier, and one due to the motor inductance and tuning capacitor. These time constants were not detected in practice, and very close agreement was found between linear theory and experiment in breadboard tests.

4.4 Servo Pre-Amplifiers, General

It had been intended to eventually use a Minneapolis-Honeywell EG113C pre-amplifier for the repeater servo, but in the interest of expediency a transistorized preamplifier was designed and built pending receipt of the intended unit.

4.4.1 D-EG113C Pre-Amplifier

The D-EG113C silicon transistor amplifier consisted of a two stage pre-amplifier and a stage of push-pull discrimination. It was designed as a printed card unit in a hermetically sealed case measuring approximately 2 3/8" x 2 3/8" x 1" with a weight of four ounces. A single external 400 cycle A.C. power source was required. The input signal could be of sinusoidal or square waveform.

Three terminal outputs produced phase sensitive full wave d.c. or a.c. currents. The maximum gain ratio expressed in milliamperes per volt (or volts per volt using 1000 ohm load resistors) was 20,000 with an associated input impedance greater than 1.5 kilohms. The gain ratio could be reduced by means of a specified external resistance to a minimum of 25 with a related increase of input impedance to a value exceeding 1 megohm. The amplifier with push pull a.c. output was capable of driving a small motor directly, or a power transistor output stage. Up to 1 watt output would be obtained with 1,000 ohm minimum load. The amplifier was provisioned to accept an additional a.c. signal as might be derived from a velocity signal generator.

4.4.2 Experimental Pre-Amplifier

Following notification of a delay in shipment of pre-amplifiers from Minneapolis, a design was prepared to safeguard delivery of a bench model repeater for initial platform testing. This amplifier is shown in Fig. 1 and was designed to produce an A.C. output of 1/2 watt into a 3200 ohm resistive load (i.e., the transistor power amplifier). Originally the circuit consisted of one stage of voltage amplification coupled to an emitter follower which in turn excited the Class A power output stage. This latter stage employed a single Texas Instruments type 970 silicon power transistor mounted in a heat sink adjacent to the case. It was necessary later to increase the input impedance of the unit. To do this an emitter follower stage was placed at the input. Impedances of the order of 100K were thus obtained. A Zener diode across the transistor collector to ground formed a decoupling filter to provide a stable bias voltage.

Gain adjustment facility was available by virtue of the provision for negative voltage feedback at the emitter resistor of the second stage transistor. A D.C. supply of 50 to 60 volts was required to obtain full power output. The four transistors were Texas Instruments Type 905, 905, 952 and 970 respectively.

An experimental breadboard amplifier was built and tested, and two packaged models were fitted to a 2-axis repeater bench model. The amplifiers gave adequate performance but had a poor output waveform.

4.4.3 Pre-Amplifier for Development Models.

The design of the above described experimental pre-amplifier was extended to cover possible use in the developmental as well as the experimental equipment. In this 2N336, 2N343 and 2N424 transistors were substituted for the Texas Instruments Type 905, 952 and 970 units.

4.4.4 Power Amplifier

A design was prepared using four Texas Instruments Type 970 n-p-n silicon power transistors in parallel push-pull. Transformer coupling was used at input and output. In addition a 40-60 volt B+ supply was required, and was to be provided by a separately packaged power supply unit. Figure 2 shows the schematic diagram and a typical section through the power amplifier.

The external size of the amplifier approximated to a cube of 2 3/8" side. Electrical connections were made to a glass sealed header on the base, and the unit was mounted by four threaded studs.

Three such amplifiers were built in packaged form and performed well on the 2-axis repeater bench model.

4.4.5 Proposed Developmental Power Amplifier

It was proposed to substitute a pair of 2N389 silicon power transistors operating in Class B push pull, for the four Texas Instruments 970 transistors used in the experimental amplifier. A typical cross section is shown in Fig. 3.

4.4.6 Power Supply Unit

A separately packaged B+ supply unit consisted of a transformer and full wave rectifier circuit using silicon diodes. A schematic and a typical cross section are shown in Fig. 4. A later design had an additional 57.5 volt winding on the transformer to excite the motor fixed phase.

5 PERFORMANCE

Linear analysis indicated that the specifications could easily be met, and predicted a frequency response which was flat to some 100 cycles.

In fact, however, amplifier and motor saturation limited the performance, and the predictions were only borne out for small signal inputs. The experimental frequency responce showed resonant peaks at a frequency varying with the signal amplitude and frequency.

