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TRANSLATION

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SOVIET NAVIGATION RADAR STATION "NEPTUN" (PART II)

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T R A N S L A T I O N

Number 352 28 Feb 1955

SOVIET NAVIGATION RADAR STATION "NEPTUN" (PART II)

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S U M M A R Y   O F   C O N T E N T S

Soviet Navigation Radar Station "Neptun" (Part II)

This report describes the Soviet navigation radar station "Neptun" and supplements the information contained in FDD Translation 346.

The report contains the complete text of the Russian-language description entitled Opisaniye Radiolokatsionnoy Navigatsionnoy Stantsii "Neptun" (Description of Navigation Radar Station "Neptun"), 33,650,007-T01 [Copy No 8147?], and the appendixes: Poyasnitel'nyye Illyustratsii k Tekhnicheskomu Opisaniyu Radiolokatsionnoy Stantsii "Neptun" (Explanatory Illustrations for Technical Description of Navigation Radar Station "Neptun"), 33,650,007-T02, Copy No 8147; Al'bom Photografiy k Tekhnicheskomu Opisaniyu Radiolokatsionnoy Navigatsionnoy Stantsii "Neptun" (Album of Photographs for Technical Description of Navigation Radar Station "Neptun"), 33,650,007-AF, Copy No 8147; and schematic diagrams of station "Neptun".

All tables and illustrations in the source have been reproduced in the text.

Pages 1 through 118

SOVIET NAVIGATION RADAR STATION "NEPTUN" (PART II)

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NOTES

Errata in Soviet Navigation Radar Station "Neptun" (Part I) (FDD Translation 346):

1. For "Usileniye po 60" [Gain by 60] read "Usileniye po B.O." [Gain for Nearby Objects].

2. For "Otr. Imp. i Metki" [Pulse and Mark Regulation], read "Otr. Imp. i Metki" [Reflected Pulses and Marks].

CONVENTIONAL SYMBOLS IN THE TEXT

Explanations for the Use of Block and Schematic Diagrams

1. Each block of the station is designated by a letter; units which make up the blocks are designated by the letter of the block in which the unit is located and a number signifying the number of the unit within its block.

Table of Designations

a. Units in the Main Indicator (Block "I")

- I-1 Frequency generator
- I-2 High-frequency rejection filter
- I-3 Movable range circle pulse-forming unit
- I-4 Trigger pulse-forming unit
- I-5 Sweep unit
- I-6 Indicator cathode-ray tube unit
- I-7 Main intermediate-frequency amplifier
- I-8 Power-supply unit
- I-9 Control panel
- I-10 Indicator scale mechanism
- I-11 Check panel
- I-12 Video mixer
- I-14 Selsyn unit
- I-15 Quadrature circuit
- I-16 Range finder
- I-17 Delay line

b. Units in the Receiver-Transmitter (Block "P")

- P-2 Superhigh-frequency unit
- P-3 Intermediate-frequency preamplifier
- P-4 Automatic frequency-control unit
- P-5 Magnetron oscillator
- P-6 Modulator with pulse-forming lines
- P-7 High-voltage rectifier
- P-8 Modulator power-supply unit

c. Units in the Remote Indicator (Block "V")

- V-1, V-2, V-3 Sweep pulse amplifiers
- V-4 Cathode-ray tube unit
- V-5 Video amplifier
- V-6 Control panel
- V-7 Check panel
- V-8 Power-supply unit
- V-9 Delay line

 Except British, Canadian & Australian per LO/CR Nov '58

d. Units in the Antenna-Waveguide Assembly (Block "A")

A-1 Antenna-waveguide assembly
A-2 Antenna drive

e. Antenna Drive Heater-Connection Block (Block "B")

2. Circuit components are designated by the following letters:

Tube	L
Resistor	R
Capacitor	C
Self-induction coil	L
Transformer	T
Choke	Dr
Relay	RE
Measuring instrument	Z
Component (switch, socket, contact plug, etc.)	D
Cable boxes, feeder	B
Cables	K

3. Each component of the circuit is given a designation which includes the character of the component, its order number in the units, and the designation of the unit in the block. For example, the designation C-09-I5 indicates the capacitor in the 9-position of the sweep unit in the main indicator.

4. The system of designations for terminals is as follows:

a. Each voltage or circuit is given a number which is marked at the terminals.

b. The terminals of different units which carry the same voltage and belong to the same circuit are designated by the same number.

c. The terminals on plugs of units in each block which are designed for connections between the blocks are numbered independently.

Terminals on the output plugs of units and blocks, to which are connected circuits common to other blocks, have a common conductor numeration for the whole station.

5. Shown on the general diagram for each block are the cables which connect that block to the other blocks of the station.

Interblock cable connections are shown on the connection diagrams of the station "Neptun" (Sketches 33,650,007-SS 1, 2, 3), on which each cable is given its own number.

I. GENERAL INFORMATION ON THE STATION

A. Purpose

The "Neptun" navigation radar station gives a picture of the water-surface navigation conditions surrounding a ship in order to allow it to sail close to banks in confined waters and along protected channels, independent of conditions of visibility.

The station guarantees the possibility of entering and leaving port, identifying the shore, and preventing collision with surface obstacles and ships encountered.

The station is recommended for installation on various ships of not less than 600 tons displacement.

B. Composition and Disposition of the Station

1. Composition of the Station

The station consists of the following separate blocks:

a. Main indicator (Block "I")
b. Receiver-transmitter with echo-box (Block "P")
c. Remote indicator (Block "V")
d. Antenna-waveguide assembly (Block "A")
e. Heater connection block (Block "B")
f. Converters for changing the ship's line voltage (ac or dc) into 230-v, 427-cycle ac current and starting-regulating apparatus

In addition, the station includes the following:

a. ZIP [Stock of measuring instruments] including control-measuring apparatus.

b. Dehydrator

c. Auxiliary equipment (telephone-communication boxes, junction boxes)

2. Dimensional Data of the Station

The dimensions, weight, and heat dissipation of each of the principal instruments of the "Neptun" station are given in the following table:

Number	Name of Instrument	Dimensions (mm)	Weight (kg)	Heat Dissipation (kw)
1	Main indicator	540x781x1,420	223	0.60
2	Receiver-transmitter	576x560x930	115	0.54
3	Echo-box	150x160x560	7.0	--
4	Remote indicator	420x533x1,345	140 + 5	0.40
5	Antenna-waveguide assembly	1,610x940x1,010	110	--
6	Heater connection block	266x143x222	5	--
7	Power-supply units			
	PR-3	410x995x465	240	1.7
	or PR-4	355x740x405	170	1.7
	or PR-1	360x940x405	145	1.3
	or PR-2	282x680x335	110	1.3
8	Starting-regulating apparatus			
	(a) Magnetic two-circuit starter	645x230x500	48	--
		or		
		645x(190)x500	40	--
	(b) Remote starting buttons	213x130x275	5	--
	(c) Compensation and regulation block	425x215x405	28	--
9	Dehydrator	400x230x400	20	0.1
10	ZIP I and ZIP II connecting ZIP [Stock of measuring instruments] to the units	--	about 117	--

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3. Disposition of the Station on the Ship

The disposition of the instruments on the ship should be such as to assure convenient access when assembling them during installation and when drawing them out of their housings for inspection or repair.

The places where the principal blocks of the station are installed must be provided with ventilation sufficient to guarantee normal room temperature regardless of the heat dissipated by the blocks of the station. In order to carry off heat generated inside a block, there must be air spaces between the walls of the block and nearby items of ship's equipment.

In spacing the blocks it is necessary to provide that the distance from the deck to gaskets or cable inputs will be such that the radius of curvature of the cables will be adequate to allow for sufficient shock-absorption movement of the blocks.

The route where the waveguide and feeders are laid should be protected from mechanical damage. Sections of the route which may be subjected to heat should be provided with heat insulation.

All instruments should be so placed as to make them the most convenient to operate.

[Comment: A hiatus occurs in the text at this point.]
... general considerations ... in view when installing the station "Neptun."

The apparatus of the station should be installed at the following posts:

a. In the wheelhouse

(1) The main indicator
(2) The heater connection block (block "B")
(3) Remote starting knob
(4) Control block for the power-supply unit
(5) ZIP [stock of measuring instruments], first line.

b. The receiver-transmitter is installed at a location determined by the type of ship and the conditions governing the location of equipment on it.

c. The remote indicator is located on the captain's bridge.

d. The antenna-waveguide assembly is located on the foremast or on a special tripod.

e. The following are located as a group in a common area as close as possible to the station:

(1) Power-supply unit with its two-circuit magnetic starter

(2) Regulation and compensation block.

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f. The dehydrator is located in direct proximity to the receiver-transmitter.

g. The telephone communication boxes for telephone communication between the posts are placed where the separate blocks are located and in direct proximity to them.

h. The junction box for connection with the telephone trunk line can be located in any dry place which is convenient for wiring between the blocks of the station.

i. The ZIP [stock of measuring instruments], second line, can be located in any dry, heated place.

4. Location of the Main Indicator (Block "I")

The main indicator is installed in the wheelhouse in direct proximity to the chart table. The face panel must face the chart. If there is a magnetic compass in the wheelhouse, the indicator should be installed not less than one meter from it.

There should not be strong sources of light near the indicator, since this will obstruct the work of the operator. The indicator should be so located that all its controls are accessible and the PPI screen can be viewed conveniently. In addition, provision should be made for drawing the indicator out of its housing to allow for inspection, replacement of tubes, or repairs.

5. Location of the Receiver-Transmitter (Block "P")

The receiver-transmitter should be located in a closed, shielded and heated place. The length of the waveguide path should not exceed 20 meters. The waveguide should be laid as straight as possible. The number of bends and turns should be kept to a minimum. The length of cable connecting the receiver-transmitter with block "I" should not exceed 30 meters.

The distance between the receiver-transmitter and the magnetic compass should not be ...

[Comment: A hiatus occurs in the text at this point.]

Echo-box EP-1 is to be installed at a distance not greater than one meter from the transmitter and is connected to the transmitter block with a cable and feeder.

6. Disposition of the Remote Indicator (Block "V")

The remote indicator is of water-resistant construction. It is installed in the bridge or head house as far as possible from the magnetic compass and not closer than one meter to it.

The front panel of the remote indicator should face toward the stern.

The length of cables connecting the remote indicator to the main indicator should not exceed 50 meters.

7. Disposition of the Antenna-Waveguide Assembly (Block "A")

So that the station will have as small a "dead zone" as possible, the antenna should be installed not more than 12-15 meters above sea level. If the antenna is set higher, this "dead zone" will increase. It is desirable to install the antenna not on a mast, but on some part of the ship's superstructure or on a special base.

In order to insure as complete as possible a circle of sweep, there should be no screening objects ahead or abeam of the antenna on the same level with it. It is also desirable that objects located astern be at a sufficient distance from the antenna.

When the antenna beam is directed parallel to the diametral plane of the ship, the index of the antenna scale should indicate zero.

In selecting the place to install the antenna assembly, care should be taken that hot gases from the funnel (or any other place) do not fall on the assembly.

Convenient access to the antenna should be provided so that necessary adjustments can be performed during installation and periodic inspections can be carried out in the process of operation.

8. Diagram of Interblock Connections

Depending on the type of current in the power line, the station can have the ten arrangements listed below, whose interblock connection diagrams are presented in the following drawings:

33,650,007-SS1 (arrangements 1 and 2)
33,650,007-SS2 (arrangements 6 and 7)
33,650,007-SS3 (arrangements 3, 4, 5, 8, 9, and 10)

Fitting the power-supply unit to the station in accordance with the type of arrangment is shown in the following table:

Arrangement No	Type of Machine Unit	Rated Voltage at Input (volts)	Type of Antenna Rotation Motor
1	PR-3	220 dc	SL-661R
2	PR-3	110 dc	SL-661R
3	PR-4	380 ac	I 10/4
4	PR-4	220 ac	I 10/4
5	PR-4	127 ac	I 10/4
6	PR-1	220 dc	SL-661
7	PR-1	110 dc	SL-661
8	PR-2	380 ac	I 10/4
9	PR-2	220 ac	I 10/4
10	PR-2	127 ac	I 10/4

C. Brief Technical Data on the Station

1. Main Indicator

(See Album of Photographs for the Station "Neptun," photos 1, 2, 3, and 4.)

The main indicator is the block which coordinates the processes taking place in the whole station. The control elements for the whole station are concentrated on the control panels of the main indicator. Strictly as an indicator, it fulfills the following functions:

a. Provides a picture of surrounding conditions on the surface of the water on the screen of the cathode-ray tube

b. Makes it possible for the mate to determine the distance to objects on the surface of the water and the direction to them

The distance to any surface object can be measured with the indicator. The accuracy of measurement fluctuates within the limits of 0.6 to 3%, depending on the range scale on which the measurement is performed.

The direction to an object can also be measured, with an error of the order of 2°.

Determination of the distance to an observed object is performed with the aid of the movable and fixed range circles, while the direction to the object is determined with the aid of the scales and the rotating sight.

The indicator uses cathode-ray tube type 31LM32 with magnetic deflection and focusing and prolonged afterglow.

The image on the screen is formed by a PPI sweep in a polar system of coordinates in which the origin coincides with the location of the ship.

The indicator has four range scales for different distance ranges.

Accurate range calculation is performed with the range finder counter by matching the movable range circle with the image of the object. Bearings are calculated on the scales of the indicator CRT with the aid of the rotating sight.

The image on the indicator screen can be oriented according to the head of the ship or, when coupled to the gyrocompass, according to the meridian.

The main indicator can be located at a distance from the transmitter such that the length of the cables connecting them does not exceed 30 meters. The length of connecting cables from the main indicator to the antenna can be up to 20 meters.

2. Receiver-Transmitter

(See the Album of Photographs for the Station "Neptun," photos 13, 14, 15, 16, and 17.)

The transmitter generates pulses of high-frequency energy with a power of the order of 30-35 kw in a pulse.

The pulse-repetition frequency is 2,700 and 675 times per second for pulse durations of 0.25 and 1, respectively. In all cases the average power generated by the transmitter is approximately 25 watts. The transmitter uses a magnetron of type MI-201. Connected to the output of the modulator is a tube type GMI-83 (G-483), from whose plate 12,000-volt pulses go to the magnetron.

The station has a receiver of the superheterodyne type with a crystal mixer and an i-f amplifier using 6Zh4 (6AS7) tubes. The sensitivity of the receiver relative to a tangential signal is not less than 1 x 10-11 watt. The tangential signal is a signal fed to the input of the receiver which shifts the amplitude of observed noises to a value equal to their natural amplitude; the image obtained on an oscilloscope screen has the form given in Figure 1 (see the Explanatory Illustrations to the Description).

The pass band of the receiver is equal to 6 Mc at the half power point. The receiver has automatic and manual frequency tuning, automatic regulation of sensitivity according to distance, and a circuit for differentiating received signals. The automatic frequency control is a follower system with rapid oscillation and slow search operating on thyratrons of type TG1-0.1/1.3 (TG-2050) and TG1-0.1/0.3 (TG-884) and based on electrical tuning of the klystron frequency.

3. Remote Indicator

(See the Album of Photographs for the Station "Neptun," photos 25, 26, 27, and 28.)

The remote indicator reproduces on a smaller scale the image obtained on the screen of the main indicator.

The remote indicator utilizes cathode-ray tube type 18LM35 with magnetic deflection and focusing and prolonged afterglow. The diameter of the screen is 175 mm.

The remote indicator has the same sweep as the main indicator and the same range scales.

Determination of distances to objects, and their bearings, on the remote indicator is performed by methods analogous to those used on the main indicator.

The image on the screen of the remote indicator is stabilized simultaneously with that of the main indicator in respect to either the head of the ship or the meridian.

The remote indicator can be located at a distance from the main indicator such that the length of cables connecting them is up tc 50 meters.

4. Antenna-Waveguide Assembly

(See the Album of Photographs for the Station "Neptun," photos 23 and 24.)

The antenna-waveguide assembly is designed for radiation and reception of electromagnetic energy, as well as channelization of it from the transmitter to the antenna, and from the antenna to the receiver. The antenna assembly is a system consisting of a slot radiator and a parabolic reflector rotating in a horizontal plane.

The reflector is an open parabolic cylinder the size of whose output aperture is 1,600 x 470 mm and whose focal length is 512 mm.

The antenna utilizes horizontal polarization. The angle of directivity of radiation in the horizontal plane is 1.6° at the half-power point. The span of the radiation diagram in the vertical plane is 20° at the half-power point. The power gain of the antenna is approximately 1,100-1,200 times that of a nondirectional radiator.

The antenna maintains continuous circular rotation in the horizontal plane at a speed of 14 revolutions per minute.

Synchronous coupling of the antenna assembly with the main indicator is accomplished with the aid of "rotating" transformers, for which selsyns of type SGS-1 and SDS-1 are used.

5. Electric Power Supply

The station takes its electric power supply from the ship's network. The "Neptun" station is designed for an ac power supply of 230 volts, 427 cycles. Depending on the type of current and the voltage of the ship's electric network, as well as on the power required by the station, the station receives its power supply from one of the following power-supply units:

a. For dc networks: "PR-3" or "PR-4"

b. For ac networks: "PR-4" or "PR-2"

The type of power-supply unit is selected by the ordering authority or by the planning organization which plans the installation and assembly of the station at its destination.

Power for the antenna-assembly drive is taken from the ship's network, while the heater and dehydrator circuits are supplied from the lighting circuit or other current sources assuring a continuous power supply. The heating elements can be connected to voltages of 110, 127, or 220 volts, ac or dc, which are accommodated by switches within the blocks of the station.

Depending on the type of unit selected, the power requirements of the station are:

a. For unit PR-3, 3.8 kw

b. For unit PR-4, 3.8 kw

c. For unit PR-1, 2.8 kw

d. For unit PR-2, 2.8 kw

In addition, 0.5 kva are required from the ship's network to supply the motor for rotation of the antenna assembly, the dehydrator consumes 100 w, and the station's heating elements draw 1200 w (300 w for each block).

The power-supply unit allows for considerable fluctuation of the ship's line voltage. It stabilizes the output voltage with an accuracy to ± 2%.

The unit is provided with manual and automatic voltage regulation.

II. DESCRIPTION OF THE OPERATION OF THE STATION AS A WHOLE

A. Purpose and Composition of the Blocks of the Station

The block diagram of the station given in drawing 33,650,007-SP contains the block diagrams of all the basic instruments of the station.

1. Main indicator - "I"
2. Receiver-transmitter - "P"
3. Remote indicator - "V"
4. Antenna-waveguide assembly - "A"

1. The main indicator, Block "I", contains the following units:

a. Frequency generator I-1 -- a quartz oscillator and two stages of sinusoidal dividers of the regenerative type.

b. Quadrature circuits I-15 -- L (phase-shifter stators), C, and R circuit producing a 90-degree phase shift of currents flowing through the phase-shifter stators.

c. Range finder I-16, containing an assembly of three induction-type phase shifters.

d. Movable range circle pulse-forming unit I-3 -- circuit for forming pulses from three sinusoidal voltages with amplifier and blocking-oscillator.

e. Trigger pulse-forming unit I-4 -- circuit for forming pulses from three sinusoidal oscillations, phantastron divider, and amplifier.

f. Sweep unit I-5 -- generator of saw-tooth range-sweep pulses, circuit for forming the balance wave, and generator of the pulses which produce the fixed range circles.

g. Cathode-ray tube unit I-6 -- cathode-ray tube, type 31LM32, with magnetic focusing and deflection systems.

h. Main i-f amplifier I-7 -- four-stage i-f amplifier, second detector, and two-stage video-frequency amplifier.

i. Power-supply unit I-8 -- 4 electron-tube rectifiers for the following:

(1) 3,200 volts;

(2) 300 volts stabilized and 550 volts;

(3) -300 volts stabilized and -150 volts;

(4) 300 volts and 150 volts, and selenium rectifier for 26 volts.

j. Control panel I-9 -- face panel of the indicator, on which the whole control of the station is centralized.

k. Check panel I-11 -- lower panel of the indicator, on which instruments to check the operation of the station and fuses are centralized.

l. Video mixer unit I-12 -- five-tube circuit designed to mix the reflected (received) signals with range-circle pulses and the electronic course mark.

m. High-frequency rejection filter I-2 -- LC filter designed to chop off frequencies above 81 kc.

n. Indicator scale mechanism I-10.

o. Selsyn unit I-14 -- "rotating" transformer SDS-1, meridionally stabilizing the images on the indicator screens, mechanically coupled with the receiving selsyn from the gyrocompass.

p. Delay line I-17 -- artificial long line composed of C and L.

2. The receiver-transmitter, Block "P", contains the following units:

a. Superhigh-frequency unit P-2 -- crystal mixer with "transmission" and "reception" cavities and "surveillance" and "stand-by" klystrons.

b. I-f preamplifier P-3 -- i-f amplifier with circuits for automatic gain control in respect to range.

c. AFC unit P-4 -- electronic follower system, with rapid klystron frequency oscillation and slow search, operating on thyratrons of types TG1-0.1/1.3 (TG-2050) and TG-0.1/0.3 (TG-884) and based on electrical tuning of the klystron frequency.

d. Magnetron oscillator P-5.

e. Modulator P-6 -- blocking oscillator with pulse-forming line.

f. High-voltage rectifier P-7, operating by a doubling circuit and supplying a rectified voltage of 14,000 v to the output.

g. Modulator power-supply unit P-8 -- electron-tube rectifiers for 1,300 and 1,000 volts.

3. The remote indicator, Block "V", contains the following units:

a. Sweep pulse amplifiers V-1, V-2, and V-3 -- amplifiers with high negative coupling in respect to the current of the deflection coils.

b. Cathode-ray tube unit V-4 -- cathode-ray tube, type 18LM35, with magnetic deflection system and magnetic focusing.

c. Amplifier unit V-5 -- amplifier of reflected (received) pulses and range-circle pulses in conjunction with the electronic-course-mark circuit and the intensifier-pulse amplifier.

d. Power-supply unit V-8 -- electron-tube rectifiers for -150 volts, 3,700 volts, +550 volts and +300 volts.

e. Control panel V-6 -- outside front horizontal panel, on which the main elements for controlling the remote indicator are centralized.

f. Check panel V-7 -- inner front vertical panel, containing instruments for checking and fuses.

g. Constant delay line V-9 -- artificial long line composed of L and C.

4. The antenna-waveguide assembly, Block "A", contains the following units:

a. Antenna-waveguide assembly A-1, consisting of the reflector, slot radiator, and capacitor transition.

b. Antenna drive A-2, including the antenna rotation motor (motor SL-661 is installed for dc network voltages, motor I 10/4 for 50-cycle ac), reduction gear, selsyn type SGS-1, and course-mark contact.

B. Principles of Operation of the Station

The station as a whole operates in the following fashion.

The quartz oscillator of frequency generator I-1 in the main indicator generates a sinusoidal voltage with a frequency of 80,905 cps. The period of this frequency is equal to the time for propagation of the radiated pulse to a distance of one mile out and back.

In the frequency generator itself the 80,905-cps voltage is divided successively by 6 and then by 5. Thus at the output of the frequency generator these are stable synchronous frequencies of 80,905, 13,484 and 2,697 cps. For simplicity the rounded-out values of these frequencies (81 kc, 13.5 kc, and 2.7 kc) will be used below.

The frequencies 2.7 and 13.5 kc (directly) and 81 kc (through high-frequency rejection filter I-2) supply three quadrature circuits of unit I-15 and the range finder phase shifters included in them.

From the phase regulators of the quadrature circuits the 81-, 13.5-, and 2.7-kc voltages go to the circuit of the trigger pulse-forming unit I-4. These pulses trigger the modulator of the receiver-transmitter.

From the rotors of the phase shifters of range finder I-16 the 81-, 13.5-, and 2.7-kc voltages go to the movable range circle pulse-forming unit I-3.

The pulses for both purposes are formed by selecting one of the half-cycles of the 81-kc frequency which coincide with one period of the 2.7-kc frequency, i.e., with one cycle of the main pulse sending frequency, which is equal to the time for propagation of a radiated pulse out to a distance of 30 miles and back. The pulse sending frequency of 675 cps is formed in the trigger pulse-forming unit I-4 with the help of the phantastron divider.

The method of pulse forming and the principles of operation of units I-3 and I-4 are treated in detail in Chapter III of this description.

A trigger pulse with a duration of 1.5 microseconds goes through delay line I-17 (the length of the delay is approximately 2 microseconds) to the input of the modulator of the receiver-transmitter.

The amplifier and first delayed blocking oscillator of modulator P-6 amplify the trigger pulse and feed it to trigger the second delayed blocking oscillator, which generates a positive rectangular pulse 0.25 microseconds or 1 microsecond in duration in operation on OBZOR [surveillance].

This pulse, with its duration determined by the forming line, is fed to the grid of the discharge tube and causes it to conduct.

The storage capacitor, charged by rectifier P-7 to 14,000 volts, discharges through the discharge tube and the magnetron, causing the magnetron to generate electromagnetic energy which goes along the waveguide, through the capacitor transition, to the antenna and is radiated into space.

The "priyem" [reception] and "peredacha" [transmission] cavities in high-frequency unit P-2 make it possible to receive and transmit on a common antenna.

The reflected signal, received by the antenna, goes to the input of the crystal mixer. The detected signals are fed to the i-f preamplifier P-3.

The signals amplified by the i-f preamplifier go by cable to the main i-f amplifier I-7, which is located in the main indicator. In the main i-f amplifier the reflected pulse is detected by the second detector and amplified by the video amplifier.

The reflected signal is fed from the cathode followers in the form of video-frequency pulses to the input of mixer I-12 and to feeder socket B-04-III of the check panel. The video signal, amplified by the mixer, goes to the control grid of the cathode-ray tube and modulates the brightness of the luminous spot on the screen.

Approximately 2 microseconds before the transmitter is triggered, the trigger pulse from the cathode follower unit I-4 goes to sweep unit I-5. The inertia of the sweep system and the deflection system of the cathode-ray tube makes it necessary for the triggering of the sweep to lead the triggering of the transmitter.

When the trigger pulse is fed to the sweep block I-5, the following are generated in it:

1. A saw-tooth current to supply the deflection system of the cathode-ray tube.

2. The intensifier pulse, which is fed to the cathode of the cathode-ray tube, insuring luminescence (the possibility of illuminating the screen) only during the operating cycle of the sweep.

3. Range circle pulses which, after amplification by the circuit of mixer I-12, go, together with video signal pulses, to the grid of the cathode-ray tube.

In unit I-5 there is a tube which regulates the current of the indicator CRT's focusing coil.

The pulse formed in the movable range circle pulse-forming circuit (in unit I-3) enters the circuit of mixer I-12, is amplified by it, and, together with the video signal pulse and the range-mark pulses, goes to the control grid of the indicator CRT.

Also fed to the output of the mixer, at the moment when the antenna beam passes through the diametral plane of the ship, is the electronic course mark pulse.

Thus the following are fed to the cathode-ray tube from unit I-6:

1. To the control grid

   a. Video signal pulses reflected from objects
   b. Movable range circle pulses
   c. Fixed range circle pulses, and
   d. Electronic course mark pulse

2. To the cathode, the intensifier pulse

3. To the deflection system, the saw-tooth sweep current, which forms the pulsed magnetic field which rotates synchronously and cophasally with the antenna.

The combination of all the signals listed above produces on the PPI screen of the main indicator a picture of the water-surface conditions surrounding the ship.

Visible on the screen are surrounding objects (in the form of luminous spots), the luminous fixed range circles, the luminous movable range circle (whose radius is varied by turning the range finder handle), and the luminous course-mark line (which indicates the direction of the ship's course).

The forms and amplitudes of the signals at the outputs of the main elements of the station, which clarify the principle of its operation, are shown in the table on the block (general) circuit of the station, drawing No 33,650,007-SP.

In order to prevent overloading and excitation of the receiver's input stages by a pulse from the transmitter and, simultaneously, to equalize the levels of signals reflected from near and far objects, the circuit is provided with an automatic gain control for the i-f preamplifier in respect to time (or distance). Simultaneously with the pulse of the modulating voltage, which is fed to the magnetron, a negative bias pulse, which then drops exponentially to zero, is supplied to the grids of the tubes of the i-f preamplifier from the second blocking oscillator.

Variations of the intermediate frequency, which can result from deviation of the magnetron or klystron frequency (due to fluctuations of the temperature inside the block or the power-supply voltage), are compensated by the circuit of the unit for automatic frequency control or ARCh [AFC] (Unit P-4). Signals detected by a special detector, to which magnetron and klystron fluctuations are fed, are supplied to the AFC input from unit P-2.

Depending on the sign of the i-f deviation from rated frequency, there is a corresponding variation of the negative voltage on the reflector electrode of the klystron, as a result of which the i-f is maintained constant with accuracy sufficient for operation of the station.

In addition to AFC, there is manual frequency control, which is regulated from the control panel of the main indicator.

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In the remote indicator the image is produced on the screen of the CRT, 18LM35, in the following manner. Through the three-phase deflection coil of unit V-4 pass currents from the output transformers of amplifiers which amplify voltages taken from resistances connected in series with the phases of the deflection coil of the main indicator. To the control grid of the CRT there are fed the reflected pulses amplified by the video amplifier and the range circle pulses taken from the corresponding circuits in the main indicator. Here also are fed the electronic course mark pulses. To the cathode of tube 18LM35 the intensifier pulse is fed. The latter is also taken from the main indicator and is amplified by the intensifier-pulse amplifier in the remote indicator.

The image of the CRT screen of the remote indicator yields a picture of water-surface conditions surrounding the ship and is in all respects similar to the image on the screen of the main indicator.

As has already been stated above, the images on both the main and remote indicator screens are produced by a PPI sweep in a polar system of coordinates where the origin coincides with the center of the CRT screen and is the position of the ship.

The image on the CRT screen can be oriented in one of two ways. If in respect to the head of the ship, then the electronic course mark, which signifies the diametral plane of the ship, will be directed at zero on the fixed scale of the indicator. If meridionally oriented, the electronic course mark will indicate the course of the ship on the fixed scale of the indicator.

When the image is stabilized in respect to the head of the ship, if the ship turns the image on the screen will move, while the electronic course will remain fixed. When the image is stabilized in respect to the meridian, if the ship turns the image on the screen will remain stationary, while only the electronic course mark will move.

The distance to an object is determined roughly on both the main and remote indicators from the fixed range circles. Accurate determination of distance is possible only on the main indicator, by superposing the movable range circle on the object and reading the distance to the object from the range finder counter.

When the image is stabilized in respect to the meridian, the direction of the electronic course mark on the fixed scale of the indicator shows the course of the ship. The sight, when matched with the object. indicates the direction of the object on the fixed scale and the course bearing of the object on the moving scale, if the latter matches the gyrocompass.

When the image is stabilized in respect to the head of the ship, the purpose of the fixed scale changes, and, when the sight is set on the object, this scale indicates the course bearings of the object.

The antenna drive produces continuous circular rotation of the antenna at a rate of 14 rpm. The antenna is driven by a motor with a shaft power of approximately 225-250 watts.

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III. MAIN INDICATOR (BLOCK "I")

A. Basic Technical Data and Description of the Operation of the Block

The general electrical diagram of the main indicator with complete specifications is given in draft No 33,650,007, page .

The main indicator is a PPI. It coordinates all the processes taking place in the station as a whole.

The principle of operation of the main indicator is as follows:

The frequency generator produces at its output sinusoidal oscillations of the synchronous frequencies 81 kc, 13.5 kc, and 2.7 kc, which have the ratio of 30:5:1 to each other.

The sinusoidal oscillations of these three frequencies go to the appropriate quadrature circuits of I-15, whose purpose is to create for each of the three frequencies a current in quadrature, i.e., shifted 90° in phase.

All three phase shifters of unit I-16 operate on the same principle: the two mutually perpendicular stator windings of the stator of the phase shifter in the range finder I-16, when fed currents 90° out of phase with each other, indicate in the appropriate windings of the phase shifter's rotor a voltage whose phase is determined by the geometric position of the rotor winding relative to the stator winding. Rotation of the rotor can vary the phase of the oscillation in its winding from 0 to 360°.

From the voltages taken from the quadrature circuits and the phase shifters in the indicator circuit, pulses for two functions are created:

a. Trigger pulses, for triggering the transmitter and the sweep unit.

b. Movable range circle pulses, used for fine range measurement.

The trigger pulses are formed from the three sinusoidal voltages which are taken from the phase-regulating potentiometers in the quadrature circuits.

The movable range circle pulses are formed from the three sinusoidal voltages which are taken from the phase-shifter rotors.

The pulses for both functions are formed by selection of one of the half-cycles of the 81-kc voltage which coincide with one cycle of the repetition frequency, 2.7 kc.

The three sinusoidal voltages with frequencies of 81, 13.5, and 2.7 kc, respectively, which enter into the formation of the movable range circle pulses make it possible to move the movable range circle over the whole extent of all the scales. Rotation of the handle of the range finder varies their phase smoothly.

The duration of the movable range circle pulse is 0.35 microseconds.

The duration of the trigger pulses is 1.5 microseconds, while the pulse repetition frequency for scales I and II is 2.7 kc; for scales III and IV, 675 cycles.

The final pulse forming, both as to shape and duration, which is necessary for excitation of the magnetron, is performed in the receiver-transmitter.

As was stated above, the trigger pulses serve not only for keying the transmitter, but also for triggering the range sweep of unit I-5. In the latter circuit there are simultaneously created fixed range circle pulses and pulses for intensification of the operating cycle of the sweep.

Received signals reflected from objects, after they have left the receiver-transmitter and have passed through the i-f amplifier and the second detector in block I-7, are mixed and amplified in the video mixer I-12 with the movable range circle, fixed range circle, and electronic course mark pulses. All these signals from the video mixer go to the control grid of the cathode-ray tube in unit I-6.

The pulses for intensification of the sweep's operating cycle from unit I-5 go to the cathode of the cathode-ray tube in unit I-6.

For synchronization with the antenna there are selsyn SGS-1, located in the antenna assembly and used as a "rotating" transformer, and the three-phase deflection coil of the cathode-ray tube. The single-phase oscillations generated by the sweep circuit are fed to the "rotating" transformer of the antenna assembly, where they are split into three waves whose phases are identical; when the antenna rotates they are amplitude modulated. When fed to the Y-connected windings of the CRT deflection coil in unit I-6, these oscillations create a pulsed magnetic field which is saw-tooth in form, increasing, and rotating, and which deflects the electron beam of the CRT from the center to the periphery. The form of the waves generated by the sweep circuit must be such that, after all transformations, the radial deflection of the spot on the CRT screen will be as linear as possible with respect to time.

The radially deflected spot forms a luminous line on the screen. When the antenna (consequently, also the luminous radius) is rotated, and when the spot is modulated in brightness by signals fed to the control grid and the cathode of the CRT, an image of the conditions surrounding the ship is formed on the screen.

To allow for orientation of the image in respect to either course or meridian, Block "I" is provided with the following:

a. The course "rotating" transformer (selsyn SDS-1 with braked rotor)

b. The gyrocompass "rotating" transformer (selsyn SDS-1 with its rotor coupled to the gyrocompass selsyn)

c. Gyrocompass repeater (selsyn SS-404) or another selsyn for receiving from the gyrocompass.

B. Detailed Description of the Units Which Make Up Block "I"

1. Frequency generator I-1 and high-frequency rejection filter I-2

The electrical schematic diagram of the frequency generator is shown in the general electrical diagram of the station, draft No 33,650,007-SE, page .

Filter I-2, which chops off the high frequencies, is pictured in the general electrical diagram, draft No 33,650,007-SE, page .

