

CHAPTER 12

OPERATING PRINCIPLES OF A REPRESENTATIVE AIR SEARCH RADAR AN/SPS-29 (PART I)

INTRODUCTION

Radar Set AN/SPS-29 comprises a large number of circuits, many of which are conventional and are found in a variety of electronic equipments. Some circuits in the system, such as radar afc, beacon afc, STC, IAGC, and FTC, are peculiar to radar systems only. The circuit operation of a representative type of each of these circuits is explained in the sections on Radar Set AN/SPS-10D in chapters 10 and 11 of this training course. Although minor modifications exist in these circuits between the AN/SPS-10D and AN/SPS-29 and among specific radar systems, the changes do not alter the operation sufficiently to warrant a further circuit consideration here. Only those circuits which are not treated earlier either in this or a previous text are analyzed. All other circuits in each major section of the AN/SPS-29 are explained with the use of block diagrams and simplified schematics.

FUNCTIONAL DESCRIPTION

Radar Set AN/SPS-29 (fig. 12-1A) is a ship-borne air-search system designed to accurately determine the distance and bearing of remote air targets. The radar operates on the principle that a finite time is required for radiofrequency energy to be transmitted to, and reflected from, the target and this finite time is proportional to the straight-line distance to the target.

The frequency coverage of Radar Set AN/SPS-29 is from 215 to 225 megacycles on ten crystal-controlled transmission frequencies. The lowest of the ten frequencies is centered at 215.5 mc. The center frequency of the remaining 9 frequencies is separated 1 megacycle progressively from 216.5 mc to 224.5 mc. The pulse recurrence rate is approximately 300 pulses per second.

The purpose of each unit of the AN/SPS-29 (as shown in fig. 12-1A) is as follows: The radiofrequency energy is produced in a transmitter group, which is essentially a master-oscillator power amplifier type transmitter.

In some radar transmitters, as in the case of Radar Set AN/SPS-10D described in chapters 10 and 11, the radar r-f output pulse is generated by keying a magnetron. The magnetron feeds its output radiofrequency through a waveguide to the antenna.

The r-f pulse for Radar Set AN/SPS-29 is initiated as a low power r-f signal in a conventional crystal-controlled oscillator, then mixed with a second crystal oscillator output to produce a sum frequency r-f output. The oscillators operate continuously. The oscillator output is fed to keyed frequency multipliers which produce r-f pulses of energy at the keyed rate and within the operating frequency range of the radar. The r-f signal pulses are amplified to the required power level of the radar set.

High amplitude modulating pulses are applied to the plates (and/or screens) of the final amplifier stages of the radar transmitter coincidentally with the application of the r-f energy pulses to the grids. The modulation pulses cause the production of a transmitter r-f output which is low in harmonic content and thus causes a minimum of interference with other shipboard equipments. The output r-f power is fed to an array of dipole antennas.

The transmitter group of the AN/SPS-29 is composed of an amplifier oscillator (with self-contained power supply) a radio-frequency amplifier, and a modulator-power supply. The amplifier-oscillator develops the radar r-f pulse at the selected frequency. This unit also provides the local oscillator signal for the radar receiver during the receiving interval. The action is considered in chapter 13 of this text.

The radio-frequency amplifier ① raises the level of the amplifier-oscillator signal, and

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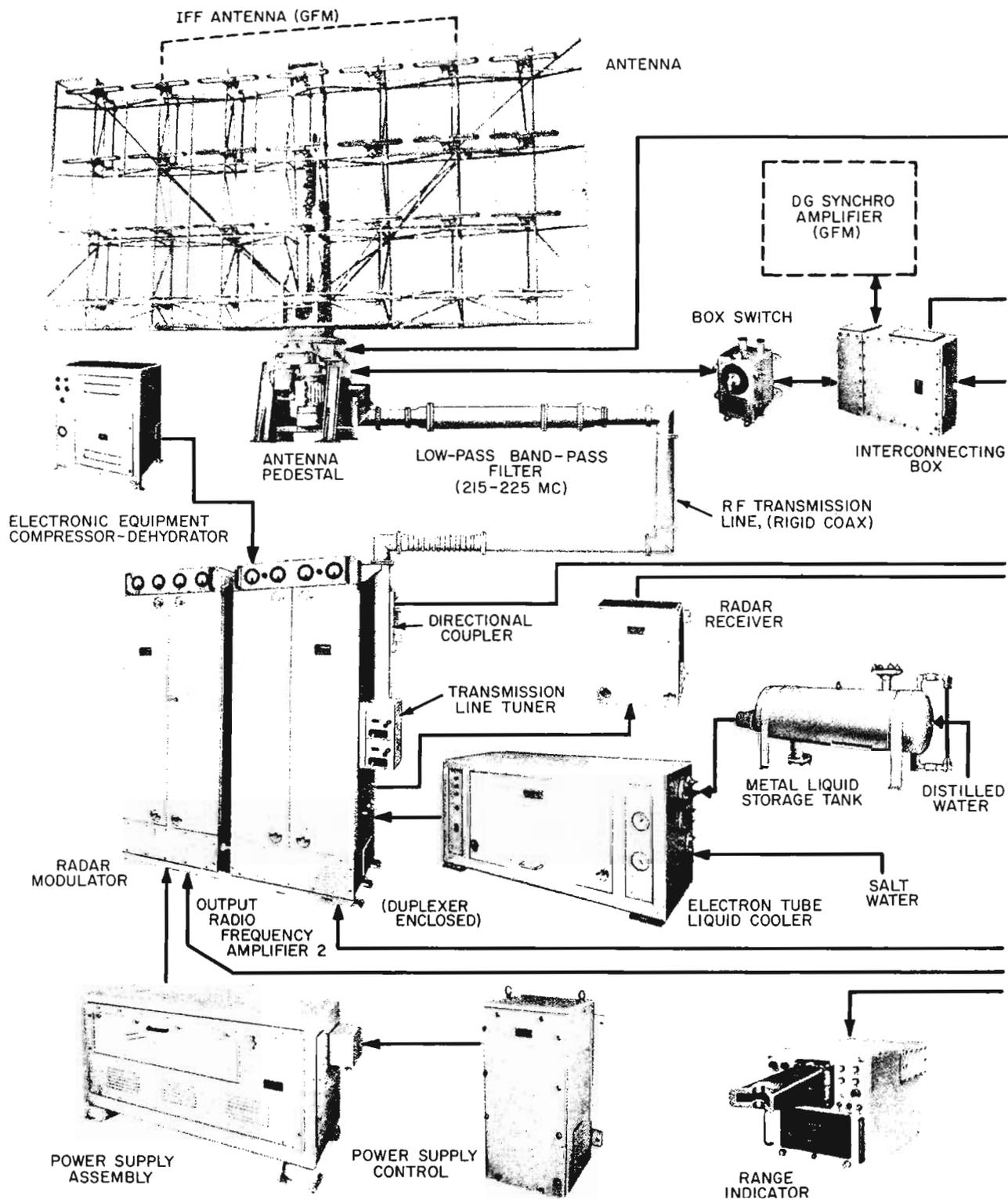


Figure 12-1, A.—Radar Set AN/SPS-29, Component Parts.

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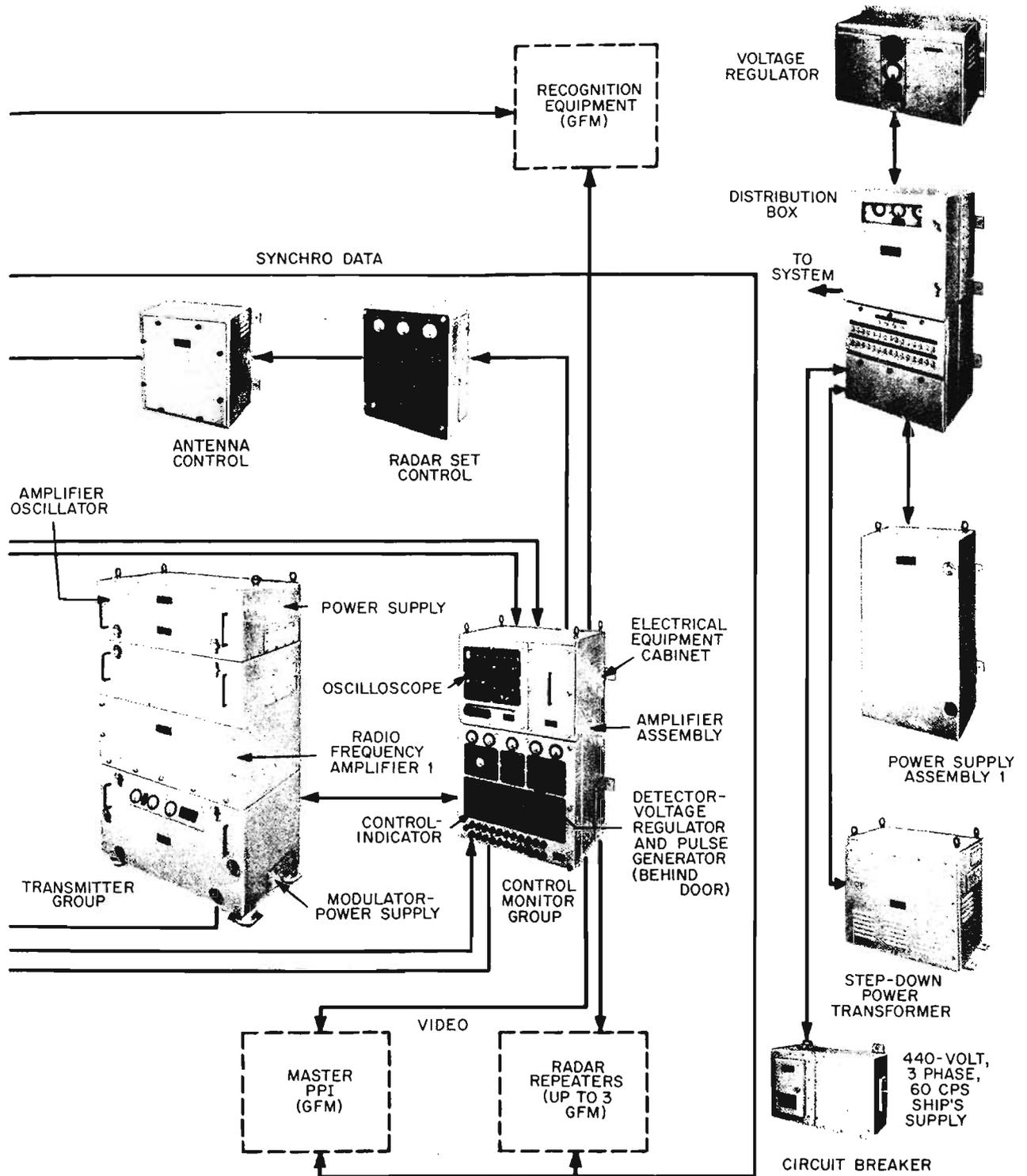
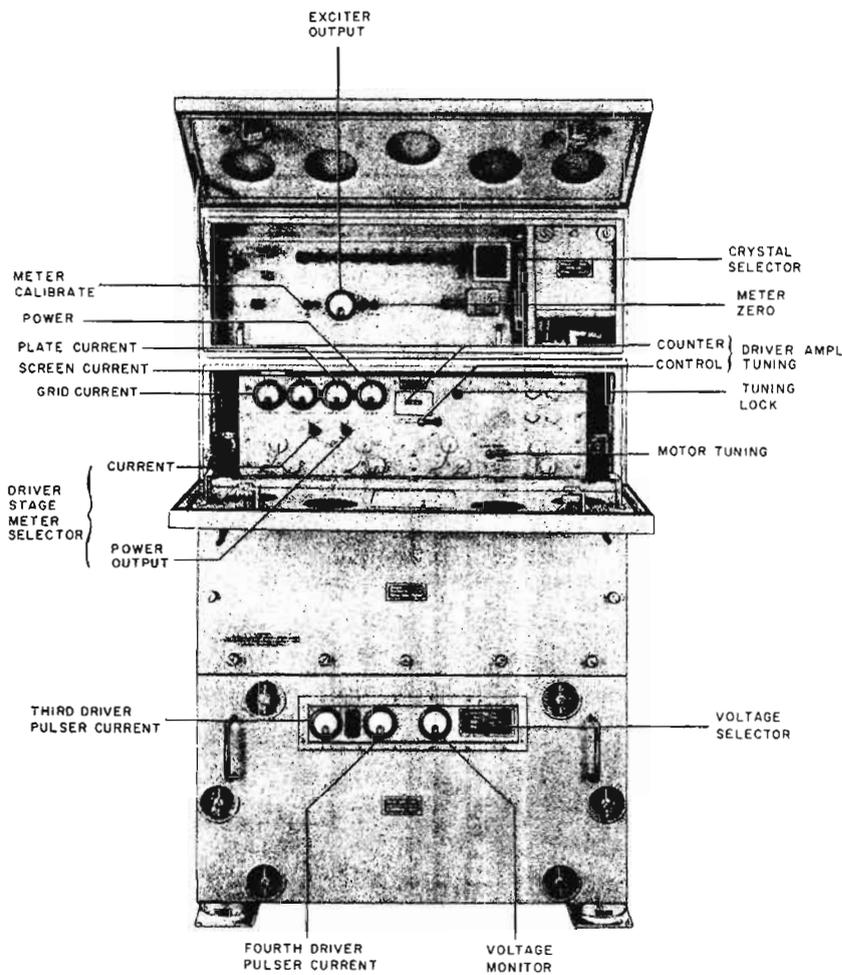
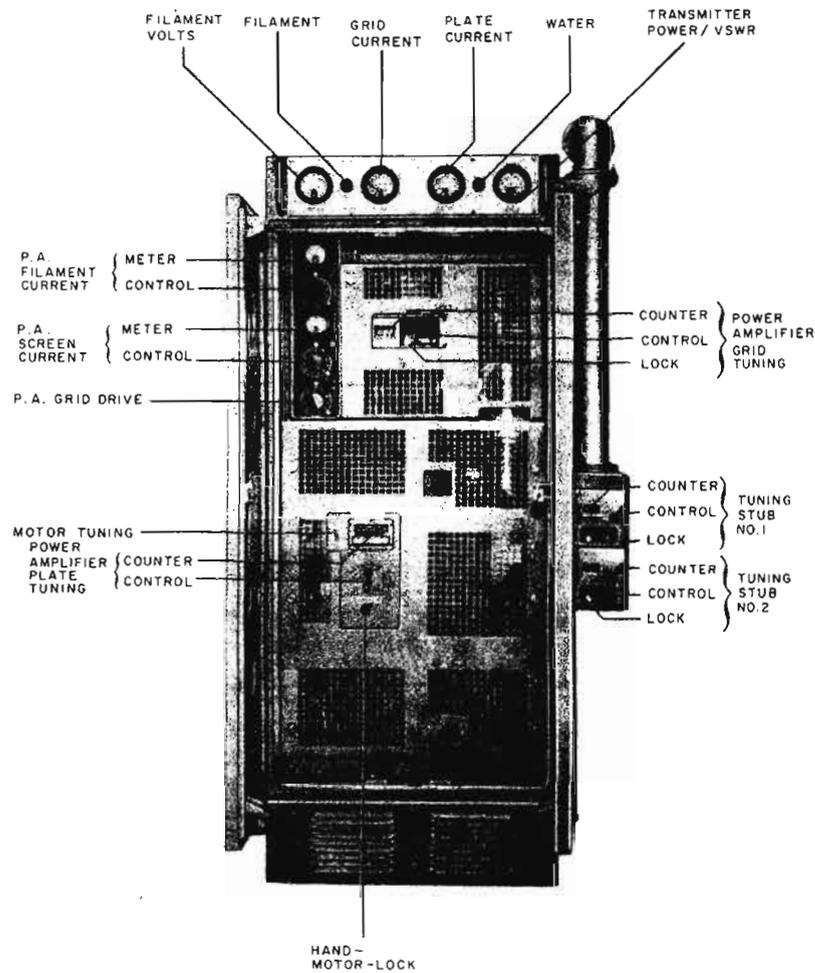


Figure 12-1, A.—Radar Set AN/SPS-29, continued.



