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REPORT

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An English-language Soviet manual entitled Aircraft MiG-21FL, Technical Description, Book IV, Electrical and Oxygen Equipment and Flight Instruments

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STATE	DIA	ARMY	NAVY	AIR	NSA	NIC	OCR	SAC

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AIRCRAFT MIG-21FL

TECHNICAL DESCRIPTION

BOOK IV

ELECTRICAL AND OXYGEN EQUIPMENT AND FLIGHT INSTRUMENTS

PART I

SECRET
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AIRCRAFT МиГ-21ФЛ

BOOK IV

PART I

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SECRET
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TECHNICAL DESCRIPTION

BOOK IV

[redacted] AND OXYGEN EQUIPMENT
AND FLIGHT INSTRUMENTS

PART I

Technical Description of Aircraft MiG-21PF comprises five books:

Book I: Performance Characteristics

Book II: Armament

Book III: Construction

Book IV: Electrical and Oxygen Equipment and Flight Instruments

Book V: Radio Equipment

The fourth book is divided into two parts:

Part I - Electrical Equipment;

Part II - Flight Instruments and Oxygen Equipment.

The book contains information on the aircraft electrical and oxygen equipment and flight instruments necessary for their study and operation.

The electrical equipment is described in this book in accordance with the circuit diagrams. The diagrams are supplemented to this book and contained in a separate folder.

For the operation of the electrical equipment use should be also made of the aircraft operating and maintenance instructions.

The book includes 98 pages. Besides, there are 3 insets: Inset No.1 to face page 8; Inset No.2 to follow Inset No.1 and Inset No.3 to face page 32.

Chapter I

GENERAL

The electrical equipment of the aircraft is a complex of electrical devices grouped into functional families and interconnected by means of wires to form various aircraft electrical systems.

The equipment is located in different parts of the aircraft framework. The access to them is ensured through special hatches.

The electrical equipment consists of power sources, current consumers and an electric circuit.

The electric circuit includes protective, control and switching devices, wires, negative connections and connectors.

Starter-generator, type TCP-CT-12000BT, that is employed for starting the engine in the starting mode and for feeding the direct current into the aircraft mains in the generating mode, is the main source of D.C. power supply aboard the aircraft. The starter-generator is driven by the aircraft power plant and after starting the engine it serves as a source of power.

While starting the engine on the ground the electric power is furnished from ground power sources or storage batteries, the starter-generator being a current consumer itself.

The starter-generator operates in conjunction with voltage regulator RVT-82 and stabilizing transformer TC-9K.

Differential reverse-current relay RMP-400T serves for automatic connection of the generator to the aircraft mains. To protect the mains from dangerous voltage rise caused by overexcitation of the generator, provision is made for circuit breaker ASB-1MA, Series III. The generator can be cut in and out by means of a switch installed on the horizontal board of the right-hand console in the cockpit.

In case of failure of starter-generator TCP-CT-12000BT the direct current will be fed to the aircraft mains from two storage batteries 15CHC-45 connected in parallel with the generator.

The capacity of the storage batteries is checked by means of integrating ampere-hour meter MCA.

For connecting the wire bundle of the ground D.C. power source provision is made for plug PDA-250MK installed on the port side of the fuselage.

Starting of the engine from the ground power source is performed through switch box KUA-6 included in the set of the ground power supply source.

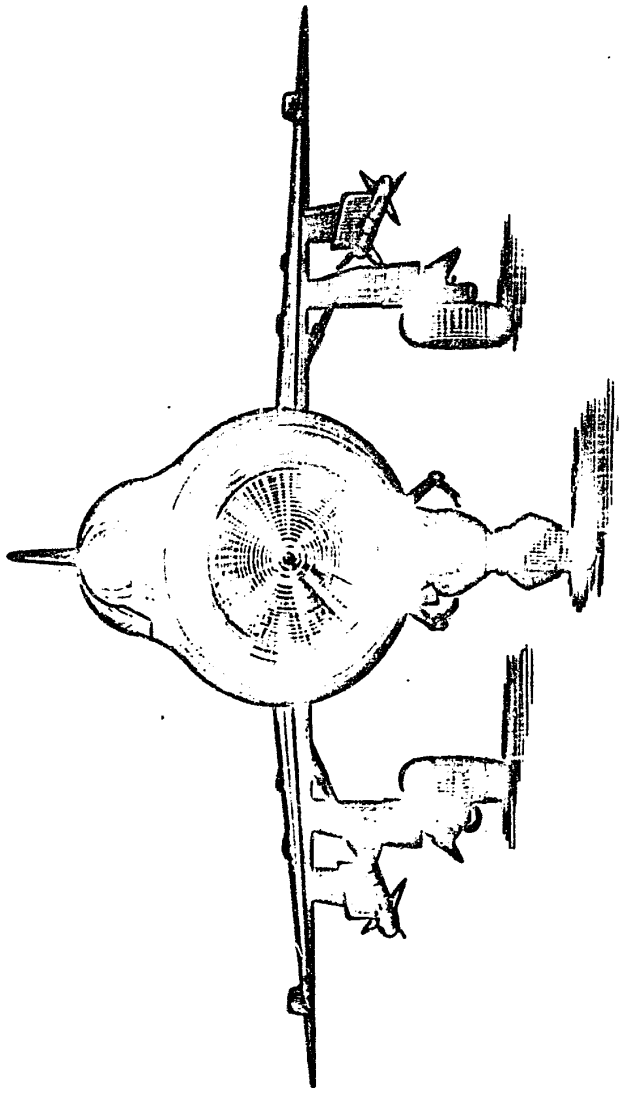

FIG.1. AIRCRAFT [illegible] (FRONT VIEW)

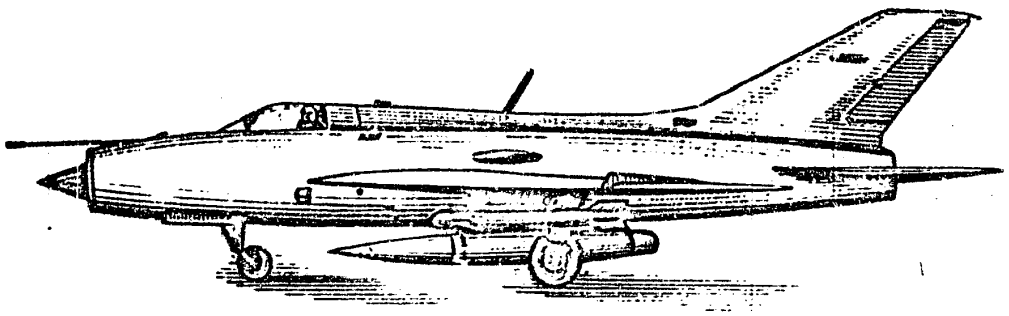

FIG.2. AIRCRAFT МиГ-21ФЛ (SIDE VIEW)

As soon as the ground power source is connected to the aircraft mains, the storage batteries and the generator become automatically disconnected.

The switch installed on the horizontal electric board of the right-hand console is designed for cutting in and out the ground power source or the storage batteries.

The voltage in the aircraft mains is checked with the aid of voltmeter B-1 installed on the instrument panel.

For checking the load current in the power supply unit provision is made for a socket to which an ammeter may be connected.

The A.C. power supply sources of the aircraft are as follows: generator СГО-8, Series II, inverter ПО-1500ВТ-3Н, inverter ПО-750А, inverters ПТ-500Ц and ПТ-125Ц and inverter ПАТ-1Ф.

Generator СГО-8, Series II, is driven by the engine. It operates in conjunction with carbon-pile voltage regulator РН-400Б.

Inverter ПО-1500ВТ-3Н operates in conjunction with control box КУ-1500ВТ.

When the engine is inoperative the A.C. ground power source is used instead of generator СГО-8, Series II, which is connected to plug НРА-200ПК and the supply circuit is disconnected from the generator.

All the inverters and generator СГО-8, Series II, being A.C. power sources are at the same time consumers of the D.C. mains voltage through the excitation circuit.

The current consumers installed on the aircraft are as follows:

(a) engine starting and mode control units;
(b) radio and radar equipment;
(c) aircraft armament;
(d) fuel system;
(e) cockpit air temperature control units;
(f) controller АРУ-3В, Series II;
(g) fire-fighting equipment;
(h) heating devices of clock, Pitot-static tube, and storage batteries;
(i) warning and illuminating equipment;
(j) flight and navigation instruments;
(k) engine control instruments;
(l) pumping unit and trimming effect electric mechanism;
(m) circuits of hydraulic and air systems, landing gear, wheel brakes, etc.

Electric power fed from the power sources to consumers is distributed in the power distribution unit (Fig.3).

The design of the power distribution unit is based on the principle of feeding direct current to all the consumers at a time from the operating generator through its main busbar, busbars Nos 1, 2, 3 and busbar A (emergency) of the cockpit electric boards (See Fig. 4).

