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# INTEGRATED SONAR, TYPE A, MOD. 3, AS INSTALLED IN U.S.S. FOSS, JULY 1948

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# INTEGRATED SONAR, TYPE A, MOD. 3, AS INSTALLED IN U.S.S. FOSS, JULY 1948

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April 14, 1949

Approved by:

Dr. H. L. Saxton, Superintendent, Sound Division

**NAVAL RESEARCH LABORATORY**

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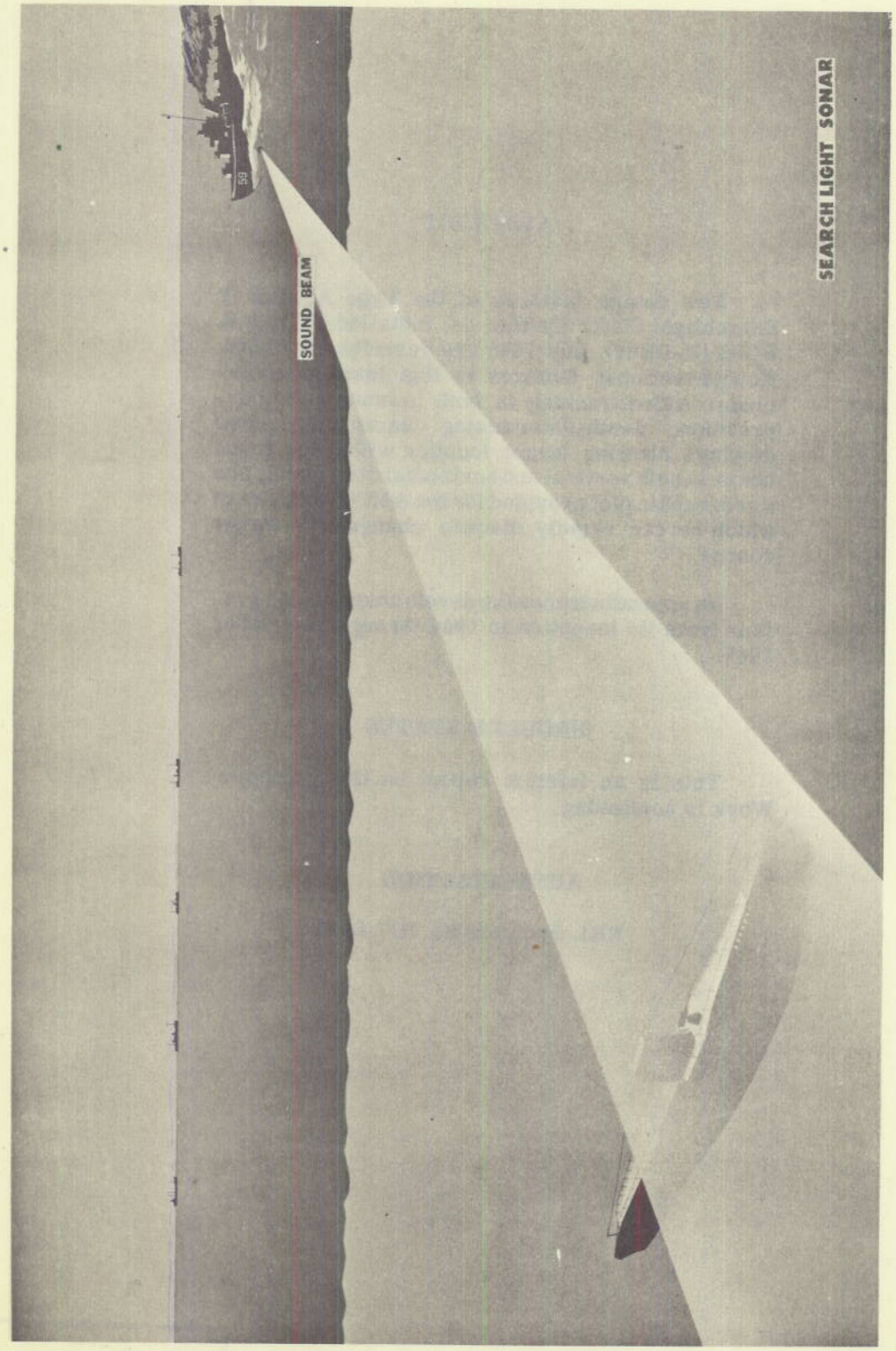



Fig. 1 - Searchlight sonar

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## ABSTRACT

New design features of the Type A, Mod. 3 Searchlight Sonar System as installed in U.S.S. FOSS (E-DE59), July 1948 are described in detail. Nonconventional features in this installation include: Aided tracking in both azimuth and in depression, depth-determining equipment, dual displays showing target location within the sound beam in both vertical and horizontal dimension, and a geographic plot provided for the ASW officer, from which he can rapidly discern changes in target course.

An appendix traces the development of the system from its inception in 1944 through September 1947.


## PROBLEM STATUS

This is an interim report on this problem Work is continuing.

## AUTHORIZATION

NRL Problem No. S07-01R C

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# INTEGRATED SONAR, TYPE A, MOD. 3, AS INSTALLED IN U.S.S. FOSS, JULY 1948

## INTRODUCTION

The original problem, set up by BuShips in June 1944 as S761R-C, called for the development of a "Dual Antisubmarine Sonar Equipment" utilizing the basic searchlight technique (see Fig. 1) with the addition of a number of novel features that experience during the war had indicated as advisable or necessary. These features were to be integrated and an experimental installation made in U.S.S. FOSS (DE59) by 15 December 1944.

By the time that the installation had been completed and preliminary tests run, 1945, the war was so advanced that it was obvious that Integrated Sonar, Type A, could not be developed and produced for fleet use before hostilities ceased. Emphasis was placed more and more on the use of the system as a tool for research on underwater sound problems, although the idea of developing an effective antisubmarine weapon was not forgotten.

Eventually NRL Problem S07-01R was set up, which included "broad research in the field of shipborne sonar for antisubmarine warfare, and applied research in allied equipment fields and in the psycho-physical aspects of operation and utilization of complex equipments." In October 1947, BuShips Problem S761R-C was closed.

This interim report on NRL Problem S07-01R is confined mainly to a description of the various components of Type A Integrated Sonar, Mod. 3, aboard the FOSS in July 1948. A history of the original installation and of Mods. 1 and 2 appear in Appendix A.

### Modifications

Major modifications in the July 1948 system include: a) unique visual presentation of sonar information, especially in the Depression Indicator, the Azimuth Indicator, and the Attack Plotter; b) a more versatile transducer; c) the mounting of a number of units on subchassis so that a faulty unit may be immediately replaced without waiting for repair; and d) the addition of a Depth Tracker, Mark 11, and of a modified Attack Director, Mark 4. New instrumentation has been provided for measurements. Strain gages indicate strains on the dome, and automatic recorders will be used in a study of system errors.

### Human Engineering

Operation complexity has been reduced to a minimum as far as each operator is concerned. With the exception of the ASW officer, each man has one, and only one, thing to do — to track the target. The new displays give each operator a better perception of the attack, and automatic data recorders have relieved him of any duties in data transmission.

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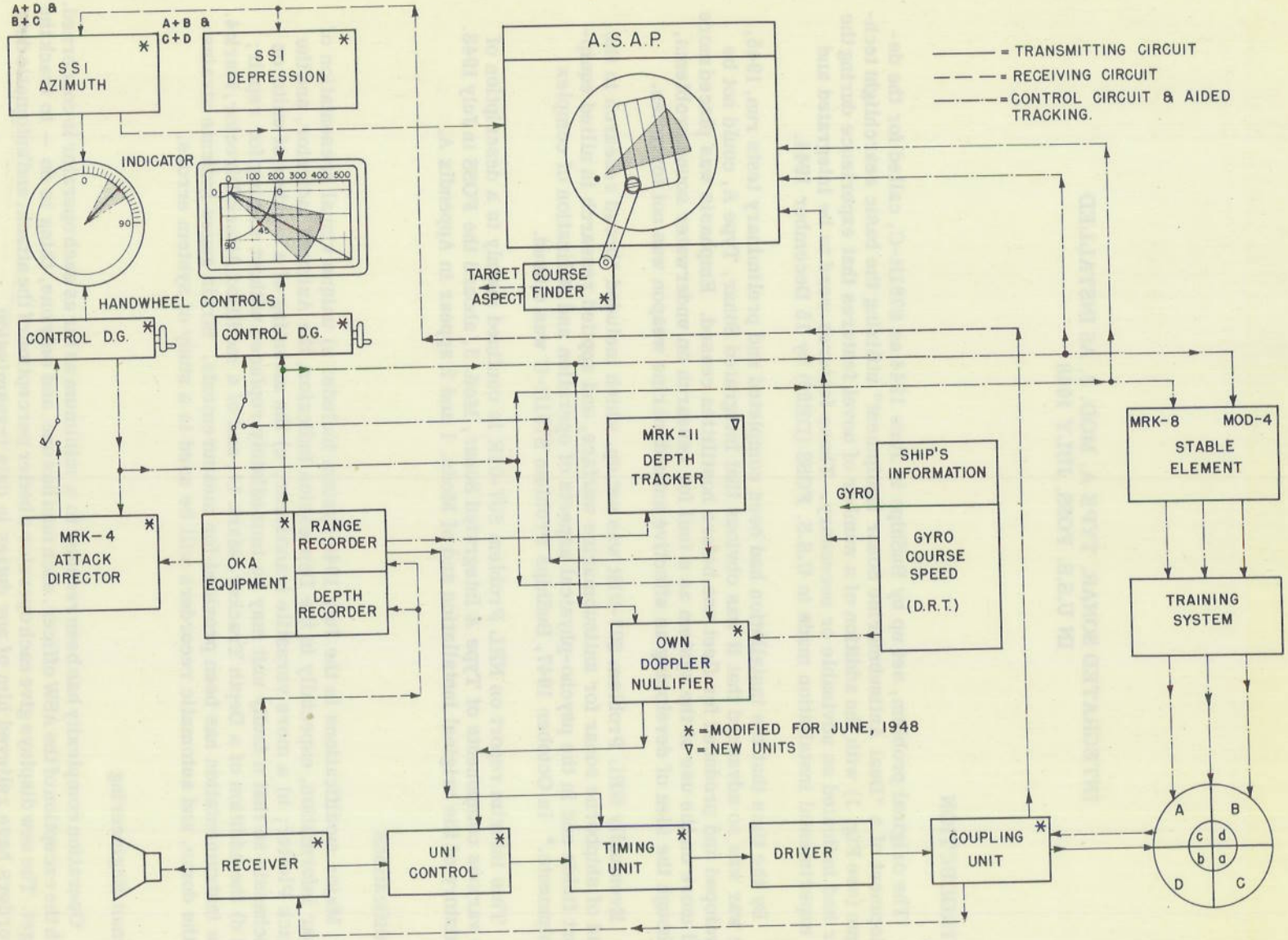



**Fig. 2 - General block diagram type A — mod. 3**

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## SYSTEM OPERATION

The operation of Type-A Sonar has become increasingly complex (see Fig. 2) as more units — many of them experimental in nature and more complicated to operate than would be the case with production or preproduction models — have been added.

During an antisubmarine attack, six operators, including the ASW officer, are required. Their stations and duties are as follows.

### Azimuth Control

Operation of the entire equipment is initially under the control of the azimuth operator, who energizes the system by pressing the "Equipment Start," "Transducer Lower," and "Train Power" switches. The display presented to this operator on a cathode-ray tube is a wedge-shaped sector scan emanating from the center of the screen and maintaining a position corresponding to the relative bearing of the transducer, rotating right or left as the transducer is trained. (See Fig. 27.). The transducer is controlled by turning a hand-wheel located at the right of the display. To maintain bearing, azimuth operator simply aligns a single pointer with the echo traces appearing on his scope.

### Depression Control

The transducer is similarly controlled in angle of tilt by the depression operator. His cathode-ray tube displays a wedge-shaped sector scan which originates at the upper left of the tube face and assumes an angle with the horizontal equal to the called-for transducer depression angle. (See Fig. 27.) To maintain the correct depression angle, the operator aligns a single pointer with the echo traces appearing on his scope. He may, if he wishes, switch to "automatic" and allow the angle computed by the Depth Recorder of the OKA equipment or from the Depth Tracker, Mk. 11, to control the depression of the transducer.

### Range Recorder

The sound range recorder operator maintains the light-beam cursor of the Range Recorder upon the target trace, thereby furnishing a continuous flow of sound range and of range-rate information to the circuits of the OKA Computer and the Mk. 4 Attack Director.

### Depth Computation

The depth recorder operator maintains the cursor of the depth recorder upon the target depth traces, thereby furnishing depth of target information to the computing circuits. Computed depth and horizontal range are made available as synchro information for remote repetition. Depth is combined with range to calculate continuously transducer depression angle. This computed angle may, if the Depression operator so desires, be placed in control of the transducer, or aided tracking in depth may be obtained from the Depth Tracker, Mark 11.


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Attack Director, Mark 4

One operator is assigned to the Mk. 4 Attack Director. This unit numbers among its outputs rate-of-change of target bearing as a synchro order. Therefore aided tracking in bearing is available to the azimuth operator at his option. Also available and remotely repeated to the flying bridge and wheelhouse is a calculated course to steer for either an ahead-thrown or stern weapon type of attack. There are also fire-control outputs.

Antisubmarine Attack Plotter (ASAP)

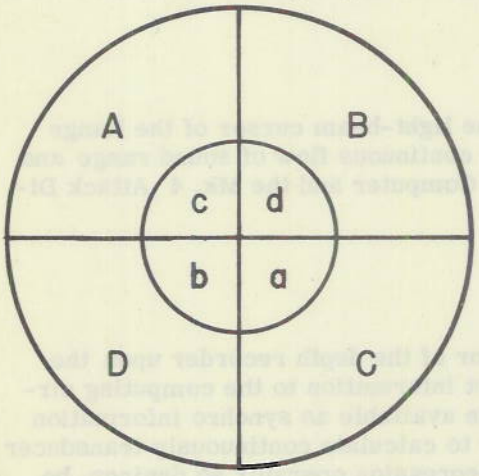
A modified Attack Plotter, Mark 1, Mod. 2, has been incorporated as an aid in studying the problem of establishing an intelligent appreciation of the tactical situation by the ASW officer. Upon the 12-inch cathode-ray tube of this equipment is presented a plan position representation of own ship, target, and sound beam. By operating the Course Finder Mark 3, Mod. 1, the operator can determine the attack course to steer, target course, or, under favorable conditions, the aspect. The information is synchro-ordered to the flying bridge and to the wheelhouse. It is planned that the operator of this equipment be the ASW officer because the Attack Plotter gives a picture of the over-all attack.

## SYSTEM DESCRIPTION

### Transducer

The transducer installed in July 1948 and used in the Integrated Sonar System, Type A, Mod. 3, is, like its predecessors, a 45 degrees X-cut Rochelle Salt crystal transducer of the "searchlight" type. It can operate at any one of the four system frequencies, (16, 24, 38, and 46 kc) at 150 watts input.

The array is split not only into quadrants but also into concentric zones, so that the basic division is into eight parts. The inner part of each quadrant, however, is connected internally to the outer part of the diagonally opposite quadrant, as indicated in Figure 3. Thus the effective division is into four sections, and the number of transducer leads is the usual four plus a common. Combinations of these sections form the "whole" for the transmitting and listening channels, and the "halves" for the Sector Scan Indicators. By this arrangement the halves (top and bottom, or right and left) overlap, and the dimension of each half in the plane of scan is increased over that of the simple quadrantally split array by one half the overlap. This dimensional increase gives greater directivity in the receiving beam associated with each SSI channel, and should make this transducer superior to those which it displaced — particularly for target-depth determination — since its greater discrimination against noise and against surface-reflected echoes will reduce the error in depression-angle measurement. The dimension of the half in the plane at right angles to the plane of scan is the full array diameter, so that no loss of directivity in that plane is involved.




Sections indicated by corresponding capital and small letters are electrically connected internally

Fig. 3 - Overlapped Transducer Design

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Since Type-A Sonar requires that the transducer be capable of training 360 degrees repeatedly, slip rings (Fig. 4) and brushes have been provided. The assembly, located at the top of the QC hoist-train shaft, consists of 27 slip rings and brushes, of which 7 have been allocated for the level- and cross-level servo-motor conductors; 10 for the level- and cross-level control-transformer conductors, and 5 for the transducer conductors. Extra rings and brushes have been provided to accommodate different multiconductor transducers.

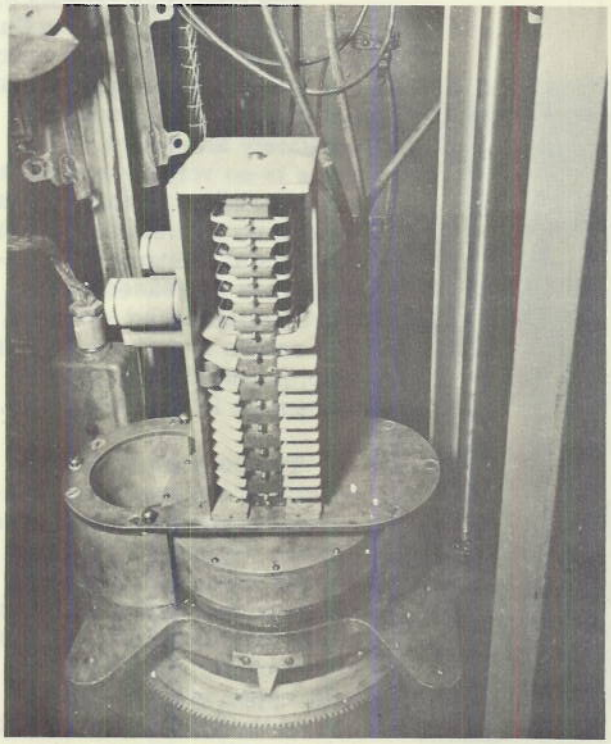


Fig. 4 - Slip ring assembly

## Coupling Unit

The Coupling Unit (Fig. 5), located in the lower sound room, makes it possible to use a common transducer for transmitting and receiving. In addition, it combines the outputs of the transducer sections as required for SSI operation (Fig. 6).

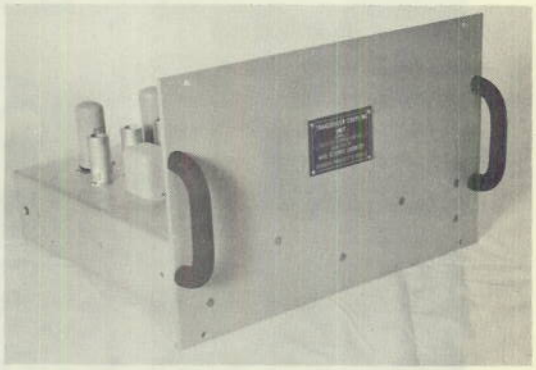


Fig. 5 - Transducer coupling unit

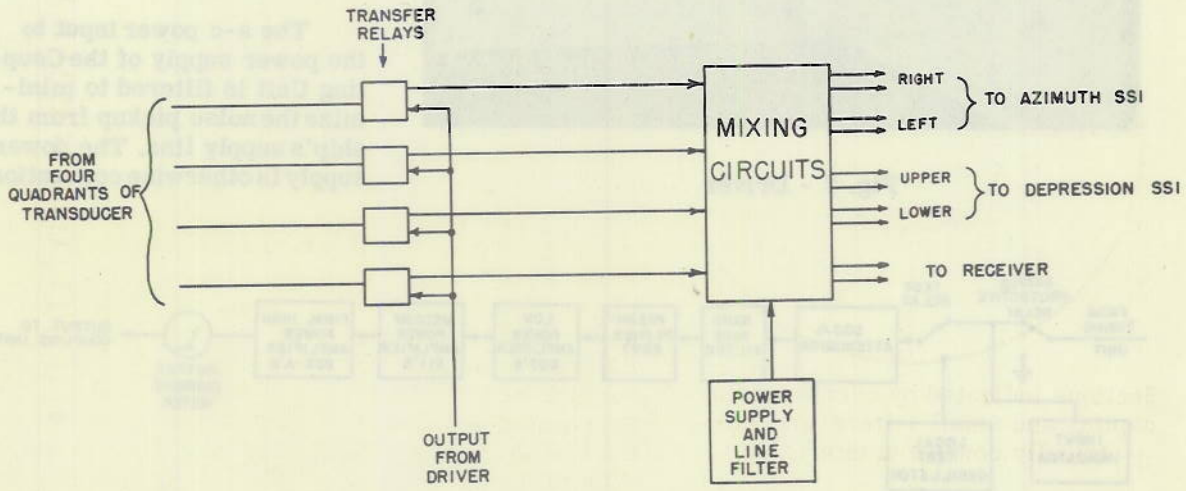



Fig. 6 - Coupling unit block diagram

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Switching from transmitting to receiving conditions is accomplished by transfer relays. These relays are hermetically sealed under high pressure and have mercury-wetted contacts designed in such a way that a film of mercury is constantly renewed on their surfaces. This eliminates one of the chief difficulties experienced with conventional transfer relays, that is, noise and erratic operation caused by contact corrosion.

The operating sequence, established in the Timing Unit, is such that the transfer relays are closed before transmission takes place and opened immediately afterward. Thus there is no voltage across the contacts at the instant of closing and no current through the contacts at the time of opening. This increases contact life by eliminating sparking. The relays are of the plug-in type, permitting prompt replacement in case of failure.

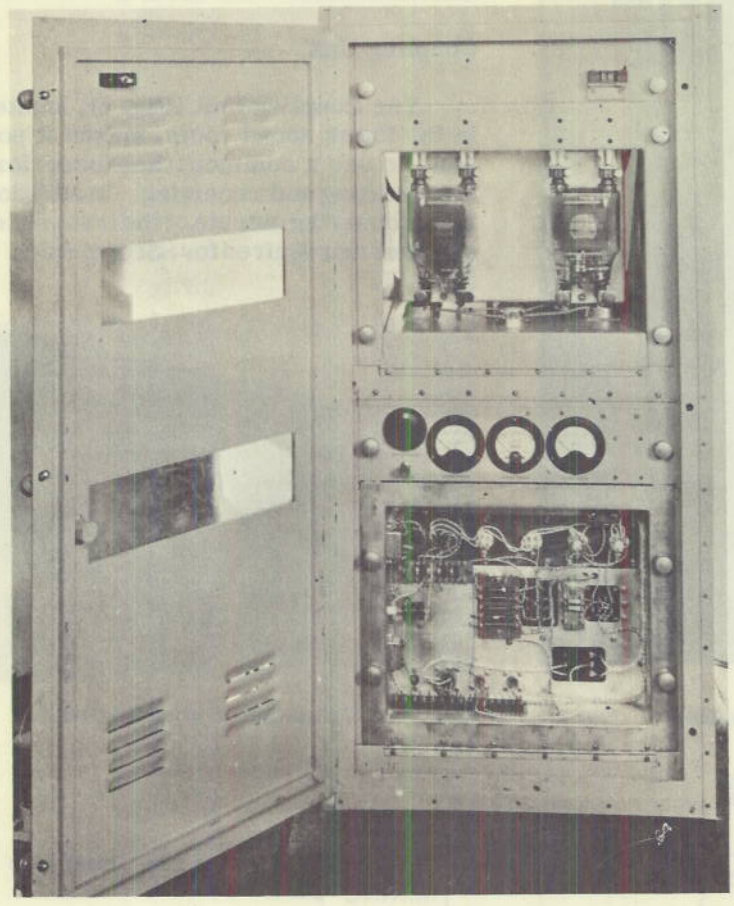


Fig. 7 - Driver

The combining circuits consist of vacuum tubes connected as common plate-load mixers (Appendix B). The signals from the transducer sections are combined in such a way that individual outputs representing right half, left half, upper half, and lower half of the transducer are obtained. All sections are combined equally to supply an output for the receiver.

The a-c power input to the power supply of the Coupling Unit is filtered to minimize the noise pickup from the ship's supply line. The power supply is otherwise conventional.

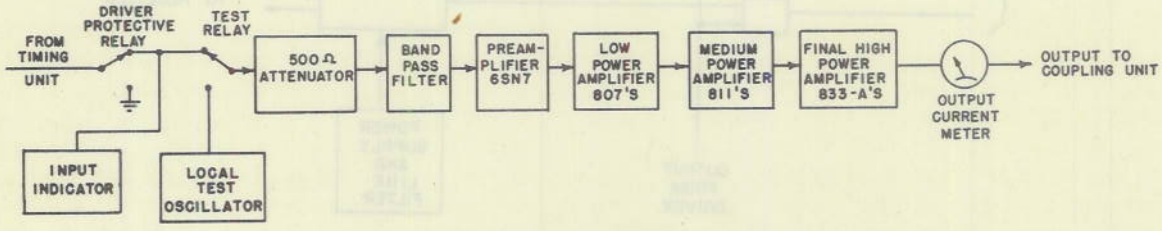



Fig. 8 - Driver block diagram

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Driver

The Driver (Fig. 7) is located in the lower sound room and consists of a three-stage untuned amplifier capable of covering the required frequency range with little variation in output. The Timing Unit provides short pulses of energy to the Driver, which amplifies these pulses and sends them to the Coupling Unit at a high power level. As an aid in determining Driver performance, a test oscillator is included. Two controls are located on the Driver panel: a test button controlling the test oscillator and an attenuator for adjusting the input signal to the correct value. Two meters on the front panel indicate the final amplifier cathode current and the output current. An electron-ray indicator tube shows the approximate amplitude of the input signal. The Driver was designed for a pulse power output of 1000 watts. The d-c operating voltages are supplied by a large dry-disc-type rectifier.

A block diagram of the Driver appears in Figure 8, and complete schematic diagrams are given in Figs. 47, 48, 49 and 50 of Appendix B.

The signal from the Timing Unit is received on a 500-ohm unbalanced line. Except during the transmission period, this signal is grounded by a relay, the purpose of which is to protect the Driver against accidental transmission when the load is removed by the Coupling Unit transfer relays. To assure complete protection, the protective relay coil is connected in series with those of the transfer relays.

From the protective relay the signal goes to the test relay and to the input indicator. The type 6E5 indicator tube shows the presence and approximate amplitude of the input signal. The test relay, controlled by a pushbutton on the Driver panel, selects either the operating signal or a locally generated test signal. This test signal is used to check Driver operation when no operating signal is coming from the Timing Unit.

The selected signal passes through a 500-ohm attenuator for adjusting the Driver input to the correct value, and then to a bandpass filter. By excluding frequencies outside the operating range of 10 to 50 kc, this filter eliminates unwanted modulation products generated in the Timing Unit.

From the filter, the signal passes through the preamplifier (6SN7), the low-power amplifier (807's), the medium-power amplifier (811's), and the final high-power amplifier (833-A's). The last three stages are all operated essentially class B for high power output and good wave shape without the necessity for tuning.

The output of the final amplifier passes through a radio-frequency ammeter to the Coupling Unit.

Driver Power Supply

The Driver Power Supply is located next to the Driver in the lower sound room. It consists of a low-voltage section and a high-voltage section, both of which employ copper oxide dry-disc rectifiers. Figure 9 is a block diagram of the Driver Power Supply. A complete schematic diagram is given in Appendix B, Fig. 50.

The high-voltage section operates from the 440-volt 3-phase ship's supply and delivers outputs of 2300 and 1150 volts. The low-voltage section operates on one phase of the 440-volt 3-phase ship's supply and delivers 500 and -120 volts. The voltages given are nominal values. A switch reduces these voltages when lower Driver output is required. Both the


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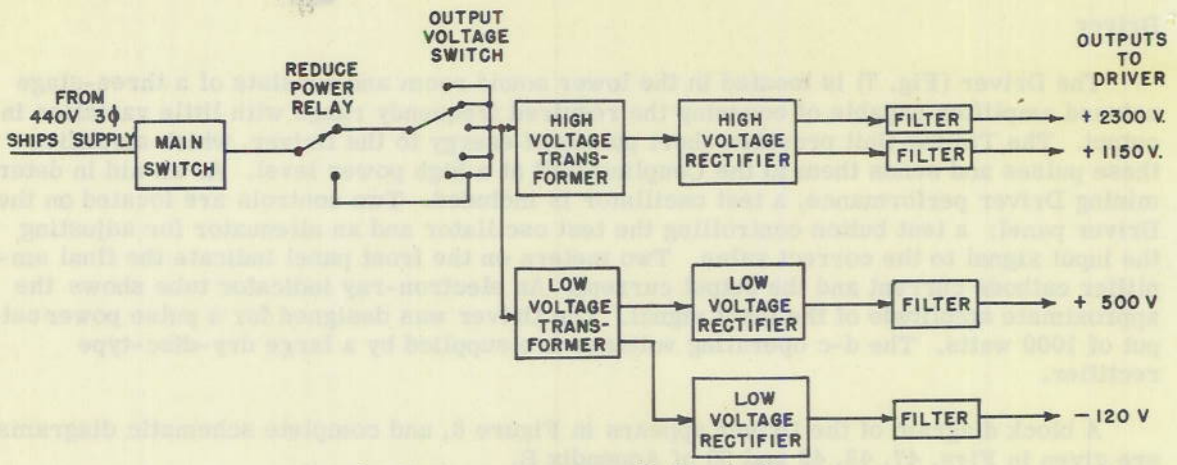



Fig. 9 - Driver power supply block diagram

high- and low-voltage sections of the supply utilize the dry-disc rectifiers connected in conventional bridge circuits. The two low voltages are obtained from two separate transformers, each with its own rectifier and filter. The two high voltages are obtained from one set of three transformers with Y-connected secondaries. A tap from the center of the Y provides full-wave rectification with half the voltage output of the bridge rectifier. Common rectifiers are therefore possible, but separate filters are necessary.

The voltage-control switch selects taps on the primaries of the high-voltage transformers, thus controlling the voltage output. The low-voltage transformers are connected to fixed taps on two of the high-voltage transformer primaries. Thus, due to the autotransformer action of the high-voltage primaries, the voltage-control switch controls both low and high voltages.

When the Driver is hand-keyed for communication or other purposes, Driver power must be reduced in order to protect the Driver and Transducer from damage. This protection is automatically afforded by a "reduce power relay," incorporated in the Driver Power Supply, which automatically connects the ship's supply to the half-voltage taps on the high-voltage transformers, and reduces the power output to 25 percent normal.

## Receiver

The Receiver (Fig. 10) is located in the control console. It amplifies the incoming sonar signals and converts them to audio-frequencies which are reproduced as sound by the loudspeaker and as visible traces by the OKA chemical recorders. Moreover, by means of the unicontrol system, the Receiver is the master frequency-control unit for the entire system.

The Receiver covers the range of frequencies from 10 to 50 kc in two overlapping bands, and also provides for three adjustable "spot frequencies" of 25, 38, and 46 kc. An audio filter is provided to limit the response at higher audio frequencies. This filter is conventional in sonar receivers. Reverberation gain control is incorporated to prevent the masking of echoes from nearby targets by reverberation. Figure 11 is a block diagram of the Receiver. A detailed schematic diagram appears in Appendix B, Fig. 51.

The first part of the Receiver is conventional in nature with the exception of a bandpass network in the signal-frequency circuit in place of one tuned circuit.

The output of the second detector is amplified in the audio amplifier and fed to the audio filter. This filter, a low-pass configuration, may be switched to cut off at 500 or 800 cycles per second (cps), or may be switched out of the circuit when not required. The audio signal is supplied to the loudspeaker in the console, to the chemical recorders, and to the reverberation-controlled gain circuits through appropriate amplifiers.

Simultaneous with the transmission of the outgoing pulse, a trigger pulse is applied to the time-varied gain (TVG) circuit which immediately reduces the gain of the i-f amplifier to prevent overloading by strong reverberations. The i-f gain is then slowly returned to normal, and the Receiver is at maximum sensitivity after a time corresponding to the usual range of reverberations. In the case of severe reverberations, however, the i-f gain is prevented from returning to normal by the reverberation controlled gain (RCG) circuits. These circuits hold the i-f gain at a value depending upon the level of the audio amplifier.



Fig. 10 - Receiver

An amplifier connected to the local oscillator supplies oscillator frequency to the unicontrol circuits in the Timing Unit and the SSI mixers. A vacuum-tube voltmeter is provided for test and alignment purposes. The meter indicates either second detector output (d-c) or RCG control voltage. Power for the Receiver is obtained from a separate power supply which is conventional in all respects.

## Frequency Selection

In order to provide instantaneous frequency shift of the entire

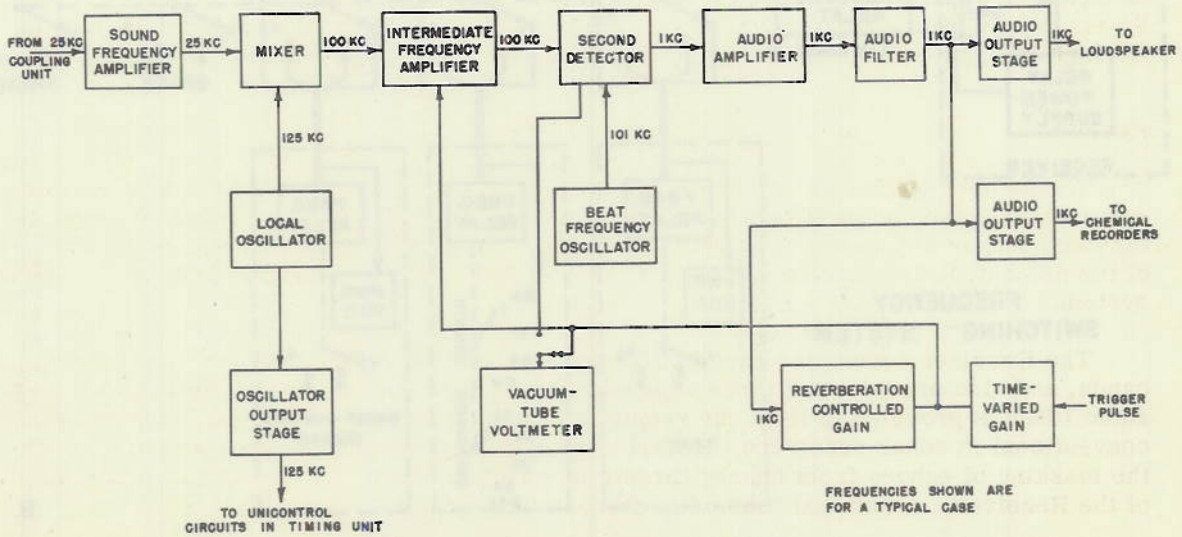
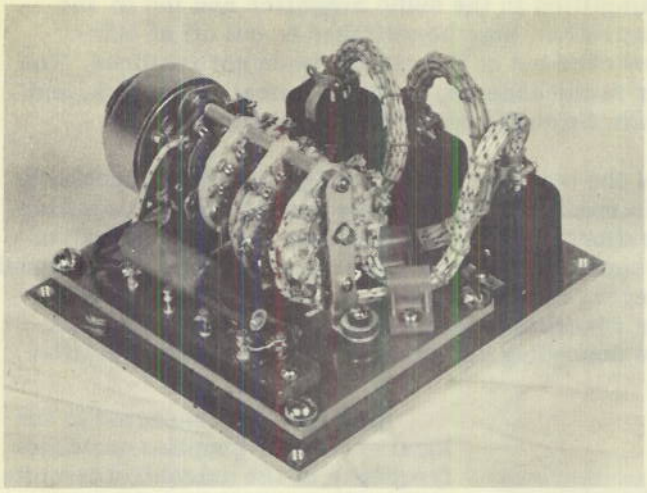



Fig. 11 - Receiver block diagram



Type A system, a single control switch is provided on the receiver front panel (Fig. 10). This switch directly controls the frequency of the Receiver and of the Driver. Also, by remotely controlling several stepping relays (Fig. 12), it selects the proper circuits in the SSI, ODN, and sweep control chassis. Figure 13 is a block diagram showing the connection of these relays.

Fig. 12 - Frequency selecting master relay

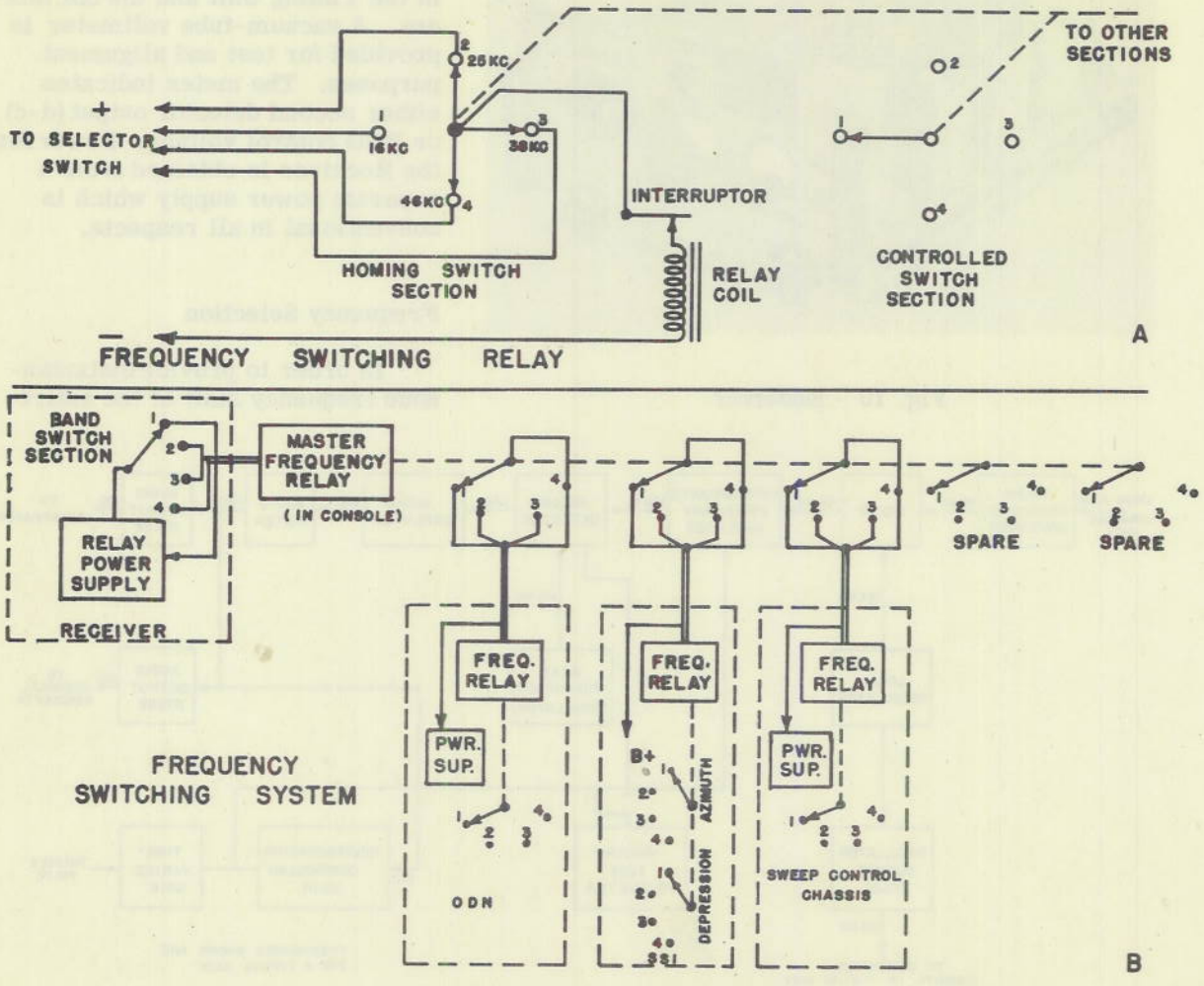



Fig. 13 - Frequency selection

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Own Doppler Nullifier

The Own Doppler Nullifier (ODN) (see Figs. 14, 15, 16, and 17) minimizes the frequency shift of returning signals caused by motion of the ship through the water. This equipment calculates the magnitude of the own doppler effect and makes an opposite correction in the transmitted frequency so that the frequency of the returning reverberations will be essentially constant, regardless of transducer position or ship's speed. The remaining frequency shift is then due to target motion.

The magnitude of own ship doppler shift is dependent on four factors. These are own ship's speed, relative bearing of the transducer, depression angle of the transducer, and operating frequency. The relation is the product of ship's speed, operating frequency, and the cosines of the relative bearing and depression angles (S.F. cos $B_1$. cos Eq). The solution ultimately appears as a change in frequency by means of a variable capacitor connected across the unicontrol oscillator tank circuit in the Timing Unit. If the computed doppler is, for example, 50 cycles up, the capacitor is automatically adjusted to increase the unicontrol oscillator frequency 50 cycles. This reduces the transmitted frequency by the same amount. Therefore, any echoes from stationary objects are restored to the proper frequency, that to which the receivers are tuned.

The ODN Computer contains a potentiometer voltage-dividing network which multiplies together the four factors concerned in doppler shift. The output of this dividing network, operating through a servo system, causes the variable capacitor to rotate through an angle proportional to the calculated shift.

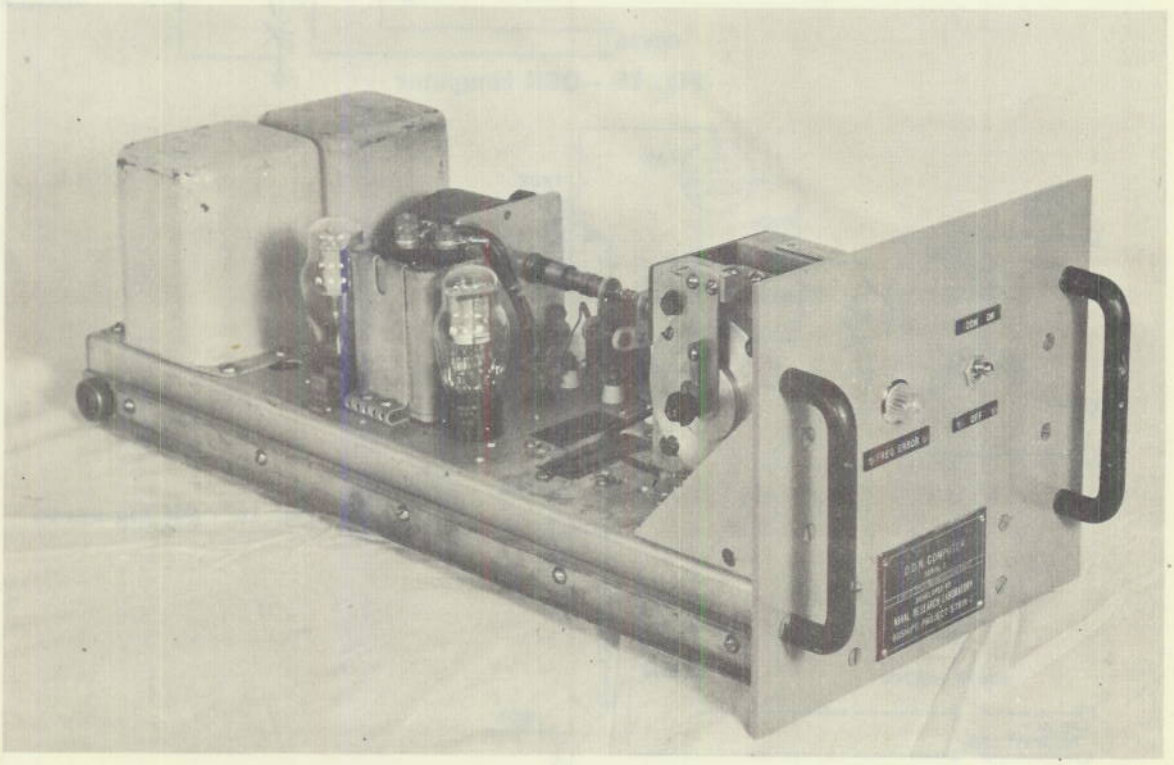


Fig. 14 - Own Doppler Nullifier

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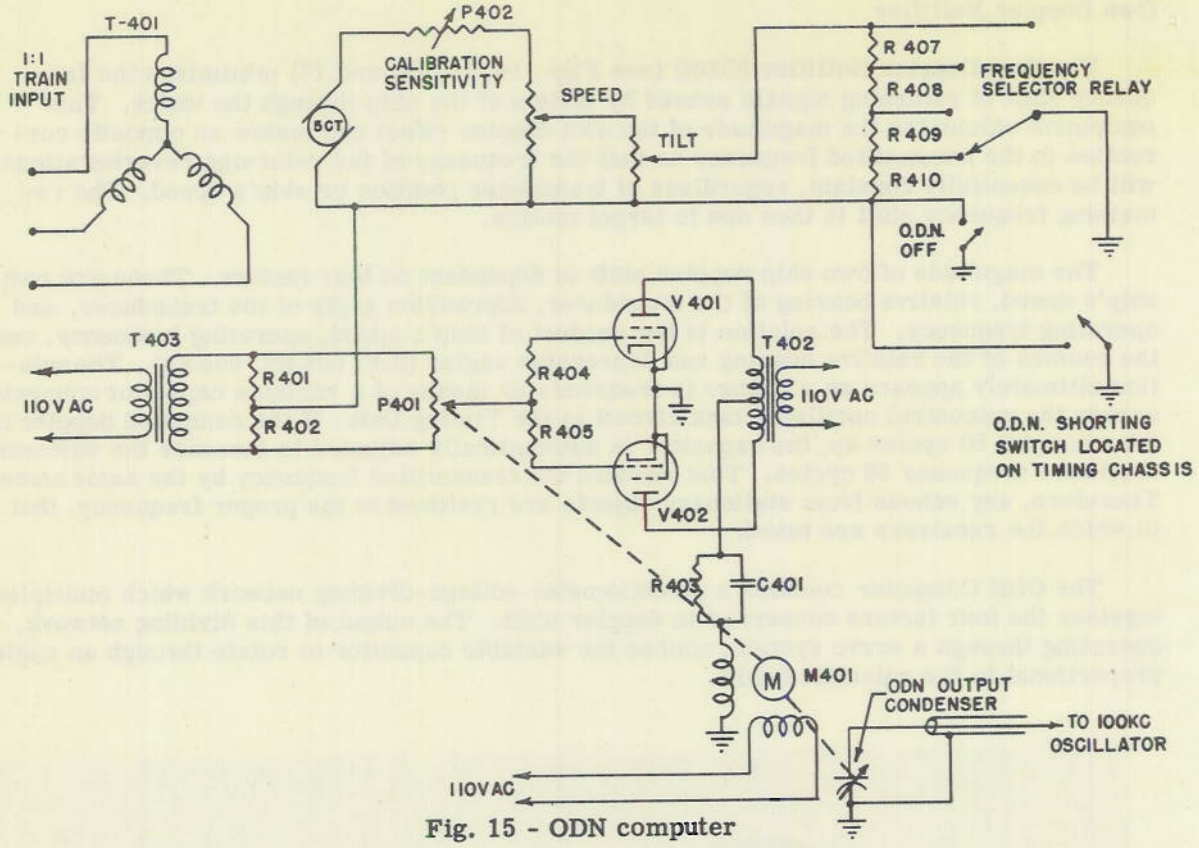



Fig. 15 - ODN computer

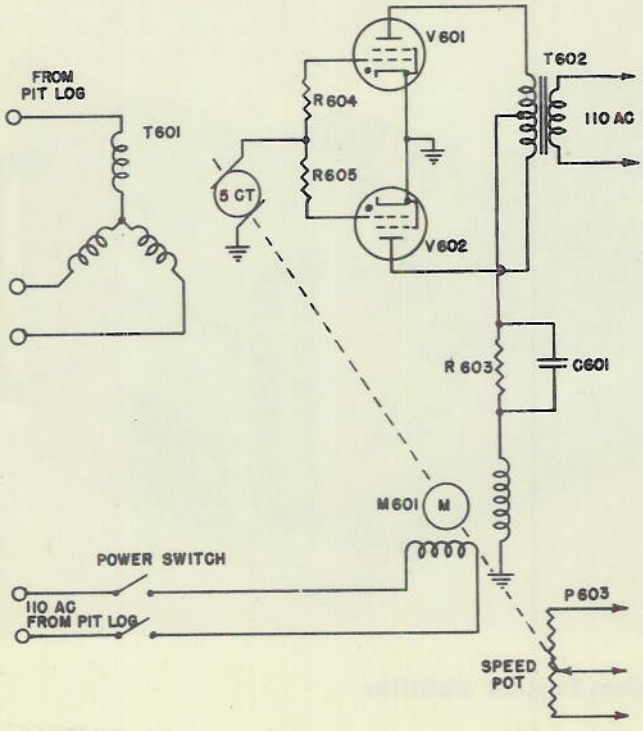



Fig. 16 - Pit log servo

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Unit where it is mixed, during transmission intervals, with the output of the unicontrol oscillator, nominally at 100 kc. The desired signal frequency, obtained as a modulation product, is passed through a filter, amplified, and delivered to the Driver.