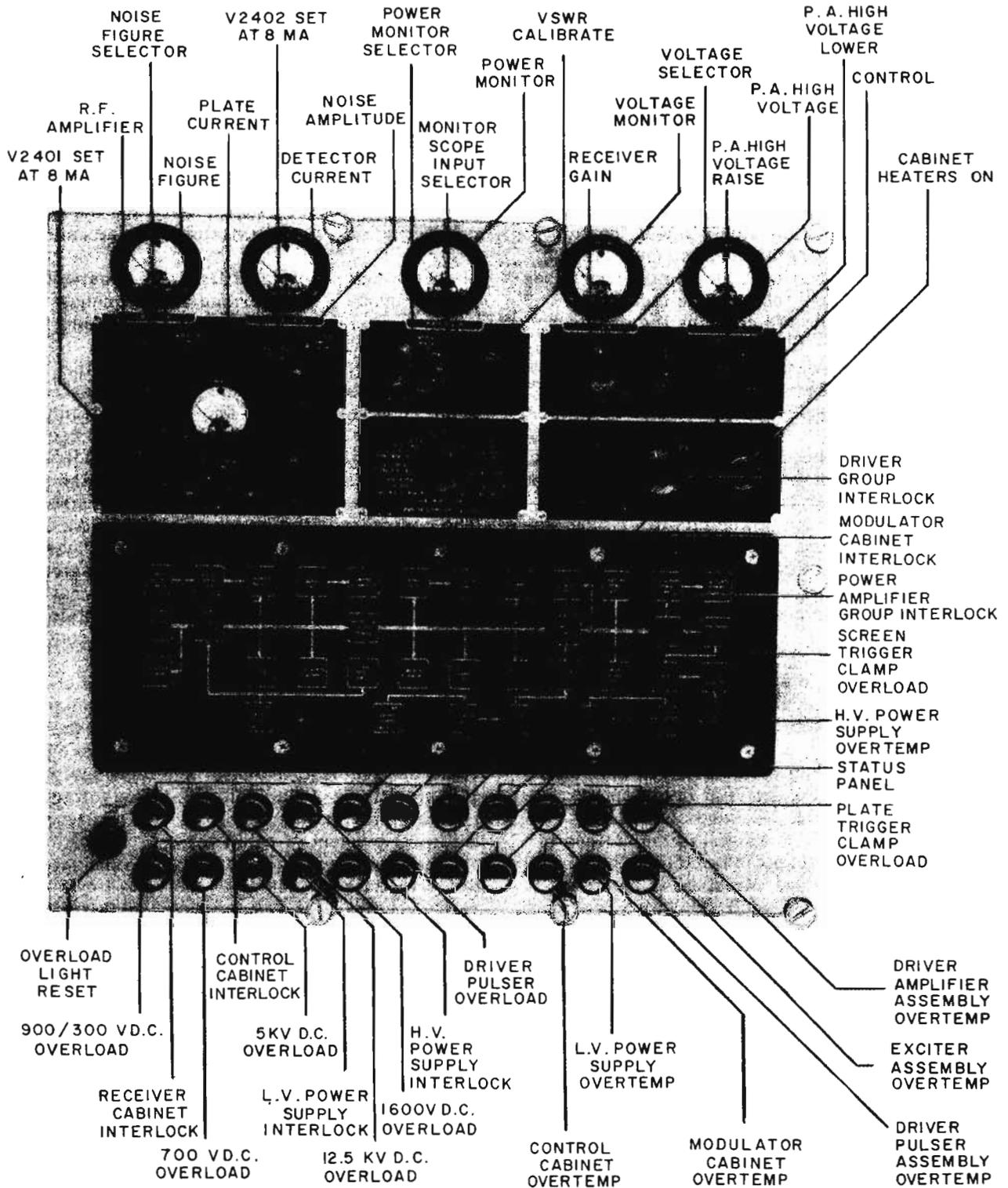
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Figure 12-1, B.—Transmitter Group of Radar Set AN/SPS-29.



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Figure 12-1, C.—Radio Frequency Amplifier of Radar Set AN/SPS-29.



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Figure 12-1, D.—Control Indicator of Radar Set AN/SPS-29.

furnishes driving power for radio-frequency amplifier ②. The latter unit is referred to as the output radio-frequency amplifier in chapters 12 and 13 of this text.

The modulator power supply of the transmitter group provides separate high voltage modulating pulses for application to the driver stages in the radio-frequency amplifier. The radar modulator develops two high voltage pulses for application to the plates and screens of the final power amplifier stage in the output radio-frequency amplifier (discussed later).

The output radio-frequency amplifier houses the power amplifier tube and its associated tuning cavities. It also contains the duplexer which permits the propagation system to be used for both transmission and reception. The output radio-frequency amplifier produces radio-frequency pulses of 750 kilowatts nominal peak power.

An electron tube liquid cooler maintains the temperature of the power amplifier stage within safe limits. Water passes through integral coolant jackets of the power amplifier tube elements. The cooling water is fed through a distribution system containing flow and temperature interlocks to a heat exchanger, and is then recirculated. The metal liquid storage tank serves as a coolant storage tank and buffer to minimize liquid surging under conditions of pitch and roll of the ship.

The electronic equipment compressor-dehydrator is used to pressurize and dehumidify the plate cavity of the power amplifier, and the radar transmission line between the power amplifier and the rotary joint in the antenna pedestal. A nominal pressure of 30 PSIG (pounds per square in. gauge) is maintained in the plate cavity and approximately 5 PSIG in the transmission line. Moisture is removed by passing the compressed air over a desiccant.

The directional coupler samples the incident and reflected power in the transmission line and feeds this sample to the control monitor group. An associated meter indicates the standing wave ratio. A transmission line tuner minimizes voltage standing wave ratio caused by impedance mismatches of the transmission line elements and the transmission line terminations. The tuner includes an adjustment for the transmission line length for the various operating frequencies of the radar set.

The antenna unit is a multielement array of folded dipoles arranged and phased to produce the desired pattern. Provisions are made for mounting a Navy type IFF antenna in a position above the radar reflector.

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The antenna pedestal provides a means of supporting and rotating the antenna at fixed speeds of 7.5 and 15 rpm. A dual coaxial rotary joint for coupling the radar and IFF signal energy to the antenna, and a synchro for transmitting single-speed bearing data, are mounted in the antenna pedestal. The antenna pedestal is also equipped with an electrical brake for remotely securing the antenna. Other components associated with the antenna are the interconnecting box, the box switch, and the antenna control.

The radar receiver utilizes the received echo to produce an intermediate frequency which is applied to the amplifier assembly in the control monitor group.

The control monitor group contains the amplifier assembly, pulse generator, oscilloscope, control indicator and electrical equipment cabinet. This unit produces the range video which is displayed on the range indicator. In addition, the video signal can be applied to as many as four PPI-type indicators as desired. The control monitoring group also acts as a local control station, provides timing triggers for the radar system and serves as a centralized monitoring point, indicating the operational status of most subassemblies in the system. The radar set control provides remote control and monitoring of the radar set.

A circuit breaker, distribution box, step-down transformer and voltage regulator control the ON-OFF condition and regulation of the a-c input power. The step-down transformer converts the 440-volt, 3-phase, a-c input into two 115-volt single-phase voltages. The voltage regulator maintains one of the 115-volt inputs within ± 1 percent of rated voltage.

The power supply assembly ① furnishes d-c potentials of +230 and +300 volts for the radar receiver. It also provides +300 volts, +700 volts, and -150 volts d-c for stages in the transmitter group, and 28 volts d-c for the tuning motors in the radio-frequency amplifier and output radio-frequency amplifier and various relays distributed throughout the system.

Power supply assembly ② produces potentials of 5.0 kv and 12.5 kv for the power amplifier screen and plate pulser circuits, respectively.

BLOCK DIAGRAM

Radar Set AN/SPS-29 ② is composed of seven sections (fig. 12-2). These sections are referred to as trigger generating, modulating, transmitting, receiving, ranging, monitoring,

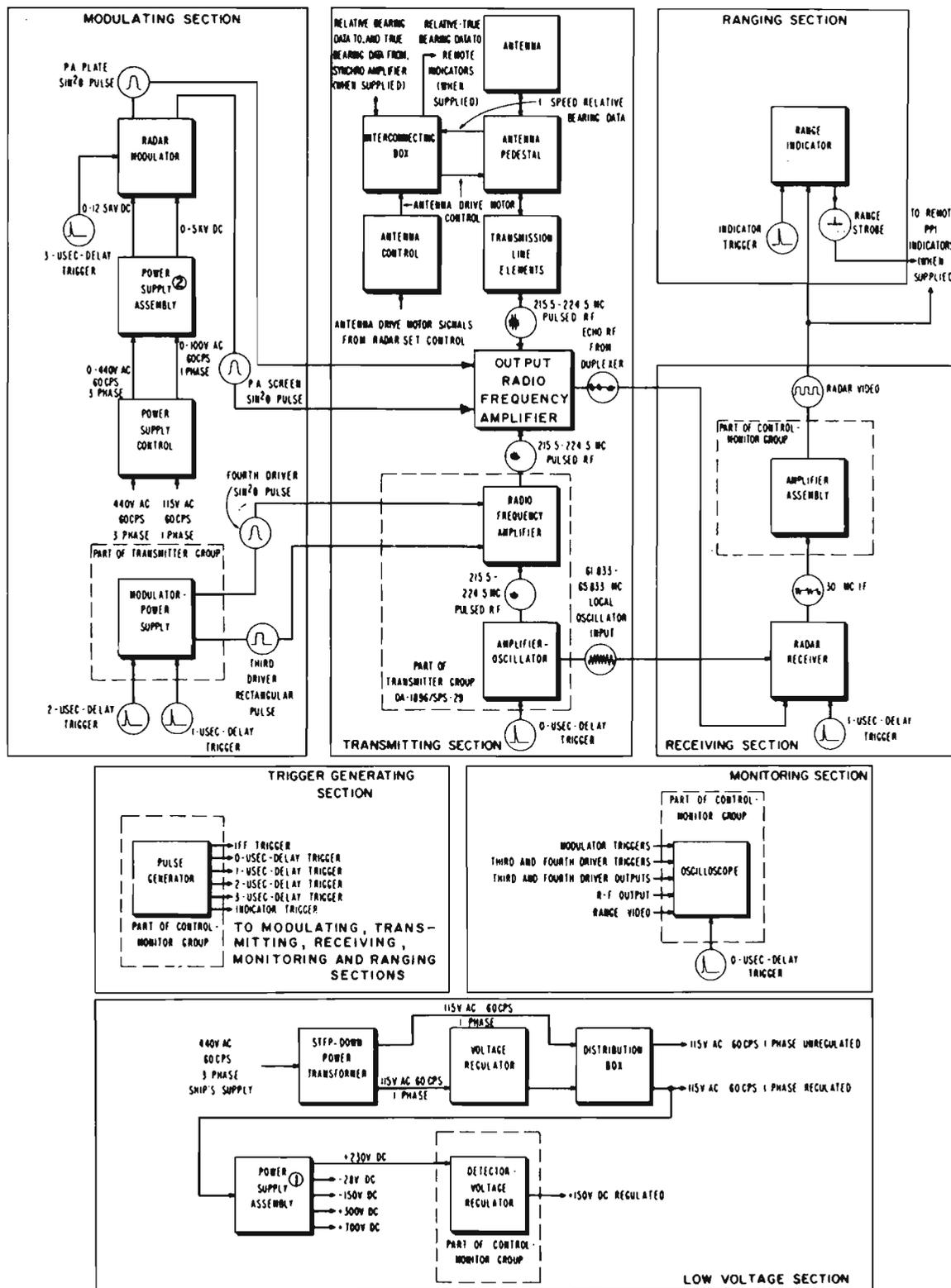


Figure 12-2.—Radar Set AN/SPS-29 Simplified Block Diagram.

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and low voltage. The waveforms produced by each of the sections and their effects on other sections of the radar system are briefly treated below. A detailed description of each of the sections is given later.

The trigger generating section serves as a centralized source of synchronizing triggers. The trigger generating circuits are contained in the pulse generator. The unit supplies an IFF trigger for the radar recognition equipment, and a variable delayed series of five timing triggers (each separated by approximately $1 \mu\text{s}$) which are utilized in the modulating, transmitting, receiving, monitoring, and ranging sections. A free-running multivibrator (shown later) serves as the master timer for the trigger generator. Provision is made for operation of the radar set with an external trigger.

The modulator-power supply of the modulating section develops separate high voltage modulating pulses for application to the third and fourth driver stages (shown later) of the radio-frequency amplifier. The radar modulator develops separate high voltage modulating pulses for application to the plate and screen circuits of the power amplifier tube contained in the output radio-frequency amplifier. These pulses approximate a $\sin^2 \theta$ shape, except for the pulse modulating the third driver amplifier which is of rectangular shape. The $\sin^2 \theta$ shape of the r-f output pulse contains fewer harmonics than would the more conventional square radar r-f pulse output, and the possibility of interference with other shipboard equipments is reduced.

The power supply assembly develops 12.5 and 5.0 kilovolts d-c for the plate and screen pulse developing circuits respectively in the radar modulator. A power supply control unit establishes the primary voltage.

The transmitting section generates the radio-frequency pulse, amplifies it to a level of approximately 750 kilowatts peak power, and radiates the r-f energy packet into space. The r-f pulse is formed in the amplifier oscillator by heterodyning the output of a crystal controlled master oscillator-multiplier section (shown later) with the output of a 30-mc crystal controlled oscillator. The master oscillator-multiplier section output is always 30 mc below the radar operating frequency. During transmission, the 30-mc oscillator output is added to the master oscillator-multiplier output in a mixer to produce the desired operating frequency. During the receiving interval the 30-mc oscillator output is removed from the mixer

and the master oscillator provides the local oscillator signal for the receiving section.

The transmitting group contains a radio-frequency amplifier which functions as an intermediate power amplifier to raise the amplitude of the r-f pulse sufficiently to drive the final power amplifier stage contained in the output radio-frequency amplifier. The power amplifier (discussed later) is a beam power tube mounted in tunable plate and grid cavities.

Note that the antenna, antenna pedestal, and transmission line elements are shared by both the transmitting and receiving sections.

The receiving section develops video signals from the echo r-f impulses for display on the range indicator or remote PPI-type indicators when supplied. A double-conversion type receiving system is used. Incoming signals from the duplexer in the output radio-frequency amplifier are amplified and initially converted to an intermediate frequency of 30 mc in the radar receiver, by using the master-oscillator output originating in the amplifier oscillator as the receiver mixer injection signal. Amplification of the 30-mc i-f pulse is accomplished in i-f preamplifier stages located in the radar receiver.

An amplifier assembly in the control monitor group provides a second frequency conversion to produce an intermediate frequency of 3.75 mc. This unit also provides further amplification of the i-f signal and video detection.

The amplifier assembly supplies the video signal to the range indicator in the ranging section. Four supplementary video output channels are available at the output of the amplifier assembly for use with other plan position indicators. The receiving system operating controls are located on the Radar Set Control (fig. 12-1A).

The ranging section accurately displays the distance of the target from the ship. The circuits of this section are contained in the range indicator.

Target video signals applied to the range indicator from the receiving section are presented on a type-A oscilloscope display at ranges of 5, 25, 100, or 250 miles. Range measurements are made by positioning the trailing edge of a range step (variable marker) for coincidence with the target pulse, and then reading out the range (in miles or yards) on counters which are mechanically linked to the range step control. A sweep expansion arrangement is included for use on any range, effecting better differentiation of closely grouped targets.

The range indicator contains provisions for accepting markers from an external marker generator for presentation on the scope with the video signal. Range strobe pulses coincident with the trailing edge of the range step are produced for application to remote indicators.

The principal components of the low voltage section are the power supply assembly, the voltage regulator, and the detector voltage regulator. The power supply assembly provides unregulated d-c potentials for stages in the modulating, transmitting, and receiving sections. As stated earlier, the voltage regulator maintains one of the 115-volt single-phase lines from the step-down transformer within one percent of rated voltage. The detector voltage regulator supplies the receiving section exclusively.

TRIGGER GENERATOR SECTION

As stated earlier, the trigger generator section (fig. 12-2) is contained in the pulse generator, which is a part of the control monitor group. This trigger generator sets the pulse repetition rate of the radar system and supplies the necessary timing triggers at adjustable timing intervals. The generated trigger pulses are used in the modulating, transmitting, receiving, monitoring, and ranging sections.

TRIGGER GENERATING CIRCUIT

Pulse repetition rate multivibrator V1801 (fig. 12-3) is free-running and serves as the master timer for the trigger generator. A PRF control (not shown) permits the multivibrator output frequency to be adjusted over a range from 290 to 310 pulses per second.

The V1801B output is fed through a cathode follower V1802A and differentiated at the grid of inverter V1802B. The inverted output of V1802B is applied through trigger selector switch S1801, to IFF trigger blocking oscillator V1803A. The blocking oscillator produces positive-going output pulses from V1803B which coincide with the positive leading edge of the input pulse at V1803A. These pulses are the IFF trigger pulses which may be fed through S1802 (in the ON position) to the IFF equipment (if used).

The radar frequency energy for the radar system is generated in the amplifier-oscillator as discussed (fig. 12-2). The r-f output of the amplifier-oscillator is keyed by a pulse which is produced in the trigger generator (fig. 12-3). Because this pulse starts the radar operating

cycle, its time of arrival at the amplifier-oscillator is considered "zero time" or zero microsecond delay.

The zero time delay pulse is produced in blocking oscillator V1805. The output pulse at the secondary of a plate transformer (not shown) of V1803A is used to trigger section A of delay multivibrator V1804. The function of V1804 is to produce an adjustable width pulse. The pulse width is adjusted to obtain the delay required between the IFF trigger and the radar trigger (between 45 and 60 μ s).

V1804 is a one-shot multivibrator. The adjustable delay is obtained by changing the multivibrator R-C time constant.

Blocking oscillator V1805 is triggered into operation at the end of the output pulse from V1804B. When triggered, V1805B produces the zero microsecond delay trigger pulse output which is fed through cathode follower V1811B to the amplifier-oscillator. This pulse initiates the radar transmitter r-f output. The V1805B output is also fed through cathode follower V1806A to delay line DL1801.