The circuit illustrating distribution of D.C. power supply among different consumers is presented in Fig.4.

Busbar No.1 installed on the left-hand electric board, the middle board of the instrument panel and on the right-hand horizontal electric board as well as busbars A of the right-hand front and rear electric boards are the busbars which feed all the consumers of primary importance. The electric energy is continuously fed to the consumers inspite of overloads in the aircraft distribution circuit and short and open circuiting in the feeding and connecting lines.

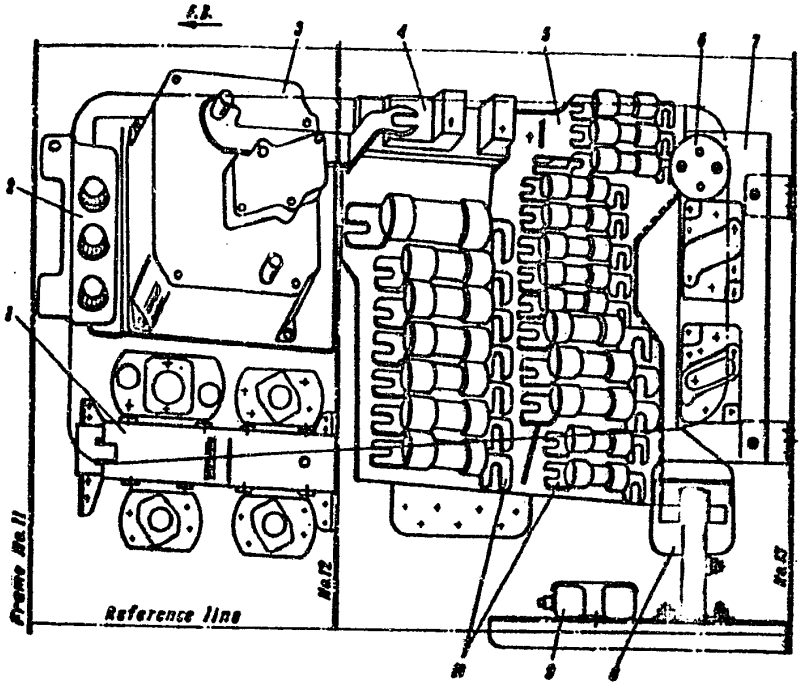

FIG.5. DIAGRAM OF POWER DISTRIBUTION UNIT

1 – unit of contactors KM-50Д and KM-100Д; 2 – bracket with fuses СП; 3 – differential reverse-current relay ДИР-400Т; 4 – ammeter shunt Ш-2; 5 – power distribution unit buster; 6 – ammeter receptacle; 7 – unit of contactors ТКД-401АТ and ТКАЗ1ДТ; 8 – stabilizing transformer ТС-9М; 9 – capacitor МБГТ-160-4; 10 – time lag fuses.

The continuity of power supply is achieved by means of the section-type busbars of the cockpit electric boards and by using circuit breakers, type АЗР-60, with free disconnection and jumpers interconnecting busbars A and busbar No.1.

The supply circuit ensures selective operation of the protective devices in case of short circuiting in the supply lines and normal distribution of loads in case of open circuiting in one or even two feeding wires.

Notes: 1. A feeding wire is a wire running from the main distribution unit (power distribution unit busbar) to the circuit breaker, type АЗР-60, installed on the distribution board in the cockpit.

2. A connecting wire (jumper) is a wire which links the busbars of the cockpit electric boards and is connected after circuit breakers, type АЗР-60.

The alternating current is fed from inverters ПО-750А and ПО-1500ВТ-3Н, generator СГО-8, Series II, and from the ground A.C. source to the consumers through the feeding wires and the busbars made of БПВЛ wire in the form of jumpers and located in the radio box, and through the fuses, type СП.

From inverter ПТ-500Ш the power is supplied through the feeding wires, jumpers and fuses contained in the supply box of the fighter directional system, gyro horizon and roll stabilization autopilot.

From inverter ПАГ-1Ф to the stand-by gyro horizon, as well as from inverter ПТ-125Ш to gyro horizon АГА-1 the power is supplied directly through the feeding wires. The diagram illustrating the distribution of the A.C. power supply to the consumers is shown in Figs 5,a and 5,b.

In accordance with their function the current consumers are arranged in groups.

The electrical and oxygen equipment and flight instruments serve the following funotional groups:

(a) power supply group;
(b) engine operation and control group;
(c) cone and anti-surge shutters control group;
(d) fuel supply group;
(e) aircraft control group;
(f) take-off and landing means group;
(g) lighting equipment group;
(h) heating equipment group;
(i) flight and navigation equipment group;
(j) armament group;
(k) radio equipment power supply group.