Corrections of the frequency of the unicontrol oscillator for own-doppler nullification are described under ODN. Figure 20 assumes no ODN correction for the typical figures given.

## Sector Scan Indicators

The Sector Scan Indicator (SSI) (Fig. 21) is an electronic device which indicates the location of a target within the sonar beam. When used for echo ranging, the conventional SSI indicates the range, angular deviation from the transducer axis, and aspect of targets within the sonar beam. In essence, the presentation is a projection of the sonar beam and anything contained therein on a plane parallel to a plane passed through its axis. In the case of the azimuth SSI, the projection is on a horizontal plane, whereas the depression SSI information is presented on a vertical plane. Figure 22 shows the type of traces produced on the SSI azimuth indicator when echo ranging on a target having four different positions in the sonar beam. In the Integrated Sonar Type A, Mod. 3, System, the SSI equipment consists of two complete SSI receivers, one for azimuth and one for depression. Both receivers are located on one chassis in the control console. In this system the azimuth SSI provides the information presented on the azimuth indicator and on the ASAP, and the depression SSI the information presented on the depression indicator. The SSI is described in detail because the theory is complex and the circuits nonconventional. It will first be assumed that the SSI is used only in a horizontal plane. Special applications in Type A, Mod. 3, will later be described.

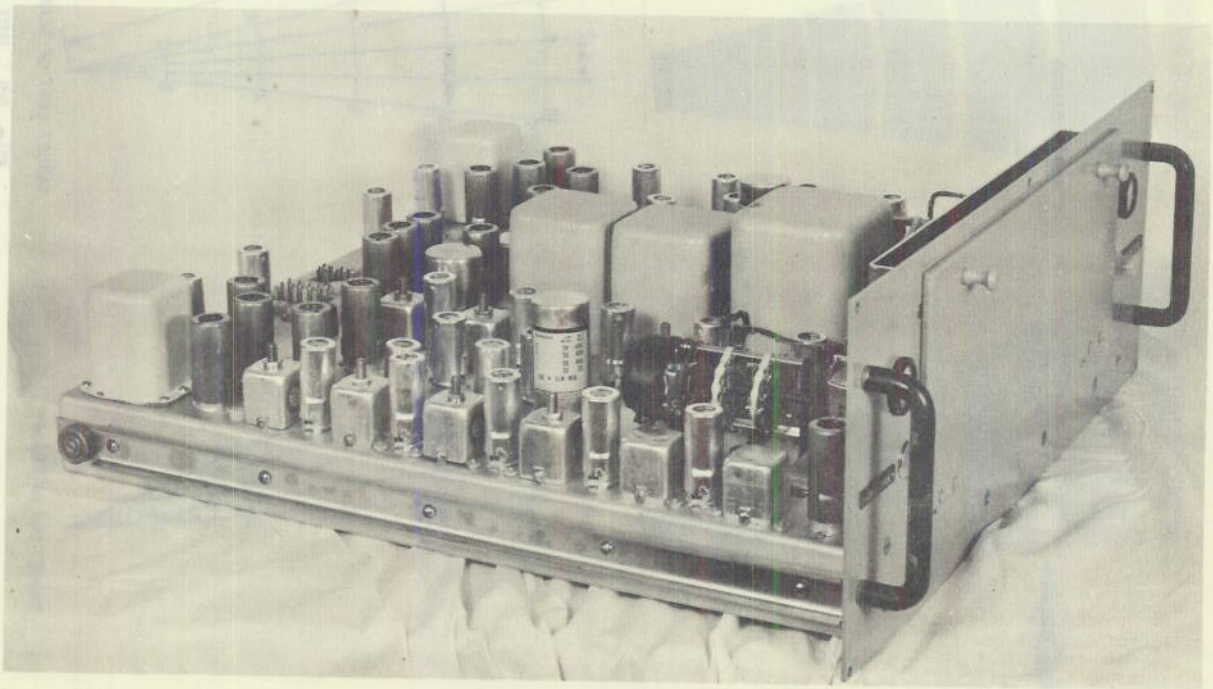


Fig. 21 - SSI amplifier

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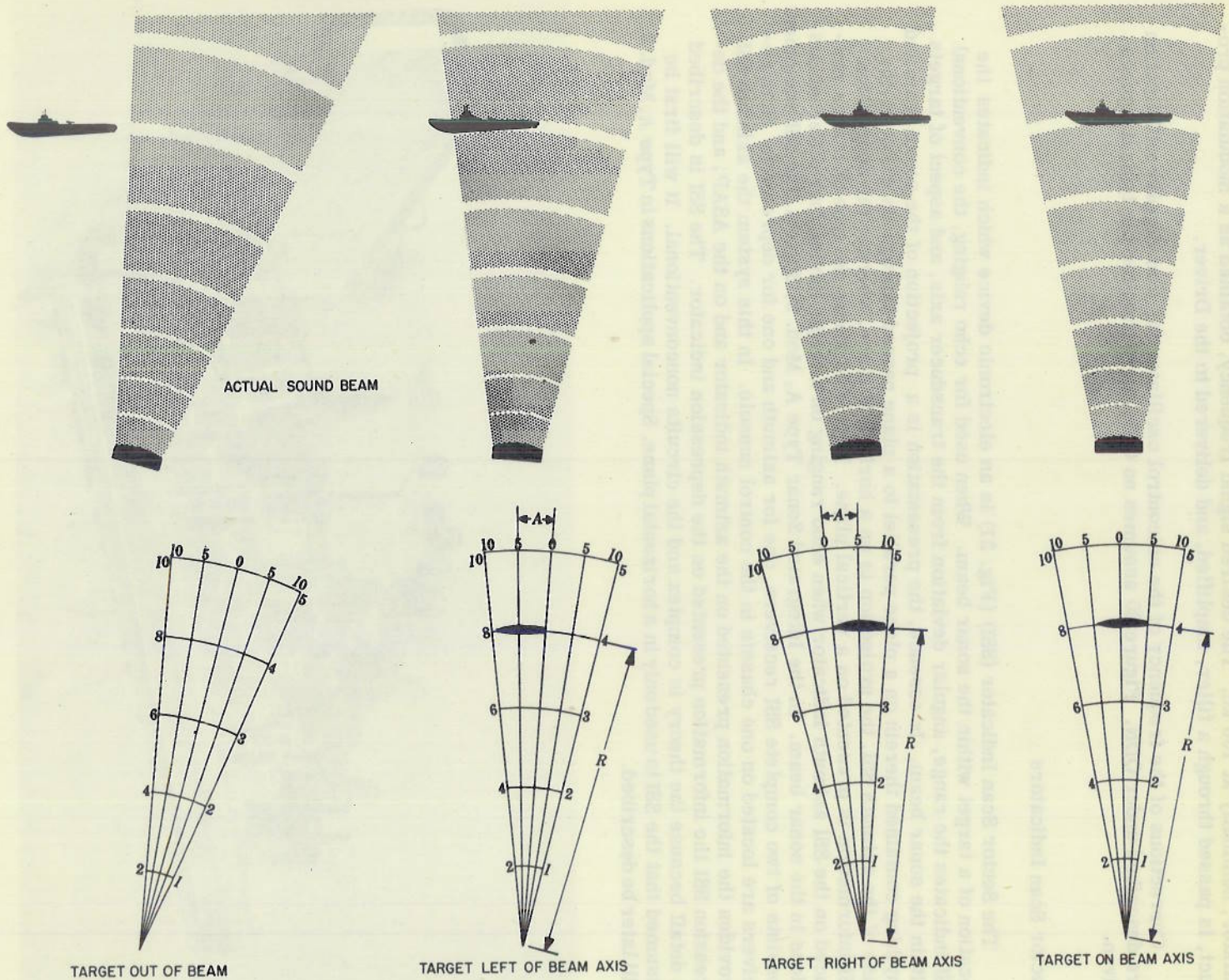



Fig. 22 - SSI azimuth display

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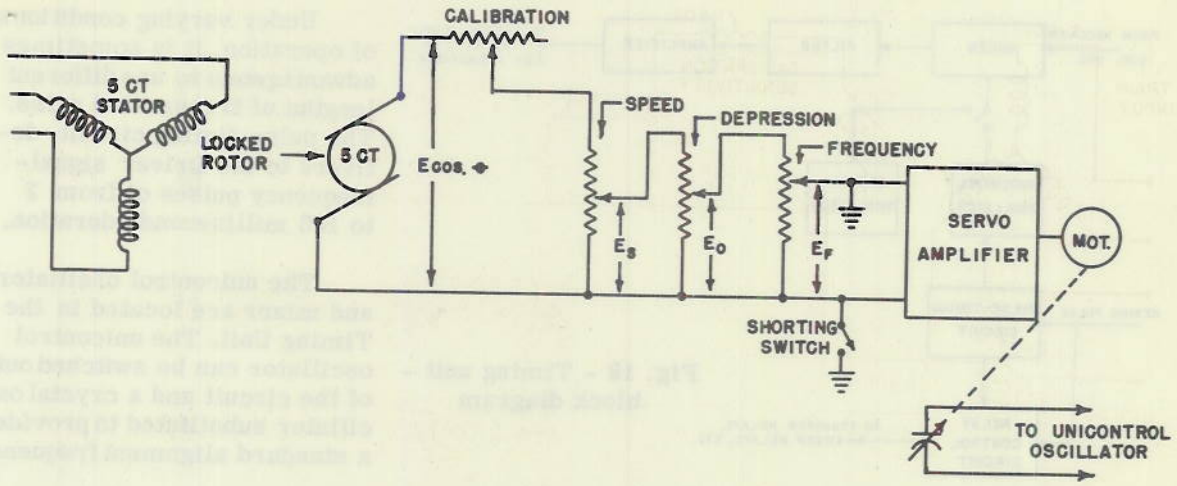



Fig. 17 - Simplified schematic of ODN

## Timing Unit

The Timing Unit (Fig. 18) is located in the control console. This unit performs five major functions: it (1) controls the mode of operation of the entire system, (2) provides the unicontrol frequency for the unicontrol system, (3) controls the Coupling-Unit transfer relays and pulse generation in proper sequence, (4) determines the length of the Driver output pulses, and (5) provides a crystal-controlled 100-kc frequency for system alignment purposes.

Figure 19 is a block diagram showing the functions of this unit. The normal mode of operation of the equipment is for echo ranging. At times it is necessary to discontinue transmission as when listening. At other times, hand keying of the Driver is required for communications. The Timing Unit provides these different modes of operation as well as the calibration and alignment signals.

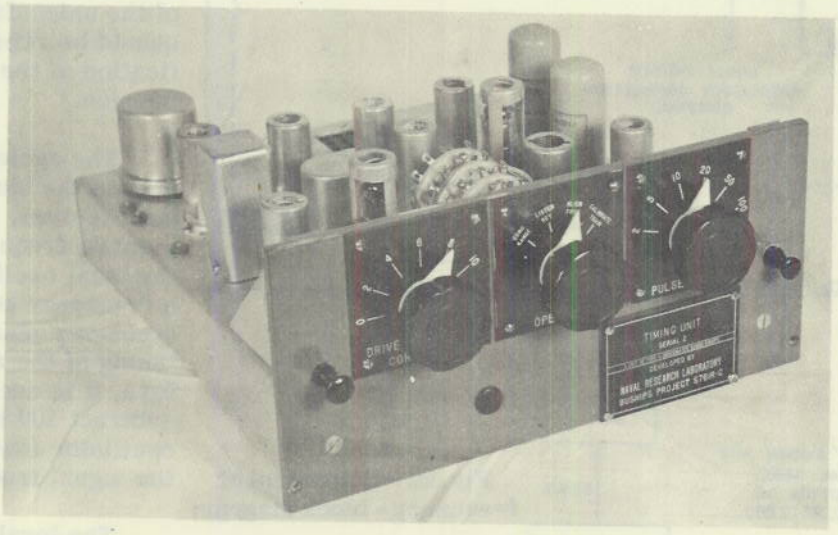


Fig. 18 - Timing unit


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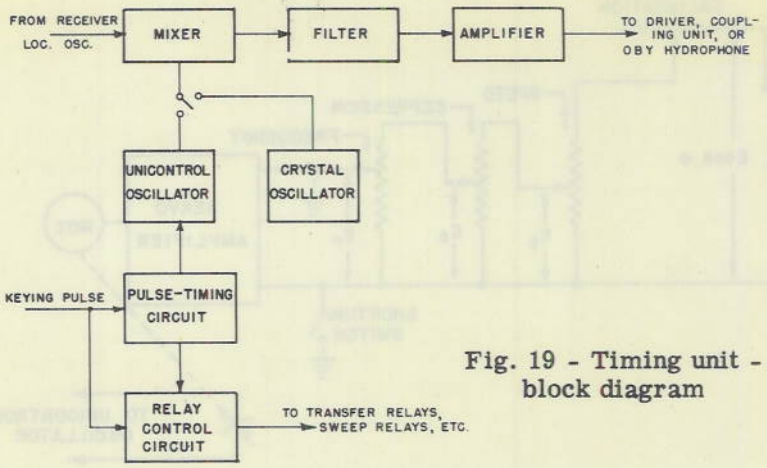



Fig. 19 - Timing unit - block diagram

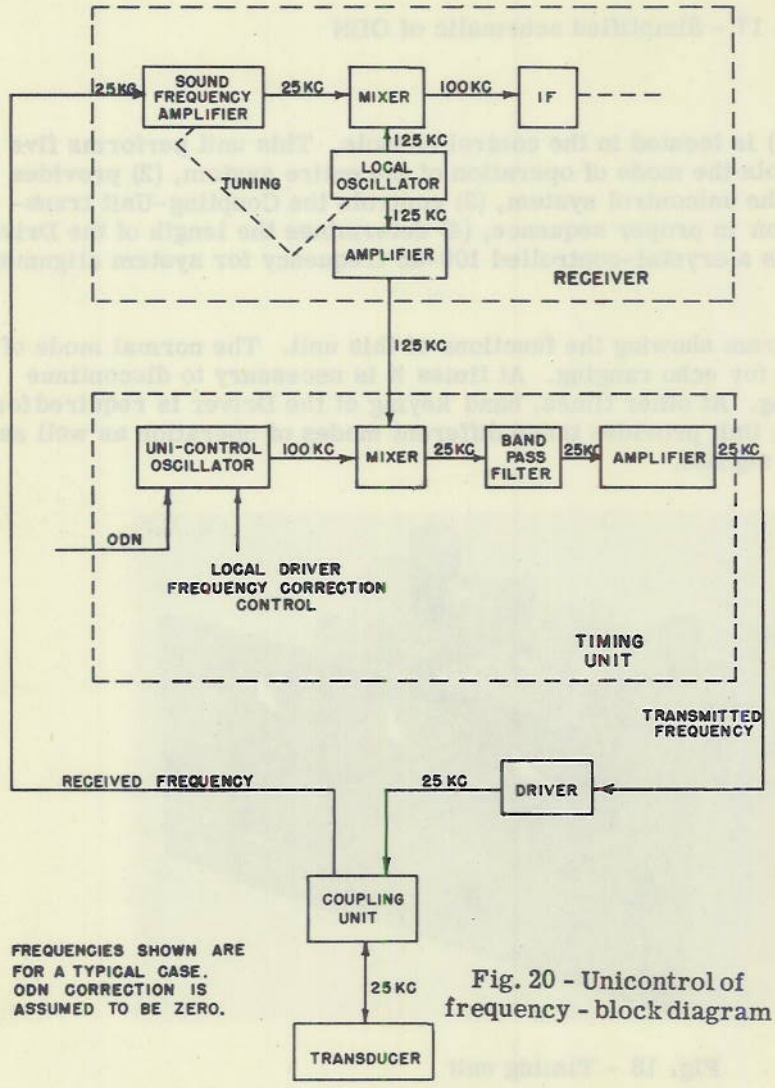



Fig. 20 - Unicontrol of frequency - block diagram

Under varying conditions of operation, it is sometimes advantageous to use different lengths of transmitted pulse. The pulse-timing circuit delivers to the Driver signal-frequency pulses of from 2 to 100 milliseconds duration.

The unicontrol oscillator and mixer are located in the Timing Unit. The unicontrol oscillator can be switched out of the circuit and a crystal oscillator substituted to provide a standard alignment frequency.

The Coupling Unit transfer relays are directly controlled by the Timing Unit so that operation of these relays is coordinated with the transmitted pulse. The relay contacts are closed prior to the time of transmission.

Unicontrol of Frequency

The unicontrol system maintains a calculated relationship between the transmitted and received frequencies. Figure 20 is a block diagram of the unicontrol system and should be referred to for clarification of the following discussion.

The cycle of operation begins in the local oscillator of the receiver. Since the intermediate frequency is 100 kc, the local oscillator is tuned to a frequency equal to the signal frequency plus 100 kc. For any tuning of the receiver, therefore, it is necessary only to subtract 100 kc from the local oscillator frequency to produce the signal frequency.

The local oscillator output, amplified, is sent to the Timing

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Theory of Operation — An SSI requires the use of a transducer split electrically into halves. When a signal reaches the transducer from the axis of the transducer, the two halves respond alike in phase. If, however, the signal is displaced angularly to the right of this axis, it reaches the right half of the transducer before it reaches the left half, giving rise to a phase lead in the right-half response ahead of the left-half response. If the signal is displaced angularly to the left of the beam axis, it reaches the left half before the right half, giving rise to a phase lead in the left half ahead of the right half. The SSI makes use of this phase difference in the two halves of the transducer to produce the trace which indicates the position of the target in the sonar beam. Range indication is provided by a time sweep which is triggered whenever the transmitter is keyed.

Figure 23 is a general block diagram of an SSI system. Two amplifying channels are used, one for each half of the transducer. These amplifiers are of the double-converter superheterodyne type with the first oscillator being common to both channels, and the second oscillators differing in frequency by 4 kilocycles. By heterodyning these two second oscillators in a combiner, a 4-kilocycle difference frequency is obtained. This difference frequency is passed through the central line of components in the diagram, and is used to synchronize a horizontal sawtooth sweep across the screen of the cathode-ray tube. The third horizontal line of components represents the means for obtaining a vertical sawtooth sweep.

The outputs of the two signal-amplifying channels are combined and shaped in the upper row of components to provide the necessary voltages for spot brightening at the proper position in each horizontal sweep when the signal is being received.

Screen Scanning — The electron beam is made to sweep across the screen linearly from left to right; to fly back rapidly to the left of the screen; and to repeat the cycle, thus forming a succession of horizontal lines. This process takes place at the rate of 4000 times a second. At the same time, a slow vertical sweep deflects the successive lines upward from

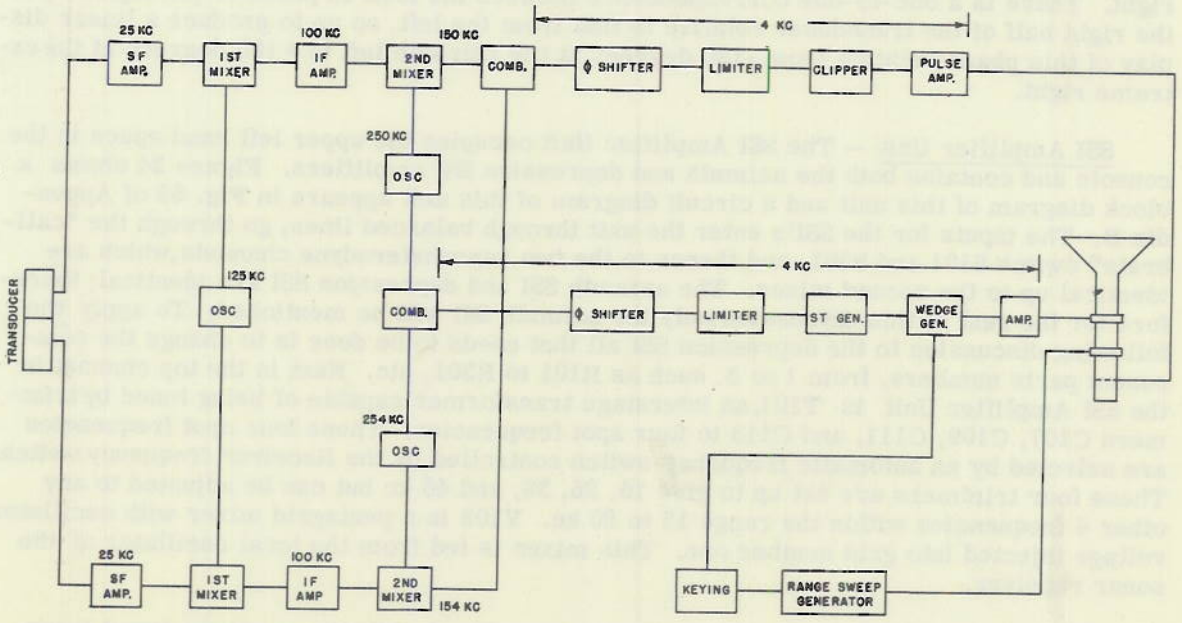



Fig. 23 - SSI general block diagram

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the bottom to the top of the screen. The width of the horizontal sweep is varied as the vertical sweep proceeds up the tube, forming a wedge-shape raster which represents the sonar beam.

Range Sweep — The vertical range-sweep is produced by a sawtooth current applied to the vertical deflection coils. The flyback from top to bottom is automatically controlled by a timing unit. The vertical rate of sweep is varied in accordance with the range in use.

Deviation Sweep — The two second local oscillators are heterodyned against each other to give a 4000-cycle per second difference frequency voltage which is distorted to produce once each cycle a pip for triggering a gas tube, thereby discharging a condenser. This discharge is used to make the sweep "flyback" from the extreme right to the extreme left. Then as the condenser charges, the spot sweeps across the screen in one cycle.

Synchronization of Sweep Pip and Spot-Brightening Pip — The two second intermediate frequencies are heterodyned against each other to give a 4000-cps difference frequency which is distorted to produce once each cycle a pip for spot brightening. Since phases (as well as frequencies) subtract in heterodyning, the spot-brightening pip leads or lags the sweep pip by the same amount as the signal inserted into the higher-frequency channel lags or leads that inserted into the lower-frequency channel. Any desired fixed phase shift may be produced in addition.

The signal from the right half of the transducer is introduced into the higher-frequency channel. Its lead produces a lag of the spot-brightening pip. In addition, 180 degrees fixed (electrical) shift is introduced. If the signals from the two halves of the transducer are in phase, then the spot-brightening pip has just the 180 degrees shift relative to the sweep pip. This means that the spot will brighten half way across the screen or on center. Any lead of the right half will introduce an equal lag in spot brightening. Thus a signal from the right of the transducer axis produces a phase lead in the output of the right half of the transducer, and a lag in spot brightening beyond passage of the sweep through center toward the right. There is a one-to-one correspondence between the lead-in phase of the signal from the right half of the transducer relative to that from the left, so as to produce a linear display of this phase relation from -180 degrees at the extreme left to ± 180 degrees at the extreme right.

SSI Amplifier Unit — The SSI Amplifier Unit occupies the upper left hand space in the console and contains both the azimuth and depression SSI amplifiers. Figure 24 shows a block diagram of this unit and a circuit diagram of this unit appears in Fig. 55 of Appendix B. The inputs for the SSI's enter the unit through balanced lines, go through the "calibrate" switch S101 and S301, and thence to the two superheterodyne channels, which are identical up to the second mixer. The azimuth SSI and depression SSI are identical; therefore for the rest of this discussion only the azimuth SSI will be mentioned. To apply the following discussion to the depression SSI all that needs to be done is to change the component parts numbers, from 1 to 3, such as R101 to R301, etc. Next in the top channel in the SSI Amplifier Unit is T101, an interstage transformer capable of being tuned by trimmers C107, C109, C111, and C113 to four spot frequencies. These four spot frequencies are selected by an automatic frequency switch controlled by the Receiver frequency switch. These four trimmers are set up to give 16, 25, 38, and 46 kc but can be adjusted to any other 4 frequencies within the range 15 to 50 kc. V103 is a pentagrid mixer with oscillator voltage injected into grid number one. This mixer is fed from the local oscillator of the sonar receiver.

The Intermediate Frequency Amplifier is comprised of the three single-tuned transformers T105, T107, and T109 and the two amplifiers V105 and V107. The gain-control voltage



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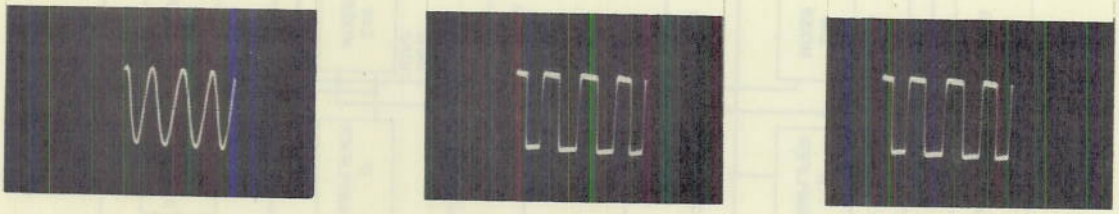
is applied to the cathodes of the two i-f tubes and the signal frequency tube, and the RCG voltage is applied to the grids of the two i-f tubes and the signal frequency tube. Up to this point the other channel of the SSI azimuth amplifier unit is identical.

V109 and V110 are the second mixers. These are pentagrid mixers similar to the first mixer except that the oscillator injection frequencies differ by 4 kc in the two. The mixer in the upper channel has an input frequency of 100 kc, an oscillator frequency of 250 kc, and therefore an output frequency of 150 kc. The mixer in the lower channel has an input frequency of 100 kc, oscillator frequency of 243 kc; hence, an output frequency of 154 kc. Transformer T111 is tuned to 150 kc and T112 to 154 kc.

V111 is a combining tube. This tube combines the output of the two i-f channels to form a 4 kc sine wave at the plate of the tube. V112A is an amplifier for this sine wave, and inductance L103 in conjunction with capacitance C158 form a 4-kc parallel-tuned circuit which acts as a 4-kc filter. This circuit also serves to introduce a high Q in the 4-kc channel which helps to discriminate against noise. Capacitors C159, C160, C161, and C162 are vernier phase shifters which are mechanically switched to provide a separate phase shifter for each input frequency. These capacitors provide a phase-shift action by shifting slightly the resonant frequency of this tuned circuit.

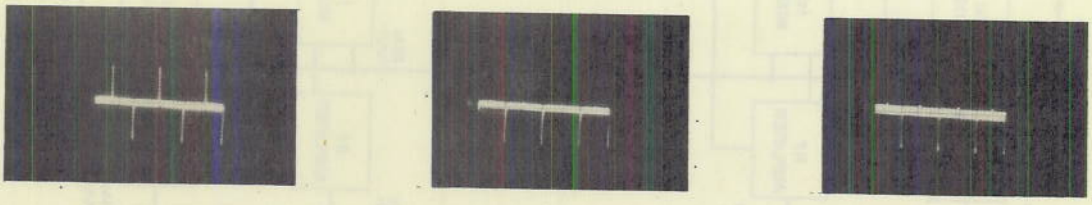
V113 and V114 are cathode-coupled limiters which convert the 4-kc sine waves into 4-kc square waves having fast rise and fall times. This type of limiter is used because the crossover points are maintained in going from sine waves to square waves regardless of sine-wave amplitude above the saturation point. Figure 25 illustrates the wave forms at various points in the 4-kc video channel. Figure 25A is the wave form at the 1st limiter grid, Figure 25B at the 2nd limiter grid, and Figure 25C at the 2nd limiter plate.

This 4-kc square wave is differentiated by resistors R140, and R141, and capacitance C164, Fig. 26A. The differentiated wave is clipped by clipper tube V115, which allows only the tips of the positive pips to pass through to the cathode-follower tube V116. Fig. 26B shows the wave form at the cathode-follower grid and Fig. 26C the wave form at the cathode-follower output. The video signal leaves the SSI Amplifier Unit through a coaxial cable to the video amplifier, which is mounted near the cathode-ray tube.



A B C

Fig. 25 - SSI waveforms



A B C

Fig. 26 - SSI waveforms

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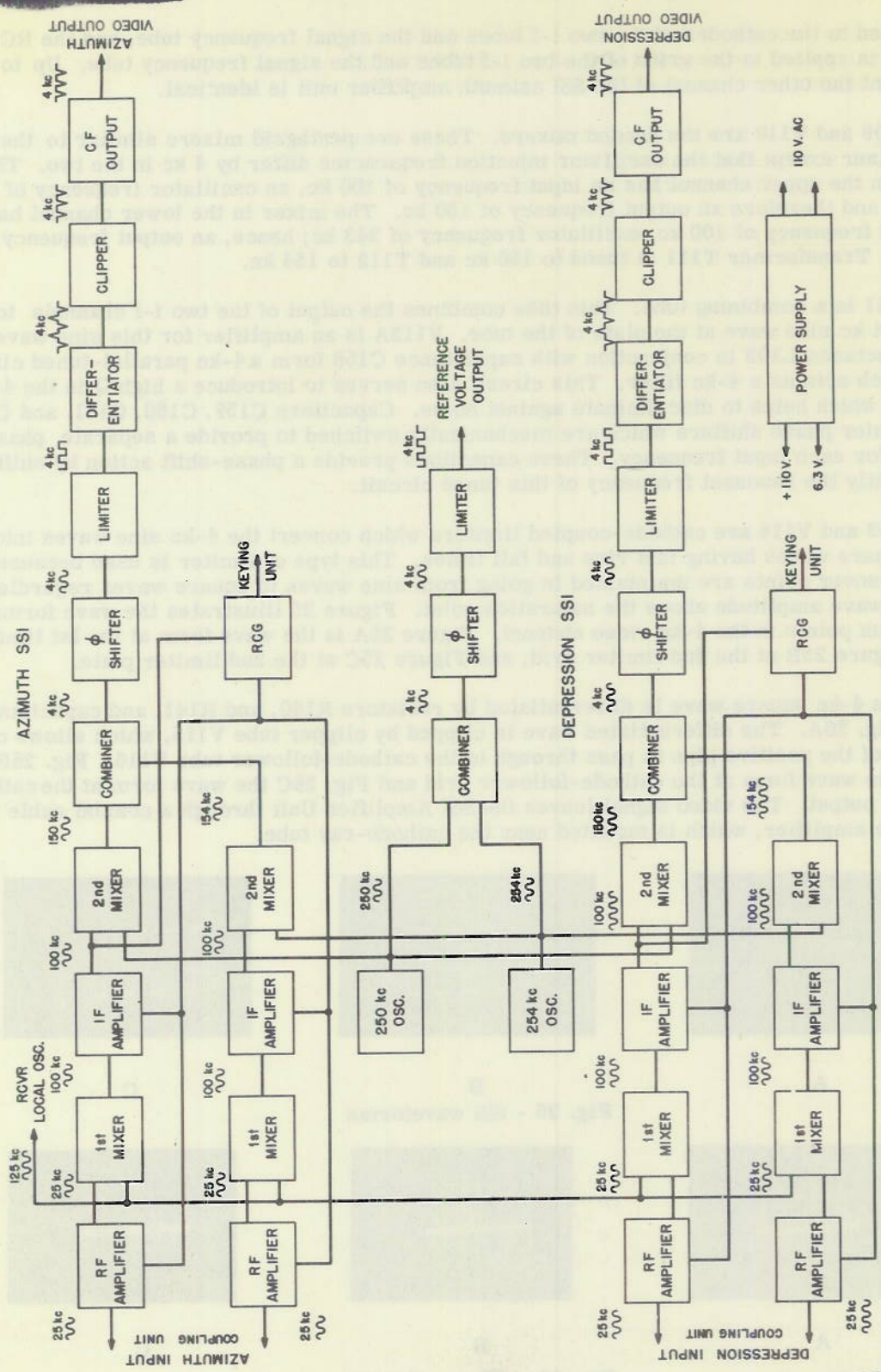



Fig. 24 - SSI unit block diagram

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V301A and V301B are the two oscillator tubes which supply the injection voltage for the second mixers of the amplifier channels. These are ordinary crystal-controlled Pierce oscillators. X301A operates at 250 kc and X301B at 254 kc.

The reference voltage for the synchronization of the 4-kc sweep is obtained by combining the output of the two crystal oscillators in the combining tube V302. The output of this tube is a 4-kc sine wave which is amplified by V303 and transformer coupled to a phase shifter comprised of the center-tapped secondary of the transformer, capacitor C314, and potentiometer R318. This is the master phase shifter and is used, in conjunction with the vernier phase shifters mentioned earlier, to calibrate the SSI indicator. V304A and V304B are amplifiers for the 4-kc reference voltage. The output of V304 is fed to the sweep unit where it is used to trigger the proper sweeps.

Signal voltage is taken from the last 100-kc i-f transformer secondary of each i-f channel, amplified by V118A and V118B, and then applied to rectifier tubes V119A and V119B. The outputs of these two rectifiers go to momentary contact switches S101 and S104. When both of these switches are in normal position, the vacuum-tube voltmeter I102 reads the output of the upper channel and when S104 is depressed I102 reads the output of the lower channel. This meter gives a quick check on the operation of the two i-f channels.

The RCG voltage is obtained by using the same rectified output that is used to indicate the condition of the lower channel. A positive keying pulse is applied to the grid of V122 each time the transmitter is keyed. This pulse causes the gas tube to conduct, discharging C181 through resistor R167. A voltage is developed across this resistor which causes C180 to charge negatively through diode V121. This charge is used as the RCG voltage source. This voltage is made to follow the reverberation-decay curve by using the d-c voltage developed by rectifier V119B to hold the voltage across C180 at the same negative value as that developed across R166, a value proportional to the reverberation intensity. The RCG voltage is applied as grid bias to the r-f and i-f tubes of both channels.

## Display System

The display system gives a visual presentation of sonar information supplied by the SSI receivers. This information is presented on three crt indicators, one for azimuth, one for depression, and one for the Attack Plotter. The azimuth and depression indicators (Fig. 27) are located on the control console, the Attack Plotter indicator in its cabinet.

Two chassis, the Sweep Control chassis, and the Wedge Generator chassis, located in the control console, contain the electronic and mechanical sweep generating circuits for all the indicators. A photograph of the Sweep Control chassis appears on Figure 28 and a block diagram of the display system is shown in Figure 29.

The Azimuth Display is a PPI which shows target bearing relative to own ship. A wedge scan starts from own ship's position in the center of the crt and moves radially in range along the proper bearing. The deflection coils for this tube are servo-driven and follow the correct called-for relative bearing. A pointer attached to the servo driver indicates the center of the wedge sweep. A servo-driven compass ring provides true transducer bearing.

The depression display is a depth position indicator which shows target position relative to own ship and to the ocean's surface. A wedge scan starts at the upper left hand corner of the tube. The angle between the horizontal and the centerline indicates the called-for depression angle to the target. The 4-kc deflection coil is servo driven, while the range



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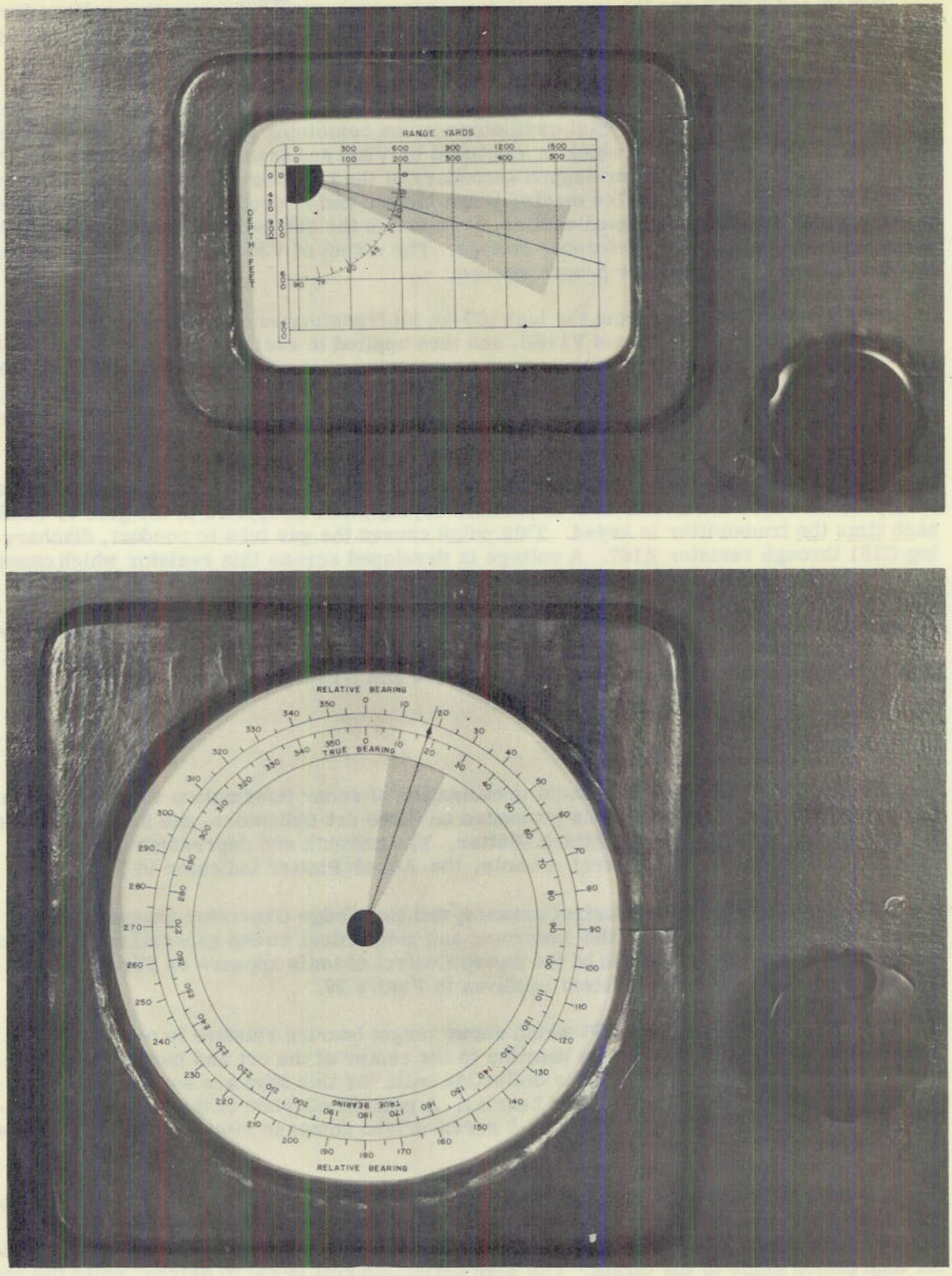



Fig. 27 - Azimuth and depression displays

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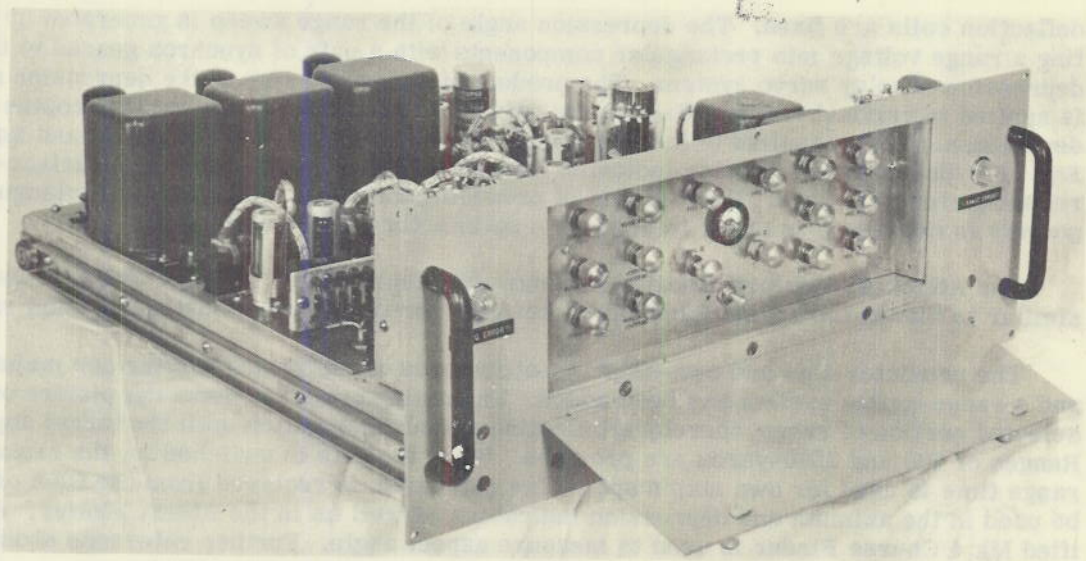


Fig. 28 - Sweep control chassis

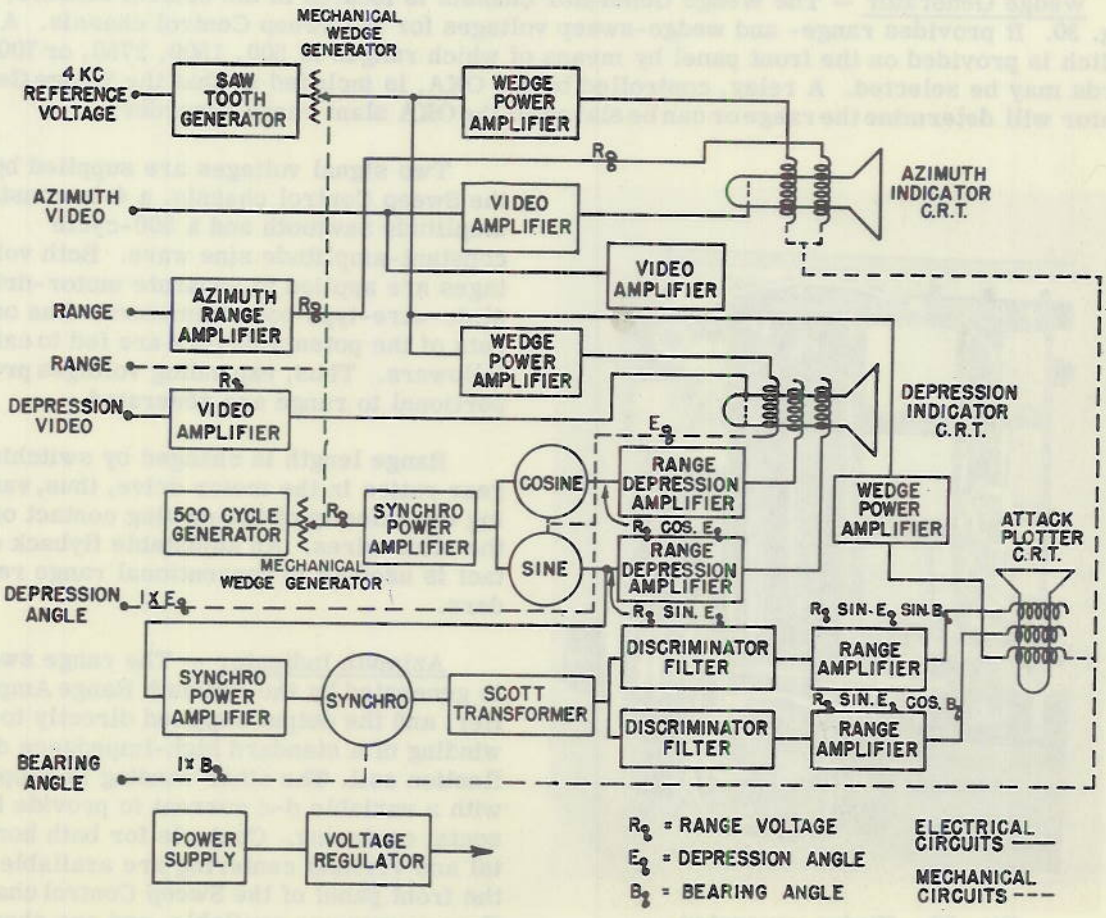



Fig. 29 - Display system block diagram

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deflection coils are fixed. The depression angle of the range sweep is generated by splitting a range voltage into rectangular components with a pair of synchros geared to the depression display servo system. The product of range and sine of the depression angle is applied to vertical range deflection coil while the product of range and the cosine of the depression angle is applied to the horizontal-range deflection coil (Rq sin Eq and Rq cos Eq). A synchro-driven pointer indicates the center of the wedge unless the surface-reflection reducing circuit is used. This method of producing the range deflection by rectangular components is necessary in order to produce a satisfactory off-center sweep.