DELAYED TRIGGER CIRCUITS

Delay line DL1801 is an artificial transmission line used to introduce the required delays between the various timing pulses supplied to the system. The line is tapped at 0.5 μ s intervals.

Output terminals 3, 5, and 7 from DL1801 provide fixed 1, 2, and 3 μ s delayed triggers respectively for use in the modulating and receiving circuits, as will be seen later. These pulses are applied respectively through cathode followers V1806B, V1807A, and V1807B to the modulating and receiving circuits.

Trigger pulses delayed by 3.5, 4.0, 4.5, or 5 μ s, for the range indicator, master PPI and remote indicators, can be obtained from taps 8, 9, 10, or 11, respectively. The adjustable delay is provided to compensate for the inherent propagation delays in the radar system transmission lines.

Blocking oscillator, V1808, utilizes the pulse received from terminal 8, 9, 10, or 11 of DL1801 to produce a sharp trigger pulse for the indicators. The V1808 output pulses are fed to the indicators through separate cathode followers V1809A, B, V1810A, B, and V1811A.

The trigger time relationship of the six trigger pulses is illustrated in figure 12-4. The delay value assigned to each of the triggers is in reference to zero delay at terminal 1 of DL1801. The 3 μ s delay trigger corresponds in time to the transmitted pulse.

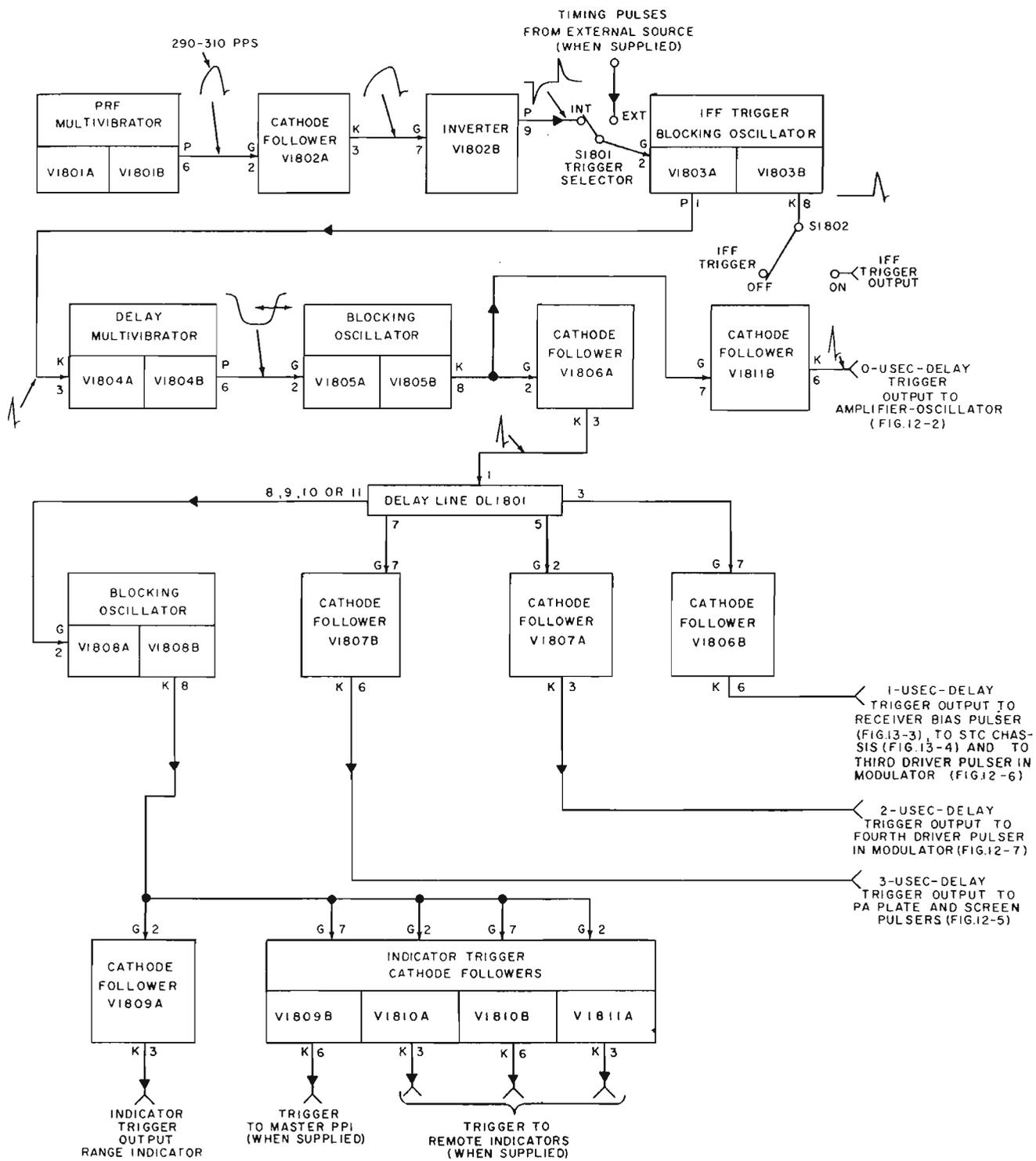


Figure 12-3.—Trigger Generator, Block Diagram. 032.208

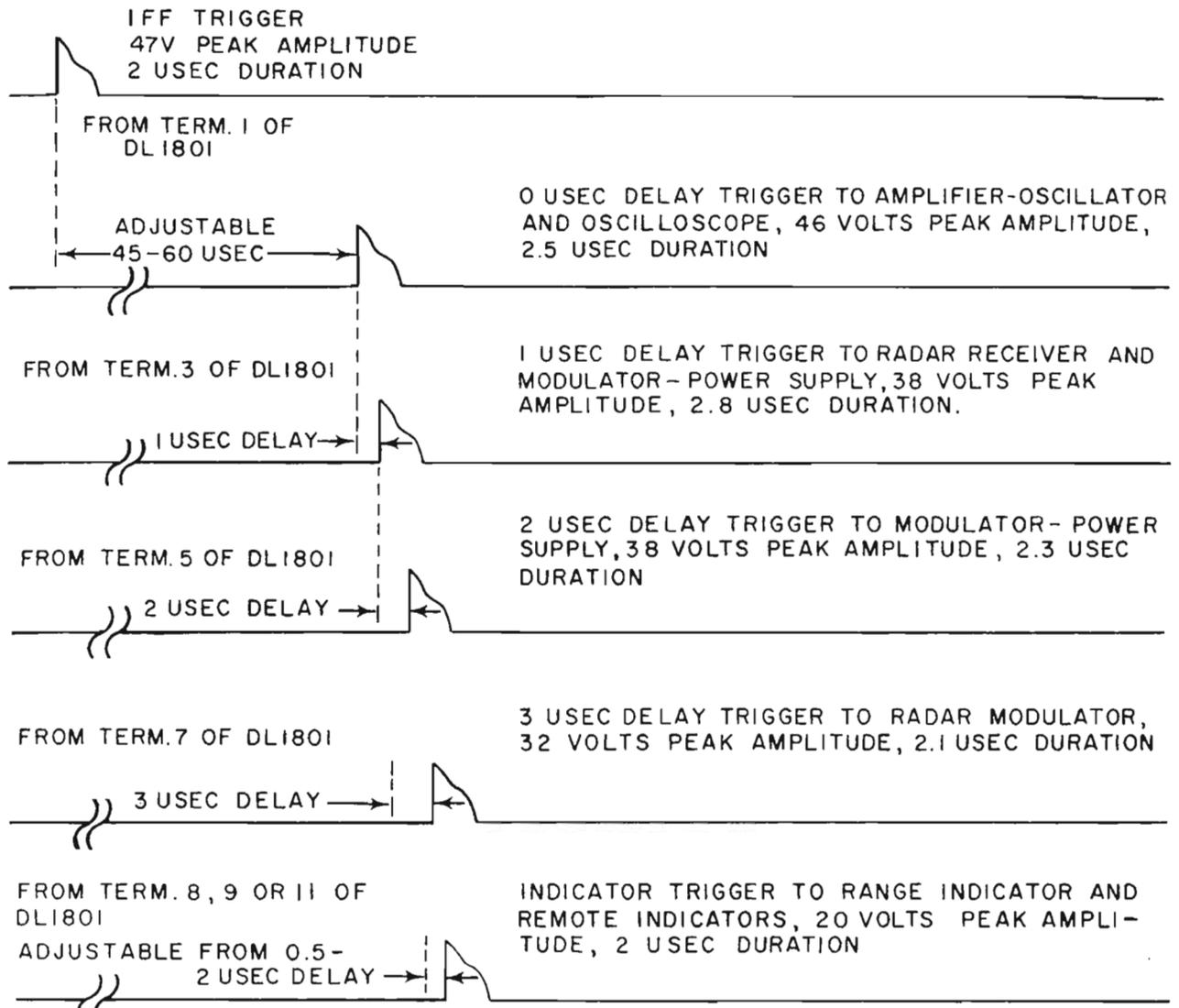


Figure 12-4.—Pulse Generator Trigger Time Relationship. ^{032.209}

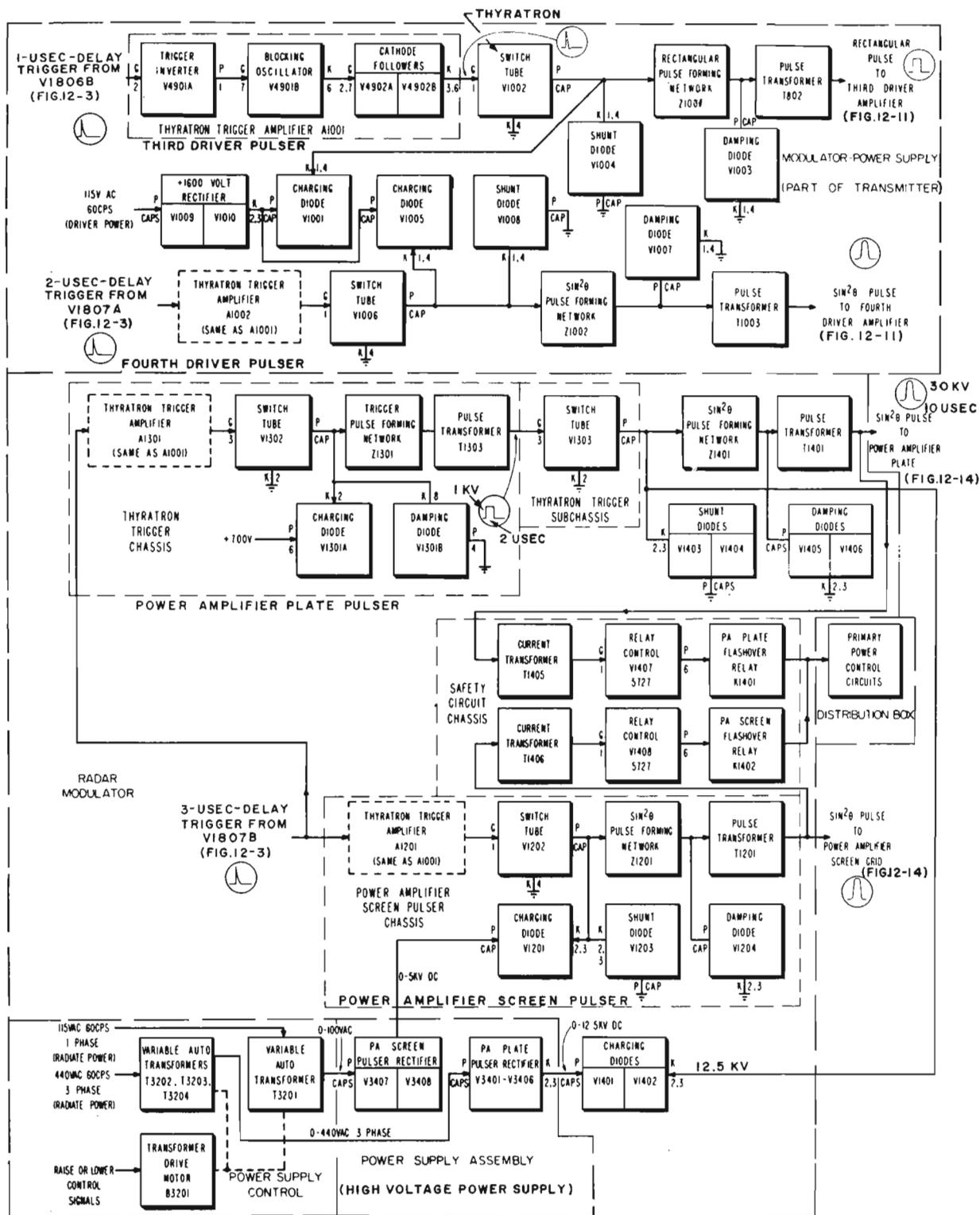
MODULATING SECTION

As stated earlier, the modulating section (fig. 12-2) creates a series of four high-potential pulses (upon receipt of triggers from the trigger generating section) for application to the third and fourth driver amplifiers and the plate and screen circuits of the output radio frequency (power) amplifier.

Separate pulser circuits are used to form each modulating pulse (fig. 12-5). The circuits comprising the third driver pulser are thyatron trigger amplifier assembly A1001, switch tube V1002, charging diode V1001, rectangular pulse forming network Z1001, pulse transformer T802, +1600-volt rectifiers V1009 and V1010,

shunt diode V1004, and damping diode V1003. These stages form a conventional modulator circuit (frequently termed "line pulser") and produce an essentially rectangular waveform for application to the plate of the third driver amplifier (described later).

In a modulator of this type, pulses are produced by means of a pulse-forming network which resembles an artificial transmission line. This network is similar to the pulse forming network in the modulator of the AN/SPS-10D discussed in chapter 10 of this training course. Energy is stored in the network and delivered to the load at the proper instant (in the form of a rectangular pulse) by discharging the artificial line through a switching device.



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Figure 12-5.—Modulating Section, Block Diagram.

Rectangular pulse forming network Z1001 serves as the energy storage and pulse forming element. The capacitance of the network charges through charging diode V1001 toward the +1600-volt supply. Through series resonant charging, the artificial line charges to nearly twice the supply voltage. Charging diode V1001 prevents discharge of the network through the power supply.

Thyratron switch tube V1002 acts as a shorting switch device to discharge the pulse forming network when the gas within the tube ionizes. The ionization of V1002 is forced by the injection of a trigger pulse at the switch tube control grid.

THYRATRON TRIGGER AMPLIFIER

Each of the pulse generating circuits is triggered by a pulse from the trigger generator (either the 1, 2, or 3 μ s delayed pulse, fig. 12-3). The input pulses trigger a thyratron trigger amplifier which consists of conventional trigger inverter, single-swing blocking oscillator, and cathode follower stages, and is identical for each of the pulse generators.

THIRD DRIVER PULSER

The third driver pulser circuit (fig. 12-6) is triggered by the 1 μ s delay trigger. The trigger is first inverted in V4901A and subsequently used to excite single-swing blocking oscillator V4901B into generating a positive-going voltage spike at its cathode. The regenerated trigger is fed through parallel-connected cathode followers (V4902A and V4902B) and through pulse transformer T4902 to the grid of thyratron switch tube V1002. Pulse transformer T4902 provides a voltage step up of 1 to 2. The cathode followers match the output impedance of the blocking oscillator to the grid circuit of switch tube V1002. The input impedance to the switch tube is relatively low when ionization occurs, necessitating isolation from the blocking oscillator (by the cathode followers) to prevent undesired reflections to the oscillator.