The locus of the peaks approximately satisfied the relation (signal amplitude) x (signal frequency)^2 = a constant. By suitable adjustment of forward and feedback gains the magnitude of the resonant peaks was reduced to a low enough figure for the repeater to be of use in initial system testing.

STATUS AT CUT-OFF

The 2 axis repeater portion of the platform computer program was terminated when the platform computer itself was cancelled. The functions of coordinate resolution and gimbal stability augmentation were achieved, as an interim measure, by the addition of a resolver and secant potentiometer to the azimuth and elevation axes respectively of the three axis repeater D-DG6000B-1. The production platform was to have these devices driven directly by the gimbals.

Layouts were completed for the Two Axis Repeater modules D-DG6002A-1 and D-DG6002A-2 and installation details were resolved with the Platform Computer project group. Procurement of long lead time parts for 3 developmental models was under way.

A bench model Two Axis Repeater was constructed and delivered to Minneapolis-Honeywell for initial platform testing. Prior to delivery it was tested in a simulated "Arrow" electrical system at Avro to assess the effect of electrical noise. Electrical pick-up was not found to be a problem, either with shielded or unshielded cables. This unit is shown in Fig. 5.

The substituting of mercury switches for accelerometers on the Stable Platform led, in turn, to simplification of the D-HG6000A-1 Platform Computer. In repackaging studies it was found advantageous to redistribute the components of the Two Axis Repeater.

In the final layout, a single casting supported the mechanism of both repeaters, and the electronic equipment was mounted on the computer chassis.

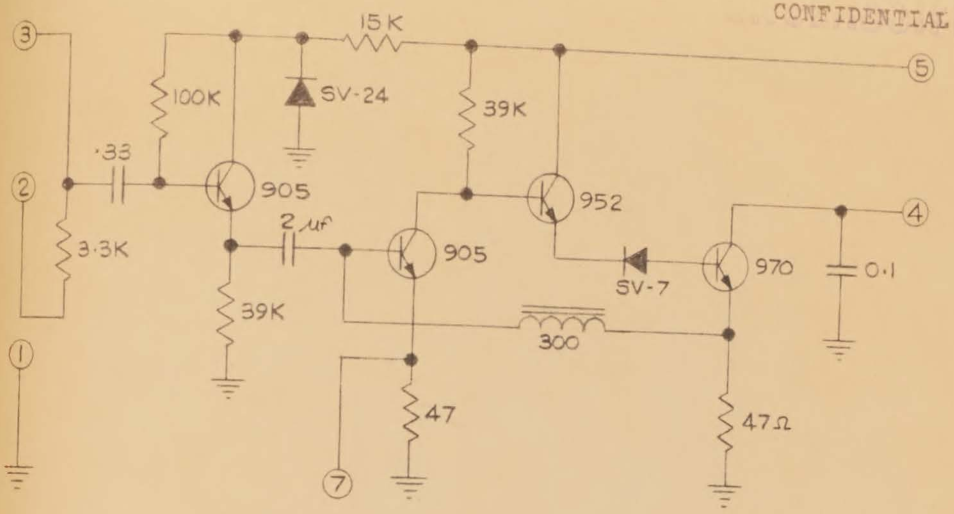
It was arranged that the repeater mechanism could be simply removed from the computer. Signal leads were taken to a back-mounted Bendix Pygmy receptacle on the computer front panel, and electrical inter-connection between the mechanism and chassis was made through a Bendix Pygmy connector on the chassis. Fig. 1 of the Platform Computer report shows the layout of components in the combined Computer-Repeater.