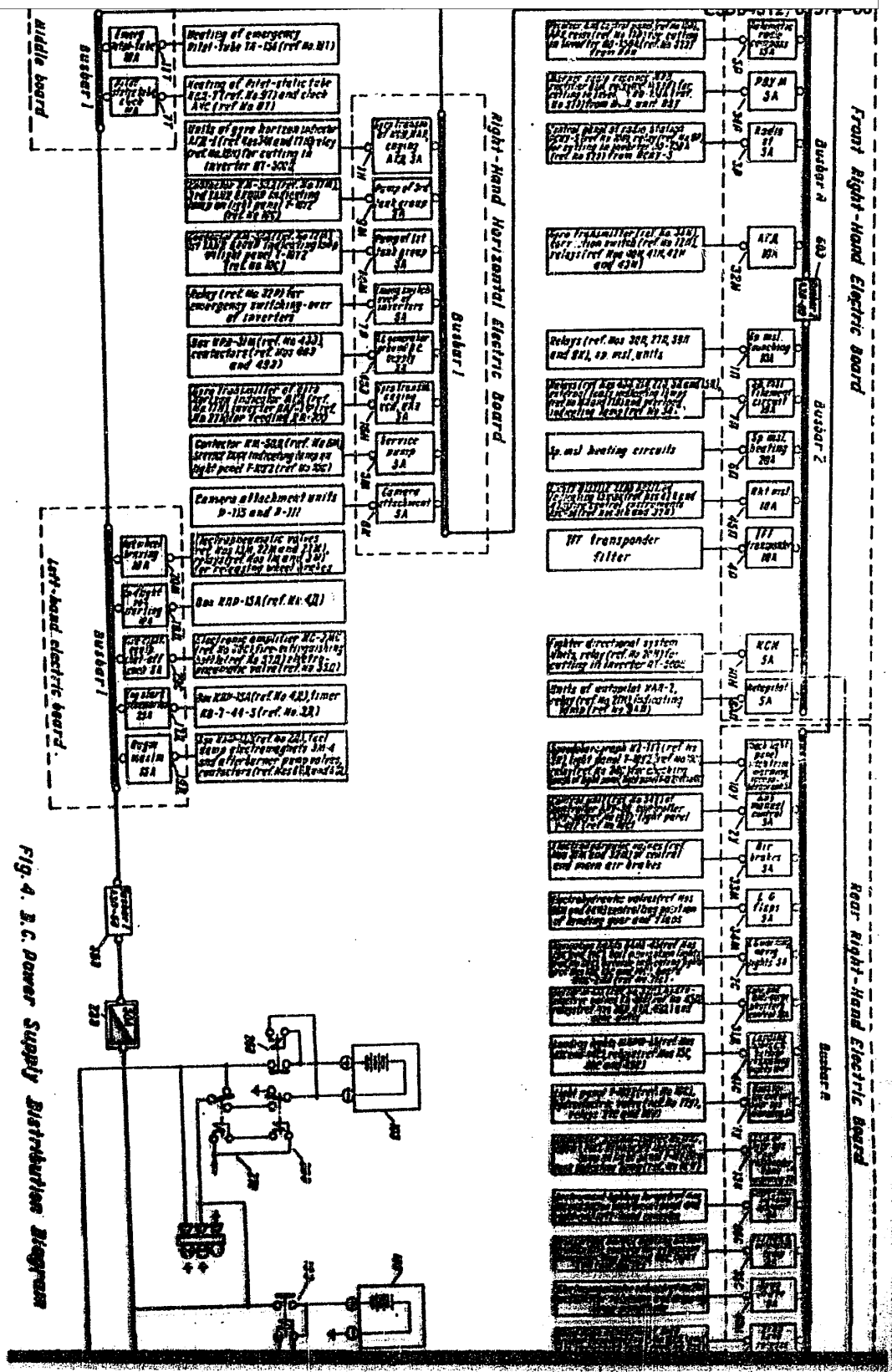

Fig. 4. D.C. Power Supply Distribution Diagram

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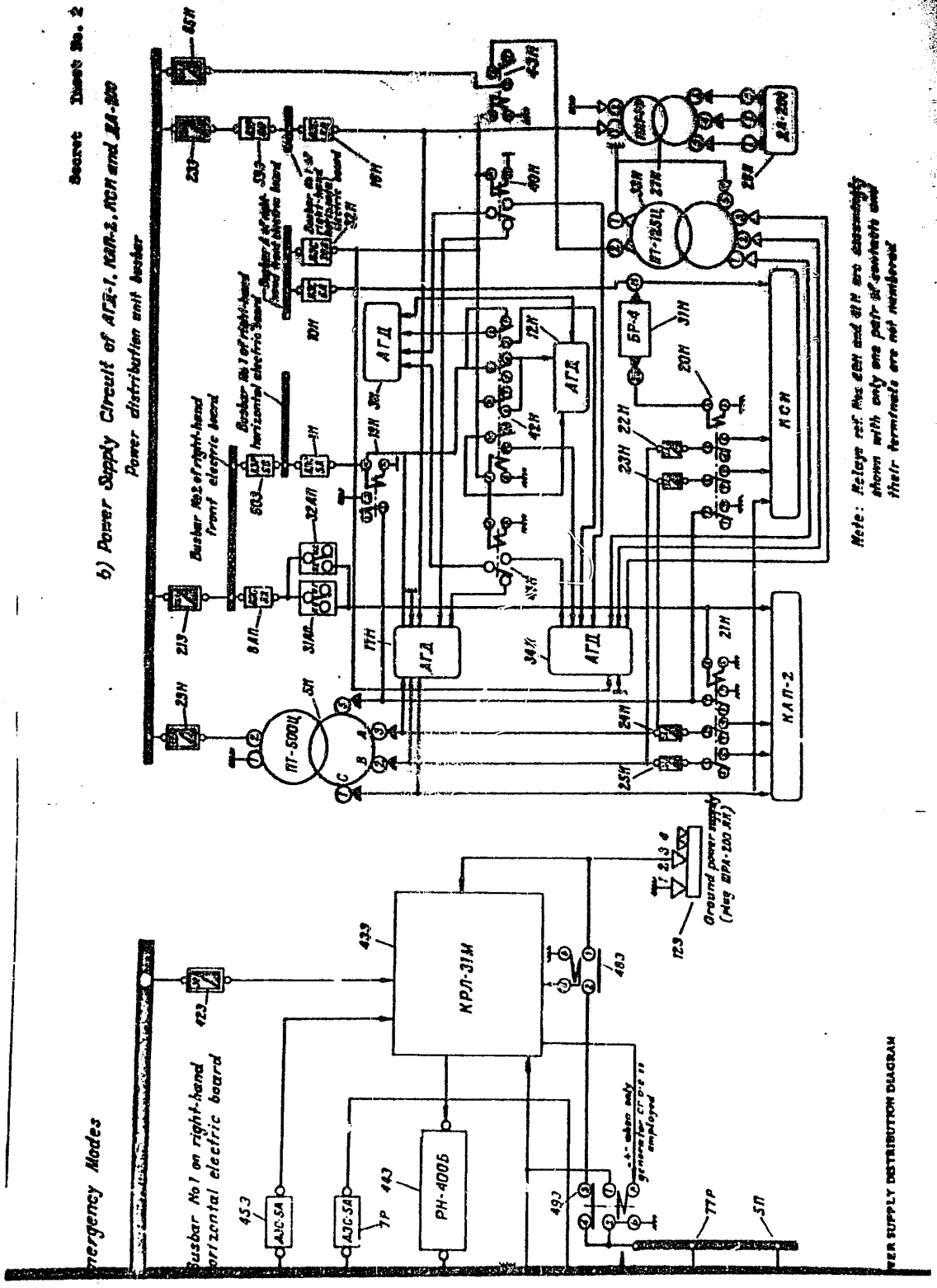
b) Power Supply Circuit of АГД-1, КАП-2, КСН and ЯП-200

Power distribution unit busbar



Chapter II

ELECTRICAL NETWORK

1. TYPE, CROSS-SECTION, LAYING AND ATTACHMENT OF WIRES

The electrical network of the aircraft is of a single-wire type with the negative pole being connected to the aircraft framework whereas the positive pole is fed to units through insulated wires.

The power consumers which are supplied through electrical filters ФП-110 and Э-37ВТ are connected to the aircraft mains by means of a two-wire circuit.

The aircraft network is mainly cabled with БПВЛТ and ПТЛ wires of various cross-sections: 0.5; 0.75; 1.0; 1.5; 2.5; 3.0; 4.0; 6.0; 8.0; 10.0; 13.0; 21.0; 70 sq.mm and with the МГВВТ wire of cross-sections: 0.5; 0.75; 1.0 and 1.5 sq.mm depending on the current consumed by units.

The БПВЛТ wires used in the aircraft network are of three different colours: red for the armament system; blue for the radio equipment and white for the electric system.

The МГВВТ wire is used for internal wiring of the relay boxes and electric boards.

The БПВЛТ wire is not heat-resistant and therefore is used in the areas with normal ambient temperature.

The ПТЛ wire is heat-resistant and used for wiring in areas with high ambient temperature: in the vicinity of the engine and afterburner.

All the wires are tied up into wire bundles using standard fittings and protective means.

The wire bundles are laid as follows:

(a) the cockpit wire bundle and the cockpit control system wire bundle are laid behind the instrument panel and along the cockpit sides behind the consoles;

(b) the upper fuselage control system wire bundle, the radio equipment power supply wire bundle, the cone control wire bundle, the fuselage nose portion (fighter directional system, gyro horizon and roll stabilization autopilot) wire bundle, the fuselage port side wire bundle, the fuselage starboard wire bundle, the lower fuselage wire bundle, the power supply wire bundles and the power wire bundles of the 1st, 2nd and 3rd groups of tanks and so on are laid in the nose portion of the fuselage;

(c) the main fuselage tail portion wire bundle and the fuselage tail portion control system wire bundle are laid in the fuselage tail portion and fin;

(d) the wire bundles of the wing leading edge portions (armament and navigation lights) and the wire bundles of the L.G. wells (flaps, landing lights, external indicating lights and L.G. wheel automatic brakes) are laid in the wing.

The wire bundles are attached by means of standard rigid and flexible fittings.

The rigid attachment elements (locks, clamps) are secured to the aircraft structure, while the flexible attachment elements serve for interconnecting separate wire bundles.

2. WIRE MARKING

The aircraft electrical network wires are marked to facilitate the installation and removal of the electric circuit wires and to make easier detection and elimination of troubles in them. The wire marking consists of letters and figures inscribed on a tag attached to every cable. A tag indicates:

1. Terminal number of the connector or unit to which the wire is to be connected (for instance 4).

2. Number of the unit included into one of the equipment groups (for instance 55).

3. Group designation (for instance P). For this purpose, the electrical and oxygen equipment and flight instruments of the aircraft are divided into 11 functional groups.

Group designation used	Description of equipment included into groups
Э	Power distribution unit, power supply sources
Д	Engine units
У	Aircraft control units
И	Electric actuators
К	Check instruments
С	Light indication and illumination systems
Т	Instrument heating equipment
Н	Flight and navigation equipment
Р	Radio equipment
В	Armament
АП	Autopilot

4. Electric line number which depends on the quantity of wires coming out of the given unit (for instance 1).

5. Reference number of the equipment (in the circuit diagram) where the wire goes to (for instance 36P).

For example, in our case the wire tag should be designated:

4 55PI - 36P

3. CONNECTION AND DISTRIBUTION DEVICES (CONNECTORS AND ELECTRIC BOARDS)

A. Connectors

To facilitate installation and removal of certain units and wire bundles, provision is made on the aircraft for various connectors.

Connectors serve for coupling electric circuit sections and units which do not require hermetic sealing (relay boxes, electric boards of the left-hand and right-hand consoles, the nose and tail portions of the fuselage, the wing and the fuselage, etc.) as well as for passing the wires through the pressurized cockpit walls.

The production connectors designed for coupling separate sections of the electric circuit are installed by the Manufacturing Plant and have figure numbers.

The electrical and oxygen equipment and flying instruments delivered by the specialized plants have their own connectors for placing them into the aircraft mains and they are marked (in the circuit diagrams) with the reference number corresponding to the unit in the set of which they are included.

B. Electric Boards

The current consumers installed on the aircraft are provided with circuit breakers and manual switch controls. The protection and switching devices are mounted on different electric boards of the left-hand and right-hand consoles in the cockpit and partially on the instrument panel.