The pulse forming network Z1001 charges through V1001 and V1003 to about +3000 volts. Upon arrival of the regenerated trigger pulse at the grid of V1002, the tube fires and discharges the pulse forming network (Z1001) through a pulse transformer T802, and the low

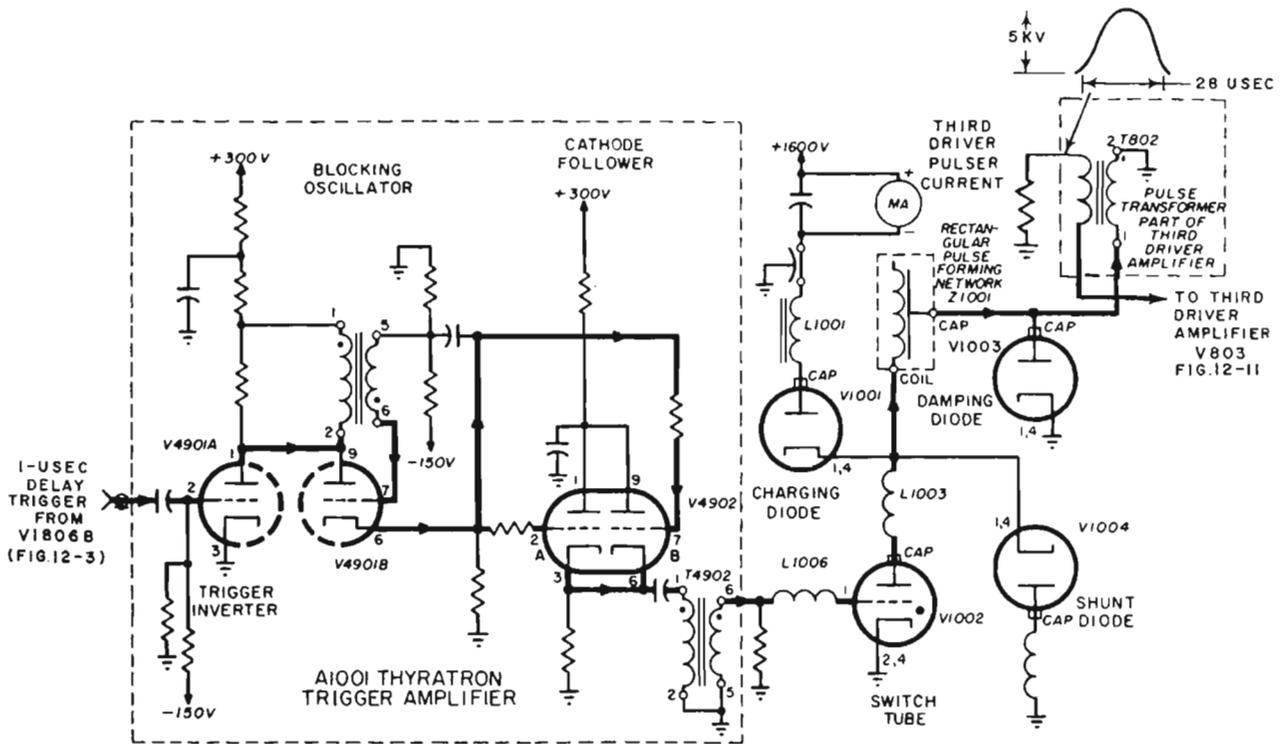


Figure 12-6.—Thyratron Trigger Amplifier and Third Driver Pulser, Schematic Diagram.

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conducting resistance of the switch tube, V1002. The output pulse at the T802 secondary is fed to the third driver amplifiers in the transmitting section (fig. 12-2).

Pulse transformer T802 (fig. 12-6) provides a voltage step-up in the Z1001 output, and matches the line impedance to that of the pulse forming network. Damping diode V1003 prevents oscillations following the discharge of the pulse forming network. Shunt diode V1004 blocks the accumulation of reverse charge in Z1001, and thereby protects the thyatron, V1002, from high negative potentials at its plate.

At the end of the Z1001 discharge period, the network capacitance recharges to its former potential (approximately 3000 volts). The charging action is completed before the arrival of the next excitation trigger at the switch tube.

FOURTH DRIVER PULSER

The circuits comprising the fourth driver pulser are shown in figure 12-7. As in the case of the third driver pulser, the fourth driver pulser can be divided into trigger shaping and pulse forming stages. The trigger shaping circuits are contained in plug-in trigger amplifier assembly A1002, which is identical to the trigger amplifier assembly that precedes the

pulser forming circuits in the third driver pulser.

The pulse forming stages of the fourth driver pulser create a positive-going $\sin^2 \theta$ shaped waveform having approximately 1200 volts peak value. The voltage pulse is then applied to a second pulse transformer (not shown) in the fourth driver amplifier where nominal potentials of 900 and 5000 volts peak are developed for the screen and plate circuits respectively of this stage.

Excitation for the fourth driver pulser is provided by the $2 \mu s$ delay trigger from the trigger generating section which appears one microsecond after the excitation pulse applied to the third driver pulser. The positive-going trigger (averaging 38 volts peak and $2.3 \mu s$ width) is applied through J1115. An amplified pulse is fed to the control grid of switch tube V1006, which initiates the generation of the $\sin^2 \theta$ pulse.

$\sin^2 \theta$ pulse forming network Z1002 contains two series resonant circuits which comprise L1 and C1 and L2 and C2, respectively. The resonant frequency of the L2-C2 tuned circuits is three times that of L1-C1. The inductance value of the two circuits is equal, but the capacitor C1 is 9 times the value of C2. Inductor L3 represents the mutual inductance between L1 and L2.

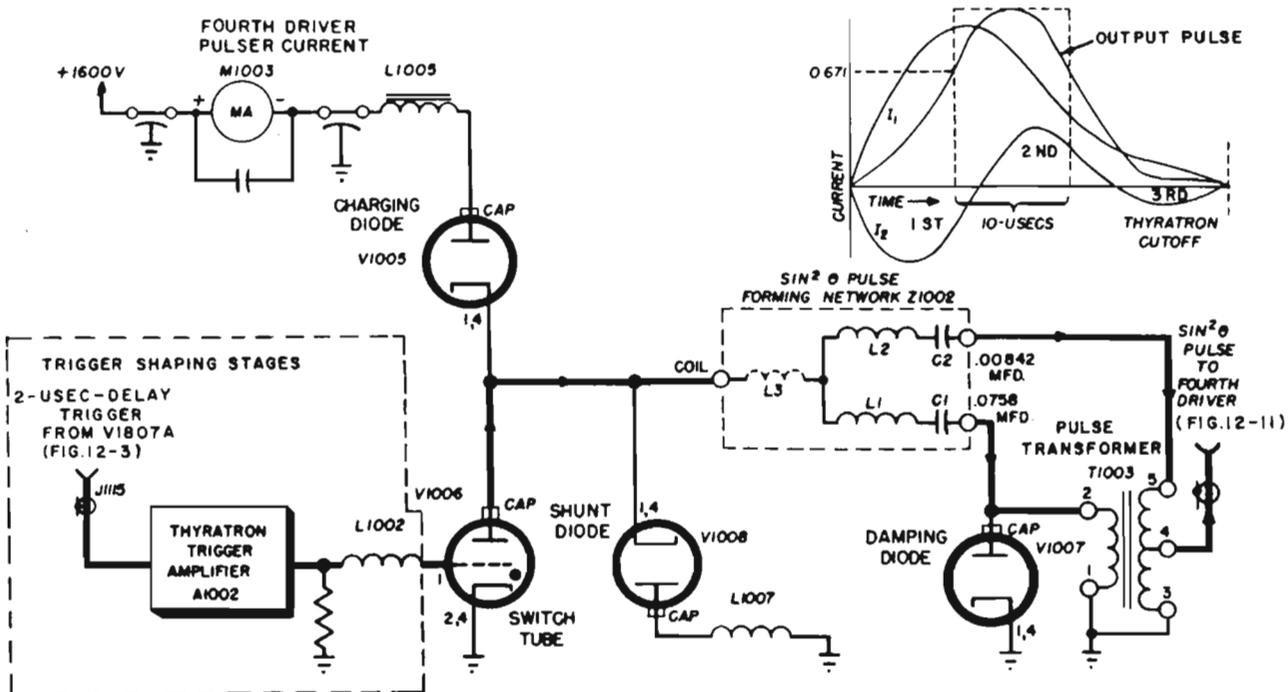


Figure 12-7.—Fourth Driver Pulser, Schematic Diagram.

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Immediately following the generation of a pulse, capacitors C1 and C2 assume a charge at a potential of about 3000 volts. This charge is accumulated from the +1600-volt supply and the resonant build-up in the tank circuits. The charge path for C1 is from ground, the 1-2 winding of pulse transformer T1003, C1, L1, L3, V1005, L1005, M1003, the +1600 volt supply and back to ground. Capacitor C2 charges in a similar fashion but through L2 and the 3-5 winding of pulse transformer T1003.

Upon arrival of the pulse from the trigger shaping stages, the switch tube V1006 fires, and both C1 and C2 discharge through the conducting resistance of V1006 and the associated windings of the pulse transformer, simultaneously generating damped sinusoidal currents in each of the discharge circuits. The output gate pulse width is the same as the conduction interval of the thyatron (V1006).

Current I_1 in L1C1 is nearly twice I_2 in L2C2. Current I_2 alternately adds to and subtracts from I_1 to produce the output pulse from T1003 (fig. 12-7).

The width of the output pulse is taken at the 0.671 voltage points since a rectangular pulse of this duration and peak voltage of 1.000 contains the same energy.

Shunt diode V1008 prevents the accumulation of reverse charge on the network capacitance C1 which might cause a reverse flow of current through V1006. Oscillations in L1C1 are damped by V1007. Thyatron V1006 is protected from current surges by L3 (the mutual inductance common to L1 and L2).

POWER AMPLIFIER SCREEN PULSER

The power amplifier screen pulser (fig. 12-5) produces a positive-going $\sin^2 \theta$ shaped voltage waveform which is used to modulate the r-f voltage at the screen grid of the power amplifier tube (shown later). The waveform is approximately 2.2 kilovolts and 10 μ s in width at the 0.671 voltage points.

The stages of the power amplifier screen pulser are excited by the 3 μ s delay trigger from the trigger generating section (fig. 12-3). Reference to the fourth driver pulser (fig. 12-5) will show the similarity of the fourth driver and screen pulser circuits. The principle of operation of the two circuits is identical.

POWER AMPLIFIER PLATE PULSER

The power amplifier plate pulser (fig. 12-5) produces the $\sin^2 \theta$ plate modulating pulse for

the power amplifier stage. The trigger pulse for the plate pulser switch tube, V1302, is produced in a conventional line pulser in the same manner as described for the third driver pulser. The action is initiated by the 3 μ s delay trigger from the trigger generating section (fig. 12-3) in coincidence with the trigger pulse to the screen pulser circuit (fig. 12-5).

The regenerated output pulse from the thyatron trigger chassis is approximately 1 kv in amplitude and 2 μ s in duration. This pulse is developed at the T1303 secondary and serves as the trigger pulse for the switch tube V1303.

The pulse forming circuits of the power amplifier plate pulser (Z1401 and T1401) produce a positive-going $\sin^2 \theta$ shaped waveform with a nominal peak voltage of 30 kv and a 10 μ s duration at the 0.671 voltage points. The circuit functions in the same manner as the corresponding stages in the fourth driver pulser discussed earlier. The plate and screen pulser outputs are fed to the power amplifier by means of insulated conductor assemblies (not shown). These assemblies terminate in corona shields at each end.

POWER SUPPLIES

The third and fourth driver pulsers (fig. 12-5) require operating d-c potentials of -150, +300, and +1600 volts. The first two voltages are obtained from the power supply assembly, in the low voltage section (fig. 12-2). The +1600 volts is developed in the modulator-power supply.

The high voltage power supply (fig. 12-5) produces the required d-c operating voltages for the power amplifier plate and screen pulsers contained in the modulator. Separate power supplies are used for each of the pulser circuits. The PA plate pulser comprises V3401 through V3406, and produces a maximum d-c potential of about 12.5 kilovolts for the power amplifier plates. The PA screen pulser rectifier includes V3407 and V3408, and provides approximately 5 kilovolts for the screen of the power amplifier tube.

TRANSMITTING SECTION

As stated earlier, the transmitting functional section generates and amplifies the radio frequency pulse, which is subsequently radiated from the radar antenna. A block diagram of the transmitting functional section is shown in figure 12-8.

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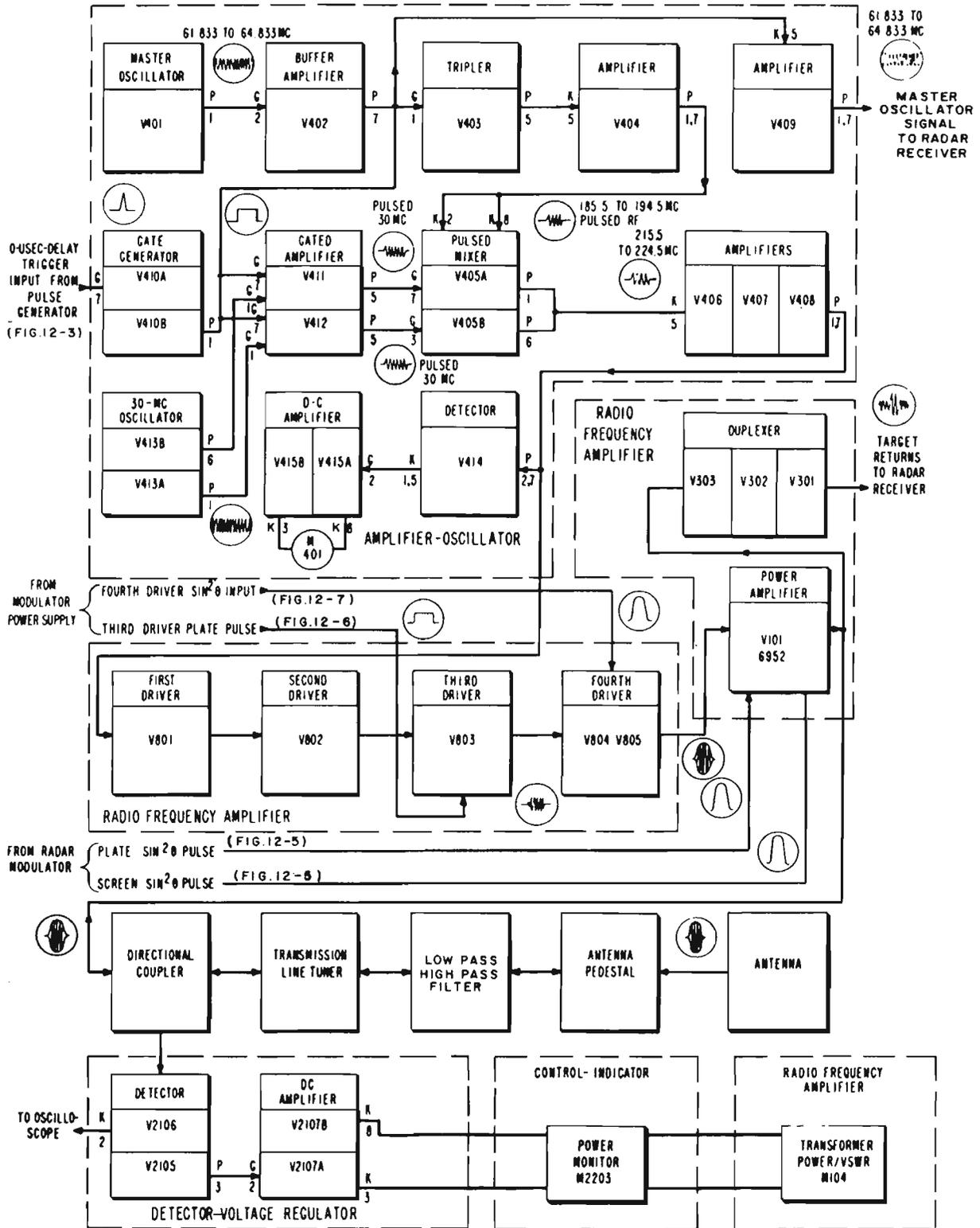


Figure 12-8.—Transmitting Section, Block Diagram.

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EXCITER

The transmitting section is divided into two major sections. These are the amplifier-oscillator (exciter) section and the radio frequency amplifier section. The exciter section generates and amplifies the r-f signal at the selected frequency. The radio frequency amplifiers contain four driver stages which increase the signal amplitude sufficiently to drive the final power amplifier (shown later).

Master Oscillator

A master oscillator, V401, supplies an r-f signal in discrete steps at intervals of 0.333 mc in the range from 61.8333 mc to 64.8333 mc. The oscillator frequency is determined by one of ten switch-selected crystals. Each crystal operates at its fifth harmonic (mode).

The master oscillator (fig. 12-9) is a crystal-controlled Colpitts. The frequency controlling crystal is selected by crystal selector switch A401. For simplicity, only one crystal and one position of the selector switch are shown.

The tank circuit, comprising L401, C401, C402, C442, and the grid-plate grid-cathode capacitance, is also resonant at the fifth harmonic of the crystal. Feedback is applied to the grid via C442 and C401. Parasitic oscillations are suppressed by R401. The selected crystal operates as a series resonant circuit at the 5th harmonic of the crystal fundamental frequency. R-f choke L402 provides high impedance to the oscillator frequency and low impedance to the d-c component of cathode

current. Capacitor C404 blocks the d-c component of cathode current from the crystals and couples the 5th harmonic of the crystal output to the cathode circuit. At the same time C404 blocks the fundamental frequency component of the crystal output from the cathode circuit.

To understand the oscillator action, assume that the V401 grid is being driven positive by a voltage developed from the flywheel effect of the oscillator tank. Note first that C442 initially charges positive to ground (as shown) due to the connection through R401 and the plate load resistors to the B supply. A positive-going grid signal swing will cause the V401 plate voltage to decrease, and the resultant charge on C442 must decrease. One discharge path for C442 is to ground and through Y401, C404, and the cathode-plate resistance of V401, and R401. Another path is through C401, in parallel with the grid-to-cathode resistance of V401, through C402 and L401.

The capacitance of C401 is small with respect to that of C402 so that the greater portion of the C442 discharge voltage will appear between the grid and cathode of V401. This positive increase in grid voltage causes a further increase in the V401 plate current and thus regenerates the initial action. The plate current of V401 continues to increase until the tube draws saturation current. At saturation, C442 stops discharging, and the negative charge accumulated on the grid side of C402 (during the discharges of C442) is now released through R402, C442, and L401. The negative voltage to ground at the top of R402 cuts off V401, and the cycle is completed by the flywheel effect of the grid tank. The oscillator output is coupled through C405 to the buffer amplifier V402 (fig. 12-8).