7 FUTURE PLANS

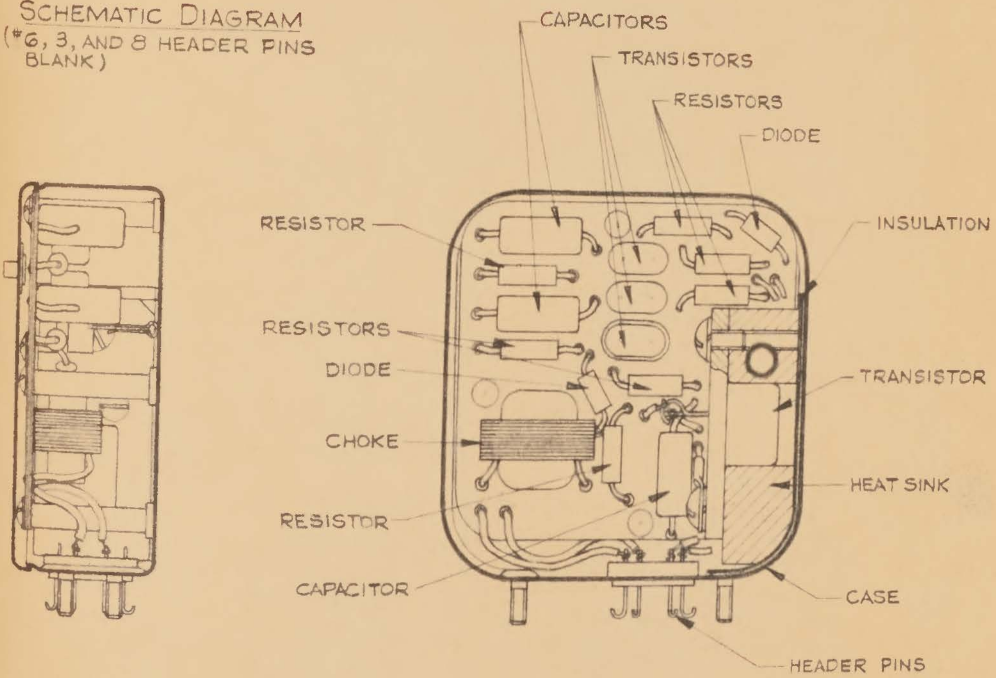
No definite future plans were made. However, if a similar device should be required for any other application, the improvements found in developing the Three Axis Repeater namely substitution of an inertia damped motor and elimination of the separate power supply would be carried through to the Two Axis Repeater.

8 CONCLUSIONS

The servo itself was of a most elementary nature, the only problems being introduced by the non-linear effects of amplifier and motor saturation. The use of the recently developed inertia-damped servo motor would significantly improve the transient response of the servo while allowing a high slewing rate.



SCHEMATIC DIAGRAM
(#6, 3, AND 8 HEADER PINS BLANK)



TYPICAL SECTIONS - PRE AMPLIFIER
2 AXIS REPEATER

FIG. 1

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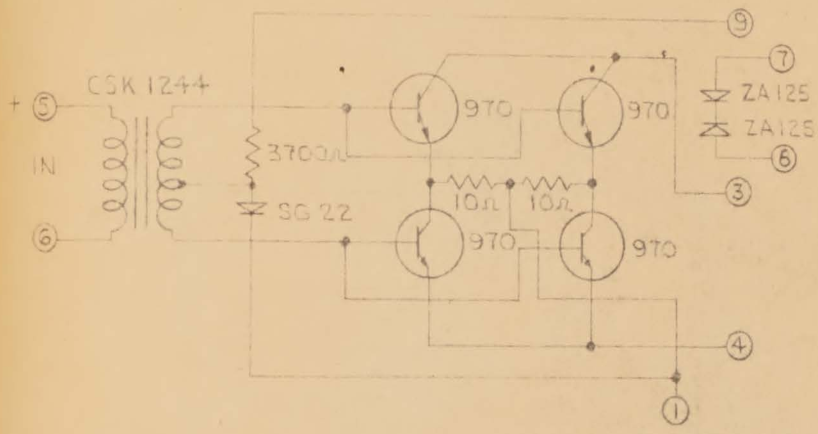
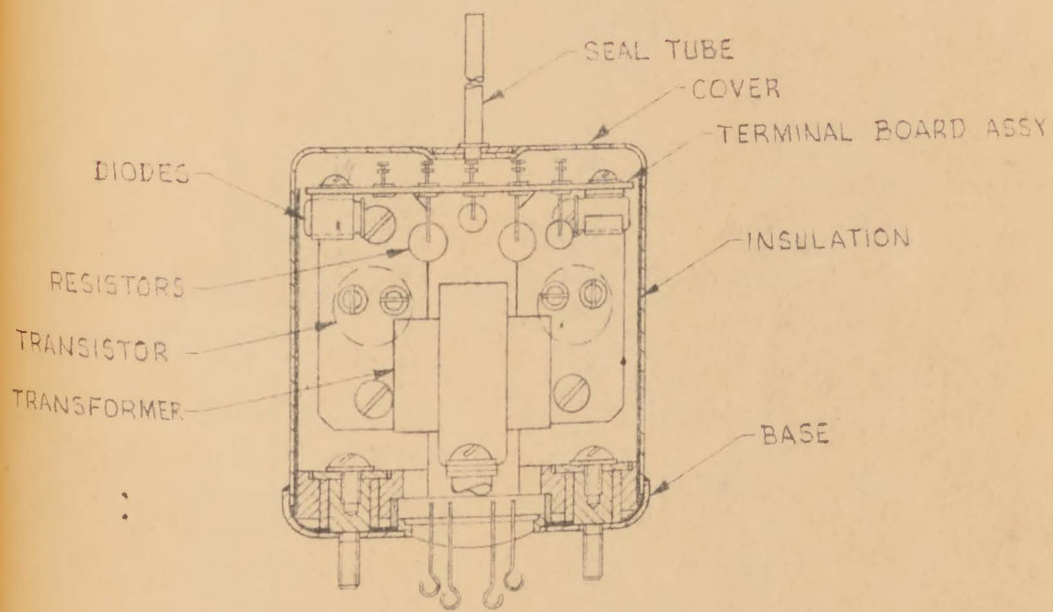
SCALE 1:1
DEC 17-58