Electric Boards of Cockpit Right-Hand Console

Ref. No. in circuit diagram	Name of component installed on electric board	Type	Purpose
1	2	3	4
	Front Electric Board of Right-Hand Console		
603	Circuit breaker	A3P-60	Protection of circuit and feeding of power supply to busbar No.2
10H	Circuit breaker	A3C-5	Protection of circuits and feeding of power supply to relay (ref. No. 20H) and fighter directional system units (KCH)
32H	Circuit breaker	A3C-5	Protection of circuits and feeding of power supply to relays (ref. Nos 40H, 41H, 42H and 43H), to gyro horizon units (AГИ) and to BK-53РШ (ref. No. 12H)
8P	Circuit breaker	A3C-5	Protection of circuits and feeding of power supply to units of radio station РСИУ and relay (ref. No. 9P)
4P	Circuit breaker	A3C-10	Protection of circuits and feeding of power supply to transponder filter (СРО)
5P	Circuit breaker	A3C-15	Protection of circuits and feeding of power supply to automatic radio compass units (АРК)
34P	Circuit breaker	A3C-5	Protection of circuits and feeding of power supply to marker receiver (МРП), relay (ref. No. 33P) and РВ-УШ
1Ш	Circuit breaker	A3C-10	Protection of circuits and feeding of power supply to relays (ref. Nos 27Ш, 30Ш, 29Ш and 9Ж) and holders (ref. Nos 11Ш and 12Ш)
6Ш	Circuit breaker	A3C-20	Protection of circuits and feeding of power supply to special missile heaters
7Ш	Circuit breaker	A3C-10	Protection of circuits and feeding of power supply to relays (ref. Nos 5Ш,

1	2	3	4
			19H, 21H, 22H and 40H), to indicating lamps (ref. Nos 16H, 17H and 38H) and holders (ref. Nos 14H and 12H)
45H	Circuit breaker	ASC-10	Protection of circuits and feeding of power supply to indicating lamps (ref. Nos 42H and 43H) and holders (ref. Nos 14H and 12H)
8AH	Circuit breaker	ASC-5	Protection of circuits and feeding of power supply to relay (ref. No. 21H), filter (ref. No. 4AH) and roll stabilization autopilot units (KAH)
6V	Switch	BT-15K	Feeding of power supply to contactor (ref. No. 24V) for cutting in MI-27T
8V	Switch	BT-15K	Feeding of power supply to actuator MI-100M (ref. No. 18V) of artificial feel spring-loaded mechanism

For the removal of the electric board from the aircraft and for quick disconnection of it from the aircraft mains its wire bundles are provided with connectors Nos 62 and 63.

Rear Electric Board of Right-Hand Console

61B	Circuit breaker	ASP-60	Protection of circuits and feeding of power supply to busbar No.3
18K	Circuit breaker	ASC-5	Protection of circuits and feeding of power supply to 23AMM-250A (ref. No. 11K), and indicating lamp (ref. No. 16K)
33M	Circuit breaker	ASC-5	Protection of circuits and feeding of power supply to hydraulic valve of the main air brakes (ref. No. 32M) and hydraulic valve of central air brake (ref. No. 31M)
34M	Circuit breaker	ASC-5	Protection of circuits and feeding of power supply to hydraulic valve of landing gear (ref. No. 36M) and hydraulic valve of wing flaps (ref. No. 44M)
40M	Circuit breaker	ASC-5	Protection of circuits and feeding of power supply to drag chute release and dropping electropneumatic valves (ref. Nos 27M and 29M)
2C	Circuit breaker	ASC-5	Protection of circuits and feeding of power supply to MMC-2MK (ref. No. 11C), indicating lamps (ref. Nos 12C and 13C), relay (ref. No. 2M), wing navigation lights BANO-45 (ref. Nos 19C and 21C) and navigation lights ANO (ref. No. 20C)

1	2	3	4
35C	Circuit breaker	A3C-5	Protection of circuits and feeding of power supply to sockets (ref. Nos 26C and 36C) and oxygen equipment set heating (KKO) (ref. No. 8T)
41C	Circuit breaker	A3C-10	Protection of circuits and feeding of power supply to relays (ref. Nos 48C and 49C) and landing lights (ref. Nos 43C and 44C)
66C	Circuit breaker	A3C-5	Protection of circuits and feeding of power supply to resistors, rheostats and instrument-lighting lamps
31Д	Circuit breaker	A3C-10	Protection of circuits and feeding of power supply to relays (ref. Nos 47Д and 49Д), hydraulic valve (ref. No. 45Д), electrohydraulic valve (ref. No. 44Д) and units УВД-2М
58Д	Circuit breaker	A3C-10	Protection of circuits and feeding of power supply to drop-tank attachment locks (ref. No. 61Д) and the corresponding indicating lamp (ref. No. 59Д)
1Т	Circuit breaker	A3C-5	Protection of circuits and feeding of power supply to units ТРТВК-45М
1У	Circuit breaker	A3C-5	Protection of circuits and feeding of power supply to control unit of controller АРУ-3В (ref. No. 5У)
2У	Circuit breaker	A3C-5	Protection of circuits and feeding of power supply to control unit of controller АРУ-3В (ref. No. 5У) and controller АРУ-3В (ref. No. 19У)
10У	Circuit breaker	A3C-5	Protection of circuits and feeding of power supply to windings of relay controlling light panel lamps, trimming effect mechanism and speedobarograph
11У	Circuit breaker	A3C-5	Protection of circuits and feeding of power supply to relays (ref. Nos 27C and 16У), valve ТА-184 (ref. No. 17У) and indicating lamps of light panel Т-10У2
22Ш	Circuit breaker	A3C-15	Protection of circuits and feeding of power supply to holders (ref. Nos 11Ш and 12Ш)
37Ш	Circuit breaker	A3C-15	Protection of circuits and feeding of power supply to relay (ref. No. 46Ш), indicating lamps (ref. Nos 16Ш and 17Ш) and holders (ref. Nos 11Ш and 12Ш)
47Ш	Circuit breaker	A3C-10	Protection of circuits and feeding of power supply to indicating lamp (ref. No. 41Ш) and locks (ref. Nos 25Ш and 26Ш) of holders (ref. Nos 11Ш and 12Ш)

1	2	3	4
61P	Circuit breaker	АЗС-10	Protection of circuits and feeding of power supply to radar station and fighter collimating sight units

The electric board is installed on the vertical portion of the right-hand console. For removal of the electric board from the aircraft and for its disconnection from the aircraft mains its wire bundle is provided with connector No. 64.

Horizontal Board of Right-Hand Console

59	Switch	МТ-15К	Connection of generator to aircraft mains
433	Circuit breaker	АЗС-5	Protection of circuits and feeding of power supply to КРА-31М (ref. No. 433), РИ-400Б (ref. No. 443) and СПО-8, Series II (ref. No. 503)
16Д	Switch	МТ-15К	Feeding of power supply to КАФ-13Д, (ref. No. 2Д)
5М	Circuit breaker	АЗС-5	Protection of circuits and feeding of power supply to contactor (ref. No. 6М) to switch on unit 495А2 of 2nd tank group (service)
9М	Circuit breaker	АЗС-5	Protection of circuits and feeding of power supply to contactor (ref. No. 17М) to switch on unit 495А2 of 3rd tank group and to corresponding indicating lamp
14М	Circuit breaker	АЗС-5	Protection of circuits and feeding of power supply to contactor (ref. No. 12М) to switch on unit 495А2 of 1st tank group and to corresponding indicating lamp
1Н	Circuit breaker	АЗС-5	Protection of circuits and feeding of power supply to gyro transmitter (ref. No. 17Н) of fighter directional system (МСН), roll stabilization autopilot (КАП) and radar station Р-1Е
16Н	Circuit breaker	АЗС-5	Protection of circuits and feeding of power supply to inverter ПАГ-1Ф (ref. No. 27Н) and gyro transmitter of gyro horizon (АГД) (ref. Nos 17Н and 34Н)
7Р	Circuit breaker	АЗС-5	Protection of circuits and feeding of power supply to relay (ref. No. 32Р)

The electric board is installed on the horizontal portion of the right-hand console.

To remove the electric board from the aircraft and disconnect it from the aircraft mains, its wire bundles are furnished with connectors Nos 66 and 67.

Electric Boards of Cockpit Left-Hand Console

Ref. No. in circuit diagram	Description of component installed on electric board	Type	Purpose
1	2	3	4
		Electric Board I	
2T	Switch	ПЗШН-20	Switching of cockpit heating
18T	Rheostat	РТ-10	Pressurized helmet heating control
21T	Push-button	5К	Switching of fast heating of pressurised helmet
16С	Switch	ПЗШН-20	Light intensity control switch of navigation lights
57С	Lamp	СМ-37	Illumination
		Electric Board II	
46М	Switch	ПКТ-15К	Seat position control
39П	Resistor	СПО-0.5--33 kilohms	Audio signal volume control
57С	Lamp	СМ-37	Illumination
		Electric Board III	
18А	Circuit breaker	АЗС-10	Protection of in-flight engine restarting circuit
19А	Circuit breaker	АЗС-15	Protection of engine augmented rating circuit
17А	Circuit breaker	АЗС-25	Protection of engine starting circuit
20М	Circuit breaker	АЗС-10	Protection of L.G. wheel automatic brake release circuit
29С	Circuit breaker	АЗС-5	Protection of fire fighting equipment circuit
57С	Lamp	СМ-37	Illumination
		Electric Board IV	
14А	Switch	2ПТ-15К	Switching off engine cranking
15А	Push-button	5К	Starting of engine
57С	Lamp	СМ-37	Illumination

To provide removal of the electric board from the aircraft and its disconnection from the aircraft mains its wire bundle is furnished with connector No. 45.