The Attack Plotter presentation is a movable-center PPI. A wedge sweep is used similar to that in the Azimuth Indicator, but with horizontal range instead of slant range.

The predictor-line and own-ship's-spot features of the Attack Plotter are maintained, and a range-gating system has been added. The gating process blanks the picture over a selected portion of range, thereby eliminating visual information until the target appears. Ranges of 500 and 2500-yards are provided. When the gate is switched in, the remaining range time is used for own ship's spot. The gate pulse is received from the OKA and may be used in the azimuth and depression indicators as well as in the Attack Plotter. A modified Mk 4 Course Finder is used to measure aspect angle. Further reference should be made to the Attack Plotter instruction book.

Wedge Generator — The Wedge Generator chassis is located in the control console, Fig. 30. It provides range- and wedge-sweep voltages for the Sweep Control chassis. A switch is provided on the front panel by means of which ranges of 500, 1500, 3750, or 7000 yards may be selected. A relay, controlled by the OKA, is included so that the Wedge Generator will determine the range or can be slaved to the OKA slant range recorder.

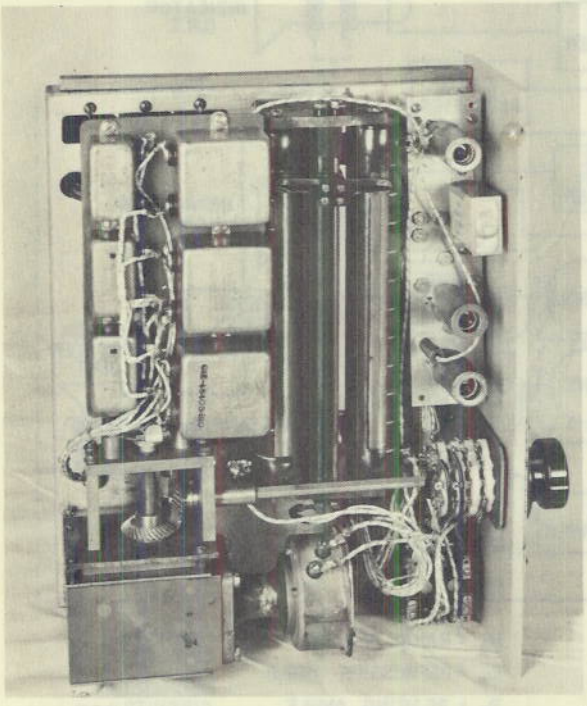


Fig. 30 - Wedge generator

Two signal voltages are supplied by the Sweep Control chassis, a 4-kc constant-amplitude sawtooth and a 500-cycle constant-amplitude sine wave. Both voltages are applied to separate motor-driven slide-wire-type potentiometers. The outputs of the potentiometers are fed to cathode followers. Thus, expanding voltages proportional to range are generated.

Range length is changed by switching gear ratios in the motor drive, thus, varying the velocity of the moving contact on the slide wires. An adjustable flyback contact is used as in conventional range recorders.

Azimuth Indicator — The range sweep is generated by the Azimuth Range Amplifier, and the output supplied directly to one winding of a standard high-impedance deflection coil. The other winding is supplied with a variable d-c current to provide horizontal centering. Controls for both horizontal and vertical centering are available on the front panel of the Sweep Control chassis. Four ranges are available, and are changed

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by a switch on the front panel of the Wedge Generator chassis. This switch connects an appropriate-sized charging condenser for the range used.

The output from the 4-kc Sawtooth Generator is supplied to the Wedge Generator chassis where it is converted to a 4-kc sawtooth with amplitude proportional to range. This expanding sawtooth is fed to the Power Amplifier and thence to the wedge deflection coil. A wedge amplitude control is provided on the front panel of the Sweep Control chassis. There are also four common wedge-amplitude controls on this panel. These controls apply to all three indicator tubes.

Video signal information is supplied by the Azimuth SSI. This signal is amplified by a video amplifier and fed to the control grid of the indicator tube. This tube is blanked during the flyback and recorder dead time. A gate period is also available and is controlled by a switch on the indicator panel.

Depression Indicator — The range-deflection voltage is supplied by the 500-cycle Generator, and fed to the Wedge Generator chassis, where it is converted to an expanding 500-cycle voltage with amplitude proportional to range. The expanding 500-cycle signal is then fed through a synchro power amplifier to a pair of 1 CT synchro stators. The rotors are geared 90 degrees apart and servo-controlled by the depression hand wheel. The output signals thus obtained from the rotors are proportional in amplitude to the sine and cosine of the depression angle. The output of each 1 CT synchro is rectified, filtered, and amplified by the Range Depression Amplifier, and thence fed to the horizontal and vertical windings of a high-impedance deflection coil. Horizontal and vertical positioning controls are available on the front panel of the Sweep Control chassis.

It will be noted that the filter circuit in the Range Depression Amplifier has a very short time constant. If the 1 CT synchros were excited by a 60-cycle signal as is conventional, the filtering would be inadequate and a hum voltage would appear on the indicator tube. If the time constant of the filter were increased to provide sufficient filtering, the tracking response of the range sweep on the indicator tube would be undesirably slow. To overcome this difficulty, a 500-cycle voltage source is used. The conventional synchros operate satisfactorily at this frequency.

The wedge sweep circuit is identical to the one used for the azimuth indicator. Figure 32 shows the depression wedge-sweep power amplifier. The wedge-amplitude control is available on the front panel of the Sweep Control chassis.

The video circuit is also identical to that of the azimuth indicator, except that in this case the signal is derived from the depression SSI receiver.

Attack Plotter — The Attack Plotter range sweep is derived from the horizontal component of the depression-indicator sweep, which is horizontal range. This signal is amplified by a Synchro Power Amplifier and fed to a 5 SCT synchro which is mechanically linked to the wedge-deflection coil in the ASAP. The output of the 5 SCT is connected to the conventional ASAP Scott transformer and discriminator circuits, the reference winding of the Scott circuit being connected directly to the 500-cycle Generator. The filters following the discriminator tubes have small time constants and rapid tracking response is obtained as in the depression-indicator circuits. The outputs of the filters are connected to potentiometers which are N/S and E/W controls. The outputs from these controls are fed to contacts on the A relay. The function of this relay is to demagnetize the indicator tube during the flyback period. Demagnetization is accomplished by applying 500 cycles to a phase-splitting network and connecting this signal to the deflection-amplifier grids. When the A relay opens, the B relay closes (Fig. 31) and feeds the predictor signal to the

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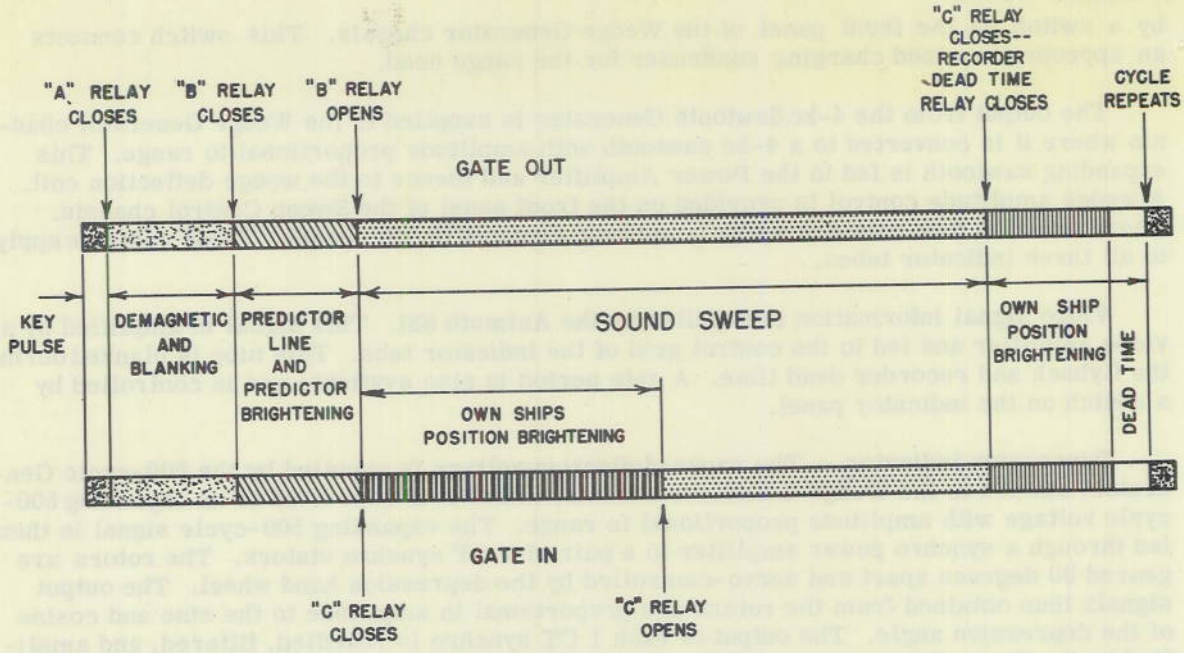



Fig. 31 - ASAP relay cycle

deflection amplifiers, and thence to the indicator tube. The predictor signal is generated in the conventional manner. A relay has been provided, however, to change the values in the voltage divider so that two predictor-signal amplitudes are available to provide for two ranges. When the B relay opens, the range-sweep signal is applied to the deflection amplifiers and thence to the indicator tube. The C relay connects the grids of the deflection tubes to course plot during flyback and recorder dead time and during the gate-closed portion of the sound sweep. A multivibrator circuit is provided to produce a gated sound or range sweep. If the Gate switch (S301) is closed, the B relay, on opening, will key the multivibrator, which in turn actuates the C relay. A contact on the OKA slant-range recorder will re-key the multivibrator at a later predetermined time during the sweep, causing the C relay to open, thus allowing SSI traces to appear on the cathode-ray indicator tubes. Controls are available on the front panel of the Sweep Control chassis for adjusting the sweep lengths for the two ranges used (500 and 2500 yards).

The wedge sweep-circuit is identical to those for azimuth and depression except that contacts on the B and C relays are provided to short the sweep voltage during the period when the predictor line is applied, and during the flyback, recorder dead time, and gate closed periods. The Power Amplifier chassis is used to supply the wedge deflection coil. Controls are available on the front panel of the Sweep Control chassis to adjust the wedge width for the four frequencies used. When using the longest range, both wedge and range sweeps are disconnected.

The video signal is supplied from the Azimuth SSI receiver and fed to a video amplifier which is identical to those used in the Azimuth and Depression Indicators. The output of the video amplifier is connected to the A relay so that negative voltage is applied to the grid of the indicator tube when the A relay closes, thus blanking the tube during the demagnetizing period. From the A relay the signal is applied to the B relay which, when actuated, will connect an alternating 60-cycle potential of the proper phase to the grid of the indicator tube, causing the predictor line to brighten. The signal is then fed to the

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C relay which, when actuated, will apply an alternating potential to the grid of the indicator, causing ship's position spot-brightening. During the range sweep, or gate-open period, A, B, and C relays are open, and video information from the azimuth SSI is applied to the grid of the indicator tube.

The B relay has a contact which, on opening, will provide a negative pulse. This pulse is fed to one grid of a "one shot" multivibrator. A gate contact is provided on the OKA range recorder and will supply a negative pulse when closed. This pulse is applied to the other grid of the multivibrator. Thus, when the B relay opens, the multivibrator will fire, causing the voltage on one of its plates to rise and the other to fall. The closing of the gate contact will fire the multivibrator again, returning it to its original condition. Thus, it will be seen that both a positive and a negative pulse are available of a duration equal to the gate-closed period. The positive pulse is fed through a switch (S012) to an amplifier tube whose plate load is the C relay coil. Therefore, the C relay will close during the gate-closed period of the range sweep. The negative pulse is fed to the screen grids of the azimuth and depression video amplifiers, causing blanking during the gate-closed period. Switches (S013) are provided in this lead to switch the gate in or out of the azimuth and/or Depression Indicators as desired. Another switch, S301, located on the front panel of the ASAP controls the ASAP gate circuit.

The C relay is closed during recorder deadtime by applying a positive voltage to the C-relay control-amplifier grid. The recorder deadtime relay unshorts a portion of a voltage divider which is connected to the B+ supply. The grid of the control amplifier is connected through a resistor to this divider. A second contact on the recorder deadtime relay unshorts a portion of voltage dividers connected to the cathodes of the Azimuth and Depression Indicator tubes, causing blanking of these tubes by greatly raising the positive cathode potentials. The third recorder deadtime relay contact is used to short the azimuth range condensers during deadtime.

The A and B relay control circuits are those used in the original ASAP circuit. For more detailed information, the ASAP instruction manual should be consulted.

Power Supply — The Power Supply is conventional supplying 400 volts at 400 ma and 3000 volts for the indicator tubes. The filament supply for the Sweep Control chassis is included in the Sweep chassis rather than in the Power Supply, thus, minimizing wiring difficulties.

Wedge Power Amplifier — This Power Amplifier (Fig. 32) is a conventional type magnetic-deflection amplifier similar to the type used in television circuits. The purpose of the amplifier is to supply a 4-kc current to the wedge deflection coils. Three identical amplifiers are used: one for the Azimuth Indicator, one for depression, and one for the ASAP indicator. R504 and C501 form a conventional RC oscillation-damping circuit. R503 and the selenium dry-disk rectifier T502 are used for raster centering. An increasing d-c component is developed by the selenium rectifier as the saw-tooth voltage increases. This d-c voltage will cause the raster to move in a horizontal direction, proportional to the 4-kc saw-tooth amplitude. By varying the degree of rectification with rheostat R503, the proper centering voltage may be applied to the deflection coil. Distortion caused by this centering control can be compensated for by adjusting the damping network.

The wedge power amplifier and all of the remaining components of the display system have been constructed as separate units. This has been done to facilitate quick replacement in case of breakdown. All of these units are assembled on a common chassis. Replacement is made by removing one of these units and replacing it with another, without need for soldering or other servicing while in the console.

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Azimuth Range Amplifier — The Azimuth Range Amplifier (Fig. 33) supplies the range sweep current to the Azimuth Indicator deflection coils. This amplifier is a conventional push-pull self-phase-inverting type, with centering voltage applied to one grid and the range-sweep voltage applied to the other grid. The range-sweep voltage is generated by charging an appropriately sized condenser through resistors R5B02 to R5B06. R5B01 sets the level to which the condenser will charge and functions as a range-length control for all ranges.

Range Depression Amplifier — The Range Depression Amplifier (Fig. 34) supplies range sweep voltage for the Depression Indicator. The sweep voltage is previously divided into rectangular components. Two identical Range Depression Amplifiers are used to amplify each component of the range signal.

The input sweep signal supplied to the Range Depression Amplifier is rectified by a conventional full-wave rectifier circuit. An LC pie section is used for filtering, and a push-pull power amplifier of the self-phase inverting type drives the deflection coil. Range length is controlled by a pot, R5C03. Centering or range start voltage is supplied to the grid of V5C01.

Voltage Regulator — The Voltage Regulator (Fig. 35) supplies a constant 250 volts over a large range of load currents and over power line variations of 100 to 130 volts.

The circuit is the standard series-Gm-type regulator using a 6AS7 dual power triode as a regulator tube and a 6AG5 pentode as a control amplifier. An OB2 gas tube is used as the reference voltage supply.

Synchro Power Amplifier — The Synchro Power Amplifier (Fig. 36) is a current amplifier which supplies a 500-cycle signal to the synchros. Two identical synchro amplifiers are used, one to drive the range depression synchros, and the other to drive the ASAP range synchro input.

The amplifier is a push-pull cathode-follower type using triode connected miniature power tubes. The driver amplifier is a conventional phase-inverter circuit.

500-Cycle Generator — The 500-cycle Generator (Fig. 37) is used as a voltage source to supply the range sweep circuits for the Depression Indicator and the ASAP.

The circuit is a conventional Hartly oscillator followed by a cathode follower. R5F03 controls the signal amplitude.

Saw-tooth Generator — The Saw-tooth Generator (Fig. 38) supplies a horizontal deflection signal to all the power amplifiers.

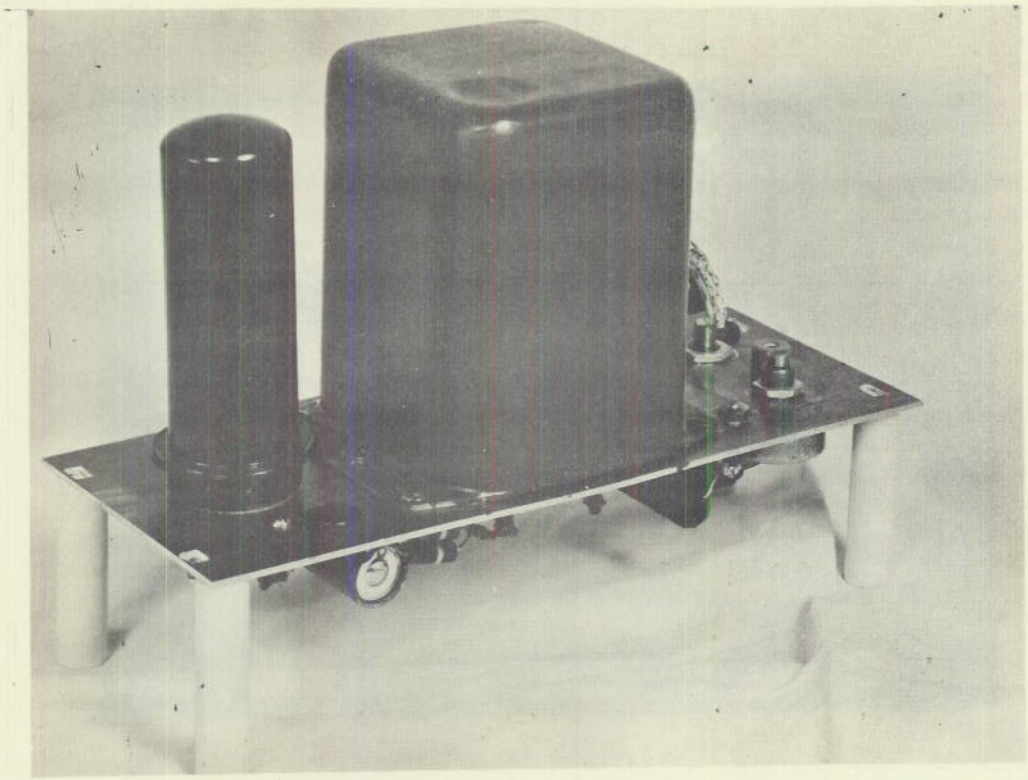
A 4-kc sine-wave input signal is converted to a square wave by a double limiter circuit (V5G01). This square wave is differentiated and used to trigger a conventional gas-tube saw-tooth oscillator (V5G02). The saw-tooth signal is fed to a cathode-follower output amplifier.

OKA Gate — A gate contact is added to the slant range recorder in the OKA equipment to provide range-gating pulses for the Type-A indicators. This contact is secured to the cursor assembly in a fixed position relative to the flyback contact. On the 1500-yard range, the gate contact will close approximately 150 yards before the target echoes are printed.

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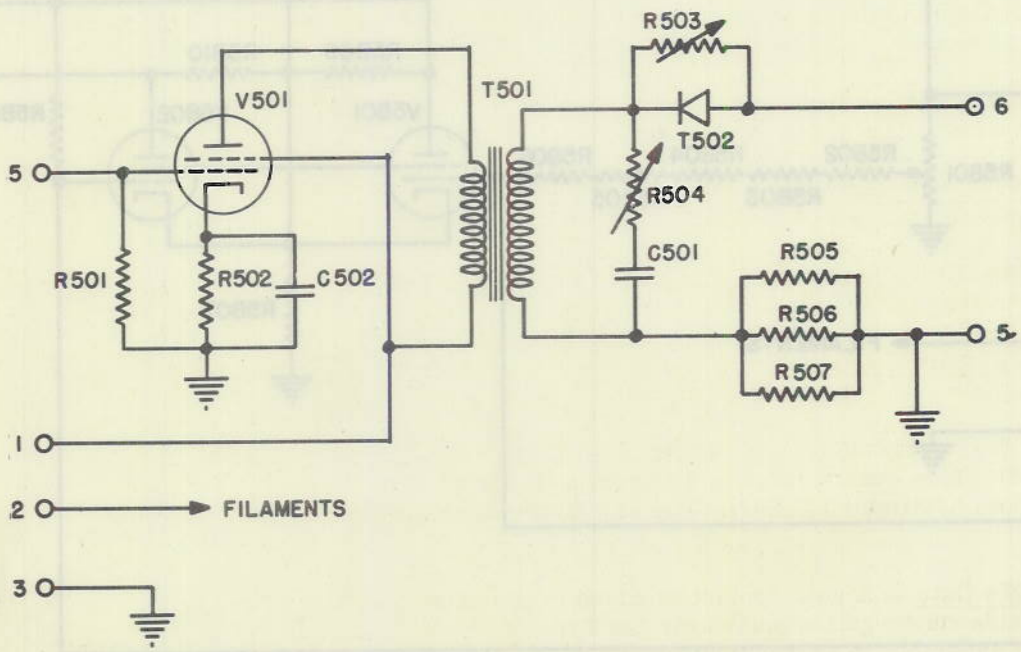
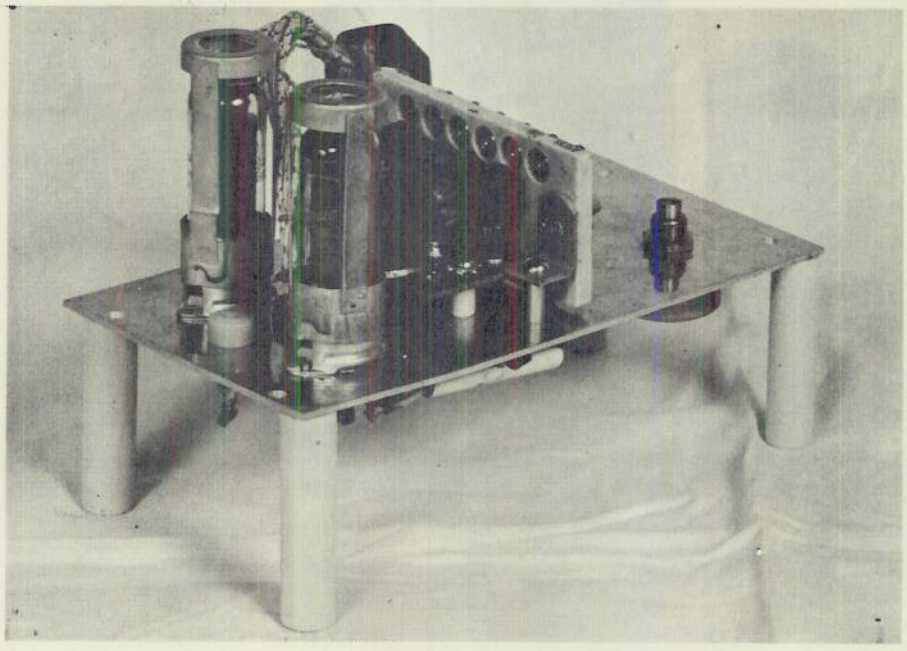



Fig. 32 - Wedge power amplifier

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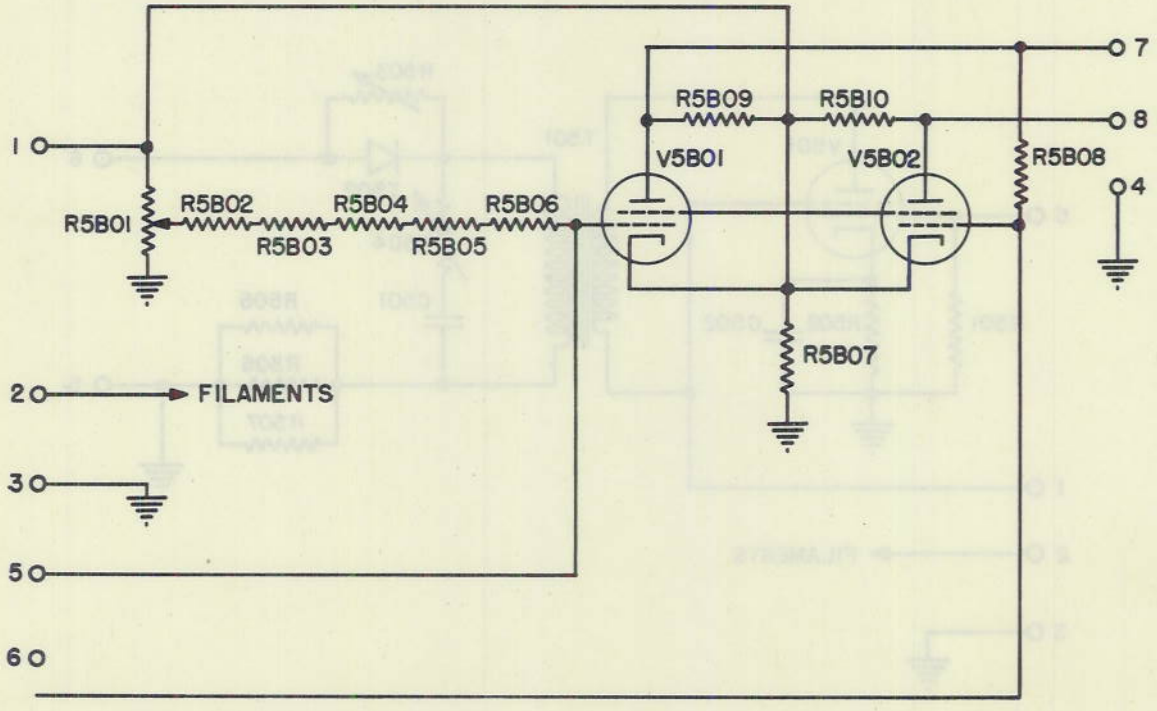
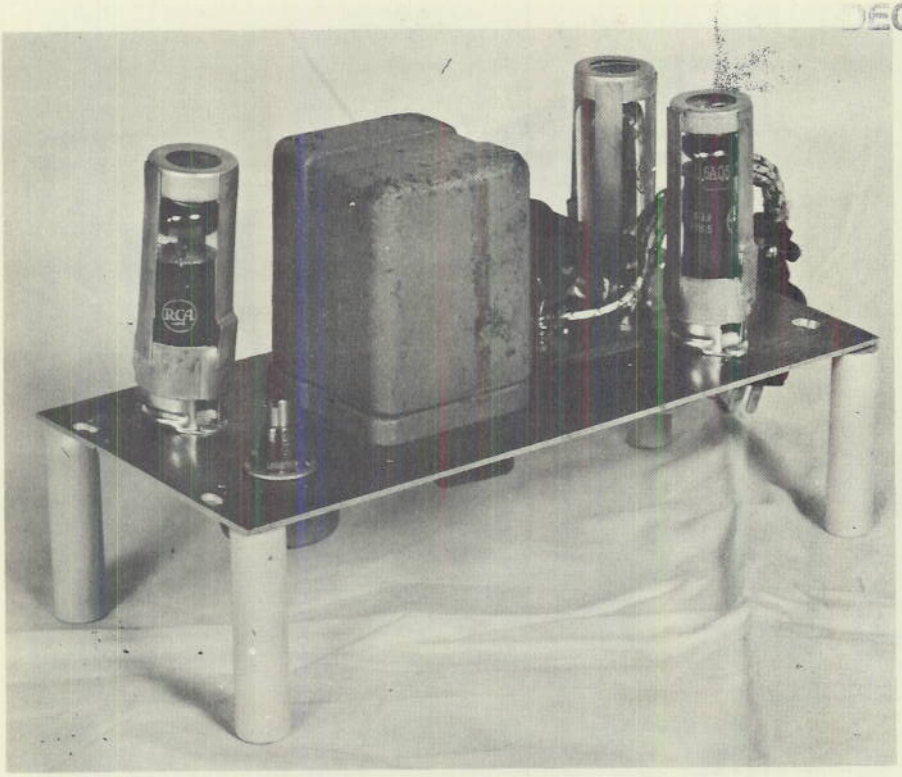



Fig. 33 - Azimuth range amplifier

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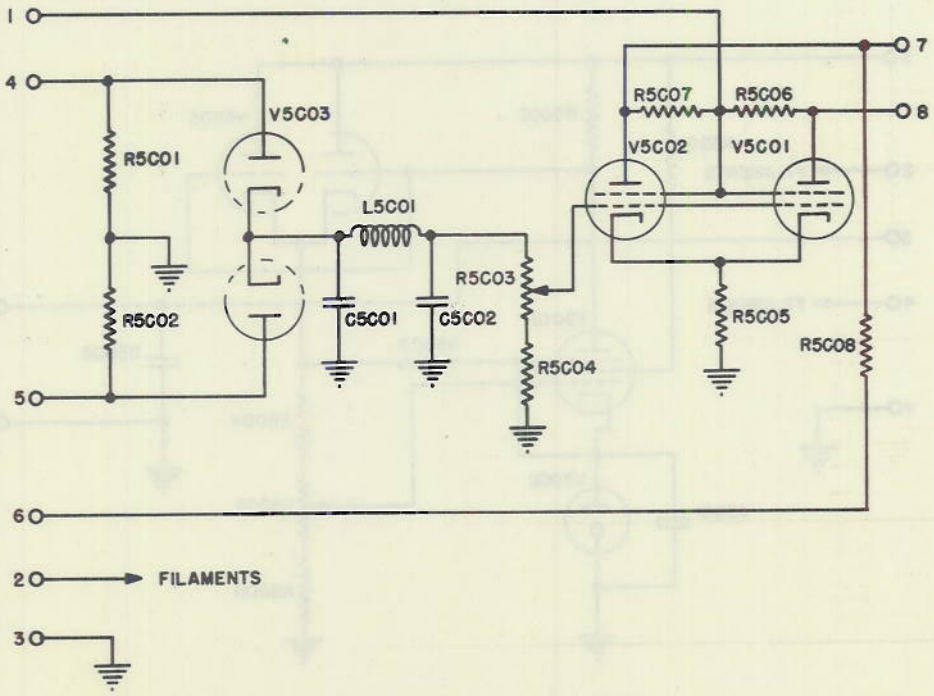


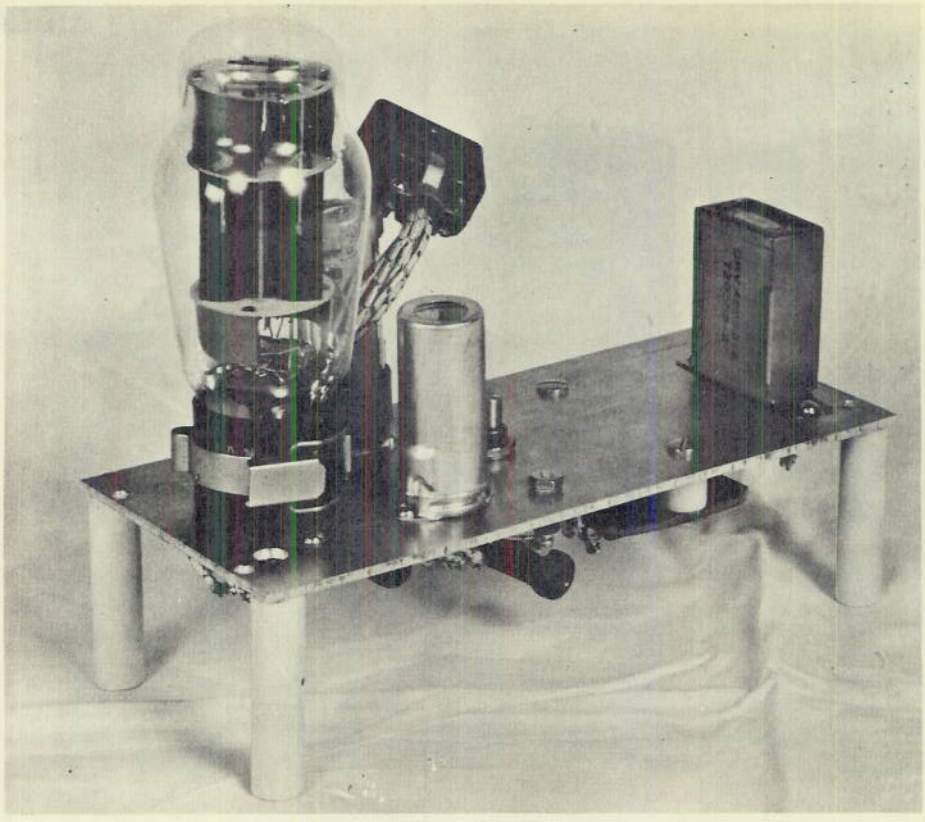

Fig. 34 - Range depression amplifier

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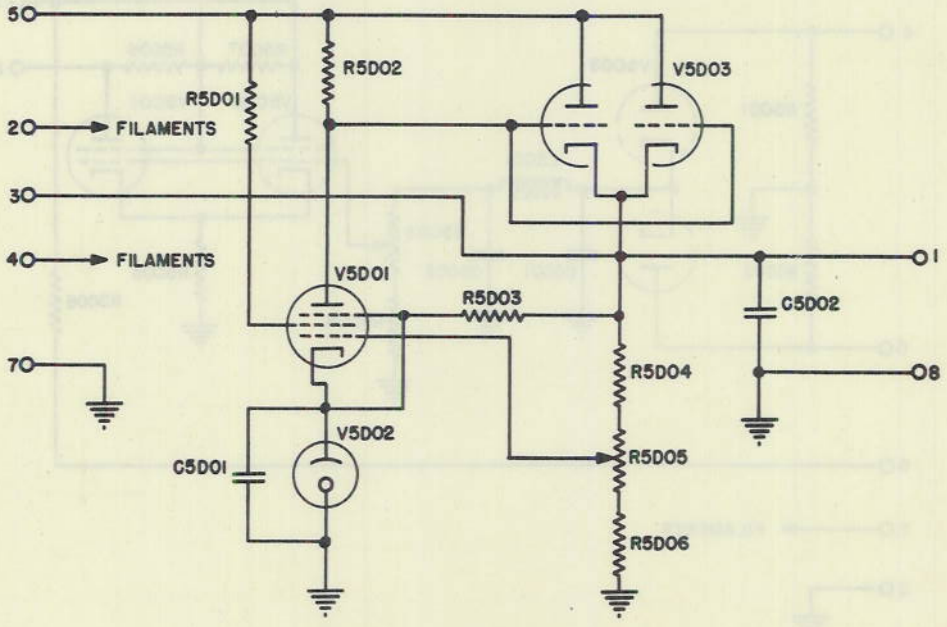
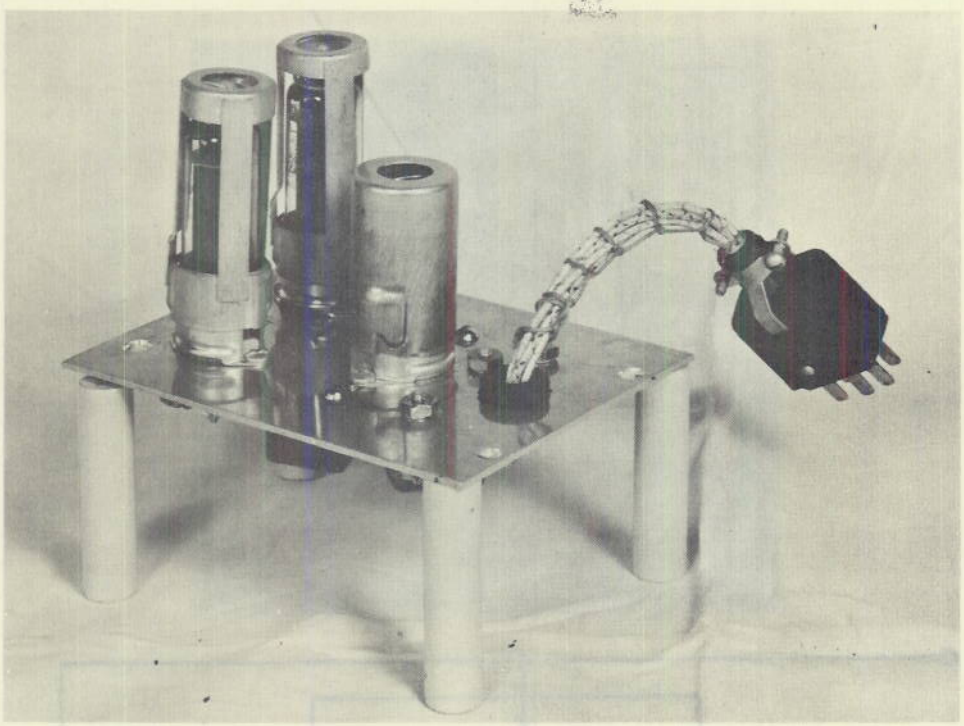



Fig. 35 - Voltage regulator

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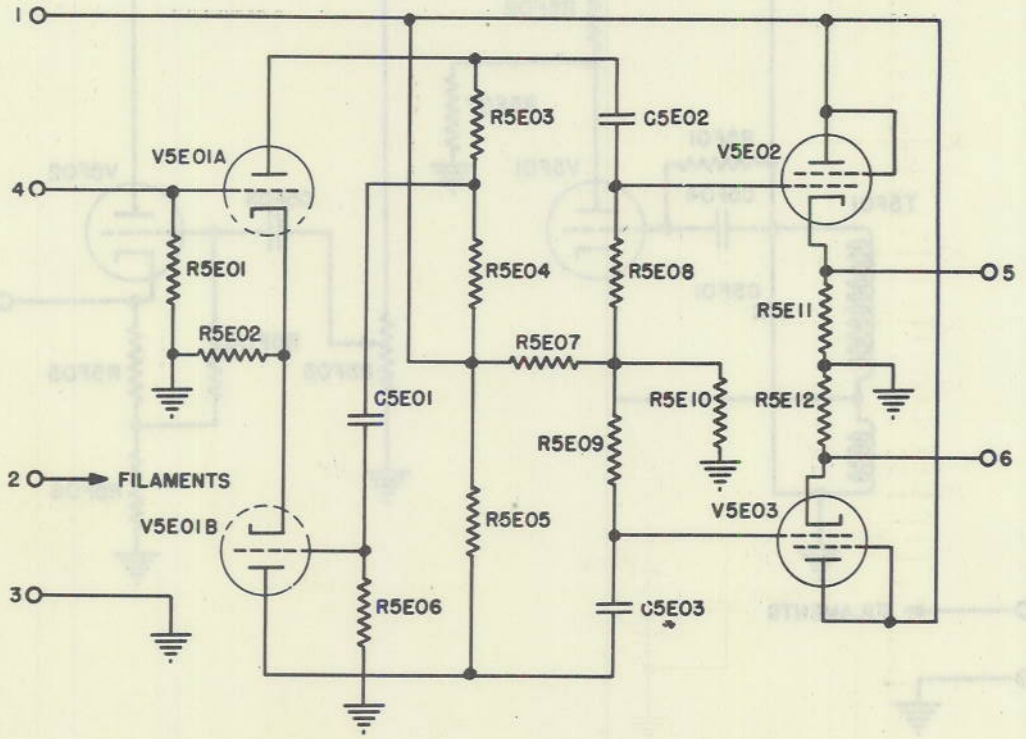
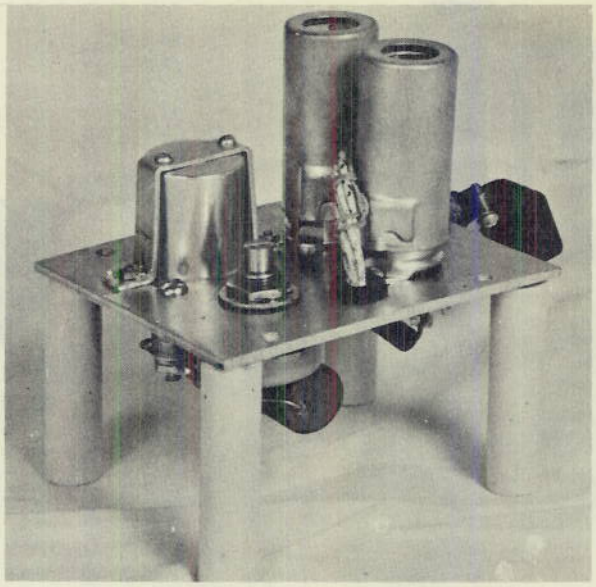



Fig. 36 - Synchro power amplifier

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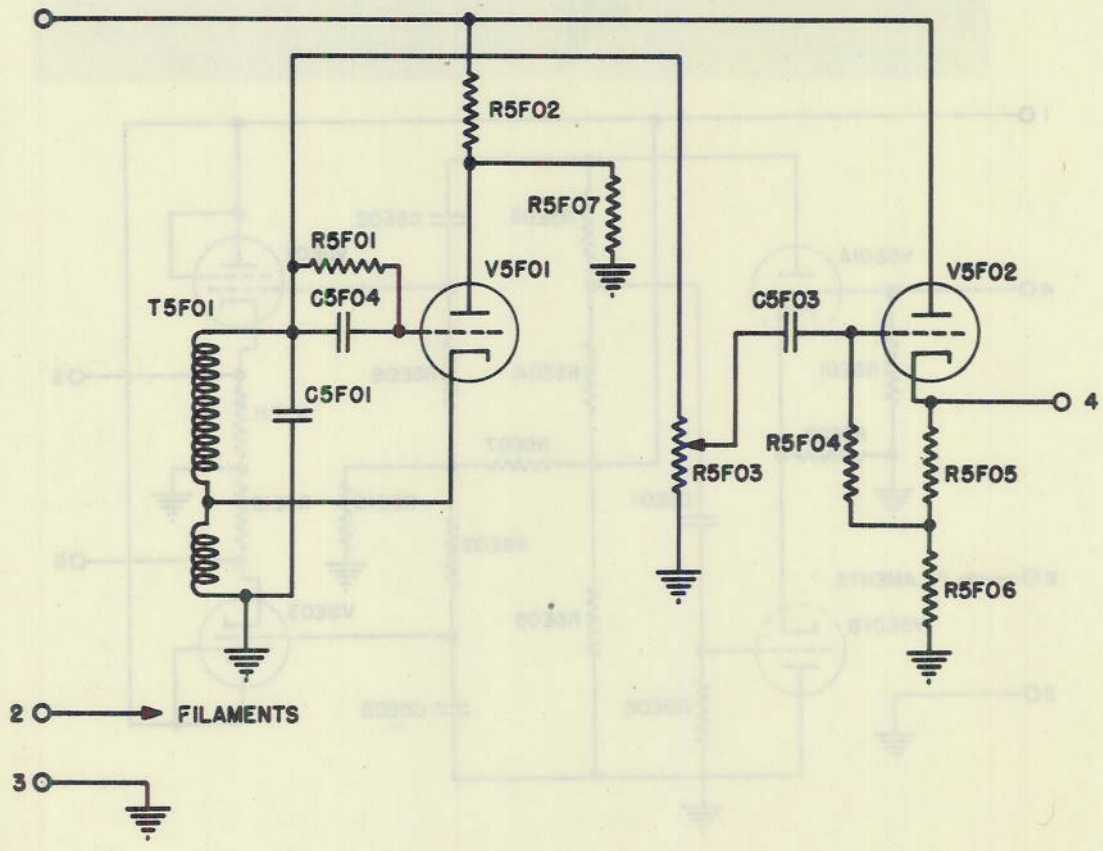


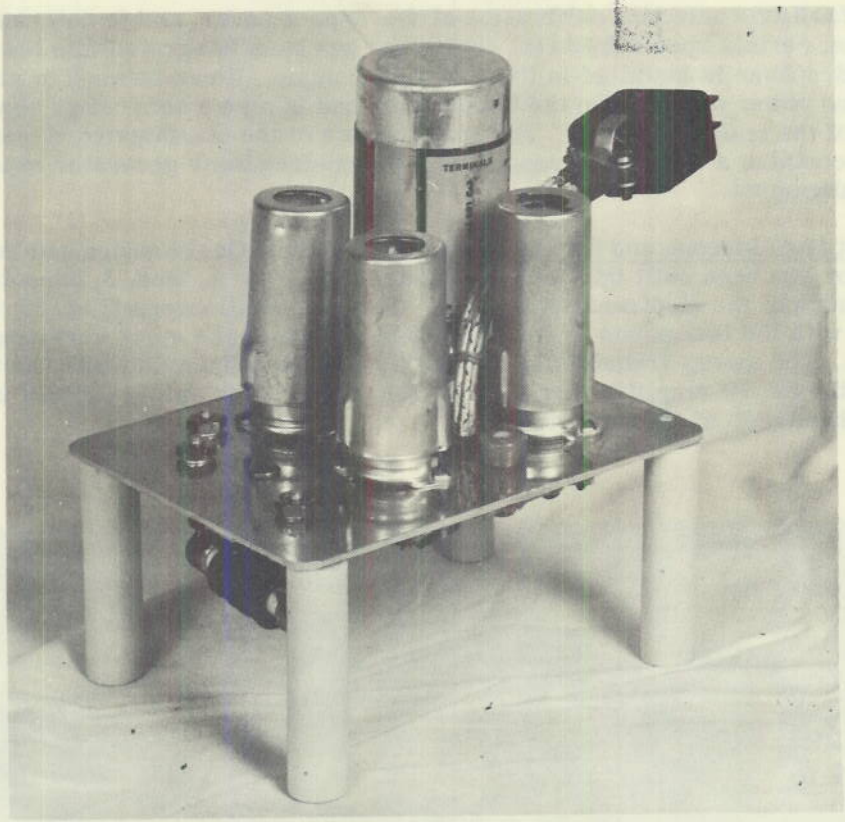

Fig. 37 - 500 cycle generator

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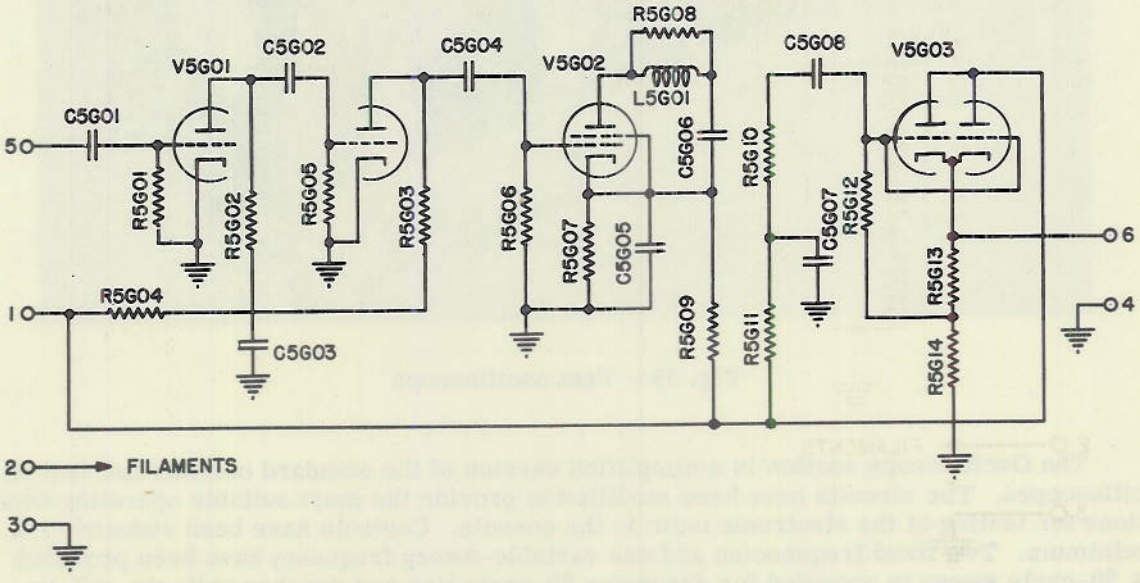



Fig. 38 - Saw-tooth generator

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Test System

To facilitate accurate calibration of the Type A sonar, and to determine over-all performance, certain specialized test equipment has been integrated into the system. A small fixed hydrophone is installed in the rear of the dome. It can be used to measure the absolute sound power output from the transducer, and is also a convenient signal source for calibration of the training system. For maintenance of the complicated electronic circuits, the console contains a test oscilloscope and a sweep-frequency generator especially designed for SSI alignment.