In accordance with the functions of the frequency generator in the indicator circuit, the following demands are made of it:

a. The frequency generator must produce three sinusoidal waves with frequencies of 80,905, 13,484, and 2,690 cycles per second, respectively (in the diagram these frequencies are given their rounded out values of 81, 13.5, and 2.7 kc, respectively) with sufficient power to supply the pulse quadrature circuits and the phase shifters and, at the same time, for stable operation of the circuits of units I-3 and I-4.

b. The voltages supplied by the frequency generator must be sinusoidal in form and with a minimum harmonic content. A high percentage of harmonics greatly impairs the phase characteristics of the range finder phase shifters.

The circuit of the frequency generator consists of a quartz oscillator and two frequency dividers.

The source of the basic stable frequency is a quartz oscillator based on tube L-01-I1, type 6P9, and a circuit with a tuned plate circuit, positive capacitive coupling to the grid, and the quartz crystal in the grid circuit. The quartz frequency is 81 kc. By means of the positive coupling, the oscillatory circuit, composed of T-01-I1 and C-02-I1, is tuned to a frequency higher than the frequency of the quartz. Depending upon the quality of the quartz, the frequency of the tuned circuit should exceed the quartz frequency by 3-15%.

From the second winding of the plate transformer T-01-I1 of tube L-01-I1 oscillations with a frequency of 81 kc are fed through filter I-2, which chops off the high frequencies in the quadrature circuit. The third winding of this transformer serves to supply the first frequency divider. The power of oscillations taken from the generator is approximately one watt.

Under certain conditions, depending on the deviations from rated values of the tube, quartz, and other parameters, the form of the curve at the output of the generator may be somewhat distorted. Since this will not allow normal operation of the range-finder phase shifter, the oscillations from the generator are fed to the quadrature circuit through the high-frequency rejection filter. The filter is so tuned that it passes the frequency of 81 kc and chops off frequencies above this, including, consequently, all its harmonic components.

To obtain the frequencies of 13.5 kc and 2.7 kc there are frequency dividers which first divide the 81-kc frequency by 6, and then the obtained frequency -- 13.5 kc -- by 5, yielding a third frequency of 2.7 kc.

The circuit of the first divider consists of tubes L-02-I1, type 6 Zh4 (6AS7), and L-04-I1, type 6P6S (6V6), while the second divider is made up of tubes L-03-I1, type 6P9, and L-05-I1, type 6P6S (6V6).

Both frequency division stages operate on the same principle and are dividers of the so-called regenerative type.

The operating principle of these dividers lies in the following: oscillations with the frequency of 81 kc from the secondary winding of transformer T-02-I1, which is connected to the plate circuit of tube L-02-I1, are fed to the grid 5 of mixer tube L-04-I1.

Since the tuned transformer T-02-I1 gives a frequency of 5/6 F, the sum and difference of the mixed frequencies goes to the grid of tube L-04-I1, i.e.,

$$F + 5/6\ F = 1\ 5/6\ F = 148.5 \text{ kc}$$

$$F - 5/6\ F = F/6 = 13.5 \text{ kc}$$

The isolation of oscillations with the frequency 5/6 F in transformer T-02-I1 results from the following: in detector tube L-04-I1, by means of the tuned circuit in its plate circuit, the frequency 1 5/6 F is filtered out, and the frequency F/6 (13.5 kc) is isolated. From this circuit (the primary winding of T-04-I1, C-17-I1, and C-27-I1) the voltage with the frequency F/6 (13.5 kc) is fed by means of transformer T-05-I1 to the quadrature circuit. Connected to the primary winding of T-05-I1 is the input of the second frequency divider. From the secondary winding of transformer T-04-I1 the voltage with the frequency F (13.5 kc) goes to the grid of multiplier tube L-02-I1, whose plate circuit includes tuned transformer T-02-I1, which separates the fifth harmonic from the frequency F/6 (13.5 kc), i.e., the frequency 5/6 F (67.5 kc). Tube L-02-I1 operates under conditions of large nonlinear distortions, as a result of which separation of the fifth harmonic is accomplished comparatively easily.

The voltage with the frequency 5/6 F (67.5 kc) from the secondary winding of the transformer, together with the input voltage of the frequency F (81 kc), is fed to the control grid of L-04-I1. Thus the path of frequency regeneration is closed with division by 6 in the process of operation of the divider.

The generation of oscillations in the divider is guaranteed, as it is in tube oscillators, by random variations of the plate current, fluctuation noises, etc.

The second divider, just as the first, is a regenerative-type divider with frequency division by 5. In the second divider the frequency $F_1/5$ (2.7 kc) is isolated in the plate circuit of tube L-04-I1, while in the plate circuit of tube L-03-I1 the frequency $4/5\ F_1$ (10.8 kc) is isolated. To the grid of tube L-05-I1 go the sum ($F_1 \quad 4/5\ F_1 = 13.5 + 10.8$ 24.3 kc) and the difference ($F_1 - 4/5\ F_1 - 13.5 - 10.8 = 2.7$ kc) of the frequencies, which are mixed in transformer T-03-I1.

The circuit of the second divider, in contrast to that of the first, has capacitive coupling between the detector and multiplier tubes as well as transformer coupling, as in the first divider. For the rest, the circuits are identical.

2. Quadrature circuits I-15 and Rangefinder I-16

The electrical schematic diagram of units I-15 and I-16 is shown in the general electrical diagram of the station, draft No 33,650,007-SE, page .

The unit of the quadrature circuits I-15 and the rangefinder I-16 is as a whole a circuit which produces:

a. The phase-regulated voltages required for the trigger pulse-forming circuit

b. The voltages, taken from the rotors of the phase shifters and smoothly variable in phase from 0 to 360°, required for forming the movable range circle pulses.

The schematic diagrams of all three quadrature circuits are identical, and they differ from one another only in the values of the elements composing them. Each of the quadrature circuits is a circuit composed of L, C, and R.

The quadrature circuits, together with the stators of the phase shifters, produce a relative phase shift of 90° in the currents passing through the two windings of the phase-shifter stators. These windings are geometrically disposed at an angle of 90° to each other.

In order to understand the principle of operation of the inductive phase shifter, imagine, for example, that in the stator winding of L-07-I16 there flows an alternating current whose phase we will assume to be 0. Then, when there is maximum inductive coupling between the rotor winding of L-09-I16 and the stator winding of L-07-I16, an emf in the same phase will be induced in the rotor winding. If the rotor is turned by 90°, it will have maximum coupling with the stator winding of L-08-I16, and the emf in the rotor winding, like that in this stator winding, will be shifted relative to the phase in the initial rotor position by 90°. If the rotor is turned by another 90°, its winding will again be maximally coupled with the stator winding of L-07-I16; however, the phase of the emf induced in the rotor will differ from that in the initial position by 180°. If the phase-shifter rotor is turned by still another 90° (i.e., the rotor will have been rotated by 270° in all), the phase of the emf induced in it will be shifted by 180° relative to the phase of the emf in the second rotor position, and by 270° relative to the phase of the emf in the original position. The intermediate positions between the points mentioned above will also correspond to intermediate values of the phase of the emf. Thus, smooth rotation of the phase-shifter rotors produces smooth variation of the phases of the voltages used in forming the range mark pulses and, at the same time, makes it possible to shift the range mark pulse in time within the limits of a cycle of the frequency 2.7 kc.

The necessary 90° phase shifts between the currents flowing through the different stator windings of the phase shifters are obtained by selection of the correct values of capacitors C-01-I15, C-02-I15, C-03-I15, C-04-I15, C-05-I15, and C-06-I15. The currents in the stator windings of the phase shifters are made equal by correct selection of the values of resistors R-04-I15, R-08-I15, and R-12-I15.

Resistors R-02-I15, R-03-I15, R-05-I15, R-07-I15, R-11-I15, and R-10-I15 serve to control the value and the phase shift of the currents flowing through the stators. The potentials on these resistors match the currents flowing through the stators, which makes it possible to observe the amplitude and the phase shift of the currents with a cathode-ray oscilloscope when adjusting the circuit.

The sinusoidal voltages are taken from phase-regulating potentiometers R-01-I15, R-05-I15, and R-09-I15 to the circuit for forming trigger pulses (unit I-4).

Potentiometer R-01-I15 is designed at the same time to regulate the phase of the trigger pulse when setting the zero on the range finder.

The values of L (phase-shifter stators), C, and R are so chosen that their total impedance, which is the load of the frequency generator, has a value of approximately 2,000 ohms.

In construction all three range-finder phase shifters (high-frequency, medium-frequency, and low-frequency) are mounted on a common shaped textolite plate. The phase shifters are coupled together by gears with transmission ratios of 30:5:1, i.e., one turn of the low-frequency phase shifter corresponds to 5 turns of the medium-frequency shifter and 30 turns of the high-frequency shifter.

The stator of the phase shifter is a solid plastic cylinder with slots containing two mutually perpendicular windings. The angle between these windings is constructed as a right angle with as high accuracy as possible. This is important, in order to minimize errors introduced into the range finder.

Both windings must be identical; if not, regulation of the pulse quadrature circuit is much more difficult. This identity is attained by appropriate winding of the stator and careful adjustment of its windings for equal inductance.

Both ends of both stator windings are led to pins on the front part of the cylinder. The cylinder is fastened to the base of the range finder. The phase-shifter rotor is a hollow plastic cylinder with ribs on its external surface to hold the winding. The rotor winding consists of four sections, two main and two compensation. All sections of the rotor are connected in series. The number of turns in the section and their mutual distribution is selected by experiment so that the change in the voltage taken from the rotor when it is rotated does not exceed ±5% and the phase variation follows the rotor's angle of rotation with a deviation of not more than ±3°.

On its front part the rotor has a shaft to which two contact rings, connected to the rotor winding, are fastened. Set on the same shaft is a spur gear with which the rotor is coupled to the kinematic system of the range finder.

The rotor is set over the phase-shifter stator, and its bearing is installed on the phase-shifter plate.

3. Unit for Forming Movable Range Circle Pulses, I-3

The electrical schematic diagram of the movable range circle pulse-forming unit is shown in the general electrical diagram of the station, draft No 33,650,007, page .

The movable range circle pulse-forming circuit is designed to form pulses for producing on the indicator screen a circle whose radius changes when the range-finder handle is rotated. This circle is produced by pulses which modulate the brightness of the spot on the screen of the indicator CRT once each cycle of the range sweep. By changing the radius of the movable range circle until it is matched up with the object it is possible to read the distance to the object from the range-finder counter. The position of the movable range circle pulse on the CRT screen depends on the time lag between the moment when the sweep and the receiver-transmitter are triggered and the moment when movable range circle pulses are created. By means of the range-finder phase shifters this lag can be set from 0 to 373 microseconds, i.e., the time necessary for passage of a pulse of high-frequency energy from the antenna to an object 30 miles away and back again. To increase the accuracy of matching, the pulse duration is made equal to 0.35 microseconds.

The pulse is formed by selecting it from the three sinusoidal oscillations with frequencies of 81, 13.5, and 2.7 kc. The circuit selects the peak of one of the 30 oscillations of the high frequency (81 kc) which coincide with one cyle of the low frequency (2.7 kc); then subsequent differentiation and formation of a pulse of small amplitude and duration is performed by the blocking oscillator.

The 2.7-kc oscillation is fed through C-04-I3 from the low-frequency phase shifter directly to the grid of the selector tube L-02-I3, type 6A7 (6SA7). The 13.5-kc oscillations are fed through a cathode follower (left triode of tube L-01-Ic, type 6N8S) to grid 8 of tube L-02-I3. The 81-kc oscillations are also fed through a cathode follower (right triode of tube L-01-I3) to grid 5 of the same selector tube.

The selector tube L-02-I3, type 6A7 (6SA7) is caused to conduct by a positive voltage fed to its cathode through resistance R-06-I3. Thus, part of the positive high-frequency half-cycle can produce a plate current in the tube only if this half-cycle coincides in time with the positive peaks of the half-cycles of the medium-frequency and low-frequency oscillations fed to grids 4 and 8 of the selector tube (see Figure 3, Explanatory Illustrations). Consequently, pulses in the plate circuit of the selector tube occur once per period of the low frequency, 2.7 kc.

By means of the differentiating action of transformer T-01-I3, whose primary winding is connected to the plate circuit of the selector tube, a differentiated pulse, whose form is pictured in Figure 2 (Explanatory Illustrations) is fed to grid 1 of amplifier tube L-03-I3.

The duration of these pulses is of the order of 1.5 microseconds. After amplification in tube L-02-I3, the pulses are fed to the grid of tube L-04-I3, tube 6N8S, which operates the locked delaying blocking oscillator. The locked delaying blocking oscillator (Figure 4) operates when tripping pulses taken from the plate 2 of tube L-03-I3 act on grid 1 of tube L-04-I3. Until receipt of the tripping pulse the tube of the blocking oscillator is locked, since a locking voltage is supplied to its grid through leakage resistors.

If the tripping pulse, amplified by the left triode of tube L-04-I3 at a moment of time t, reduces the potential on plates 2 and 5 and, at the same time, increases the potential on grid 4 through transformer T-02-I3 and capacitor C-08-I3 to a value higher than the locking voltage of the tube, then a current will flow through the tube causing a further drop of the potential e_a [plate] and a further rise in the potential e_g [grid] through the transformer. This process, called the blocking effect, snowballs, with the result that the tube opens momentarily and the circuit itself becomes capable of holding the tube in the conducting state independent of the tripping pulse. After a moment in time t_1 the tube is in such a condition (the potential on the grid is greater than that on the plate) that the steepness of its characteristic is so small that variation of the voltage in its grid produces practically no change in its plate current.

In the time interval from t_1 to t_2 capacitor C-08-I3 becomes charged with the grid current, and the magnetization current of transformer T-02-I3 grows. As a result of this, the plate current of the tube will also rise. However, these variations in voltage and current take place much more slowly than the variations which take place in the tripping process. Therefore, the tube will be in the conducting state for some time (in our case, for 0.35 microseconds).

As the voltage on the grid decreases, the magnetization current of the transformer increases, and the operating point of the tube gradually shifts to the region on the characteristic where the steepness takes on ever greater significance. At the moment in time t_2 the steepness of the characteristic reaches a value at which the conditions for existence of the blocking effect again are fulfilled. The reduced voltage on the grid starts to cause an already noticeable reduction of the tube's current, which leads to a reduction of the voltage on the transformer windings. As a result of this, there takes place a further, more intensive decrease in the voltage U_g on the tube, and this causes still further reduction of the plate current. Thus, there arises a reverse snowballing process, similar to that described above, but acting in the opposite direction.

The blocking oscillator is finished for this operating cycle, but after the charge in capacitor C-08-I3 has run off through a leakage resistor the circuit is again ready to operate from the next tripping pulse. Thus, from winding 2-4 of transformer T-02-I3 a pulse of 0.35 microseconds in duration goes to grid 4 of the output triode of tube L-03-I3 whose cathode circuit is common with that of tube L-01-I12, type 6Zh4 (6AG7), of the video mixer. The amplitude of the pulse is adjusted with regulator PKD [Movable Range Circle], which varies the locking voltage fed to grid 4 of tube L-03-I3. If the locking voltage is high, then, owing to the high cutoff, the amplitude of the pulse at the output is low; if the locking voltage is reduced, the cutoff is reduced, and the amplitude of the pulse at the output increases. The regulator PKD is mounted on the control panel of the main indicator.

4. Trigger pulse-forming unit I-4

The electrical schematic diagram of the circuit of the trigger-pulse forming unit is shown in the general electrical diagram of the station, draft No 33,650,007-SE, page .

The trigger pulse-forming circuit produces pulses to trigger the transmitter and the circuit of sweep unit I-5.

The duration of the pulses at the output of the circuit is 1.5 microseconds for all scales. The final forming of the pulses which control the magnetron is performed in the transmitter, depending on the pulse repetition frequency, which is different for the different scales. Thus, for the 1st and 2d scales the pulse repetition frequency is 2.7 kc, while for the two other scales it is 675 cycles.

The operation of this circuit, like that of the preceding pulse-forming circuit (see Figure 3a), is based on the same principle of the selection of one of the high-frequency half-cycles which coincides with a low-frequency cycle. Consequently, in order to obtain pulses with a frequency of 2.7 kc, the high-frequency sinusoidal oscillations of 81 kc from the phase-regulating potentionmeter R-09-I15 are fed directly to grid 5 of selector tube L-01-I4, type 6A7 (6SA7), the sinusoidal oscillations of 13.5 kc from phase-regulating poteniometer R-05-I15 are fed to grid 8 of the selector tube, and the low-frequency sinusoidal oscillations with the frequency of 2.7 kc are fed to grid 4 of the same tube.

At the moment when the selector tube opens, the voltage on its plate drops. The voltage pulse (negative) corresponding to the truncated half sine wave of the 81-kc frequency goes from the plate of the tube to grid 4 of tube L-02-I4. The pulse form is pictured in Figure 5.

From the plate 5 of tube L-02-04 the pulse is fed to grid 4 of tube L-03-I4, type 6P7. When the range scale switch on the control console is set in the position for the 1st or 2d scales, tube L-03-04 operates as an ordinary cathode follower.

When the range scale switch is set in the 3rd or 4th position, a negative pulse, taken from plate 8 of tube L-03-I4, triggers the phantastron circuit, consisting of tubes L-04-I4, type 6N8S, and L-05-I4, type 6A7 (6AS7). In this case tube L-05-I4 should be considered as a pentode whose screen grid is a system of three grids: a positive pulse is fed to the second and fourth grids, and they operate as a screen grid; the third grid is an auxiliary control grid. The potential on the latter grid determines the distribution of the cathode current between the plate and screen grid. If the voltage on the third grid has a high negative value relative to the cathode, all the electrons go to the screen grid, and the plate current is cut off. Increasing the voltage on the third grid produces the reverse process.

In our case (Figure 6), in the absence of a tripping pulse supplied from outside, the first grid is under the potential of the cathode, since its leakage resistor R-19-I4 is connected to the positive voltage source, and a high screen-grid current flows in the tube. As a result, this voltage on the cathode considerably exceeds the voltage on the third grid, and there is no plate current.

When a negative trigger pulse is fed to cathode 3 of tube L-04-I4, a momentary potential drop is formed on grid 4 (and consequently on cathode 6) of the cathode repeater and on grid 5 of phantastron L-05-I4. The voltage drop on the grid of phantastron L-05-I4 causes a drop in the voltage on cathode 6 relative to grid 8 of the same tube, and a plate current appears in the tube. The plate current causes a voltage drop on the plate which, through the cathode follower, acts on grid 5 of the phantastron tube. However, this process can not go so far as to close the phantastron tube with respect not only to its screen, but also to its plate current, since in the absence of plate current there can be no reduction of the potential on the control grid. This circumstance makes the circuit balance itself in a definite portion of the tube characteristic. In this portion the plate current characteristic will rise smoothly until that point where the increased potential on grid 5 will cause it to grow.

At the moment in time t_2 the plate current will cease to rise and start to drop, while the screen current will start to rise, as a result of the fact that the current in the cathode (voltage on it) reaches a considerable value, and the tube begins to close in respect to the third grid. After the moment of time t_2 there begins the snowballing process of tipping the circuit in the direction opposite to that described above, because the increase in the voltage on grid 5 leads not to an increase, but rather to a reduction in the value of the plate current due to the lowered potential of the third grid relative to the cathode.

Thus, ends the cycle of phantastron pulse formation caused by the trigger pulse.

The duration of the phantastron pulse depends on the value of the maximum potential on the plate of tube L-05-I4, which in its turn is governed by the controllable positive voltage on cathode 3 of the clamping diode L-04-I4. By raising the maximum voltage on the plate of tube L-05-I4 the duration of the phantastron pulse is increased.

Variation of the potential on cathode 3 of tube L-04-I4 and, by the same token, variation of the duration of the phantastron pulse in this case is performed with the toggle switches SHKALA DAL'NOSTI [Range Scale] and OBZOR-REZERV [Surveillance-Stand-by]. The negative pulse produced by the phantastron circuit is fed from cathode 6 of the right triode of tube L-04-I4 through capacitor C-08-I4 and resistors R-10-I4 and R-13-I4 to grid 4 of tube L-03-I4. The duration of the negative phantastron pulse is such that it closes tube L-03-I4 for a period of three pulses of the repetition frequency. As a result, when the repetition frequency is 2.7 kc, only every fourth pulse will pass through tube L-03-I4 and, by virtue of this, the frequency will be divided by 4.

The right triode of tube L-02-I4 is connected to the clamping triode and is used to take off the additional bias arising from the grid currents of tube L-03-I4.

From cathode 5 of the output tube L-03-I4 a pulse of 1.5 microseconds duration and 10-15 volts amplitude (see Figure 7) is supplied to the input of unit I-5 and, simultaneously, through the delay line I-17 to the receiver-transmitter.

5. Sweep unit I-5

The electrical schematic diagram of sweep unit I-5 is shown in the general electrical diagram of the station, draft No 33,650,007-SE, page .

The sweep unit serves to form:

a. Range sweep pulses
b. "Balance wave" pulses designed to set the beginning of the range sweep
c. Pulses which create the fixed range circles; and
d. Pulses to intensify the operating cycle of the range sweep.

The circuit of unit I-5 can be divided into three main paths according to their purposes: range sweep pulse-forming path; "balance wave" forming path; and fixed range circle pulse-forming path.

First, let us examine the operation of the part of the circuit of unit I-5 designed for forming the range sweep pulse. The positive trigger pulse with a potential of 12 volts and duration of 1.5 microseconds, generated in unit I-4, goes to the input of the control amplifier, i.e., is fed to cathode 3 of the left triode of tube L-01-I5, whose grid 1 is grounded. As a result, the phase of the amplified pulse does not change, and at the plate a pulse amplified to 40 volts, and also positive, is obtained.

The process taking place in the right triode of tube L-01-I5 of the control amplifier is examined on page . From the plate load R-02-I5 of tube L-01-I5 the signal, which has been amplified to the required value, is fed to grid 1 of tube L-02-I5, type 6N8S (6N8M) of the locked (delaying) multivibrator with cathode coupling.

In this circuit (Figure 9), if the trigger pulse is absent, the right triode of L-02-I5 (whose grid is connected to a positive voltage source) conducts, resulting in a positive voltage on the cathodes of both triodes. The voltage on grid 1 of the left triode (+ 75 volts) is set by selecting the values of R-05-I5 and R-06-I5 such that this voltage is less than the potential of the cathodes (+ 100 volts) but is sufficient to close the left triode of tube L-02-I5.

The trigger pulse causes the appearance of plate current in the left triode of L-02-15 and, consequently, the reduction of the voltage on plate 2 relative to the ground. Because of capacitor C-05-I5 the voltage on the grid of the right triode of L-02-I5 falls to the same value relative to the ground; since the right triode is connected in cascade with the cathode load, the voltage on the cathode also drops.

Decreasing the voltage on the cathode causes the voltage on the grid relative to the left triode of L-02-I5 and the latter's plate current to increase.

The process of tripping the circuit takes place in a snowballing fashion, and the right triode continues to remain closed. As capacitor C-05-I5 discharges, the voltage on grid 4 of L-02-I5 rises, and, when it reaches a value equal to the voltage for opening the tube, the right half of L-02-I5 is opened. Then the second tripping process (in the reverse direction) takes place. The plate current of the right triode raises the potential on the cathode until it is sufficient to close the left triode, while the increase of the voltage on its [the latter's?] plate helps to open the right triode. The duration of the multivibrator pulse is determined by the time constant of R-10-I5 + C-05-I5, which in this case is $6.8 \times 10^6 \times 2000 \times 10^{-12} = 13{,}600$ microseconds.

Capacitor C-04-I5 increases the steepness of the front of the pulses supplied by the left triode of the multivibrator.

When the amplified trigger pulse is received at the multivibrator input (grid 1), the multivibrator begins to operate and simultaneously supplies a rectangular signal (from plate 2 of negative, and from plate 5 of positive polarity), which continues until a control signal of negative polarity enters the input of the multivibrator (grid 1 of tube L-02-I5). This signal at the necessary moment in time causes the process of reverse tripping, for which reason it is always earlier than if the process were allowed to rise arbitrarily, i.e., for 13,600 microseconds.

The duration of the rectangular pulses generated by the multivibrator determines the duration of the range sweep cycle and the time for intensification of the operating cycle of the sweep.

The negative rectangular pulse from the plate 2 of the left triode of L-C2-I5 goes to control grid 4 of tube L-04-I5, type 6P9, of the sweep oscillator. Until it receives the signal, tube L-04-I5 conducts current. Therefore, capacitor C-10-I5 in the case of the 1st scale (or capacitors C-11-I5, C-46-I5, or C-13-I5 for the other range scales) is charged only to a very slight potential difference. When grid 4 of the saw-tooth oscillator receives the rectangular negative signal, the current through tube L-04-I5 is abruptly cut off, and capacitor C-10-I5 begins to become charged through resistor R-17-I5. The initial part of the exponential curve comprises approximately 10% of the maximum charge voltage of the capacitor and is used for the range sweep.

The steepness of the increasing the charge is determined by the time constant of the circuit of R-17-I5 and C-10-I5. It is adjusted through selecting the value of the capacitance connected to the circuit which is switched on and off by the range-scale switch. The positive pulse taken from the plate 5 of tube L-02-I5 serves to combine the fixed circles and set them in the position indicating the correct distance to objects (see page   of this Description).

From the saw-tooth voltage generator (tube L-04-I5) the signal is received simultaneously at the input of the range sweep preamplifier and at the grid of the right triode of tube L-01-I5 (the control amplifier).

Let us examine the processes involving the control amplifier, tube L-01-I5.

As the voltage on one of the capacitors, for example, C-10-I5, rises, the grid potential of the locked right triode of tube L-01-I5 of the control amplifier also rises. As a result, the voltage on the common plate load R-02-I5 of both control amplifier triodes starts to drop. When this voltage drop reaches the value required for reverse operation of the multivibrator, the latter returns snowballing to its original position. The negative pulse ceases to act on grid 4 of tube L-04-I5, capacitor C-10-I5 discharges relatively rapidly to the sweep oscillator tube, and the circuit returns to its original state.

The time relationships of the forms of the voltages on the plates of the control amplifier, multivibrator, and sweep oscillator tubes are given in Figure 10.

The start of the saw-tooth sweep voltage is determined by the moment when the circuit input receives the trigger pulse. The cutoff of the sweep current is determined by the potential selected for operation of the control amplifier and the multivibrator. The steepness of the [voltage] rise (in other words, the velocity of the sweep cycle) is determined by the time constant of R-17-I5 and C-10-I5. The amplifier of the range sweep, i.e., of the pulse for the sweep's operating cycle pulse (tubes: left triode of L-05-I5, type 6N8S [6N8M]; L-06-I5, type 6AG7; and L-07-I5, type GU-29 [G-829]), contains three stages of amplification and operates with high negative coupling in respect to the current of the output amplification stage (tube L-07-I5) with the first stage (left triode of tube L-05-I5). This coupling results from the current flowing through the resistance (which is common for both tubes) at the cathode (R-35-I5, R-104-I5, R-36-I5, or R-97-I5, depending on the position of the range scale switch). Tubes L-05-I5, L-06-I5, and L-07-I5 operate as linear amplifiers. A voltage proportional to the output of tube L-07-I5 is fed from resistor R-35-I5, or one of the other three, back to the cathode of L-05-I5.

The feedback is negative, since an increase of the voltage on the grid of tube L-05-I5 causes a reduction of the voltage on the grid of tube L-06-I5, a voltage rise on the grid of L-07-I5, and (as a result of the fact that tube L-07-I5 is a cathode follower) an increase of the voltage also on the primary winding of the output transformer and on R-35-I5. Consequently, the rise in the grid-ground voltage of tube L-05-I5 leads to an increased potential at the cathode of tube L-05-I5, as a result of which the grid-cathode voltage comprises only a small part of the grid-ground voltage.

As a result of the negative feedback, the current in the output transformer winding has almost the same form as the grid-ground voltage, i.e., the output voltage of the sweep oscillator. Tubes L-05-I5, L-06-I5, and L-07-I5 amplify the voltage of the grid-cathode circuit of tube L-05-I5 almost 500 times. Therefore, if the form of the feedback current (consequently, also the feedback voltage) deviates from the grid-ground saw-tooth form even very slightly, there will appear a grid-cathode voltage sufficient after amplification to balance the difference in the forms of the saw-tooth oscillator voltage and the feedback voltage created by the current of output tube L-07-I5. This voltage on R-35-I5 (and, consequently the current through it) will then have a saw-tooth form like that of the sweep oscillator voltage. Connected to the plate circuit of the output state is one half of the primary winding of transformer T-01-I5. The secondary winding of the latter is connected to the "rotating" transformer (selsyn type SGS-1, mounted in the base of the antenna assembly).

So much for the range sweep pulse-forming path.

The output current of transformer T-01-I5 consists of a series of pulses separated by intervals. One current cycle is a sweep pulse and an interval, as shown in Figure 11 b.

In the primary winding of the output transformer there flows a pulsed current containing a dc component (see Figure 11 a), whose value is indicated by the dotted line.

If this single-directional current passes through the deflection coil, then the beam, under the influence of the magnetic field created, will be deflected from the center to the periphery. Thus, the origin of the sweep (point "B"), corresponding to the zero time value of the current, will coincide with the center of the screen.

Since neither the output nor the "rotating" transformer will pass the dc component of the current, essentially an alternating current will be fed to the deflection coil (see Figure 11 b). This current will create a two-directional deflection field, and the origin of the sweep (point "B") will not coincide with the center. Coinciding with the center, instead of point "B," will be point "A," which is the point of intersection of the sweep current curve with the line which divides the curve into two parts such that the positive and negative "half-cycles" of the current curve are equal in area.

In a PPI with radial sweep it is necessary to have a fixed point (the center of rotation) for the origin of the sweep cycle, which corresponds to the zero moment of time. At the zero moment of time the instantaneous value of the ac component of the current in the deflection coil must be at the zero level.

In the circuit of unit I-5 being discussed, this is accomplished with the aid of a "balance wave" with equally great "area" (Figure 12).

The balancing current begins to act at once after the end of the sweep current cycle and is turned off before the beginning of the following sweep cycle.

The area bounded by the "balance wave" curve is adjusted in such a way that the level in the interval of "ozhidaniye" [delay] will be equal to 0, and the origin of the sweep current curve will also be at this level. As a result of the rotation of the sweep line, only point "B" (Figure 12) is independent of the delay interval.

Increasing the area of the "balance wave" for the same value of the sweep current pulse on the first range scale produces "Razdvizhka Tsentra" (Expansion of the Center).

The operation of the path for forming the "balance wave" is treated below.

From the plate load R-08-I5 of the multivibrator, a positive pulse is fed to grid 4 of tube L-03-I5, type 6AG7. This tube operates as a paraphase amplifier, the signal being limited by currents arising in the grid circuit of L-03-I5. The principle of operation of the circuits which are coupled with tube L-03-I5 will be examined when the path for forming fixed range circle pulses is discussed.

From the plate load R-12-I5 of the paraphase amplifier, a rectangular negative pulse goes to the differentiating circuit, which consists of C-32-I5 and R-58-I5. The positive pulse generated as a result of the differentiation (Figure 13) of the rear edge of the inverted U-shaped pulse from the paraphase amplifier at a moment of time t_2 triggers the phantastron circuit, which consists of tube L-12-I5, type 6A7 (6SA7), and the left triode of tube L-13-I5, type 6N8S (6N8M). The principle of operation of the phantastron is given in the description of unit I-4. The phantastron circuit in unit I-5 differs from the phantastron circuit in unit I-4 only by the fact that in it [the former?] the phantastron is triggered by a positive pulse to screen control grid 8 (3rd grid from the cathode), and variations of voltage on the plate are supplied to the phantastron grid not through the cathode follower, but directly through capacitor C-32-I5.

The pulse formed by the phantastron is taken from resistor R-65-I5 through the integrating circuit of R-37-I5 and C-35-I5. This pulse originates immediately following the saw-tooth range sweep pulse which lasts for a period of time from t_1 to t_2. The integrating circuit reduces the rate of rise of the "balance wave" pulse voltage, thus protecting the output transformer T-01-I5 from overvoltages which occur in it when there are abrupt current variations.

The "area" of the "balance wave" pulse is changed by varying the duration of the pulse generated by the phantastron. In practice this is accomplished as follows: (a) in steps, with the range scale switch; (b) smoothly, with the potentiometers for "Tsentrovka Razvertki" (Sweep Centering) R-88-I5, R-89-I5, R-54-I5, and R-55-I5. In the process of operation these potentiometers are used to synchronize the origin of the range sweep cycle with the center of the CRT screen of the indicator. "Expansion of the center" is performed by switching in resistor R-93-I5 with the aid of toggle switch "Razdvizhka Tsentra" (Expansion of the Center).

The integrated voltage pulse is fed to grid 4 of the amplifier consisting of the following tubes: right triode of tube L-13-I5, type 6N8S (6N8M), tube L-14-I5, type 6N8S, and tube L-15-I5, type GU-29. This amplifier operates exactly like a sweep pulse amplifier with high negative coupling in respect to the current of output tube L-15-I5. To the plate circuit of tube L-15-I5 is connected one half of the primary winding of the output transformer, which operates on the "rotating" transformer which is mounted in the base of the antenna-waveguide assembly.

As was stated above, unit I-5 forms the sweep pulses, fixed range circle pulses, intensifier pulses, and "balance wave" pulses. The formation of all these pulses takes place simultaneously on receipt of the trigger pulse. Therefore, the main indicator circuit is provided with circuits to make it possible to select the necessary relationship between the times of formation of all these pulses.

Thus, the growth of current in the deflecting coil, caused by the sweep pulse, begins only 2.4 microseconds after the trigger pulse has been fed to the control amplifier. Figure 14 shows the time relationship between the pulses generated by the different parts of the circuit of unit I-5.

In order that the radiation of a pulse by the transmitter will coincide in time with the beginning of the increase of the current in the deflection coil, the pulse which triggers the transmitter is fed through a 2-microsecond delay line (0.4 microseconds is the time it takes for the pulse to travel along the cable to the transmitter and through the transmitter circuits). Thus, the origin of the sweep cycle in the indicator corresponds accurately with the moment of radiation of high frequency energy into space. So that the time of formation of the intensifier pulse and the fixed range circle pulses will coincide with the moment when a pulse is radiated into space, unit I-5 is provided with a circuit making it possible to select the necessary time relationship. This circuit makes it possible to shift the fixed range circles and set them in the position which indicates the correct distance to an object. The operating principle of this circuit is as follows: the positive pulse from the multivibrator is sent to the grid of the amplifier, tube L-03-I5, through resistor R-14-I5. The amplifier tube operates under grid-limit conditions. The forms of the multivibrator pulse, the pulse going to the amplifer grid, and the pulse at the plate are shown in Figure 17.

The amplitude of the pulse from the multivibrator is 180 volts. The spread of the amplifier tube characteristic is 7-10 volts (without grid currents). Obviously, when the grid bias on tube L-03-I5 is changed, pulses will be generated at its plate whose front edges are shifted in time. If such a bias is fed to the grid that the tube will open only at the very peak of the pulse, then the front edge of the pulse at the plate will noticeably lag behind the front edge of the multivibrator pulse (in this case by 3-3.5 microseconds). If the grid bias is low, then the tube will open almost simultaneously on receipt of the pulse from the multivibrator, while its whole positive part will be cut off through limitation by grid currents.

As a result, at the output, i.e., at plate 8 of tube L-03-I5, there will be an inverted-U-shaped pulse which is unchanged in amplitude and has its front edge shifted in time by varying the bias with potentiometer R-64-I5. This potentiometer is accessible under the slit in the panel of unit I-5 and carries the designation "Smeshch Im Podsvetki" (Shifting the Intensifier Pulse). It serves to set the range circles at the required positions on the cathode-ray tube.