BUFFER AMPLIFIER

Buffer amplifier V402 isolates the master oscillator from the effects of the varying load created by the keying of tripler V403. The buffer amplifier is a conventional class A r-f amplifier. The buffer amplifier output is simultaneously applied to tripler V403 and amplifier V409. The amplified V409 output is impedance matched to the receiver where it is used as the local oscillator signal in the receiver mixer. This process is treated in detail in chapter 13 of this training course.

Gate Generator

The master oscillator output to V403 (via V402) is multiplied in V403 only when a gate pulse is applied to V403 from V410.

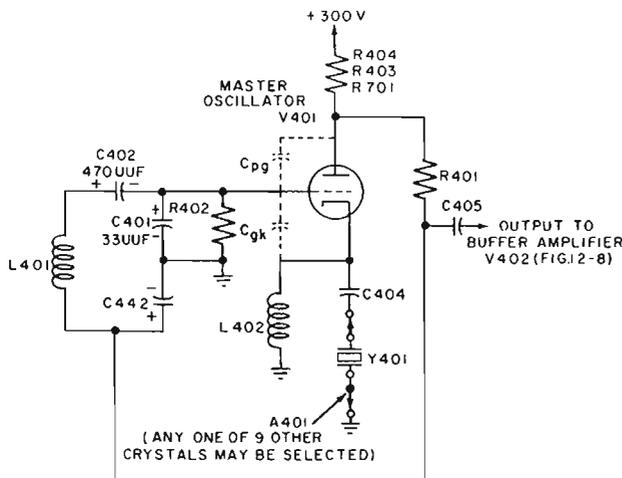


Figure 12-9.—Master Oscillator Stage.

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The 0 μ s delay trigger pulse, generated by V1805 in the trigger generating section (fig. 12-3) is coupled to the grid of gate generator V410A (fig. 12-8). This pulse is approximately 45 volts peak and 2.5 μ s in duration.

Gate generator V410 (fig. 12-10) is connected as a one-shot multivibrator. The arrival of the 0 μ s delay trigger pulse at the V410A grid causes the generation of a 30 μ s positive-going, output gate pulse from V410B. This pulse reduces a fixed cutoff bias on the grid of V403 (fig. 12-8) sufficiently to allow the stage to function as a tripler and thereby multiply the master oscillator output. The resultant frequency is in the range from 185.5 to 194.5 mc, depending upon the selected master oscillator crystal.

The tripler output is amplified in V404. In addition to amplifying the signal, a transformer in the V404 plate circuit (not shown) provides impedance matching to the cathodes of pulsed mixer V405.

As stated earlier, the frequency operating range of the AN/SPS-29 radar set is from 215 to 225 megacycles. The tripler and amplifier (V403 and V404) output must be increased by 30 mc to produce an output frequency in this range. The frequency increase is accomplished by heterodyning the V404 output with a 30-mc signal in a gated or pulsed mixer V405. The 30-mc signal is generated in 30-mc oscillator V413. The gate pulse for the mixer (V405) occurs simultaneously with the gate pulse to the tripler (V404) so that the two signals are applied to the mixer during the same period. The sum frequency produced in the V405 mixer yields an output frequency in the operating range of the radar set (215.5 to 224.5 mc).

30-mc Oscillator

The 30-mc oscillator, V413A and B (fig. 12-10) is a crystal-controlled, push-pull, tuned-plate type oscillator. To operate a push-pull oscillator the cathodes of the two tubes used must be connected together directly or through a very low impedance. Crystal Y411 effectively connects the V413A and V413B cathodes together through its low third-harmonic series resonant impedance. At all other frequencies, L405 and the capacitance of the crystal holder provide a high impedance between the two cathodes to suppress the generation of undesired frequencies.

Feedback between the oscillator grids is accomplished by C435 and C436. The method of providing feedback is similar to that used in a free-running multivibrator.

The 30-mc oscillator push-pull plate load consists of adjustable inductor L404 and capacitor C433. The V413A output is applied to the V412 control grid while the V413B output is applied to the grid of V411. Thus, the grids of V411 and V412 are fed 180° out of phase.

Gated Amplifier and Pulse Mixer

The gated amplifier, V411 and V412 (fig. 12-10), under the influence of the 30 μ s trigger pulse from gate generator V410B, amplifies the 30-mc output of V413A and B and supplies the amplified signal to the control grids of push-pull operated pulsed mixer V405. The mixer also receives at its cathode the tripler V403 output (from fig. 12-8) via amplifier V404, as discussed. The mixer (fig. 12-10) combines these signals to produce a sum frequency in the operating range of the radar transmitter.

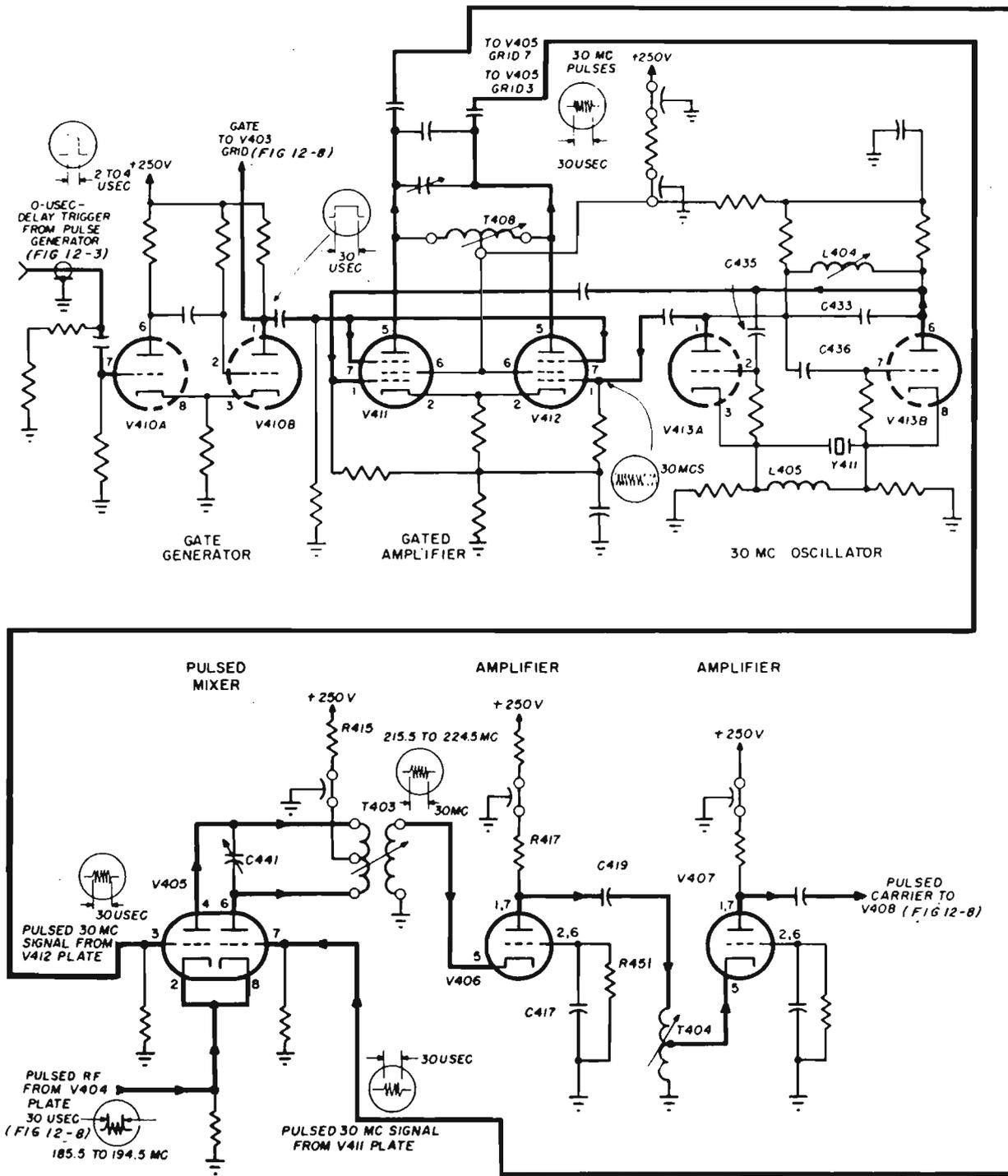
The sum frequency output of V405 is developed in the tuned circuit comprising C441 and the T403 primary. The secondary of T403 supplies the 215.5 to 224.5 mc to the amplifier, V406, cathode.

Amplifier V406 is operated with series grid leak bias. During portions of each negative input half cycle at the V406 cathode, the grid and plate draw a current. The grid current charges the upper plate of C417 negative to ground. During other portions of each input cycle V406 is cut off and C417 slowly discharges through R451. This action produces a negative grid cathode voltage which biases V406 beyond cutoff.

The V406 output appears across plate load resistor R417 and is coupled through C419 to transformer T404. This transformer is self-resonant in the 215.5 to 224.5 megacycle range. Amplifier V407 functions the same as V406. The V407 output is fed through another amplifier, V408 (fig. 12-8) to a detector stage, V414, and to the first driver stage, V801.

Exciter Output Meter Circuit

The amplified r-f signal from V408 (fig. 12-8) can be termed the "exciter" r-f output because it is, in effect, the exciting signal for the driver stages of the transmitter. The r-f input to detector V414 is rectified and filtered and applied to the A section of a d-c amplifier, V415. The d-c amplifier comprising V415A and V415B is a bridge circuit with a meter (M401) connected across its diagonally opposite corners. For zero input the bridge is balanced and the meter indicates zero current. When the



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Figure 12-10.—Gate Generator, 30-mc Oscillator, and Pulsed Mixer.

CIRCUITRY OF SHIPBOARD ELECTRONICS EQUIPMENT

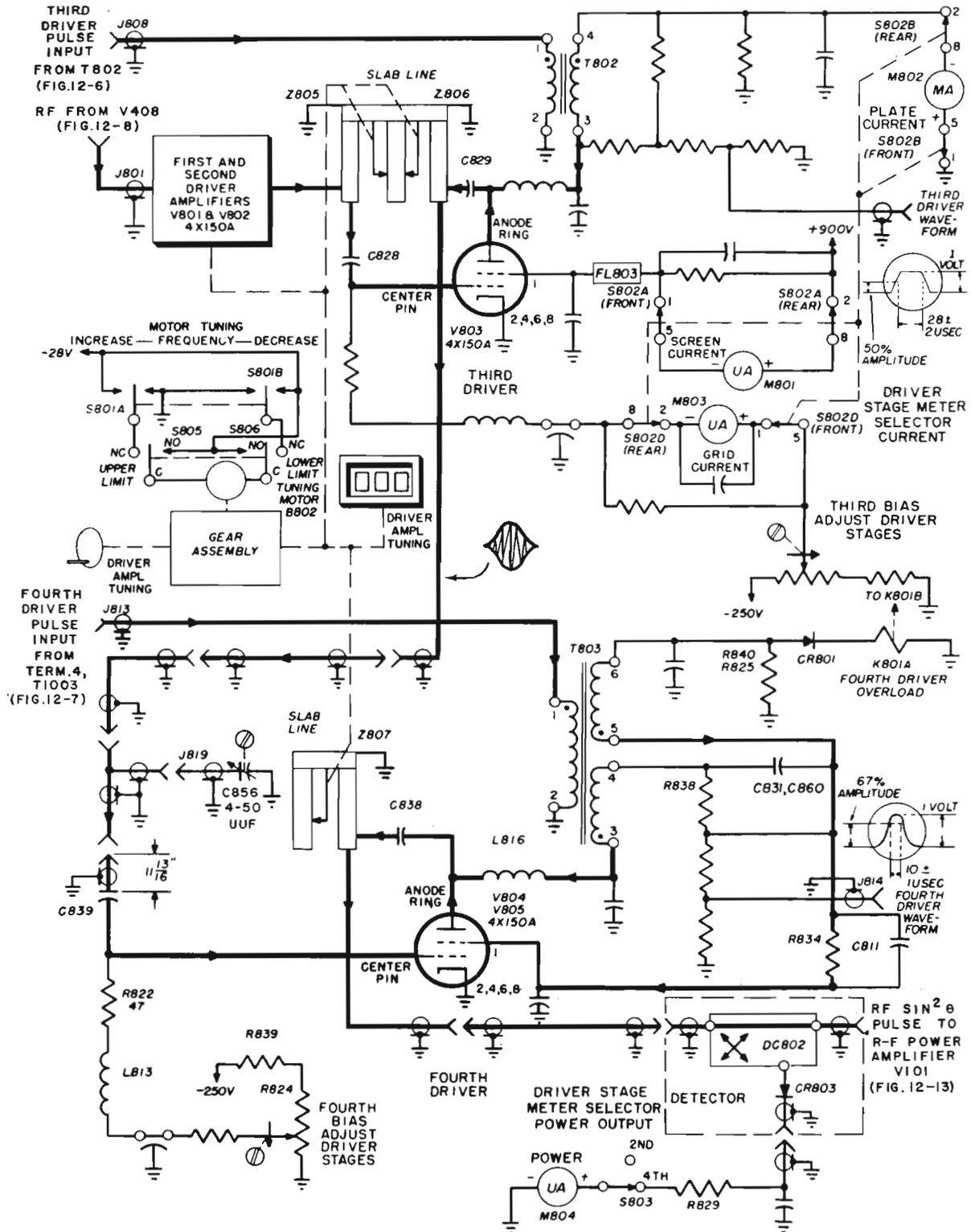


Figure 12-11.—Third and Fourth Driver Amplifiers.

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r-f exciter pulses are applied to the bridge, M401 will indicate the amount of exciter output current. Thus, M401 is helpful in setting the amount of drive signal at the input to the first driver, V801.

RADIO FREQUENCY AMPLIFIER

The radio frequency amplifier (fig. 12-8) contains four driver stages which increase the r-f signal pulse amplitude sufficiently to drive the power amplifier which is the final stage of the transmitter. The first, second, and third driver stages are identical. For simplicity, only the third and fourth driver stages are discussed in detail.

Third Driver

The third driver stage (fig. 12-11) uses a 4X150A tetrode, V803, while the fourth driver uses two of the same type tubes (V804 and V805) in parallel (one tube shown). The 4X150A type tube is used for its power capabilities, high gain, and low interelectrode capacitance over that of a high power triode.

The 215.5 to 224.5 mc r-f pulse from output amplifier V408 (fig. 12-8) is coupled to the grid section of the first driver, V801 (fig. 12-11). After amplification in the first and second drivers (V801 and V802), the pulse is coupled from the plate of the second driver, V802, to the grid of third driver V803, via grid tuning stub Z805, and coupling capacitor C828.

A cross section of the grid and plate stubs (Z805 and Z806) is shown in figure 12-12. The grid stub, Z805, is tuned by a movable shorting plate to an equivalent quarter wavelength at the radio frequency of the input pulse. Thus, the input path is a high impedance to develop a large voltage at the V803 grid. The input signal is fed to the grid stub via a coaxial line at the 50-ohm impedance point on the stub.

The tuning plates of the grid and plate stubs are positioned by a gear train which is driven by tuning motor B802 (fig. 12-13). The mechanical coupling of all the driver amplifier tuning plates are identical, hence only coupling for the third driver amplifier (V803) is shown in detail. The frequency to which the driver amplifiers are tuned is obtained from the driver amplifier tuning indicator and a calibration chart (not shown).

The plate voltage of V803 (fig. 12-11) is not a d-c positive voltage as might be expected, but is only that voltage provided by the third driver (modulating) pulse produced in the third driver

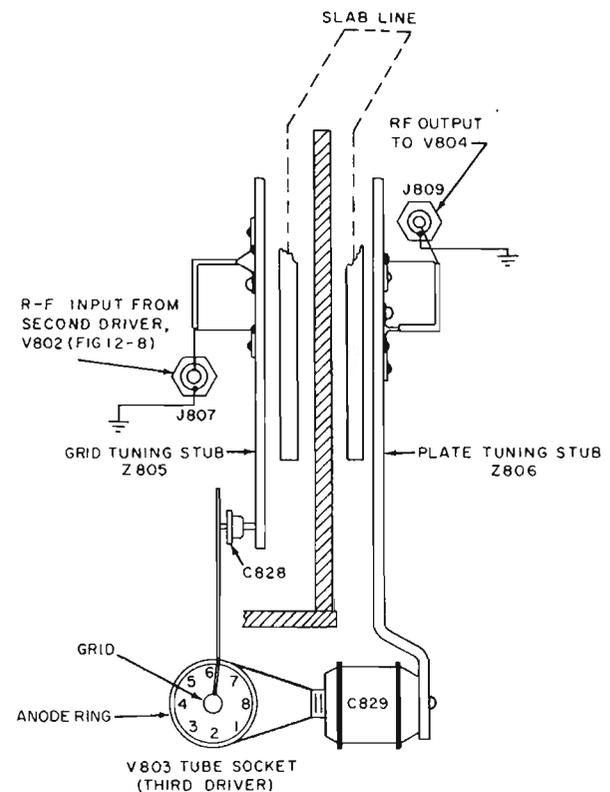


Figure 12-12.—Third Driver Grid and Plate Tuning Stubs, Z805 and Z806.