To provide removal of the electric board from the aircraft and its disconnection from the aircraft mains the wire bundle of the electric board is furnished with connector No. 44.

To provide removal of the electric board from the aircraft and its disconnection from the aircraft mains,the wire bundle of the electric board is furnished with connector No. 41.

1	2	3	4
		Electric Board V	
83Д	Switch	ВГ-15К	Cone control
84Д	Switch	ППНГ-15К	Anti-surge shutters control
85Д	Switch	ВГ-15К	Switching of automatic or manual cone control
57С	Lamp	СМ-37	Illumination

4. PROTECTION OF ELECTRIC CIRCUIT

The following types of circuit breakers and safety fuses are used on the aircraft as protective elements of the electric circuits:

(a) circuit breakers - types АЗС and АЗР;

(b) safety fuses - types МП and СП.

The circuit breakers and safety fuses are placed in the circuits depending on the circuit current intensity and are marked in accordance with their rated values. For example: АЗС-5, АЗР-60, СП-5, МП-75, etc.

5. SWITCHING EQUIPMENT

A. Types of Switching Equipment

The switching equipment installed on the aircraft includes:

(a) relays, types ТКЕ21ПДТ, ТКЕ22ПДТ, ТКЕ52ПДТ, ТКЕ52ПДТ, ТКЕ56ПДТ, ТКЕ24ПДТУ and ТКЕ26ПДТУ;

(b) limit switches, types ВК2-140Р, ВК2-200Р and А-802-ВК2-141;

(c) microswitches, types А303, А701 and А703;

(d) switches, types ПК-4, 2ППГ-15К, ППГ-15К, ППНГ-15К, ППГ-15К, ПЗПН-20, ВТ3602014 and ВТ30602020;

(e) switches, types ВГ-15К and 2ППГ-15К;

(f) contactors, types КМ-50Д, КМ-100Д, КМ-400Д, КП-500Д, КП-400Д, ТКЕ-12ПДТ, ТКЕ-501ДТ and ТКД-511ДТ;

(g) push-buttons, types 5К, 204К, 205К and 512.

The switching equipment is mainly arranged in relay and contactor boxes as well as on the electric boards. The arrangement of boxes and electric boards is illustrated in Fig. 6.

B. Relay and Contactor Boxes

A relay box consists of a base and a cover. The base houses different switching and protective equipment. The wires are made out and brought out of the box either as a wire bundle furnished with a connector or directly through the connector attached to the base wall.

The box base or cover has a marking near the place where a protective or switching device is installed which indicates the reference number of the device in the circuit diagram and its purpose.

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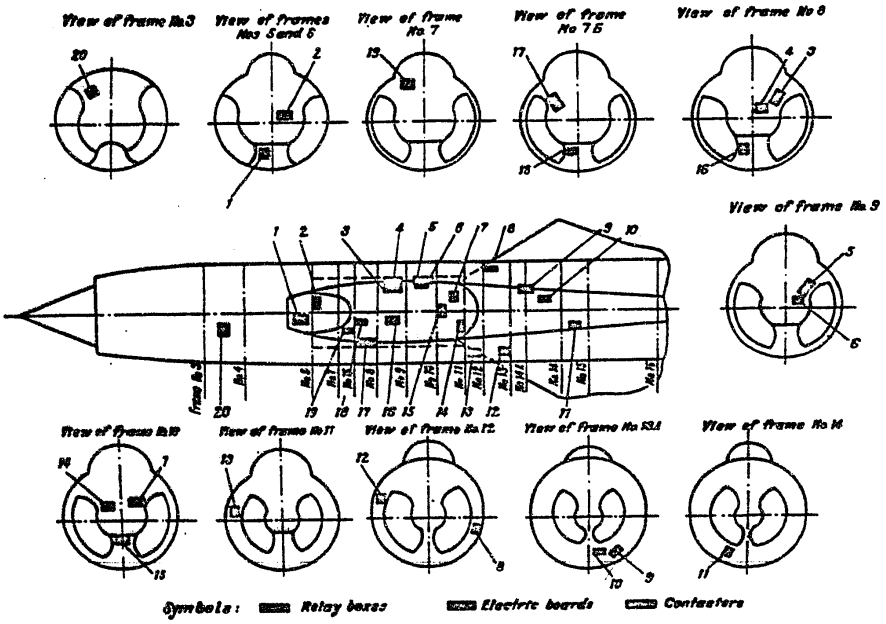

Note: All frames are shown as viewed forward

FIG.6. ARRANGEMENT DIAGRAM OF RELAY, CONTACTOR AND FUSE BOXES AND ELECTRIC BOARDS

1 – radio equipment fuse and relay box; 2 – signalling and lamp testing relay box; 3 – fuse electric board of right-hand console; 4 – horizontal electric board of right-hand console; 5 – rear electric board of right-hand console. 6 – fuse box on right-hand console; 7 – fuse and resistor box for navigation light and inspection lighting circuits; 8 – starboard relay box; 9 – starting contactor and resistor box; 10 – engine testing control relay box; 11 – processing box; 12 – contactor unit; 13 – contactor unit; 14 – automatic switching relay box for launching special missiles; 15 – current battery cut-in and change-over contactor box; 16 – control and ignition circuit protection box; 17 – electric boards of left-hand console; 18 – fuse and anti-surge observer control box; 19 – switching box of armament power supply circuits; 20 – box to start inverter PT-1000 and supply AP.3-1, KAP.2 and KCH.

Box to Start Inverter PT-500Sh and Supply Gyro Horizon (AGA-1), Roll Stabilization Autopilot (KAP-2) and Fighter Directional System (KSN)

Nos	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	Relay	TKE21PDT	19N	Switching of starting circuits of inverter PT-500Sh to feed gyro horizon (AGA)
2	Relay	TKE52PDT	20N	Switching of starting circuits of inverter PT-500Sh and 36 V A.C. supply circuits of fighter directional system units (KSN)
3	Relay	TKE52PDT	21N	Switching of starting circuits of inverter PT-500Sh and 36 V A.C. supply circuits of roll stabilization autopilot units (KAP)
4	Fuse	SP-5	22N	Protection of supply circuit of fighter directional system units (KSN)
5	Fuse	SP-5	23N	Protection of power supply circuit of fighter directional system units (KSN)
6	Fuse	SP-1	24N	Protection of power supply circuits of roll stabilization autopilot units (KAP)
7	Fuse	SP-1	25N	Protection of power supply circuits of roll stabilization autopilot units (KAP)
8	Relay	TKE26PDAIV	40N	Switching of circuits to change over gyro horizon indicator (AGA) to gyro transmitter of fighter directional system (KSN) and roll stabilization autopilot (KAP)
9	Relay	TKE26PDAIV	41N	
10	Relay	TKE24PDAIV	42N	
11	Relay	TKA12PDAIV	43N	Switching of starting circuits of inverter PT-125Sh (ref. No. 33N)

The box is installed in a hatch between frames Nos 3 and 4, port side.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, the box is furnished with connectors Nos 79 and 80.

Cone and Anti-Surge Shutters Control Box

Nos	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	Relay	ТКЕ21ПДТ	36Д	Switching of supply circuits of hydroelectric valve ГА-184 to open anti-surge shutters during augmented rating
2	Relay	ТКЕ52ПДТ	47Д	Interlocking at Mach = 1.35

The box is installed between frames Nos 7 and 8 in the lower portion of port side.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, the box is furnished with connector No. 89.

Storage Battery Cut-In and Change-Over Contactor Box

Nos	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	Contactor	КМ-400Д	193	Switching of 1st storage battery
2	Contactor	КМ-400Д	263	Switching of 2nd storage battery
3	Contactor	КП-400Д	273	Switching of storage batteries to 48 V while starting the engine
4	Contactor	КП-400Д	283	Switching of storage batteries to 48 V while starting the engine

The box is installed between frames Nos 10 and 11 along the axis of symmetry in the lower front accessories compartment.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, its wire bundles are furnished with two connectors Nos 86 and 88.

Control and Ignition Circuit Protection Box

Nos.	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	Contactor	КП-50Д	27Д	Connection of series resistor to ignition circuit while starting the engine
2	Resistor	СП-0.3 ohm	28Д	Regulation of voltage in ignition circuit while starting the engine
3	Fuse	МП-20	29Д	Protection of ignition circuit
4	Fuse	МП-20	30Д	Protection of ignition circuit

The box is installed between frames Nos 8 and 9 in the front lower accessories compartment, port side.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, its wire bundles are furnished with two connectors Nos 92 and 93.