From the plate load R-12-I5 of the paraphase amplifier, the amplified signal of negative polarity is fed to the circuit which forms the fixed range circle pulses. The negative inverted-U-shaped signal, when it arrives at grid 4 of the open left triode of tube L-08-I5, type 6N8S (6N8M), closes the latter and provides surge excitation for the oscillatory circuit which is located in the cathode circuit of tube L-08-I5. Then the oscillations of the circuit of L-03-I5 and C-47-I5 (or one of the other circuits corresponding to the remaining 3 range scales) are amplified and limited in the circuit consisting of the right triode of tube L-08-I5 and tube L-09-I5, type 6N8S. The differentiating circuit consisting of C-24-I5 and R-47-I5 is connected to plate 2 of tube L-09-I5. The positive pulses differentiated by this differentiating circuit trigger the delaying blocking oscillator, which operates on tube L-10-I5, type 6N8S. The operating principle of the blocking oscillator is explained in the description of unit I-3. In the secondary winding 2-5 of transformer T-02-I5 pulses are induced with a duration of 0.25 microseconds and a repetition frequency equal to the natural frequency of the oscillatory circuit which is connected to the circuit of cathode 6 of tube L-08-I5. From the secondary winding of transformer T-02-I5 the pulses from the blocking oscillator enter the grid of tube L-11-I5 of the cathode follower. The amplitude of the pulses is regulated by varying the bias on grid 1 by means of the potentiometer "NKD" [fixed range circles], R-04-I9, which is mounted on the control panel I-9 of the indicator. From the cathode load of tube L-11-I5 the signal goes to grid 4 of tube L-02-I12 in the video mixer. The input resistance of unit I-12, R-01-I12, is used as the cathode load.

The oscillation frequency of the oscillatory circuits is so chosen that the period of the oscillations corresponds to the distance chosen between the pulses for the given position of the range scale switch. Thus, on the first range scale they are spaced 0.5 miles apart, while on the second scale they are 1 mile apart. On the 3rd scale they are 5 miles apart, and on the last 10 miles.

From the cathode load R-53-I5 of tube L-11-I5, a rectangular signal of negative polarity goes to the cathode of the cathode-ray tube in unit I-6. This is the pulse for intensifying the operating cycle of the range sweep.

From the cathode load R-13-I5 of the paraphase amplifier, a rectangular signal of positive polarity is fed to the remote indicator as the pulse for intensifying the operating cycle of the remote indicator's range sweep.

Sweep unit I-5 contains tube L-16-I5, type 6AG7, which is designed to regulate the current in the focusing coil of the cathode-ray tube. Varying the automatic bias on the grid of this tube with potentiometer "Fokus" (Focus), R-01-I9, which is mounted on the control panel I-9, changes the value of the focusing current and, consequently, also the quality of the cathode-ray tube focusing.

As was stated above, unit I-5 forms the sweep pulses, fixed range circle pulses, intensifier pulses, and "balance wave" pulses. The formation of all these pulses takes place simultaneously on receipt of the trigger pulse. Therefore, the main indicator circuit is provided with circuits to make it possible to select the necessary relationship between the times of formation of all these pulses.

Thus, the growth of current in the deflecting coil, caused by the sweep pulse, begins only 2.4 microseconds after the trigger pulse has been fed to the control amplifier. Figure 14 shows the time relationship between the pulses generated by the different parts of the circuit of unit I-5.

In order that the radiation of a pulse by the transmitter will coincide in time with the beginning of the increase of the current in the deflection coil, the pulse which triggers the transmitter is fed through a 2-microsecond delay line (0.4 microseconds is the time it takes for the pulse to travel along the cable to the transmitter and through the transmitter circuits). Thus, the origin of the sweep cycle in the indicator corresponds accurately with the moment of radiation of high frequency energy into space. So that the time of formation of the intensifier pulse and the fixed range circle pulses will coincide with the moment when a pulse is radiated into space, unit I-5 is provided with a circuit making it possible to select the necessary time relationship. This circuit makes it possible to shift the fixed range circles and set them in the position which indicates the correct distance to an object. The operating principle of this circuit is as follows: the positive pulse from the multivibrator is sent to the grid of the amplifier, tube L-03-I5, through resistor R-14-I5. The amplifier tube operates under grid-limit conditions. The forms of the multivibrator pulse, the pulse going to the amplifer grid, and the pulse at the plate are shown in Figure 17.

The amplitude of the pulse from the multivibrator is 180 volts. The spread of the amplifier tube characteristic is 7-10 volts (without grid currents). Obviously, when the grid bias on tube L-03-I5 is changed, pulses will be generated at its plate whose front edges are shifted in time. If such a bias is fed to the grid that the tube will open only at the very peak of the pulse, then the front edge of the pulse at the plate will noticeably lag behind the front edge of the multivibrator pulse (in this case by 3-3.5 microseconds). If the grid bias is low, then the tube will open almost simultaneously on receipt of the pulse from the multivibrator, while its whole positive part will be cut off through limitation by grid currents.

As a result, at the output, i.e., at plate 8 of tube L-03-I5, there will be an inverted-U-shaped pulse which is unchanged in amplitude and has its front edge shifted in time by varying the bias with potentiometer R-64-I5. This potentiometer is accessible under the slit in the panel of unit I-5 and carries the designation "Smeshch Im Podsvetki" (Shifting the Intensifier Pulse). It serves to set the range circles at the required positions on the cathode-ray tube.

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From the plate load R-12-I5 of the paraphase amplifier, the amplified signal of negative polarity is fed to the circuit which forms the fixed range circle pulses. The negative inverted-U-shaped signal, when it arrives at grid 4 of the open left triode of tube L-08-I5, type 6N8S (6N8M), closes the latter and provides surge excitation for the oscillatory circuit which is located in the cathode circuit of tube L-08-I5. Then the oscillations of the circuit of L-03-I5 and C-47-I5 (or one of the other circuits corresponding to the remaining 3 range scales) are amplified and limited in the circuit consisting of the right triode of tube L-08-I5 and tube L-09-I5, type 6N8S. The differentiating circuit consisting of C-24-I5 and R-47-I5 is connected to plate 2 of tube L-09-I5. The positive pulses differentiated by this differentiating circuit trigger the delaying blocking oscillator, which operates on tube L-10-I5, type 6N8S. The operating principle of the blocking oscillator is explained in the description of unit I-3. In the secondary winding 2-5 of transformer T-02-I5 pulses are induced with a duration of 0.25 microseconds and a repetition frequency equal to the natural frequency of the oscillatory circuit which is connected to the circuit of cathode 6 of tube L-08-I5. From the secondary winding of transformer T-02-I5 the pulses from the blocking oscillator enter the grid of tube L-11-I5 of the cathode follower. The amplitude of the pulses is regulated by varying the bias on grid 1 by means of the potentiometer "NKD" [fixed range circles], R-04-I9, which is mounted on the control panel I-9 of the indicator. From the cathode load of tube L-11-I5 the signal goes to grid 4 of tube L-02-I12 in the video mixer. The input resistance of unit I-12, R-01-I12, is used as the cathode load.

The oscillation frequency of the oscillatory circuits is so chosen that the period of the oscillations corresponds to the distance chosen between the pulses for the given position of the range scale switch. Thus, on the first range scale they are spaced 0.5 miles apart, while on the second scale they are 1 mile apart. On the 3rd scale they are 5 miles apart, and on the last 10 miles.

From the cathode load R-53-I5 of tube L-11-I5, a rectangular signal of negative polarity goes to the cathode of the cathode-ray tube in unit I-6. This is the pulse for intensifying the operating cycle of the range sweep.

From the cathode load R-13-I5 of the paraphase amplifier, a rectangular signal of positive polarity is fed to the remote indicator as the pulse for intensifying the operating cycle of the remote indicator's range sweep.

Sweep unit I-5 contains tube L-16-I5, type 6AG7, which is designed to regulate the current in the focusing coil of the cathode-ray tube. Varying the automatic bias on the grid of this tube with potentiometer "Fokus" (Focus), R-01-I9, which is mounted on the control panel I-9, changes the value of the focusing current and, consequently, also the quality of the cathode-ray tube focusing.

6. Indicator Cathode-Ray Tube Unit I-6 and Selsyn Unit I-14

The electrical schematic diagram of units I-6 and I-14 is given in the general electrical diagram of the station, drawings No 33,650,007-SE.

The main indicator uses cathode-ray tube type 31LM32 with a screen diameter of 300 mm. In the diagram the tube is designated as L-01-I6.

The basic data on tube type 31LM32 are as follows: heater voltage -- 6.3 v, ac or dc; heater current -- 0.6 ± 0.06 amperes; focusing -- magnetic; deflection -- magnetic; afterglow -- prolonged; color of luminescence -- yellow-orange.

The operating conditions of the cathode-ray tube are as follows: voltage on the second plate -- 3,200 volts; voltage on the accelerating electrode -- 300 volts; blocking voltage on the modulating electrode -- 25 ÷ 70 volts relative to the cathode.

For the purpose of facilitating observation, the tube is set in an inclined position at an angle of 30° between the axis of the tube and the vertical.

As we know, in addition to the image of the navigation conditions surrounding the ship, the following must be visible on the screen of the indicator tube:

a. Fixed range circles, which make possible rough determination of the distance to reflected objects

b. Movable range circle for accurate range determination

c. Luminous mark indicating the ship's course.

In order to form these, the following signals are fed to the electrodes of the cathode-ray tube:

a. To the CRT's modulating electrode, from the plate of tube L-04-I12 in the video mixer, the pulses from reflected objects and the pulses which form the movable and fixed range circles; and from cathode 8 of thyratron L-05-I12 the pulses of the electronic force mark

b. To the cathode of the CRT, pulses for intensifying the operating cycle of the range sweep.

A saw-tooth current is fed to the deflection coil from selsyns SDS-1, unit I-14. A fixed yoke with the 3-phase deflection coil surrounds the throat of the tube. When the saw-tooth 3-phase current is passed through the phase windings, a radial sweep line, which rotates synchronously with the antenna, is formed.

The spot is focused on the screen of the cathode-ray tube by means of potentiometer "Fokus" (Focus), R-01-I9, which is mounted on the check panel and varies the automatic grid bias on tube L-16-I5 in the sweep circuit. The focusing coil of the cathode-ray tube is connected to the plate circuit of tube L-16-I5. In order to reduce the effect of power-supply voltage fluctuations on the focusing, the focusing tube used is pentode 6P9, whose plate current depends little on the plate voltage.

The brightness of the "NKD" [Fixed Range Circles] marks is regulated by potentiometer R-04-I9, which is mounted on the control panel.

The power supply of the CRT is taken from the general power supply unit I-8.

Connected in series with the phase windings of the deflection coil are resistors R-01-I6, R-02-I6, and R-03-I6, which are designed to take off the saw-tooth voltages from which the range and azimuth sweep is formed in the remote indicator.

Unit I-6 also contains relay RE-01-I6, which has six groups of contacts for switching the deflection coil from the selsyn with the braked rotor to the selsyn with the rotor which is coupled to the gyro-compass selsyn. This relay is controlled by the toggle switch "Kurs-Nord" (Course-North), D-02-I9, which is mounted in the control panel I-9.

Azimuth sweep is obtained in the main and remote indicators by means of selsyn unit I-14 and selsyn SGS-1, which are located in the base of the antenna-waveguide assembly, and the deflection coil in unit I-6. In the azimuth sweep circuit, selsyns SGS-1 and SDS-1 are used as "rotating" transformers, i.e., transformers in which the coupling coefficient is changed depending on the angle of rotation of one winding (rotor winding) relative to the other windings of the transformer (stator windings).

The operating principle of the azimuth sweep is as follows. Let us examine a simplified sweep circuit (see Figure 15), which contains the "rotating" transformer of the antenna assembly SGS-1 and the deflection coil. When the saw-tooth pulses of the sweep current pass through the rotor winding of the "rotating" transformer, a magnetic flux will appear in the rotor winding which will induce an emf, corresponding to the position of the rotor, in all three phase windings of the stator. The stator windings are set at an angle of 120° to each other. The value of the emf induced in the windings will be proportional to the coefficient of coupling between the stator winding and the rotor winding. Connected to the stator windings is the three-phase deflection coil, whose windings are also set at an angle of 120° to each other. In the deflection coil there appears a current whose value will correspond to the emf in the different phase windings of the "rotating" transformer to which it is connected. The sum of these currents will create a magnetic flux in the same direction as that created by the rotor windings of the "rotating" transformer.

When the rotor is turned, the ratio of currents in the different phase circuits will be changed in such a way that the magnetic flux in the deflection coil will rotate and deflect the beam in a direction strictly following the rotation of the rotor of the "rotating" transformer. Thus, for example, if the rotor of the "rotating" transformer turns one revolution, then the sweep line, starting from the center of the screen, will also turn one revolution in the same direction.

If the rotor of the "rotating" transformer is mechanically coupled to the antenna and is so matched that the direction of the antenna beam in space corresponds to the direction of the sweep line on the screen of the indicator tube, then azimuth sweep is formed by rotation of the antenna.

If in the circuit shown in Figure 15 differential selsyn SDS-1 (Figure 16) is used as the "rotating" transformer, then turning the rotor of this transformer can cause the sweep line (and, consequently, the image) to rotate in some direction such that the angle of rotation of the sweep line on the indicator tube must be equal to the angle of rotation of the rotor of the "rotating" transformer SDS-1.

The station "Neptun" is equipped with 2 differential selsyns, one with a braked rotor, and the other coupled with the gyrocompass.

Thus, in the selsyn unit I-14 there are:

a. "Rotating" transformer M-01-I0, selsyn type SDS-1. The rotor of the selsyn is braked, and when it operates with the deflection coil it produces an image oriented in respect to the diametral of the ship. Selsyn M-01-I0 is located outside of unit I-14, although electrically it is directly connected with the selsyn unit.

b. "Rotating" transformer M-02-I14, selsyn type SDS-1 with its rotor coupled to the gyrocompass selsyn and the moving scale of the indicator. When the deflection coil operates with this "rotating" transformer, the image is oriented according to the meridian.

c. Gyrocompass selsyn M-01-I14, type SS-404 or SS-153, or other type whose rotor is coupled with the rotor of selsyn M-02-I14 and the moving scale of the indicator. This selsyn guarantees synchronous and cophasal rotation of the rotor of selsyn M-02-I14 with the coil of the gyrocompass.

Operation of the indicator with its image oriented in respect to the diametral of the ship consists in the following. Orientation of observed objects is performed relative to the diametral plane of the ship, which is indicated on the screen of the CRT as a luminous line passing from the center of the CRT through 0 on the fixed scale. When the ship changes course, the image on the screen of objects surrounding the ship will move, while the luminous course mark will remain fixed on the 0 of the fixed scale of the indicator.

Stabilization of the image according to the meridian is introduced so that, no matter what the course of the ship, the image of fixed objects will not move around the center of the screen and will be oriented according to the meridian. In this case the course is indicated by a luminous line which moves around the screen to conform to changes in the ship's course, while 0 on the fixed scale indicates the direction to north.

When changing course the ship turns relative to the objects surrounding it, and since the antenna rotates together with the ship, if measures are not taken, the image on the screen will also rotate.

Stabilization of the image in respect to the meridian means that, when the ship changes course, an additional angle is introduced into the azimuth sweep with such a value that the image on the screen does not rotate. This is accomplished by the following process. The rotor of the "rotating" transformer M-02-I14 is turned by selsyn M-01-I14, which is in turn coupled to the gyrocompass, in such a way that the angle of rotation of the "rotating" transformer's rotor is equal but opposite in sign to the angle of rotation of the gyrocompass scale and, consequently, also to the value of the change in course.

In this case the image remains stationary on the screen.

7. Main Intermediate-Frequency Amplifier (Unit I-7)

The schematic diagram of the main i-f amplifier is given in the general diagram of the station, draft No 33,650,007-SE. The main i-f amplifier, unit I-7, is designed to amplify the intermediate-frequency signals taken from the i-f preamplifier in the receiver-transmitter and to convert them into video signals.

The main i-f amplifier consists of four i-f amplification stages, a detector, and two video amplifier stages.

The signal from the output of the i-f preamplifier goes through the coaxial cable to the input box B-01-I7 and through transformer T-01-I7 to the grid of tube L-01-I7. Connected in parallel with the primary winding of the transformer is resistor R-01-I7, which is necessary for matching with the cable and for introducing attenuation into the grid circuit of tube L-01-I7.

The secondary winding of the transformer is connected to the grid circuit of tube L-01-I7. The grid circuit is made up of inductor L-01-I7 and the input capacitance of the tube, and it is tuned to a frequency of 33 Mc.

Tube L-01-I7 operates under class-A conditions and obtains automatic bias through resistance R-03-I7 and capacitance C-01-I7 at the cathode.

Included in the plate circuit of the tube is load resistance R-02-I7, the voltage from which is fed through capacitor C-03-I7 to the grid circuit of tube L-02-I7. This circuit is made up of the natural capacitances in the circuit and inductance L-02-I7; it is tuned to a frequency of 27 Mc.

The following two i-f amplifier stages, from a circuit point of view, do not differ at all from the stage of tube L-02-I7, and they differ from one another only by their resonant frequencies. The circuit which is tuned by inductance L-03-I7 is set at a frequency of 33 Mc, while the circuit which is tuned by inductance L-04-I7 is set at a frequency of 27 Mc.

Tube L-04-I7 is the last i-f amplification tube and operates on the second detector L-05-I7, type 6Kh6S. The load of tube L-04-I7, in contrast to those of the preceding stages, is not a circuit, but a band filter which has a resonant frequency of 30 Mc and a pass band of about 5.5 Mc.

The filter is made up of the natural capacitances of the circuit and the inductances L-05-I7 and L-06-I7.

Capacitor C-16-I7 is a divider, while capacitor C-17-I7 is the coupling element between the two circuits of the filter.

Tube L-05-I7 is the second detector of the receiver. The filament of this tube is fed through choke L-07-I7, whose presence guarantees maintenance of the receiver's tuning on replacement of tube L-05-I7, since the cathode-filament capacitance is not normalized. The load of the second detector is resistor R-17-I7, which is shunted, in order to pass the i-f, by capacitor C-19-I7. In order to prevent the i-f from entering the video amplifier path, a filter composed of resistor R-18-I7 and inductance L-08-I7 is connected between the detector load and the video amplifier. This filter, together with the input capacitance of the video amplifier tube, forms a circuit with high input impedance.

Moreover, there is between the output of the second detector and the grid of the first video amplifier tube a signal differentiating circuit "MPV". This circuit consists of C-20-I7 and R-19-I7 with a low time constant. When the operator desires, this circuit can be turned on with the aid of relay RE-01-I7.

The function of the "MPV" [Low Time Constant] circuit is to divide objects on the basis of distance when the interval between them is too small for comparison with the length of the high-frequency transmitter pulse in space. The operating principle of this circuit, whose diagram is shown separately in Figure 18, is most conveniently examined by means of the following example. Let us take two observed objects, the interval between which is less than the length of a pulse in space (Figure 19). In this case it is evident that, as a result of the multiplication of signals from these two objects, the voltage pulses on the output of the second detector will have the form shown in Figure 20.

Since signal limitation takes place in the final stages of the video amplifier, then in practice the peak (overhang) will be cut off and, instead of two separate signals, we will obtain one elongated signal.

If between the second detector and the video amplifier there is connected a C and R circuit with a low time constant in comparison with the duration of the pulse, the form of the signal at the video amplifier input in this case will be as shown in Figure 21, and the signals from the two closely spaced objects will be separated from each other. However, this is still not sufficient, since in the input signal of the video amplifier there are positive pulses which produce dark spots on the screen behind the objects. In order to avoid this phenomenon a germanium detector is connected in parallel with the impedance of the "MPV" [low time constant] circuit, which is connected with its polarities such that the positive peaks are practically completely chopped off.

The video amplifier consists of one voltage amplification stage with tube L-06-I7, type 6Zh4 (6AS7), which produces an almost twenty-fold voltage amplification, and a stage consisting of two cathode followers, using tubes L-07-I7 and L-08-I7, type 6AG7, which provides a separate receiver signal output to the mixer I-12.

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8. Video Mixer (Unit I-12)

The schematic diagram of the video mixer is shown in the general electrical diagram of the station, drawing No 33,650,007-SE.

The video mixer is designed to mix the receiver signals and the pulses which form the fixed range circles, the movable range circle, and the ship's course mark, and to amplify these signals to the values necessary for brightness modulation of the cathode-ray tube.

The video mixer is a 5-tube circuit containing the following tubes: L-01-I12, type 6Zh4 (6AS7); L-02-I12, type 6AG7; L-03-I12, type 6Zh4; L-04-I12, type G-807; and L-05-I12, type TG1-0.1/1.3 (TG-2050).

The receiver video signals from unit I-7 and the fixed range circle pulses from unit I-5 go to the total input resistance of the video mixer R-01-I12, which is the total cathode load of tubes L-11-I5 and L-07-I7. Through capacitor C-05-I12 the signal is fed to grid 4 of tube L-02-I12. This tube operates as a cathode follower with cathode load R-07-I12. From resistance R-07-I12 the signals go through divider capacitor C-06-I12 by feeder RK-3 to the remote indicator.

The movable range circle pulses, which are formed at resistor R-03-I12 (this resistance is the cathode load of tube L-03-I3), go through capacitor C-01-I12 to the grid 4 of tube L-01-I12 and are amplified by it. The input signal of the video mixer is fed through divider capacitor C-04-I12 to grid 4 of tube L-03-I12, whose plate 8 is connected with plate 8 of tube L-01-I12. At resistance R-10-I12, i.e., at the common plate load of these tubes, the amplified signals which form the fixed range circles and the video signals are put together with the movable range circle pulses.

From the plate load R-10-I12, which is common for all the tubes, the signals go through divider capacitor C-10-I12 to grid 3 of the power output amplifier tube L-04-I12. The voltage on grid 2 of tube L-04-I12 is varied with regulator R-31-I12, and in this manner the limit value of the amplitude of the output signal is varied. In the plate circuit of tube L-04-I12 the signals of all pulses which are fed to the different inputs of the video mixer are amplified. These signals are fed from the plate of amplifier tube L-04-I12 through divider capacitor C-11-I12 to the modulating electrode of the CRT in unit I-6.

Also fed to the modulating electrode of the CRT are the pulses of the electronic course mark of the ship which are taken from the cathode load, potentiometer R-08-I9, which is mounted on the control panel I-9.

The electronic course mark pulses are formed in the following manner. In the antenna drive there is a microswitch D-06-A7, which closes the circuit each time that the beam of the antenna, while it is rotating, coincides with the course of the ship. This microswitch closes the circuit of grid 5 of the thyratron L-05-I12 to the "ground" and in this way takes off the negative bias, firing the thyratron. The moment the contact is closed, capacitor C-15-I12, which charges through resistor R-19-I12, discharges through the circuit consisting of the fired thyratron, resistor R-20-I12, and resistor R-08-I9 in the cathode circuit of the thyratron. The resistance in the cathode circuit can be used to regulate the value of the voltage pulse obtained and, in this way, the brightness of the line indicating the ship's course.

The pulse obtained from the thyratron in this manner, its duration determined by the time constant of the discharge circuit, i.e., C-15-I12 and R-20-I12, together with R-08-I9 and the internal resistance of the thyratron, is fed through capacitors C-14-I12 and C-21-I12 to the modulating electrode of the indicator CRT.

9. Control Panel, Unit I-9

The schematic diagram of the control panel is given in the general electrical diagram of the station, drawing No 33,650,007-SE.

The location of the station's controls is visible in the photographs.

The whole station is controlled from control panel I-9, except for starting the power-supply unit, which is turned on and off from the remote control point set close to the indicator. When the power-supply unit is started, the left yellow signal lamp on the vertical part of the control panel, marked "~ 230 v," L-02-I9, will light up, indicating that there is a power-supply voltage of 230 volts, 427 cycles in the indicator.

The station itself is turned on with the switch "Pitaniye" (Power Supply), D-06-I9, which is mounted in the middle of the horizontal part of the control panel. Then the indicator is connected with the power-supply unit I-8, and the power-supply voltage is fed to the receiver-transmitter and the remote indicator.

After 5 minutes (the automatic time delay in block "P") the station is ready for momentary switching to the position "Rezerv" (Stand-By) or "Rabota" (Operation), depending on the position of the "Rezerv-Rabota" switch, D-05-I9, which is mounted to the left on the horizontal part of the control panel.

Between the switches "Rezerv-Rabota" and "Pitaniye" there is located the range-scale switch D-01-I9, which is mechanically coupled with switch D-03-I5 of the sweep unit. Taken as a whole, this switch, which consists of 8 contacts in four positions and two directions each [4 double-pole double-throw switches?], switches over all circuits in units I-9 and I-5 when changing from one range scale to another.

To the right of switch "Pitaniye" are located the range-finder counter and handle, which are coupled with phase-shifter block I-16. The counter is calibrated in units of 0.002 miles or 0.02 cable lengths (3.7 meters).

The minimum scale division of the range finder should not be considered as the limit of accuracy of distance measurement, since errors in measuring range depend in large measure on the other components of the error.

Mounted on the vertical part of the control panel are the following control elements of the station:

a. Rheostat "Osveshcheniye Shkal" (Scale Illumination), R-22-I9, which is used to regulate the brightness of illumination of the indicator-tube scale

b. Toggle switch "MPV" [Low Time Constant], D-08-I9, which turns on the differentiating circuit in the receiver, thus rendering the image of the target on the indicator screen sharper

c. Toggle switch "Razdvizhka Tsentra" (Expansion of the Center), D-09-I9, which turns on the circuit in sweep unit I-5, causing the origin of sweep cycle on the first range scale to begin to describe a circle on the indicator screen; in this manner determining angles more accurately when sighting on nearby objects

d. White signal lamp "~ 230 v," L-02-I9, which indicates whether the power supply of 230 v, ac, 427 cycles, is being fed to the indicator

e. Yellow signal lamp "Vklyuch" (On), L-09-I9, which indicates whether power-supply unit I-8 is turned on and whether the plate voltages which supply the circuits of the units of the indicator are present

f. Red signal lamp "Rabota" (Operation), L-04-I9, which indicates that the transformers of the high voltage rectifiers in the receiver-transmitter are turned on and, consequently, high-frequency pulses of electromagnetic energy are being generated

g. Toggle switch "Kurs-Nord" (Course-North), D-02-I9, in the position "Kurs" (lower position), which turns on image stabilization on the screen in respect to the diametral of the ship; and in the position "Nord" (North) (upper position), which turns on indicator-screen image stabilization in respect to the meridian

h. Toggle switch "ARCh-RRCh" [AFC-Manual Frequency Control], D-03-I9, for switching from automatic frequency control to manual, and back

i. Toggle switch "Obzor-Rezerv" (Surveillance-Stand-By), D-15-I9, which serves to switch the station from operation on "Obzor" [surveillance] to operation on the stand-by channel

j. Microswitch "Vobbulyatsiya" (Wobbulation), D-11-I9, which turns on and off the wobbulation of the echo box

Toward the top of the inclined part of the control panel, mounted from left to right, are:

a. Potentiometer "Yarkost'" (Brightness), R-29-I9, which regulates the brightness on the modulating electrode of the CRT and, thus, the brightness of the image.

b. Potentiometer "PKD" [Movable Range Circle], R-07-I9, the brightness regulator for the movable range circle.

c. Potentiometer "NKD" [Fixed Range Circles], R-04-I9, the brightness regulator for the fixed range circles.

d. Potentiometer "Otmetka Kursa" (Course Mark), R-21-I9, which regulates the brightness of the course mark.

e. Potentiometer "Fokus" (Focus), R-01-I9, which is accessible under the slit, with the aid of which the focusing-coil current is regulated.

f. Potentiometers "R. N. Obzor" [Manual Tuning Surveillance] and "Rezerv" (Stand-By), R-16-I9 and R-17-I9, accessible under the slit, with which to perform rough manual tuning of the klystrons in operation on "Obzor" and on "Rezerv", when the toggle switch "ARCh-RRCh" [AFC-Manual Frequency Control] is in the "RRCh" position.

g. Potentiometer "Sovmeshcheniye" (Combination), R-30-I9, which serves for regulation of the voltage on the reflector of the "Obzor" (Surveillance) klystron, L-04-I2.

h. Potentiometers "R. N. Obzor" [Manual Tuning, Surveillance] and "R. N. Rezerv" [Manual Tuning, Stand-By], R-15-I9 and R-14-I9, for manual tuning of the klystron when operating the station on "Obzor" and "Rezerv"; tuning is performed only with the toggle switch "ARCh-RRCh" in the position "RRCh"; the handle of the regulator has a lock.

In the middle on the top are mounted measuring instrument Z-01-I9 and switch D-12-I9, which are designed for measuring the crystal current when the station is operated on either "Obzor" or "Rezerv."

On the bottom of the inclined part of the control panel the following are mounted: on the left, potentiometer "Usileniye" (Gain), R-05-I9, the receiver gain regulator; and on the right, potentiometer "Usileniye po B. O." [Gain for Nearby Objects], R-09-I9, which regulates the range of operation of the automatic gain control according to the distance.

Mounted below the cathode-ray-tube frame is the toggle switch "Girokompas" (Gyrocompass), D-04-I9, which is designed to turn on and off the synchronous coupling between the indicator and the gyrocompass.

10. Check Panel I-11

The schematic diagram of the check panel is given in the general electrical diagram of the station, drawing No 33,650,007-SE.

The check panel contains auxiliary elements which are necessary only in the process of tuning and checking.

In order to check the operation of the main indicator circuit without interrupting the operation of the station, the check panel of the indicator is fitted with boxes to which the most important check points of the circuit are connected. Thus, the boxes marked "2.7 kgts" (2.7 kc), "13.5 kgts" (13.5 kc), and "81 kgts" (81 kc), (B-03-I11, B-07-I11, and B-06-I11) tap the output voltages of the frequency generator. These voltages are taken from the secondary windings of output transformers T-06-I1 and T-05-I1, as well as from the high-frequency filter output (unit I-2).

The box "Razvertka" (Sweep), B-05-I11, taps the saw-tooth sweep pulse taken from the cathode of tube L-07-I5 in the sweep unit.

The box marked "ZI" [Trigger Pulse], B-03-I11, taps the output of the trigger pulse-forming circuit I-4 through capacitor C-06-I4 from cathode 5 of tube L-03-I4.

Box "Vkhod Smesitelya" (Mixer Input), B-04-I11, taps the input of unit I-12, making it possible from this point to check the receiver video signals and the fixed range circle pulses, which go to grid 4 of tube L-02-I12.

Box "PKD" [Movable Range Circle], B-02-I11 taps the output of the movable range circle pulse-forming circuit, i.e., cathode 6 of tube L-03-I3. At this point the form and amplitude of the movable range circle pulse are checked.

The box marked "Vykhod Smesitelya" (Mixer Output), B-01-I11, taps cathode 4 of the video mixer output tube L-04-I12. At this point all signals fed to the brightness-modulating electrode of the CRT can be checked.

The forms of the curves and the values of the voltages fed to the check boxes are given in the Instructions on Operation of the Station "Neptun."

The power-supply voltages are checked with two measuring instruments, one of which (Z-01-I11) measures the network voltage of 230 v, 427 cycles, while the other (Z-02-I11), with the aid of switch D-16-I11, is connected to the different rectified-voltage circuits. In addition, instrument Z-02-I11 is used to measure the magnetron current.

In order to measure with instrument Z-01-I11, it is necessary to press the button "~ 230 (X2)", D-15-I11.

The check panel is fitted with 3 toggle switches:

a. Toggle switch "Motor Ant" (Antenna Motor), D-21-Ill, which is designed to turn on and off the motor which rotates the antenna.

b. Toggle switch "Kamera" (Echo-Box), D-17-Ill, to turn on and off the echo-box, which is designed to facilitate tuning of the receiver-transmitter part of the station. With the aid of the echo-box it is also possible to check the receiver-transmitter path of station for correct working order.

c. Toggle switch "Osveshcheniye" (Illumination), D-18-Ill, which turns on and off the check-panel illumination.

Mounted on the lower part of the check panel are fuses for all the station's power-supply circuits:

a. Four fuses, one for 0.5 amperes, and three for 2 amperes (D-14-Ill, D-13-Ill, D-12-Ill, and D-11-Ill, respectively) are located in the circuits of the primary windings of the transformers for the power-supply rectifiers in unit I-8.

b. Fuse rated at 3 amperes, D-07-Ill, which is in the 230-v power-supply circuit of the remote indicator

c. Fuse rated at 3 amperes, D-06-Ill, which is in the 230-v 427-cycles power-supply circuit for the receiver-transmitter

d. Fuses rated at 20 amperes, D-05-Ill and D-04-Ill, in the general power-supply circuit, fed from the units at the location

Mounted on the lower left of the check panel are sockets (D-01-Ill and D-02-Ill) for connecting a soldering iron and lights necessary during repair of the apparatus. The voltage on the sockets is 230 v, 427 cycles. Maximum current that can be drawn is 2 amperes.

11. Power-Supply Unit I-8

The schematic diagram of the power-supply unit I-8 is given in the general electrical diagram of the station, draft No 33,650,007-SE.

Power-supply unit I-8, which is mounted in the lower part of the indicator, develops a dc voltage for supplying all the units in the indicator and certain units in the receiver-transmitter, as well as voltage for supplying the filaments of the indicator tubes.

All voltage and current values necessary for operating the units of the indicator and some units of the receiver-transmitter are cited in Table No 1. The voltage cited in the table are obtained by conversion of the main power-supply voltage, 230 volts, 427 cycles.

In order to obtain the necessary voltages, the following 5 rectifiers, which go into unit I-8 are used:

a. High-voltage rectifier for 3,200 volts

b. Stabilized rectifier for +300 volts, from which the +550-volt unstabilized voltage is also obtained at the same time

c. Stabilized rectifier for -300 volts and -150 volts

d. Rectifier for 300 volts and 150 volts

e. Selenium rectifier for -26 volts

In addition, unit I-8 contains a filament transformer which supplies the filaments of all tubes in the indicator. It has two filament windings, both operating at a potential 6.3 volts, one delivering 11.2 amperes, the other 16.8 amperes.

The high-voltage rectifier which serves as the power supply for cathode-ray tube 31LM32, unit I-6, operates on kenotron L-01-I8, type 2Ts2S (2x2). The rectifier is a half-wave circuit, and the filter is U-shaped, made up of resistors R-03-I8 and R-04-I8 and two capacitors C-01-I8 and C-02-I8. The required ac voltage is supplied to the rectifier from transformer T-01-I8.

The rectifier for 300 volts stabilized and 550 volts unstabilized has 2 rectifier tubes, L-07-I8 and L-02-I8, whose plates are supplied from the common step-up winding of transformer T-02-I8.

The rectifier for +300 volts utilizes a circuit with electronic stabilization, under which the load current of the rectifier goes through two power tubes, L-03-I8 and L-04-I8, type 6P3. The resistance of these tubes is automatically varied when the voltage on the rectifier output is changed, thus compensating for the change.