Test Oscilloscope and Sweep Generator — A Test Oscilloscope and Sweep-frequency Generator has been built into the Integrated Sonar Type A, Mod. 3, console to simplify the maintenance of the electronic equipment. The test oscilloscope (Fig. 39) is used in conjunction with the test points in the electronic units to make quick servicing of these units possible. The sweep-frequency generator is used in conjunction with the test oscilloscope to align the SSI i-f amplifiers accurately for phase. This unit is located in the console, on the left-hand side of the third deck.

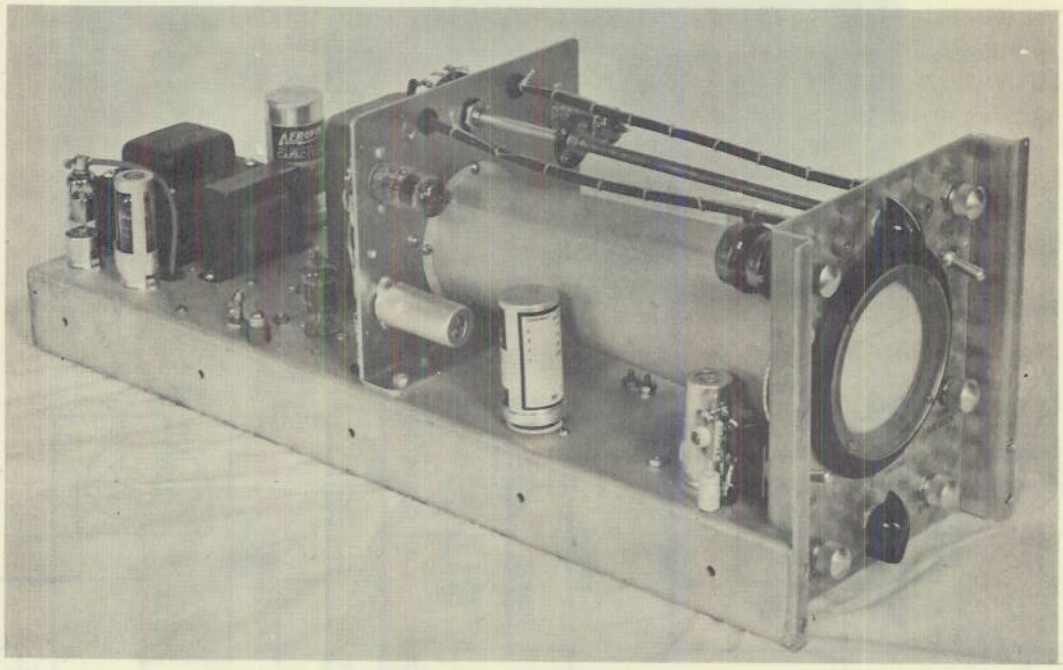


Fig. 39 - Test oscilloscope

The Oscilloscope section is a simplified version of the standard commercial test oscilloscopes. The circuits have been modified to provide the most suitable operating conditions for testing of the electronic units in the console. Controls have been reduced to a minimum. Two fixed frequencies and one variable-sweep frequency have been provided. A 20-cycle sweep is provided for observing 60-cycle line and synchro voltages, a 1-kc sweep for observing the 4-kc reference and sweep SSI voltages, and a variable sweep (10 to 30 kc) for observing the r-f and i-f voltages of the SSI and receiver.

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The Sweep Generator section of this unit consists of an oscillator whose frequency is swept from 23 to 27 kc one hundred and twenty times a second, a cathode-follower output tube, and an attenuator. The frequency is swept by using a saturable reactor type of oscillator coil. The oscillator coil is wound on a powdered-iron slug which is placed between the poles of a hypersil core. Another coil is wound around the hypersil core. The hypersil coil is energized by 60-cycle power. This causes the flux through the oscillator coil to change 120 times each second which changes its inductance and hence the frequency of oscillation 120 times a second.

## Aided Tracking

Aided Tracking Azimuth — Aided tracking in train is obtained from the Attack Director, Mark IV, Mod. 1. The synchro order from this instrument is only a rate order having no relation to the true bearing of the transducer. It is therefore necessary to change this order to true bearing before placing the Attack Director in control of transducer bearing. This is accomplished by matching the two pointers in the Initial Comparison Unit which is mounted on the left side of the console. The order is then converted in the Sperry Amplifier, mounted on the after bulkhead, and sent to the console where the azimuth operator introduces with the handwheel any corrections which may be required in the computed rate-of-change of target bearing.

Aided Tracking Depression — Aided tracking in depression may be secured either from the Tracker Mk 11 or from the OKA equipment. The output of the tracker is a rate order which must be converted to one of position in the comparison unit before it is employed. The depression operator introduces with the handwheel any corrections which may be required in the computed rate of change of depression angle.

## Sonar Dome

The dome (Fig. 40), mounted on the keel line, is streamlined and free-flooding. The portion of the dome comprising the sound beam window is constructed of rubber reinforced with imbedded steel-lattice members. The configuration of the members is designed to offer as little distortion to the pattern of the sound beam as possible while maintaining the required structural strength. For test and alignment purposes, an OBY hydrophone is mounted at 184 degrees relative bearing.

## Capsule

The capsule (Fig. 41) is a sound-transparent metal cylinder supported by the training shaft. It surrounds the transducer and the servo-positioning mechanisms (Fig. 42), and is completely filled with a special lubricant the acoustical impedance of which closely matches that of sea water. During operation, the entire assembly is lowered into the dome.

## Hoist-Train Gear

The hoist-train mechanism (Fig. 43), located in the underwater-sound room is capable of hoisting the capsule from its operating position in the dome to a point above the keel line of the ship. Electrical control of the "hoist-lower" operation can be initiated from either the sonar hut or the underwater-sound room. Provision is made for hand operation by an endless chain in case of power failure.


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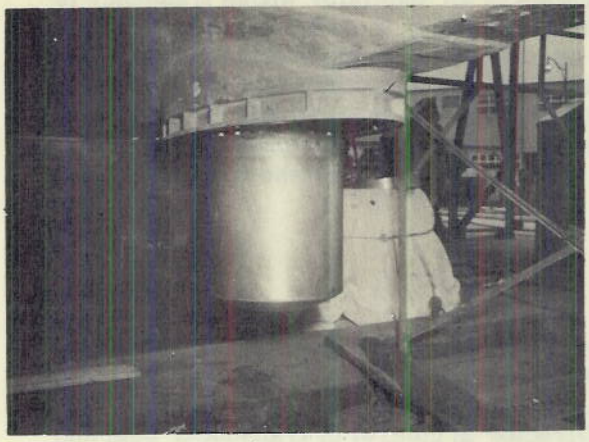


Fig. 40 - Sound dome

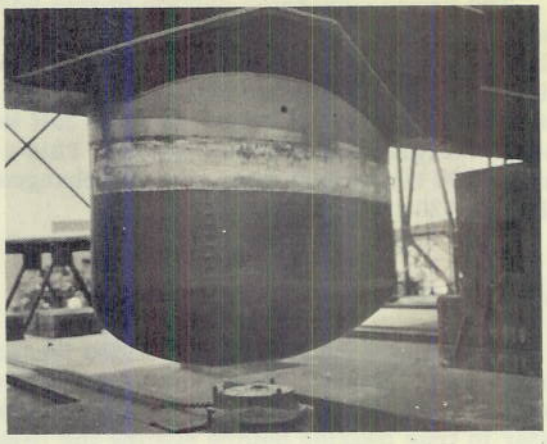


Fig. 41 - Transducer capsule



Fig. 42 - Transducer mounting

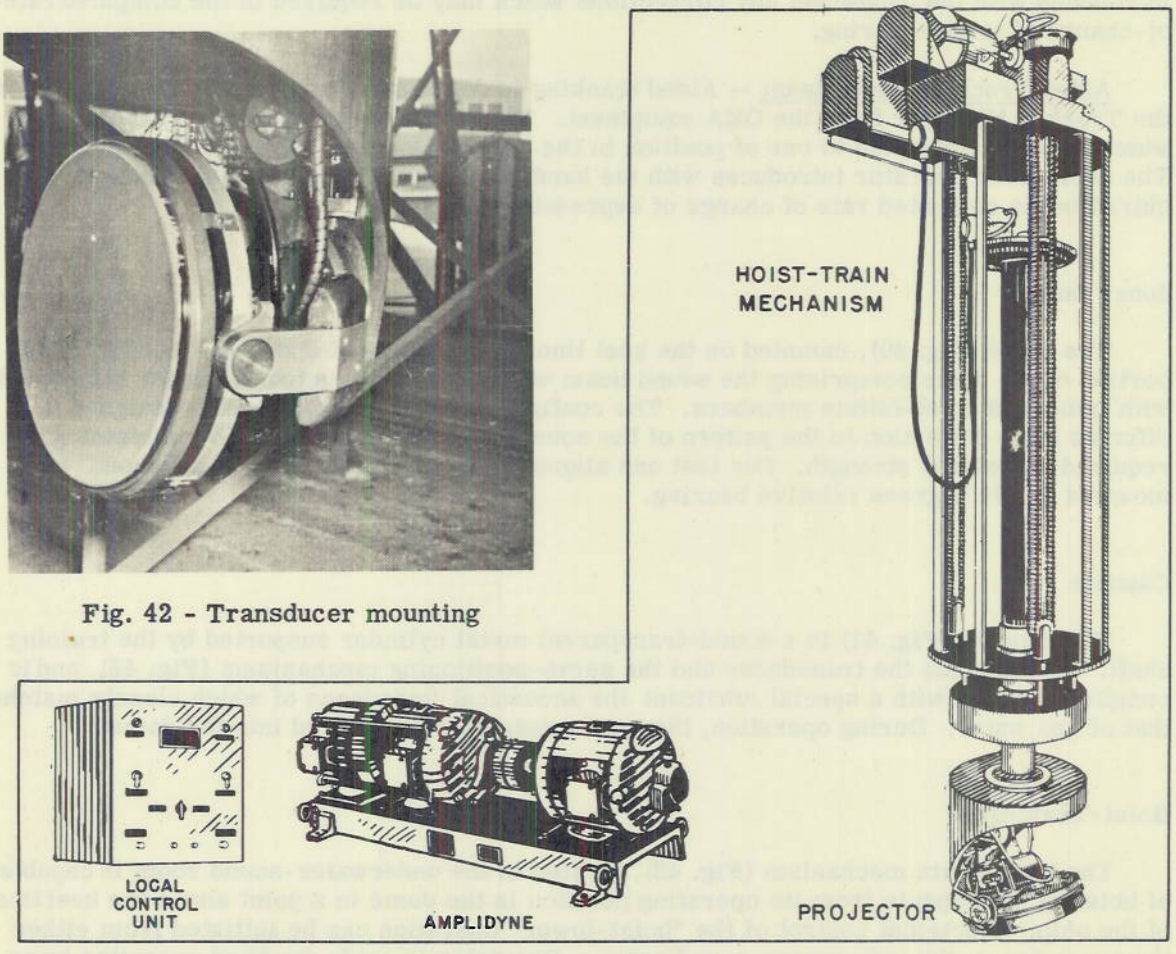



Fig. 43 - Hoist-train system

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An amplidyne power amplifier positions the transducer when train orders are received from the control console, from the gyro compass, or from the local station in the underwater sound room. The training shaft is equipped with slip rings (Fig. 4) so that the transducer can be trained repeatedly through 360 degrees.

### Transducer Control

Individual operators control the transducer in train and in depression angle with handwheels (Fig. 27) on the console. Displays are provided which enable the operators to maintain center of target contact in bearing and depression by proper manipulation of the handwheel controls.

An electro-mechanical servo system is used to control the transducer in its three axes of motion. The transducer is positioned about the cross-level axis, however, only by the stable element.

### Stable Element

The stable element employed is the Mark 8, Mod. 4, manufactured by the Westinghouse Electric Corporation. It is mounted in the IC room beside the gyro compass, and provides stabilization of the transducer in the level and cross-level axes. The stable element is a gyro-controlled instrument whose servo outputs control the transducer so that the sound path to the target remains unaffected by either the roll or the pitch of the ship.

## OPERATIONAL RESEARCH

By operational research is meant the process of continued evaluation and modification of systems and equipments under varied operating conditions. Since operational research requires a fully trained team, sonar operators have already been trained at the laboratory. Emphasis has been placed on tests devised to determine the ability and accuracy of the equipment in maintaining contact with the target under varying conditions. It is planned that special effort be spent on the study of depth determination, aided tracking performance and requirements, operator psychology, and system errors.

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# APPENDIX A

## HISTORY OF EARLY DEVELOPMENT

### Original Problem

The Integrated Searchlight Sonar had its inception in a series of conferences between BuShips (Code 940) and the Naval Research Laboratory in April 1944. It was decided that NRL would undertake to study searchlight design, and to develop and construct an integrated sonar equipment which NRL believed would meet the requirements for surface-ship installation with particular attention to the problem of a deep submarine. Items involving any considerable amount of research, development, and further tests were not to be considered because of the time limitations on any program that was to be available for the war. A formal problem (S761R-C) was established in June 1944, which requested accuracies in range of ±5 yards, in bearing of ±.25° and in depth ±5 feet at a range of 500 yards. It also requested the depth equipment to be capable of ranging at 1000 yards and of accurate ranging inside 800 yards. The completion date of the installation was set as 15 December 1944.

As a result of conferences among representatives of BuShips, BuOrd, the Tenth Fleet, the Harvard Underwater Sound Laboratory, and the Naval Research Laboratory, the NRL Integrated Searchlight System was designated as Type A, and the Harvard Integrated Scanning System as Type B.

### Basic Features of Type-A Integrated Sonar

The Type-A Sonar was based on the use of basic searchlight techniques which had been successfully used during the war, with the addition of certain features which experience had indicated as necessary. A larger quantity of data, increased accuracy, and continuity of the flow of data were factors deemed particularly necessary for fire-control apparatus. The following features of the NRL design were at that time novel to sonar equipment.

Stabilization of Transducer — In order to make conditions favorable for the reception of more continuous and accurate sonar data, it was essential to have stabilization of the transducer so that the sound beam could remain on the target regardless of the pitch and roll of the ship. A three-axis system was adopted wherein the searchlight transducer was stabilized in bearing, level, and cross level. A particular advantage of the three-axis system as compared with the simpler two-axis system is that the horizontal and vertical splits of the transducer are fixed in space. The result is greater accuracy in indication of bearing and depression angles in the SSI's.

Depression of the Transducer — Experience had shown that it was essential to have a depression mechanism if the beamed-type transducer was to be held on a deep submarine. Since it was also of increasing importance to be able to determine the depth of the target, it was felt that it would be possible to calculate this from the depression angle and the slant range. Corrections for temperature gradients were not included in the original installation.

Sector Scan Indicators — Another approach to the basic problem of more continuous and accurate data was made by the use of NRL Sector Scan Indicators (SSI), two of which



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were used simultaneously on the one transducer. By means of these equipments the angular deviation of the target from the axis of the sonar beam was separated into horizontal (azimuthal) and depression deviations. This made possible the control of the stabilized transducer by two sonar operators, one for bearing and the other for depression, in the same method as in gun control. Two features of the SSI which were not common with other Bearing Deviation Indicator systems are: (1) a presentation which permits a quantitative measure of the amount of deviation from the true axis of the beam (proportional deflection) and (2) a phase-comparison method which requires very little averaging ("Instantaneous" indication).

Electronic Relay — Use of an all electronic means for transferring the transducer from the driver to the receiver and the SSI receiver inputs was made possible by the development of a special switching tube developed by the Sound Division. Combining the two-way-split transducer into the various combinations necessary for proper operation of the system would require a complicated relay system. Since short-pulse operation was desired, the intrinsic value of electronic means of switching appeared to have many advantages.

Dome — A trainable, tiltable transducer required the use of a dome which was sound transparent not only on the front and sides but also on the bottom and possibly astern. In particular this transparency was not be be interfered with by internal bracing that might cause phase displacements which would interfere with the accurate working of the SSI systems. Development of a type of dome which would fully meet these requirements was initiated, but since this would take more time than was available a compromise dome had to be used. Thus a 57" welded-on corregated dome was procured for the initial installation.

Transducer — Because of the SSI input requirements, a quadrant-split transducer was essential. It was desired to have a broad and flat frequency range, and the band from seventeen to thirty-four kilocycles was considered sufficient.

Attack Director — Concurrent with the development at NRL, the Bureau of Ordnance was developing an Attack Director which was to be ready in May 1945. Proper interconnections were provided to accomodate this necessary part of the Type-A installation. Therefore, aided tracking in azimuth, target aspect, and rate-of-change of horizontal range would be available.

Original Installation

In October 1944, the U.S.S. FOSS (DE59) was acquired for the installation of the Type-A Sonar System. The first major component to be installed was the stabilized transducer system and its associated control circuits. This work, completed in December 1944, was done at the Washington Navy Yard, where all cables and test equipment were installed; and at the Brooklyn Navy Yard, where all drydocking work was done. Necessary electronic equipment was temporarily installed for preliminary stabilization tests. In order to obtain a quick test in cold water, a week of operation was conducted in the New London area. The remainder of the initial stabilization tests were conducted in the Port Everglades area where better facilities were available. Results of these preliminary tests indicated that the installation gave improved echo-ranging and listening performance because of stabilization against roll and pitch. Comparative performance tests were made by switching the stabilization in and out. During this testing period a great amount of water noise was observed. It was supposed that the corrugated dome caused turbulence or cavitation in its motion through the water, and procurement was immediately initiated to obtain a smooth-sided dome.

The electronic component units of the Type-A system were installed at the Charleston Navy Yard, South Carolina. At that time, the ship was placed in drydock and the stabilization



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components were carefully checked and found to be in good condition. The corrugated dome was replaced by a thin smooth-walled dome which was not entirely satisfactory but was the only one obtainable. The work was completed by 17 February 1945, and the ship returned to Port Everglades for evaluation tests.

AsDevLant Tests — The tests of Type-A system conducted by AsDevLant were extensive and included a great number of items which required ingenuity and resourcefulness on the part of the evaluating personnel. Instead of attempting one grand test of the system, it was decided to group various items into sets of related matters and to run special tests for each such group. Most of this work was done with movie cameras. The tests which AsDevLant set up were:

(1) To test (a) the accuracy of the level and cross-level orders given by the stable element, and (b) the fidelity with which the transducer followed these orders.

(2) To test (a) the accuracy with which the stable element followed the train orders of the control stack, (b) the accuracy with which the transducer followed the train orders of the stable element, and (c) the accuracy with which the transducer followed the depression orders of the stack.

(3) To determine from actual submarine runs (a) the error between actual submarine bearing and the actual transducer bearing, and (b) the error under average conditions between actual submarine bearing and the bearing ordered by the operator.

(4) To test the accuracy of the depression system and its SSI.

(5) To investigate, if practicable, the possible effects of lag in the sonar system.

From each ping, data were recorded on film for: range; ordered train and actual train; ordered depression and actual depression; transducer level and cross level; both SSI indications; optical horizon level and cross level; relative bearing of camera; and, finally, actual bearing of target.

Results — This preliminary investigation (the AsDevLant tests) revealed that the transducer training system was not sufficiently accurate for proper evaluation of the stabilization and SSI systems. The basic difficulty was essentially historical in that in order to try out the basic features in a short length of time available existing equipment parts had to be used. These were used with the full recognition that individually they contained inherent limitations. Nevertheless, upon investigation, it was found that by increasing the power supplied to level and cross-level motors and by the addition of damping circuits the performance could be materially improved.

Experience gained during this period also indicated other desirable changes and improvements. The method of true- and relative-bearing indication involved the use of drum-type dials. Actual operation brought out the deficiencies of the drum-dials. It was found that the moving numbers were almost impossible to read. It was the consensus that the indication should provide a conventional flat-type display with a fixed outer scale for relative bearing and a movable inner scale for gyro repeater, and with an intermediate "bug" showing transducer bearing. New panels were made incorporating these features and other changes (such as the elimination of SSI paralax) which were found desirable. The limitation in training caused by the necessity of limit switches on the QCO hoist-train gear proved to be too great in operation, and, since the attack director was to be added soon, slip rings were deemed a necessity.

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A third method of attack consisted of simultaneous observations of total signal intensity and spot deviation on a single cathode-ray-tube presentation. Altogether, some 900 photographic exposures were taken and several hundred were analyzed.

The data obtained indicated that reflection from the surface of the sea was responsible for a good part of the fluctuation observed. It was verified that fluctuations were at a maximum for a particular depression angle. For the XQB-30 transducer, the maximum was observed at about $5^{0}$ (i.e. for a submarine at 200 feet, the maximum effect occurred at a range of 1000 yards). A definite correlation between vertical SSI deviation and signal amplitude was observed, each downward fluctuation being accompanied by a weakening of the signal and each upward fluctuation by an increase of the signal. This result is explainable by the theory of interference by the surface reflection.

Aided Tracking — During this study, it became apparent that the Mark-8, Mod-0 Stable Element was limited in the amount of stabilization it could provide and that it had a bad tendency to overrun on rapid changes of bearing. This effect was especially bothersome when operating at 46 kc since the resulting narrow beam made it difficult to hold contact. In April 1946, the FOSS reported at NRL dock for a week's overhaul of all electronic and directing gear components. At this time, a new system for stowage of spare parts was installed to ease the problem of maintenance.

Schedules for May and June 1946 were cancelled when the services of the FOSS were required in the New York area, and a review of the work to date was undertaken.

The major problem appeared to be that of holding contact. Tests had demonstrated that if sufficiently wide beams of the transducer in both horizontal and vertical planes are employed, it is possible for both operators to follow the target in both train and depression without too much skill. As the beam is narrowed to a sufficient extent to make depth determination possible at longer ranges, greater operator skill and teamwork is necessary in order that the depression operator may not cause the train operator (or vice versa) to get off the target and lose contact. Although the SSI's appeared to offer definite advantages in preventing this, it was not deemed to be a sufficient safeguard. It was desired to add the OKA equipment for aided tracking and depth computation, but the space available was insufficient.

The difficulties experienced in the directing gear were greatly reduced by the installation of a Mark-8, Mod-4 Stable Element at the Brooklyn Navy Yard in July 1946, and tests were continued.

Noise Measurements — Dome noise levels were measured during August in order later to compare the performance of the 60-inch reinforced rubber dome which was then being constructed for the FOSS. Considerable noise was observed when the ship's screws were not turning and it was supposed that vibrations set up by the turbines were transmitted through the hull. Only a small increase in noise was observed from 10 to 15 knots, but a considerable increase between 15 and 20 knots caused a reduction in maximum range.

Ranging Off Bottom — Transmission studies were resumed by the Propagations Group during August in which the possibility of extending sound ranges by echo ranging via the bottom reflection was explored (Fig. 44). With a good reflecting bottom it was found that clean echoes could be received from a submarine target. When the submarine is below a sharp thermocline, this method can be used to penetrate the shadow zone caused by the bending of the sound beam. An investigation of multiple-path reception previously observed at short range failed to reveal any connection between the effect and volume scattering.

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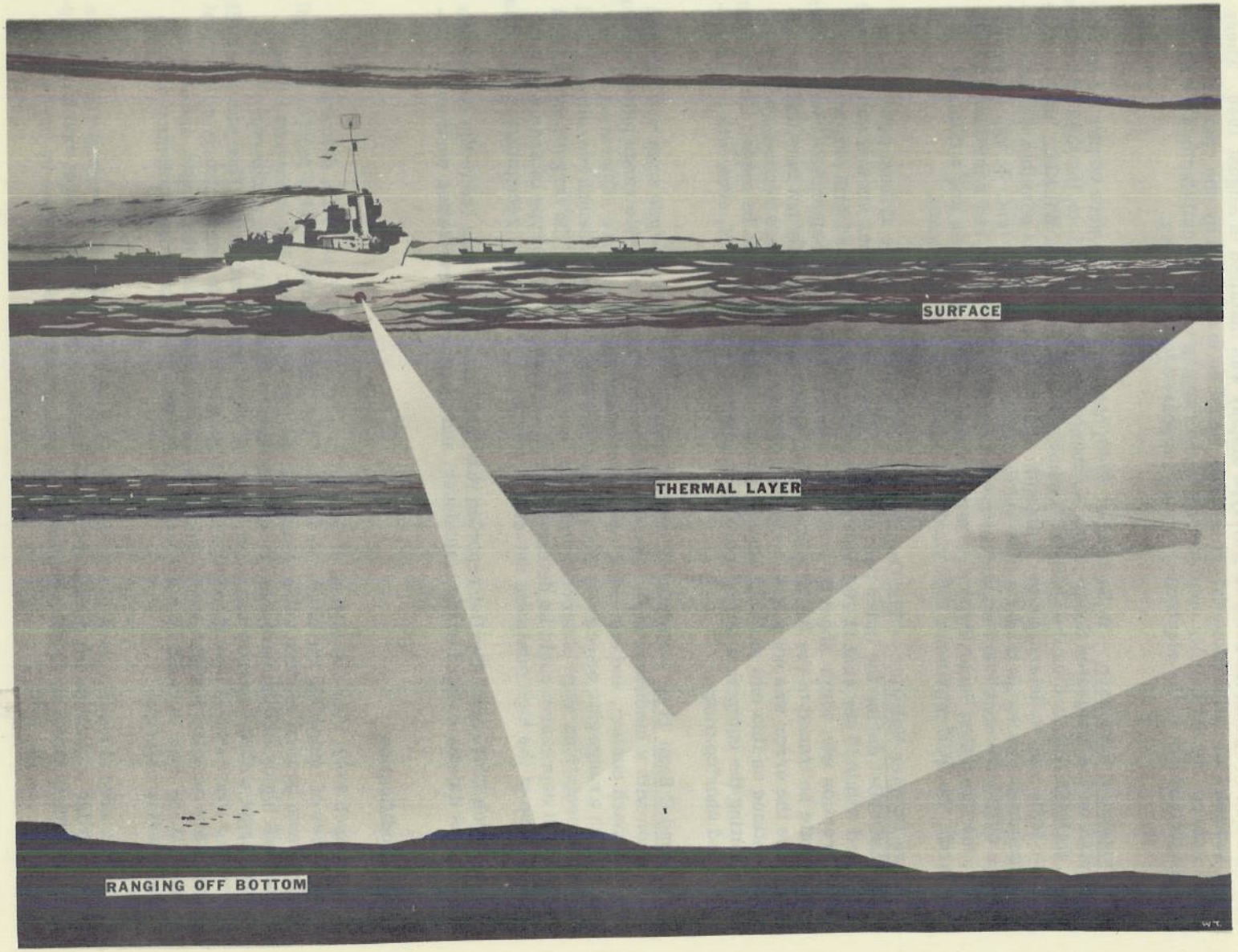



Fig. 44 - Ranging off bottom

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C Scan — In an attempt to develop a single indicator combining the displays of the azimuthal and depression SSI's on a C-type display was installed in August 1946. These tests showed that satisfactory target tracking could be maintained by one operator with a noise source, but the results obtained with echo ranging were not satisfactory because the time constants in the electronic circuits appeared to be too long.

Systems Comparison — In September 1946, comparison tests were conducted by SurAsDevDet on the Integrated Sonar, Type A, aboard the U.S.S. FOSS, on the QHB aboard the U.S.S. SARSFIELD, and on the QGB-QDA combination in the U.S.S. WILKIE. The purpose of these tests was to determine the maximum and minimum ranges possible with the various equipments using as target a fleet submarine at a depth of 80 feet. It was observed that the QHB gave consistent maximum ranges of over 2500 yards and a minimum of 125 yards, the Integrated Sonar, Type A, a maximum range of 2000 yards and a minimum of 100 yards, the QGB maximum 2000 yards and a minimum of 150 yards.

Own Doppler Nullifier — The Own Doppler Nullifier unit of the system was studied by SurAsDevDet during the latter part of 1946. These investigations showed that this unit corrected within 10 per cent at 18 knots and that the error increased with ship's speed. The correction was within about 50 cycles for normal operating frequencies. Some of this error could be traced to the Pit Log equipment, which was evidently not functioning properly since the error was not a linear function of ship's speed. It was recommended that work continue on this unit and that corrections for depression angle be made. The personnel operating the equipment were favorably impressed with the ODN, even with the above-mentioned shortcomings.

Second C Scan Trial — In March 1947, a second trial of the C-type scan was made in conjunction with a modified range recorder which contained a variable range gate, a motor-driven flyback contact, and electrical outputs of range and range rate. Operation of the C-scan with a range gate on echo ranging gave inconsistent results, although two-dimensional aspect presentations were observed, and under certain conditions, the target's position in azimuth and depression could be determined simultaneously. This type of scan was not used because of the high minimum detectable signal power and poor recognition differential.

In March 1947, SurAsDevDet reported that their analysis of data led to the conclusion that serious defects existed in the transducer, and that further evaluation must await correction.

Second Modification

In March 1947, representatives of OpDevFor, SurAsDevDet, and NRL discussed the possibilities of improving the characteristics of the Type-A Sonar to help meet operational requirements against modern submarines such as the Type XXI. Experience had shown that without highly skilled personnel it was difficult to hold contact on a high-speed submarine target with the narrow beam required for depth measurements. This was especially true when a close run to the submarine was required. It was therefore clearly evident that devices were necessary which would aid the operators in tracking the target, and it was agreed that the Type A could be modified and available target tracking equipment added to help attain this objective.

Thus a second modification to the basic Type A was undertaken and completed by June 1947. In order to provide the necessary space for the addition of the target-tracking equipment, BuShips authorized an enlargement of the sonar hut. This was done by the tender

U.S.S. GRAND CANYON at Norfolk. The equipment installed at this time included the OKA, ASAP, and Course Plotter. Although the Attack Director, Mark IV, Mod. 1, was not available during this period, necessary cabling was provided in anticipation of its installation at a later date.

During the twelve-day availability of the FOSS at NRL, the necessary changes and additions to the electronic portion of the system were accomplished. Many of the electronic chassis had been previously removed for a complete overhaul and check at the Laboratory. The frequency tuning circuits were replaced by a system of spot-frequency switches, thus eliminating critical tuning. The electronic-keying chassis was replaced by a mechanical method since experience had shown that the maintenance problem of the electronic method outweighed its advantages. New slip rings and a new electronic coupling unit were added in anticipation of the multisegment transducer installation. A course finder, Mk. 3, Mod. 1, was installed.

After leaving Washington, the FOSS reported at the Charleston Naval Shipyard for repair of storm damage. At this time all work not accomplished at Norfolk was completed. The driver output was increased from 100 to a maximum of 1000 watts to a resistive load. A complete check of the entire system was made within the limits of existing conditions.

The FOSS arrived at Key West in early June, and an immediate check on the beam pattern of the transducer confirmed the earlier observations of SurAsDevDet. The transducer had not been changed when the ship was at Charleston since no replacement was then available. Inasmuch as the new transducer under development would not be ready for another month, work continued on noise measurement until 20 June 1947, when the transducer failed completely and operations had to be suspended.

Later inspection of this transducer revealed two difficulties. The short circuit was located at the cable seal joint which prevents the capsule oil from seeping by capillary action up the cable to the slip rings. The poor beam pattern reported earlier by SurAsDevDet were without doubt caused by the fact that some of the crystals in the lower left quadrant had melted and had deposited on the bottom inside face of the transducer.

As corrective measures, the 200-millisecond pulse length was eliminated, and the driver power output was automatically reduced to half power when the hand key was operative. This was done on the assumption that the transducer crystals were damaged by an excessive duty cycle.

Transducer (XQB 35), installed in July 1947, contained a novel crystal array. The first modification of the Type A was essentially to improve depth determination by the use of higher frequencies resulting in a narrow sonar beam. The knowledge gained from its operational use established the importance of additional significant factors. In addition to overcoming the difficulty of holding a target, the second modification was directed toward the improvement of the beam pattern of the transducer. A split transducer such as the XQB 30 used in the first modification had poor patterns of any half relative to the whole of the crystal array, even at higher frequencies. The importance of good half-transducer beam patterns is paramount when SSI's are used, especially when discrimination between direct and surface reflected signals is necessary. Specifically, it is essential that the rate of change of response of both upper and lower halves of transducer with sound angle be high at the horizon. In the design of this new transducer (XQB 35), some compromises had to be made. One of the more serious consequences was the broadening of the main beam to such an extent that it required use of the higher frequencies for satisfactory results. It was believed, however, that if steady, reliable signals were obtained, the limitations inherent in this design could be corrected. The crystals were grouped in small

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rectangles to form a square array of nine sections. Electrical combination of these elements provides four overlapped quadrants which were further combined into halves for the SSI receivers.

The installation of this transducer was accomplished by replacing the entire capsule. The new capsule contained larger tilt and cross-level motors. The greater power available resulted in decreasing the reversal time by a factor of ten. In addition, an oil-tight terminal block was fixed to the end of the hoist-train shaft. This method not only eliminated the requirement for a special means of blocking the castor oil from seeping up the signal leads, but also decreased the time necessary for changing capsules. Replacing the capsule as a unit proved to be a valuable procedure since the unit could be tested for balance and other critical features of operation at the Laboratory, thereby greatly reducing drydocking time. The Attack Director, Mark IV, Mod.1, was installed during this period and connected into the system.

Dome — The new 60-inch reinforced rubber dome was also installed during the drydocking period in July 1947. This dome had been under procurement for some time and represented several years' work in the development of rubber as a sonar dome material.

Rubber had been extensively used as a window for transducers because of its excellent impedance match to sea water. But the curing of rubber in the large streamlined shapes necessary for domes presented a difficult problem. In cooperation with the B.F. Goodrich Company, NRL succeeded in producing the first all-rubber dome with sound transparent bottom and sides.

Tests — Soon after the ship was waterborne, beam patterns taken indicated a defect which was traced to an open circuit in one of the input leads from the transducer. Since the transducer was primarily designed for use with depth measurement and the loss of this segment ruined the pattern, the operational plans had to be cancelled.

The cause of the open circuit to section 8 was later traced to the rubber seal packing around the cable near the backing plate. The condition of the cables in this packing was similar to the condition found in the cable of the XQB 30.

Results — A letter report on the results of the evaluation to 1 July 1947 was submitted by SurAsDevDet in which they recommended that in order to permit test and proper evaluation of the many desirable features of the Type A, the following must be done:

(a) A new, larger transducer must be provided

(b) Shifting of frequency must be instantaneous

(c) Control must be simplified

(d) The entire system must be fully integrated and engineered into one set.

Modifications — Preceding scheduled yard availability at the Boston Navy Shipyard, (September 1947) the U.S.S. FOSS reported at NRL August 1947 for a week for minor corrections and additions to the electronic units. Meters were installed in the driver for ease in quick checking of performance. The OBY was reinstalled, since operational experience had shown the need for a quick over-all performance check of the system. An additional gyro-compass synchro amplifier to supply the inputs to the Attack Plotter, Course Plotter, and Attack Director, was installed to reduce the load on the directing gear amplifier. The aided tracking azimuthal 36-speed converter was replaced at this time. Additional facilities such as a-c power outlets for light cords, soldering irons, and test equipment were included.

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During yard availability at the Boston Navy Shipyard in late September 1947 the new rubber dome was found to be badly encrusted with barnacles. The ship had been in southern waters only twenty-two days. It was observed that the synthetic rubber panel of the dome (GRS-Goodrich 76NE7) had noticeably less barnacles than the natural rubber panel (Goodrich 8388). Anti-fouling paint (AF29) was applied to the dome before the ship returned to the water.

* * *

## APPENDIX B
## SCHEMATIC DRAWINGS

Since the figures presented in the text of this report have often been simplified, or have been concerned with a single component, a more comprehensive group (Figs. 45 thru 74) is here presented in order to show more clearly the integration of the entire system.

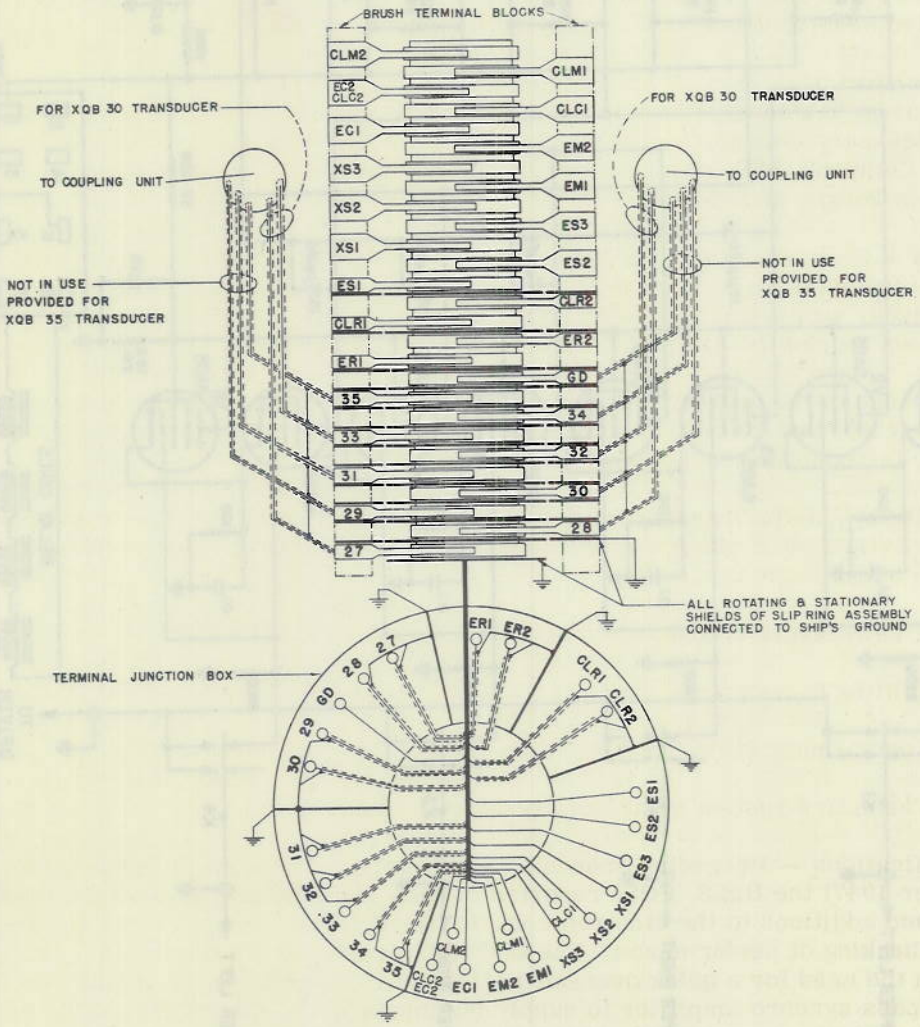



Fig. 45 - Slip ring assembly

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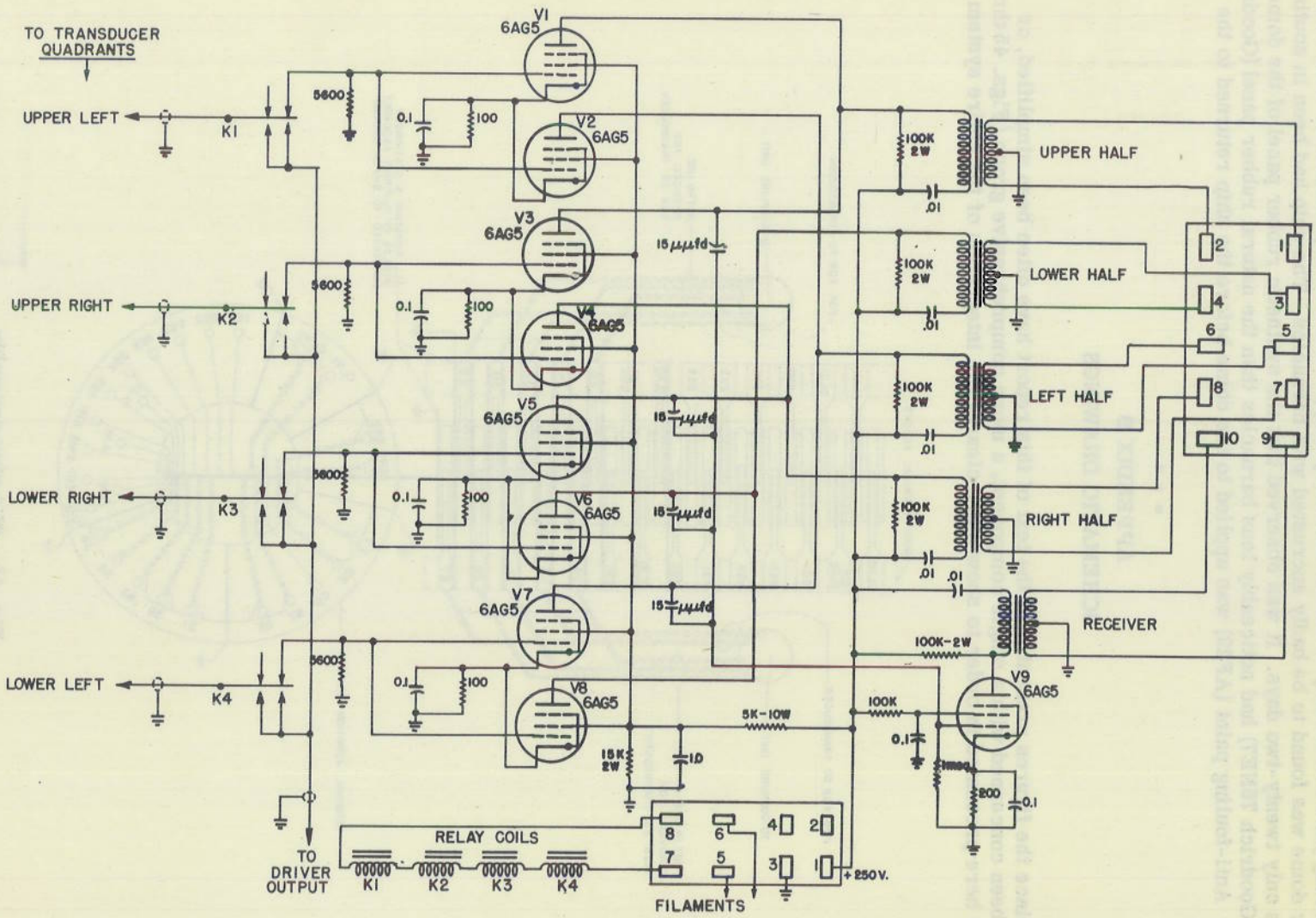