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pulser (fig. 12-6). The pulse has a 5 kv amplitude and 28 μ s duration, and occurs at the V803 plate (fig. 12-11) in coincidence with the r-f pulse from V802 at the V803 grid. The V803 output is a 28 μ s modulated r-f pulse envelope which is developed in the plate stub tuner, Z806, and coupled to the control grid of the fourth driver (V804 and V805) through a 50-ohm coaxial cable. The line is tuned by C856.

Fourth Driver

The fourth driver tubes, V804 and V805, are connected in parallel to provide the high power required to drive the final power amplifier in the transmitter (discussed later). A fixed grid bias from the R824 arm supplements the grid leak bias developed by C839 and the grid-to-ground resistors as a result of the large input driving signal. Grid inductor L813 provides a high r-f impedance to ground without essentially affecting the d-c grid bias.

During the time the 28 μ s r-f pulse is present at the V804 and V805 grids, the $\sin^2 \theta$ (modulating) pulse from the fourth driver pulser

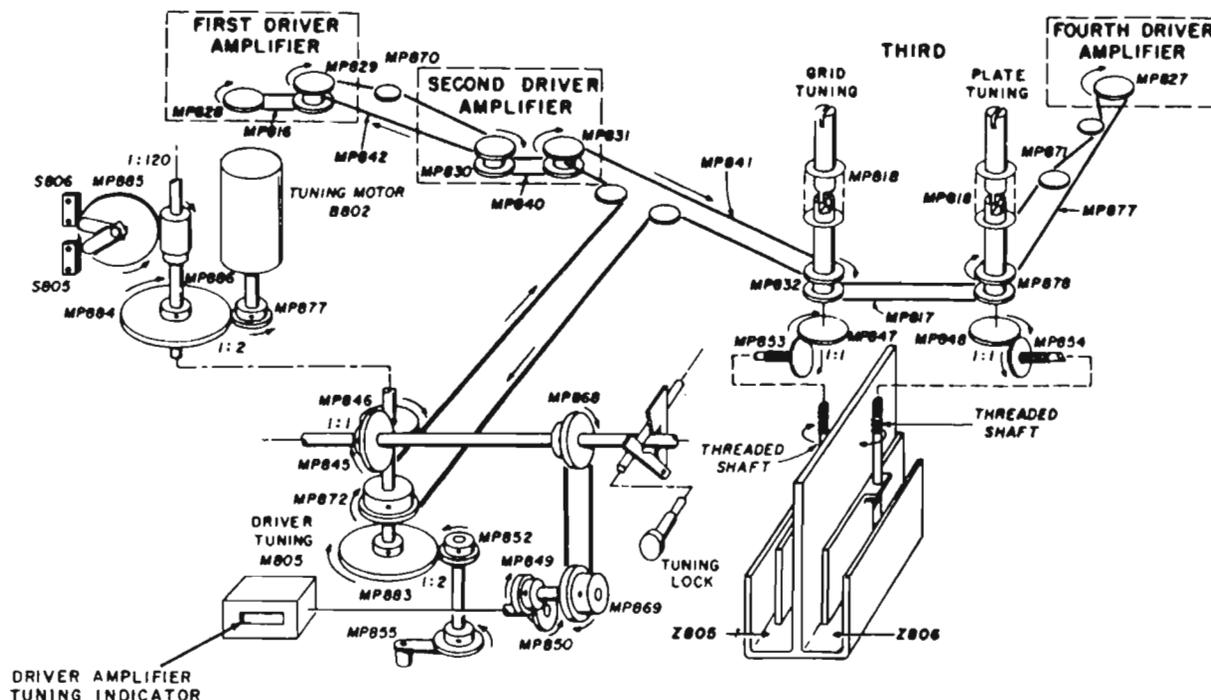


Figure 12-13.—Driver Tuning Gear Train. ^{032.218}

(fig. 12-7) is applied to the V804 and V805 plates and screens (fig. 12-11) via T803. The pulse developed in the 4-3 winding is applied to the plates while the pulse in the 6-5 windings is applied to the screens. Plate tuning stub Z807 (which is tuned in the same manner as Z805 and Z806) is tuned to act as a quarter wavelength resonator, and is connected through C838 in shunt with the fourth driver plate load, L816.

The fourth driver output is taken from the 50-ohm impedance point on Z807 and is coupled through directional coupler DC802, to the grid cavity of power amplifier V101 in the radio frequency amplifier (fig. 12-14).

The fourth driver screen current is monitored by a meter (not shown) which is connected by a switch across the shunt network comprising R834 and C811. The same meter can be switched across R838 and capacitors C831 and C860 to measure the fourth driver plate current.

The AN/SPS-29 radar system is protected against overload at the fourth driver by fourth driver overload relay K801A. If the drop across R825 and R840 (in series) exceeds the Zener (reverse voltage breakdown) characteristics of diode CR801, that is, if the screen and plate currents of the fourth driver amplifier

become excessive, relay K801A energizes. The result is that the high voltage power supplies of the radiate circuits (not shown) are deenergized and radiation ceases.

Directional Coupler

The directional coupler, DC802, couples a small portion of the outgoing power from the fourth driver to a diode detector, CR803. The diode in conjunction with R829, C835, and M804 rectify and filter the input r-f power. The meter, M804, is calibrated to indicate the peak power output. A similar circuit (not shown) is incorporated in the second driver amplifier circuit.

POWER AMPLIFIER

The power amplifier (fig. 12-14), which is called a "cavity amplifier," is essentially a tuned plate tuned grid r-f power amplifier. The power amplifier tube (V101) is a tetrode with all elements water cooled.

The r-f circuits of V101 consist of grid and plate cavities which are tunable within the range of 215.5 to 224.5 megacycles. The $\sin^2 \theta$ r-f pulse from the fourth driver (fig. 12-11) is coupled through sliding jack, J102 (fig. 12-14)

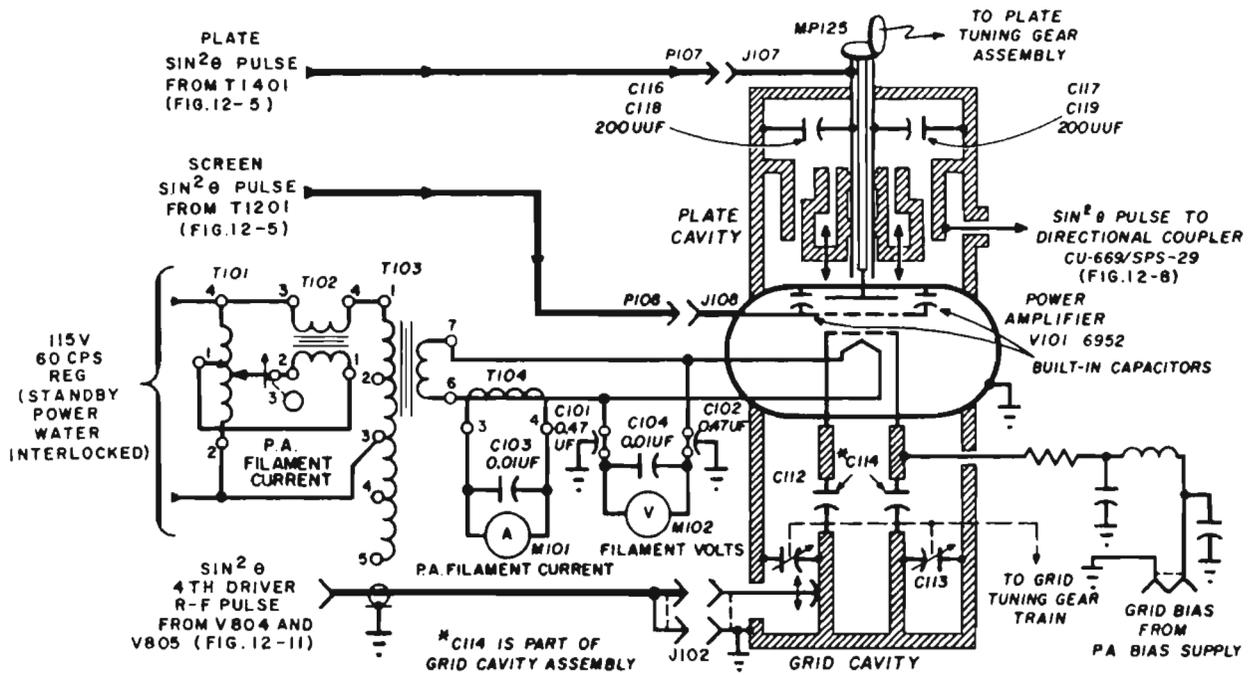


Figure 12-14.—Radio Frequency (Power) Amplifier Circuit.

to the center conductor of the V101 grid cavity. The sliding jack (J102) can be adjusted for optimum impedance matching to the cavity input. The grid cavity is tuned by variable capacitors C112 and C113, which are driven by a manually operated gear train (not shown).

The power amplifier receives a grid bias potential from the PA bias supply (not shown) which operates the stage class B. The V101 grid is isolated from ground by built-in capacitor C114.

Simultaneously with the application of the r-f $\sin^2 \theta$ pulse to the grid cavity, a $\sin^2 \theta$ modulating pulse (discussed earlier) is applied to the V101 screen grid while another $\sin^2 \theta$ pulse is applied to the V101 plate. The plate circuit consists of two choke cavities, one within the other. The position of the internal cavity is adjustable. Moving the inner cavity with respect to the outer cavity alters the resonant characteristics to tune the V101 plate for the various frequencies in the radar operating range.

The output of the power amplifier is coupled from the innermost to the outermost choke cavity, from which it is fed to a directional coupler (fig. 12-8). The power amplifier plate cavity (fig. 12-14) is thus analogous to

transformer-coupled tank circuits. The center cavity is positioned by a motor-driven gear train (not shown).

You will recall that the power amplifier plate and screen pulsers in the modulating section are triggered by the $3 \mu s$ pulse from the trigger generator section. Thus, the output r-f pulse from the transmitter corresponds with the $3 \mu s$ pulse from the pulse generator (see fig. 12-4).

The plate cavity may be tuned manually by rotating the power amplifier plate tuning control located on the radio frequency amplifier (fig. 12-1, D). The grid cavity is manually tuned by the PA grid drive control.

WATER COOLING SYSTEM

Each of the elements in the power amplifier tube, V101, are water cooled to ensure safe operating temperatures. An external picture of the power amplifier and the various hoses through which the cooling water flows are shown in figure 12-15A. An exploded view of the power amplifier is shown in figure 12-15B. The cooling process requires the flow of approximately 8.6 gallons of water per minute (GPM).

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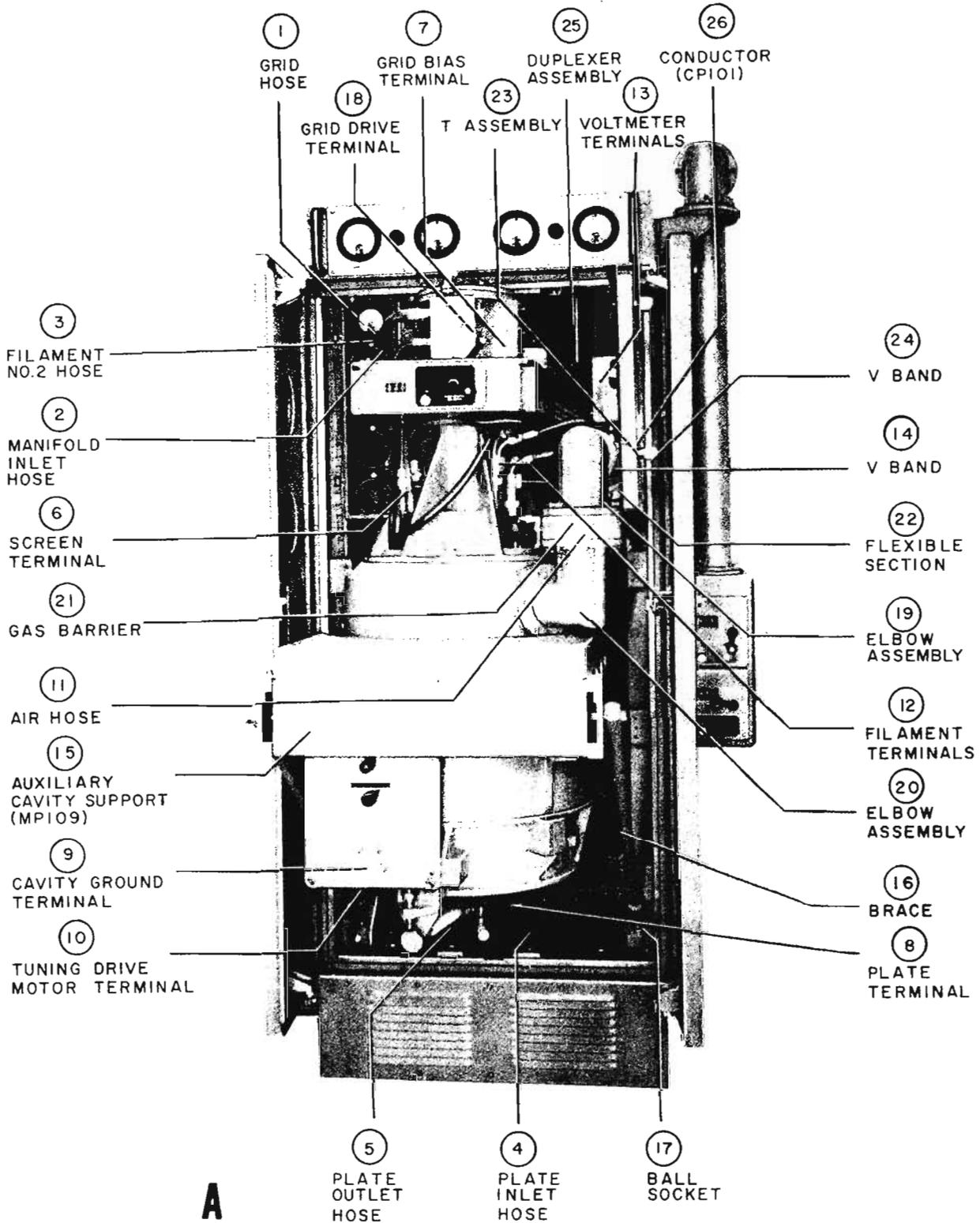


Figure 12-15A.—Power Amplifier Tube and Cavity Assembly.

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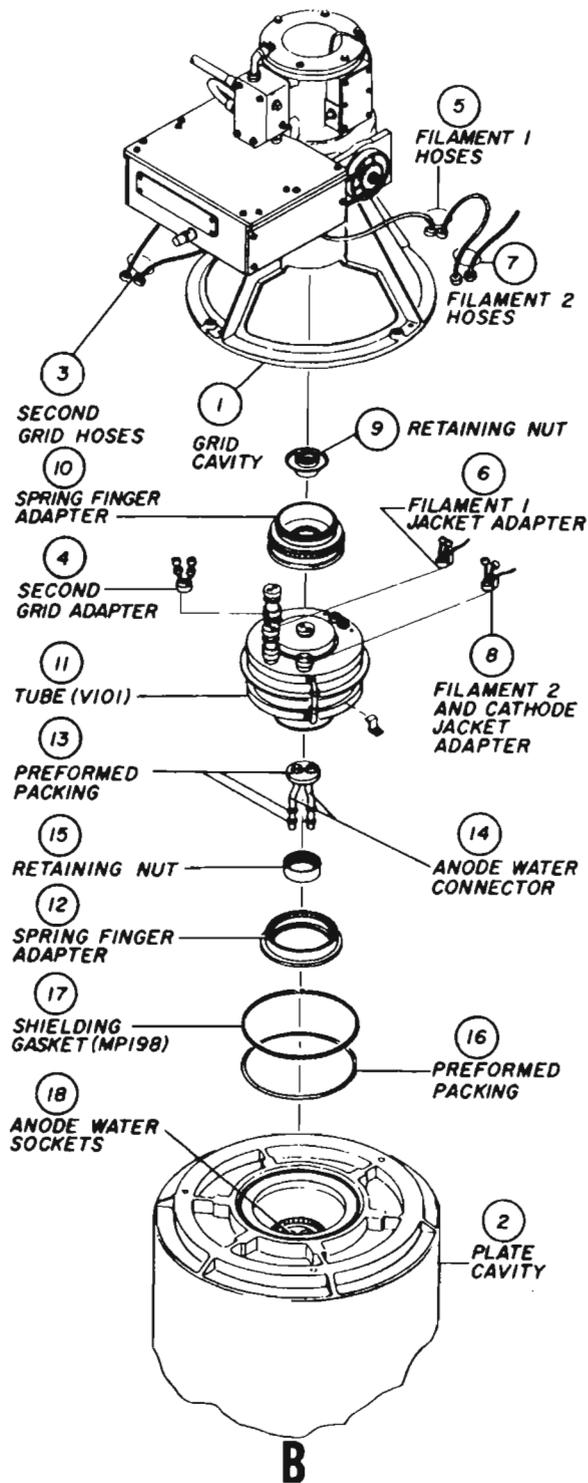


Figure 12-15B.—Power Amplifier Tube and Cavity Assembly.