Table No 1

	~6.3 Volts	300 v Stabilized	-150 v Stabilized	-26 v	+150 v	+300 v	+300 v Stabilized	+500 v	3,200 v
Unit I-1	2.5 a	--	--	--	--	58 ma	--	--	--
Unit I-3	2 a	--	2 ma	--	0.4 ma	15 ma	--	--	--
Unit I-4	2.3 a	--	7 ma	--	--	34 ma	--	--	--
Unit I-5	12.8 a	--	12 ma	--	0.7 ma	70 ma	85 ma	45 ma	--
Unit I-6	0.9 a	--	--	--	--	11 ma	--	--	2 ma
Unit I-7	3.55 a	--	--	--	95 ma	--	--	--	--
Unit I-12	3 a	--	1 ma	--	--	115 ma	--	--	--
Units of Block "P"	--	7.5 ma	--	1.3 a	50 ma	--	25 ma	--	--
Total	27.0 a	7.5 ma	22 ma	1.3 a	146 ma	303 ma	110 ma	45 ma	2 ma

The stabilization process proceeds in the following manner. For any random increase in the potential on the output of the rectifier there is an increase of the potential of grid 4 of tube L-05-I8, type 6Zh4 (6AS7), whose cathode 5 is always under a dc potential stabilized by tube L-06-I8, type SG4S (150-S-5-30). The increased potential on grid 4 causes a reduction in the potential on plate 8 of tube L-05-I8 and grids 5 of tubes L-03-I8 and L-04-I8, thus increasing the resistance of these tubes and decreasing their output voltage. Decreasing the output voltage starts a process which is the reverse of that described above. Since these processes take place instantaneously, the voltage on the output remains practically constant.

The stabilized rectifier for +300 volts operates on tubes L-07-I8, type 5Ts3S (5I4S), L-03-I8 and L-04-I8, type 6P3, L-05-I8, type 6Zh4 (6AS7), and L-06-I8, type SG4-S (150-S-5-30). Potentiometer R-23-I8 serves to regulate the value of the stabilized voltage within the limits 260 to 340 volts. This stabilized rectifier insures a constant rectified voltage within the limits of ±0.5 percent for fluctuations in the voltage on the primary winding of the transformer of ±20 percent.

The rectified voltage +550 volts is taken from the output of a filter composed of capacitor C-04-I8 and choke Dr-02-I8, to the input of which is supplied the voltage rectified by tube L-02-I8.

The stabilize rectifier for -300 volts and -150 volts uses the same circuit as the stabilized rectifier for +300 volts, the only difference being that in the latter the positive output voltage terminal, relative to which the voltages -150 v and -300 v are taken from the corresponding circuit point, is grounded. The rectifier uses tubes L-14-I8, type 5Ts3S (5I4S), L-13-I8, type 6P3, L-09-I8, type 6Zh4 (6AS7), and L-08-I8, type SG4S (150-S-5-30).

The rectifier supplying the unstabilized voltage +300 v and +150 v operates on tubes L-10-I8 and L-12-I8, type 5Ts3S, and L-11-I8, type 5Ts4S, which in turn are supplied from transformer T-03-I8.

The selenium rectifier for 26 volts is a Gratz full-wave circuit using 2 selenium stacks, type VS-45-46, which are connected in parallel. The rectifier is supplied for transformer T-05-I8.

When the switch "Pitaniye" (Power Supply), which is located on the control panel, is set in the position "Vkl" (Off), in unit I-8 it turns on the filament transformer T-04-I8, which is at the same time the transformer which supplies the stabilized rectifier for -300 v and -150 v, and transformer T-05-I8 for the 26-volt selenium rectifier. Simultaneously 230 volts, ac, are fed to the receiver-transmitter and the remote indicator. The cathode-ray tube and all indicator circuits must be protected from the possibility of the plate voltage being switched on when there is no bias voltage. Therefore, in the rectifier circuit, transformers T-01-I8, T-02-I8, and T-03-I8 are energized through the contacts of relay RE-01-I8, whose winding is supplied from the rectified voltage -150 volts.

C. Description of the Construction of Block "I"

The construction of the main indicator insures free access to all its units and mechanisms mounted inside the block for their inspection, repair, or replacement. The block is constructed of a prefabricated cast housing with a steel chassis which slides out of it and on which are mounted all units and mechanisms of the block.

Fastened on the top of the chassis is the control panel with control knobs and scales. The angle-measuring scales and the cathode-ray tube, which is fastened under them, are mounted at an angle for convenient viewing of the screen.

Mounted on the upper part of the chassis are the following:

1. Selsyn unit--I-14

2. Cathode-ray tube unit--I-6. The shield for the cathode-ray tube is made of permalloy for the purpose of screening out magnetic fields of the indicator and the magnetic field of the earth.

Mounted in the left middle part of the chassis are the following:

1. Frequency generator--I-1.

2. Main intermediate-frequency amplifier--I-7.

Mounted in the middle part of the indicator chassis are the following:

1. Sweep unit--I-5.

2. Quadrature circuit unit--I-15.

3. Range-finder unit--I-16.

Mounted in the right side of the chassis are the following:

1. Contact plug for coupling the indicator units with the contact plug of the chassis.

2. Pulse-forming units--I-3 and I-4.

Mounted on the rear of the chassis are the video mixer I-12, the strip with resistors R-01-I6, R-02-I6, and R-03-I6, which are connected in series with deflection coil of unit I-6, and the relay which actuates the "rotating" transformers of selsyn unit I-14.

Mounted at the bottom of the chassis is power-supply unit I-8.

The open construction of the chassis of the individual units allows for performance of inspection after assembly without removing them from the chassis. The cables are led in through the bottom of the rear side, where in the lower part of the housing the common terminal strip is located.

The upper front of the chassis is covered with a removable duralumin sheet, while the lower part is fitted with a door, behind which are located check panel I-11 with the fuses and measuring instruments which are mounted on it.

The block is cooled during operation by air convection around its outer walls and by means of the hinged cover which is placed in the upper part of the rear wall of the housing.

Block "I" is set on shock-absorbing pads.

IV. RECEIVER-TRANSMITTER (BLOCK "P")

A. Function and Principle of Operation

The schematic diagram of the receiver-transmitter is shown in the general electrical diagram (see drawings No 33,650,007-SE).

The main purpose of the receiver-transmitter (block "P") is the generation of pulses of superhigh-frequency energy.

So that the transmitter and receiver can operate on the same antenna, this block contains a rhumbatron system of electrical "reception-transmission" [T-R] switching. The receiver-transmitter block contains the input superhigh-frequency part of the receiver, with heterodyne, crystal frequency converter, and i-f preamplifier.

Block "P" operates in the following manner. Trigger pulses with a duration of 1.3 microseconds and a voltage on the order of 12 volts enter the input of the first modulator stage, P-6, from the main indicator by a coaxial feeder through box B-01-P6.

In the modulator these pulses are converted into powerful rectangular pulses with the duration of 0.25 and 1 microseconds and a voltage of 12,000 volts, approximately, which go to the magnetron.

From the magnetron output the superhigh-frequency pulses are fed through the electrical rhumbatron switch "Priyem-Peredacha" [T-R] (unit P-2) to the antenna radiating system. The reflected pulses received by the same antenna go through the "reception" rhumbatron cavity to the waveguide cavity of the crystal mixer in the receiver, unit P-2. From the mixer output the i-f pulses received as a result of conversion of the signal frequencies (frequency of the magnetron or the reserve channel and the klystron heterodyne) are fed through a short coaxial feeder and box B-03-P3 to the i-f preamplifier, unit P-3. From the output of unit P-3 the amplified signal pulses go through box B-01-P3 and coaxial feeder No 24 to the main receiver amplifier, unit I-7, in the main indicator block.

B. Detailed Description of Units Composing Block "P"

1. Modulator (Unit P-6)

The electrical schematic diagram of the modulator is shown in the general electrical diagram of the station (drawings No 33,650,007--SE).

The modulator is designed to convert the trigger pulses which enter from the main indicator into powerful pulses of rectangular form and a voltage of about 12,000 volts, which are in turn fed to the cathode of magnetron L-01-P5.

The modulator contains the following stages:

a. Trigger-pulse amplifier and first blocking oscillator

b. Second blocking oscillator for rectangular pulses

c. Power keyer and suppressor diode.

a. Trigger-Pulse Amplifier
The simplified diagram of this stage is given in Figure 22.

The circuit utilizes a twin triode, type 6N8S. In the absence of trigger pulses, the right triode of tube L-01-P6 is locked by a negative bias on grid 4 which is equal to 22 volts. The bias voltage is fed through resistor R-02-P6 from voltage divider R-21-P6 and R-20-P6 (see the diagram of unit P-6). The automatic bias voltage on grid 1 of the triode is equal to 10 volts.

The positive trigger pulse goes to grid one of the left triode and is amplified. The pulse on the plate of the triode has negative polarity. When there is a decrease in the voltage on the plate (for an unchanged power-supply voltage), there is a decrease in the voltage on the grid winding of the blocking oscillator's pulse transformer T-01-P6 (the windings are connected to meet each other). The voltage increase on the grid winding of the transformer is transferred to grid 4 of the blocking oscillator through capacitor C-02-P6. When the positive voltage on the grid of the right triode compensates for the negative bias, the process of pulse formation begins in the previously locked blocking oscillator. The voltage of the pulse on the output winding of the blocking-oscillator transformer reaches a value of 250 volts. This positive pulse, with an amplitude of 20 volts, is fed through capacitor C-03-P6 to trigger the second blocking oscillator.

The repetition frequency of these pulses exactly corresponds to the frequency of repetition of the pulses for triggering the transmitter, which come from the main indicator. The form of pulses at the input of the amplifier can be checked at feeder box B-02-P6, while those at the output of the first blocking oscillator can be checked at plug socket D-04-P6.

b. Second Rectangular-Pulse Blocking Oscillator

The simplified diagram of the blocking oscillator is shown in Figure 23.

The oscillator tube used is a dual beam tetrode; type GI-30 (KFN2D), whose plates and grids (control) are connected in parallel. The rectangular pulse generator is a delaying blocking oscillator with pulse transformer T-02-P6 and pulse-forming circuits. As the element which determines the duration and form of the pulse, the grid circuit of the blocking oscillator contains special pulse-forming circuits which are switched, when changing from one pulse duration to another, by means of two relays, RE-01-P6 and RE-02-P6, which are controlled from the indicator by range scale switching ("Obzor-Rezerv" [Surveillance-Stand-by]).

The pulse-forming circuits are equivalent to sections of two-conductor long lines of different lengths, with the aid of which rectangular pulses of different durations are formed.

The generation of rectangular pulses is based on the principle of the charging of an ordinary two-conductor line or special pulse-forming circuit from a dc source through a resistance numerically equal to the characteristic impedance of the line. At the charge resistance a rectangular voltage pulse is obtained whose duration is entirely determined by the discharge time of the line, i.e., the length of the line (Figure 24). If at some moment a voltage E is impressed, then voltage equal to E/2 are applied, at first to the line and to the resistance, equal to the input resistance of the line. Then, as the voltage wave goes from the beginning to the end of the line and back, the line becomes charged until its voltage equals E.

Now the total voltage is established on the whole line, and the current through resistance R_3 stops.

Thus, the voltage on resistance R_3 is equal to E/2 and exists for the time $t = 2\ell/C$, where ℓ is the length of the line, and C is the rate of wave propagation along the line.

As the equivalent of the long line in the modulator, special pulse-forming circuits are used (Figure 25) which are calculated from the conditions for obtaining the same period of oscillations as in a two-conductor long line. The pulses obtained from such forming circuits differ from those obtained on two-conductor long lines by less steepness of their front and rear edges and the presence of oscillatory phenomena on the "flat" part of the pulse (Figure 26).

However, the smoothing action of the blocking oscillator, in whose circuit the pulse-forming circuits operate, insures the generation of a practically rectangular pulse form. In the absence of a pulse from the first stage, the tube of the second blocking oscillator, L-02-P6, is locked by a 92-volt negative grid bias, which is taken from the voltage divider R-18-P6 and R-19-P6 (see electrical diagram of unit P-6) through R-04-P6.

When the positive trigger pulse from the first blocking oscillator is fed to the grid of tube L-02-P6 through capacitor C-03-P6, the second blocking oscillator generates a single pulse. The forming circuit is charged by a dc grid current through the grid-cathode gap in tube L-02-P6 from the grid winding of pulse transformer T-02-P6, which acts as a dc current source. The voltage on its grid is maintained at a constant level for the whole time it takes to charge the forming circuit. As soon as the pulse-forming circuit is charged, the grid current, which is at the same time the pulse-forming circuit charging current, ceases and the tube is closed until receipt of the next trigger pulse by the negative bias on the control grid. The obtained rectangular pulse, with a voltage of 1,100 volts and a duration determined by the parameters of the pulse-forming circuit, is taken from the output winding of pulse transformer T-02-P6 and is fed to the control grid of L-03-P6. One-tenth of the amplitude of the pulse taken from the voltage divider consisting of R-10-P6, R-11-P6, C-29-P6, and C-28-P6, is fed along a feeder to trigger the circuit "Usileniye po B.O."[gain for nearby objects] of the receiver in unit P-3. The rectangular-pulse blocking oscillator receives a plate power-supply of +1,350 volts and a screen supply of +400 volts from unit P-8.

c. Power Keyer and Suppressor Diode

The power keyer (Figure 27) consists of power-keyer tube L-03-P6, type GMI-83 (G-483), storage capacitor C-03-P7 (which is connected in series with the magnetron), high-voltage rectifier P-7, charge circuit R-01-P7, and diode L-04-P6.

In the absence of pulses on the output of the rectangular-pulse generator, tube L-03-P6 is closed by a negative bias of -750 volts, which is fed to the control grid. During this time the storage capacitor C-03-P7 is being charged from the high-voltage rectifier P-7 through resistances whose total value is equal to 21 kilohms (see Figure 28). The charge current of capacitor C-03-P7 passes through the circuit formed by resistor R-01-P7, diode L-04-P6, milliammeter "Tok Magnetrona" (Magnetron Current), and overload relay RE-03-P8. The voltage on the plate of tube L-03-P6, when capacitor C-03-P7 is being charged, varies according to how much this capacitor is under-charged, and at the end of the time interval between pulses it is equal to 14,000 volts.

When the grid of the modulator tube receives the positive pulse from the output of the second blocking oscillator, the resistance of the tube becomes small (approximately 150 ohms), and the storage capacitor C-03-P7 is connected in parallel with the magnetron. Since the voltage drop on tube L-03-P6 is low (2,000 v), the cathode of the magnetron is under a voltage of -12,000 volts relative to its grounded plate. At this point the magnetron begins to allow current to pass and generates a superhigh-frequency pulse. As a result of the relatively high-capacitance of storage capacitor C-03-P7 and the small time during which it discharges to the magnetron oscillator (2 microseconds), the voltage on the magnetron remains, for all practical purposes, equal to 12,000 volts for the whole pulse generation period.

When the positive pulse on the grid stops, the modulator tube again is closed, and storage capacitor C-03-P7 is charged from the high-voltage rectifier. To protect the modulator tube from possible arcing between the plate and the screen grid, spark discharger D-02-P6 is connected in parallel with the screen grid.

In order to improve the form of the voltage pulse on the cathode of the magnetron (to shorten its rear edge) the circuit of L-01-P5, R-02-P5, and diode L-04-P6 (see Figure 29) is used. In order to explain the operation of this circuit of L-01-P5 and R-02-P5, let us suppose, to start with, that it were absent. During time t, when there is a negative voltage of -12,000 volts on the cathode of the magnetron, the parasitic capacitance of the circuit to the chassis C_3, which is equal to approximately 70 micromicrofarads, is charged correspondingly to 12,000 volts. This capacitance discharges through the leakage resistance of the circuit according to the exponential law, since the magnetron at voltages lower than its operating voltage has a large internal impedance. In the whole time during which the voltage on the cathode of the magnetron is decreasing, the magnetron generates noises and interferes with the reception of pulses reflected from nearby objects. The graph of the variation of voltage on the cathode of the magnetron is shown in Figure 30a.

If the special circuit L-01-P5 and R-02-P5 is connected in parallel with capacitance C_3, then the capacitor will discharge in the newly-formed circuit in an oscillatory manner, as is shown in Figure 30b.

The time in which the decrease in voltage on the cathode of the magnetron takes place, in this case considerably less, is approximately 0.2 microseconds. In order to eliminate the oscillatory process, after the basic pulse is passed, diode L-04-P6 is turned on, thus shunting the circuit when the voltage on the cathode of the magnetron becomes positive. The resulting graph of the voltage on the magnetron's cathode is shown in Figure 30b by the heavy line. The average value of the current charging the storage capacitor C-03-P7 is equal to the average discharge current of capacitor C-03-P7 to the magnetron and to the circuit of L-01-P5 and R-02-P5, which shunts the magnetron. The charging of current of capacitor C-03-P7 (magnetron current) is measured in the high-voltage rectifier circuit of the transmitter (unit P-7). The magnetron current can be measured with the instrument mounted on the check panel of the indicator.

Included in the charging circuit of storage capacitor C-03-P7 is overload relay RE-03-P8, which is mounted in unit P-8. This relay cuts out high-voltage rectifier P-7 in case the current consumption should, for any reason, rise above the normal value.

The modulator receives its power-supply voltage from modulator power-supply unit P-8 and the power-supply unit of block "I" (I-8).

The modulator receives ac voltages of 6.3, 26, and 2.5 volts, as well as ac voltages of +1,350, +400, -750, -26, +300, and -300 volts.

The modulator receives its high voltage of +14,000 volts from the high-voltage rectifier unit P-7, which is mounted near the modulator.

2. High-voltage Rectifier P-7

The electrical schematic diagram of unit P-7 is shown in the general electrical diagram of the station, drawings No 33,650,007-SE.

High-voltage rectifier P-7 is a voltage-doubling circuit using capacitors C-01-P7 and C-02-P7.

Serving as rectifier tubes are diodes, type V1-0.1/30 (705A).

A simplified diagram of P-7 is shown in Figure 31.

The rectifier delivers a dc voltage of about 14,000 volts at a load current of about 10 ma. High-voltage transformer T-01-P7 and tube-filament transformer T-02-P7 are located in one hermetically sealed housing, filled with oil. The filament transformer is turned on when the station is turned on, while the high-voltage transformer is turned on with

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the aid of relay RE-02-P8 when the switch "Rezerv-Rabota" (Stand-by -- Operation) is in the "Rabota" position, and when the time-delay relay system has been tripped (see below).

The high-voltage rectifier is set up on a metal chassis on which are mounted the high-voltage transformer; tubes type V1-0.1/30, the capacitors of the doubling circuits C-01-P7 and C-02-P7, and storage capacitor C-03-P7, which are fastened on high-voltage insulators.

The high-voltage rectifier is fitted with a metal block contact which grounds the high-voltage terminal when the front door of the lower compartment of the block is opened.

3. Modulator Power-Supply Rectifier P-8

The electrical schematic diagram of unit P-8 is shown in the general electrical diagram of the station, drawing No 33,650,007-SE.

The modulator power-supply rectifier P-8 consists of the filament transformer for the modulator tube T-01-P8, plate transformer T-02-P8, 2 kenatrons, type V1-0.03/13, which operate in the circuit of the rectifiers for +1,350 volts and -1,000 volts, and the voltage-divider circuits. In addition, the combined relays for control of the transmitter are constructionally a part of the unit.

The rectifiers for +1,350 and -1,000 volts are half-wave rectifiers (Figure 32).

The voltages +400 and -750 volts are taken from the voltage dividers in the circuits of the +1,300 and of -1,000 volt rectifiers (R-01-P8, R-02-P8, R-03-P8, R-04-P8, R-05-P8, R-06-P8, R-07-P8, R-09-P8, R-10-P8, R-11-P8, and R-12-P8).

The system of relays of the power-supply unit operates in the following manner. When the station is turned on, the network voltage is fed to transformer T-01-P8; this supplies the filament voltage to all tubes in the receiver-transmitter. At this moment time-delay thermal relay RE-05-P8 starts to operate.

After 1.5 minutes contacts 1 and 3 of relay RE-05-P8 are closed, and relay RE-01-P8 trips, in turn switching in the primary winding of transformer T-02-P8 (contacts 11 and 12), which supplies the +1,350-volt and -1,000-volt rectifiers. Then the heater voltage of the thermal relay (26 volts, ac) is switched from the first time-relay RE-05-P8 to the second time-delay relay RE-06-P8 (contacts 2 and 4) with the aid of relay RE-01-P8 (contacts 2, 1, 3).

After heating, thermal-relay RE-06-P8 actuates relay RE-07-P8 (contacts 4, 3), which in turn switches in the circuit of high-voltage power-supply relay RE-02-P8.

Relay RE-04-P8 takes heat from thermal time-delay relay RE-06-P8 (contacts 1, 2, 4) and blocks the circuit of the winding of relay RE-07-P8.

The dc voltage which turns on "Rele VN" [High-voltage relay] (26 volts "rabota" [operation]) through the contacts of relay RE-07-P8 is fed to the winding of "Rele VN", Re-02-P8, which, with the aid of contacts 1 and 2, switches the network voltage to the high-voltage transformer of the transmitter, T-01-P7.

Simultaneously, as the voltage to the high-voltage tranformer (contacts 2, 3) is turned off, the filament voltage of the magnetron is reduced (resistance R-01-P5 is connected in series with the primary winding of T-01-P5).

If there is arcing in the magnetron or in the power modulator tube, or if there is a breakdown in the high-voltage circuit, and should the current consumed from the high-voltage rectifier increase, overload relay RE-03-P8, which breaks the circuit of the primary winding of the high-voltage transformer, is actuated. There are three signal lamps in unit P-8 which indicate when various elements of the block are turned on: "Vklyucheno" (On) for the whole block; "Rezerv" (Stand-By) for the modulator; and "V.N." [High-Voltage] for the high-voltage. The lamps are turned off with the aid of terminal block contact D-09-TO if the door of block "P" is closed.

In order to switch on and off the high voltage in the transmitter, which is necessary in tuning the high-frequency receiver system P-2, there are two buttons, "Vkl.V.N." [High Voltage On] and "Vykl.V.N." [High-Voltage Off] in unit P-8. To check the magnetron current in the transmitter, unit P-8 is fitted with a special socket labeled "Tok Magnetrona" (Magnetron Current).

Unit P-8 is connected to the modulator P-6 by means of stranded conductors with connectors on the ends. By means of another stranded conductor (right) the unit is connected to the terminal plug of the block, D-04-PO.

4. Magnetron Oscillator P-5

The electrical schematic diagram of the magnetron oscillator is shown in the general electrical diagram of the station, drawings No 33,650,007-SE.

The generator of superhigh-frequency pulses in the transmitter is the magnetron with permanent magnet D-01-P5. The magnetron's plate is grounded, and modulating high-voltage negative pulses are fed to its cathode. The magnetron is heated from special transformer T-01-P5 with a heater winding which is well insulated from the chassis; there is low capacitance between the heater winding and the chasis (see Figure 27). The transformer is fastened to the upper cover of the lower compartment, close to the magnetron. The magnetron is cooled during operation of the station by fan D-02-P5. The second sleeve of the fan is used to cool modulator tube L-03-P6, type GMI-83 (G-483).

To improve the thermal operating conditions of the magnetron cathode, when switching on the high voltage to the magnetron, TURN DOWN ITS HEATER VOLTAGE.

This is done in order not to increase the cathode temperature above normal when switching on the high voltage to the magnetron. Overheating of the cathode leads to a reduction of the service life of the magnetron. If the heater voltage is not turned down, a certain part of the electron flow from the cathode, after considerable acceleration by the electric field of the plate, falls to the surface of the cathode. Then all the energy of the fast electrons is released at the magnetron's cathode in the form of heat, causing overheating of the cathode.

The magnetron's heater voltage is turned down with the aid of resistance R-01-P5, which is connected through relay RE-02-P8 in series with the primary winding of the magnetron's heater transformer T-01-P5.

In order to match the impedances of the magnetron and the waveguide transmission line, the first elbow of the waveguide beyond the magnetron is fitted with a special reactive phase-shifter D-08-P2, which consists of a dielectric wedge, whose position in the waveguide can be changed by rotating an adjusting screw.

The magnetron and its magnet are located in the right side of the block, above modulator power-supply unit P-8, and fastened to the vertical wall of the block by means of 4 screws. The magnetron is secured in the center of the magnet's magnetic field by means of 4 wing nuts. The waveguide is connected to the magnetron by a special removable lock.

The high-frequency energy output is delivered through the waveguide transmission line connecting the transmitter with the antenna system through the high-frequency system of the rhumbatron "Priyem Peredacha" [T-R] switch.

5. Superhigh-Frequency Unit P-2

The electrical schematic diagram of unit P-2 is given in the general electrical diagram of the station, drawings No 33,650,007-SE.

The superhigh-frequency unit makes possible operation of the transmitter and receiver on a common antenna.

Unit P-2 includes:

a. Klystron oscillator with 2 klystrons L-04-P2 and L-03-P2

b. Receiver-mixer detector crystals D-01-P2 and AFC-system mixer crystal D-02-P3;

c. Rhumbatron receiver cavity with two L-02-P2 and transmission cavity with tube L-01-P2.

The klystron is a low-power (5-15 mw) generator of superhigh-frequency energy. The tube construction includes a cavity resonator circuit, which is turned with a screw. The range of frequency variation obtainable with the help of the mechanical tuning screw is equal to 240 Mc.

In addition, by varying the voltage on the reflector electrode, the frequency can be changed by 20-25 Mc.

The receiver-mixer cavity has, in addition to the "Obzor" (Surveillance) klystron heterodyne, one more klystron, which is switched on when the station is set for operation on the stand-by channel (with the aid of relay RE-02-P4). This second klystron for the stand-by channel is tuned to a frequency different from that to which the surveillance klystron is tuned.

The surveillance klystron feeds the receiver-mixer cavity and the AFC-system mixer; in order to regulate the power fed to the mixer cavities, there are 2 screws for regulating the coupling with the cavities (D-11-P2 and D-12-P2).

In order to indicate the power going to the crystals, microammeters are used which measure the current of the mixer crystals.

The crystal currents can be measured directly from the instrument mounted on the control panel of the indicator. In addition, using two other microammeters, which are mounted on the panel, it is possible to measure the crystal currents in the receiver-transmitter block. Measurement of crystal currents in the receiver-transmitter block must be performed when tuning the high-frequency system of the receiver (P-2, P-4). For normal operation of the mixers, the crystal currents must be within the limits shown in the Instructions for Operation of the Station. The crystal currents are adjusted by turning the coupling adjustment screws D-11-P2 and D-12-P2.

Tuning the klystrons to a definite frequency consists of electrical tuning to maximum crystal current with the aid of the tuning knob on unit P-4 and mechanical tuning of the klystron with the aid of the special key with an insulated handle. Mechanical tuning of the klystrons is performed according to the maximum signals from objects or the maximum of pulses from the echo-box, when tuning the "Obzor" (surveillance) klystron; and according to the minimum of crystal current in the circuit for tuning to the stand-by channel, when tuning the second klystron.

After both klystrons have been tuned to the necessary frequencies, electrical trimming of the klystron frequency can be performed from the indicator control panel with potentiometers "R. N. Obzor" [Manual Tuning Surveillance] and "R. N. Rezerv" [Manual Tuning, Stand-by].

The energy of reflected signals goes to the receiver crystal mixer from the main waveguide through reception rhumbatron L-02-P2. The signal to control the AFC system is composed of pulses from the magnetron oscillator, which are fed from the main waveguide (block "P") through the limiting attenuator to the AFC-mixer cavity. To provide for operation of the reception rhumbatron L-02-P2, a dc voltage of approximately -600 volts is fed to its firing electrode (cap on the tube) from the rectifier for -1,000 volts (unit P-8) through a resistance of 2.7 megohms. The normal current in the circuit of rhumbatron L-02-P2 is 70-120 microamperes.

The klystrons are supplied with a voltage of +300 volts to the chassis and a voltage of approximately -150 to -180 volts to the plate cap, relative to the chassis of block "P". Heater voltages of 6.3 volts are fed to both klystrons. When switching to reception of "rezervnyy kanal" (Stand-By Channel) signals, the voltage of +300 volts is switched over from the "Obzornyy" (Surveillance) klystron by means of relay RE-02-P4, which is located in the AFC unit, P-4.

Unit P-2 is connected to the AFC unit, P-4, by a shielded stranded cable which terminates at junction box D-01-P4 and through which all voltages to klystrons L-03-P2 and L-04-P2 are fed.

P-2 is supplied with the following voltages: 6.3 volts; +300 volts to the plate of "Obzor" (Surveillance) klystron; +300 volts to the plate of the "Rezerv" (Stand-By) klystron; and voltages of -150 to -175 volts to the reflector-electrodes of both "Obzor" and "Rezerv" klystrons. By means of two short coaxial feeders, unit P-2 is connected with the AFC unit, P-4, and the i-f preamplifier, unit P-3.

Through these feeders the output of the receiver's crystal converter is connected with the input of the i-f preamplifier (P-3), and the output of the AFC crystal converter is connected to the input of the i-f amplification stage of the AFC unit (P-4). By these feeders the crystal currents are transmitted to units P-3 and P-4. The main waveguide system "Priyem-Peredacha" [T-R], D-05-P-2, is connected with the waveguide section which leads from the receiver-transmitter block to the antenna. This latter section of the waveguide is fitted with a special electromagnetic waveguide short-circuiting element D-10-P0, which opens the waveguide path when the station is turned on and voltages are being supplied to fire the receiving rhumbatron, and which closes it when the station is turned off. In this case the receiver crystal converter is protected from the action of neighboring radar stations.

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6. Intermediate Frequency Preamplifier P-3

The electrical schematic diagram of the i-f preamplifier is shown in the general electrical diagram of the station, drawings number 33,650,007-SE.

The function of the i-f preamplifier is initial amplification of the signal which comes from the crystal mixer. The amplifier input is connected through a short feeder to the output of crystal mixer D-01-P2. The output of the i-f preamplifier is connected through a long feeder to the main i-f amplifier input, which is located in the main indicator block (unit I-7). In unit P-3 there is time automatic gain control of the receiver "VARU po B.O." [Time Automatic Gain Control for Nearby Objects].

Unit P-3 consists of three stages. Of these, two are i-f amplication stages on tubes L-01-P3 and L-02-P3, type 6Zh4, and a stage for regulating amplification for nearby objects "VARU po B.O.," tube L-03-P3, type 6N8S.

The first stage has, at its input, transformer T-01-P3, which is connected in series with self-induction coil L-01-P3 and is tuned, together with the capacitance of the circuit, to a frequency of 33 Mc. The capacitance of the circuit is the input capacitance of the tube and the capacitance of the wiring. The plate load of the first stage is the circuit formed from self-induction coil L-02-P3 and the total input capacitance of tube L-02-P3, as well as the output capacitance of tube L-01-P3.

The plate voltage for the tube is supplied through resistance R-07-P3. Between the first and second i-f amplifier stages there is a divider capacitor C-18-P3. The circuit, which includes self-induction coil L-02-P3, is tuned to a frequency of 27 Mc.

The second stage using tube L-02-P3, type 6Zh4, amplifies the signals which come from the output of the first stage. The plate circuit of the tube consists of self-induction coil L-03-P3 and capacitor C-21-P3, plus the output capacitance of the tube and the wiring. The voltage is taken from transformer T-02-P3, which is connected in series with self-induction coil L-03-P3. Transformer T-03-P3 is loaded with the long coaxial feeder. The plate circuit of the second stage is tuned to a frequency of 33 Mc.

The third stage -- "VARU po Blizhnim Ob'yektam" [Time Automatic Gain Control for Nearby Objects] -- operates on tube type 6N8S. The left half of the tube is an ordinary amplifier of the voltage of the pulses which trigger the VARU [Time Automatic Gain Control] circuit; they are fed from unit P-6 by the feeder. The negative bias on the grid of L-C3-P3 is adjusted with the knob "Usileniye [po] B. O." [Gain for Nearby Objects]. The amplitude of the pulse in the plate circuit of the left triode is varied, depending on the value of the bias.

The right triode is connected to the diode and operates as a rectifier, through which capacitor C-20-P3 is charged. This capacitor is charged during the time of existence of the pulse with a positive charge on its grounded case and, after the end of the pulse, discharges to resistance R-19-P3.

The negative voltage, which decreases according to the discharge rate of capacitors C-20-P3, C-02-P3, and C-05-P3 through resistors R-19-P3, R-09-P3, and R-05-P3, is fed to the control grids of tubes L-01-P3 and L-02-P3 in the i-f amplifier. Supplying the grids of the i-f amplifier tubes with a negative voltage, which decreases after generation of the pulse by the transmitter, leads to a corresponding reduction of the gain factor of the two i-f amplifier stages. The extent of regulation of "gain for nearby objects" is varied by selecting the bias on the left triode of L-03-P3 with the knob "Usileniye po B. O." [Gain for Nearby Objects] on the main indicator. The rate of change of the gain factor of the receiver can be varied by turning the knob of resistor R-19-P3, which is mounted on the face side of unit P-3 in the transmitter. Graphs of voltage variation at circuit points are shown in Figure 33.

7. Automatic Frequency Control Unit P-4

The electrical schematic diagram of unit P-4 is shown in the general electricial diagram of the station, drawings No 33,650,007-SE.

The AFC unit of the receiver serves to maintain a constant i-f under possible frequency deviations of the magnatron oscillator or the klystron heterodyne.

If, for example, the magnetron frequency is 9,300 Mc, while the i-f of the receiver is 30 Mc, then the frequency of the klystron heterodyne can be either 9,330 or 9,270 Mc. For correct operation of AFC system, the heterodyne frequency must be higher than the magnetron frequency. Then Fkl - Fmagn = F i-f. Now let us suppose that the magnetron frequency changes from 9,300 to 9,315 Mc; the i-f, for the same klystron frequency, will be 9,330 -9,315 = 15 Mc.

In order to make reception possible, the klystron heterodyne frequency must be increased by 15 Mc. This can be done by manual rotation of the knob "Nastroyka-Obzor" (Tuning-Surveillance), but with the aid of the AFC unit, the frequency of the klystron oscillator can be automatically varied so that the difference Fkl -Fmagn remains constant and is equal to the i-f of the receiver (30 Mc). The AFC unit has the following elements (see Figure 34):

a. AFC crystal mixer

b. Discriminator, which generates a voltage whose value and polarity depend on the frequency fed to its signal input. If pulses of a frequency higher than 30 Mc are fed to the discriminator input, the pulses at the output of the discriminator amplifier will have negative polarity; if lower than 30 Mc, their polarity will be positive (Figure 35).

c. Thyratron executor circuit, which converts the control pulses generated by the discriminator into a voltage which is fed to reflecter electrode of the klystron (Figure 36).

The signals which control the AFC system are fed to the AFC mixer cavity from the main waveguide path through the attenuator. The AFC operates in the following manner.

To the discriminator input of the AFC system (unit P-4) i-f pulses are fed. Pulse conversion is performed in the special AFC mixer cavity (unit P-2). Attenuated pulses from the magnetron and energy from the receiver klystron heterodyne are fed to the crystal mixer cavity. The i-f at the output AFC mixer is determined by the difference in frequency between the klystron heterodyne and the magnetron. In the discriminator the i-f pulses are converted into dc pulses, whose amplitude and polarity depend on the value of the i-f in accordance with the frequency characteristic of the discriminator.

After one stage of voltage amplification, the pulses from the discriminator output are fed to the input of the thyratron executor circuit. The executor circuit consists of two stages: the "Sledyashchiy" (Control) and the "Poiskovyy" (Search) stage. The first stage is a delayed thyratron saw-tooth oscillator.

When the positive pulse with a voltage of 10-15 volts is fed to the grid of thyratron L-02-P4, the tube is opened, and the capacitor C-17-P4, which is connected between the plate and the cathode, discharges through the conducting thyratron. The voltage on the plate of the thyratron sharply decreases, and after the thyratron has again been closed (owing to the reduction in the plate voltage), it begins to increase as capacitor C-17-P4 becomes charged through resistor R-13-P4. The plate voltage of tube L-04-P4 is simultaneously the power supply for the integrating circuit of C-18-P4 and R-14-P4. If tube L-04-P4 is closed, its plate voltage increases up to the value of the power-supply voltage. The voltage on capacitor C-18-P4 rises as this capacitor becomes charged through resistors R-14-P4 and P-13-P4 from the +150-volt source.