Fig. 46 - Coupling unit

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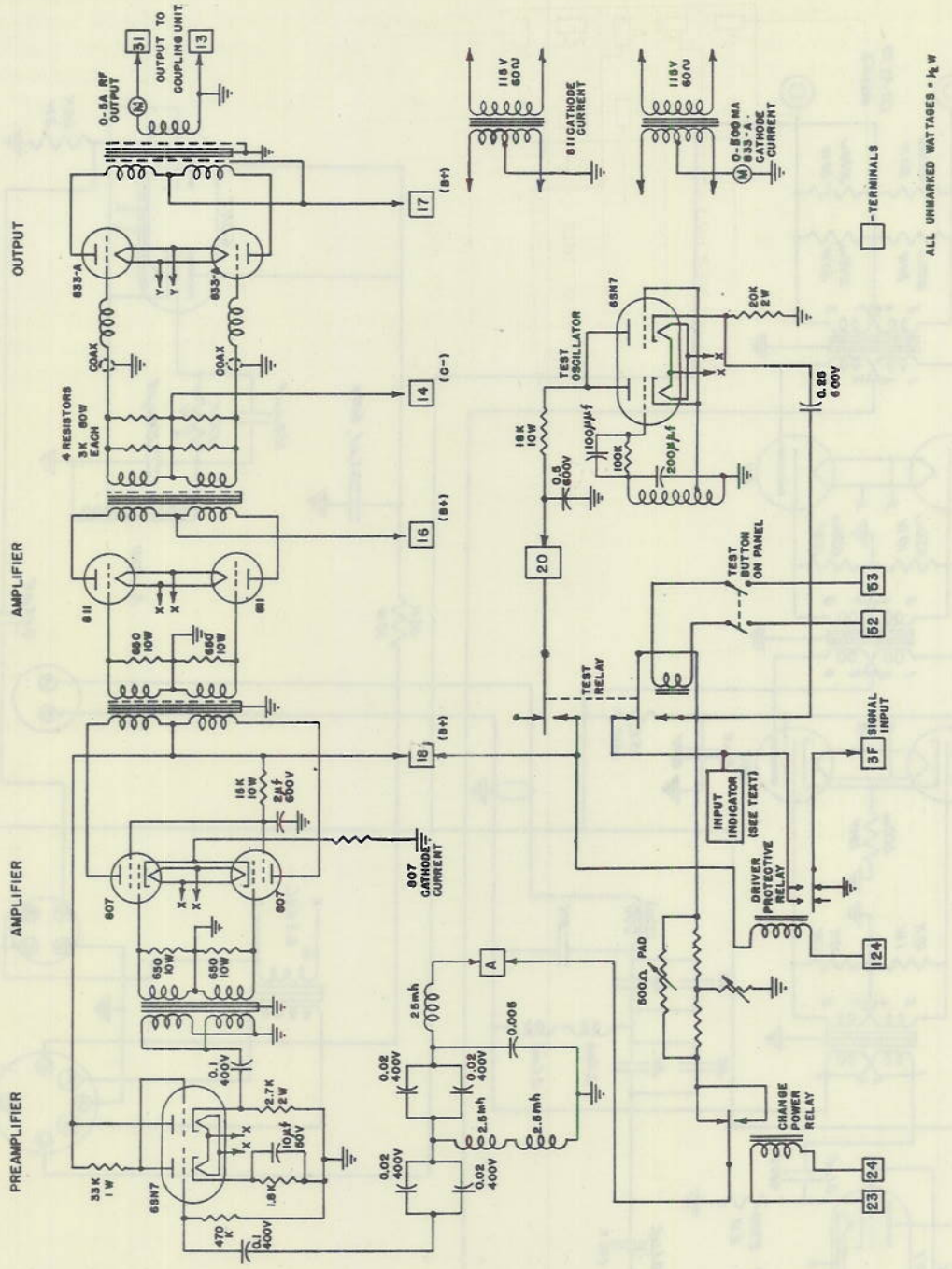



Fig. 47 - Driver (simplified diagram)

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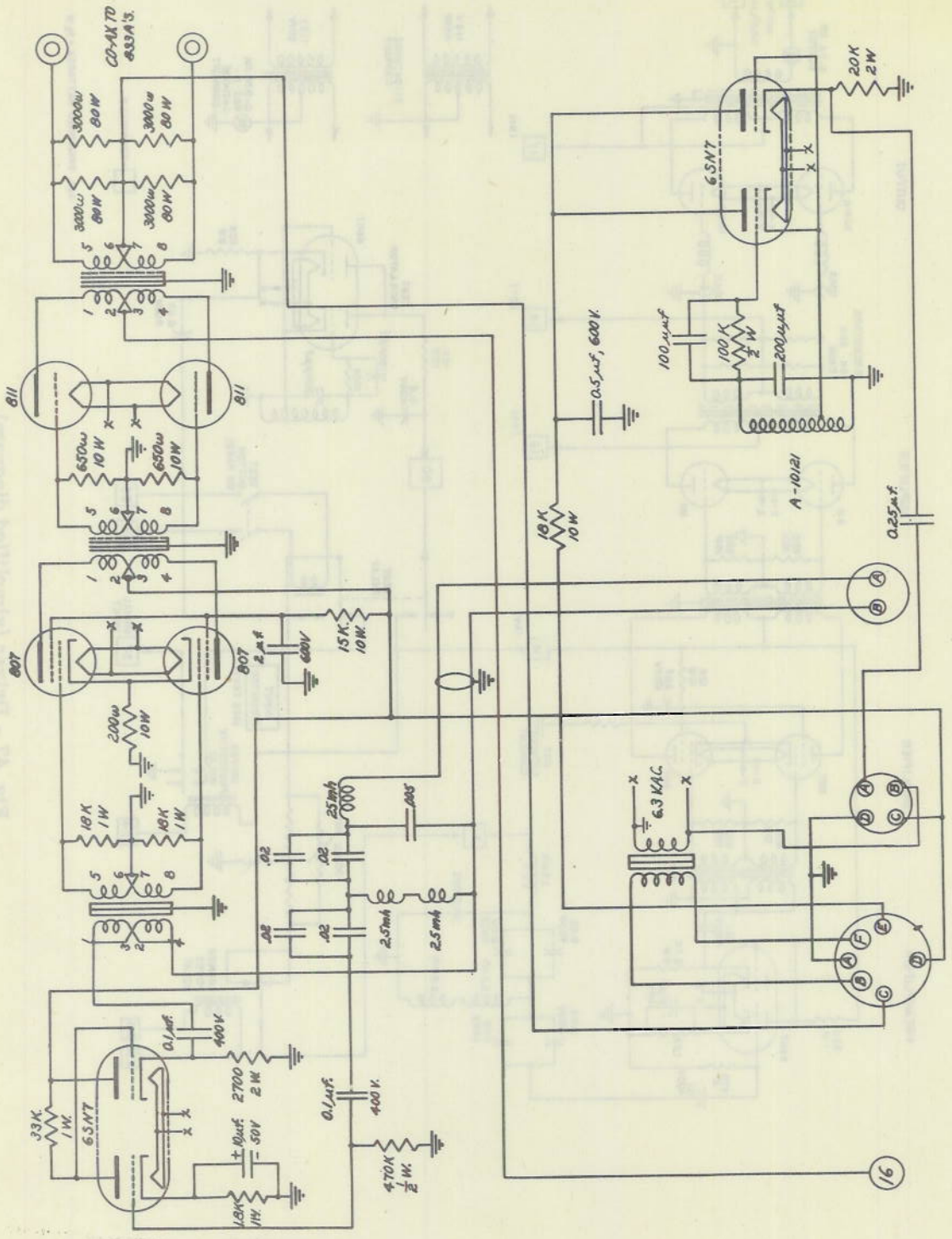



Fig. 48 - Driver preamplifier and test oscillator

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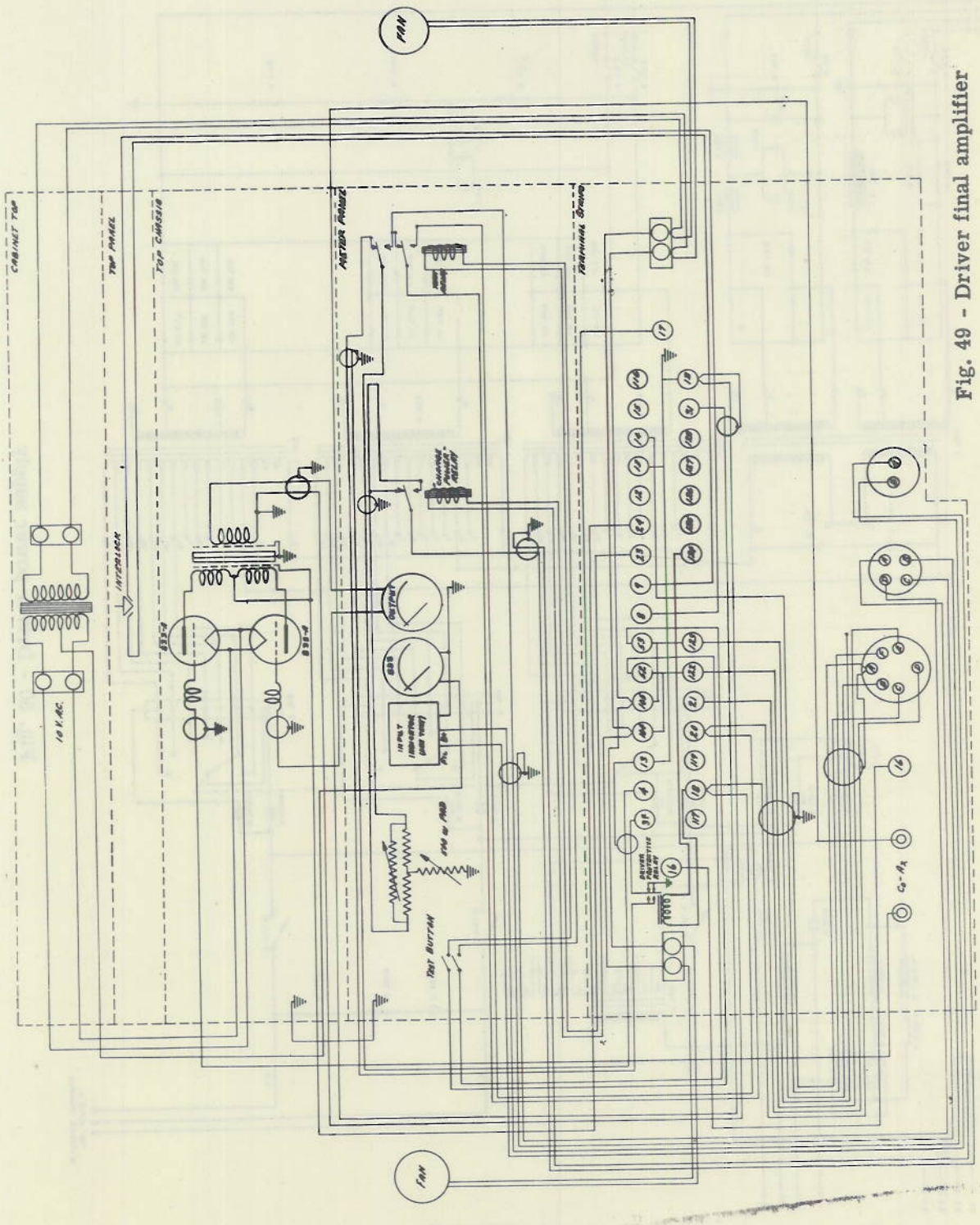



Fig. 49 - Driver final amplifier

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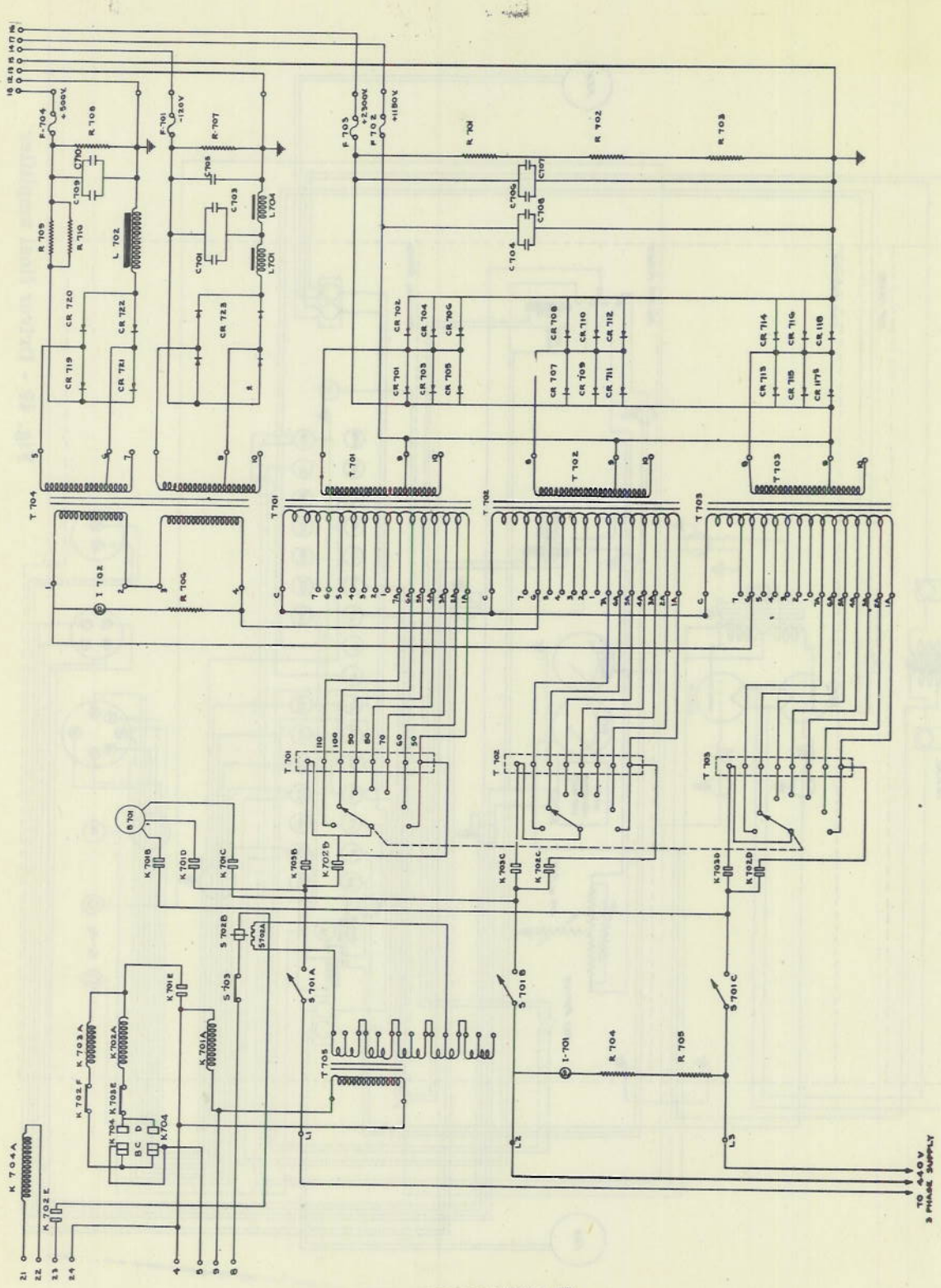


Fig. 50 - Driver power supply

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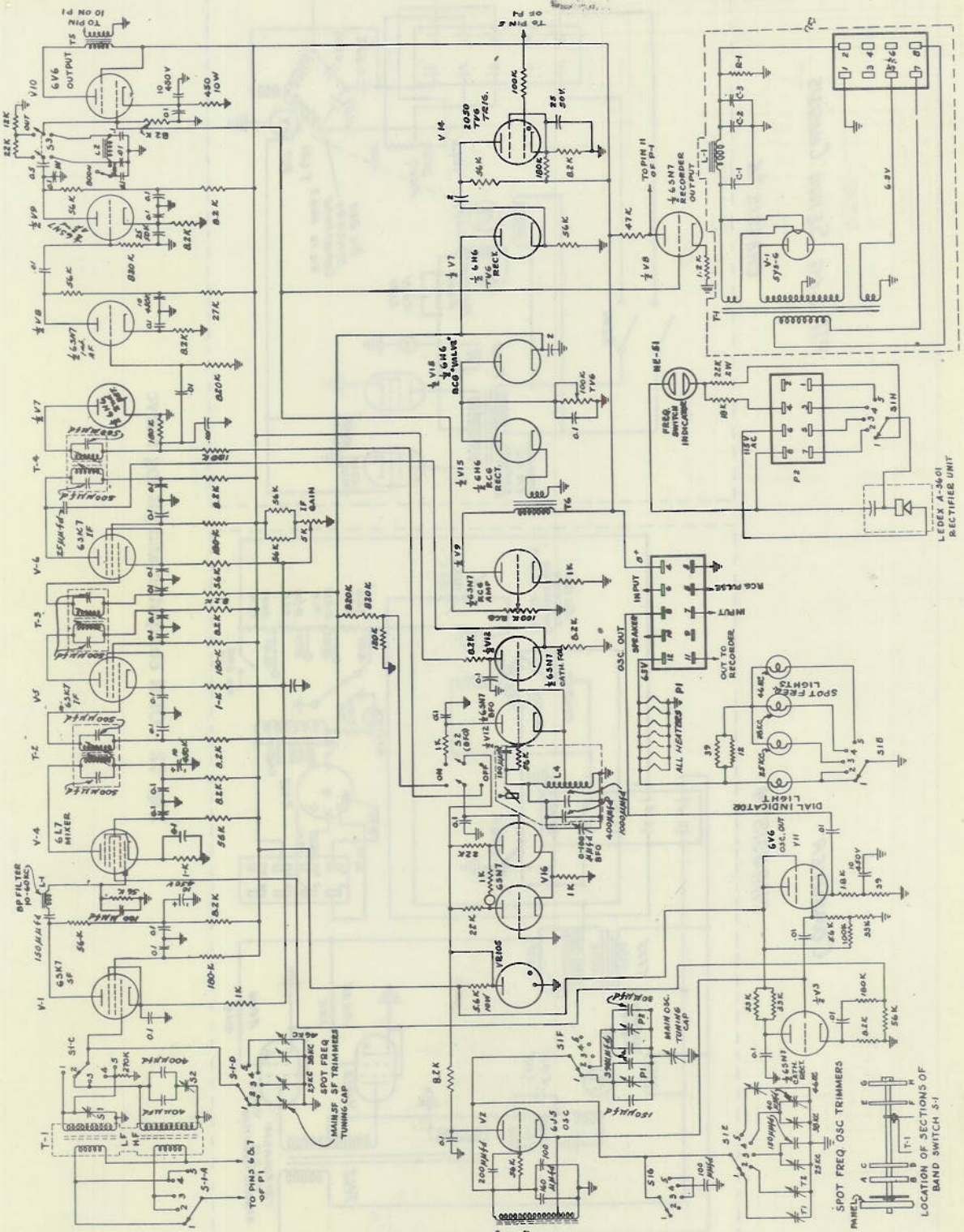



Fig. 51 - Receiver

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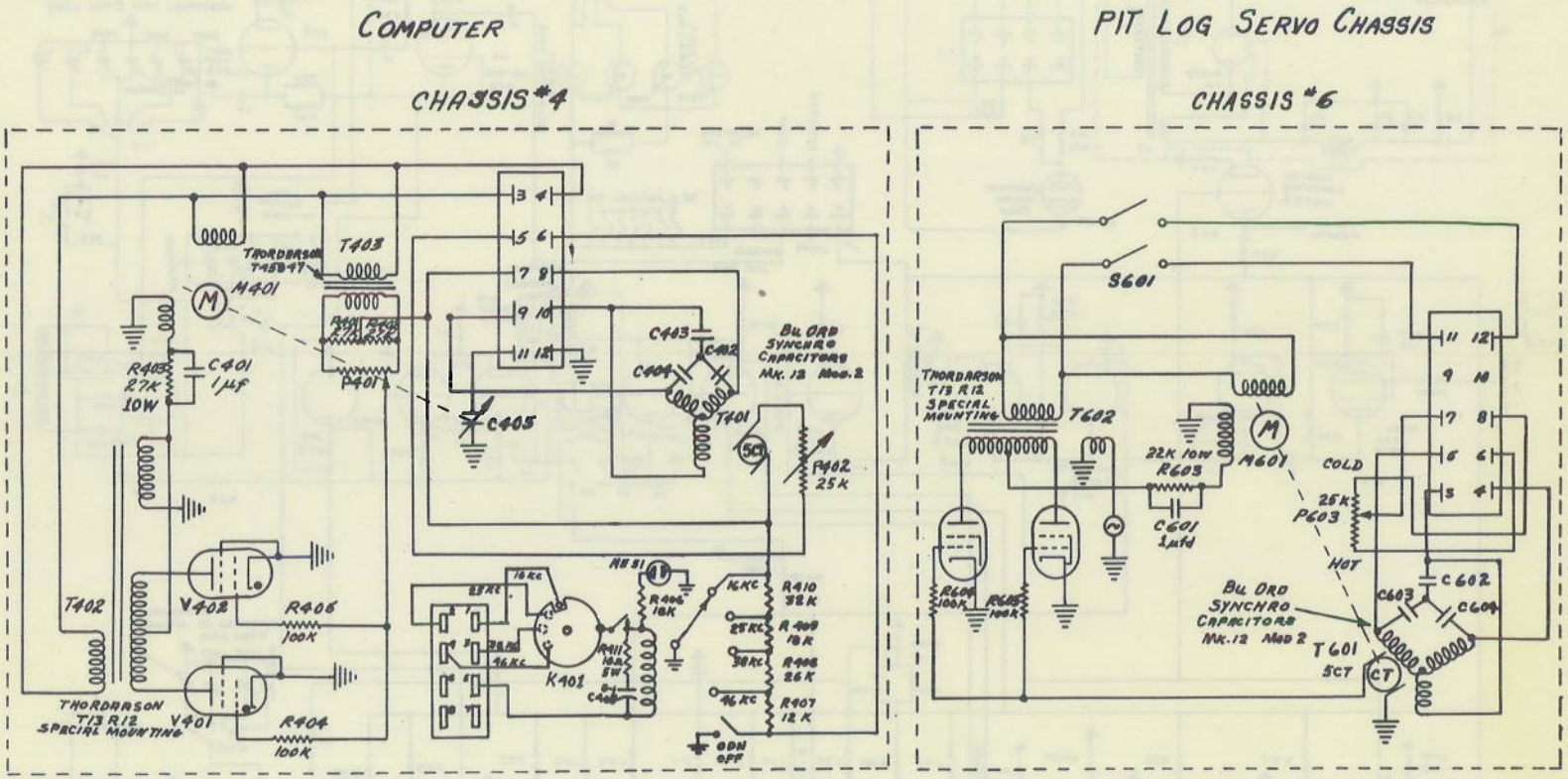



Fig. 52 - ODN computer and pit log servo

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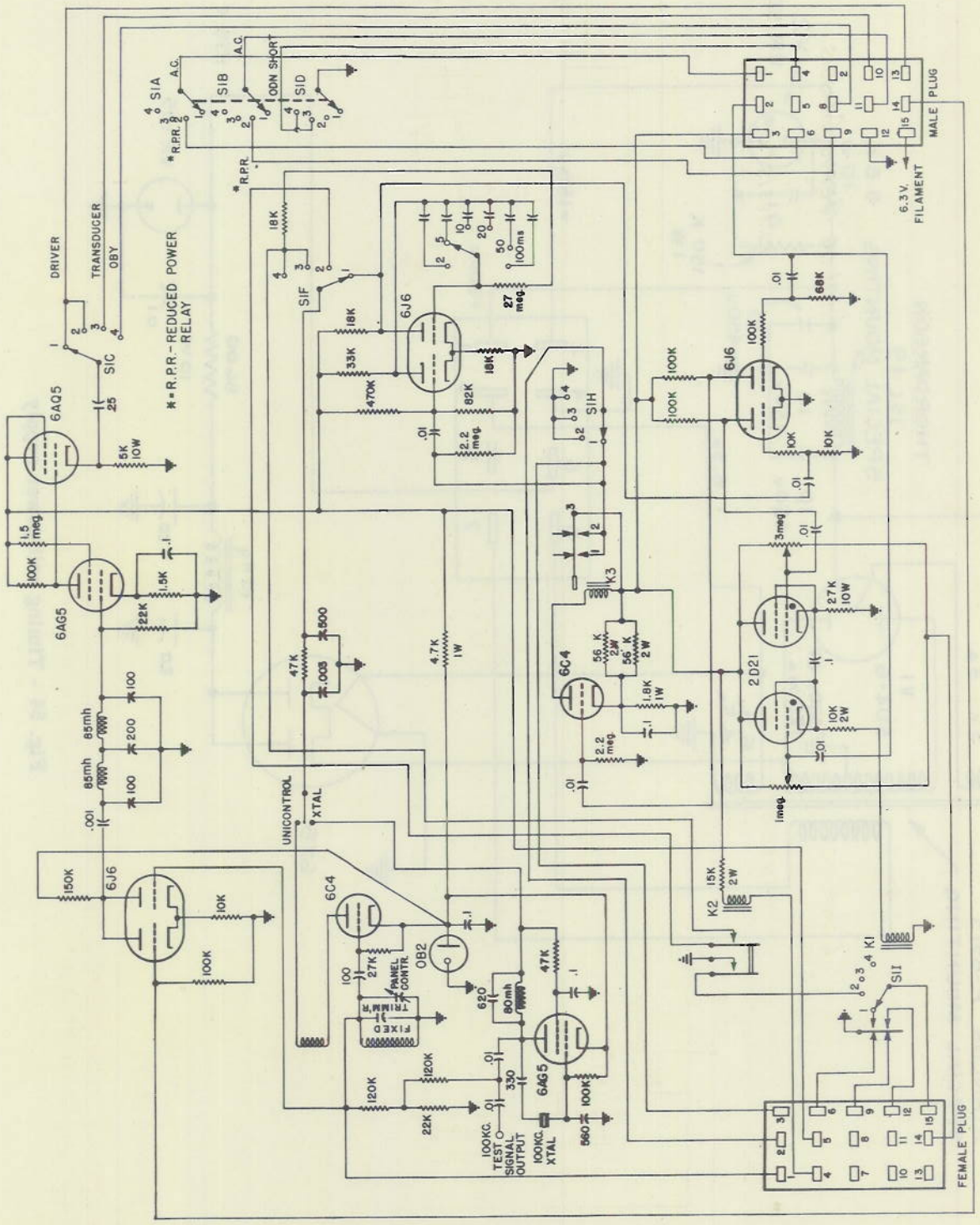



Fig. 53 - Timing unit

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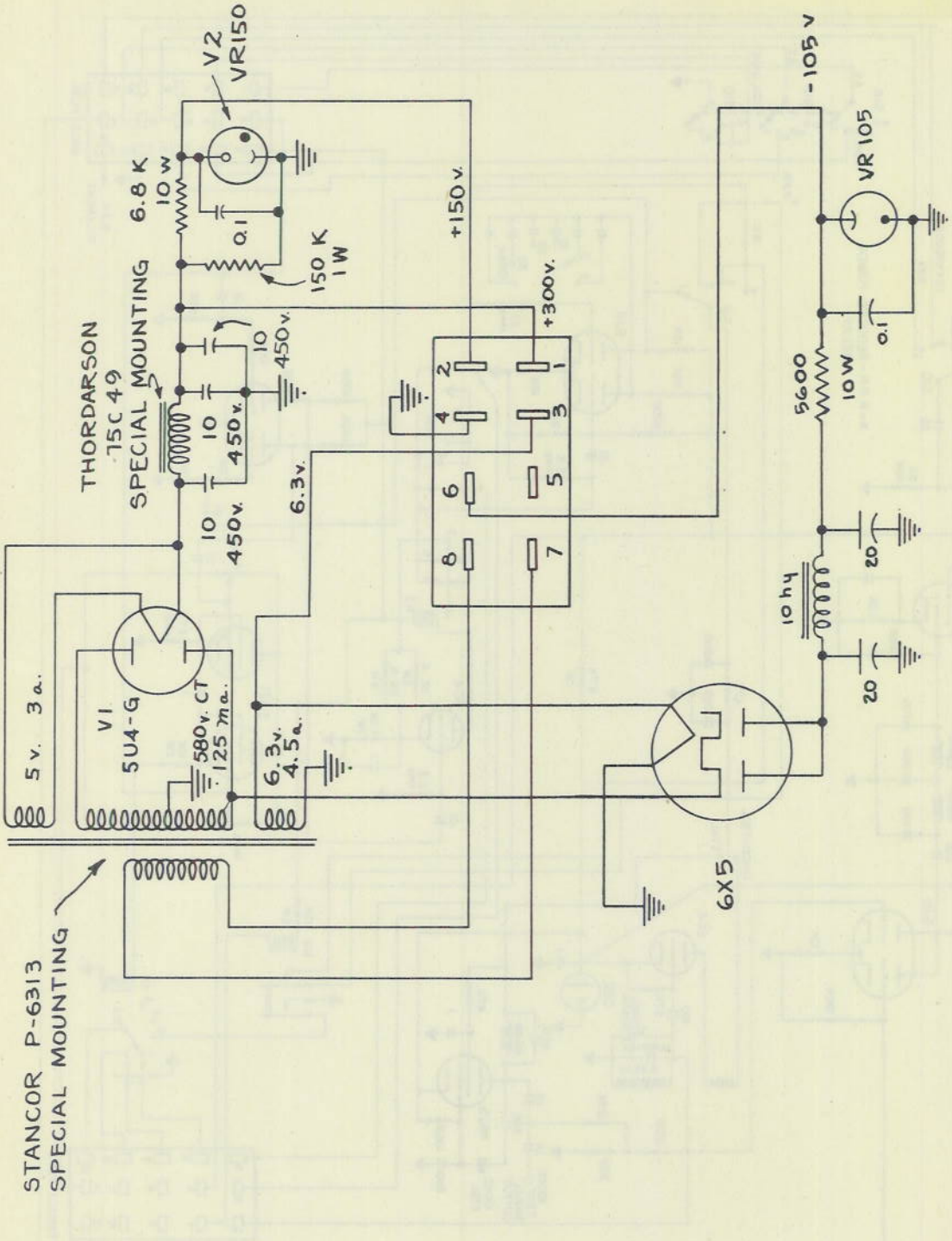



Fig. 54 - Timing unit power supply

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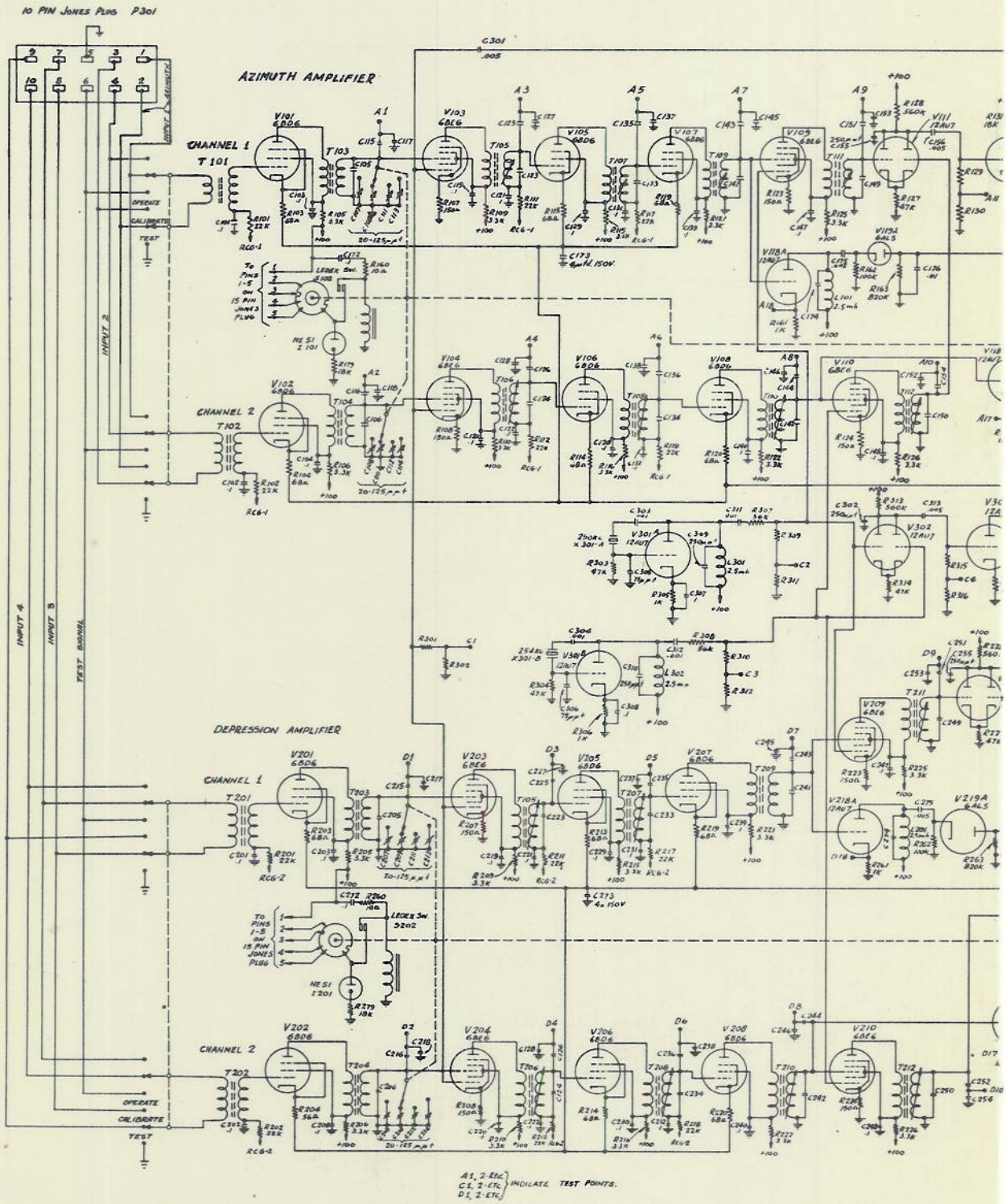
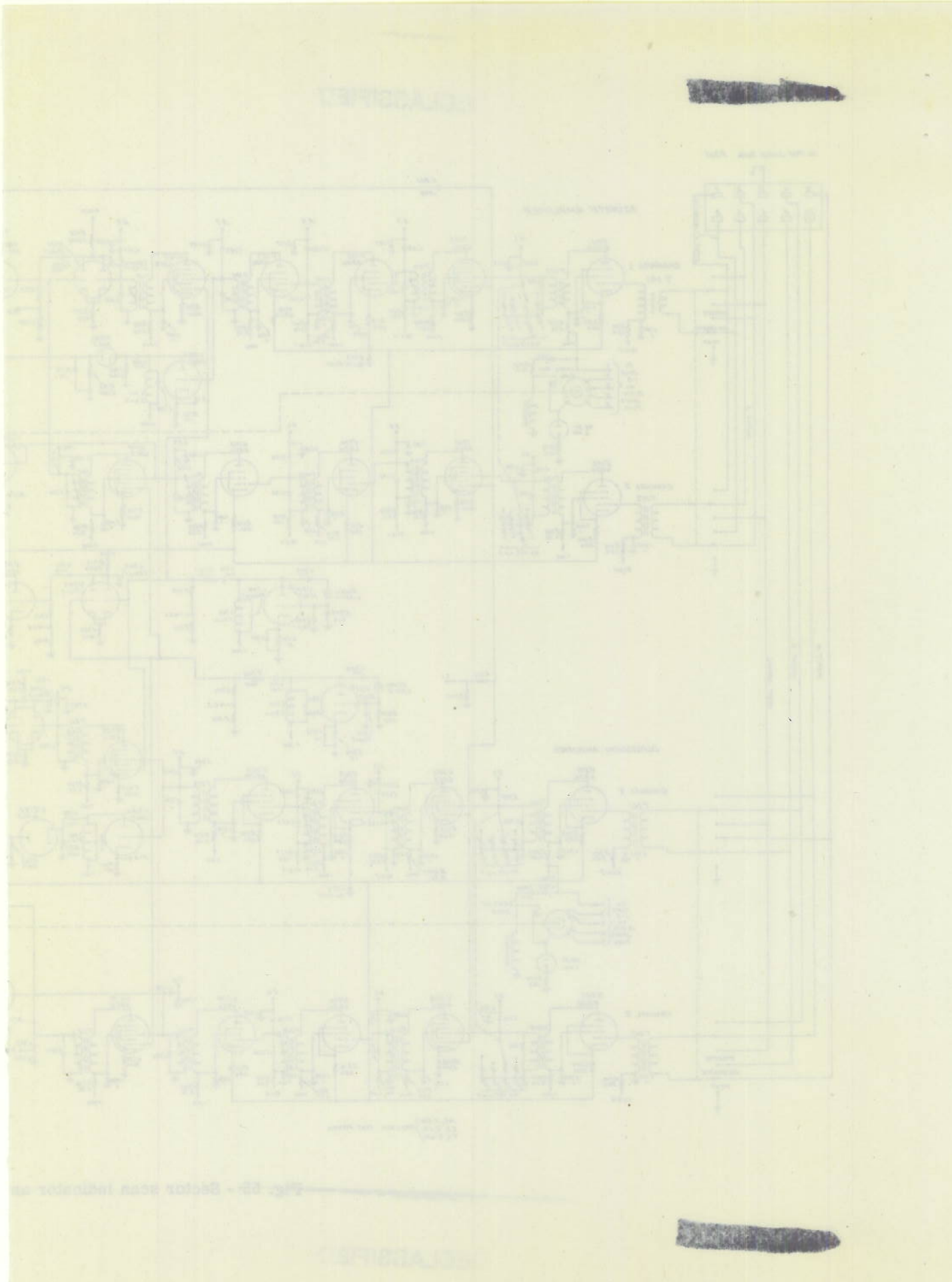
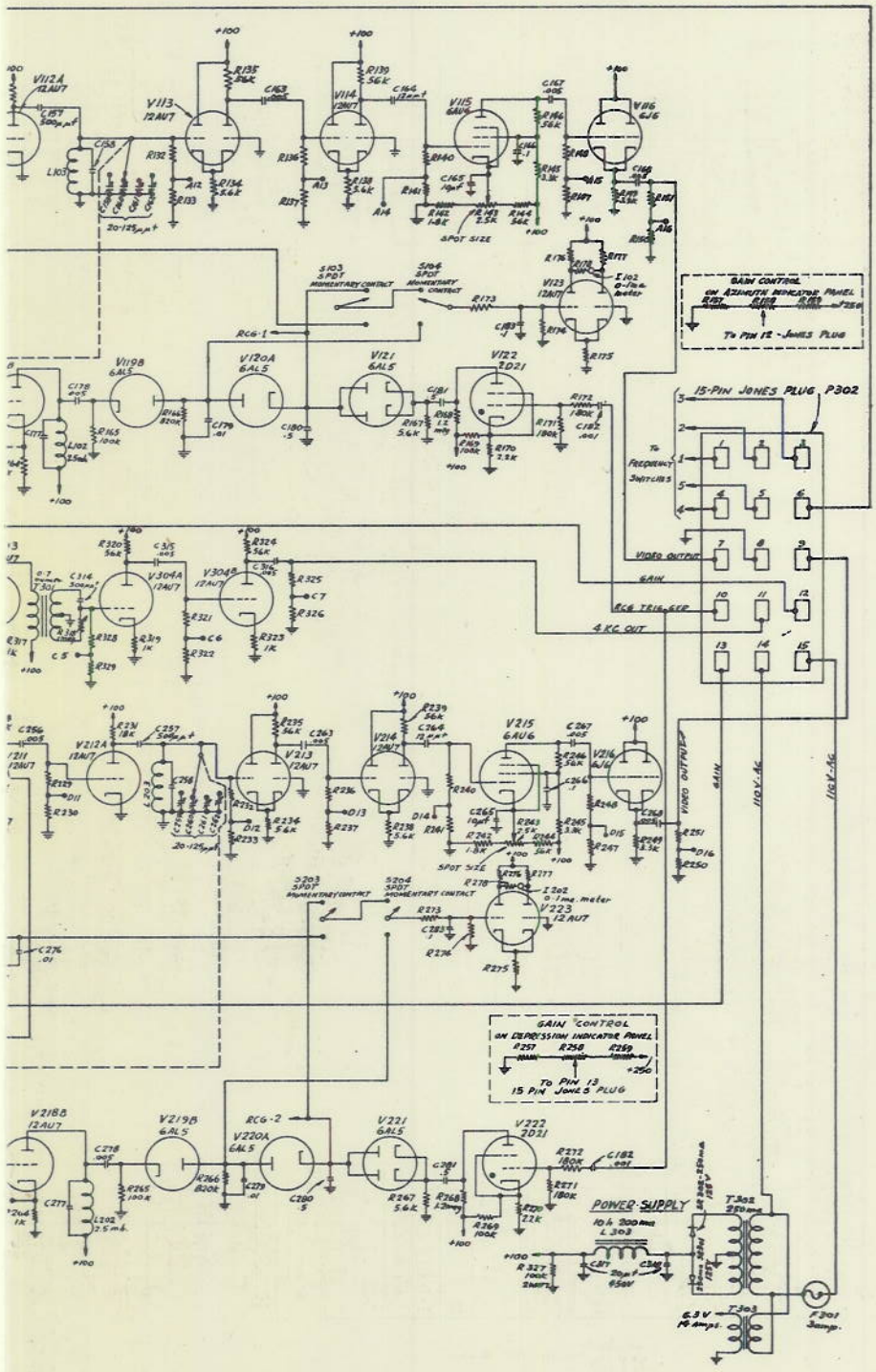



Fig. 55 - Sector scan indicator an

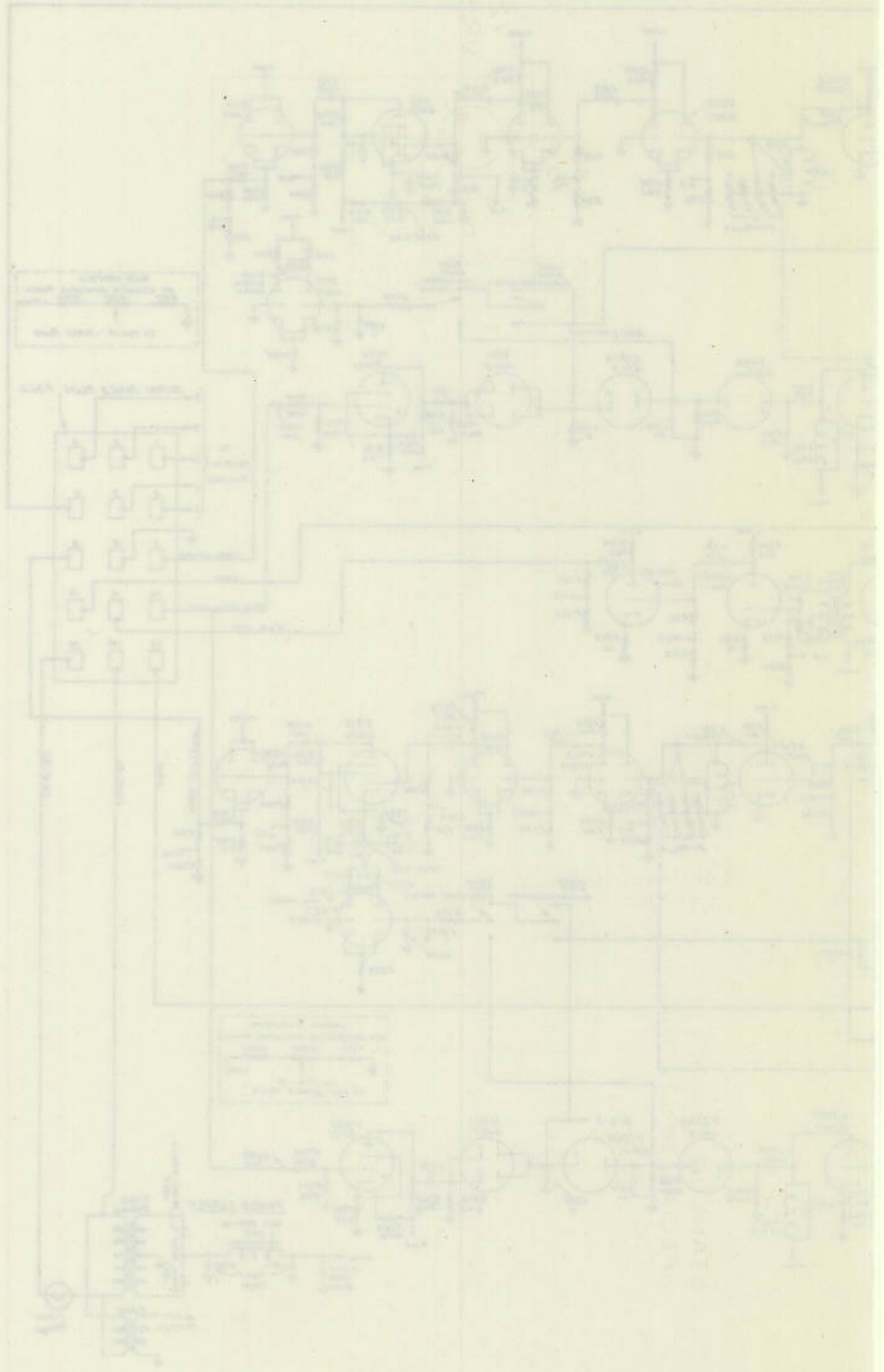
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15-PIN JONES PLUG P302
GAIN CONTROL ON AZIMUTH INDICATOR PANEL
To PIN 12 - JONES PLUG
GAIN CONTROL ON DEPRESSION INDICATOR PANEL
To PIN 13 15 PIN JONES PLUG
POWER SUPPLY
VIDEO OUTPUT
4 KC OUT
SPOT SIZE
RCG-1
RCG-2
To FREQUENCY SWITCHES
110 V. AC
6.3 V 4 Amps.