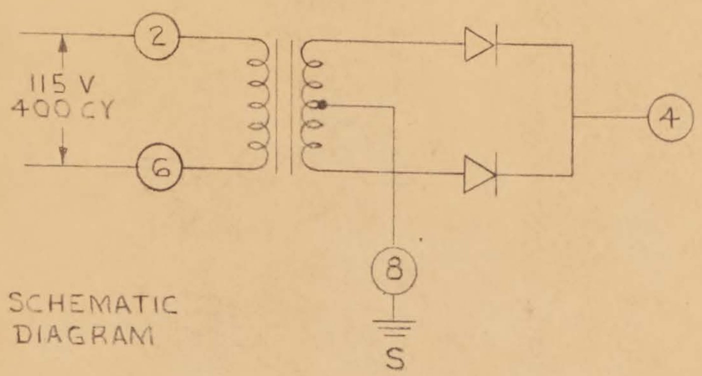
SCHEMATIC WIRING DIAGRAM



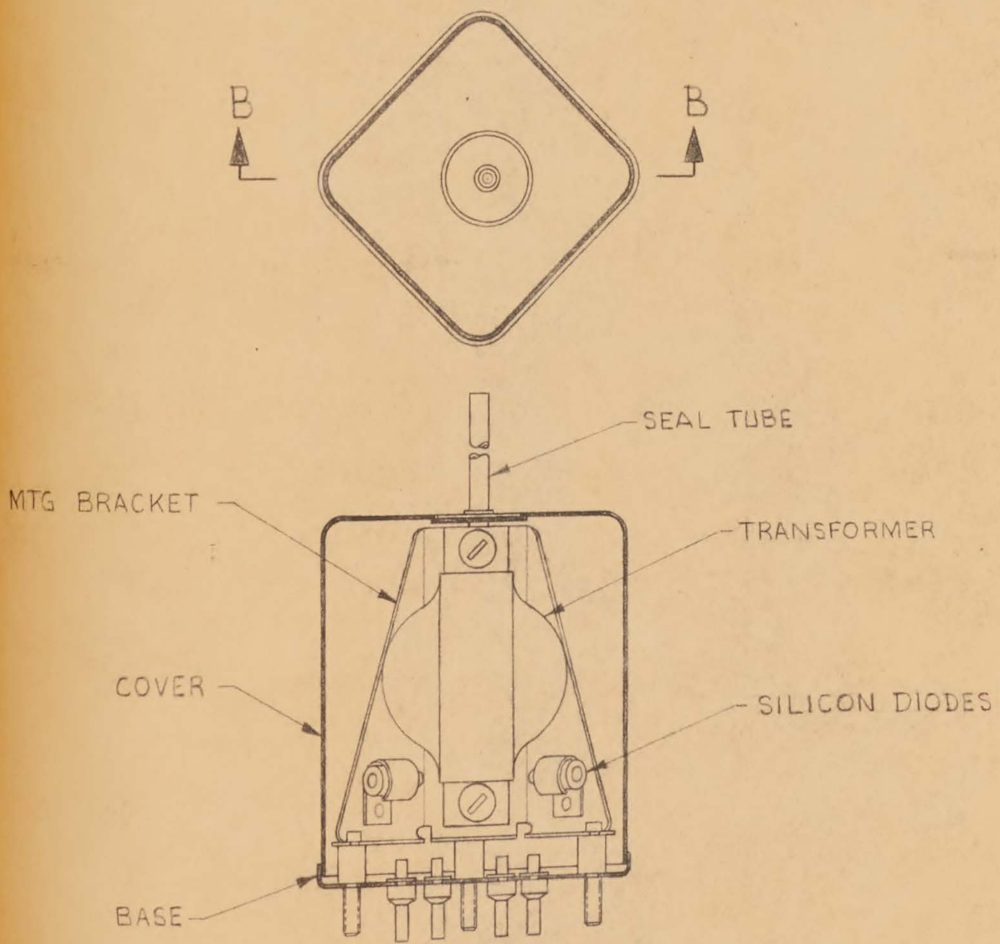
POWER AMPLIFIER
2 AXIS REPEATER

SCALE 1:1
DATE 12-16-58

FIG