Starting Contactor and Resistor Box

Nos	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	Resistor	СЦ-0.05 ±10%	53	Reduction of generator voltage while generator starting
2	Contactor	КМ-400А	373	Shunting of starting resistor
3	Contactor	КМ-400А	383	Connection of starting resistor to generator starting circuit in starting mode

The box is installed between frames Nos 13А and 14 in the lower portion of starboard side.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, the box wire bundle is furnished with connector No. 115.

Fuse and Resistor Box for Navigation Light and Instrument Lighting Circuits

Nos	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	Resistor	ПЭВР-25-15	17С	Navigation light control
2	Fuse	СЦ-2	23С	Protection of navigation light supply circuits
3	Fuse	СЦ-2	53С	Protection of instrument lighting supply circuits
4	Fuse	СЦ-2	54С	Protection of console lighting supply circuits
5	Resistor	ПЭВР-30-27	60С	Reduction of voltage in supply circuits of emergency group instrument lighting
6	Resistor	ПЭВР-25-11	61С	Reduction of voltage in instrument lighting supply circuits
7	Resistor	ПЭВР-25-11	62С	Reduction of voltage in console lighting supply circuits

The box is installed in the cockpit near frame No. 11 to the right of the seat.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, the box is furnished with connector No. 56.

Signalling and Lamp Testing Relay Box

Nos	Name of component included in box	Type	Ref. number in circuit diagrum	Purpose
1	Relay	TKE56ПДТ	24C	Switching of lamp testing circuits of light panel T-10Y2
2	Relay	TKE56ПДТ	25C	Switching of lamp testing circuits of light panel T-10Y2
3	Relay	TKE56ПДТ	26C	Switching of lamp testing circuits of light panels T-10Y2 and T-4Y2
4	Relay	TKE21ПДТ	9K	Feeding of power supply to camera attachment when firing button is depressed
5	Relay	TKE22ПДТ	2M	Switching of L.G. extension position indicating circuits
6	Relay	TKE21ПДТ	40П	Switching of overload signalling circuits while launching special missiles
7	Relay	TKE53ПДТ	46П	Switching of external loads signalling circuits and disconnection of bomb position signalling circuits
8	Relay	TKE53ПДТ	49П	Switching of ROCKET MISSILE ZERO POSITION and TACTICAL DROP lamps testing circuits
9	Relay	TKE52ПДТ	59П	Connection of bomb release circuits

The box is installed in the cockpit between frames Nos 6 and 7, starboard.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, the box is furnished with connectors Nos 26, 27 and 28.

Engine Mode Control Relay Box

Nos	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	2	3	4	5
1	Relay	TKE53ПДТ	65Д	Switching of delay circuits, cutting off afterburner fuel when afterburner is off
2	Relay	TKE22ПДТ	66Д	Switching of circuits, setting jet nozzle flaps in maximum position after starting the engine
3	Relay	TKE22ПДТ	67Д	Switching of circuits, setting jet nozzle flaps in augmented position while starting the engine

1	2	3	4	5
4	Contactor	ТКК12ПАТ	70Ж	Switching of processing box control circuits
5	Relay	ТКЕ52ПАТ	71Ж	Switching of afterburner fuel control circuits

The box is installed between frames Nos 13А and 14 in the starboard lower portion.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, the box is furnished with connector No. 113.

Starboard Relay Box

Nos	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	Relay	ТКЕ53ПАТ	11З	Interlocking of starting circuit of starter-generator ГСР-СТ-12000БТ when ground supply is connected
2	Relay	ТКЕ53ПАТ	10З	Connection of supply circuits of major power consumers when powerful source is on
3	Relay	ТКЕ53ПАТ	51З	Protection of relay ЭМР-400Т and voltage regulator РУТ-82, when applied voltage is 48 V, i.e. when storage batteries are connected in series
4	Relay	ТКЕ21ПАТ	26Ж	Interlocking of ground supply source during starting
5	Relay	ТКЕ52ПАТ	1М	Switching of electropneumatic valve designed for releasing nose wheel when main right wheel is released
6	Relay	ТКЕ52ПАТ	3М	Engagement of electropneumatic valve designed for releasing nose wheel when main left wheel is released
7	Relay	ТКЕ53ПАТ	15С	Switching of L.G. position external indicating lights
8	Relay	ТКЕ21ПАТ	46С	Connection of major power consumers when generator is on or when ground supply source is connected
9	Relay	ТКЕ12ПАТ	48С	Switching of landing light control circuits
10	Relay	ТКЕ56ПАТ	49С	
11	Relay	ТКЕ52ПАТ	12Т	Connection of storage battery heating circuit
12	Relay	ТКЕ21ПАТ	85П	Switching of supply circuits of OVERLOAD ON relay winding

The box is installed between frames Nos 12 and 13, starboard side.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, its wire bundles are furnished with three connectors Nos 111, 112 and 108.

Radio Equipment Fuse and Relay Box

Nos	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	2	3	4	5
1	Resistor	ВС-30Б	463	Voltage control of generator СГО-8, Series II
2	Switch	ПЭПН-20	473	Switching of circuits for measuring voltage in generator СГО-8, Series II and inverters ПО-750А and ПО-1500ВТ-3И
3	Resistor	РС-4	583	Voltage control of inverter ПО-1500ВТ-3И
4	Fuse	СП-2	21А	Protection of transformer supply circuit, 115/36 V
5	Relay	ТКЕ52ПДТ	49А	Starting of inverter ПО-750А from cone and connection of A.C. supply circuits of controllable cone system
6	Fuse	СП-5	50А	Protection of supply circuits of controllable cone system
7	Fuse	СП-2	6К	Protection of supply circuit of thyratron breaker ПТ-56И
8	Fuse	СП-2	33С	Protection of supply circuit of electronic amplifier НС-2МС
9	Relay	ТКЕ52ПДТ	9Р	Starting of inverter ПО-750А from radio station РСИУ-5 and switching of supply circuits of radio station РСИУ-5
10	Fuse	СП-5	12Р	Protection of supply circuits of radio station РСИУ-5
11	Relay	ТКД103ДТ	14Р	Switching of supply circuits of radar station
12	Relay	ТКЕ21ПДТ	17Р	Starting of inverter ПО-750А from automatic radio compass (АРК-10)
13	Fuse	СП-2	19Р	Protection of supply circuit of automatic radio compass (АРК-10)
14	Fuse	СП-5	23Р	Protection of supply circuit of socket КЗА
15	Relay	ТКЕ21ПДТ	27Р	Starting of inverter ПО-750А while switching on electronic amplifier НС-2МС

1	2	3	4	5
16	Relay	ТКЕ56ПДТ	32Р	Emergency starting of inverter ПО-1500ВТ-3П and switching of radar station emergency cut-off circuits
17	Fuse	СП-2	37Р	Protection of supply circuit of marker receiver (МРП) and radio altimeter (РВУ)
18	Relay	ТКЕ52ПДТ	59Р	Starting of inverter ПО-750А from marker receiver (МРП) and radio altimeter (РВУ)
19	Relay	ТКЕ52ПДТ	72Р	Starting of inverter ПО-1500ВТ-3П from radar station
20	Socket	МР20П2НГ6	73Р	Check of voltage in inverters ПО-750А and ПО-1500ВТ-3П and generator СГО-8, Series II
21	Fuse	СП-15	74Р	Protection of radar station supply circuits
22	Relay	ТКЕ21ПДТ	76Р	Switching over of radar station supply circuits in emergency mode
23	Fuse	СП-15	77Р	Protection of radar station supply circuits
24	Relay	ТКЕ21ПДТ	4П	Switching of supply circuits of launcher (АПУ)
25	Fuse	СП-5	5П	Protection of supply circuits of launcher (АПУ)
26	Relay	ТКЕ21ПДТ	15П	Switching of A.C., 115 V supply circuit to port side special missile while starboard one departs

The box is installed between frames Nos 5 and 6 near the axis of symmetry, port side, lower portion.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, its wire bundle is furnished with connector No. 76.

Processing Box

Nos	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	2	3	4	5
1	Switch	ВГ-15К	12А	Switching of ground check circuit of oxygen supply
2	Switch	ВГ-15К	20А	Switching of supply circuit of electromagnetic dump valve
3	Switch	ЗПНН-45	22А	Switching of engine processing circuit

1	2	3	4	5
4	Fuse	НП-5	23Ж	Protection of ignition indicating circuit and electromagnet supply circuit of carburettor valve II
5	Fuse	НП-10	24Ж	Protection of ignition coil supply circuit of main combustion chamber
6	Fuse	НП-10	25Ж	Protection of ignition coil supply circuit of main combustion chamber
7	Relay	ТКЕ52ПДТ	16У	Disconnection of aileron booster from booster hydraulic system
8	Switch	ВГ-15К	72Ж	Disconnection of starting fuel supply valve while processing the engine
9	Relay T_5	ТКЕ21ПДТ	82Ж	Power supply to altitude correction valve (ref. No. 85Ж)
10	Switch	ВГ-15К	83Ж	Power supply to altitude correction valve (ref. No. 85Ж) on the ground

The box is installed between frames Nos 14 and 15, port side, lower portion.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, its wire bundles are furnished with two connectors Nos 101 and 103.