The increased potential on capacitor C-18-P4, through voltage-divider resistors R-15-P4 and R-16-P4 is transferred to the reflector electrode of the klystron, which is connected to the middle point of the divider, as a decreased negative voltage. The second end of divider R-15-P4 and R-16-P4 is under a negative potential supplied from the -300-volt source (Figure 36).

When the negative voltage on the reflector electrode of the klystron is reduced, the frequency of the oscillations generated by the klystron is also decreased.

Reduction of the potential on the reflector electrode continues until the reduced klystron frequency reaches such a value that the difference between the klystron frequency and the magnetron frequency is equal to 30 Mc.

After transition of the i-f at the discriminator input through a value equal to 30 Mc, transmission of positive dc pulses begins at the discriminator output. The graph of the variation of frequency of the klystron heterodyne and of voltage at the discriminator output is shown in Figure 37. These graphs can be obtained in the absence of the control thyratron, L-04-P4, which normally stops the search when positive pulses appear at the discriminator output and when a voltage is supplied to the reflector electrode of the klystron which varies linearly in time, generated by tube L-05-P4, the "search oscillator."

The first positive pulse with a voltage of 10-15 volts opens thyratron L-04-P4. From this moment the decrease in voltage on the reflector electrode of the klystron ceases as a result of the fact that the rise in voltage on capacitor C-18-P4 also stops. For some time after receipt of the positive pulse at the grid of thyratron L-04-P4, the voltage on the plate of L-04-P4 is less than the potential on capacitor C-18-P4, and the capacitor discharges through resistor R-14-P4.

Now the voltage on the reflector electrode of the klystron (negative voltage) rises. But after capacitor C-17-P4 becomes charged until its voltage is greater than that on capacitor C-18-P4, a new cycle of the charging of capacitor C-18-P4 begins, and accordingly the negative voltage on the reflector electrode of the klystron begins to decrease.

The value of the voltage at which the potential on the reflector of the "search" klystron stops decreasing is determined by the ratio between the klystron and magnetron frequencies. In case one of these frequencies varies, there will also be a variation in the value of the voltage on the reflector electrode of the klystron at which the "search" stops and near which fluctuation of the voltage occurs (see Figure 38).

In case of breaks in the AFC, should the potential on capacitor C-18-P4 rise higher than the value at which the i-f is within the limits of the region of the discriminator characteristics, the special "search" stage, which is based on thyratron TGl-0.1/0.3, provides for discharging capacitor C-18-P4 and thus renews the conditions for operation of the control stage, L-04-P4.

P-4 is composed of five stages. The first stage is an i-f amplifier using tube L-01-P4, type 6Zh4, with discrimination transformer T-01-P4 in the plate circuit. The grid surface of the amplifier is tuned to a frequency of 30 Mc by means of self-induction coil L-01-P4.

The second stage, the discriminator detector, operates on tube L-02-P4, type 6Kh6S. The discriminator's load is the circuit composed of R-06-P4, R-07-P4, C-11-P4, and C-12-P4.

The third stage is a dc pulse amplifier using tube L-03-P4, type 6Zh4. The amplifier input is connected directly to the output of the discriminator (cathode of L-02-P4), while the output is connected through capacitor C-14-P4 to the grid of thyratron L-0-P4, which is the control tube of the executor circuit of the AFC system.

The fourth stage, the control, operates on thyratron L-04-P4, type TGl-0.1/1.3. Tube L-04-P4 is locked by a negative bias on its control grid and is opened when its control grid receives a positive pulse with a voltage of 10-15 volts. Then the capacitor C-17-P4 discharges through the conducting tube. The plate voltage of tube L-04-P4 is the power supply for the integrating circuit of R-14-P4 and C-18-P4. The voltage from C-18-P4 is fed through the voltage divider, R-16-P4 and R-15-P4, to the reflector electrode of the klystron; it is also the plate voltage of the "search" thyratron L-05-P4.

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The fifth stage is the "search" thyratron saw-tooth voltage generator, which operates on tube L-05-P4, type TG1-0.1/0.3. The thyratron has a fixed negative bias on its control grid. It is opened when the plate voltage increases to higher than normal, thus causing the search for the necessary klystron frequency to begin.

When there are no pulses at the discriminator output, the stage is the generator of a linearly varying voltage. Under normal operation of the AFC, the thyratron is closed and operates only in cases of breaks in the AFC. When the switch "ARCH-Ruchnaya" [AFC-Manual] on the control panel of the indicator is in the position "Ruchnaya", the plate of thyratron L-05-P4 is disconnected by means of relay RE-01-P4 from resistance R-15-P4 (Figure 39). Under these conditions resistor R-15-P4 is connected to potentiometer R-30-I9, labelled "Sovmeshcheniye" (Combination), which is located in the indicator, in the circuit of the -300-volt voltage divider. When toggle switch D-03-P4 in block "P" is switched to the "ARCh" [AFC] position, resistor R-16-P4 is switched from potentiometer R-18-P4 to resistor R-20-P4, whose second end is led to the indicator control panel and connected to variable resistor R-16-19, "R. N. Obzor Grubo" [Coarse Manual Tuning, Surveillance]. Then the receiver is tuned manually from the indicator by turning the knob "R. N. Obzor" [Manual Tuning, Surveillance].

If the toggle switch "ARCh-Ruchnaya" [AFC-Manual], which is located in the receive-transmitter block (P-4), is set in the "Ruchnaya" position, then resistor R-16-P4 is switched from R-20-P4 to R-18-P4, and the receiver can be tuned only by means of the knob "R. N. Obzor," which is located in unit P-4 of the receiver-transmitter block.

Leading to the AFC unit is a strand of power-supply conductors for units P-4 and P-2. They are 230 v, ac, +300 v, -300 v, +150 v and -26 v.

In the unit are located the relay for "ARCh-Ruchnaya" switching RE-01-P4, and the relay for "Obzor-Rezerv" (Surveillance Stand-by) switching, RE-02-P4, which are controlled during operation of the station from the main indicator. The unit is mounted in the left side of the upper compartment of block "P".

C. Echo-Box

The part of the station for tuning the receiving path, the echo-box, is placed close to the receiver-transmitter.

The echo-box is a high-Q resonant circuit connected by a coaxial feeder with the waveguide path of the station. If the echo-box circuit is tuned to the frequency of the transmitter (magnetron frequency), any time it has been excited by a transmitter pulse, natural oscillations (echo) will continue in the circuit for a prolonged period of time. The pulse composed of oscillations from the echo-box circuit is received by the station's receiver as equivalent to received signals.

The echo-box includes a circuit-tuning knob and a wobbulation motor which, by displacing the piston in the circuit, varies its frequency (wobbling the tuning frequency of the echo-box). The echo-box is turned on and off by means of an electromagnetic shutter which is controlled from the indicator panel (toggle switch "Kamera" (Echo-Box). The frequency-wobbulation motor of the echo-box is turned on from the indicator with the button "Vobbulyatsiya" (Wobbulation).

D. Description of Block "P" as a Whole

The following control operations for the receiver-transmitter are performed from the main indicator: switching the power-supply voltage on and off; varying the extent of time automatic gain control of the receiver for nearby objects, "VARU po B.O"; electrical tuning of the frequency of the klystrons; switching from manual tuning to automatic (AFC); checking the detector currents of the receiver, the AFC, and the "Rezerv" (Stand-By) circuit; checking the magnetron current; switching back and forth between the "Rezerv" and "Obzor" (Surveillance) klystrons; and varying the duration of pulses and the repetition frequency.

To facilitate checking, adjustment, and tuning of the block, some transmitter control elements are repeated on the block "P" itself: the "ARCh-Ruchnaya" [AFC- manual] switch; "Obzor" tuning; "Rezerv" tuning; and the switches "Rezerv-Rabota" [Stand-By -- Operation] "V.N.Vkl -- Vykl" [High Voltage, On -- Off]; "Toki-Kristallov" (Crystal Currents); and"Tok Magnetrona" (Magnetron Current). These are located on the appropriate walls of units of the block.

The block is fitted with the following sockets: "Tok Magnetrona" (Magnetron Current), D-01-P8; "Tok Kr ARCh" [crystal current of AFC detector] D-01-P4; "Tok Kr" [crystal current of receiver detector], D-01-P3; "Rezerv" (Stand-By) tuning current, D-14-P2; toggle switch "ARCh-Ruchnaya" [AFC-manual]; and knob for electrical tuning of the receiver for operation of the station under "Obzor" and "Rezerv" conditions.

The order in which block "P" is switched on is not particularly important, since the transmitter is equipped with an automatic time-delay system which insures that the separate units of the block will be turned on in normal sequence.

The receiver-transmitter block has two compartments, separated by an iron partition. The lower compartment has its own door with high-voltage blocking. The block as a whole is fitted with a removable front wall. The side and rear walls of the block are fastened to the chassis of the block by means of screws with countersunk heads. In the top of the block there is a trap door with a removable cover, through which unit P-2 is tuned and tubes in units P-2 and P-3 are replaced. The power-supply and control cables go down through the bottom of the block's housing and terminate in a contact plug. Down through the bottom of the housing go three feeders which connect the receiver-transmitter with the main indicator.

Mounted in the lower compartment of the block are the magnetron with its magnet (unit P-5, heater transformer T-01-P5, the motor-driven fan, the high-voltage rectifier P-7, and the modulator P-6 with its rectifier, P-8. Mounted in the upper compartment are the high-frequency head P-2, i-f preamplifier, P-3, and automatic frequency control unit P-4. The echo-box should be secured close to the receiver-transmitter instrument. The waveguide output from the receiver-transmitter goes through the top cover of the block. In the first elbow of the waveguide path at the receiver-transmitter output there is a waveguide T-joint, to which the coaxial feeder from the echo-box is connected.

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Beyond the waveguide T-joint there is a directional coupler which is necessary for measuring the operating conditions of energy transmission in the waveguide line.

The separate units inside the inside block "P" are so located that all tuning, checking, and tube replacement can be performed by removing the front wall and through the upper trap door.

All units in the block can be removed from the housing after disconnecting their power-supply leads from the appropriate contact plugs.

In order to protect the operator from high voltage when opening the doors of the block, the door is provided with blocking which turns off the power-supply circuit of the station. In addition, the lower compartment of the instrument has its own high-voltage blocking, both electrical and mechanical, which operates when the front door of the compartment is open.

Drying and heating of the block is performed with heater resistances. The heater is turned on from the heater block.

The whole of block "P" is set on shock-absorbing pads, which can be fastened directly to the deck.

V. ANTENNA WAVEGUIDE ASSEMBLY (BLOCK "A")

A. Function and Make-up of the Block

The electrical schematic diagram of the antenna-waveguide assembly is shown in the general electrical diagram of the station, drawings No 33,650,007-SE. The function of the antenna-waveguide assembly is to channel energy from the transmitter to the antenna, radiate it into space, and to channel the energy reflected from surrounding objects back to the receiver.

The antenna-waveguide assembly consists of two units, A-1 and A-2. Unit A-1 is, strictly speaking, the antenna-waveguide assembly. Unit A-2 is the antenna drive containing the motor-selsyn group and heater.

B. Detailed Description of the Units Comprising Block "A".

1. Antenna- waveguide Assembly, Unit A-1

The antenna-waveguide assembly includes the antenna, rotating joint, and the waveguide path. The antenna consists of a slot radiator and reflector. The schematic picture of the antenna- waveguide assembly is given in Figure 40, where 1 is the reflector; 2, the slot radiator; 3, polystyrene disk; 4, 5, and 6, metal matching disks; 7, rotating joint; 8, waveguide path; 9, dielectric "plug", and 10, the receiver-transmitter.

Energy from the transmitter enters the waveguide path and passes through the rotating joint to the slot radiator of the antenna.

The slots radiate the energy fed to them toward the reflector and create the necessary distribution of energy in the reflector. The reflector gathers the energy up into a narrow beam like the mirror of a normal searchlight (see Figure 41).

The horizontal directivity diagram of the antenna (distribution of the electrical field radiated by the antenna in the horizontal plane) has the form shown in Figure 43.

The antenna radiates energy into space and receives back that part of it which is reflected from surrounding objects which happen to be within the zone of operation of the antenna beam. The energy received by the antenna passes through the rotating joint and the waveguide path into the receiver.

Separation of the paths of the energy in transmission and in reception is performed in the receiver-transmitter.

For a PPI, the antenna rotates at a rate of 14 rpm.

To connect the waveguide which rotates along the antenna to the fixed waveguide which goes to the transmitter, there is a rotating joint.

It consists of two sections of round waveguide which are connected by means of a capacitive contact (not directly, but across a gap of a predetermined value). The waveguide path serves to channel energy from the transmitter to the antenna and from the antenna back to the receiver. It consists of several pieces of waveguide with rectangular cross section. The individual parts of the waveguide path are connected by means of flanges of two types (flat, and with ring-shaped grooves). These are used to couple only different type flanges. Such a coupling insures transmission of energy with minimum losses.

To match the input and output impedances of the individual sections of the antenna-waveguide path, quarter-wave metal disks are used. These disks are set in the waveguide near the slot radiator and at the input and output of the rotating joint (see Figure 40).

At the beginning of the waveguide path is mounted a dielectric "plug", which separates the interior space of the waveguide from the interior space of the transmitter; this is necessary when using the special dehydrator to dry the waveguide.

2. Antenna Drive (Unit A-2)

The antenna drive serves to rotate the antenna and the "rotating" transformer of azimuth sweep. Making up this unit are the antenna-rotating motor, reduction gear, "rotating" transformer, course-mark contact, and heater.

The antenna is rotated by an electric motor. When the network voltage is 110 or 220 volts, dc, motor type SL-661 is used, while if the network carries 127 v /220 v or 220 v /380 v, ac, motor type I10/4 is used. The reduction gear provides for rotation of the antenna at a rate of 14 rpm. This rate is maintained, whichever of the above meters is installed, by means of exchangeable gears. The "rotating" transformer

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has the function in the circuit of creating azimuth sweep for the cathode-ray tubes of the main and remote indicators. The "rotating" transformer used is selsyn type SGS-1.

The course-mark contact serves to close the circuit of grid 5 of tube L-05-I2 of the course-mark generator, indicating the course of the ship on the indicator screen. It is a contact which makes at the moment when the antenna passes the direction of the head of the ship. The circuit is closed by a cam disk which is coupled to the antenna shaft by a 1:1 gear transmission.

In addition, the unit contains a heater consisting of four 75-watt wire resistances of 40 ohms each. The resistances are connected in such a way that they can be hooked up to a network with a voltage of 110 v, 127 v, or 220 v, for which the conductors at plug D-19-B, which is mounted on the antenna drive, are switched appropriately. If the network has a voltage of 220 v, conductor 15 is connected to contact 76, and conductor 14 to contact 65. If the network voltage is 110 v or 127 v, conductor 15 is switched from contact 76 to contact 72, while contact 65 is connected with a shorting bar to contact 76.

C. Description of the Construction of Block "A"

Constructionally, the antenna-waveguide assembly is divided into the waveguide path, drive, base, and antenna. The waveguide path is a rectangular pipe, 10.2 x 22.9 mm or 12.6 x 22.5 mm in cross section. The interior surface of the waveguide is silvered and, for protection from corrosion, coated with a thin layer of paint.

The drive is a cast unit containing the rotating joint, antenna-rotating motor, reduction gear, "rotating" transformer, course-mark contact, and heater.

Protruding from the drive is the antenna-rotating shaft, which is a pipe (coupled by means of the reduction gear) to the motor. Fastened to the flange of this pipe is the cast silumin base. The reflector is fastened to the base with four bolts, and pins insure that it is mounted correctly.

The reflector is a silumin casting in the shape of a parabolic cylinder with a diameter of 1,600 mm, a height of 470 mm, and a focal length of 512 mm.

The slot radiator is a waveguide section of rectangular cross section. On the wide side of the waveguide there are five openings in a checkerboard pattern.

The dimensions of the openings are 11 mm x 5.5 mm. The output openings are covered on top with a fine (2-mm) polystyrene plate.

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VI. REMOTE INDICATOR (BLOCK "V")

A. Function and Principles of Operation of the Block

The electrical schematic diagram of the remote indicator is given in general electrical diagram of the station in drawing No 33,650,007-SE. The wiring diagram of connections between the units of block "V" is pictured in drawing No 36,291,060-SM.

The remote indicator, like the main indicator, is a PPI. The remote indicator makes it possible to observe on a somewhat reduced scale the image obtained on the screen on the main indicator.

In contrast with the main indicator, the remote indicator has no movable range scale for accurate range measurement, and the distance to objects can be determined only approximately, by means of the fixed range circles.

The remote indicator is a separate block connected with the main indicator by connecting cables.

The remote indicator has range scales identical with those on the main indicator.

Switching of the range scales is performed from the control panel of the main indicator.

The remote indicator is supplied by cable from the main indicator with saw-tooth sweep pulses, the intensifier pulse, and video signals, as well as fixed range circle pulses.

The sweep pulses are taken from resistors connected in series with the windings of the main-indicator deflection coil. In the remote indicator these pulses are amplified by three amplifiers and fed to the deflection coil.

The intensifier pulses from unit I-5 and the video signals with fixed range circle pulses from unit I-12 in the main indicator go to the remote indicator, are amplified by the appropriate amplifiers, and are fed to the electrodes of the cathode-ray tube.

The combination of all the above-mentioned signals produces on the screen of the cathode-ray tube an image like that on the main indicator screen.

B. Detailed Description of the Units Composing Block "V"

1. Sweep Pulse Amplifiers, Units V-1, V-2, and V-3

The electrical schematic diagram of the sweep pulse amplifier is pictured in the general electrical diagram of the station, drawings No 33,650,007-SE.

Each of the three amplifiers operates on one of the sections of the three-phase deflection coil. The input of each amplifier receives a voltage taken from a resistance which is connected in series with a section of the deflection coil of the main indicator. As a result, the form of the input voltage coincides with the form of the current flowing through the appropriate section of the deflection coil.

The sweep amplifiers amplify these voltages in such a way that the current in a section of the remote indicator's deflection coil varies in time in exactly the same manner as the current in the corresponding section of the main indicator's deflection coil.

The form of the input voltage is a combination of the forward deflection half-wave and the reverse balance half-wave (see Figure 43). When the antenna rotates, the value and sign of these half-waves vary.

The sweep amplifier is a 4-tube circuit in which tube L-01-V1, type 6Zh4, has the function of the balancing stage; tube L-02-V1, type 6Zh4, is the preamplifier; tube L-03-V1, type 6Zh4, is the phase inverter; and tube L-04-V1, type GU-29 (G-829) is the power amplifier.

The input voltage is fed simultaneously to the grid of the balance stage (L-01-V1) through a divider consisting of C-02-V1, R-05-V1, and R-04-V1 to the cathode of the preamplifier tube L-02-V1.

The amplified voltage taken from the plate load of R-13-V1 of this tube is fed through capacitor C-05-V1 and R-22-V1 to grid 6 of the output twin tetrode L-04-V1 and through capacitor C-04-V1, a divider consisting of resistors R-12-V1 and R-09-V1, and resistor R-11-V1 to grid 4 of the phase-inverter tube L-03-V1. From the plate load, R-19-V1 of the phase inverter tube, the voltage is fed through capacitor C-08-V1 and resistor R-25-V1 to grid 2 of the second half of the twin tetrode L-04-V1.

In the plate circuit of twin tetrode L-04-VI, which operates on a push-pull circuit, is transformer T-01-V1. The primary winding of this transformer is shunted by resistors R-28-V1 and R-29-V1, while the secondary operates in series with a low resistance R-31-V1 in one of the three sections of the remote indicator's deflection coil.

A voltage proportional to the current in a section of the deflection coil is taken from resistor R-31-V1 and fed to the cathode of tube L-01-V1 of the balance stage. This voltage is fed to the cathode in the same phase as the input signal fed to the grid of the same tube. Therefore, in case of complete equality of the forms of the curves of the input signal voltage and the voltage of the current feed back taken from resistor R-31-V1 in the tube's plate circuit, the balancing will not occur at any voltage. In the case of inequality of the forms of the curves of these voltages there will appear on the plate load of the R-02-V1 a difference potential, which is fed through capacitor C-03-V1 and R-07-V1 to the grid of preamplifier tube L-02-V1.

This difference voltage, subtracted from the input signal, corrects the output signal and makes its wave-form approximate that of the instantaneous values of the input signal voltage.

2. Video Amplifier (Unit V-5)

The electrical schematic diagram of the video amplifier is pictured in the general electrical diagram of the station, drawings number 33,650,007-SE.

The video amplifier, unit V-5, fulfills the following functions:

a. Amplification of the receiver video signals and fixed range circle pulses

b. Amplification of the pulses for intensification of the operating cycle of the range sweep

c. Creation of pulses which form the electronic course mark

In addition, this block contains tube L-04-V5, type 6P9, which is designed to regulate the current in the focusing coil.

The video amplifier operates in the following manner. The receiver video signals and the fixed range circle pulses go from the cathode load, R-07-I12, of tube L-02-I12 in the video mixer of the main indicator to the video amplifier input. These signals are amplified by tubes L-01-V5, type 6Zh4 and L-02-V5 type 6P9.

The input signals, both received signals and fixed range circle pulses, are fed from the main indicator through a delay line. The delay line is introduced in the video signal path in order to compensate for the delay in the current increase in the deflection coil. From the output of the delay line the video signals are fed to grid 4 of the preamplifier stage, tube L-01-V5, type 6Zh4. From the plate load of this tube, which consists of correcting self-induction coil L-01-V5 and resistor R-04-V5, the signal is fed through capacitor C-05-V5 to grid 4 of tube L-02-V5. The degree of limiting of the input signal is regulated in tube L-02-V5 by means of potentiometer R-24-V5, which is included in the screen-grid circuit and thus, depending on the value of the screen voltage, balances the brightness of illumination of the different objects on the CRT screen.

From the plate load R-08-V5 and L-02-V5 of tube L-02-V5, the amplified and limited signals go through capacitor C-07-V5 into unit V-4 to the control electrode of the cathode-ray tube, which also receives the course-mark pulses from the cathode of thyraton L-03-V5.

The generation of course-mark pulses is performed by the circuit in exactly the same manner as in the main indicator.

The video amplifier has uniform frequency characteristics within the limits of $\pm$ 20 percent in the frequency range from 500 cycles to 6 Mc and a maximum gain factor of 15.

The intensifier-pulse amplifier amplifies the pulse received from the main indicator. This amplifier operates on twin triode L-05-V5, type 6N8S. The first half of this twin triode operates as a preamplifier. From its plate load (resistor R-18-V5) the pulse is fed through capacitor C-11-V5 to the grid of its second half. In the absence of an intensifier pulse, this triode is opened by a positive voltage on its control grid supplied through resistor R-19-V5. Here there will be a positive voltage on the order of + 60 volts on the cathode load (resistor R-22-V5 of the tube). This voltage is fed to the cathode of the cathode-ray tube and locks it. The positive pulse, with an amplitude of 10 volts received from the main indicator and amplified by the first stage, locks the cathode follower (right half of tube L-05-V5) and, consequently, opens the cathode-ray tube.

The cathode load (resistor R-22-V5) is shunted by constant-capacitance capacitor C-13-V5, and with the aid of the latter the front of the intensifier pulse is shifted in time in accordance with the delay time of the pulse delay line and with the beginning of the range-sweep cycle.

3. Cathode-Ray Tube Unit V-4

The electrical schematic diagram of unit V-4 is given in the general electrical diagram of the station, drawings No 33,650,007-SE.

The remote indicator uses cathode-ray tube type 18LN35 with a screen diameter of 175 mm.

The basic data of tube type 18 LM 35 are as follows:

a. Afterglow -- prolonged

b. Focusing -- magnetic

c. Deflection -- magnetic

d. Heater voltage -- 6.3 volts, ac or dc

e. Color of luminescence -- yellow-orange

Cathode-ray tube operating conditions: voltage at second plate, + 3,700 volts; voltage at accelerating electrode, + 250 volts; closing voltage on modulating electrode, — 25 +70 volts relative to the cathode.

In addition to the CRT itself, this unit contains the deflection coil and the focusing coil.

In order to obtain an image on the screen of the CRT, the following voltages are fed to the CRT unit:

a. To the three sections of the deflection coil L-01-V4, sawtooth currents from the three sweep amplifiers V-1, V-2, and V-3.

b. To the modulating electrode of the CRT are fed the receiver video signals which have been amplified by the video amplifier, the fixed range circle pulses, and the pulses for the ship's course mark.

c. To the cathode of the CRT are fed the pulses for intensifying the operating cycle of the sweep.

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d. To the focusing coil L-02-V4 is fed the plate current of tube L-04-V5 type 6P9 which is located in the video amplifier. Its plate current and, consequently, also the focusing of the CRT beam, are varied by changing the value of resistance R-01-V6 (cathode circuit of the tube), which is located on the control panel.

The brightness of the image on the CRT screen is regulated with potentiometer R-06-V5 which is located on the control panel. This potentiometer adjusts the value of the negative bias voltage on the modulating electrode on the cathode of the cathode-ray tube. In order to maintain constant brightness of the illumination on the CRT screen when switching from one sweep-rate scale to another, resistances R-08-V7 and R-07-V7 are automatically introduced into the brightness-regulation circuit by means of relays RE-02-V7, RE-03-V7, and RE-04-V7.

4. Power-Supply Unit, V-8

The schematic diagram of the power-supply unit V-8 is given in the general electrical diagram of the station, drawings No 33,650,007-SE.

The power-supply unit, V-8, which is mounted in the lower part of the remote indicator, develops dc voltages and the tube-filament voltages for supplying all units of the remote indicator, by converting the main power-supply voltage of 230 volts, 427 cycles. In order to obtain the required voltages, the following four rectifiers, which are part of unit V-8 and are mounted on one chassis, are used.

a. High-voltage rectifier for 3,700 volts, the plate-voltage source for the cathode-ray tube.

b. Rectifier for + 550 volts, the plate-voltage source, with total current consumption of 210 ma.

c. Stabilized rectifier for + 150 volts, yielding simultaneously + 300 volts unstabilized; the 150-volt source is calculated for a current of 30 ma, while the 300-volt source is calculated for 250 ma.

d. Stabilized rectifier for — 150 volts, power-supply source for bias circuits, with total current consumption of 15 ma.

The heater circuits of the remote indicator are supplied from transformer T-03-V8. It has a heater winding and delivers a current of 15 amperes at a voltage of 6.3 volts.

The high-voltage rectifier which supplies the cathode-ray tube 18LM35 in unit V-4 operates on kenotron L-01-V8, type 2Ts2S. It is a half-wave rectifier. The filter is U-shaped, composed of resistors R-03-V8 and R-04-V8 and capacitors C-01-V8 and C-02-V8.

The discharging circuit consists of resistors R-07-V8, R-08-V8, etc., up to R-15-V8.

The rectifier receives the necessary ac voltage from transformer T-01-V8.

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The rectifier for 550 volts is a full-wave circuit operating on tube L-02-V8, type 5Ts3S (5U4G), whose plates are supplied from the step-up winding of transformer T-02-V8. The filter is U-shaped and consists of choke Dr-01-V8 and divided capacitor C-03-V8.

The rectifier for 150 volts stabilized and 300 volts unstabilized operates on a full-wave circuit with tubes L-03-V8 and L-07-V8, type 5Ts4S, whose plates are supplied from the common step-up winding of the same transformer, T-02-V8.

The filter consists of choke Dr-02-V8 and capacitors C-04-V8 and C-05-V8.

After it has passed through the filter, the voltage of + 300 volts is tapped to supply a number of plate and screen circuits of the tubes in the block. Simultaneously, the +300 volts are fed to stabilovolt L-06-V8, type SG4S (150-S-5-30), through resistor R-16-V9.

The obtained stabilized voltage of +150 volts is used to supply plate and screen circuits in the balance stages of the sweep amplifiers.

The rectifier for —150 volts stabilized operates on a full-wave circuit with tube L-04-V8, type 6Ts5S (6Kh5), whose plates are supplied from transformer T-03-V8.

The rectifier's filter consists of choke Dr-03-V8 and divided capacitor C-08-V8.

The rectified voltage is stabilized by stabilovolt L-05-V8, type SG4S (150-S-5-30) and resistance R-17-V8. The stabilovolt is shunted by capacitor C-09-V8 in order to improve decoupling for high-frequency currents.

When the power-supply switch is set in the position "Podgotovka" (Preparation), transformer T-03-V8, which supplies the heater circuit and the bias-voltage rectifier for -150 volts, is turned on. In order to protect the cathode-ray tube and all circuits of the remote indicator from the possibility of turning on the plate voltage in the absence of a bias voltage, the circuit of check panel V-7 is provided with breakdown relay RE-10-V7, whose winding is supplied from the -150-volt rectifier. This relay switches in transformers T-01-V8 and T-02-V8.

In the "Rabota" (Operation) position the relay contacts are connected in series with the contacts of the power-supply switch.

5. Control Panel (Unit V-6)

The electrical schematic diagram of the control panel is pictured in the general electrical diagram of the station, drawings No 33,650-007-SE.

The arrangement of control knobs is shown in Photo 29, which also shows the location of the signal lamps. All control knobs on the remote indicator, with the exception of the power-supply switch, are mounted on the upper plate of the chassis, the control panel. Power supply switch D-03-V6 is mounted on the front wall of the housing. The remote indicator is turned on with this switch. The lamps located on the control panel signal that the power-supply is turned on. When the switch is set in the position "Podgotovka" (Preparation), the left signal lamp L-06-V6 lights up, signaling that the filament and bias circuits are turned on. When the switch is set in the "Rabota" [Operation] position, the right signal lamp L-05-V6 lights up, indicating that the plate voltage is being fed to the remote indicator.

The remaining four lamps, L-01-V6, L-02-V6, L-03-V6, and L-04-V6, indicate what range scale is being used.

The knobs on the control panel have the following inscriptions: "Shkala" (Scale); "Yarkost" (Brightness); "Osveshcheniye Shkal" (Scale Illumination); "Fokus" (Focus); "Otmetka Kursa" (Course Mark); and "Vizir" (Sight).

The knob "Shkala" is used to set the moving scale.

Potentiometer R-06-V6 (knob "Yarkost") is used to adjust the bias on the modulating electrode of the cathode-ray tube and, therefore, the brightness of the image.

Potentiometer R-05-V6 (knob "Osveshcheniye Shkal") is used to adjust the brightness of illumination of the scales.

Potentiometer R-01-V6 (knob "Fokus") is used to set optimum focusing of the image on the screen.

Potentiometer R-02-V6 (knob "Otmetka Kursa") is used to regulate the brightness of the course mark.

The knob "Vizir" is used to set the sight line in the required direction. "Vizir" is designed to facilitate the reading of course angles and directions to objects.

6. Check Panel (Unit V-7)

The electrical schematic diagram of the check panel V-7 is given in the general electrical diagram of the station, drawings 33,650,007-SE.

In order to check the operation of the remote indicator circuit without interrupting the operation of the station, the check panel is fitted with boxes to which voltages from different circuit points are fed. Thus, two boxes "I usil", "II usil", and "III usil" [Amplifiers I, II, and III] (B-01-V7, B-02V7, and B-03V7) are fed the voltages of the sweep pulses taken from amplifiers I, II, and III. These voltages are tapped from resistors R-31-V1, R-31-V2, R-31-V3, which are connected in series with the secondary windings of output transformers T-01-V1, T-01-V2, T-01-V3 and the appropriate windings of deflection coil L-01-V4.

Box B-04-V7 "Otr. Imp. i Metki" [Reflected Pulses and Marks] taps the voltages of the reflected pulses and the range circles amplified by the video amplifier.

Box B-05-V7 "Impul's Podsvetki" (Intensifier Pulse) is connected to the output of the intensifier-pulse amplifier (cathode 6 of tube L-05-V5).

The waveforms and voltage values fed to the check boxes are given in the Instructions on Operation of the Station "Neptun".

The power-supply voltages are checked with multi-scale voltmeter Z-01-V7, which, by means of switch D-01-V7, is connected to the different rectified voltage circuits.

Mounted on the control panel are the fuses, the potentiometer "Amplitude Razvertki" (Sweep Amplitude), R-03-V7, which is accessible under the slit and regulates the sweep amplitude of the remote indicator, as well as socket D-08-V7 for plugging in a soldering iron.

The fuses are mounted in the following manner (left to right):

a. Fuse for 3 a, D-06-V7, which is in the general circuit supplying the voltage of 230 v, 427 cycles

b. Fuse for 3 a, D-05-V7, which is placed in the second conductor of the same circuit, which goes through the blocking and the circuit breaker

c. Fuse for 3 a, D-04-V7, which is placed in the primary winding of the transformer which supplies the filament and bias circuits

d. Fuse for 2 a, D-02-V7, which is placed in the primary winding of the transformer which supplies the +300-volt and +500-volt plate circuits

e. Fuse for 2 a, D-03-V7, which is placed in the circuit of the signal lamp "Rabota" (Operation)

C. Description of the Construction of Block "V"

The external view and layout of the remote indicator are visible in Photos 29 and 30.

All the circuit parts of the remote indicator are mounted on a common chassis, which slides into the water-resistant cast housing. The controls of the remote indicator are mounted on the upper plate of the housing, the control panel.

In the center of the upper plate there is a round window through which the screen of the cathode-ray tube is visible, along with the moving and fixed scales and the sight. This window is sealed by a protective plexiglas disk which serves simultaneously as a light filter.

The CRT screen can be viewed through a tube with an optical system which magnifies the image by 1.5 times.

The construction of the remote indicator allows the chassis to be fully drawn out of the housing for inspection, replacement of tubes, or repair. The chassis is rigidly connected to the front wall and slides out with it. In order to draw the chassis out of the housing, it is necessary to unscrew the bolts which fasten the front wall to the housing.

In order to permit access to the check panel and the junction plug to which the cable from the main indicator and the heater block is connected, there is a window in the front wall closed by a special plate. This plate is fastened with bolts to the front wall of the block.

The units of the remote indicator are mounted on a common chassis. Located in the upper part of the chassis are the cathode-ray tube in its shield, the scale mechanism, the illuminating lamps, and the signal lamps.

Located below are the video-amplifier unit and, along the front wall, the check panel. In the middle part the sweep amplifiers are located, and in the lower part the power-supply unit.

Block "V" is set on shock-absorbing pads, which protect it from shock and vibration.

VII. HEATER-CONNECTION BLOCK (BLOCK "B") AND TELEPHONE COMMUNICATION

A. Heater-Connection Block (Block "B")

The electrical schematic diagram of the heater-connection block is given in the electrical diagram of the block, draft No 36,739,023-SE. The assembly diagram of the block is given in draft No 36,739,023-SM.

Block "B" serves for turning on and off the heating elements comprising the heater system of the station. The heater system is designed to maintain the required temperature inside the blocks of the station when the temperature of the air is low and also to heat the station if it has been under conditions of high humidity for a long time and requires drying.

Each block of the station has four heating elements, which are supplied through block "B". When the switch D-09-B on the heater block is set in the position "Vklyucheno" (On), the heater circuits of the individual blocks of the station are ready to be turned on. In order to supply power to the heater elements of blocks "I," "P," "V," and "A," it is necessary to actuate the appropriate toggle switch (D-06-B, D-07-B, D-05-B, D-05-B, and D-08-B). For each block there is a signal lamp (L-05-B, L-04-B, L-06-B, and L-07-B), which will indicate when the heater elements of that particular block are receiving power. The heater circuit is so constructed that when block "I" is turned on, the heating elements in the main indicator and the receiver-transmitter are automatically turned off, while when block "V" is turned on, the heating elements in the remote indicator are automatically turned off. The heating elements of the antenna-waveguide assembly remain turned on even when it is operating.