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Separate water-filled jackets for each tube element permit independent cooling. The coolant necessary to maintain the elements at safe operating temperatures is provided by the electron tube liquid cooler (fig. 12-1, A). The part of the hydraulic system contained in the radio frequency amplifier is shown in figure 12-16.

In operation, the metal liquid storage tank supplies makeup coolant water for that lost in the cooling unit and hydraulic system and also acts as an expansion tank when the coolant water becomes heated. The tank must be manually filled with distilled water.

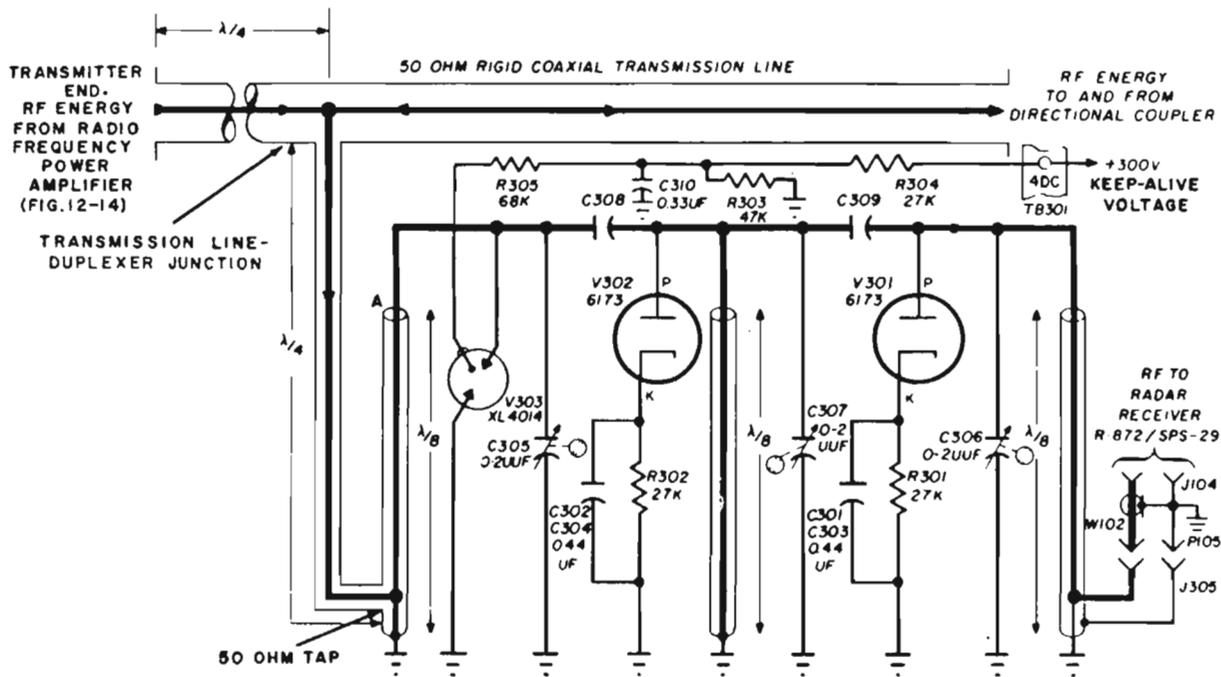
Rotary pump U4601 forces coolant water through pressure regulating valve U4603 and coolant filter U4622 to the various coolant jackets of the power amplifier tube. Approximately 7 GPM flow through the plate jacket while the remainder is split between the jacket for grid 1 (control grid) in one path, and through the series arrangement of grid 2 (screen grid), filament 1 jacket, and the filament 2 and cathode jackets in the other path. The main flow through the plate jacket is monitored by thermometer M108, and flow indicator M107.

The pressure in all three paths and the temperature of paths one and two combined are monitored by pressure switches S113 through S115, and thermostats S116. These switches act as interlocks to control the application of power to the filament of the power amplifier tube V101 (fig. 12-14).

DUPLEXER

During transmission, the duplexer (fig. 12-17) effectively disconnects the radar receiver from the transmission line to prevent the high r-f energy transmitter pulses from entering and damaging the first stages of the receiver. The length of the line between the transmitter and duplexer line junction is effectively one-quarter wavelength. The energy from the transmission line is fed to the duplexer through another one-quarter wavelength stub. This stub is connected to a 50-ohm impedance point on a one-eighth wavelength stub at the duplexer input.

The one-eighth wavelength stub acts as a step-up autotransformer to produce a potential at TR-tube, V303, sufficiently high to fire the tube at low r-f input amplitudes from the transmission line. A keep-alive voltage on V303 allows the tube to conduct at the beginning of the transmitter pulse. The input r-f potential



032.223

Figure 12-17.—Duplexer.

is also applied to diodes V302 and V301 through C308 and C309 so that both diodes conduct on positive half-cycles of the r-f signal.

The combined conductions of the TR tube and the diodes create a low impedance at Point A, $3/8$ wavelength from the transmission line duplexer junction. This results in a reflection of a high impedance at the transmission line input, and the r-f energy transmitter pulses pass down the transmission line rather than through the duplexer to the receiver.

Capacitor C305 tunes the input one-eighth wavelength line to resonance in the 215.5 to 224.5 mc range. Capacitors C307 and C308 perform the same function for their respective one-eighth wavelength stubs.

During the receiving interval (transmitter off) a short circuit in effect appears at the transmitter end of the transmission line, which is one-quarter wavelength away from the transmission line duplexer junction. The high impedance reflected to the transmission line duplexer junction permits the received echo to travel down the transmission line and the duplexer one-quarter wavelength stub to the 50-ohm tap on the one-eighth wavelength duplexer input stub. The received signal is then passed through C308 and C309 to the radar receiver.

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As with all radar systems, a transmitter pulse precedes the receiving interval. It has been shown that the diodes V302 and V301 conduct during the transmitter pulse through their cathode impedances R302-C302 and R301-C301, respectively. Because of the large time constant of these networks with respect to the pulse repetition rate of the radar system (approximately 300 pps) the positive voltage developed at the V302 and V301 cathodes to ground during transmission cannot be appreciably reduced between pulses. The action is similar to that of a clamping circuit, and the cathodes of V302 and V301 are biased positive to ground.

The echo energy level during reception is not high enough to cause the TR tube to conduct, nor is it high enough to overcome the positive bias at the V302 and V301 cathodes. Thus, these tubes do not conduct and the echo signal is passed through the duplexer to the receiver via J305.

POWER AND VSWR MONITOR

The determination of transmitter power and the standing wave ratio on the radar transmission line require equipment capable of sensing incident and reflected waves. A device which

differentiates between these two waves traveling in opposite directions in the transmission line is called a directional coupler.

Directional Coupler

The directional coupler for the AN/SPS-29 radar system is located in the r-f energy transmission path between the power amplifier and transmission line tuner (fig. 12-8). The device is a resistive loop type coupler which is situated in a section of rigid coaxial transmission line.

The directional coupler consists of two sections, each the same as that shown in figure 12-18A. One section is responsive to the incident components on the line while the other responds to the reflected component.

Lines 1 and 4 represent the rigid coaxial main line. Lines 2 and 3 are formed from another coaxial line whose inner conductor is made into a loop inside the main line and whose outer conductor is made common to the outer conductor of the main line. For this discussion, each of the lines is considered to be terminated in its characteristic impedance.

A general explanation of the directional coupler operation is as follows: The incident electromagnetic wave traveling down the main line in the direction shown will cause electric and magnetic energy components in the loop and a resultant current in lines 3 and 2. Line 3 is terminated in its characteristic impedance so that the current which flows in this section will cause the generation of a true power which is totally dissipated by Z_{O3} . If the main line energy consists of the incident wave only, two voltages which are equal and opposite in phase will be generated in line 2 and the resultant line 2 current will be zero. Likewise, the line 2 output voltage is zero.

The method by which the currents are produced in lines 2 and 3 is explained with the aid of the simplified (equivalent) circuit in figure 12-18B. Because of the physical arrangement of the inner and outer conductors of the main line, a capacitance will exist between the conductors which is equally distributed in all directions around the line. An examination of any cross section of the line will show two capacitors, C1 and C2, each of which connects from the center conductor of the main line to the common outer conductor of lines 1 through 4. The voltage established across these capacitors when r-f energy is propagated down the line is developed by the electric field in the main line. Thus the voltage across C1 is due to the E field applied to lines 3 and 2 in parallel.

The loop "L" can be considered as an inductance which is connected in series with lines 3 and 2. When r-f energy passes down the main lines, the H field induces a voltage in the loop, a portion of which is applied in series with lines 3 and 2. A resultant current flows through lines 3 and 2 in series.

During the instant when the main line voltage e_1 has the polarity shown, the C1 voltage (created by the electric field) tries to produce a current i_2 through Z_{O2} in the direction shown by the solid arrows, while the e_2 voltage induced in L (by the magnetic field) tries to produce a current i_2' through Z_{O2} in the opposite direction. If the voltage components e_{C1} and e_2 are equal and in phase, as will be the case when there is no reflected voltage on the main line, the total current through Z_{O2} (in line 2) will be zero and no power will be dissipated in the line 2 impedance Z_{O2} . However, in line 3 the current components are additive and power is dissipated in Z_{O3} .

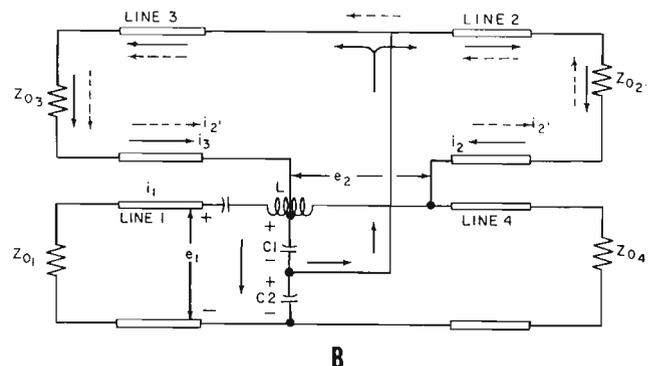
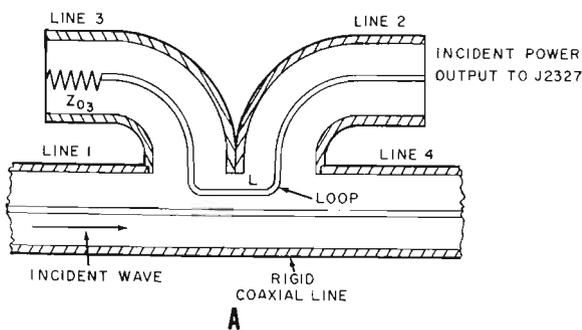


Figure 12-18.—Directional Coupler.

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If a reflected component does exist on the main line, voltages e_{C1} and e_2 will be out of phase (one reaching its maximum amplitude before the other). Total cancellation of currents in Z_{O2} will not occur and a resulting power output from line 2 which is proportional to the incident component of the main line energy will be developed at Z_{O2} .

From this discussion, it can be seen that when no reflected component exists on the main line, zero power is dissipated in line 2. However, power is delivered to the directional coupler at all times, requiring that some portion of the coupler must be capable of dissipating the total coupler power regardless of the relationship of the incident and reflected power on the main line.

Total power dissipation is accomplished in the following manner: During the instant of zero current through Z_{O2} (as described above) the voltage across $C1$ causes a current i_3 through Z_{O3} . The value of Z_{O3} is the same as the characteristic impedance of line 3 so that all of the power delivered to the coupler, when there is no reflected voltage, is dissipated in Z_{O3} .

If a reflected voltage does exist on the main line, e_1 and e_2 are out of phase, and voltage e_2 will cause a current i_2 to flow through Z_{O2} and Z_{O3} in series. This action causes power dissipation in the line 2 and line 3 impedances. As foretold, the power delivered to Z_{O2} is proportional to the relative magnitudes of the incident and reflected voltages on the main line.

The output power from Z_{O2} is fed to the power and VSWR (voltage standing wave ratio) circuits (fig. 12-8) for detection and amplification. A meter and meter selector switch (not shown) located on the power monitor permits the reading of the incident power, the reflected power, and the voltage standing wave ratio. The meter can also be connected into a VSWR calibrate circuit.

TRANSMISSION LINE TUNER

The purpose of the transmission line tuner (fig. 12-8) is to minimize the voltage standing wave ratio caused by impedance mismatches of the transmission line elements and transmission line terminations. Its effect is to adjust the transmission line length for the various operating frequencies in the operating range of AN/SPS-29. The correction is accomplished by introducing shunt impedances in the line to remove any reactive component.

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The transmission line tuner (fig. 12-19) consists of two coaxial stubs, approximately one-half wavelength long, which are spaced one-eighth wavelength apart. The stubs contain shorting blocks which may be moved up or down to vary the effective length of the stub. The movement of the shorting blocks is accomplished by mechanically gearing to a handcrank.

The impedance mismatch (reactance) at the input to the tuner is nullified by positioning the shorting block of stub No. 2 and the one-eighth wavelength section to cancel the reactive impedance of the line. In the same manner, the shorting block of stub No. 1 is adjusted so that its impedance in parallel with the input impedance of the one-eighth wavelength section presents the characteristic impedances at the input to the low-pass band-pass filter which follows (fig. 12-8).

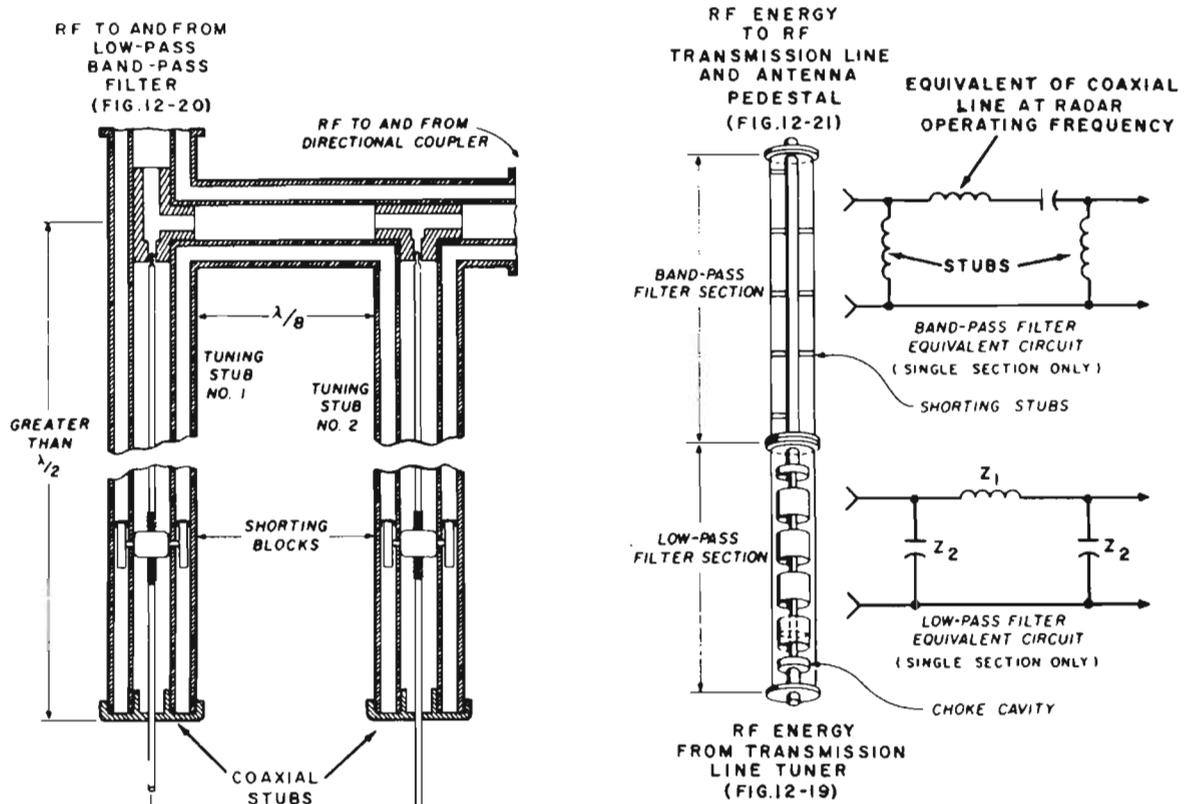
Two sections of transmission line type filters are used; one is a low-pass filter (fig. 12-20) which rejects harmonic content in the radar output pulse, and the other is a band-pass filter which rejects frequencies lower than the fundamental. The r-f energy from the transmission line tuner is coupled to a section of transmission line adapter (not shown) which acts as a transformer to match the 50-ohm impedance of the transmission line to the impedance of the low-pass filter section.

The center conductor of the low-pass filter passes through a series of cavities which act as chokes. The inductive action of these chokes and the capacitive shunting effect of components in each section make up a conventional low-pass pi-type filter as shown in the equivalent circuit. This type filter is also called a constant K filter because the product of the impedances Z_1 and Z_2 is always equal to a constant (K^2).