## Amplifiers



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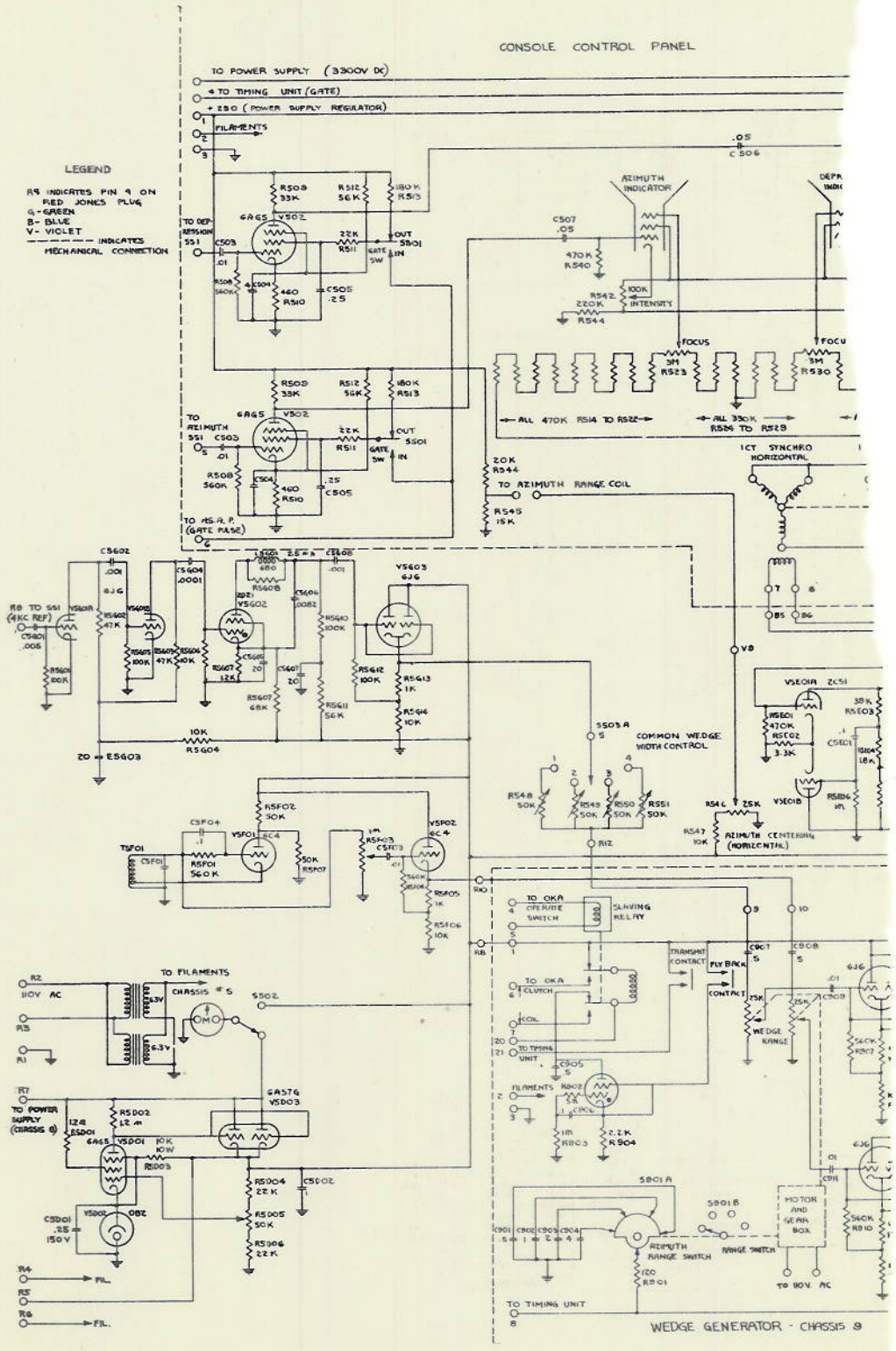
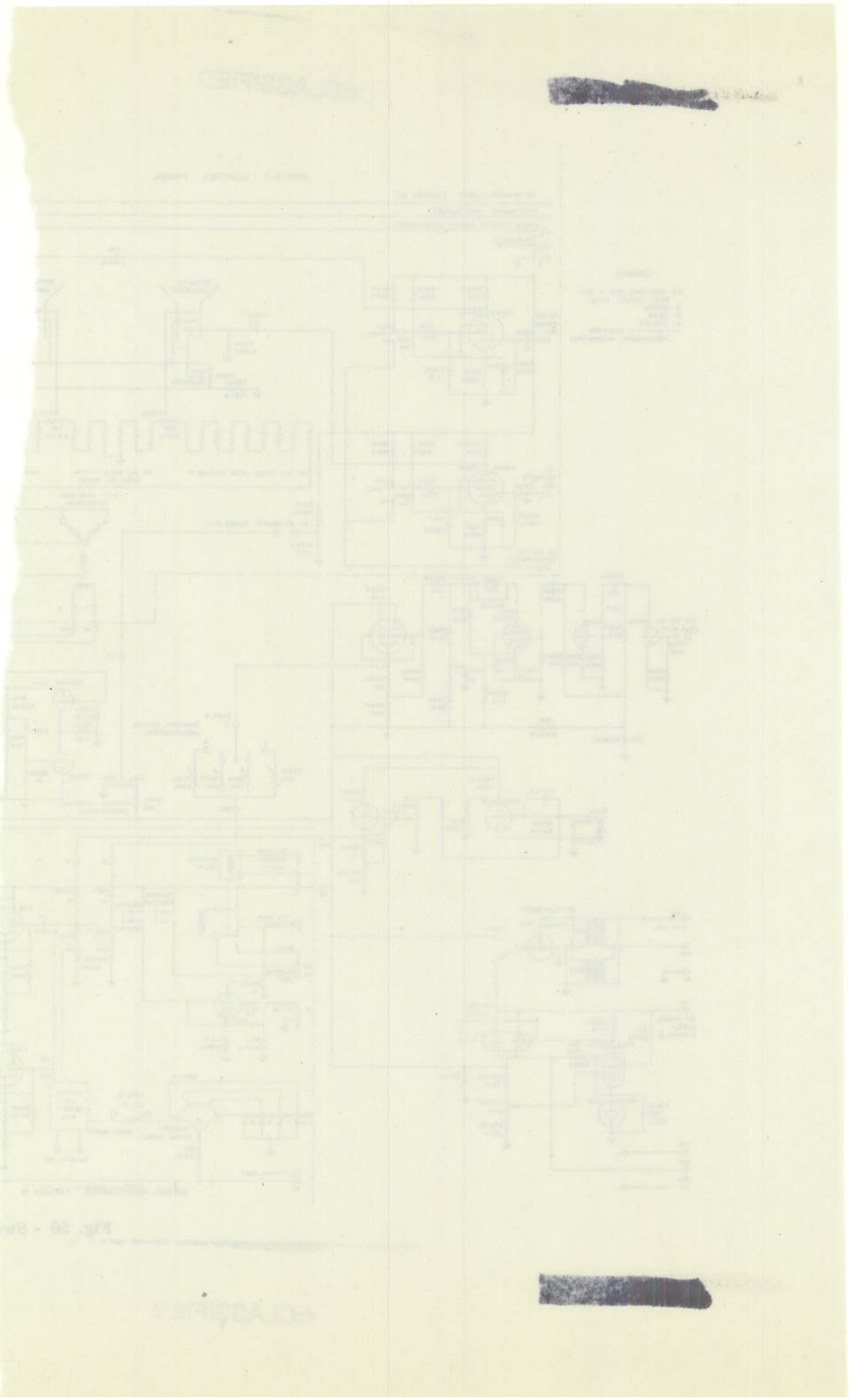
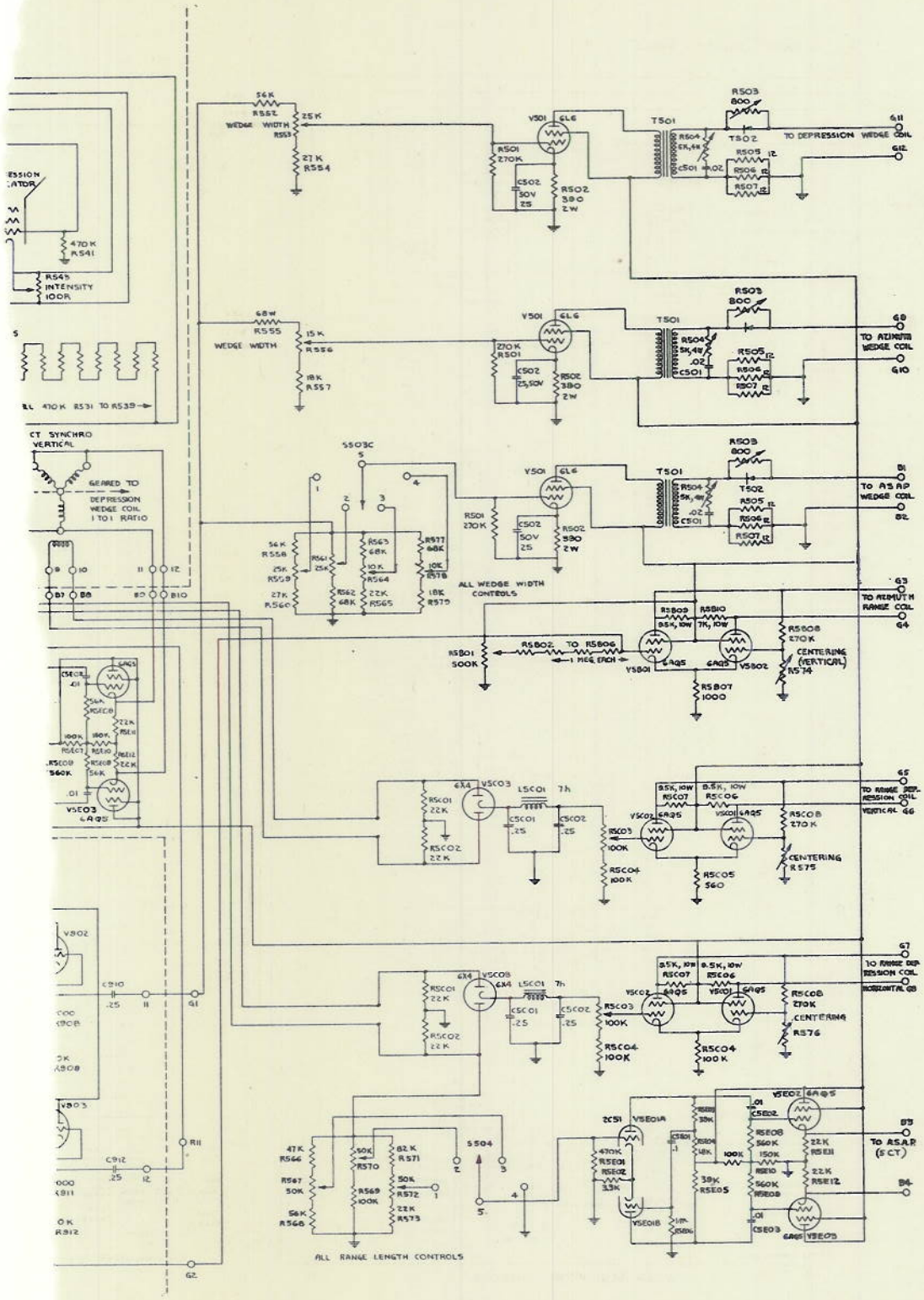



Fig. 56 - Swe

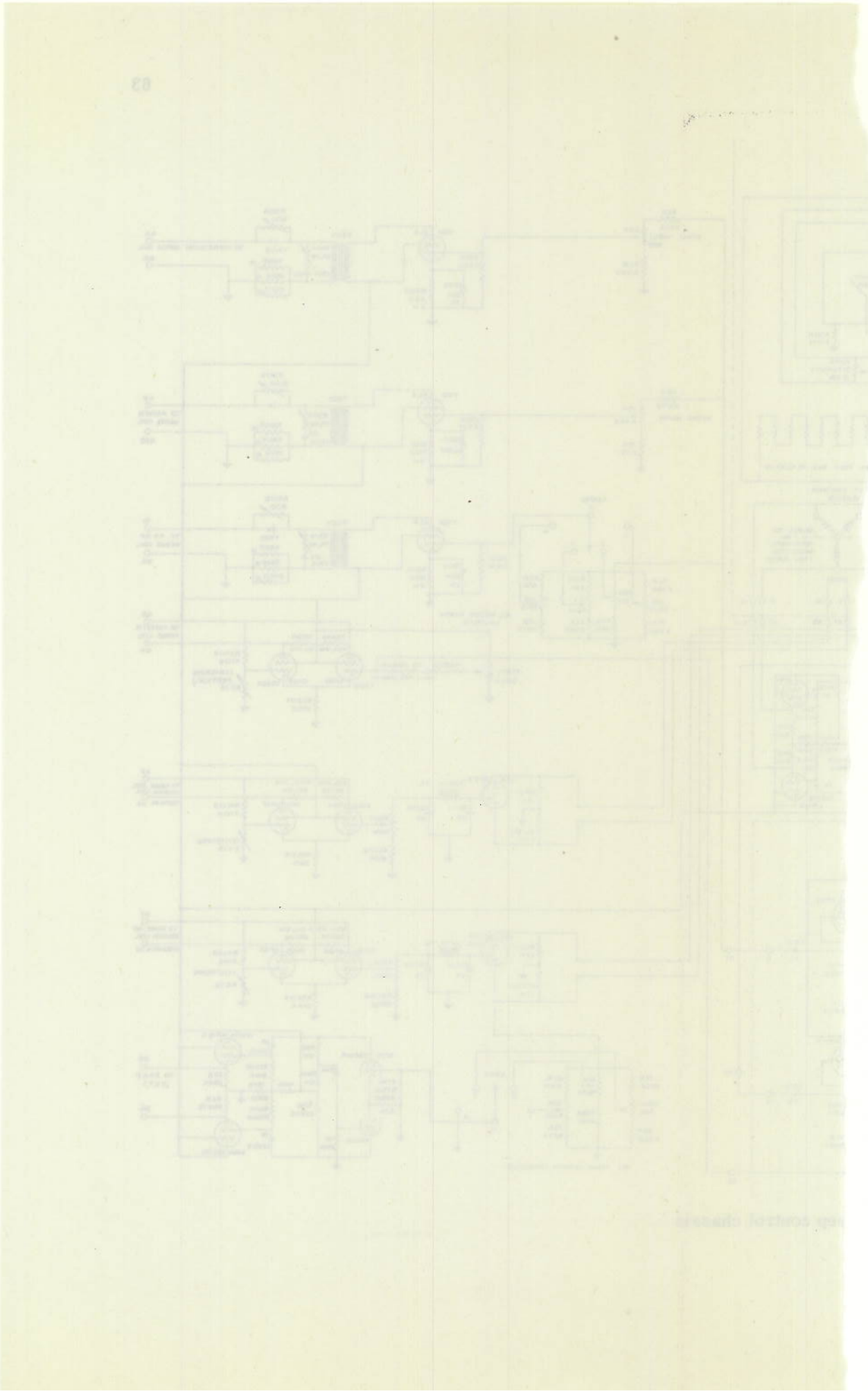
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eep control chassis



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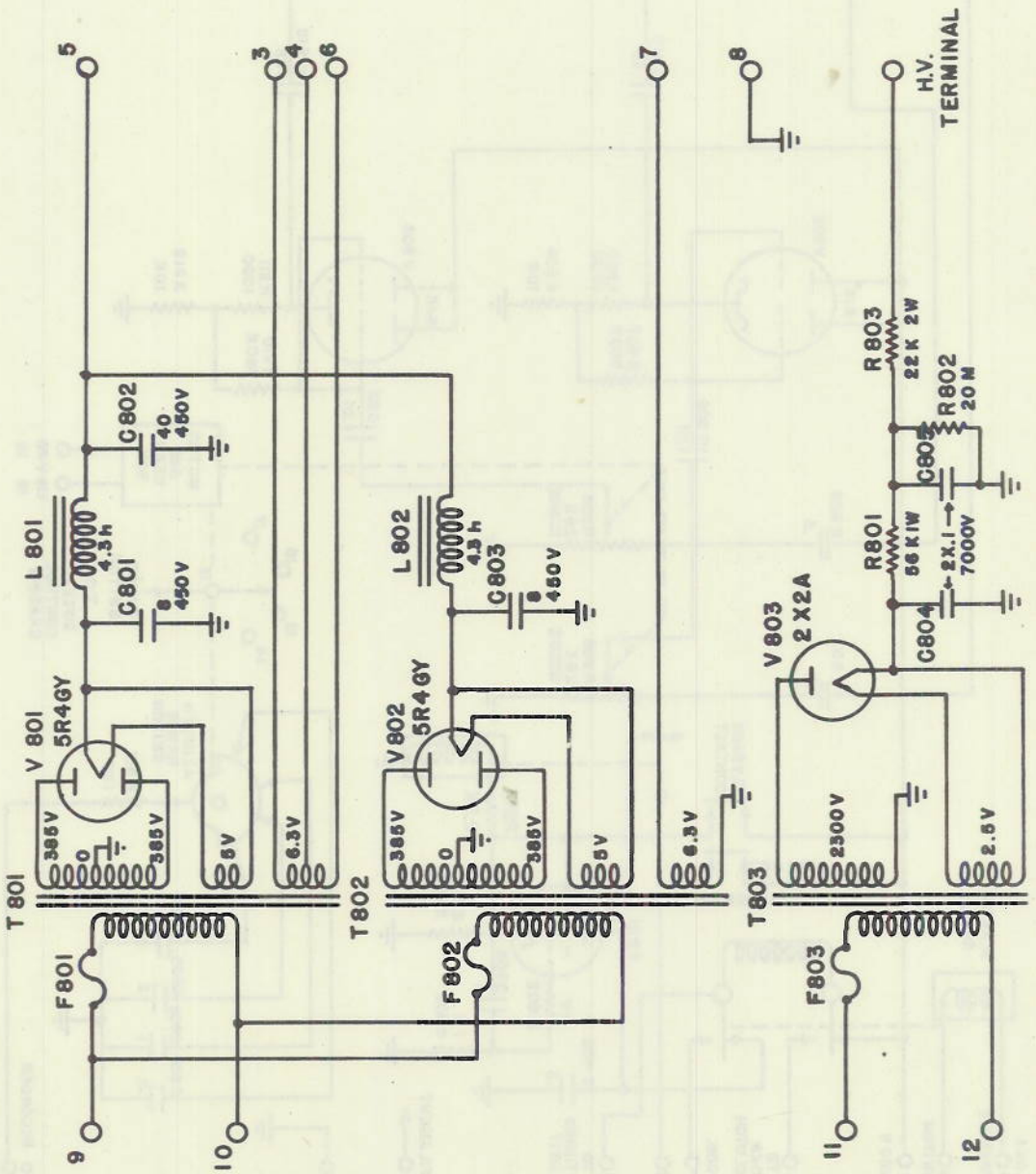



Fig. 57 - Sweep power supply

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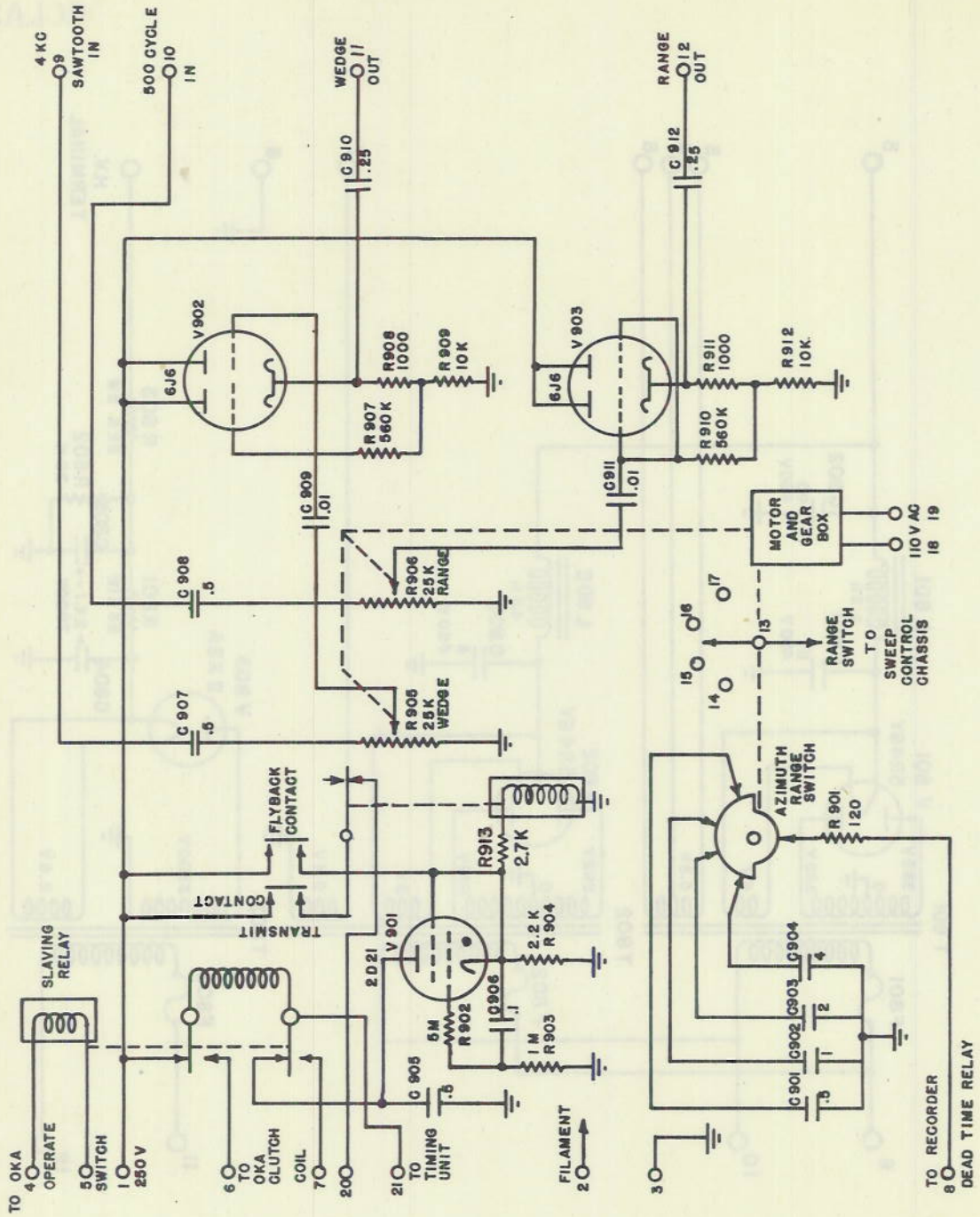



Fig. 58 - Wedge generator

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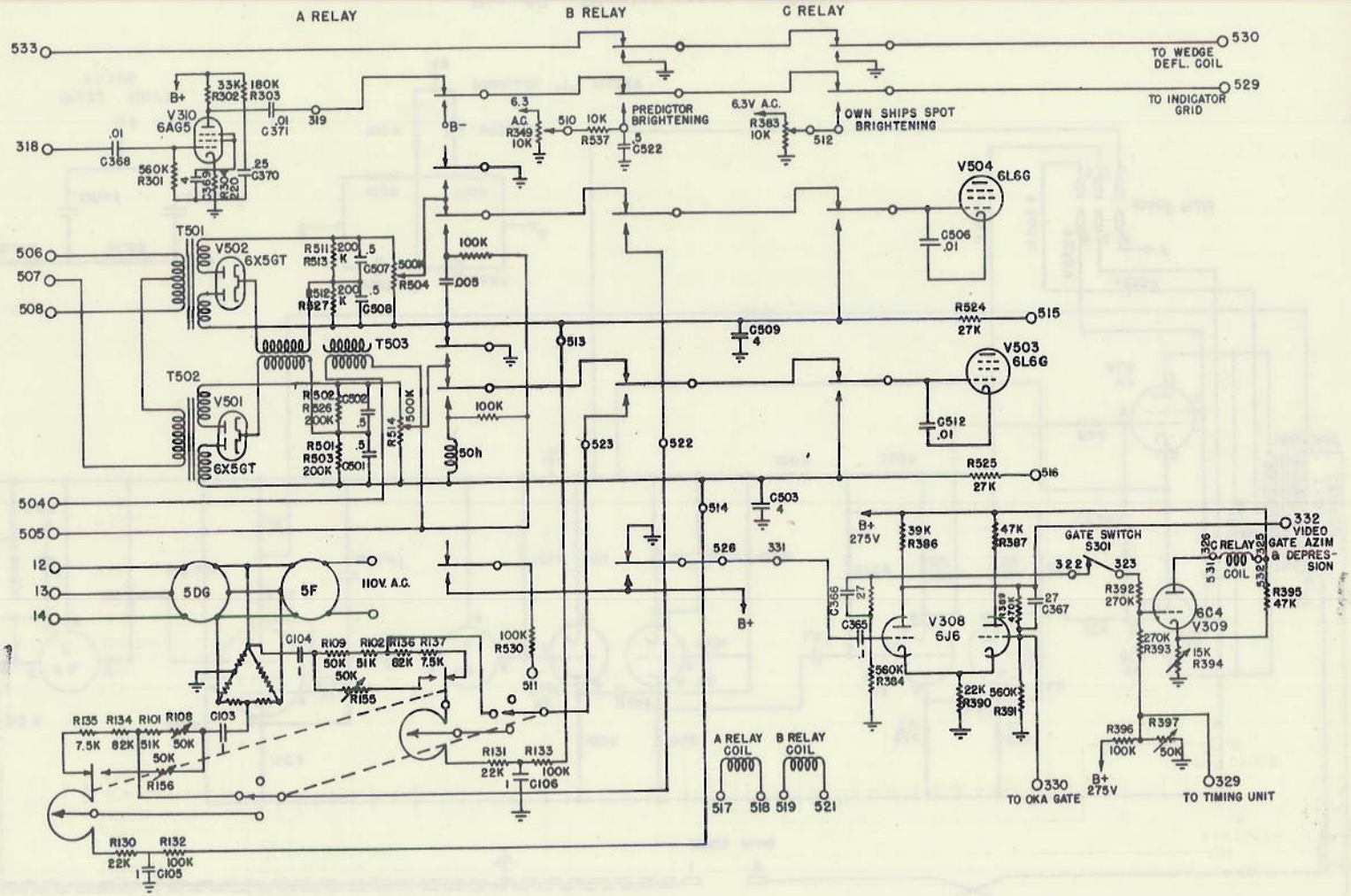



Fig. 59 - ASAP modifications

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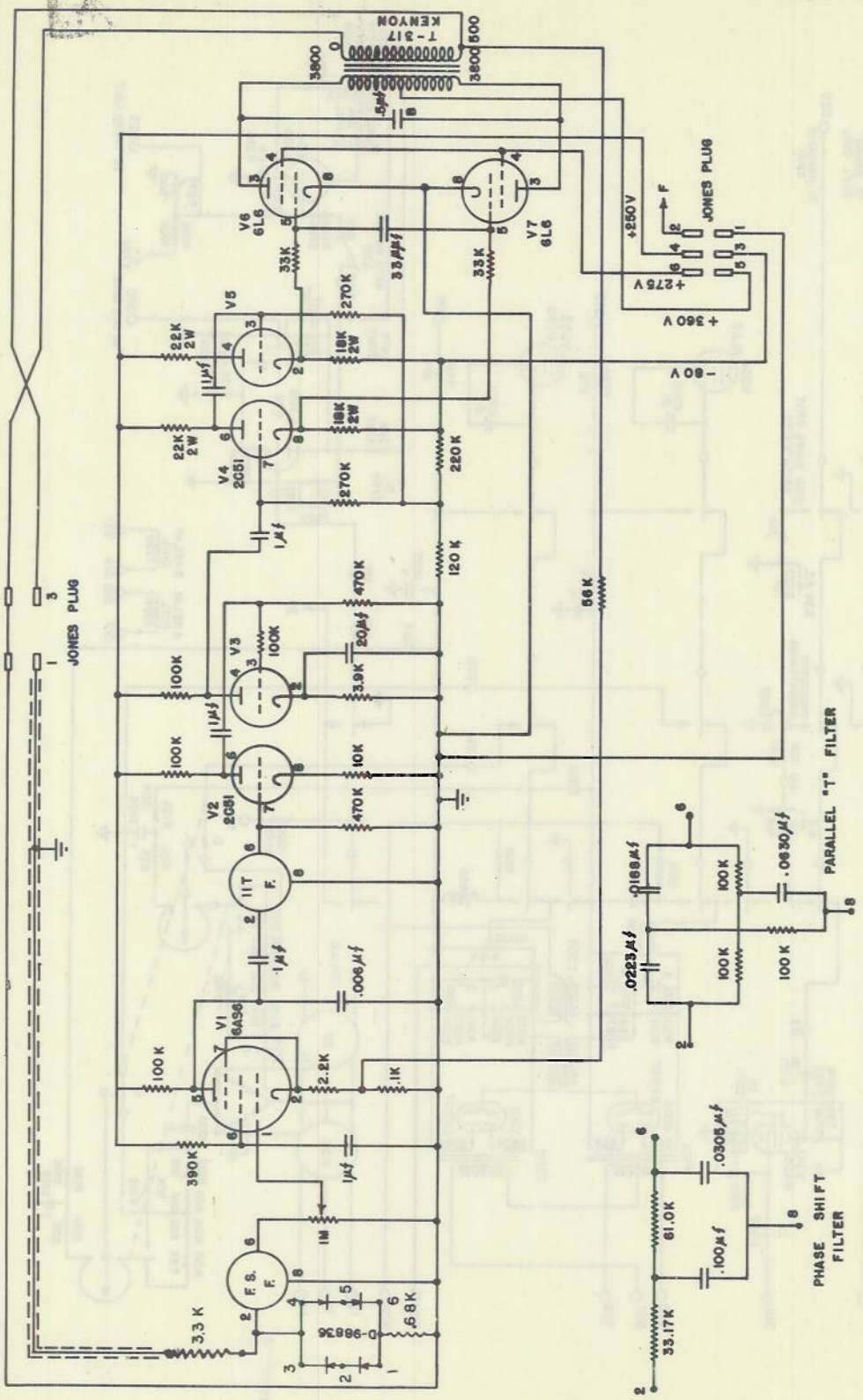



Fig. 60 - Display servo amplifier

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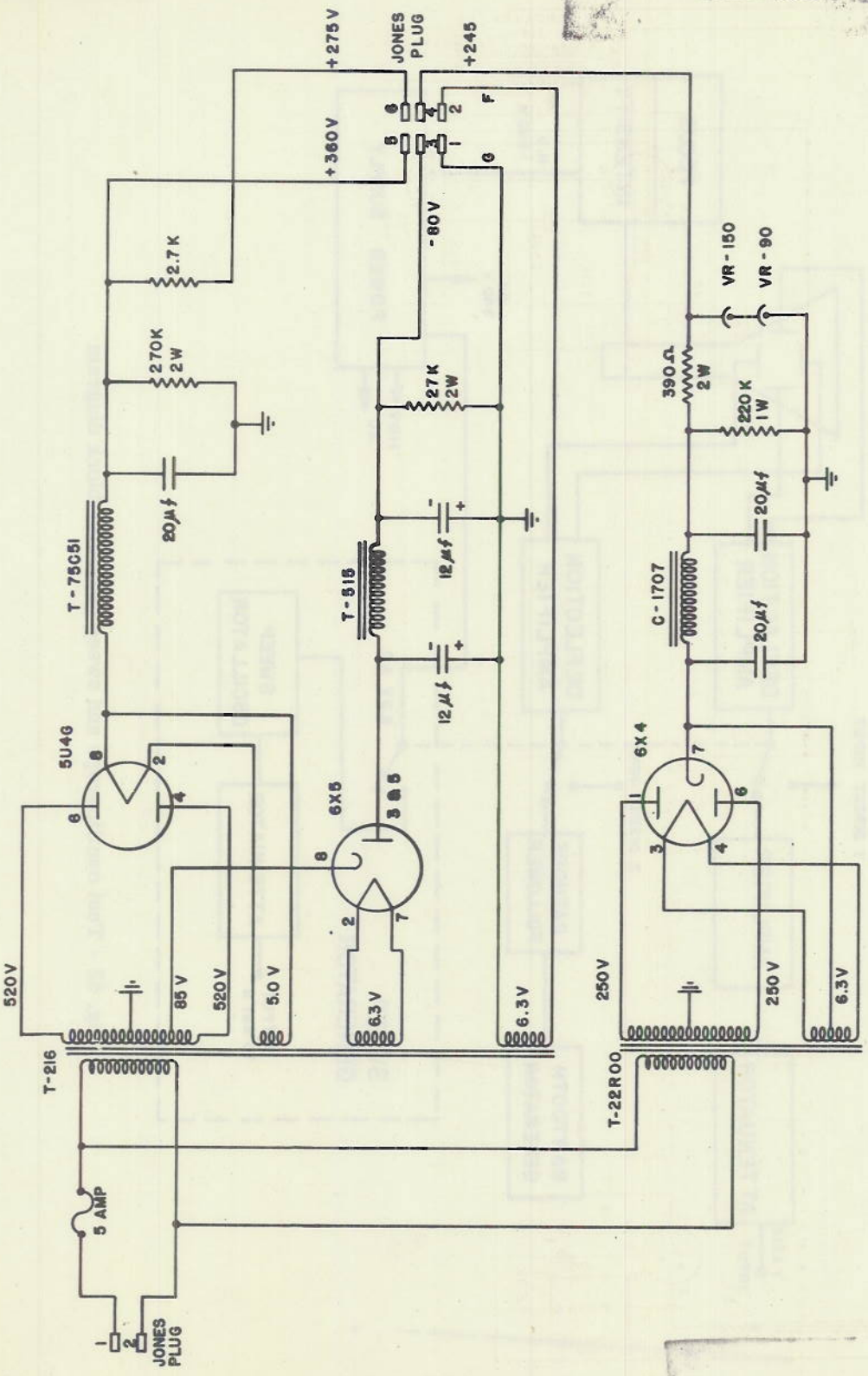



Fig. 61 - Display servo amplifier power supply

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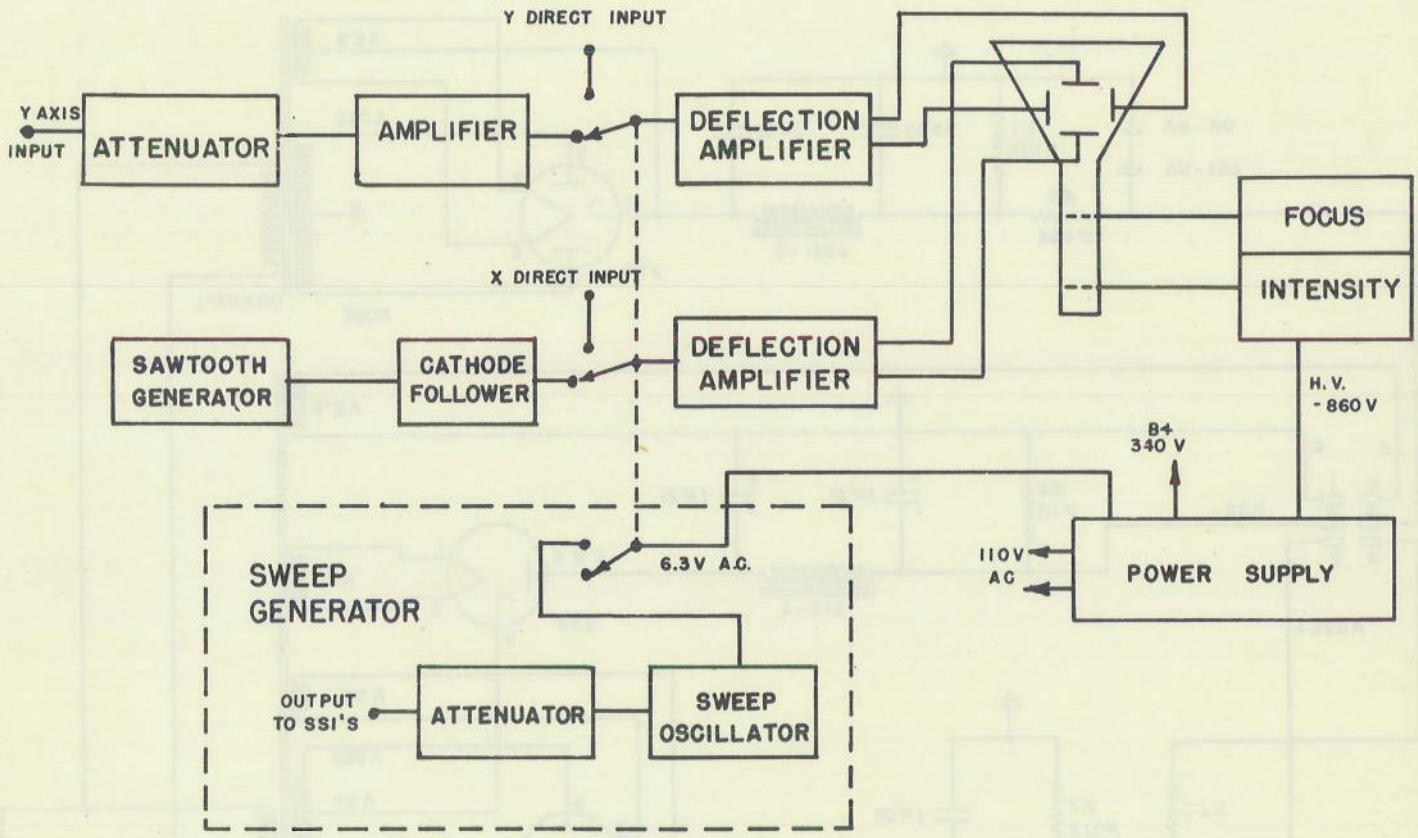



Fig. 62 - Test oscilloscope and sweep generator block diagram

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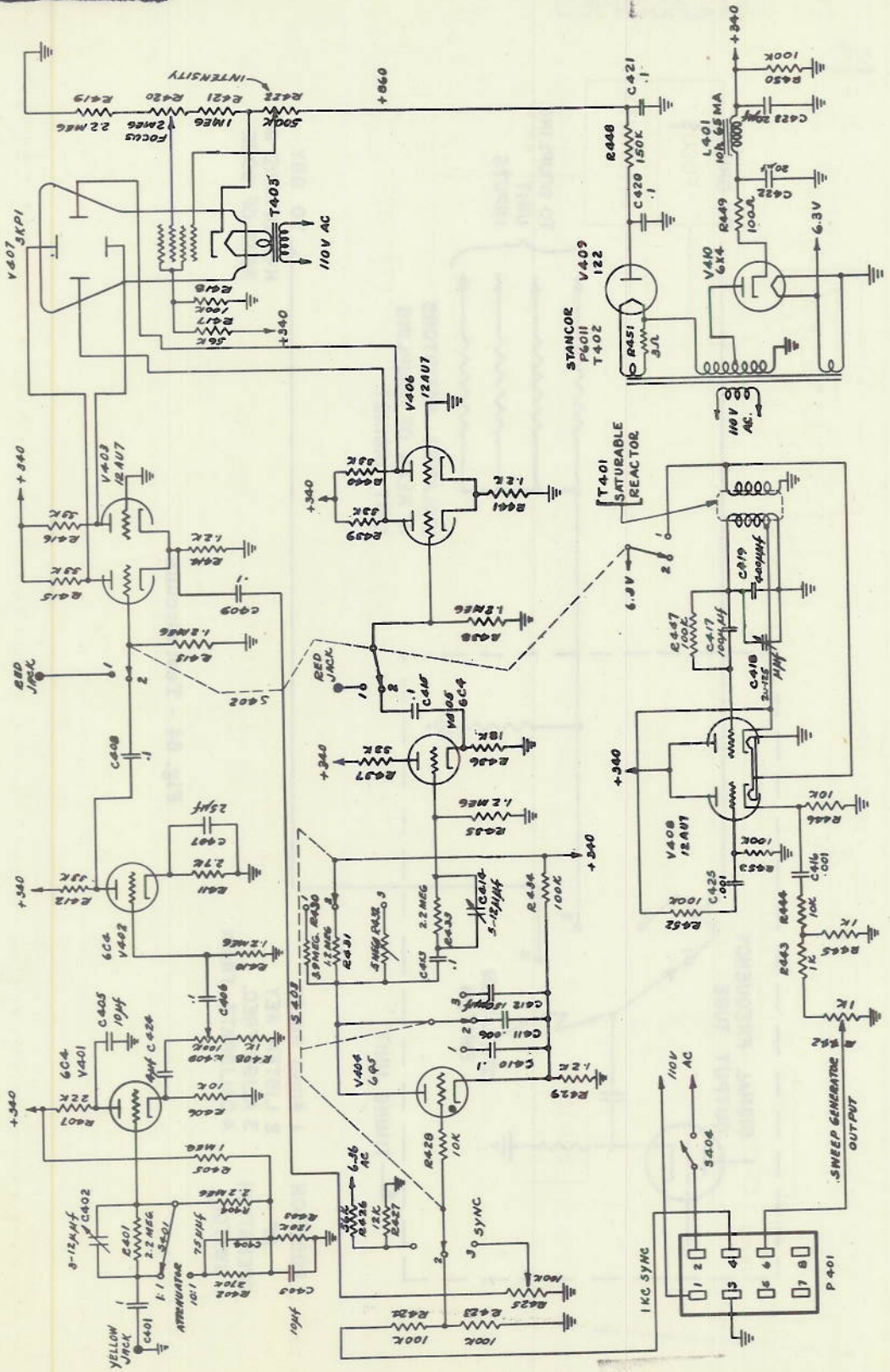



Fig. 63 - Test oscilloscope

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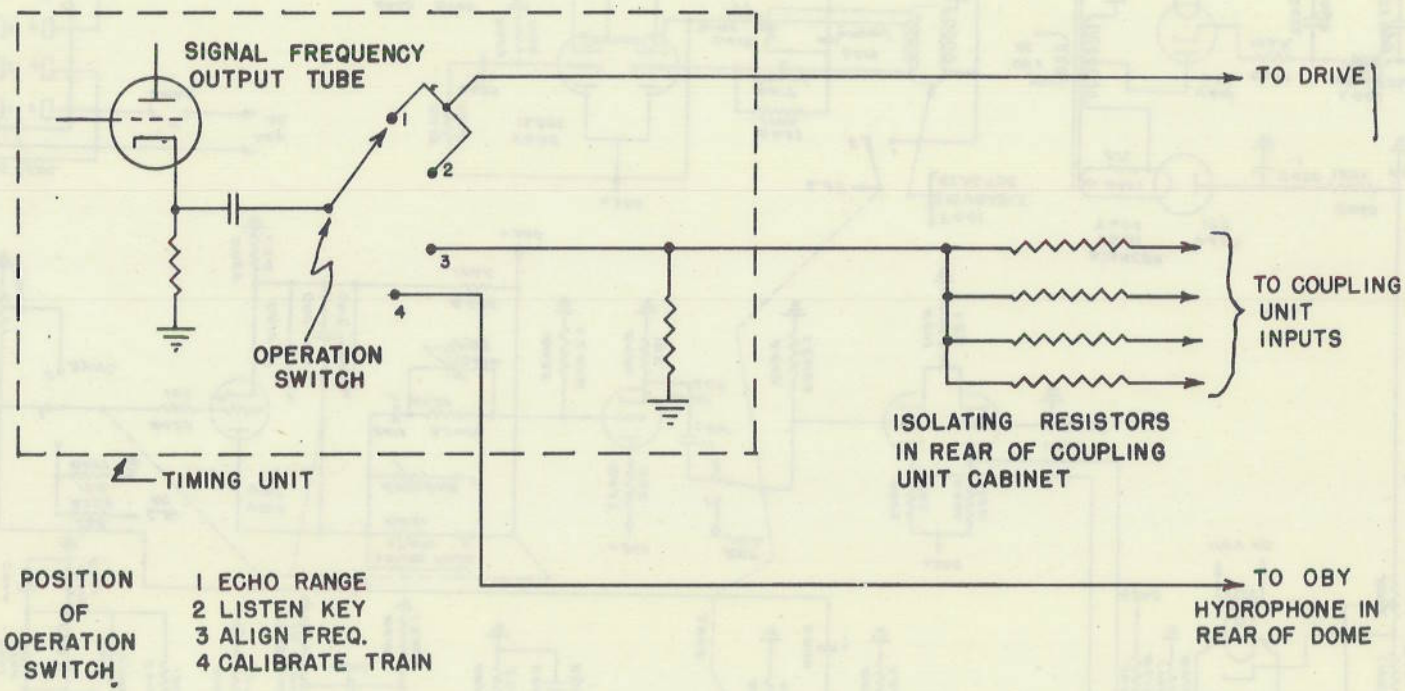