Constructionally, the heater block is a distribution box with a cover which can be opened. All the elements of the blocks are mounted on the cover, while the wiring which leads to the block is fastened to the base.

The heater block is located close to the main indicator.

B. Telephone Communication

When regulating and tuning the station, it is convenient if the operators working at separate blocks can communicate with each other.

Telephone communication serves this purpose with the station "Neptun." With it operators can carry on conversations while they are at blocks "A," "V," "I," "P," and at the power-supply units. Set close to each of these blocks of the station is a telephone communication box into which to plug a telephone set. For line switching there is a junction box which must be located in a dry part of the ship, in a place convenient for laying cables to it from the blocks of the station. The conductors going from the telephone communication boxes to the junction box are connected in parallel. Complete telephone communication equipment includes two telephone sets MT-B.

VIII. CONTROL-MEASURING APPARATUS

To perform necessary control measurements, as well as small scale repair and tuning of the station, a number of control-measuring instruments are required. For this purpose the control panel and check panel of the indicator are equipped with the following:

1. Ac measuring instrument EV-46 for measuring the network voltage

2. Dc measuring instrument M-52 with switch and shunts for measuring the average magnetron current and the voltages supplied by the indicator's rectifier: -26v, + 150 v, -150 v stabilized, + 300 v, — 300 v stabilized, + 300 v stabilized, and 550 v

3. Measuring instruments for measuring crystal currents

The receiver-transmitter is equipped with the following:

1. Echo-box type EP-1, which enables the receiver-transmitter to be tuned in the absence of targets

2. Directional coupler, connected to the transmitter as the first waveguide section

Using the directional coupler, the graduated attenuators, and the detector section, the traveling coefficient of the whole antenna-waveguide path of the station can be checked with a synchroscope.

The remote indicator is equipped with measuring instrument M-52, with switch and shunts, for measuring the rectifier voltages of — 150 v, + 300 v, + 550 v, and + 3,700 v.

The station has the following control-measuring apparatus attached to it:

1. Panel with two microammeters for 100 microvolts
2. Universal measuring instrument AVO-5
3. Synchroscope 25-I
4. Megger M-1101

In addition the following are recommended:

1. Tube tester IL-12
2. Crystal-detector tester IKD-1
3. Suitable signal generator (service type)

Appendixes I, II, and III follow:

Appendix I. Explanatory Illustrations for Technical Description of Navigation Radar Station "Neptun"

Irregular Noises

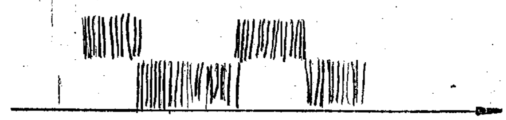

Fig. 1.

Action of a tangential signal on Noises

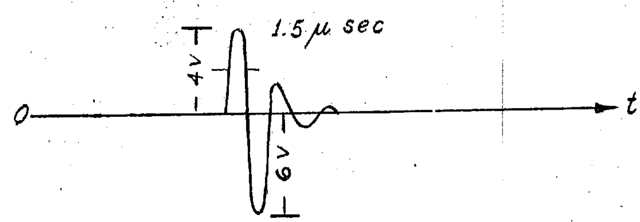

Fig. 2

Differentiated pulse on the grid of tube L-03-I3

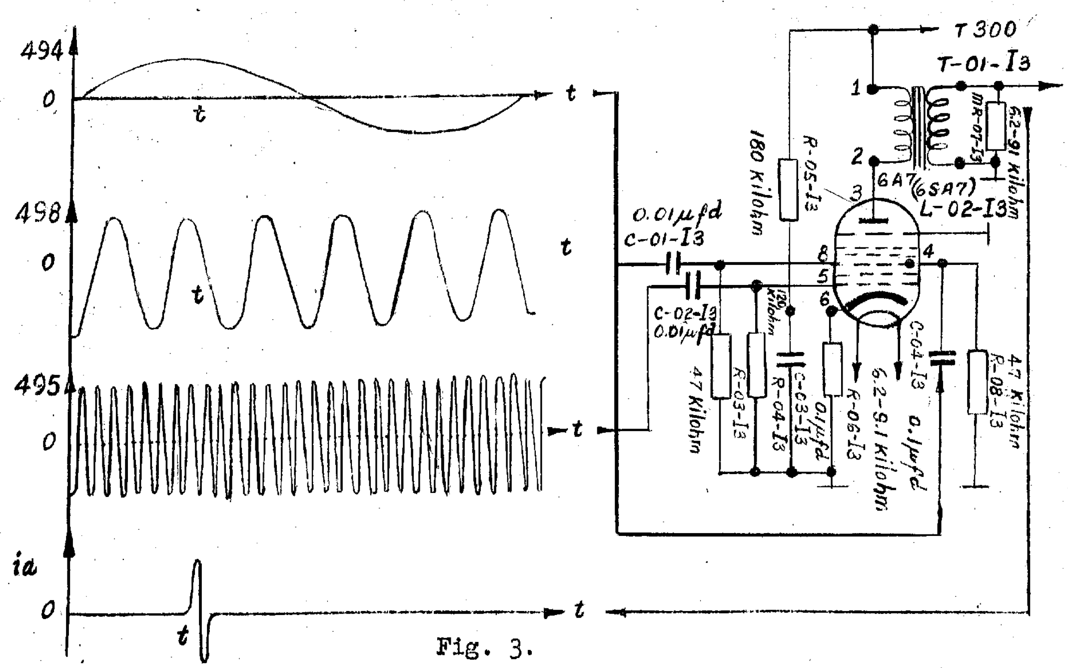

Fig. 3.

Circuit and Operation of the Selector tube of Unit "I-3"

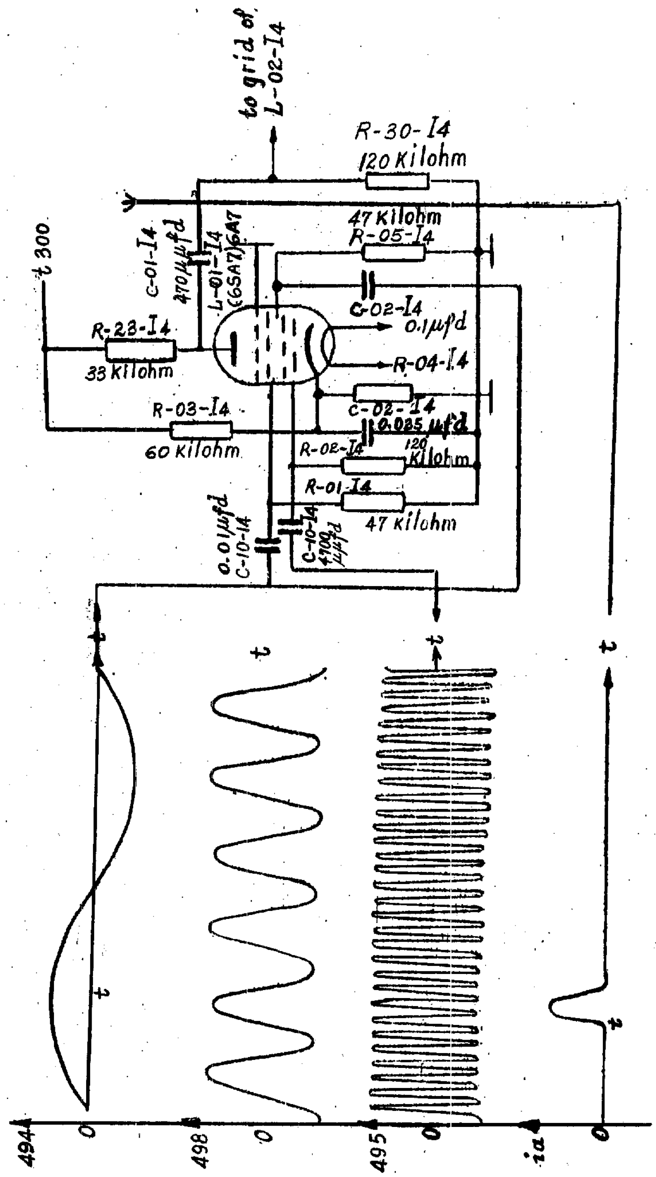

Fig. 3a.

Circuit and Operation of the Selector Tube of Unit "I-4"

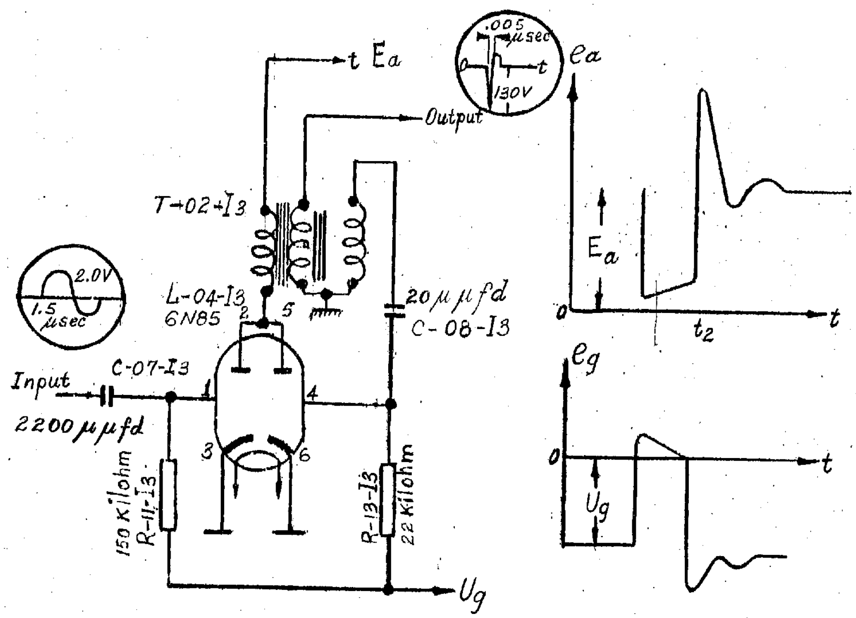

Fig. 4.

Circuit of the Closed Delaying Blocking Oscillator

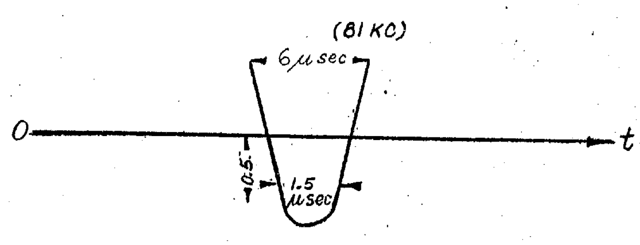

Fig. 5.

Pulse Form on Grid 4 of Tube L-02-I4

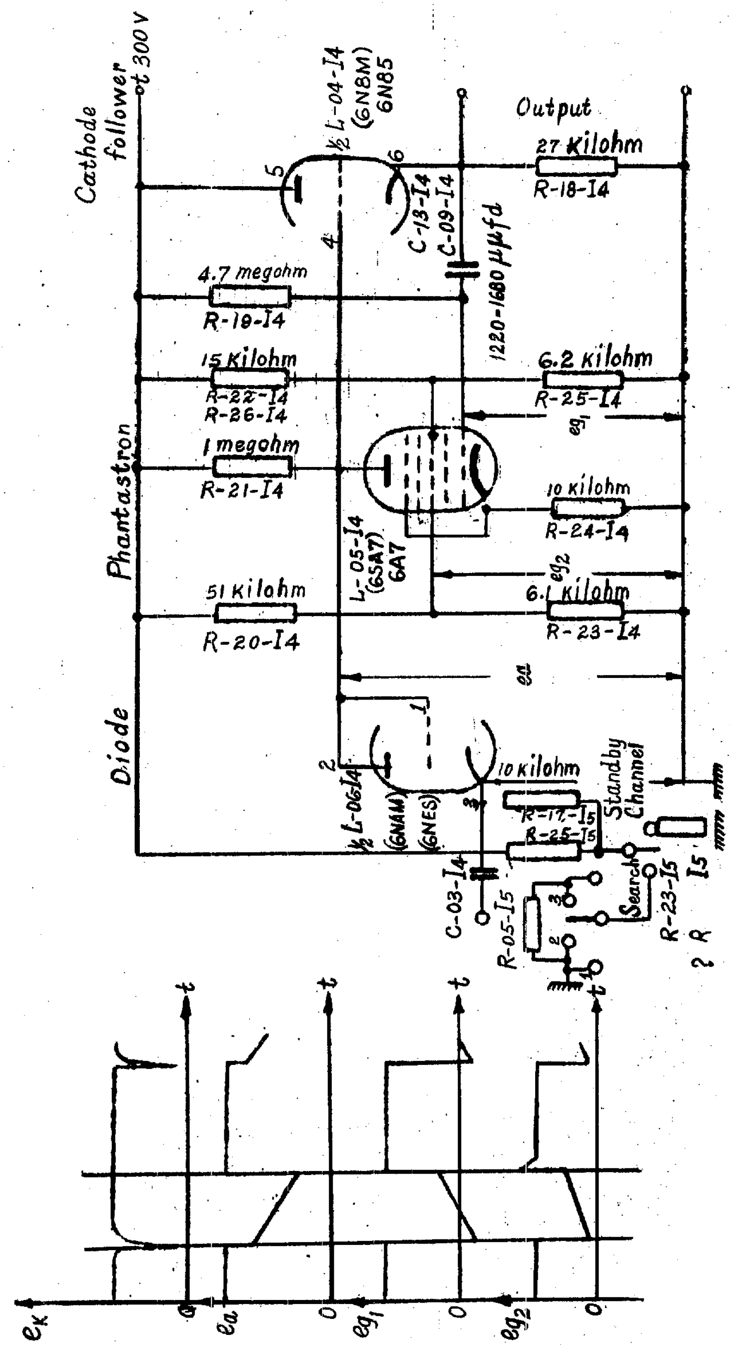

Fig. 6.

Phantastron Circuit

S-E-C-R-E-T
NOT RELEASABLE TO FOREIGN NATIONALS

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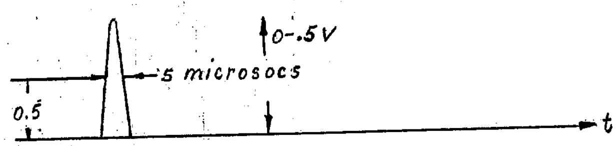

Fig. 7.

Pulse at the Input of I-5 and I-7

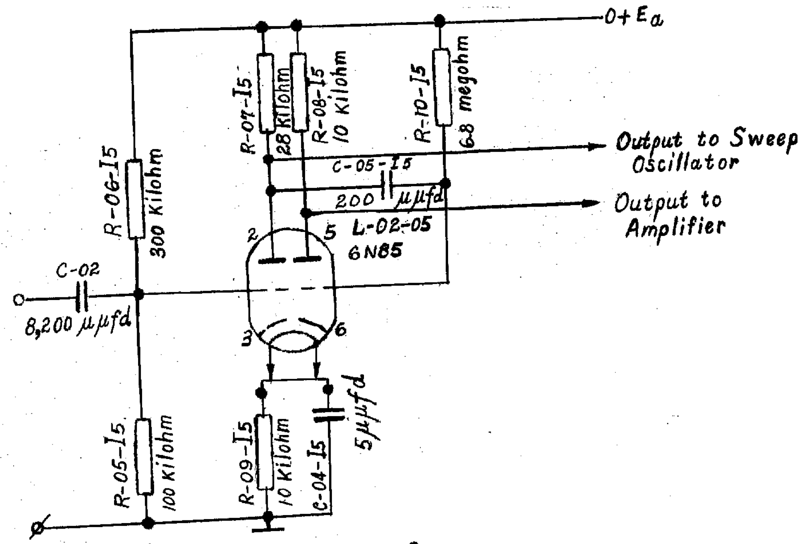

Fig. 8.

Circuit of a Closed (delay) Multivibrator

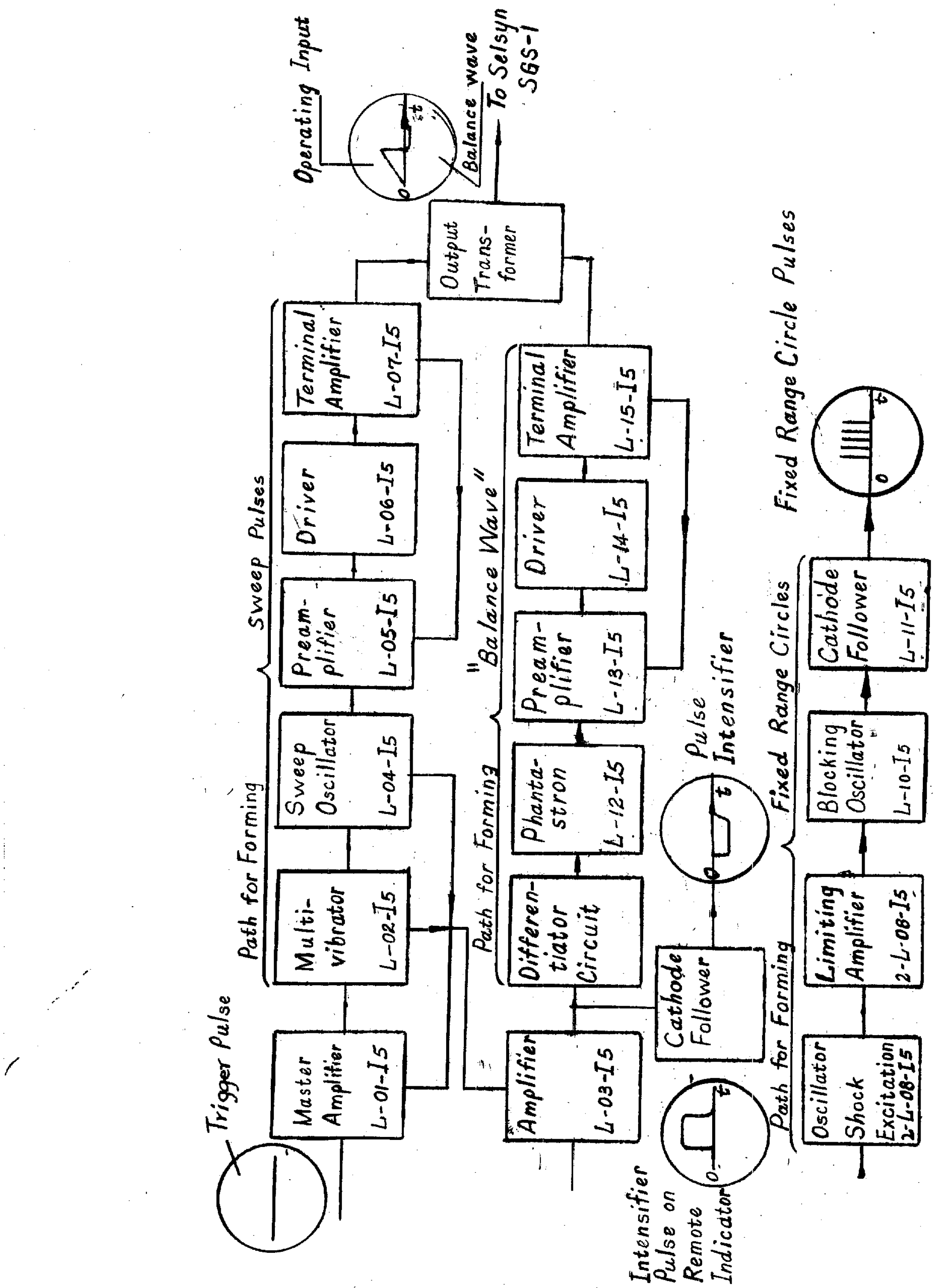

Fig. 9.

Main Block Diagram of Unit I-5

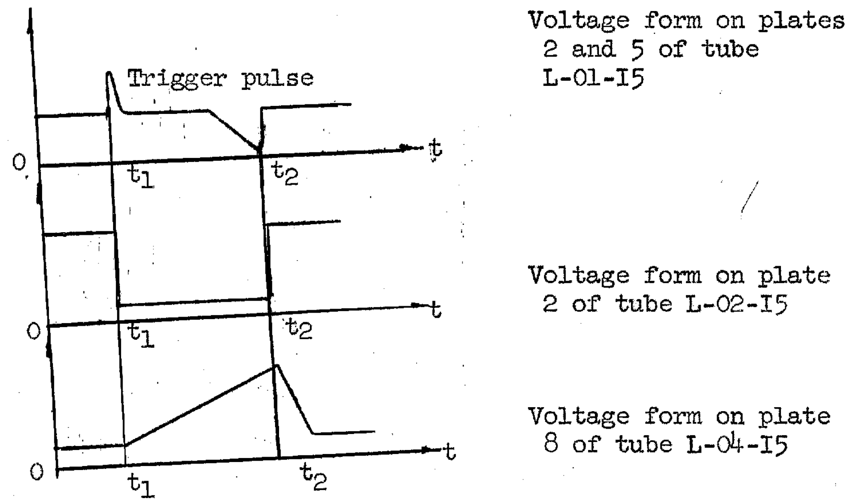

Fig. 10.
Relationship (momentary) of the voltage forms on the plates of tubes in I-5

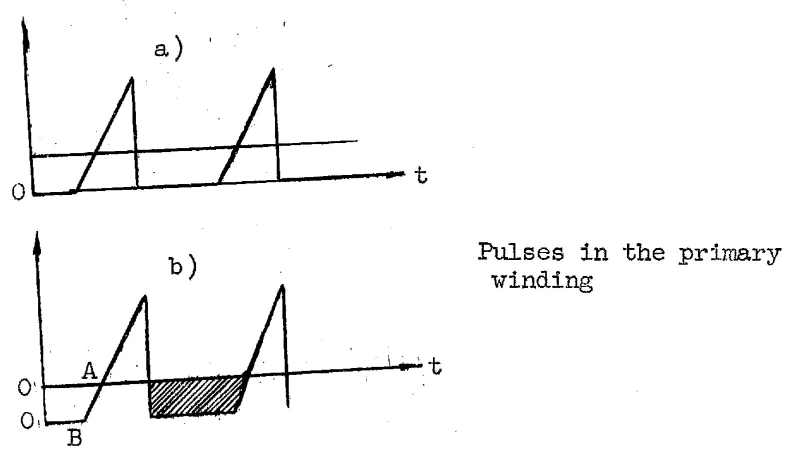

Fig. 11.

Current form in the output transformer T-01-I5

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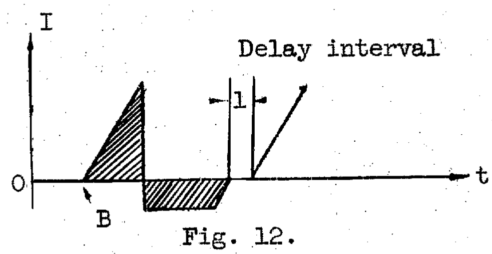


Fig. 12.

Oscillogram of Current in the Deflection Coil

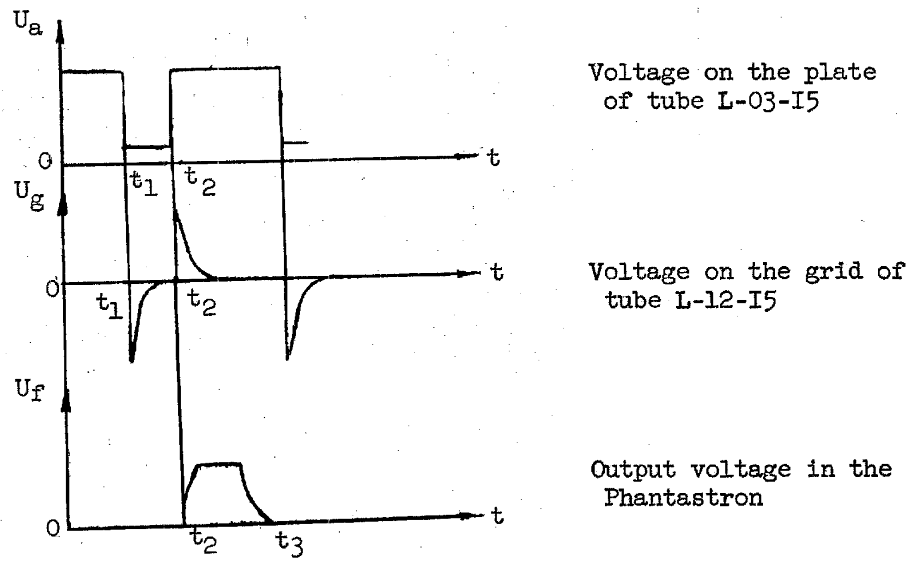


Fig. 13.

Oscillogram of Voltages in Block I5

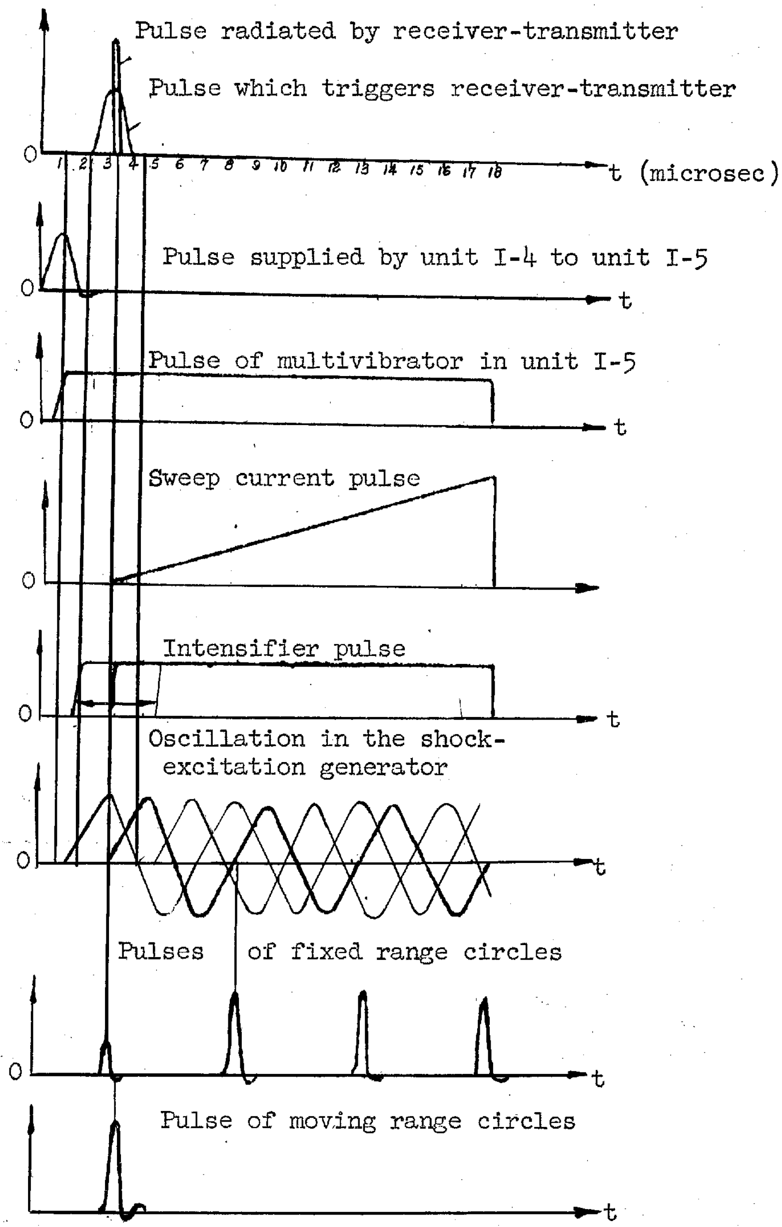


Fig. 14

Momentary pulse relationships in the I-5 circuit

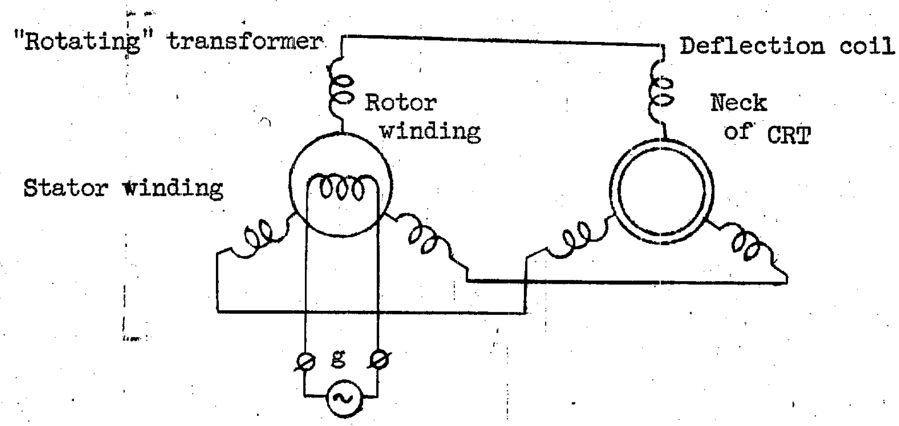


Fig. 15.

Simplified circuit of azimuth sweep

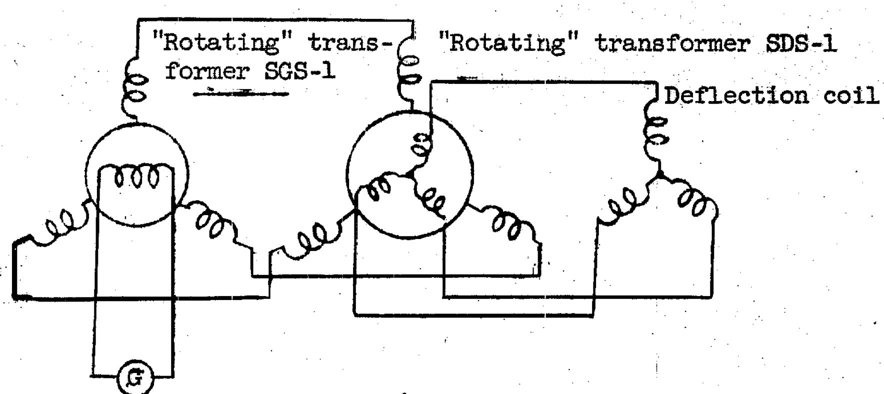
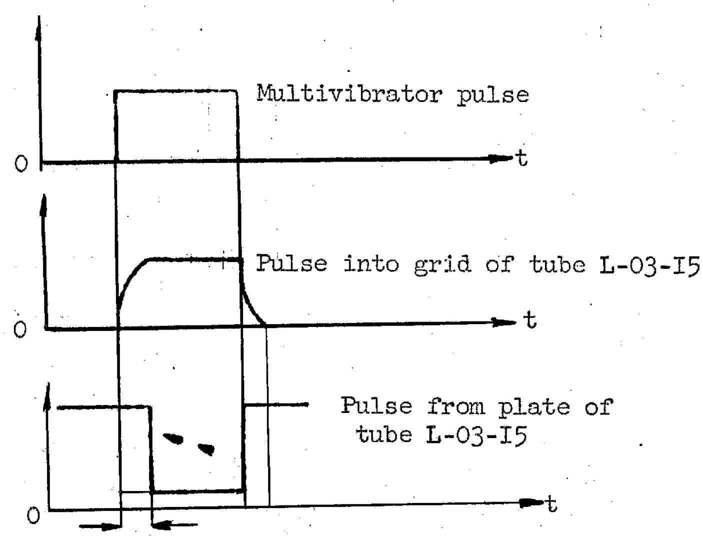


Fig. 16.

Azimuth sweep circuit with rotating transformer



Range of shifting of front edge of pulse

Fig. 17.

Pulse forms of the multivibrator on the grid and plate of L-03-I5

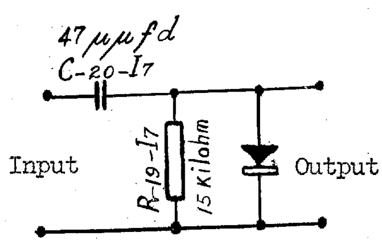


Fig. 18.

Diagram of circuit "MPV"

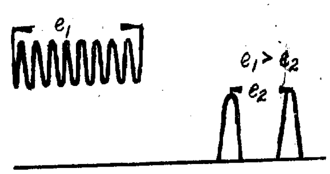


Fig. 19.

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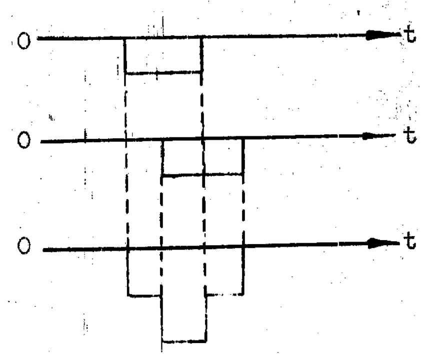

Pulse form at the output of second detector (L-05-I7)

Fig. 20.

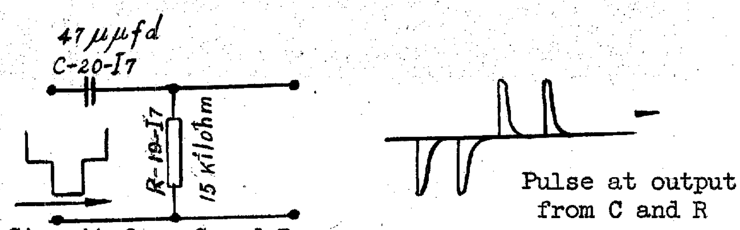

Fig. 21.

Influence of circuit from C and R (with small time constant) on pulse form after the second detector

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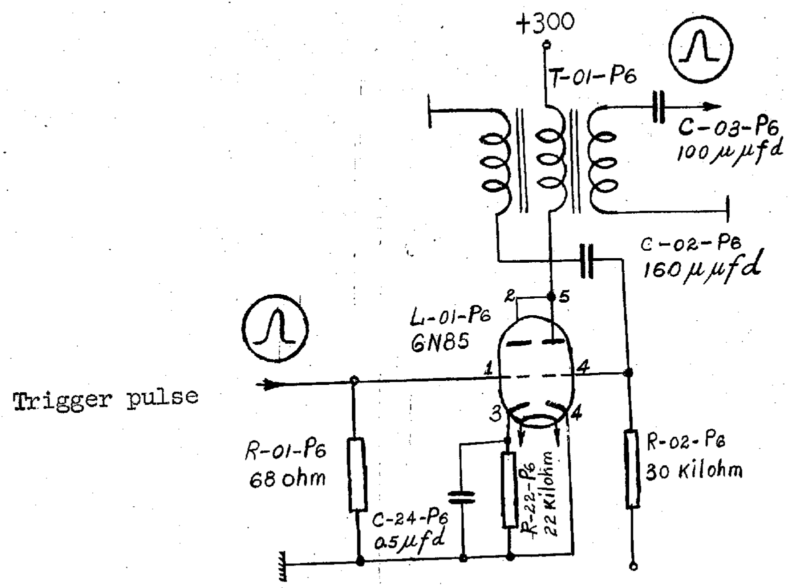


Fig. 22.