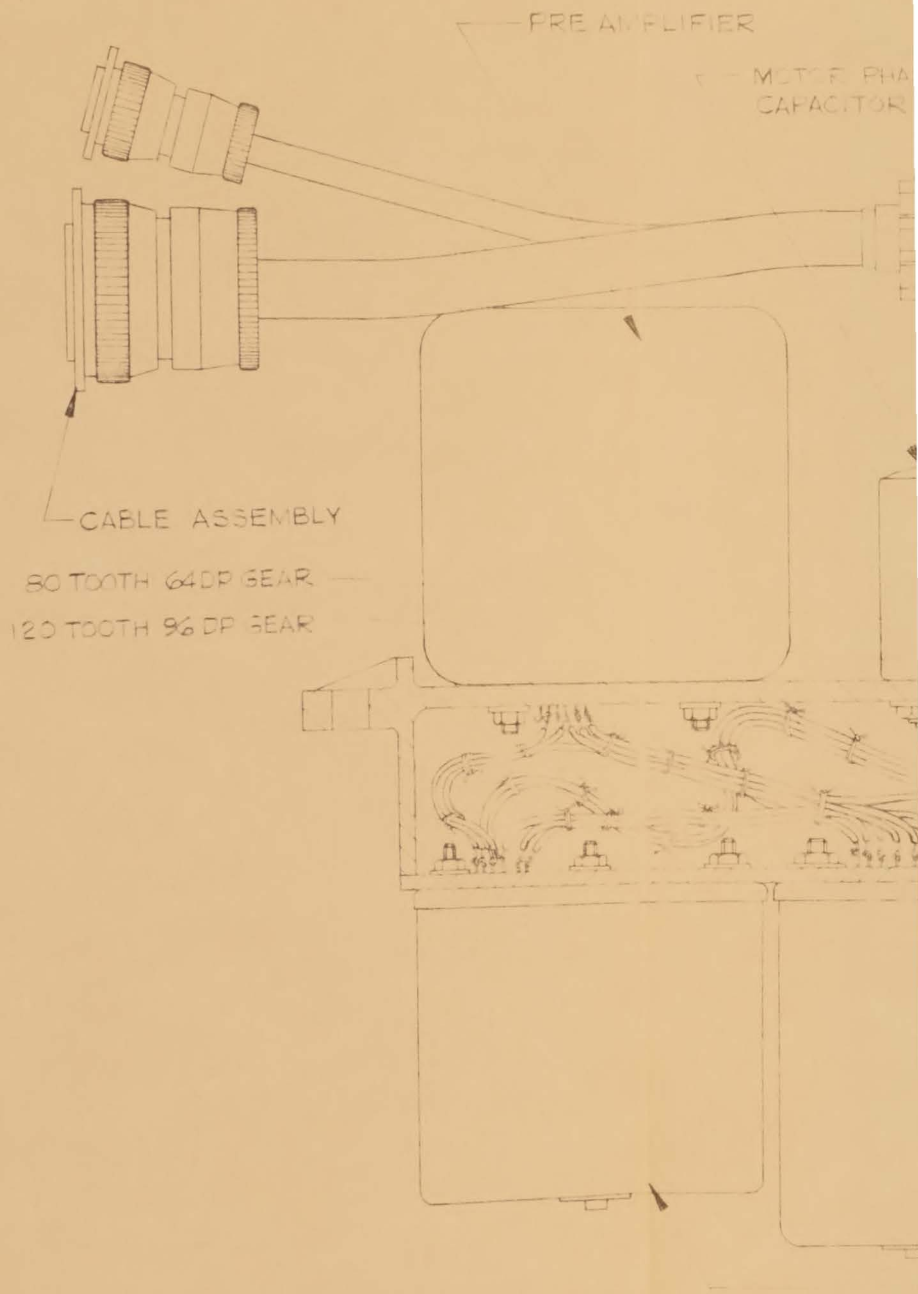


SCHEMATIC
DIAGRAM

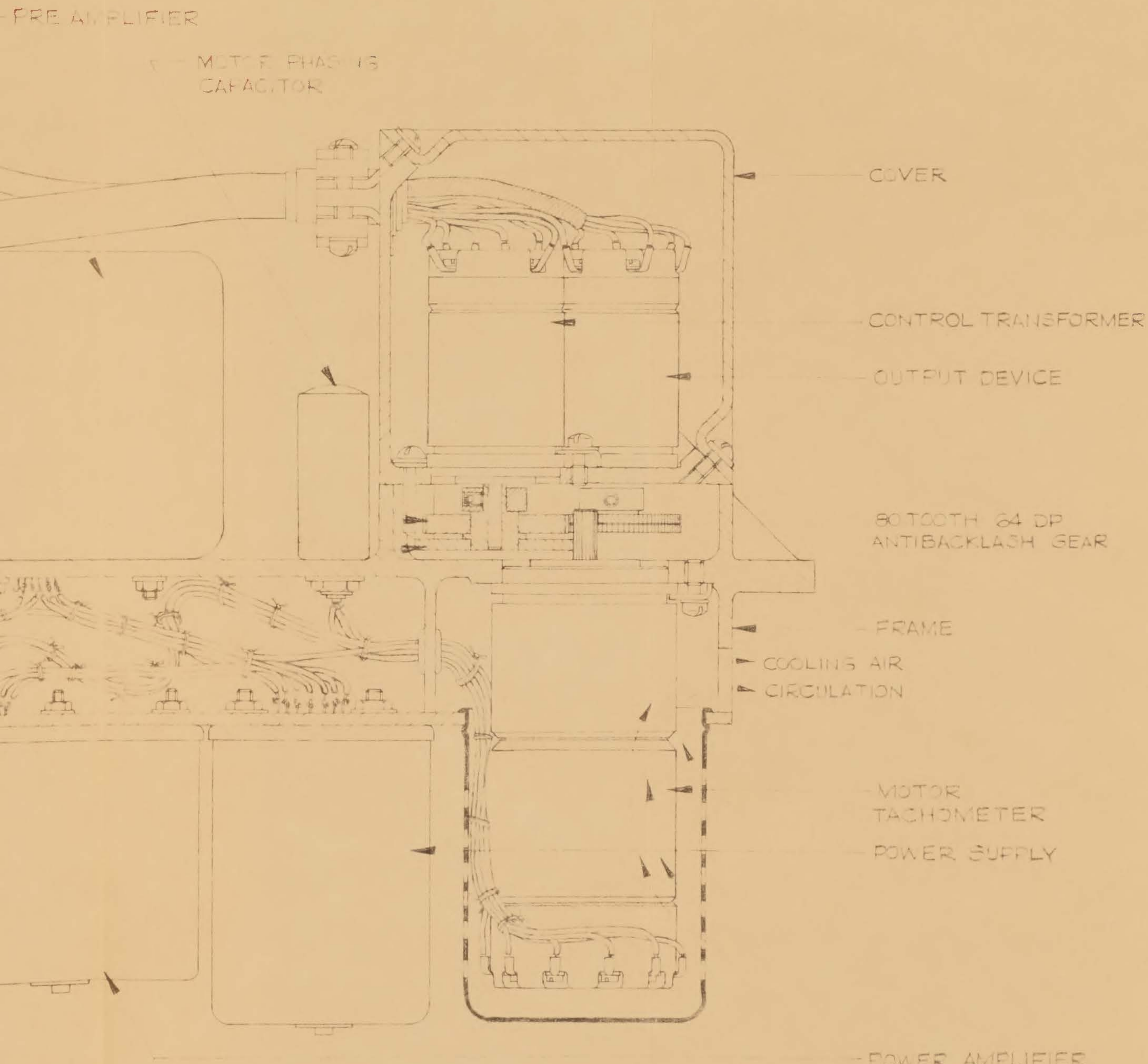


TYPICAL SECTION - POWER SUPPLY
2 AXIS REPEATER - FIG. 4

SCALE - FULL
DATE - 12-15-58



TYPICAL SECTION – MODU
2 AXIS REP



YPICAL SECTION - MODULE - REPEATER SERVO
2 AXIS REPEATER
FIG. 6

HC/MP Document CR-ED 1066

SCALE 1:1
DEC 16 - 58