Fig. 64 - Test circuits

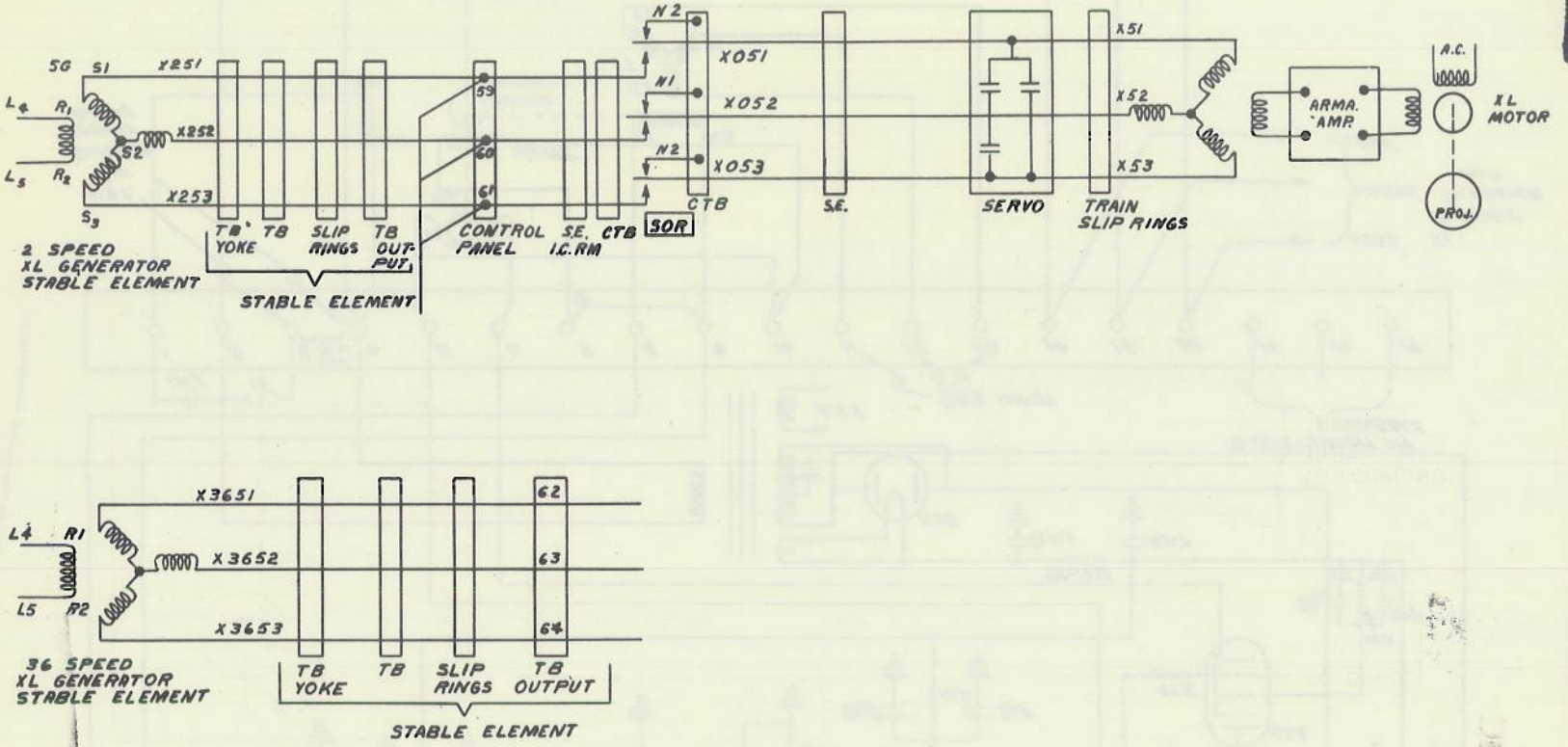



Fig. 65 - Transducer cross level stabilization

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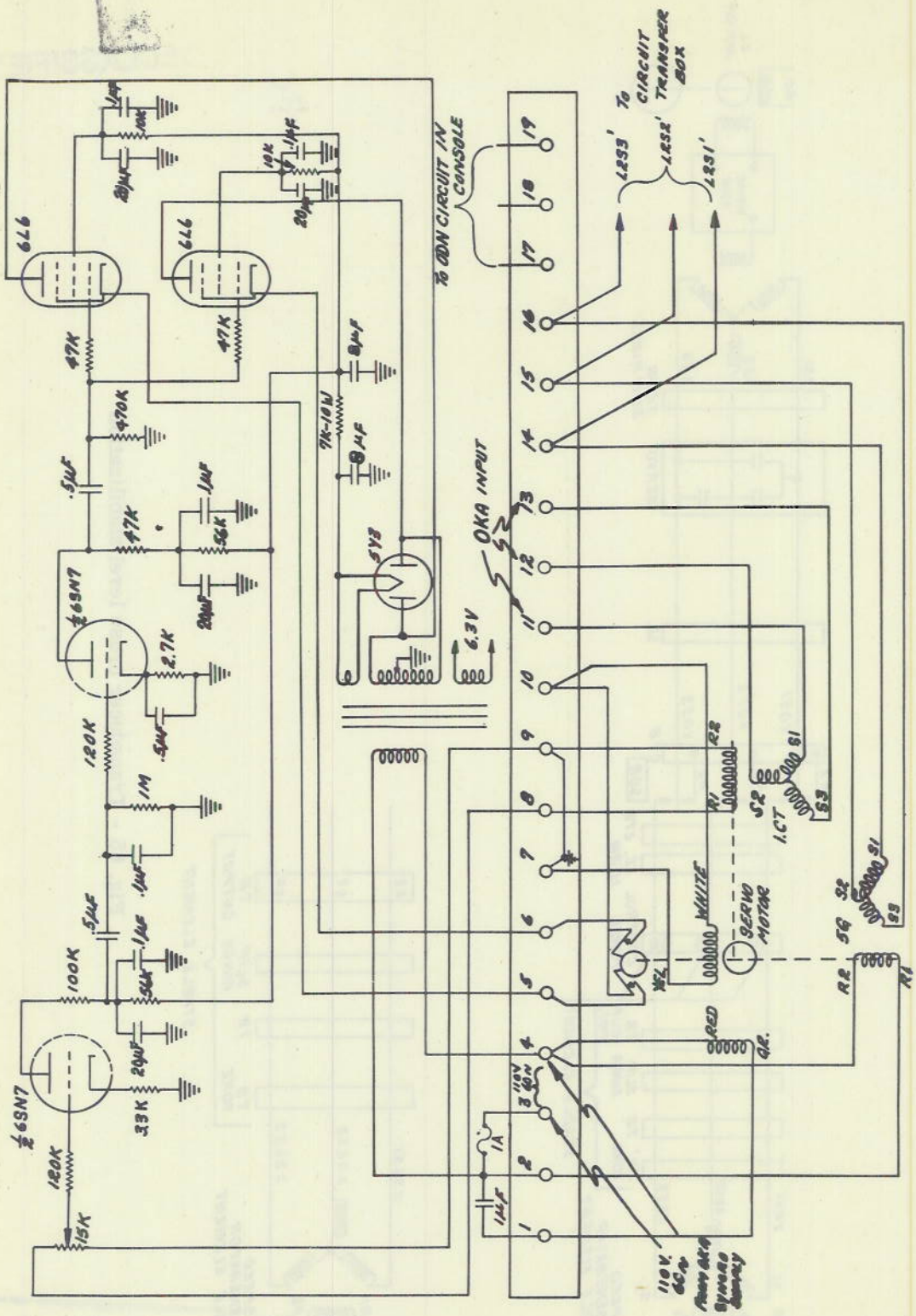



Fig. 66 - Size 1 to size 5 synchro converter

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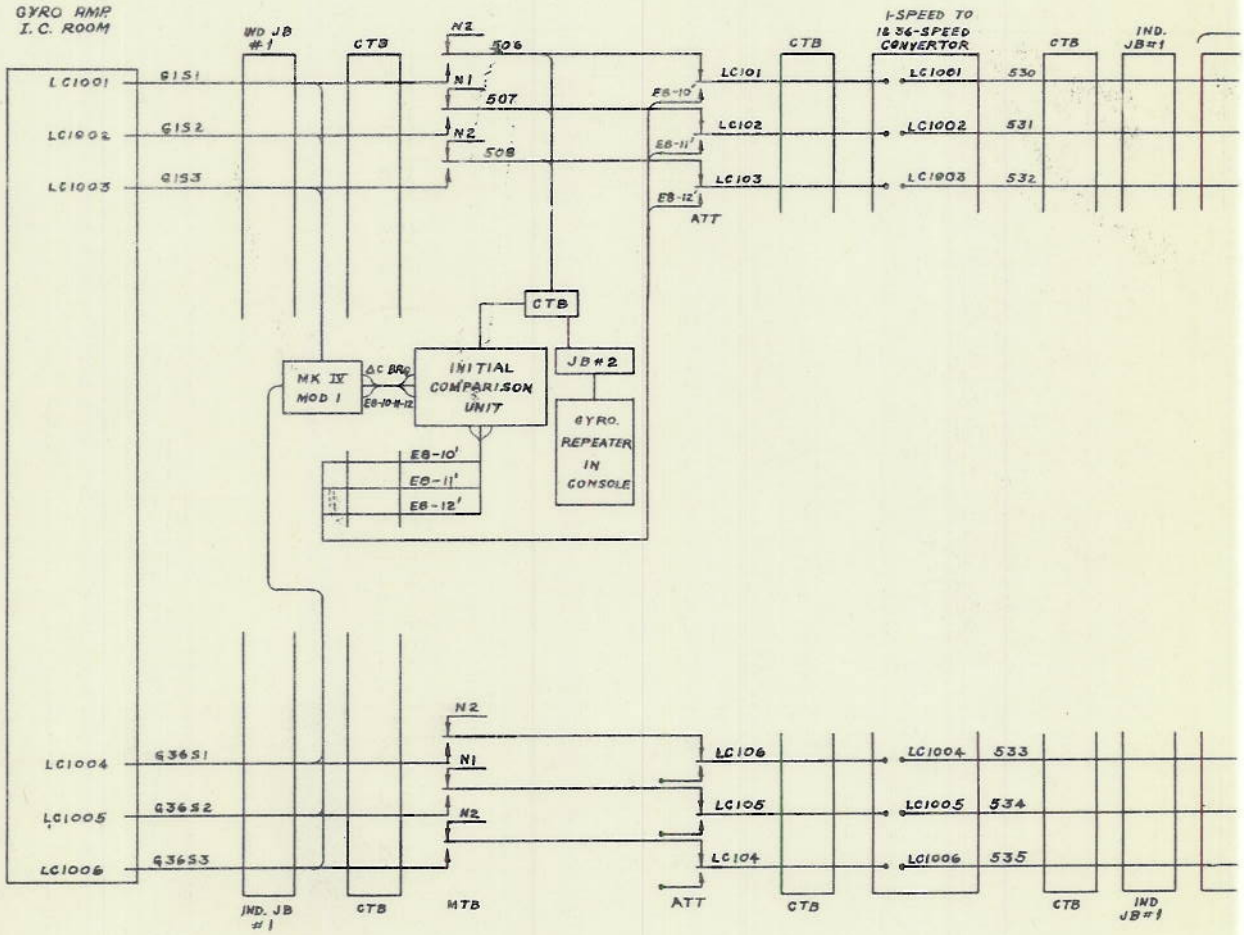
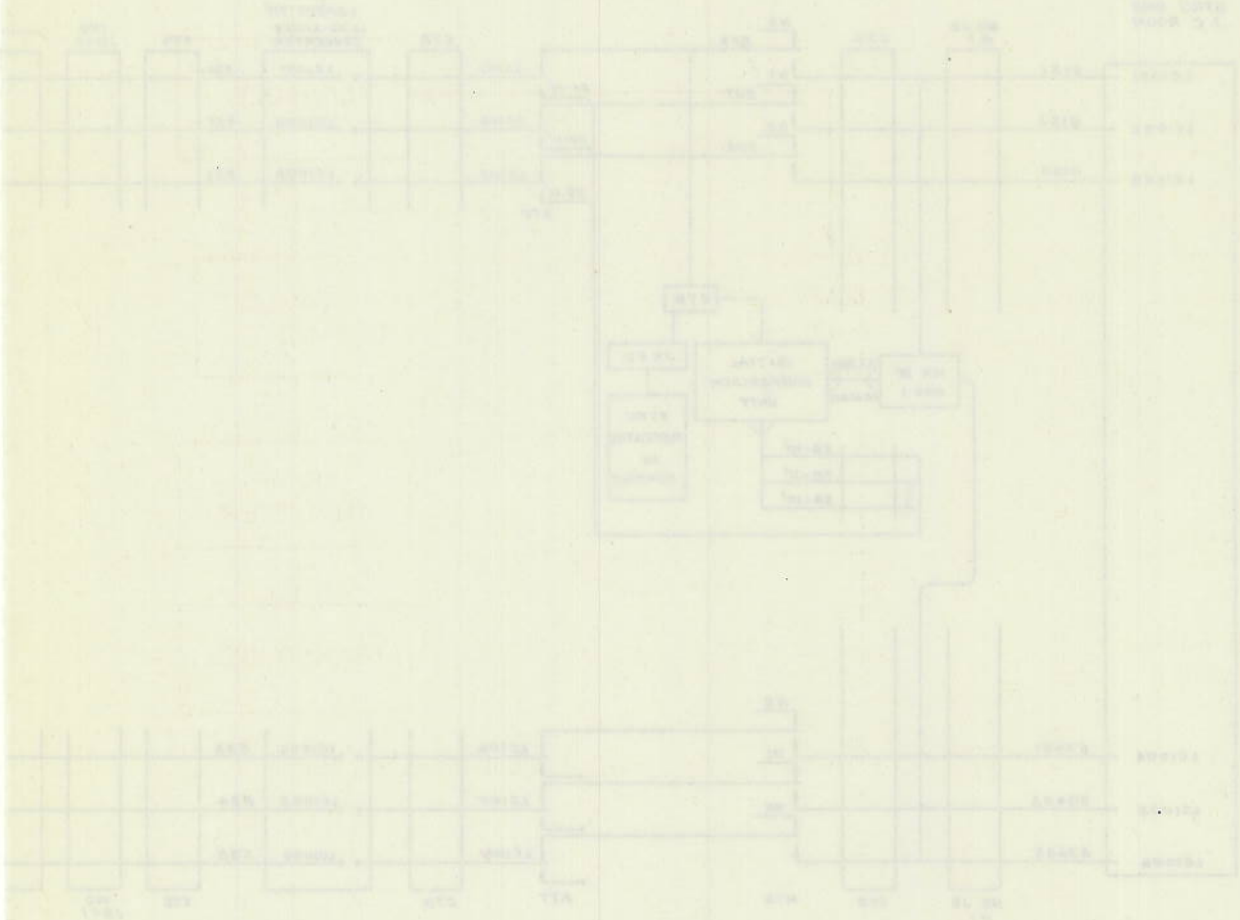
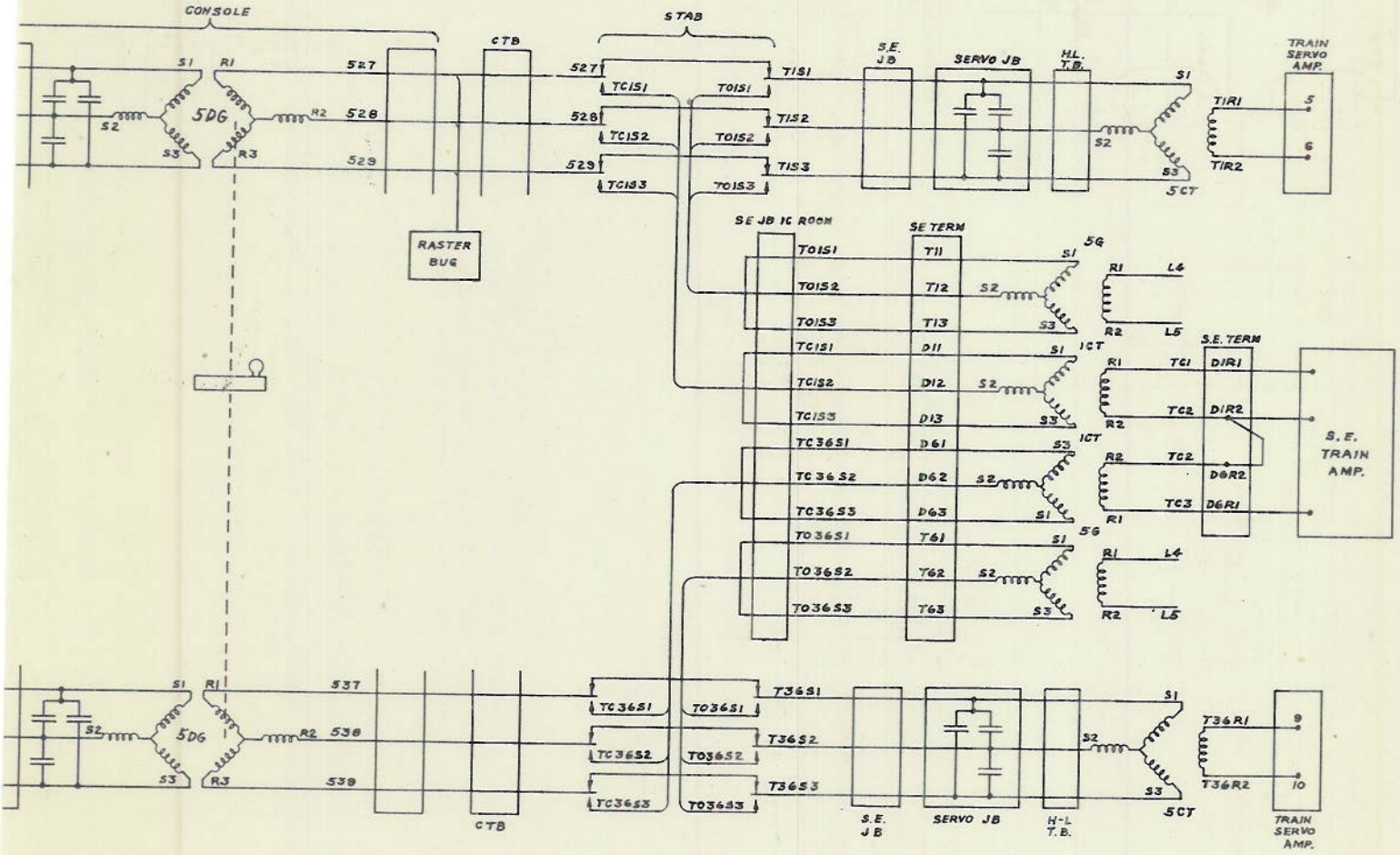



Fig. 6

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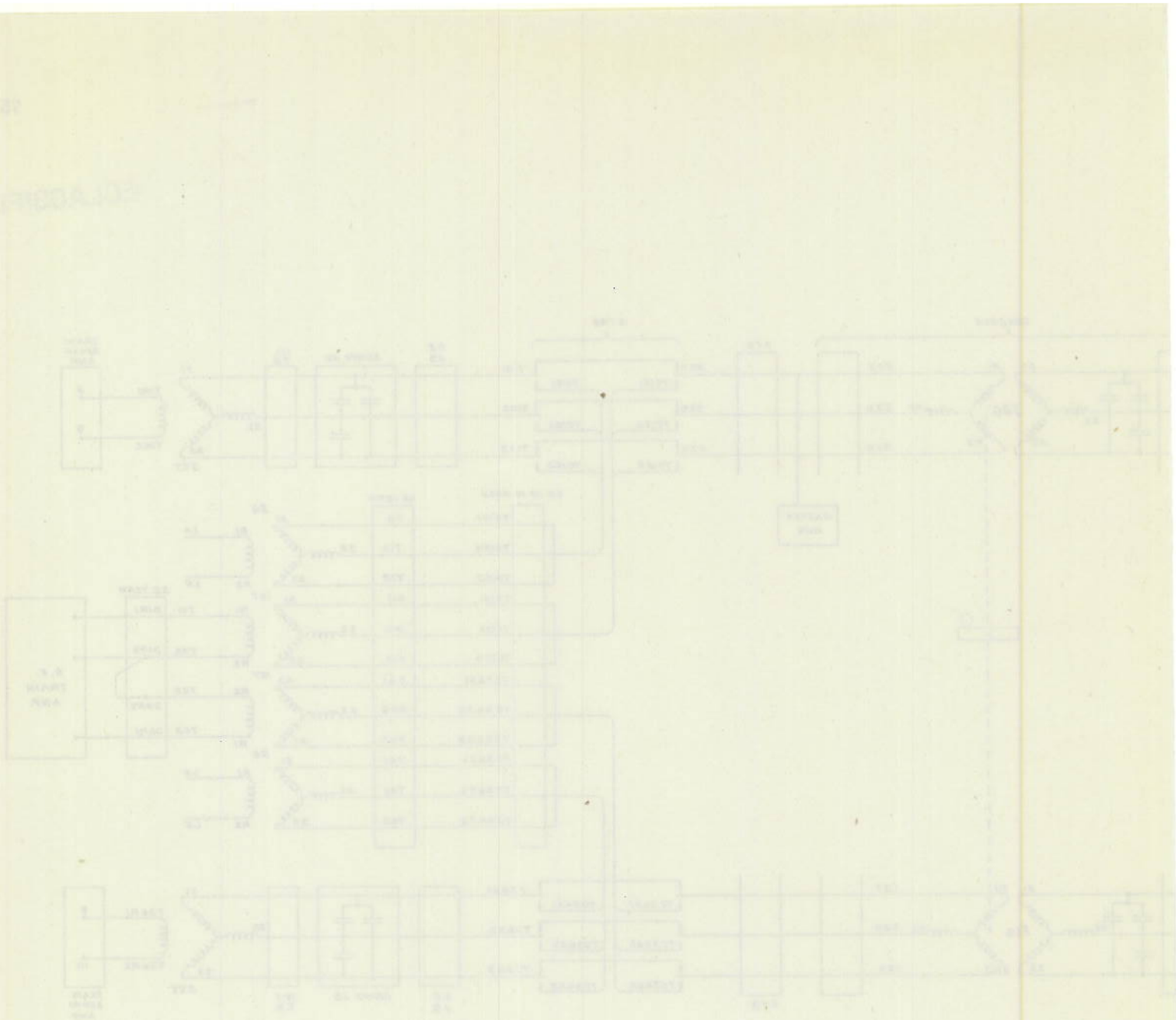


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7 - Transducer train control

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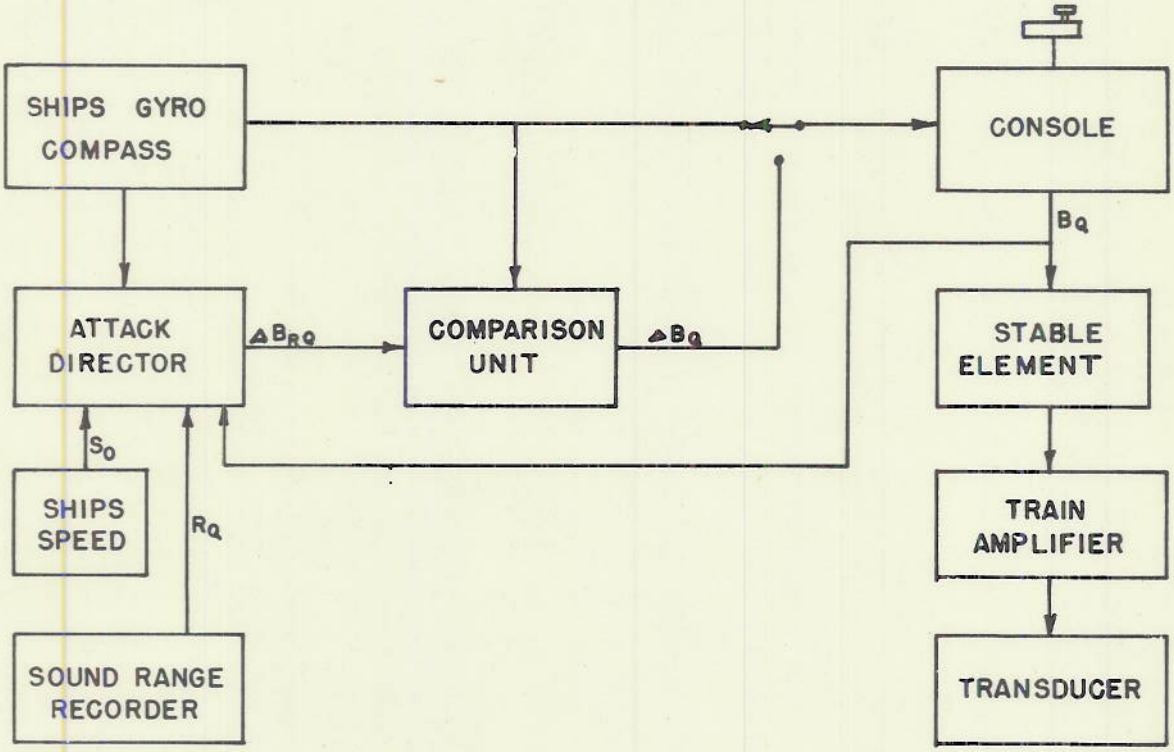
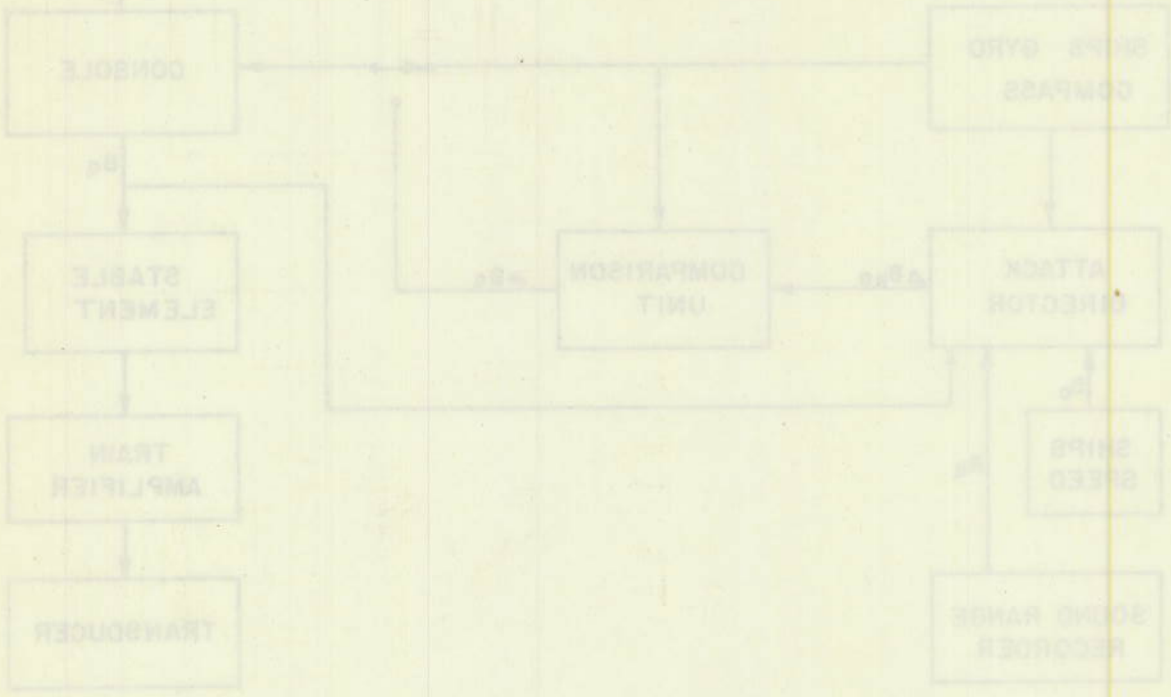



Fig. 68 - Azimuth transducer control system with optional aided tracking

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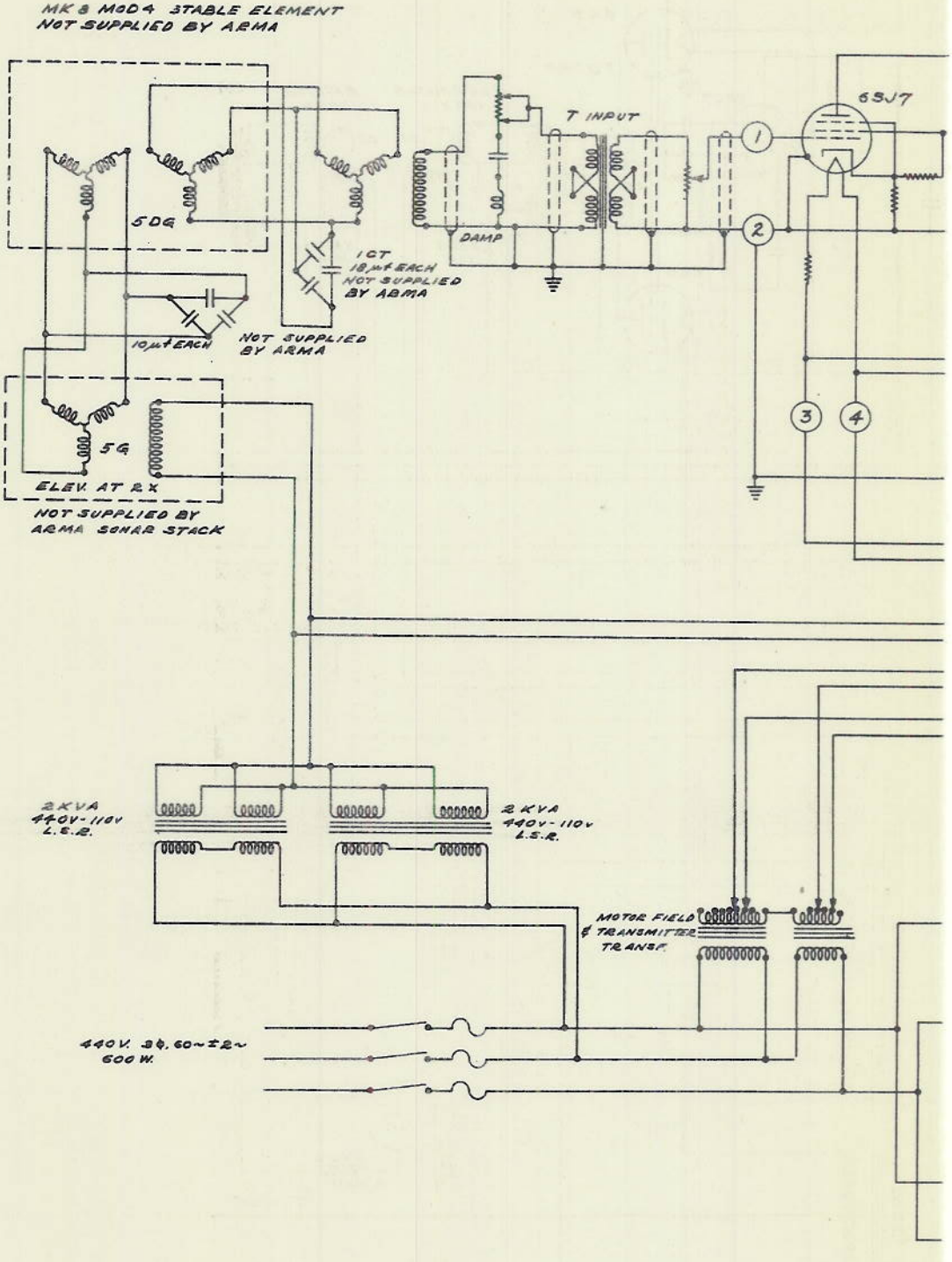
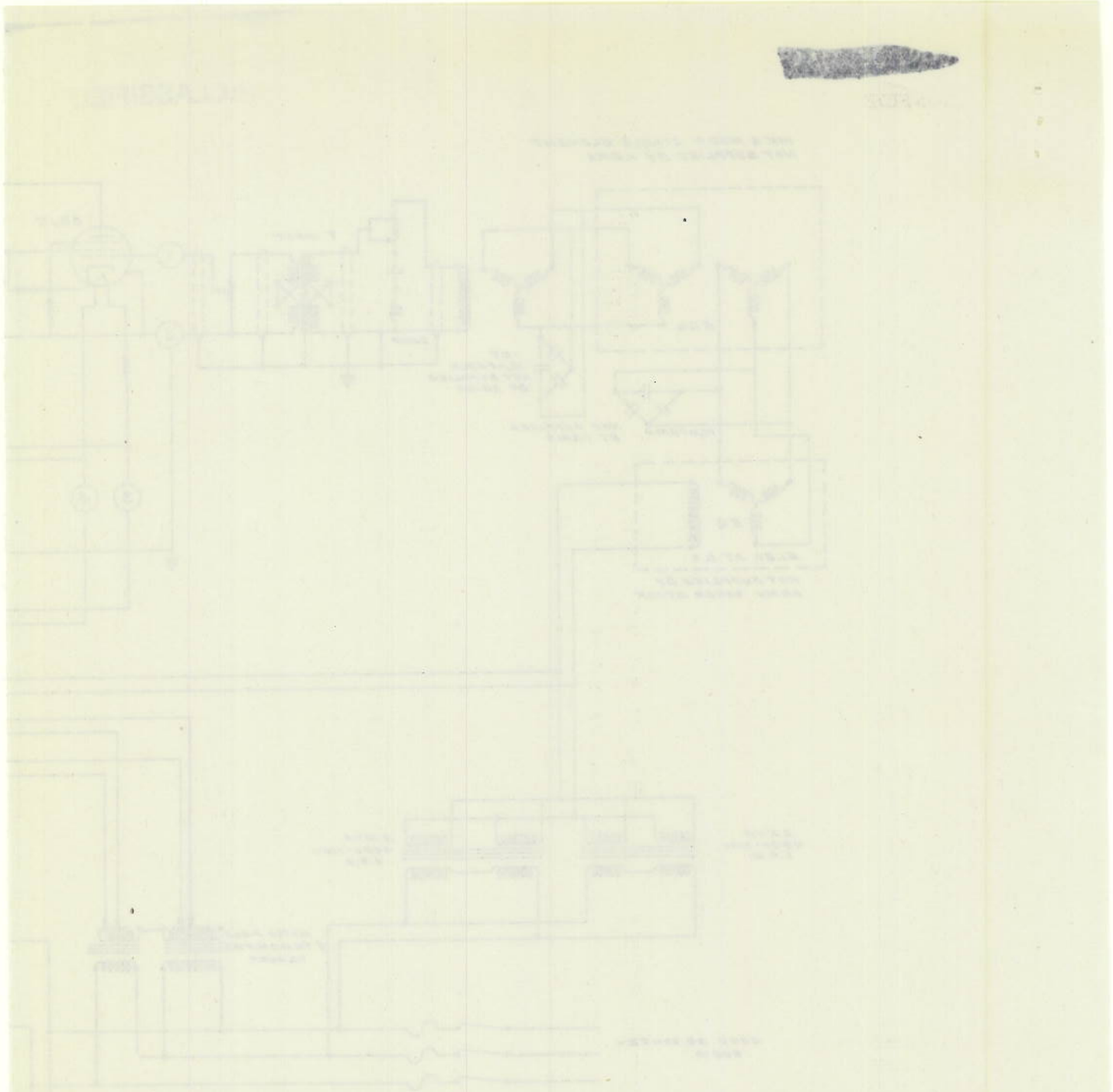
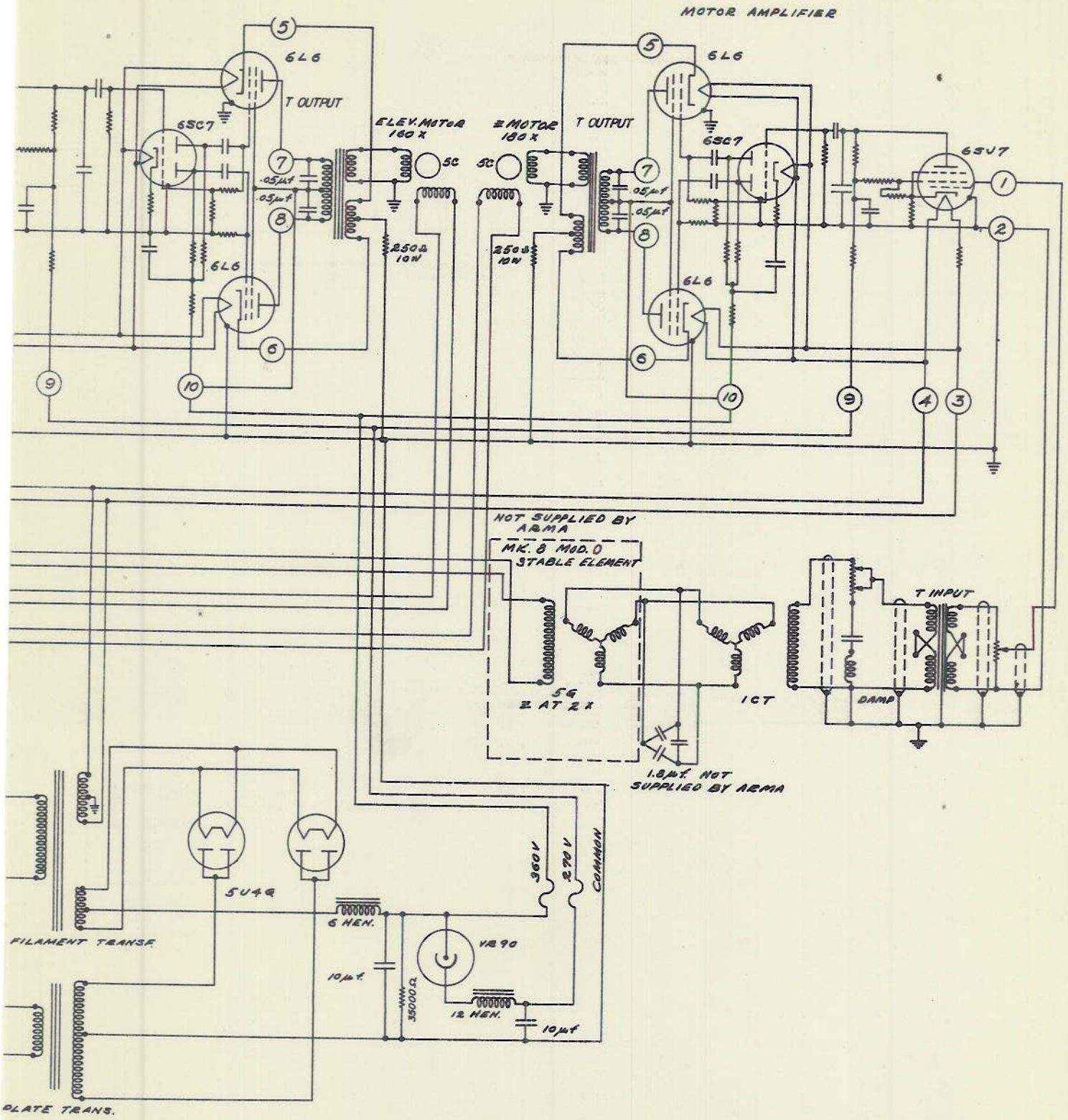



Fig. 69 - Arma level a

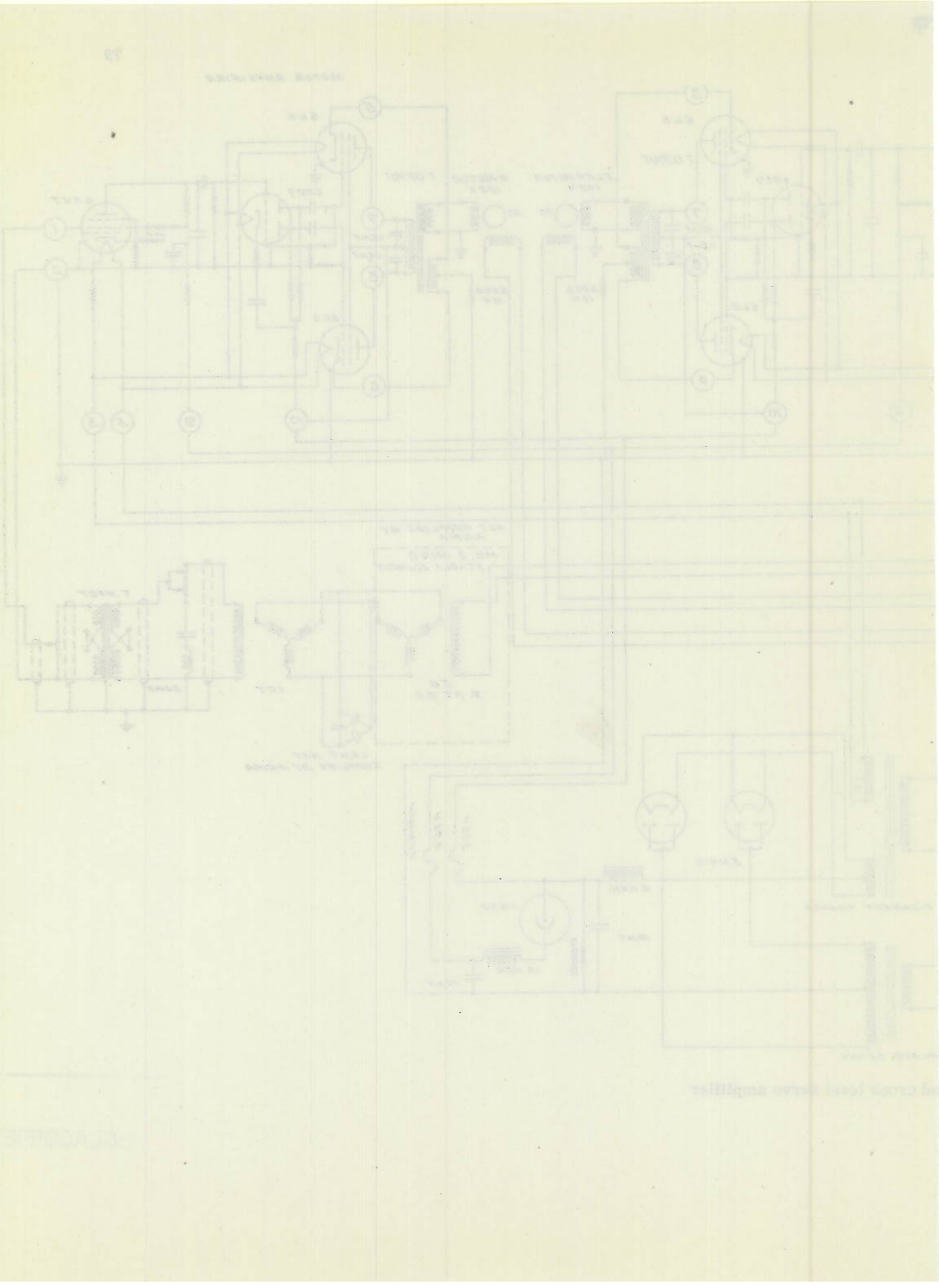
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nd cross level servo amplifier

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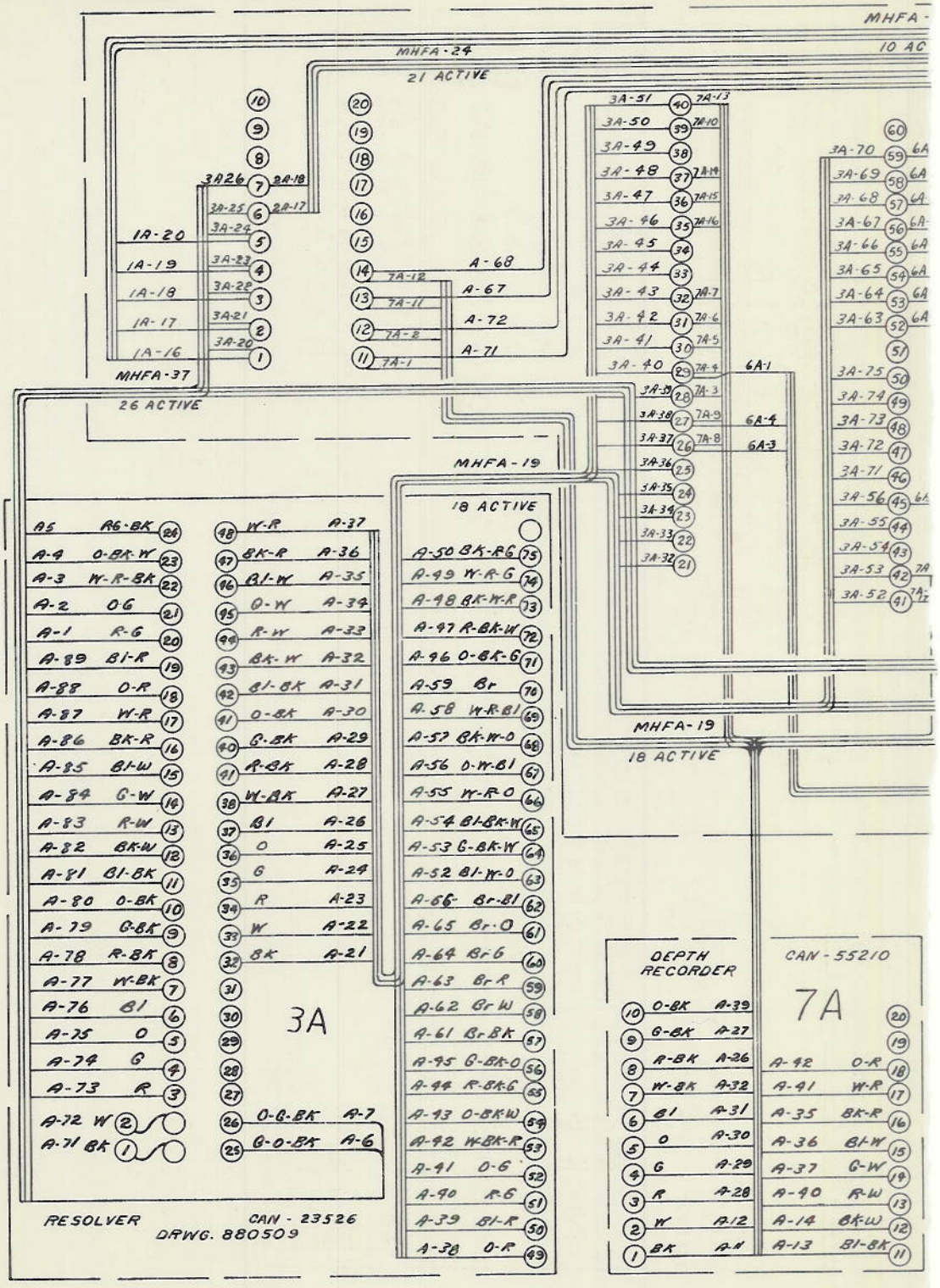
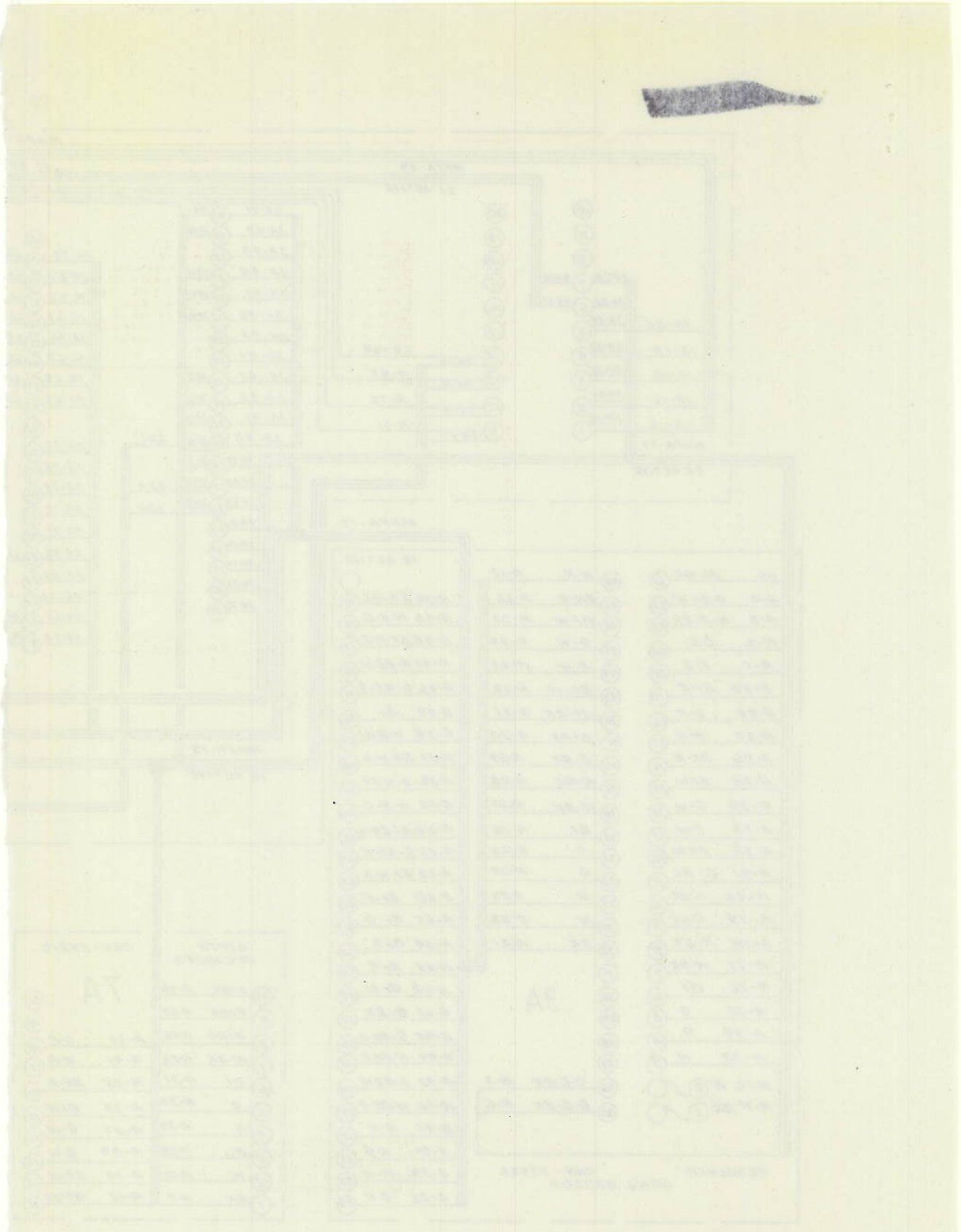