Diagram of trigger-pulse amplifier and first blocking oscillator

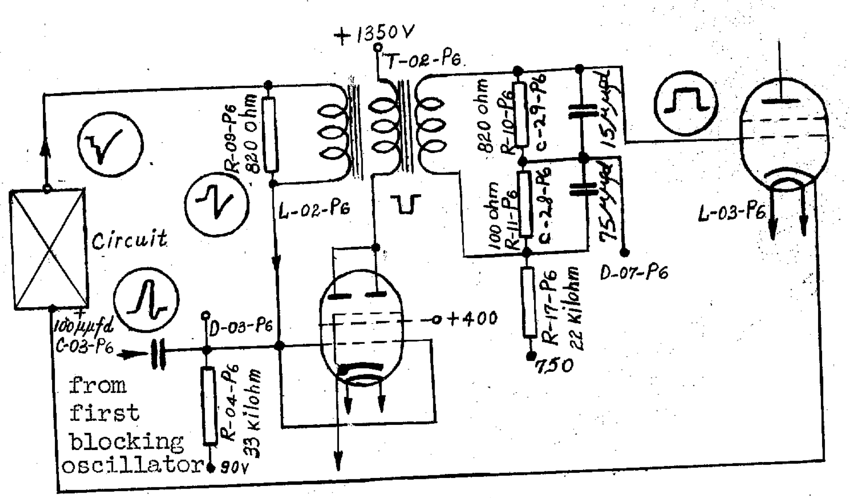
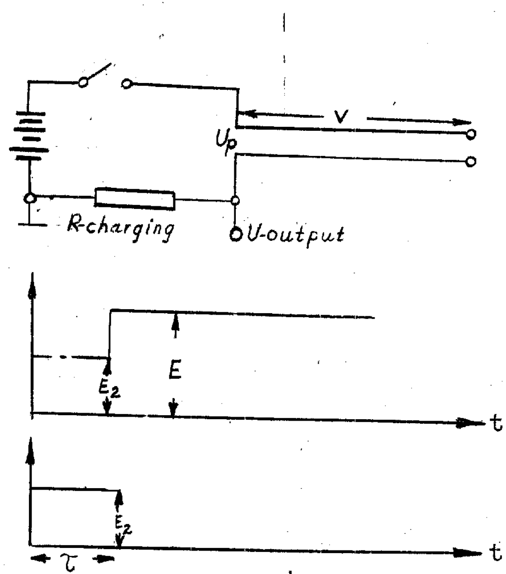


Fig. 23.

Diagram of second blocking-oscillator for rectangular pulses



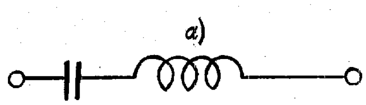
Rcharging - charging resistance equal to input (wave) resistance of line

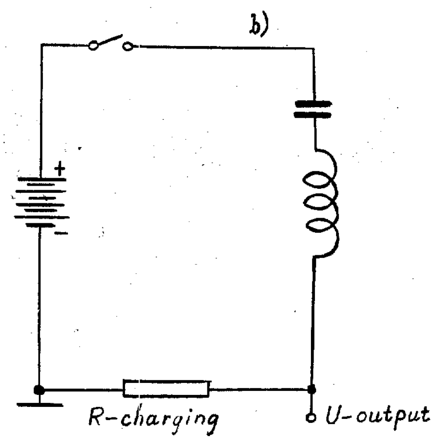
τ - pulse duration
$\tau = \frac{2\ell}{s}$ where

ℓ = line length
s = velocity of wave propagation along the line

Fig. 24.

Charging diagram of a two-wire line and curve of voltages on line and on charging resistance





a) forming circuit

b) charging diagram of the forming circuit

Rcharging = *w* *where*

w = characteristic (wave) resistance of the forming circuit

Fig. 25.

Diagrams of forming circuit and charging circuit

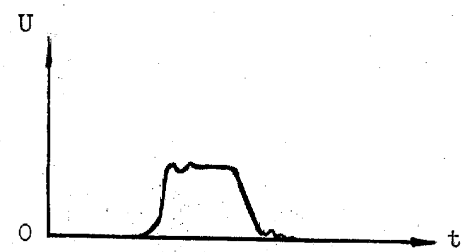


Fig. 26.

Pulse, obtained with aid of charge from forming circuit in blocking oscillator circuit

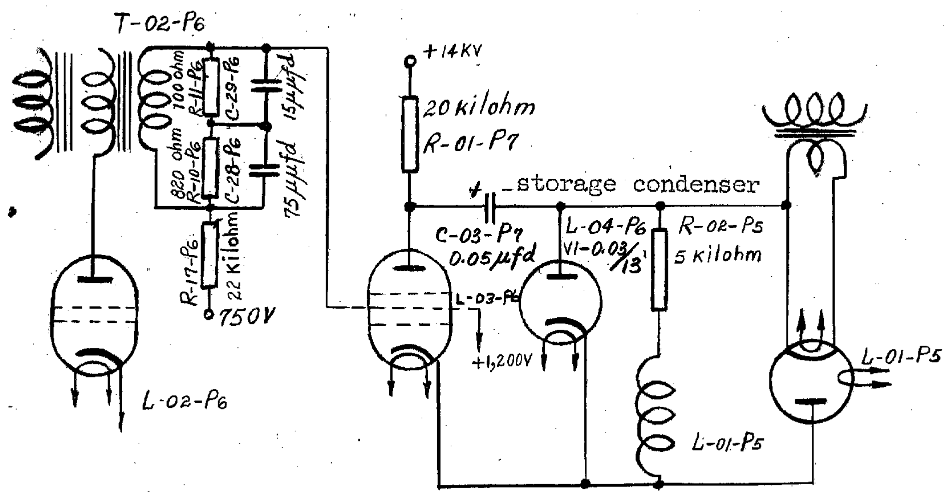


Fig. 27.

Diagram of power keyer

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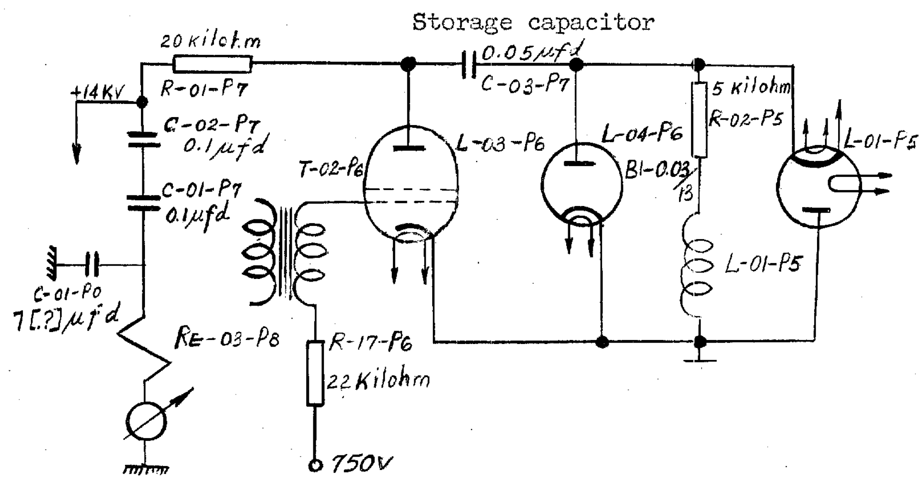

Fig. 28.

Power-supply circuit for power keyes

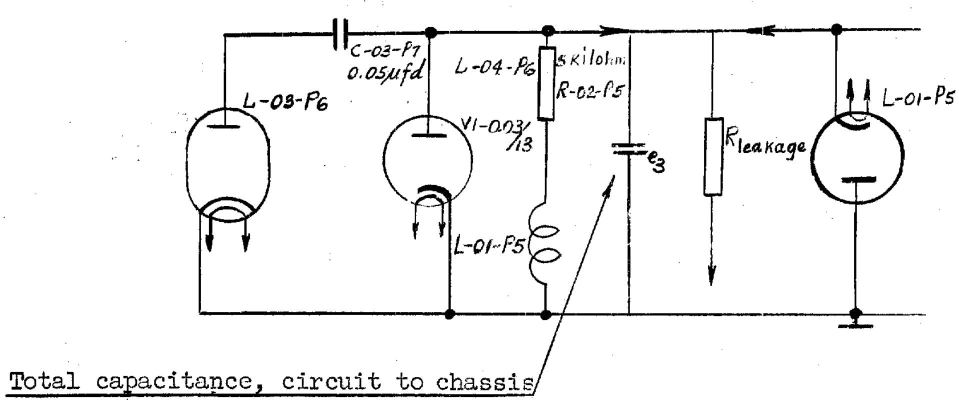

Fig. 29.

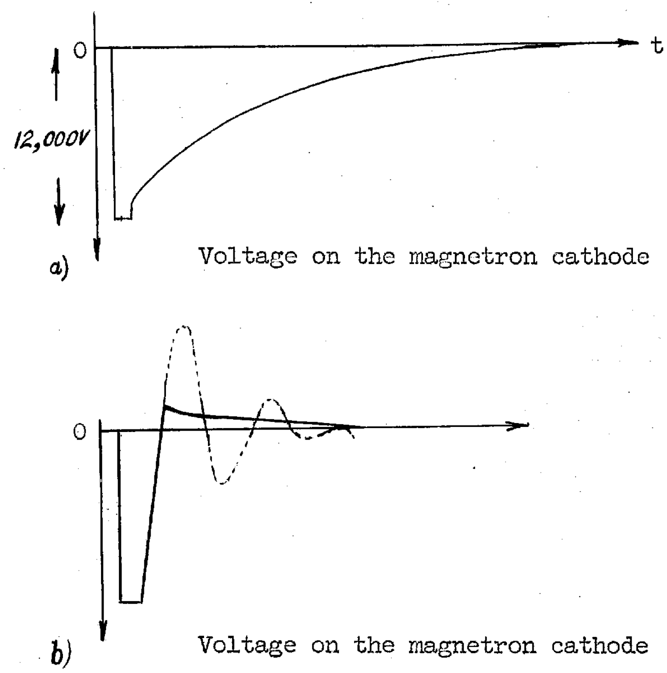

Fig. 30.

a) Curve of voltage on magnetron cathode in absence of circuit R-02-P5, L-01-P5

b) Voltage on magnetron cathode with R-02-P5 and L-01-P5

Dotted line shows voltage curve in absence of diode

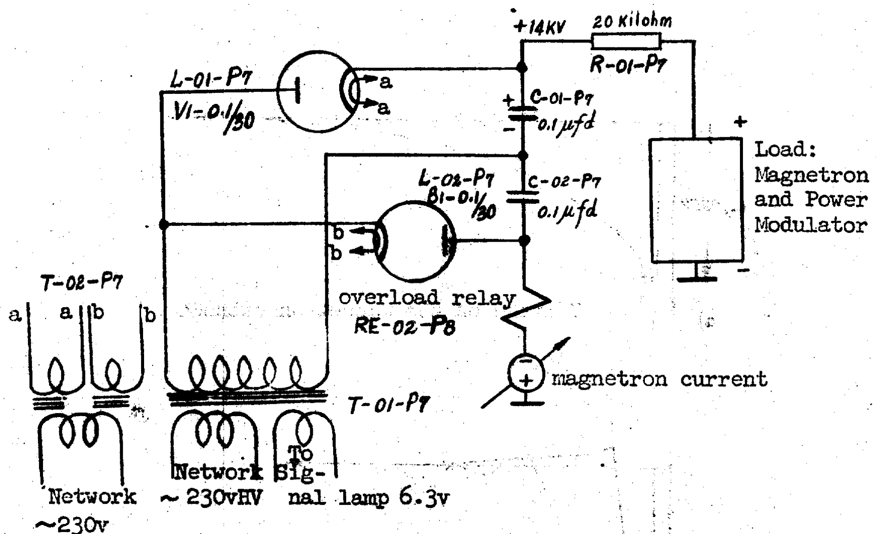

Fig. 31.

Rectifier circuit P-7

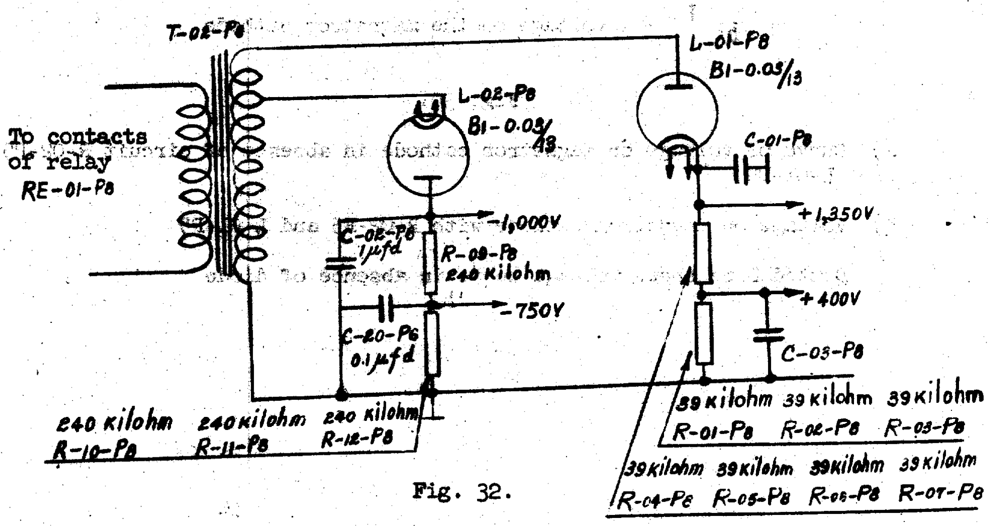

Fig. 32.

Rectifier circuit P-8

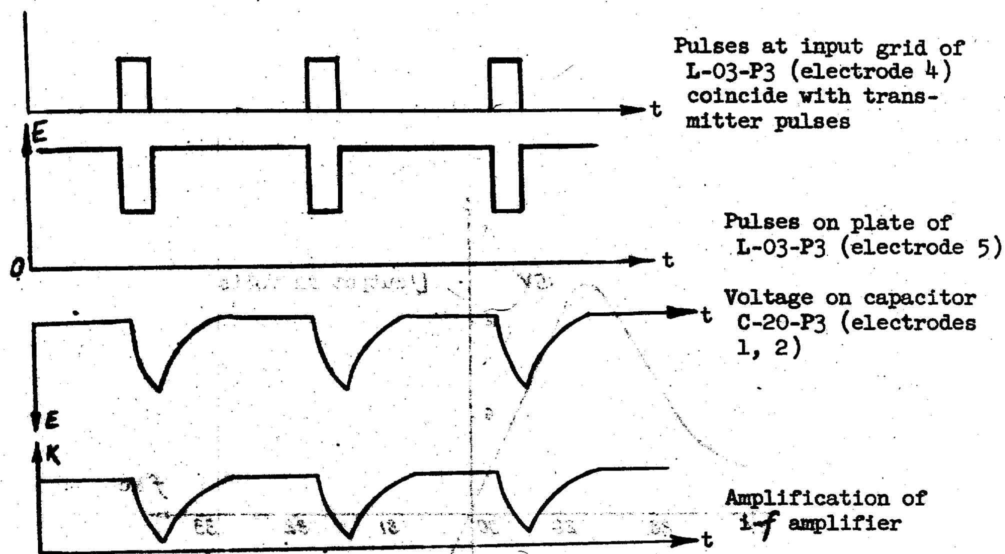

Fig. 33.
Curve of voltages at several points of circuit P-3

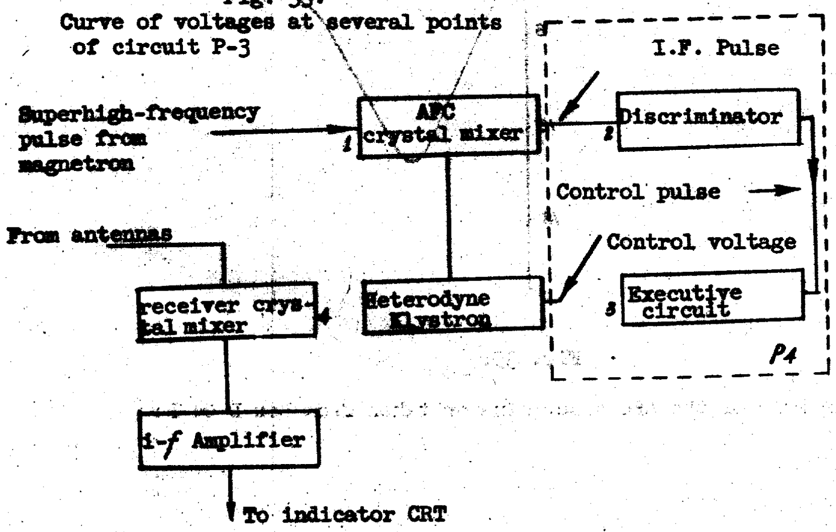

Fig. 34.

Block diagram of AFC system

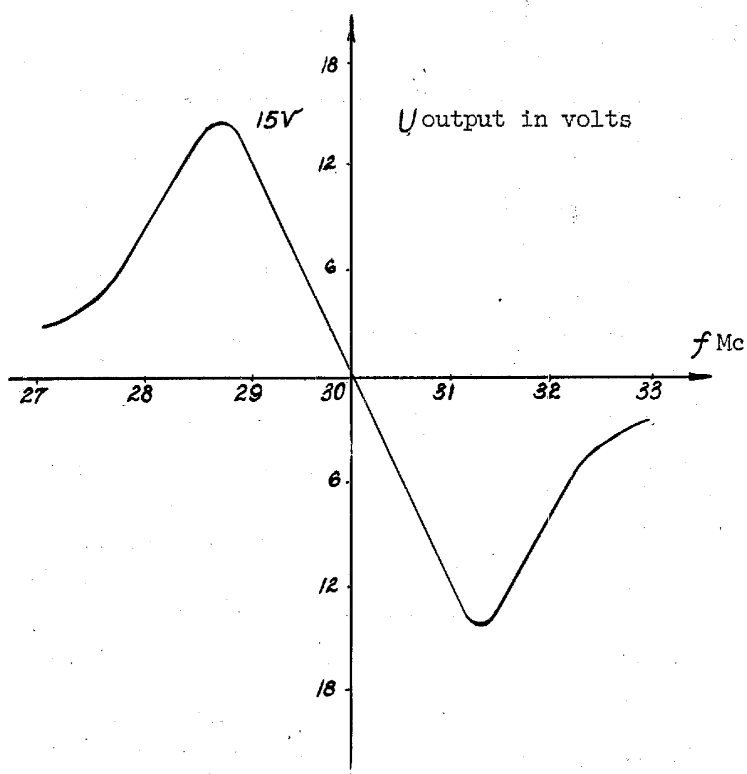

Fig. 35.

Characteristic of the AFC discriminator taken from box D-04-P4

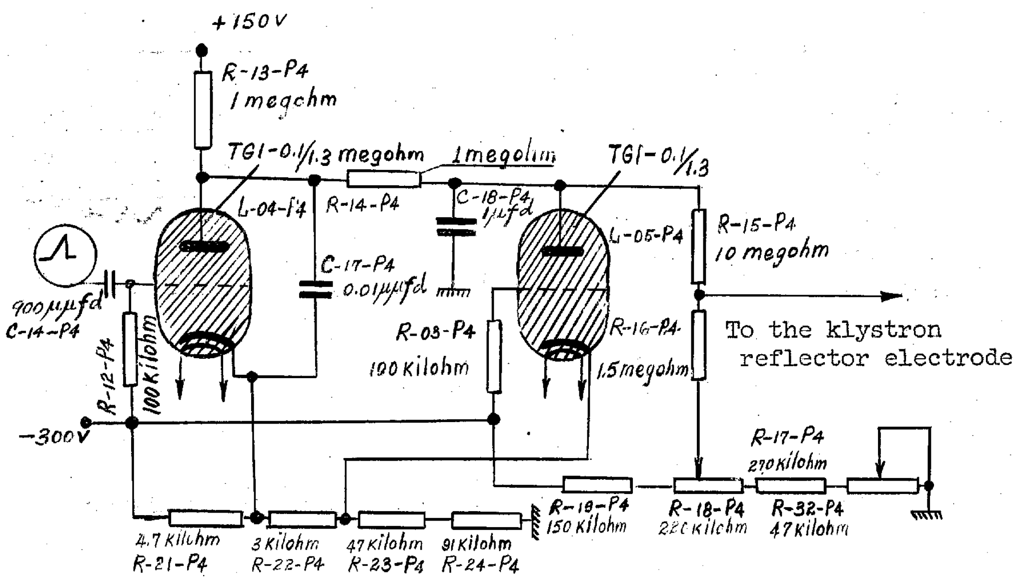

Fig. 36.

Circuit of Thyratron Executive System

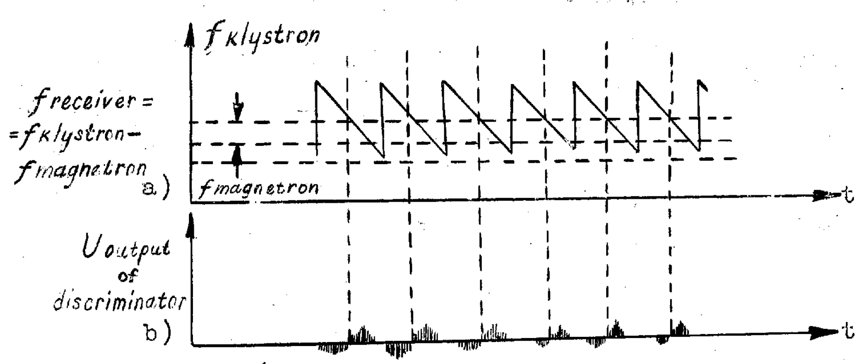

Fig. 37.

a) Curve of frequency variation in the klystron with time under "poisk" [search] operating condition

b) Curve of voltage at discriminator output under "poisk" [search] operating condition (with an open circuit to the discriminator)

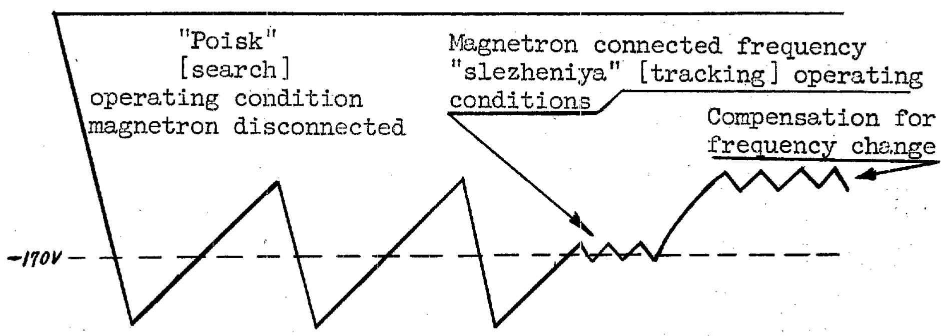

Fig. 38.

Curve of voltage on the reflector electrode of the klystron oscillator

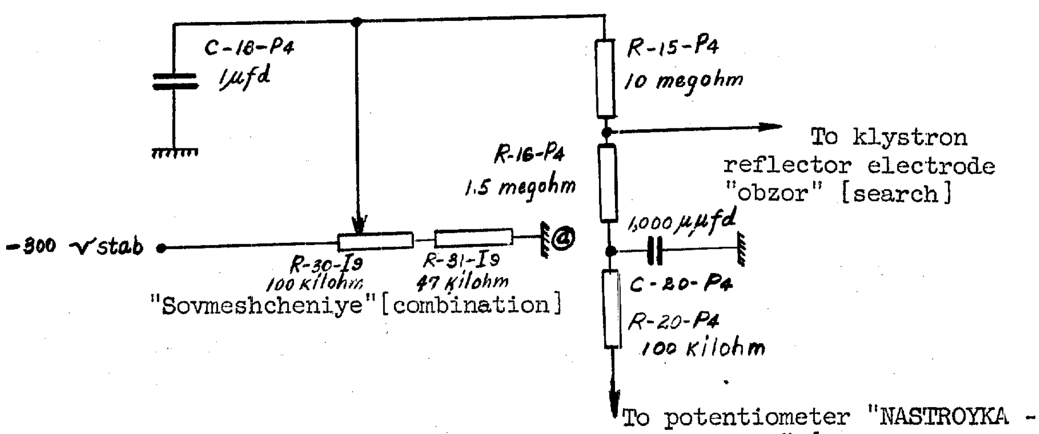

Fig. 39.

Circuit for control of klystron frequency tuning with manual tuning from the indicator

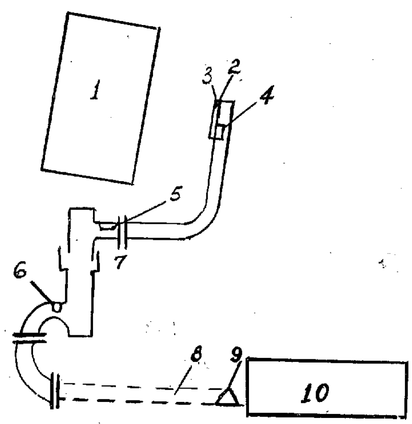

Fig. 40.

Schematic diagram of antenna waveguide path

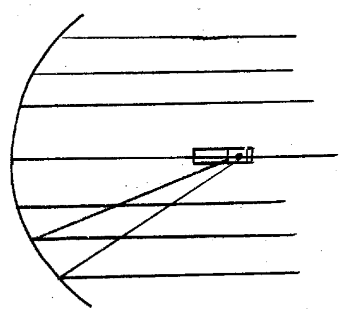

Fig. 41.

Schematic diagram of the action of the reflector

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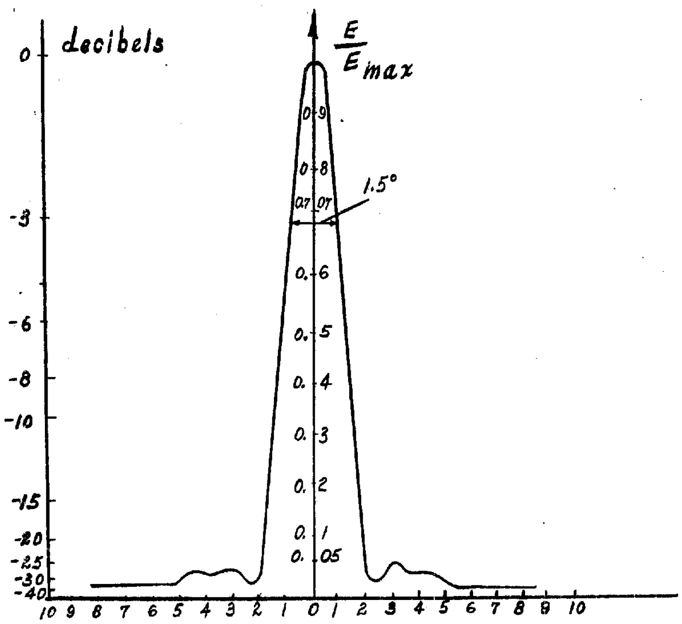


Fig. 42.

Diagram of antenna directivity (in a horizontal plane).

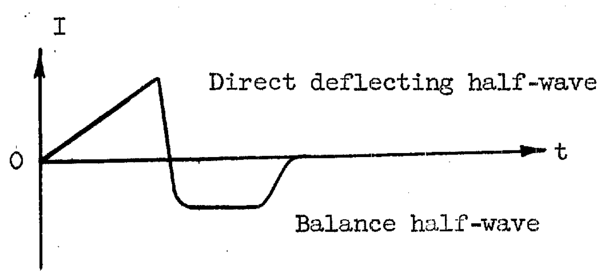


Fig. 43.

APPENDIX II

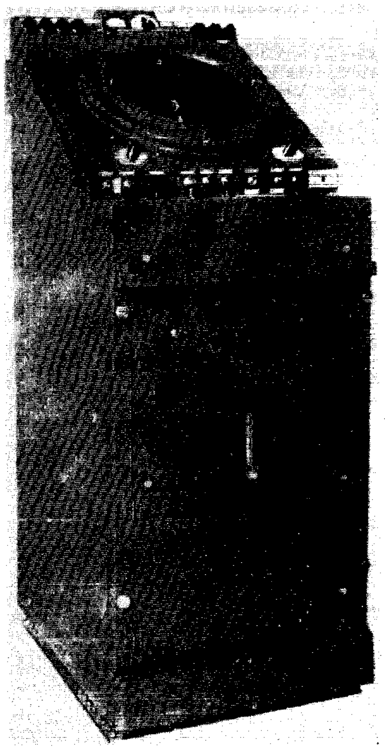


PHOTO 1. MAIN INDICATOR (BLOCK "I"). EXTERNAL VIEW.

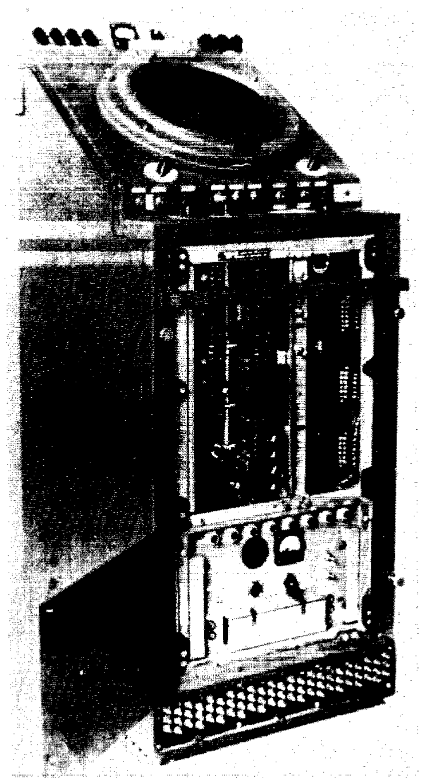


PHOTO 2. MAIN INDICATOR (BLOCK "I") IN HOUSING WITH FRONT PANEL OFF AND CHECK PANEL OPEN. FRONT VIEW.

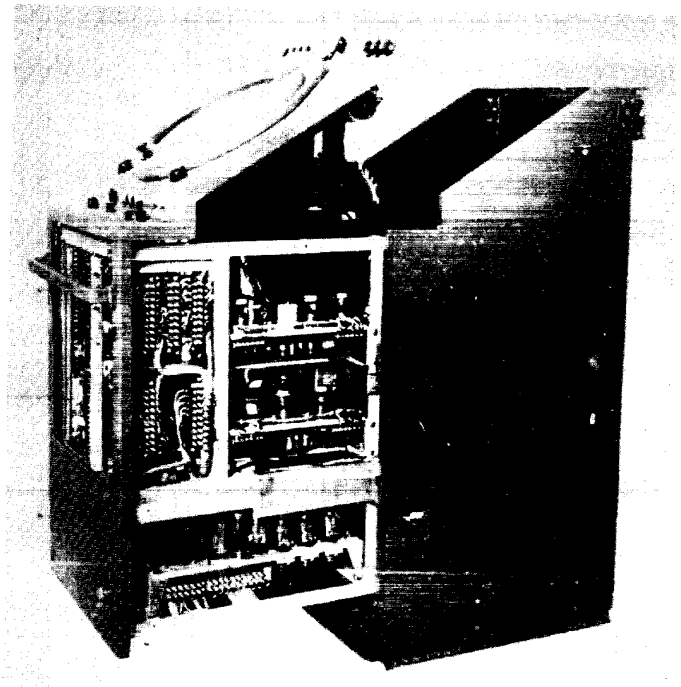


PHOTO 3. MAIN INDICATOR (BLOCK "I") PULLED OUT OF ITS HOUSING. RIGHT VIEW.

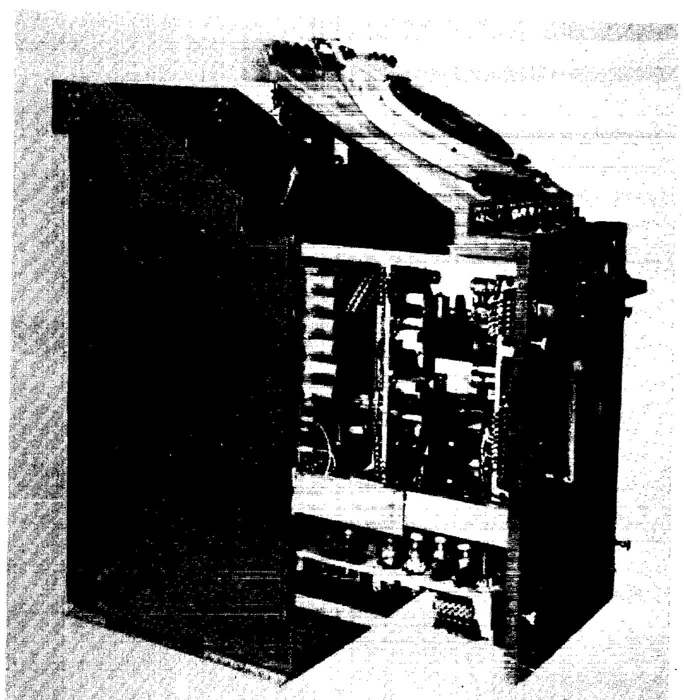


PHOTO 4. MAIN INDICATOR (BLOCK "I") PULLED OUT OF ITS HOUSING. LEFT VIEW.

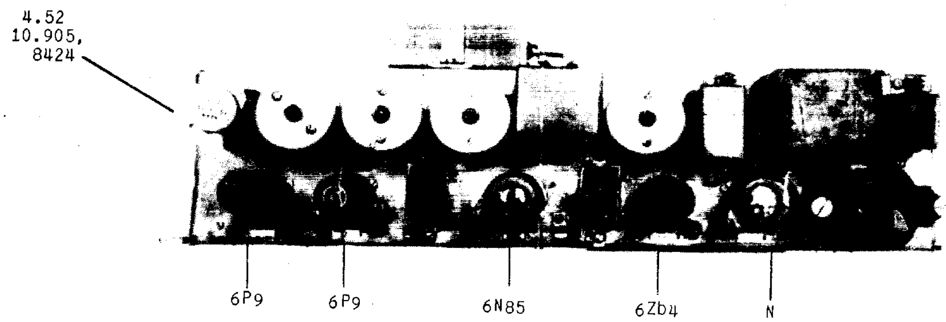


PHOTO 5. FREQUENCY GENERATOR (UNIT I-1). VIEW FROM TUBE SIDE.

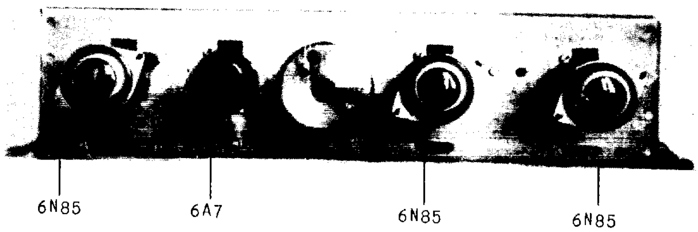


PHOTO 6. UNIT I-3. FOR FORMING MOVABLE RANGE CIRCLE PULSES. TOP VIEW.

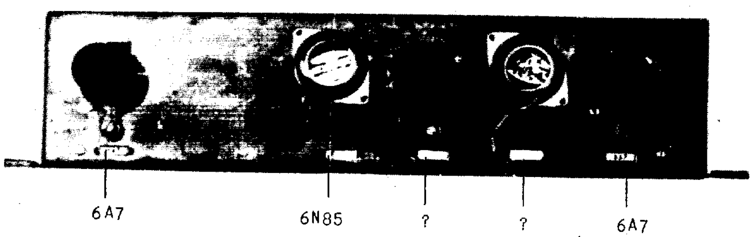


PHOTO 7. UNIT I-4. FOR FORMING TRIGGER PULSES. TOP VIEW.