Some of the choke cavities are larger than others. In the larger cavities the center conductor connects to the midpoint so that they are actually two choke cavities back to back. Thus, frequencies above the pass region are rejected.

The band-pass filter section consists of four sections of coaxial transmission line shorted at one-half wavelength points by inductive stubs. Because the coaxial transmission line acts like a series resonant circuit at the radar operating frequency (see band-pass equivalent circuit) and the shorting stubs behave as inductances, the half wave section is equivalent to a band-pass filter.

Below the band-pass frequency the transmission line moves away from a series resonant circuit and the stubs appear as short circuits.



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Figure 12-20.—Low-pass Band-pass Filter.

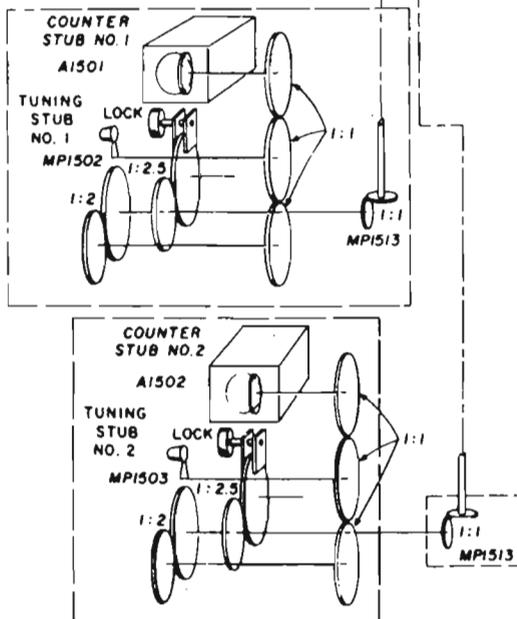
The band-pass filter section of the coaxial line will act as a pass network to harmonics of the fundamental frequency (the equivalent network does not apply). However, the low-pass filter section discussed above removes the undesirable harmonics that may be present, with the result that only the fundamental frequency is transmitted.

R-F TRANSMISSION LINE

The line which connects the below-deck components of the radar set to the antenna pedestal is a 50-ohm air-dielectric rigid coaxial line. Elbows of 45 and 90 degrees are used where bends are necessary. A short flexible section of coaxial line is used to connect the rigidly mounted line to the shock-mounted transmission line tuner.

ROTATING JOINT OF ANTENNA PEDESTAL

A rotating joint located in the antenna pedestal (fig. 12-1, A) provides a means of conducting the r-f energy from the stationary antenna pedestal to the rotating antenna array. A rigid



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Figure 12-19.—Transmission Line Tuner.

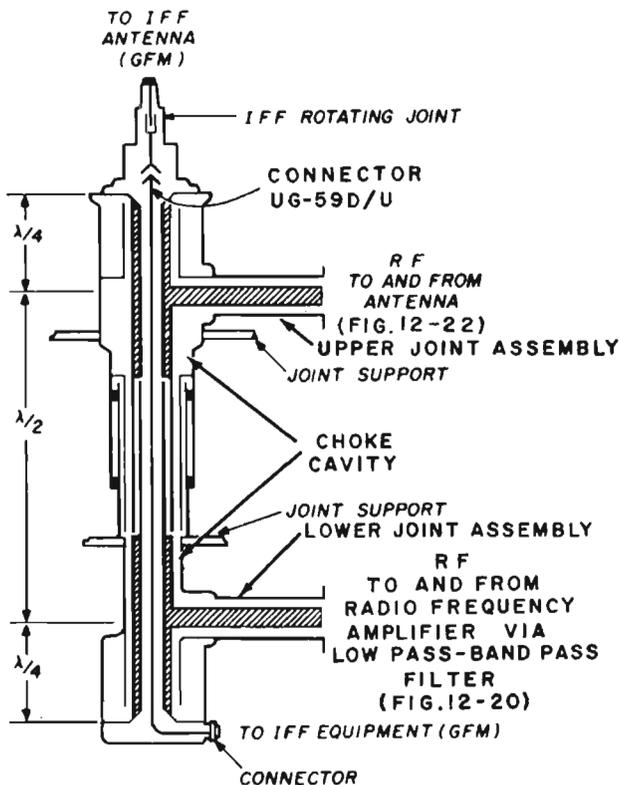


Figure 12-21.—Rotating Joint.

r-f coaxial line connects the low-pass band-pass filter (fig. 12-20) to the lower (stationary) section of the rotating joint (fig. 12-21). The upper section of the rotating joint is connected through rigid coaxial line to the feed array of the rotating antenna.

The rotating joint is of coaxial design. Currents are maintained across the mechanical discontinuity created between the rotary and stationary joints by a choke cavity. The cavity is approximately one-half wavelength long measured between the input of the lower joint assembly and the output of the upper joint assembly. In this manner, the high impedance of the break appears as a low impedance one-quarter wavelength away, which coincides with the r-f input and output connections. Thus, the r-f line appears continuous to r-f energy entering the antenna pedestal.

The center conductor of both the rotating and stationary sections extends beyond the r-f junction points approximately one-quarter wavelength before the physical construction of the antenna pedestal causes a d-c short to exist. The reflected impedance from these two points will be high one-quarter wavelength

away. Thus, the r-f energy flows only towards the break at the rotating point.

When an IFF antenna is used, the IFF signal is coupled through a separate transmission line to the IFF input of the antenna pedestal. The transmission line passes through the center of the r-f conductor. Near the top of the rotating joint, the IFF conductor is coupled to a standard IFF rotating joint. The IFF antenna is connected to the IFF connector at the top of the rotating joint.

ANTENNA

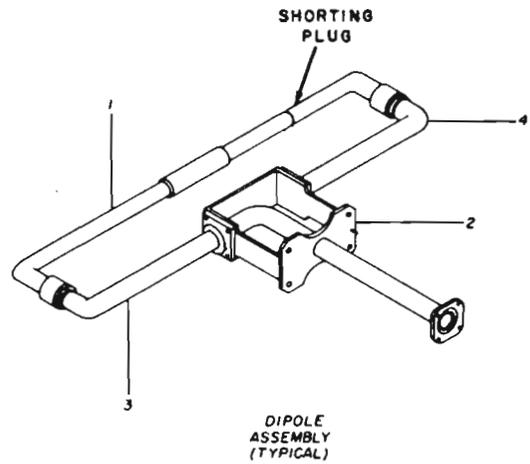
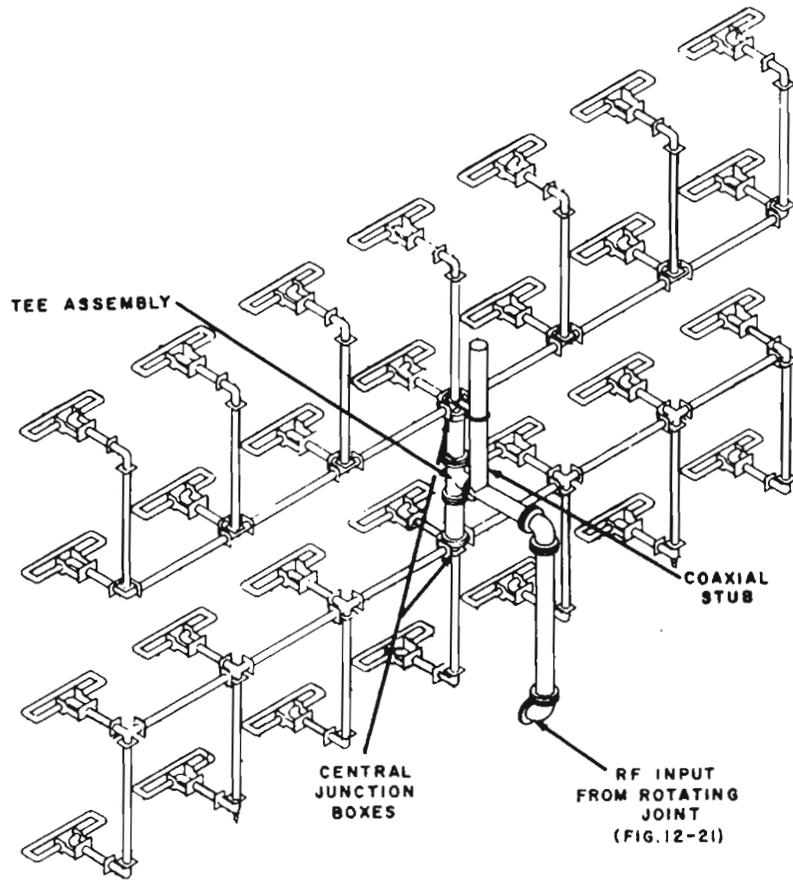
The fundamental principle of antenna is that currents, alternating at a radio frequency and flowing in a conductor of finite length, will produce electromagnetic fields which will radiate from the conductor into space. The AN/SPS-29 radar antenna (fig. 12-22) consists of a system of dipoles (conductors) which serve to radiate or intercept energy in the form of electromagnetic waves.

A pulse beam of high power r-f energy is transmitted, and subsequent echoes received. The beam is relatively narrow in azimuth and broad in the vertical plane.

The antenna dipoles are connected in a broadside array, so named because electromagnetic radiation is almost entirely limited to its "broadside" as perpendicular to the antenna plane. This arrangement virtually eliminates antenna side lobes and results in high concentration of the major part of the radiated power in the primary radiation lobe.

The r-f energy is fed from the rotating joint of the antenna pedestal through a rigid coaxial line to the input of the antenna (fig. 12-22). Immediately after the antenna input connection, a fixed tuning section is placed in the antenna feed line. The tuning section reduces the voltage standing wave ratio in the line, thereby permitting transmission of greater power through the feed line and providing a good impedance match.

Tuning is obtained by means of a shunt-susceptance (coaxial stub) which tunes out the reactive components of the mismatch. The resultant impedance at this point is a minimum reactive component, but a resistive (real) component too small to match the coaxial transmission line. A quarter-wave transformer section is added to transform the real component to the 50-ohm impedance of the transmission line. The resultant impedance matching reduces the overall antenna and pedestal voltage standing



DIPOLE ASSY.	CONSISTS OF			
	1	2	3	4
E4701	E4715	E4713	E4714	E4730
E4702	E4728	E4713	E4714	E4730
E4703	E4729	E4713	E4714	E4730
E4704	E4731	E4713	E4714	E4730

Figure 12-22.—Antenna Array. 032.228

wave ratio to less than 1.5:1 over the 215 to 225 mc band.

The tie assembly, which forms the central distribution point of the antenna feed array, is connected to the tuning section of the antenna. Power is divided equally at the tie assembly to feed the upper and lower halves of the antenna feed array. The section from the center tie assembly to the central junction boxes is one-quarter wavelength long. The one-quarter wavelength section reflects high impedance to the tie assembly thus providing maximum r-f energy transfer into the two halves of the antenna feed array.

Power divides at each central junction box. The two horizontal arms are connected to low impedance coaxial lines and will therefore absorb the major share of the power available at the central junction box.

The horizontal arms feed junction boxes on each side of the central junction box. At each junction box, power is divided to feed the dipoles in front of the box, the dipole above or below the box, and the next junction box. The dipole immediately in front of the central junction box is fed a slightly smaller amount of power than the horizontal arms. A vertical run feeds power to the dipole above or below the junction box (above in the upper half of the

antenna, and below in the lower half). The vertical and horizontal spacing of all adjacent junction boxes is one-half wavelength. This requires that the adjacent dipoles in the vertical and horizontal runs be of reverse polarity to produce in-phase radiation.

The folded dipoles are approximately one-quarter wavelength in front of the reflector. Each dipole is fed by a coaxial line inside one arm. The feed line, three-quarter wavelength long, also serves as an impedance transformer to connect the 200 ohms feed point impedance of the dipole to the 52-ohm impedance of the junction box flange.

At the feed points, currents inside the outer conductor of the feed line flow onto the outside conductor of the antenna, exciting half of the dipole. Currents on the inner conductor of the feed line are fed, through a shorting plug between the inner and outer conductors, to the outer half of the dipole. Proper current distribution to produce the lowest side lobe levels is obtained by varying the position of the shorting plugs for groups of dipoles in the array. The grouping of the dipoles is necessary because of the coupling effects between adjacent dipoles.

The radar receiver, range indicator, and oscilloscope are discussed in chapter 13 of this text.

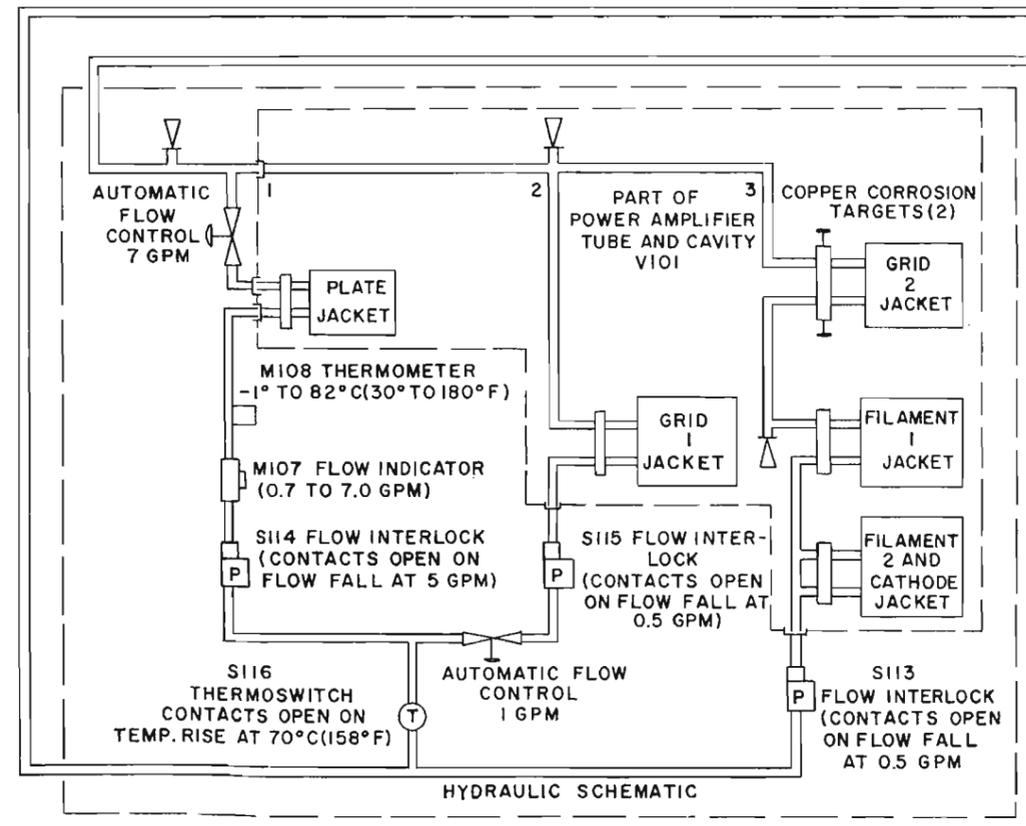
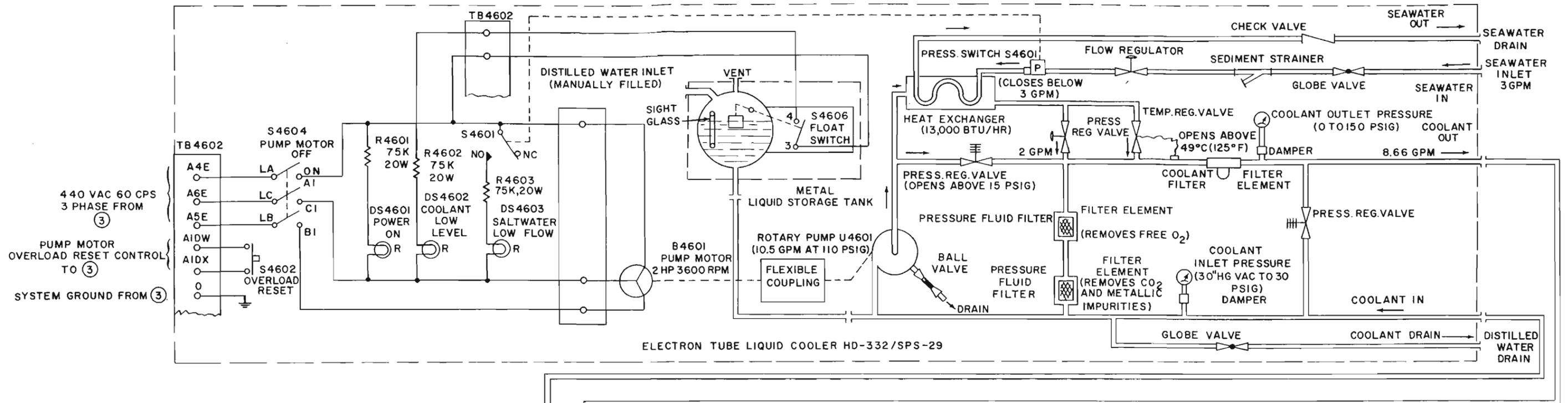


Figure 12-16.—Electron Tube Liquid Cooler and Hydraulic System.