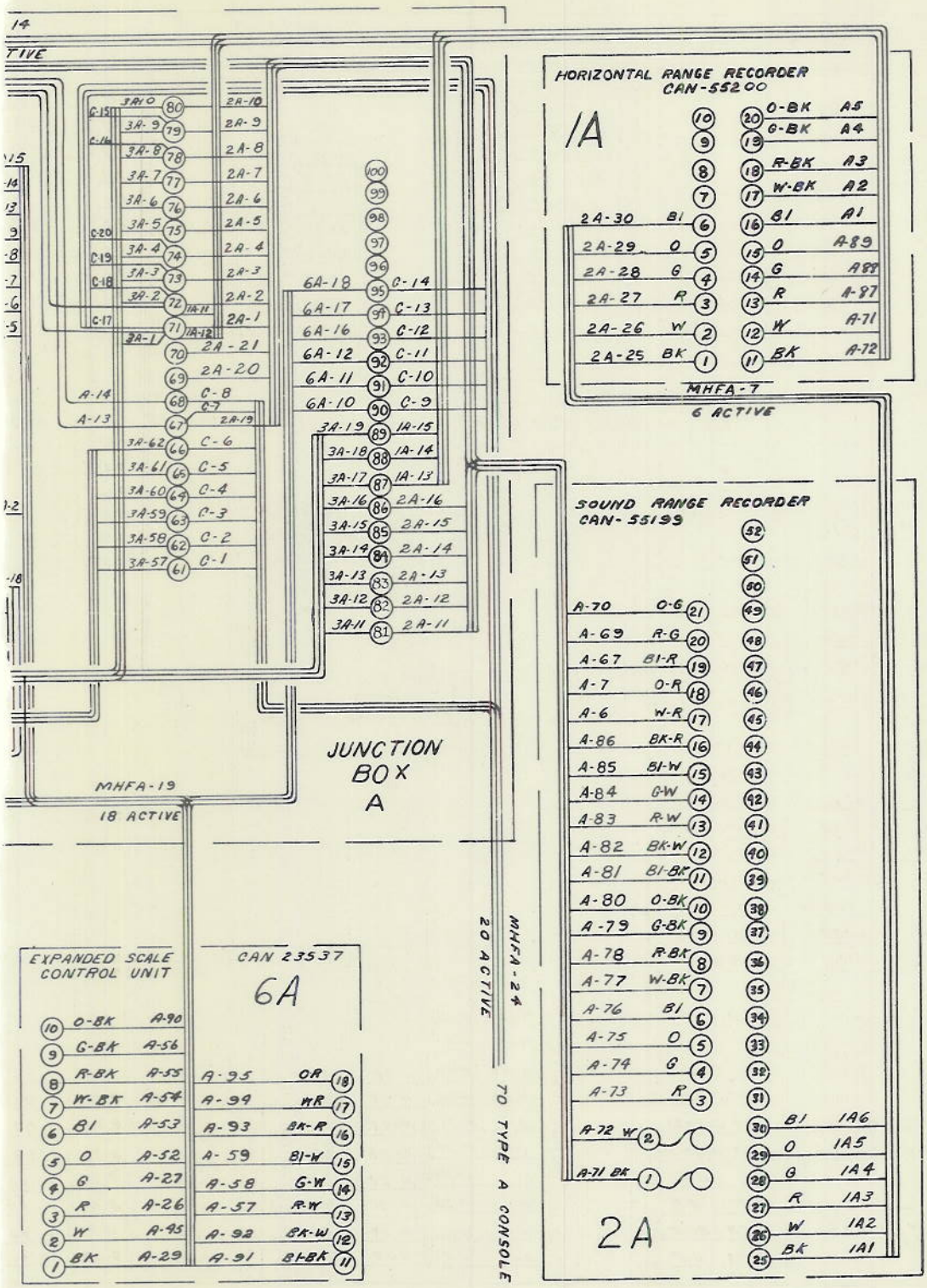

Fig. 70 - Interconnections diagram mo

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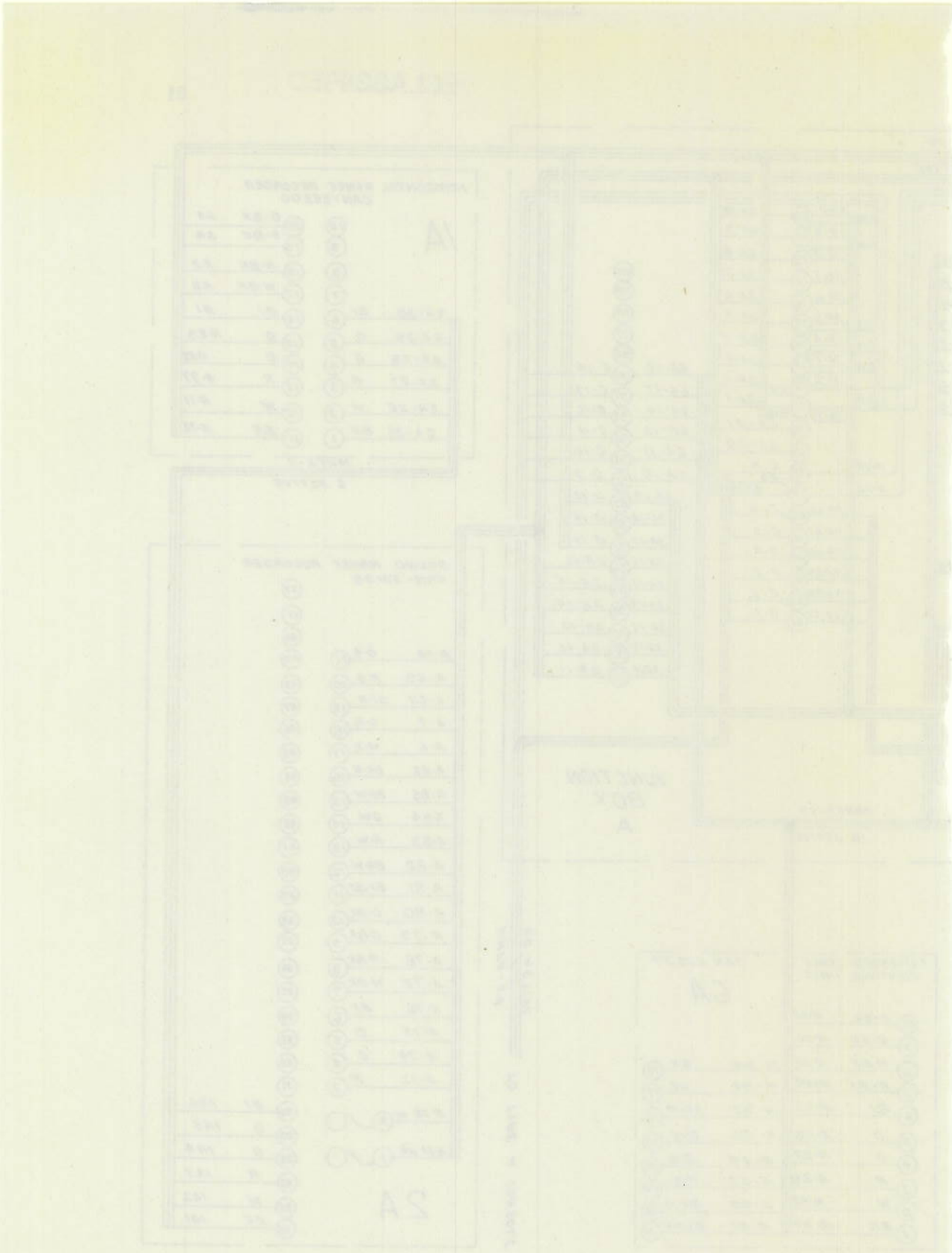
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del OKA sonar resolving equipment

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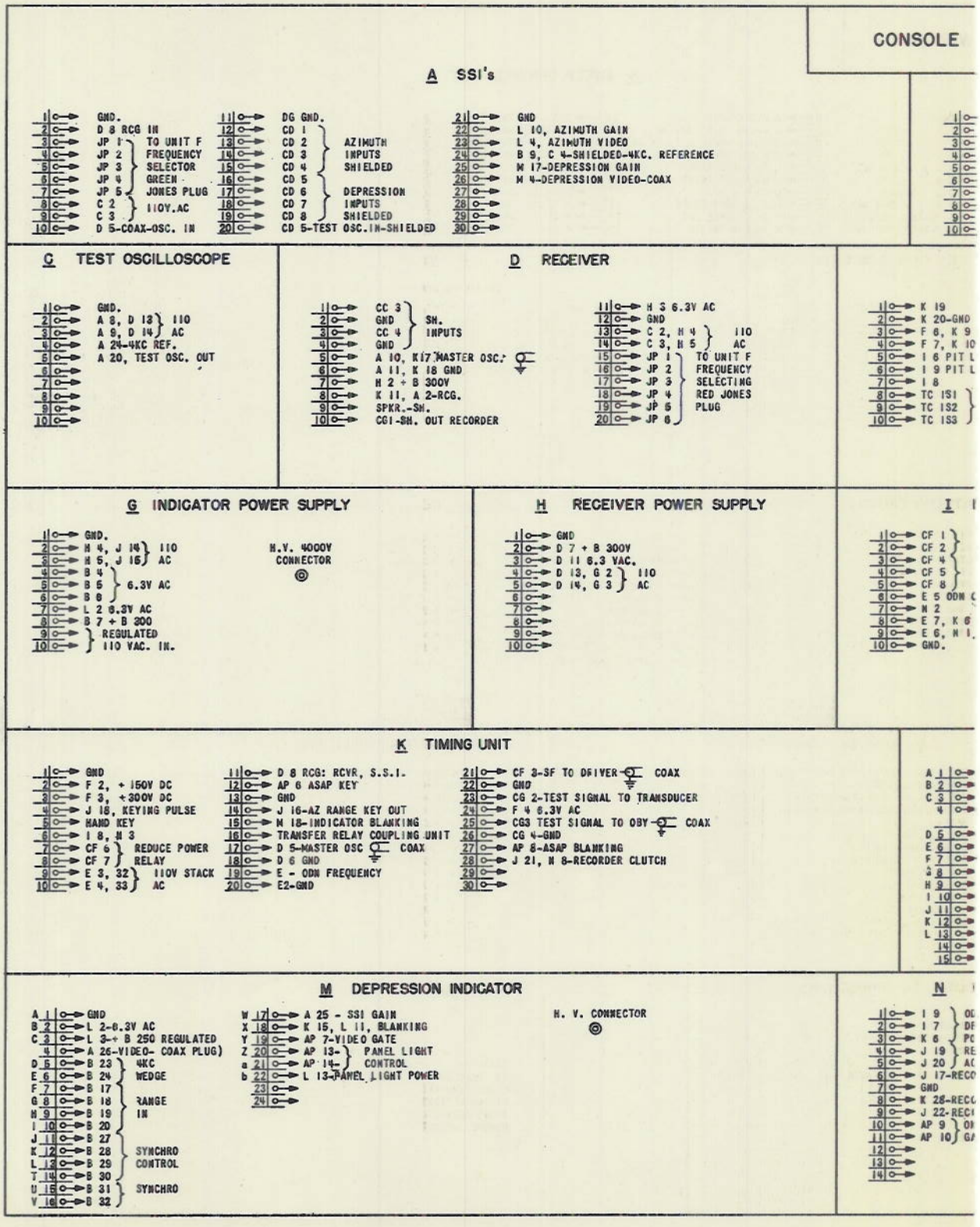



Fig. 71 - Con

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## WIRING

### B SWEEP CONTROL UNIT

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| GND. | | J 6-500~ IN SH. | | L 5 | TWIST AZ | M 15 | TWIST | JP 9 | |
| F 6 | 110V AC | J 4-4KC. S.T. OUT SH | | L 6-GND | 4KC WEDGE | M 16 | DEP. SYNCHRO | JP 10 | |
| F 7 | | J 5-4KC WEDGE S.T. IN SH | | M 5 | TWIST DEP. | J 9 | | L 9-CENTERING | |
| G 4 | | J 8-AZ. RANGE | | M 6-GND | 4KC WEDGE | J 10 | RANGE | AP 4-500~ REF OUT | |
| G 5 | 6.3 U.AC. | L 7- AZ RANGE | | AP 11 | A.P. 4KC | J 11 | SELECTOR | AP 2 500~ RANGE | |
| G 6 | + C.T. | L 8- OUT TWIST | | AP 12-GND | WEDGE | J 12 | | AP 3 WEDGE | |
| G 8 + B 300V | | M 7 | | M 11 | 2-TWIST | J 13 | | AP 14 500 YD | |
| J 3, + B 250V REG | | M 8 DEPRESSION | | M 12 | DEP. | JP 6 | TO UNIT F | PREDICTOR | |
| A 24-4KC. REF. | | M 9 RANGE OUT | | M 13 | SYNCHRO | JP 7 | GREEN JONES | RANGE. | |
| J 7-500~ OUT SH | | M 10 2 TWISTS | | M 14 | CONTROL | JP 8 | PLUG | | |

### E ODN COMPUTER

| | | | |
|---|---|---|---|
| | | | TO UNIT F |
| | JP 7 | RED | |
| | JP 8 | JONES | |
| 110V | JP 9 | PLUG | |
| AC | JP 10 | FREQUENCY | |
| OG SERVO | JP 11 | SELECTING | |
| OG SERVO | | | |
| STATOR | | | |
| 1:1 ORDER | | | |
| TRAIN | | | |

### F TIMING UNIT POWER SUPPLY

SWITCHING SPARES

| | | | |
|---|---|---|---|
| GND | | | |
| K 2 +150 VDC | | JONES PLUG BLUE (1-5) | |
| K 3 +300 VDC | | | |
| K 24 6.3V AC | | | |
| GND | | | |
| B 2, E 3 | 110V | JONES PLUG BLUE (6-10) | |
| B 3, E 4 | AC | | |

JONES PLUGS ON SIDE

| RED | | GREEN | | |
|---|---|---|---|---|
| 1 (D15) | 7 (E11) | 1 (A3) | 6 (B38) | 11 |
| 2 (D16) | 8 (E12) | 2 (A4) | 7 (B39) | 12 |
| 3 (D17) | 9 (E13) | 3 (A5) | 8 (B40) | |
| 4 (D18) | 10 (E14) | 4 (A6) | 9 (B41) | |
| 5 (D19) | 11 (E15) | 5 (A7) | 10 (B42) | |
| 6 (D20) | 12 | | | |

BLUE

| | | |
|---|---|---|
| 1 (F11) | 6 (F16) | 11 |
| 2 (F12) | 7 (F17) | 12 |
| 3 (F13) | 8 (F18) | |
| 4 (F14) | 9 (F19) | |
| 5 (F15) | 10 (F20) | |

### PIT LOG SERVO

| |
|---|
| PIT LOG |
| AC |
| STATOR |
| PIT LOG |
| SYNCHRO |
| COMPUTER |
| ODN |
| DEPRESSION |
| POTENTIOMETER |

### J WEDGE GENERATOR

| | | | | | |
|---|---|---|---|---|---|
| GND. | | B 35 | 3750 YDS | K 28-RECORDER CLUTCH | |
| G 7, L 2 6.3V AC | | B 36 | RANGE SELECTOR | N 9-RECORDER CLUTCH | |
| B 8, L 3 + 250 REG | | B 37 | 6000 YDS RATOR | | |
| B 12, 4KC. S. T. IN | | G 2, 32 | 110V | | |
| B 13, 4KC WEDGE S.T. OUT | | G 3, 33 | STACK AC | | |
| B 11-500~ OUT | | K 14-AZIMUTH RANGE KEY N.O. | | | |
| B 10-500~ IN | | N 6-RECORDER KEYING PULSE IN | | | |
| B 14-AZ.RANGE OUT | | K 4-KEYING PULSE OUT | | | |
| AP 13-PREDICTOR RANGE | | N 4 | RECORDER | | |
| B 33 | 500 YARDS | N 5 | AC | | |
| B 34 | 1500 YARDS | | | | |

### L AZIMUTH INDICATOR

| | |
|---|---|
| GND | |
| J 2, M 2 6.3V AC | |
| J 3, M 3-+ B 250 REGULATED | |
| A 23-VIDEO COAX (COAX PLUG) | |
| API- | |
| B 21 | WEDGE |
| B 22 | 4KC. IN |
| B 15 | AZ. RANGE IN |
| B 16 | TWIST |
| B 43-CENTERING | |
| A 22-SSI GAIN | |
| M 18-BLANKING | |
| AP 7-VIDEO GATE | |
| M 22-PANEL LIGHT POWER | |

H.V. TERMINAL ◎

### AP ATTACK PLOTTER

| | | |
|---|---|---|
| L 4-VIDEO | | |
| B 45 | 500~ RANGE | |
| B 46 | WEDGE | |
| B 44-500~ REF. | | |
| GND. | | |
| K 12-ASAP KEY | | |
| L 12, M 19-VIDEO GATE | | |
| K 27-BLANKING | | |
| M 10 | OKA | |
| M 11 | GATE | |
| B 25 | 4KC | |
| B 26 | WEDGE | |
| J 9-500 YD. PREDICTOR RANGE-M 20 | | |
| B 47-500 YD. PREDICTOR RANGE-M 21 | | |

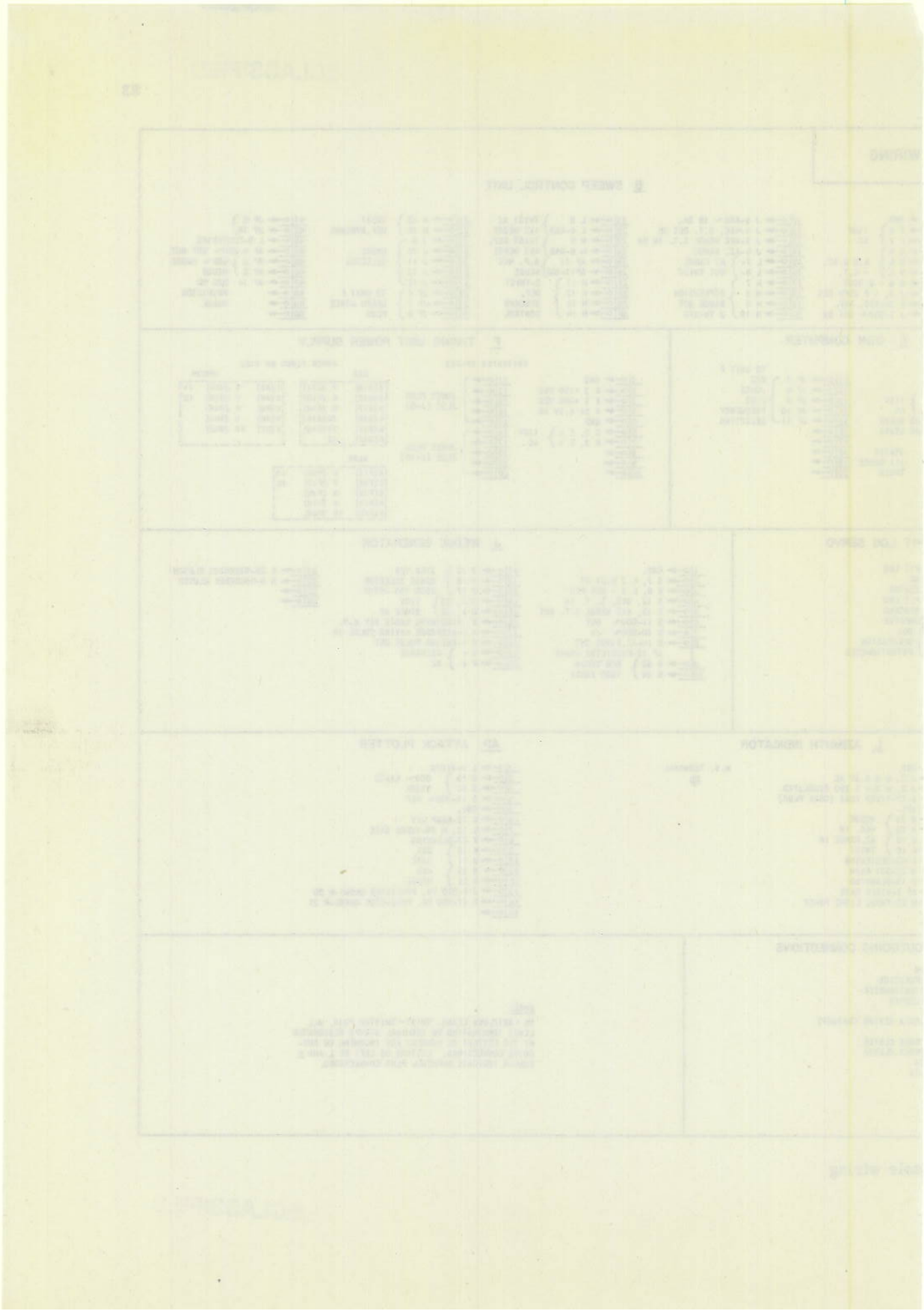
### OUTGOING CONNECTIONS

| |
|---|
| IN |
| EPRESSION |
| TENTIOMETER |
| CORDER |
| |
| RDER KEYING CONTACTS |
| |
| RDER CLUTCH |
| RDER CLUTCH |
| A |
| TE |

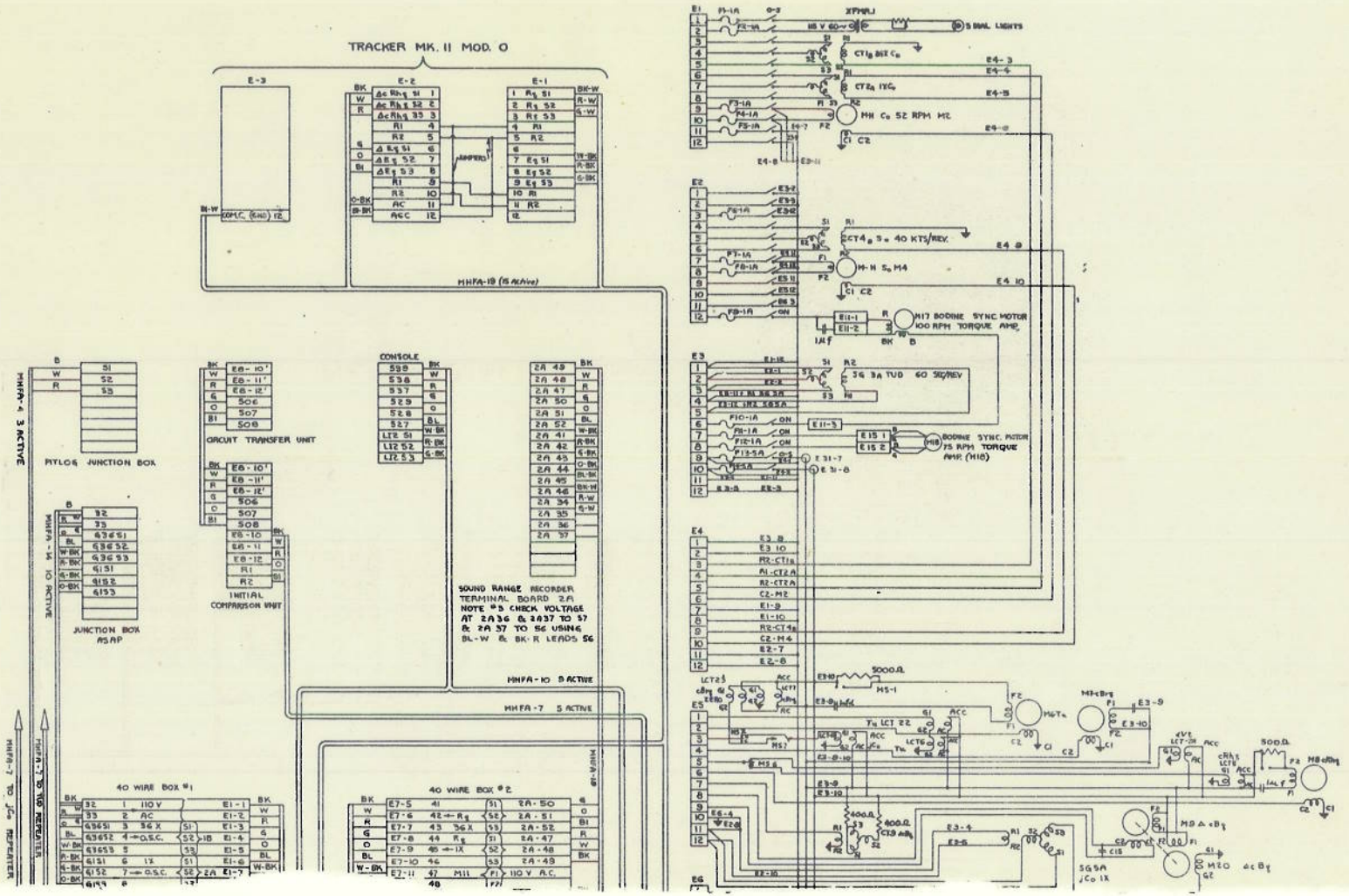
NOTE:
SH = SHIELDED LEADS. TWIST = TWISTED PAIR. ALL LEADS TERMINATING ON TERMINAL STRIPS DESIGNATED BY TWO LETTERS OR NUMBERS ARE INCOMING OR OUTGOING CONNECTIONS. LETTERS ON LEFT OF L AND M BOARDS INDICATE AMPHENOL PLUG CONNECTIONS.

sole wiring

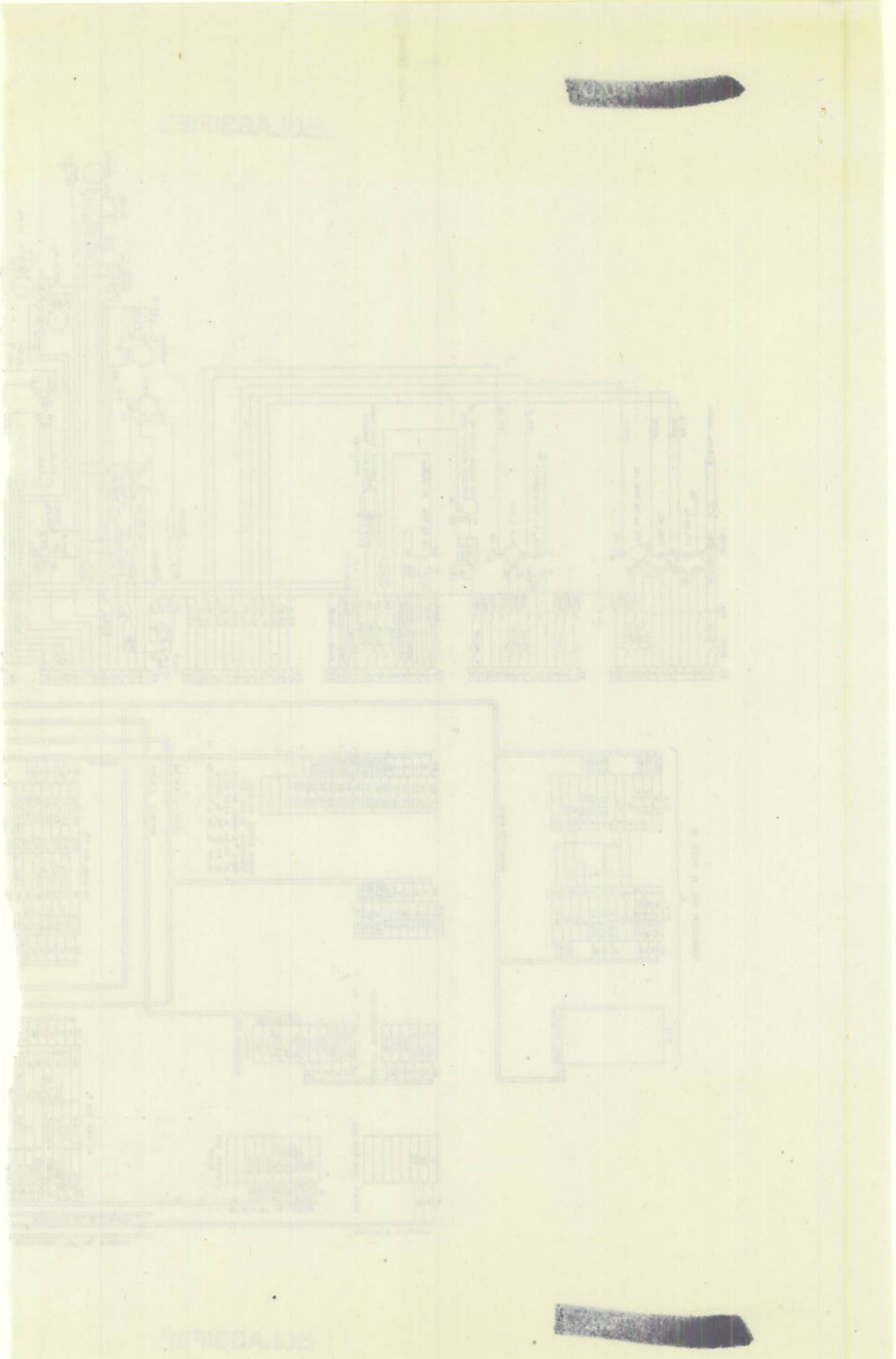
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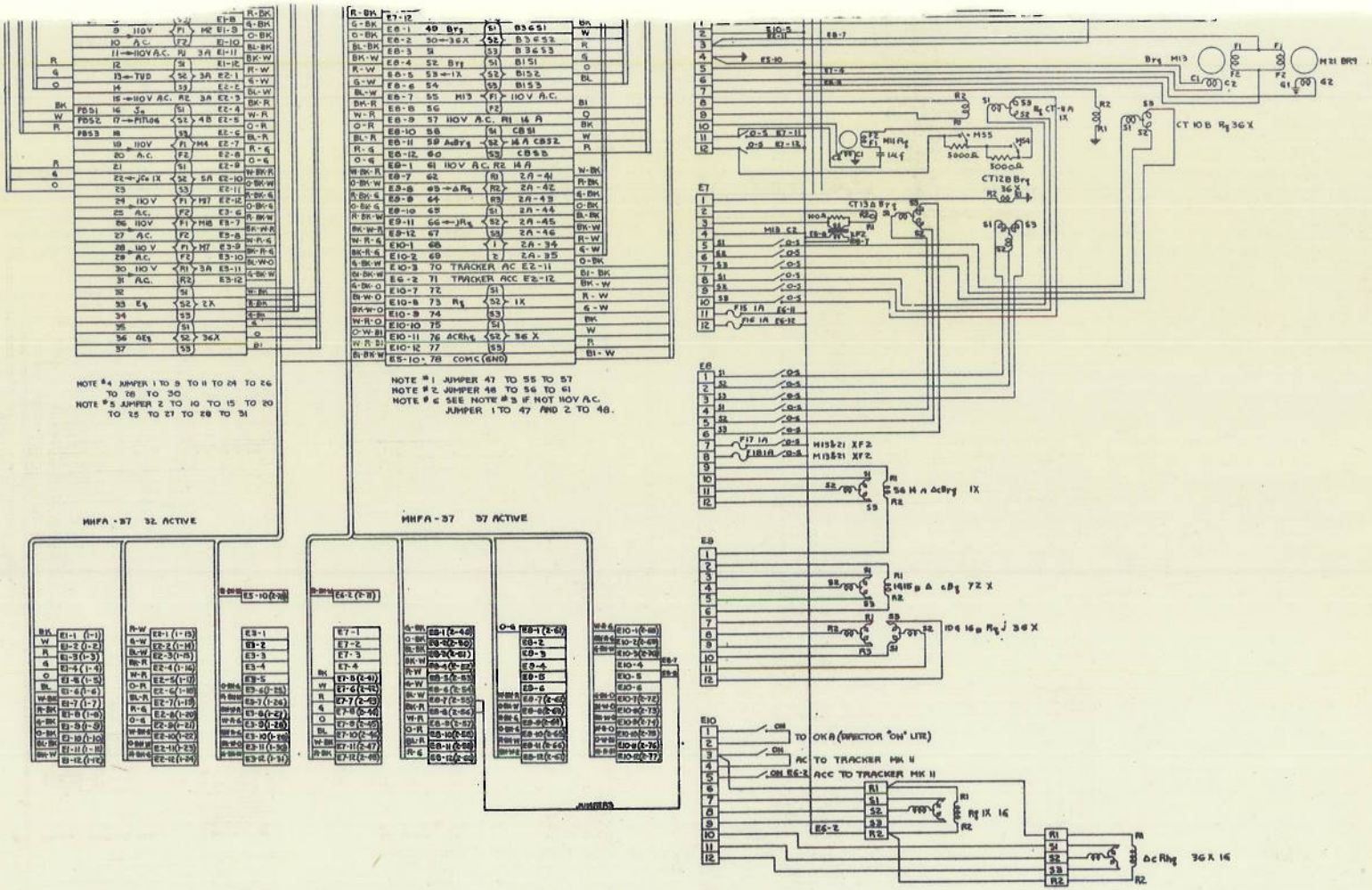
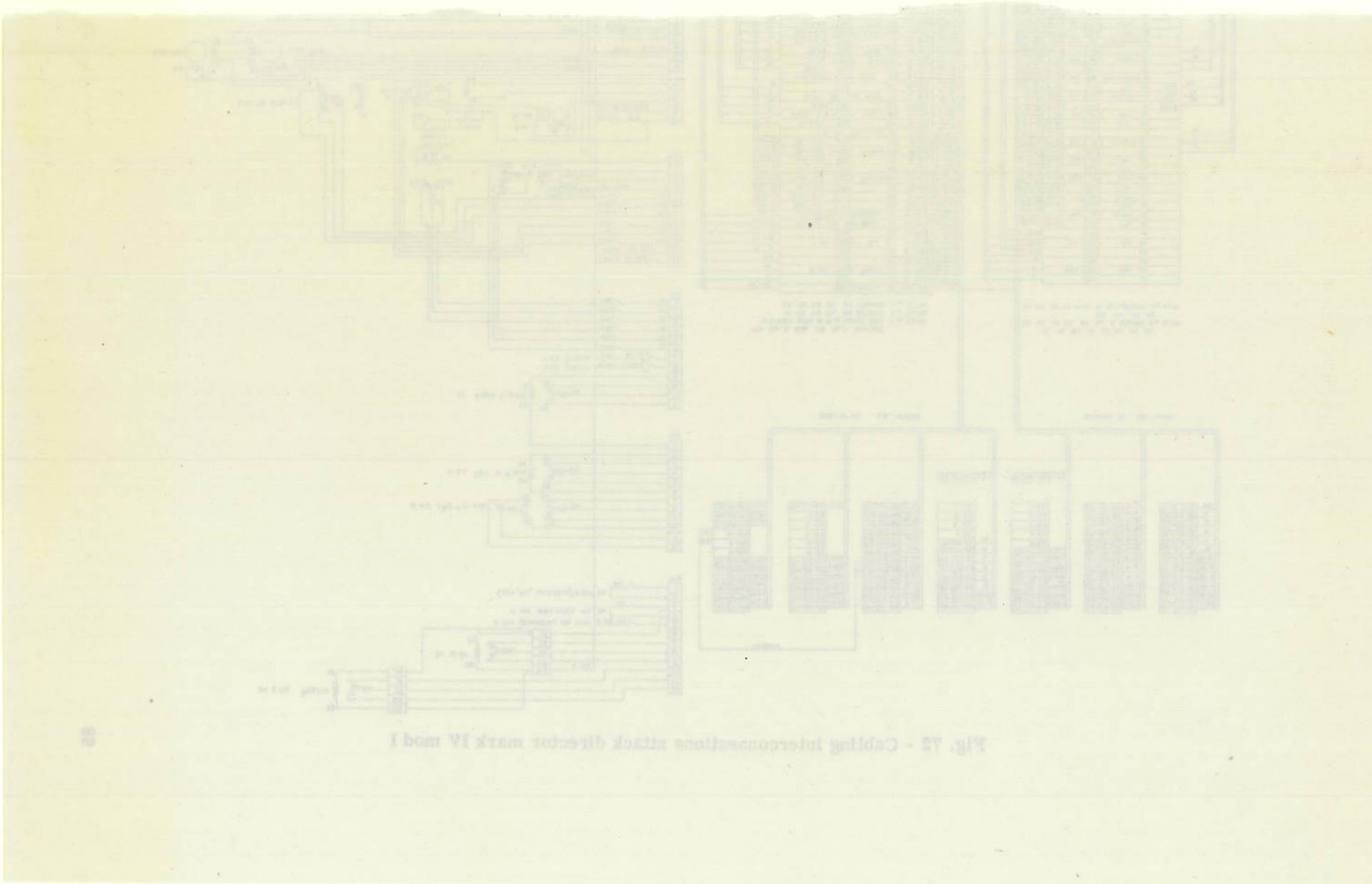


Fig. 72 - Cabling interconnections attack director mark IV mod I



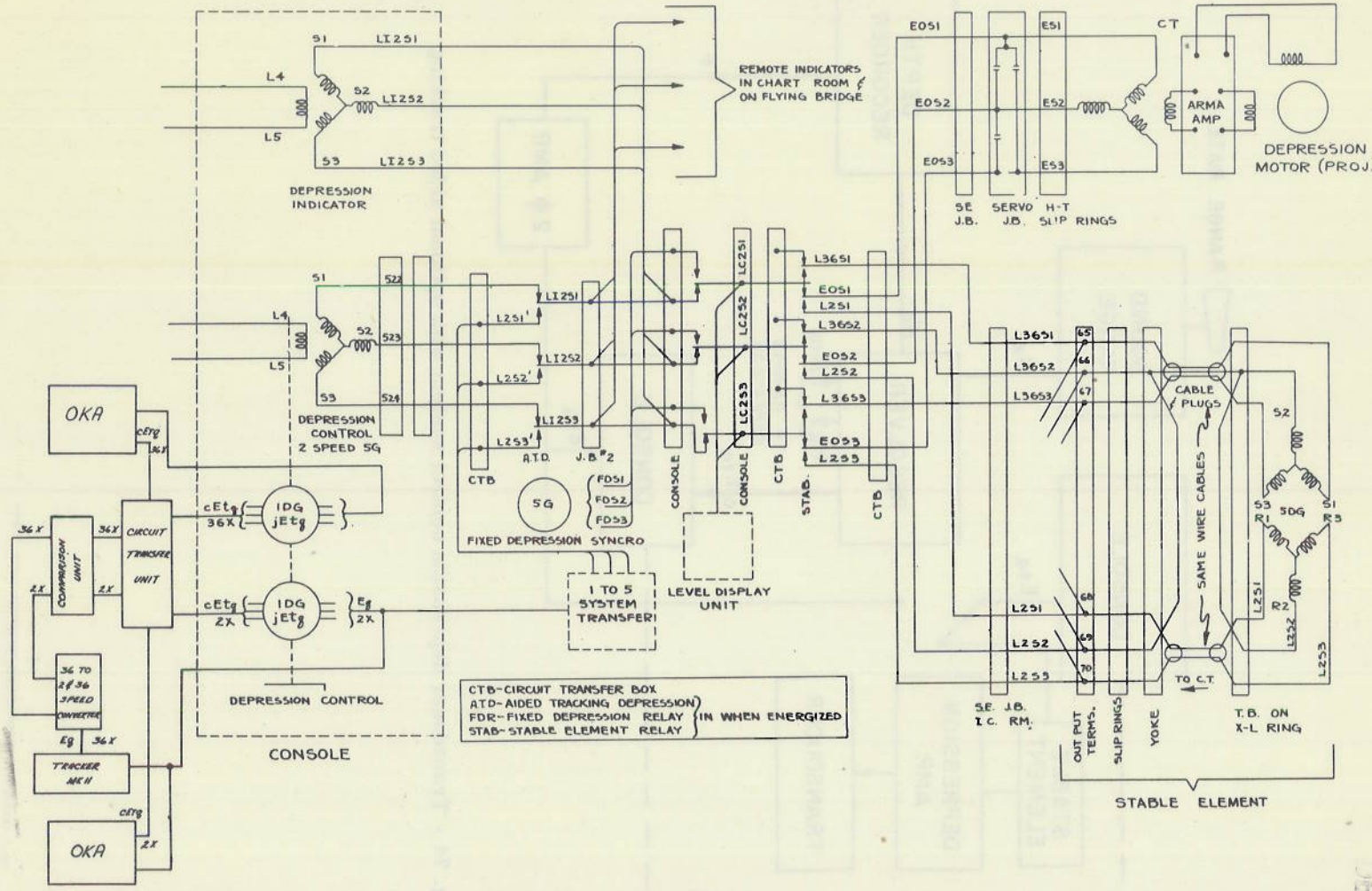



**Fig. 73 - Transducer level stabilization and depression control**

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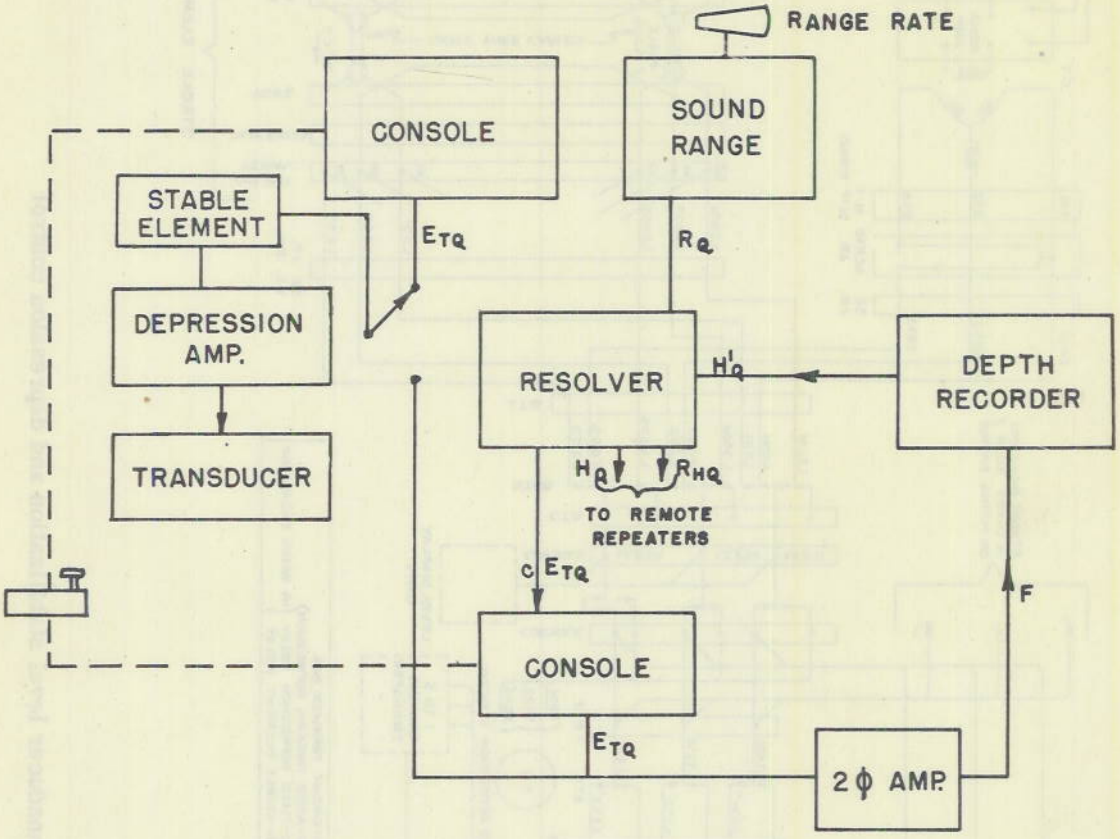



Fig. 74 - Transducer depression control system with optional aided tracking


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