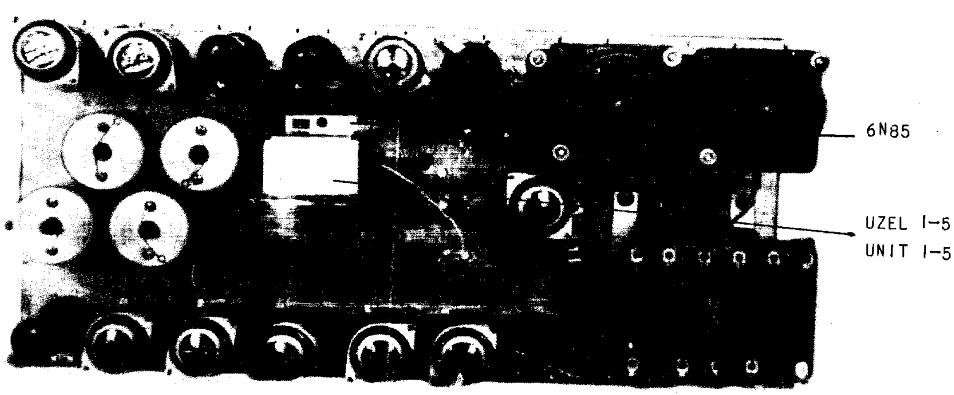


PHOTO 8. SWEEP UNIT I-5. VIEW FROM TUBE SIDE.

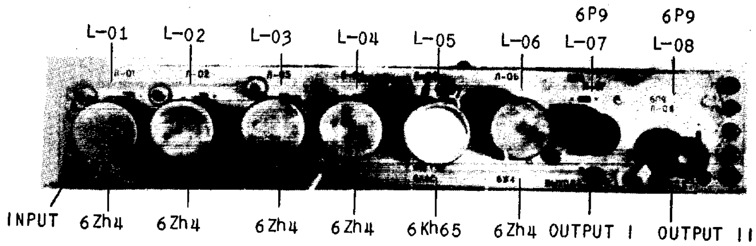


PHOTO 9. MAIN I-F AMPLIFIER I-7. VIEW FROM TUBE SIDE.

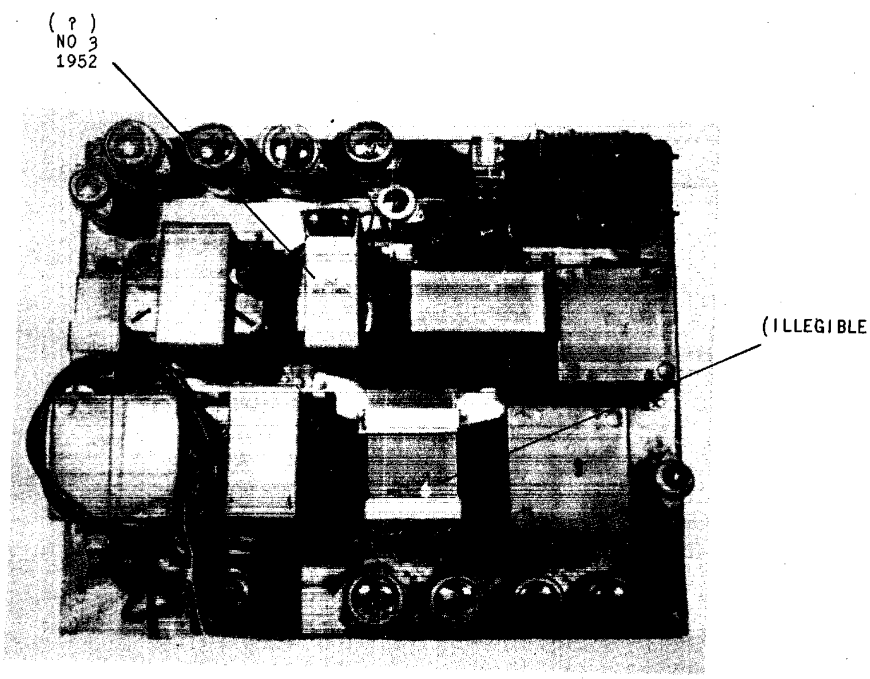


PHOTO 10. POWER-SUPPLY UNIT I-8. TOP VIEW.

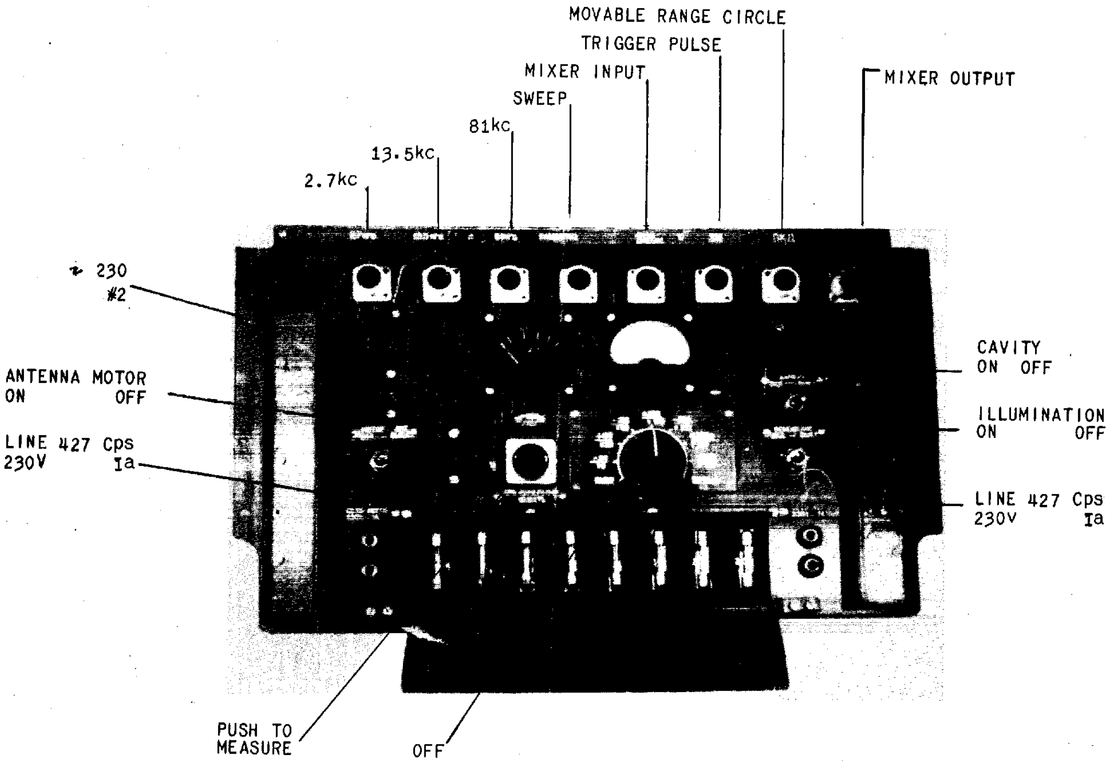


PHOTO 11. CONTROL PANEL I-11. FRONT VIEW.

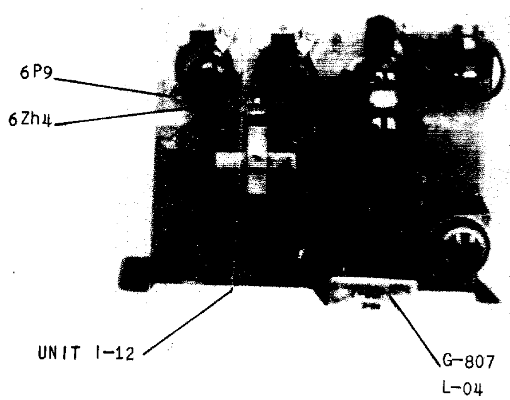


PHOTO 12. VIDEO MIXER I-12. VIEW FROM TUBE SIDE.

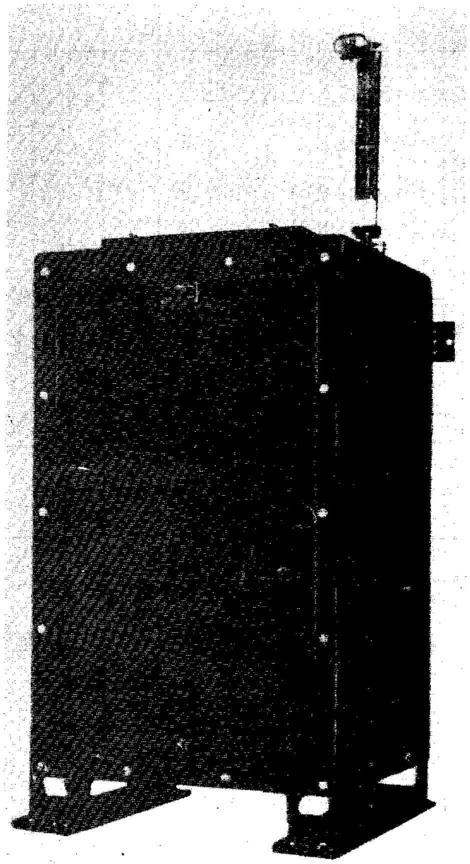


PHOTO 13. RECEIVER-TRANSMITTER (BLOCK "P"). EXTERNAL VIEW.

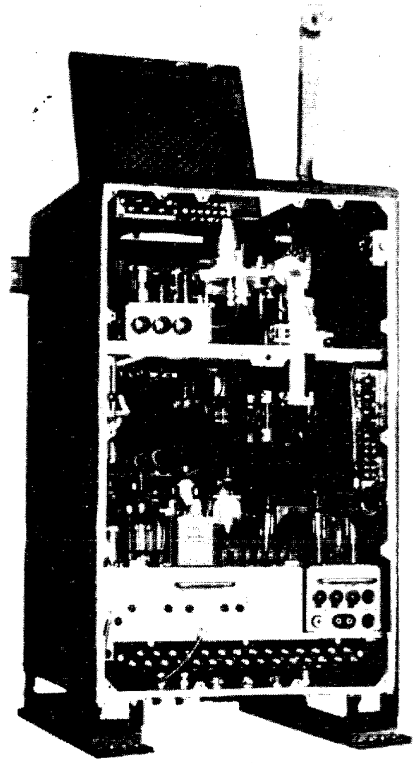


PHOTO 15. RECEIVER-TRANSMITTER (BLOCK "P"). FRONT VIEW WITH DOOR REMOVED AND MAGNETRON COMPARTMENT OPEN.

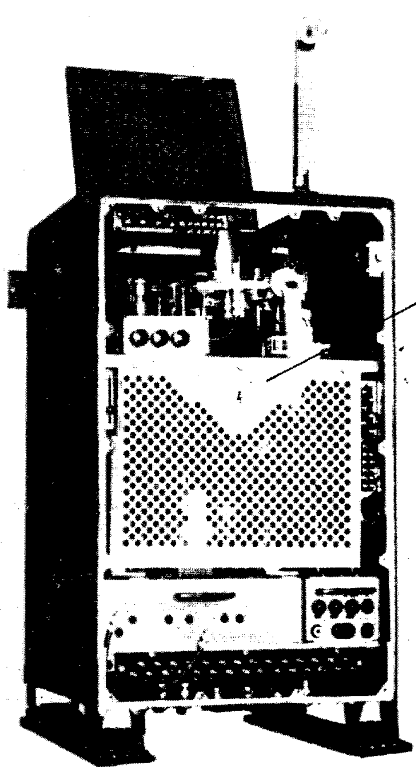


PHOTO 14. RECEIVER-TRANSMITTER (BLOCK "P"). FRONT VIEW WITH DOOR OPEN.

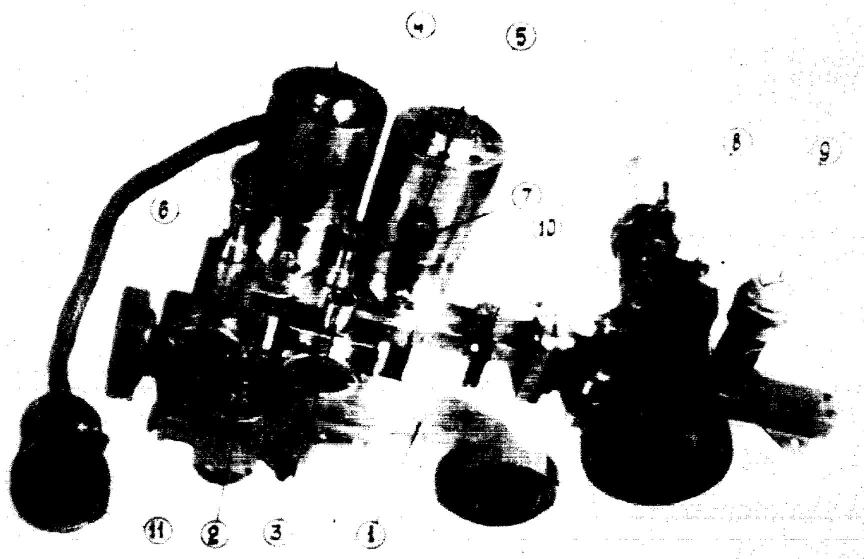


PHOTO 16. RECEIVER-TRANSMITTER (BLOCK "P"). HIGH-FREQUENCY SYSTEM. TOP VIEW (1986).

1. MAIN WAVEGUIDE
2. TRANSMISSION CAVITY RR-200
3. RECEPTION CAVITY RR-201
4. SEARCH HETERODYNE K-200
5. "REZERV" (STAND-BY) HETERODYNE K-200
6. AFC CRYSTAL DK-S 200
7. SIGNAL CRYSTAL DK - S 200
8. RESONANCE WAVEMETER
9. WAVEMETER DETECTOR DK - S 200
10. RESONATOR ATTENUATOR
11. HETERODYNE POWER-SUPPLY PLUG

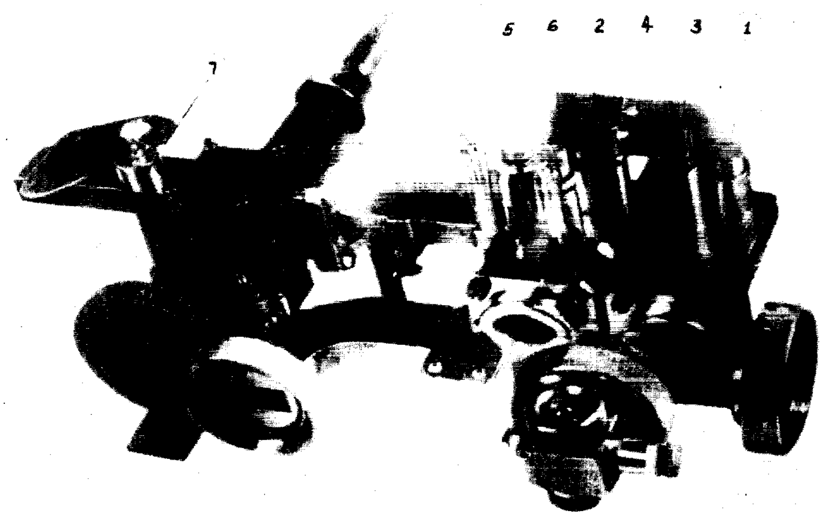


PHOTO 17. RECEIVER-TRANSMITTER (BLOCK "P"). HIGH-FREQUENCY SYSTEM. BOTTOM VIEW.

1. FEEDER OUTPUT OF AFC CONTROL SIGNALS
2. FEEDER OUTPUT OF RECEIVED SIGNALS
3. SCREW FOR COUPLING HETERODYNE WITH AFC DETECTOR D-12-P2
4. SCREW FOR COUPLING SURVEILLANCE HETERODYNE WITH SIGNAL DETECTOR D-11-P2
5. SCREW FOR COUPLING "REZERV" (STAND-BY) HETERODYNE WITH DETECTOR OF SIGNALS FROM "REZERV" (STAND-BY) D-10-P2
6. SCREW FOR TRIMMING THE RECEPTION CAVITY D-13-P2
7. OUTPUT SOCKET FOR THE RESONATOR SIGNAL

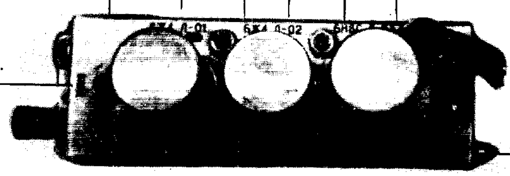


PHOTO 18. I-F PREAMPLIFIER P-3. TOP VIEW.

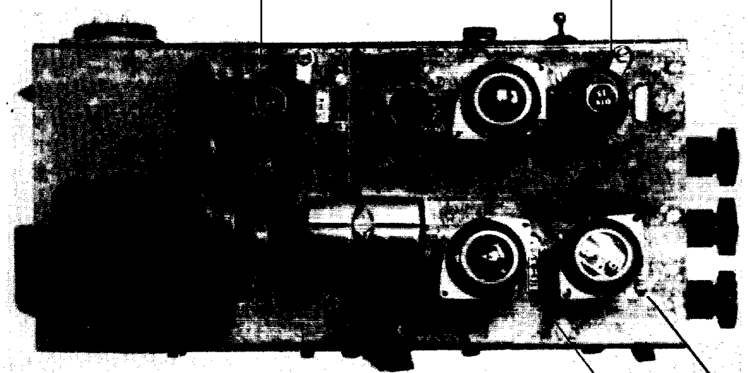


PHOTO 19. AFC UNIT P-4. TOP VIEW.

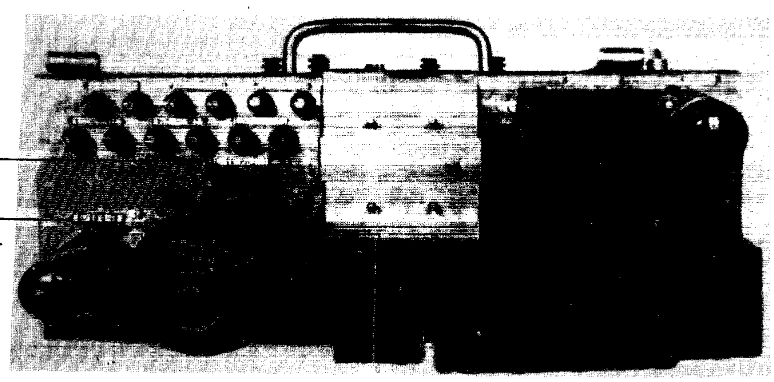


PHOTO 20. MODULATOR WITH PG FORMING LINE P-6.

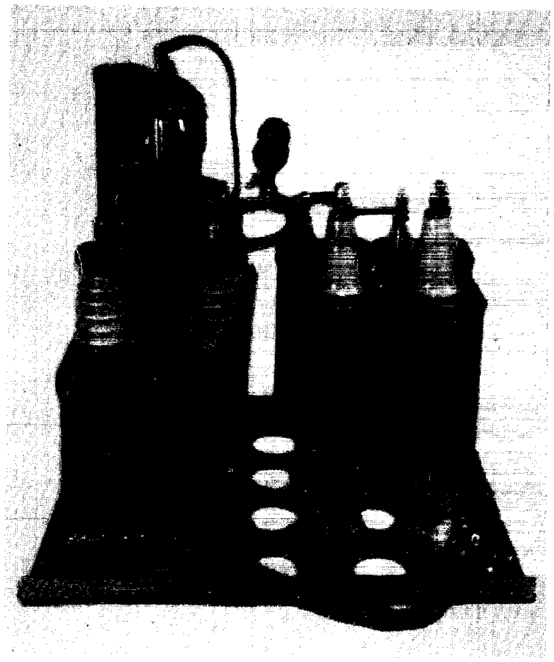


PHOTO 21. HIGH-VOLTAGE RECTIFIER P-7. TOP VIEW.

V1-0.03/1? V1-0.03/13

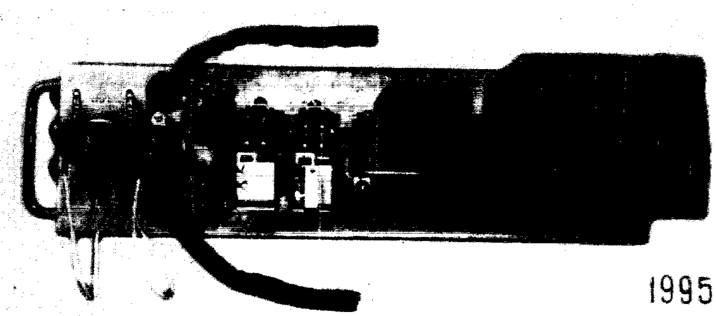


PHOTO 22. MODULATOR POWER-SUPPLY UNIT P-8

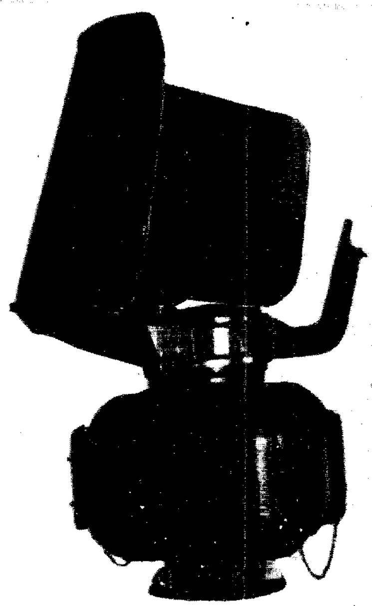


PHOTO 23. ANTENNA-WAVEGUIDE ASSEMBLY (BLOCK "A"). EXTERNAL VIEW.

PHOTO 24. ANTENNA-WAVEGUIDE ASSEMBLY (BLOCK "A"). VIEW WITH COVERS OF ROTATION DRIVE REMOVED.

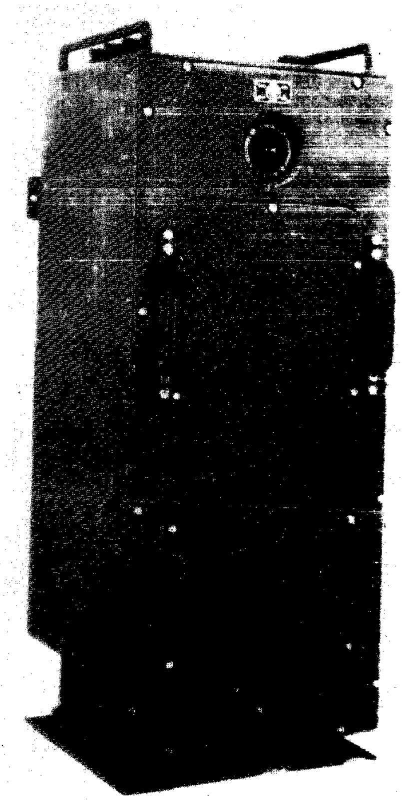


PHOTO 25. REMOTE INDICATOR (BLOCK "V"). EXTERNAL VIEW.

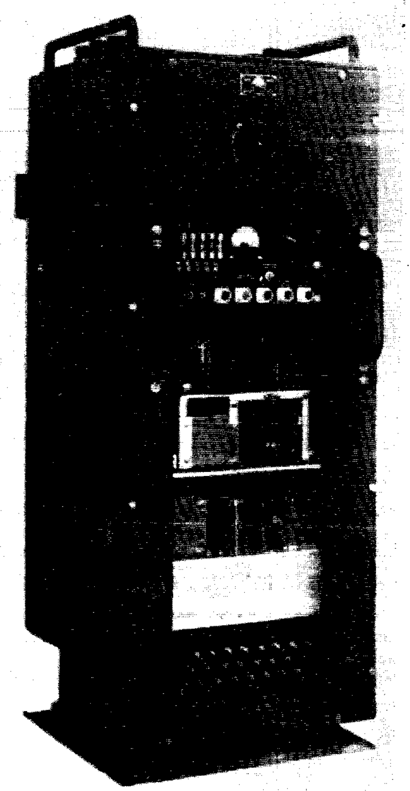


PHOTO 26. REMOTE INDICATOR (BLOCK "V"). FRONT VIEW INTO HOUSING WITH FRONT PANEL REMOVED.

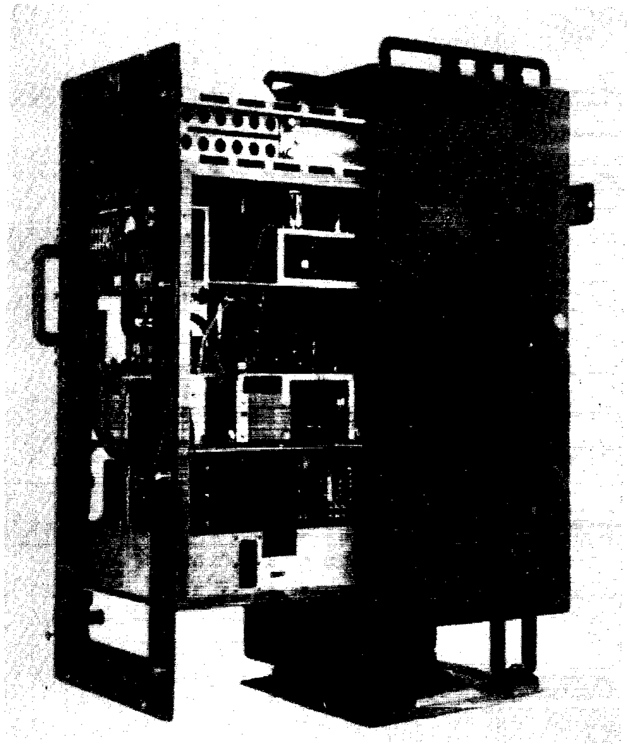


PHOTO 27. REMOTE INDICATOR (BLOCK "V") PULLED OUT OF ITS HOUSING. RIGHT VIEW.

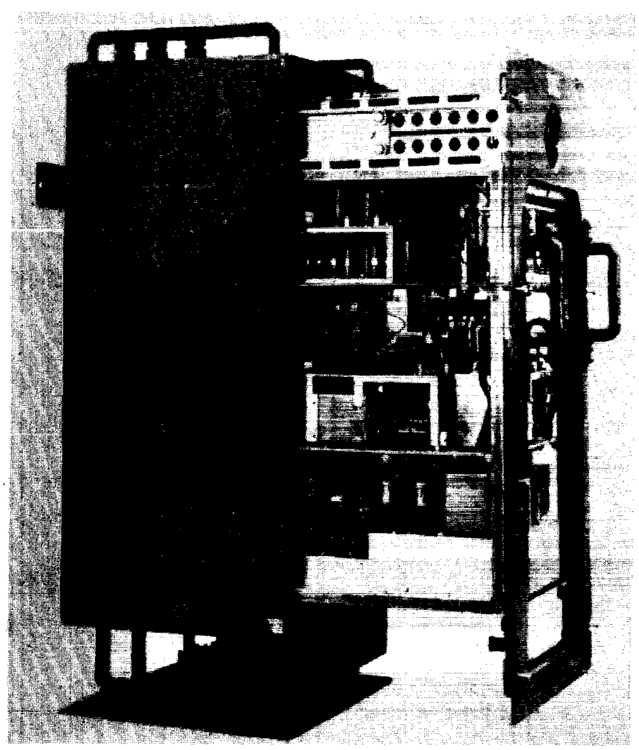


PHOTO 28. REMOTE INDICATOR (BLOCK "V") PULLED OUT OF ITS HOUSING. LEFT VIEW.

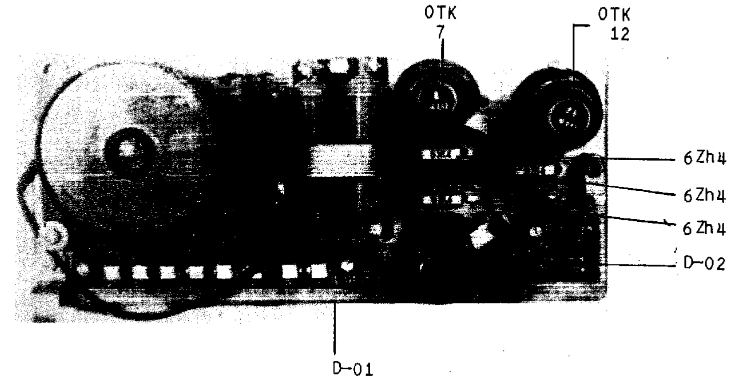


PHOTO 29. SWEEP PULSE AMPLIFIER V-1. TOP VIEW.

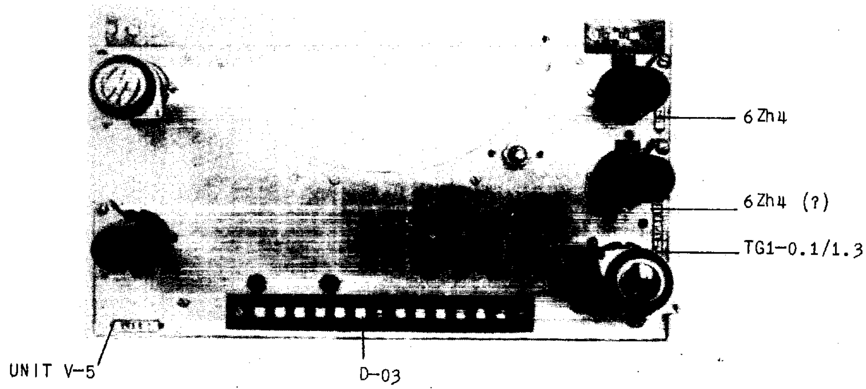


PHOTO 30. VIDEO AMPLIFIER V-5. TOP VIEW.

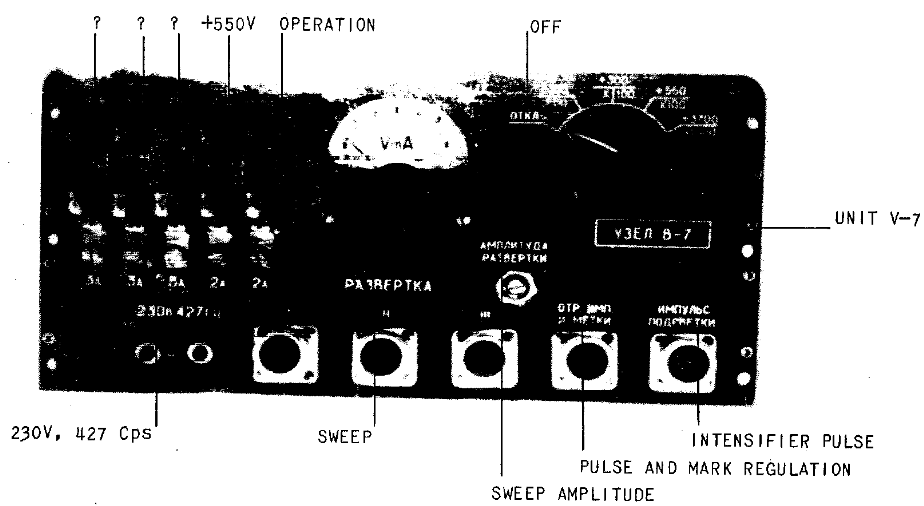


PHOTO 31. CHECK PANEL V-7. FRONT VIEW.

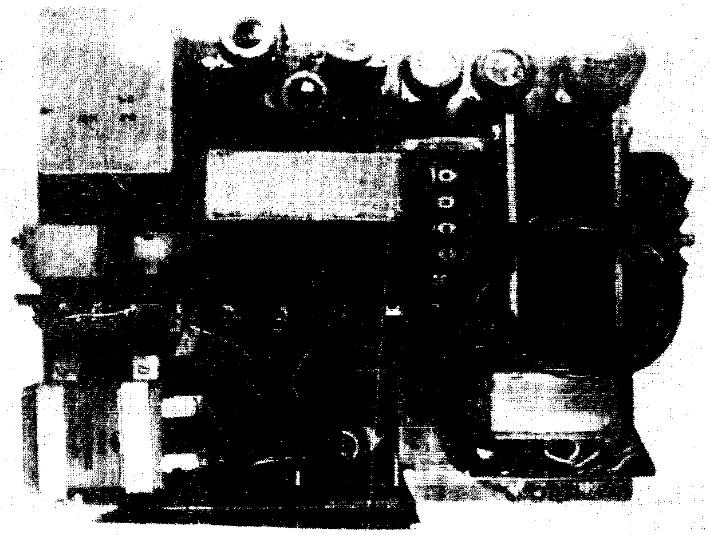


PHOTO 32. POWER-SUPPLY UNIT V-8. TOP VIEW.

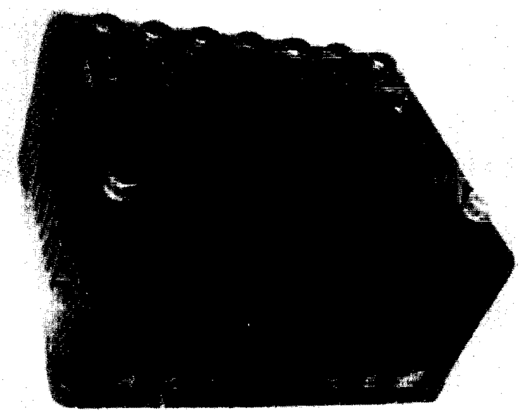
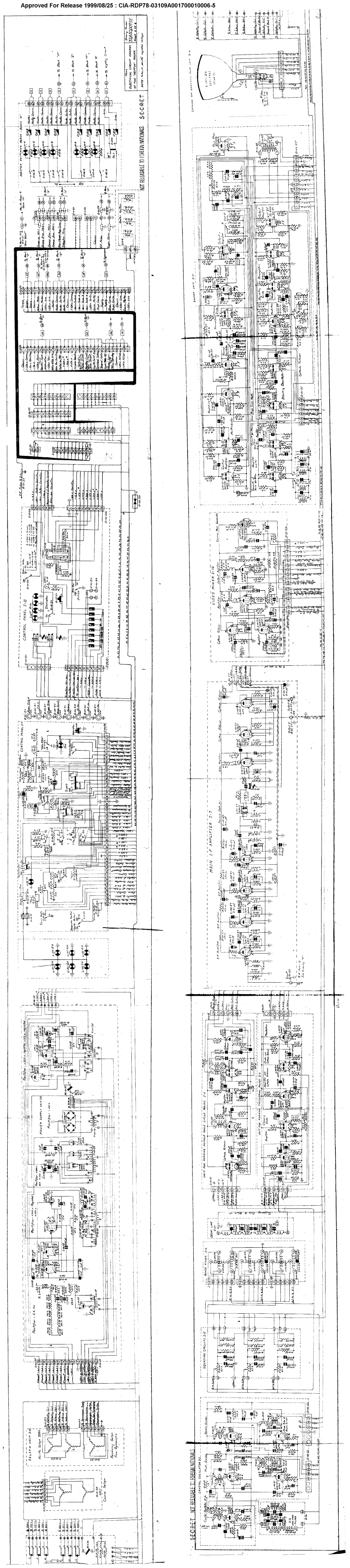


PHOTO 33. HEATER BLOCK (BLOCK "B"). EXTERNAL VIEW.

PHOTO 34. HEATER BLOCK (BLOCK "B"). VIEW WITH COVER OPEN.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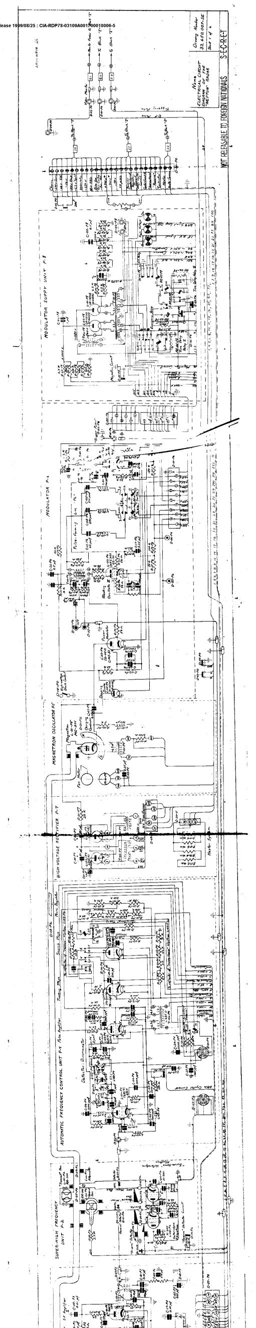
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