Contactor Unit

Nos	Name of component included in box	Type	Ref. number in oil it diagram	Purpose
1	Contactor	КМ-50Ж	6И	Switching of pump of 2nd group of tanks
2	Contactor	КМ-50Ж	12И	Switching of pump of 1st group of tanks
3	Contactor	КМ-50Ж	17И	Switching of pump of 3rd group of tanks
4	Contactor	КМ-100Ж	24У	Connection of supply circuits of pumping unit ЭН-27Т

The contactor unit is installed in the power distribution unit between frames Nos 11 and 12, port side.

Relay Box of Armament Switching Circuits

Nos	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	Relay	ТКЦ12ПД5Т	17Э	Switching of supply circuits of major power consumers when powerful supply source is connected
2	Relay	ТКЦ12ПД5Т	33Э	Switching of supply circuits of major power consumers when powerful supply source is connected
3	Relay	ТКЕ52ПД5Т	2П	Switching of rocket missile launching circuits
4	Relay	ТКЕ52ПД5Т	3П	Interlocking of special missile and rocket missile launching circuits with respect to nose L.G.
5	Relay	ТКЕ21ПД5Т	9П	Interlocking of external loads launching circuits with respect to main L.G. when major power consumers are connected
6	Relay	ТКЕ52ПД5Т	30П	Switching of external loads launching circuits
7	Relay	ТКЕ21ПД5Т	27С	Disconnection of no-pressure-in-booster-hydraulic-system indicating circuit

The box is installed on the left-hand upper electric board of the instrument.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, its wire bundles are furnished with three plug connectors Nos 29, 30 and 32.

Contactor Unit

Nos	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	Contactor	ТКЦ50ПД5Т	483	Switching of A.C. consumers from generator СТО-8, Series II to ground power source
2	Contactor	ТКЦ51ПД5Т	493	Switching of A.C. ground power supply

The contactor unit is installed in the power distribution unit between frames Nos 12 and 13, port side.

Fuse Box on Right-Hand Console

Box	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	Push-button	204K	12Y	Feeding of power supply to relay (ref. No. 16Y) and to valve TA-184 (ref. No. 17Y)
2	Fuse	CII-1	55C	Protection of supply circuit of left-hand console instrument lighting
3	Fuse	CII-1	67C	Protection of supply circuit of right-hand console instrument lighting
4	Fuse	CII-1	68C	Protection of supply circuit of instrument panel lighting
5	Fuse	CII-1	69C	Protection of circuit feeding instrument panel lighting
6	Switch	BT-15K	20T	Feeding of power supply to relay (ref. No. 12T) and to heating of cover of storage battery (ref. No. 13T)
7	Fuse	CII-10	6P	Protection of supply circuit of radar station units (P-IX)
8	Fuse	CII-10	8P	Protection of supply circuit of radar station units (P-IX)
9	Push-button	204K	69P	Simulation of MP-1.35

The box is installed on the vertical portion of the right-hand console.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, its wire bundle is furnished with connector No. 65.

Automatic Switching Relay Box for Launching Special Missiles

Box	Name of component included in box	Type	Ref. number in circuit diagram	Purpose
1	Relay	[illegible]	19C	Output of departure signal from port or starboard side special missile launcher during automatic control
2	Relay	[illegible]	20C	Interlocking of departure signal from starboard side special missile launcher
3	Relay	[illegible]	21C	Interlocking of departure signal from port side special missile launcher
4	Relay	[illegible]	22C	Switching of audio signal from special missile launcher during automatic control

The box is installed in the cockpit behind the rear frame No. 11, port side.

To provide removal of the box from the aircraft and its disconnection from the aircraft mains, its wire bundle is furnished with connector No. 52.

6. NEGATIVE LINE CONNECTING

The negative wires are connected to the aircraft metal structure by means of cable shoes which are secured to anchor nuts with bolts.

To protect the metal parts from corrosion and to mark the places where the negative wires are to be attached to the aircraft structure, the places are painted with nitroenamel NKB-7157 of red colour.

Chapter III

ELECTRICAL SYSTEMS

1. POWER SUPPLY SYSTEM

General

The power supply system is designed to feed direct and alternating current to the consumers installed in the aircraft. The operation of aircraft power system is performed by the electric devices listed in the Table below.

Nos	Ref. number in circuit diagram	Description	Type	Qnty	Installation place
1	2	3	4	5	6
1	13	Starter-generator	TCP-CT-12000BT	1	Engine, frames Nos 26 to 28
2	20	Differential reverse-current relay	ДМР-400Т	1	Power distribution unit, frames Nos 11 and 12, port side
3	33	Voltage regulator	РУТ-82	1	Fuselage, frames Nos 12 and 13, starboard side
4	43	Ammeter shunt	Ш-2	1	Power distribution unit, frames Nos 12 and 13, port side
5	63	Capacitor	МБГТ-160-4	2	Power distribution unit, frames Nos 12 and 13, port side and frames Nos 12 and 13, starboard side, upper portion
6	73	Transformer	ТС-9Н	1	Power distribution unit, frames Nos 12 and 13, port side
7	83	Fuse	СК-5	1	Power distribution unit, frames Nos 11 and 12, port side

1	2	3	4	5	6
8	93	GENERATOR switch	ВГ-15К	1	Horizontal electric board of cockpit right-hand console
9	103	Storage battery	15СНС-45	2	Frames Nos 7Б to 10, lower accessories compartment
10	113	Relay	ТКЕ53НАТ	1	Relay box, frames Nos 12 and 13, starboard side
11	123	Plug of A.C. ground supply wire bundle connector	НРА-200НК	1	Lower accessories compartment, frames Nos 10 and 11, along the axis of symmetry
12	133	Plug of D.C. ground supply wire bundle connector	НРА-250НПК	1	Frames Nos 12 and 13, fuselage, port side
13	143	BATTERY: AIRCRAFT - GROUND switch	2ВГ-15К	1	Horizontal portion of cockpit right-hand console
14	153	Socket	48К	1	Power distribution unit, frames Nos 12 and 13, port side
15	163	Voltmeter	В-1	1	Right-hand portion of instrument panel
16	173	Relay	ТКЕ-12НАТ	1	Relay box, left-hand upper electric board of instrument panel
17	183	Relay	ТКЕ-53НАТ	1	Relay box, frames Nos 12 and 13, starboard side
18	193	Contactor	КМ-400А	1	Contactor box, frames Nos 10 and 11, lower accessories compartment
19	253	Extension resistor	ВС-20	1	Horizontal electric board of right-hand console
20	263	Contactor	КМ-400А	1	Contactor box, frames Nos 10 and 11, lower accessories compartment
21	273	Contactor	КП-400А	1	Contactor box, frames Nos 10 and 11, lower accessories compartment
22	283	Contactor	КП-400А	1	Contactor box, frames Nos 10 and 11, lower accessories compartment
23	803	Switch box of ground power supply sources	КПА-6	1	Ground equipment
24	813	Overload circuit breaker	АЗП-1МА, Series III	1	Frames Nos 13 and 13А, lower portion, along the axis of symmetry

1	2	3	4	5	6
25	823	Fuse	НП-15	1	Power distribution unit, port side, frames Nos 12 and 13
26	833	Relay	ТКИ-12ПАТ	1	Relay box, left-hand upper electric board of instrument panel
27	843	Fuse	НП-5	1	Fuselage, port side, frames Nos 11 and 12, lower portion
28	853	Fuse	НП-5	1	Power distribution unit, frames Nos 11 and 12, port side
29	873	Contactor	КМ-400Д	1	Starting contactor and resistor box, frames Nos 13А and 14, starboard side, lower portion
30	883	Contactor	КМ-400Д	1	Starting contactor and resistor box, frames Nos 13А and 14, starboard side, lower portion
31	893	Fuse	СП-5	1	Power distribution unit, frames Nos 11 and 12, port side
32	903	Indicator	МСА-К	1	Middle board of instrument panel
33	913	Shunt (ВНС)	МСА-К	1	Lower accessories compartment, frames Nos 8 and 9, along the axis of symmetry
34	923	Fuse	НП-30	1	Power distribution unit, frames Nos 12 and 13, port side
35	933	Control box	КРА-31М	1	Accessories compartment, frames Nos 14 to 16, starboard side, upper portion
36	943	Voltage regulator	РН-400Б	1	Accessories compartment, frames Nos 14 to 16, starboard side, upper portion
37	953	Circuit breaker	АЗС-5	1	Horizontal electric board of right-hand console
38	963	Extension resistor	ВС-90Б	1	Relay box, frames Nos 5 and 6, port side, lower portion
39	973	Switch	ПЗПН-20	1	Relay box, frames Nos 5 and 6, port side, lower portion
40	983	Contactor	ТКИ-501ЛТ	1	Power distribution unit, frames Nos 12 and 13, port side

1	2	3	4	5	6
41	498	Contactor	ТКБ-511БТ	1	Power distribution unit, frames Nos 12 and 13, port side
42	508	Generator	СГО-8, Series 31	1	Engine, frames Nos 26 to 28, starboard side, lower portion
43	518	Relay	ТКБ-530Д	1	Relay box, frames Nos 12 and 13, starboard side
44	528	Inverter	ПО-750А	1	Lower accessories compartment, frames Nos 8 to 10
45	488	Inverter	ПО-1500БТ-8Н	1	Accessories compartment, frames Nos 5 and 6, starboard side
46	548	Control box	КУ-1500	1	Accessories compartment, frames Nos 5 and 6, port side
47	558	Fuse	ПП-5	1	Accessories compartment, frames Nos 5 and 6, port side
48	568	Fuse	ПП-100	1	Power distribution unit, frames Nos 12 and 13, port side
49	578	Fuse	ПП-75	1	Power distribution unit, frames Nos 12 and 13, port side
50	588	Extension resistor	РС-4	1	Relay and fuse box, upper accessories compartment, frames Nos 5 and 6, port side
51	5Н	Inverter	ПТ-500Ц	1	Upper accessories compartment, frames Nos 3 and 4, starboard side
52	27Н	Inverter	НАГ-1Ф	1	Cockpit, frames Nos 10 and 11, starboard side

The main components of the power supply and distribution system are arranged as shown in Fig. 7.

Functioning of Circuit Connecting D.C. Power Supply Sources to Aircraft Mains

In all cases when the power is not fed from starter-generator ПСР-СТ-12000БТ the aircraft mains may be supplied either from the ground source or from the airborne storage batteries.

After the engine is started and the starter-generator starts to operate in the generating mode the aircraft mains is fed from the main power supply source - starter-generator ПСР-СТ-12000БТ.

The ground supply source is connected to the aircraft mains by means of the plug and socket of connector ИРА-250МПК (ref. No. 133) through box КПА-6 (ref. No. 803) included into the set of ground supply sources; the box contains

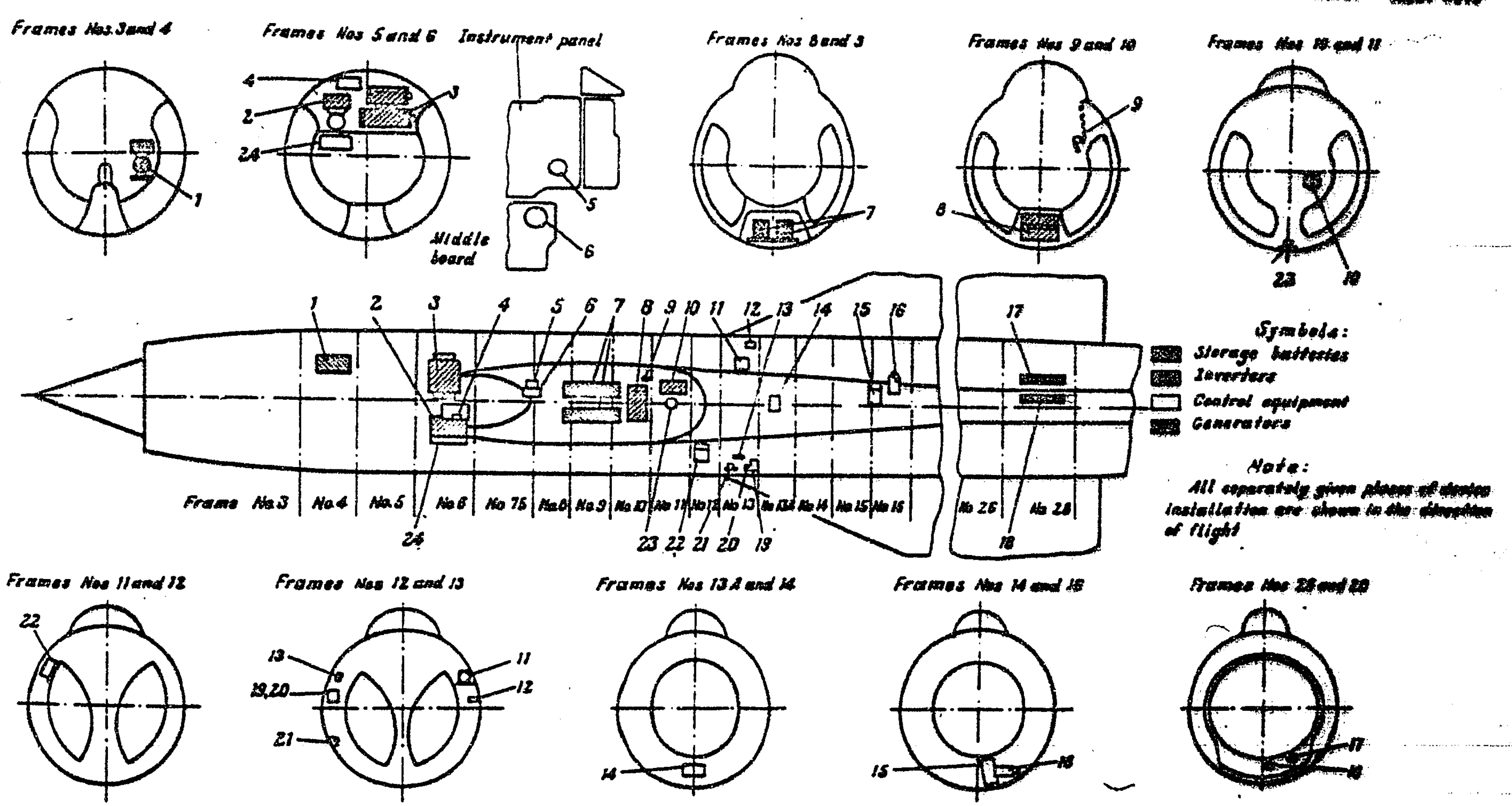

FIG.7. ARRANGEMENT DIAGRAM OF MAIN ELECTRICAL DEVICES AND INVERTERS IN POWER SUPPLY AND DISTRIBUTION SYSTEM

1 – inverter ПТ-200Ц; 2 – inverter ПТ-125Ц; 3 – inverter ПО-1500ВТ-2Ш; 4 – resistors [illegible] and [illegible]; 5 – voltmeter В-1; 6 – integrating ampere-hour meter ИСА; 7 – storage batteries 15СЦС-45; 8 – inverter ПО-750А; 9 – resistor ВС-20; 10 – inverter ПАГ-1Ф; 11 – voltage regulator РУГ-82; 12 – capacitor [illegible]; 13 – ammeter receptacle; 14 – overvoltage circuit breaker АЗП-1МА; 15 – box КРА-[illegible]; 16 – voltage regulator [illegible]; 17 – generator СГ-8-8, Series II; 18 – generator [illegible]; 19 – stabilizing transformer ТС-[illegible]; 20 – capacitor [illegible]; 21 – plug ШРА-[illegible] for connecting D.C. power supply; 22 – differential reverse-current relay [illegible]; 23 – plug [illegible] for connecting A.C. power supply; 24 – control box [illegible].

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wrong polarity.

The ground sources are connected as follows. The contacts of the ground power sources are connected to power contacts "+1", "-1" and "+2", "-2". From terminal 5 of the connector (ref. No. 188) the positive voltage is applied to the windings of the relays (ref. Nos 113, 26A, 46C) designed for interlocking the ground power source.

The relay (ref. No. 113) operates and its contacts 1-2 break the circuit connecting the generator with the differential reverse-current relay (ref. No. 22) through the switch (ref. No. 93) thus disconnecting the generator from the aircraft mains.

Contacts 5-4 and 8-7 of the relay (ref. No. 113) open the supply circuits of the contactor windings (ref. Nos 263 and 193). The contactors (ref. Nos 263 and 193) release their contacts and disconnect the storage batteries (ref. No. 103) from the mains power distribution unit busbar. At the same time contacts 8-9 of the relay (ref. No. 113) close the negative circuit of contactors K_5 and K_6 of the box (ref. No. 303). Contactors K_5 and K_6 operate, close their contacts and connect the ground power sources (in parallel) to the mains distribution unit busbar (one source directly to the busbar and the other one, through contacts 2-1 of the contactor (ref. No. 273).

The relay (ref. No. 26A) operates and its contacts 1-2 deenergize the winding of the relay (ref. No. 27A) which is designed for switching over the supply circuit of the ignition units while starting the engine (the ignition coils and electromagnetic valves of the engine) from one storage battery No.1 to two series-connected batteries No. 1 and No. 2 (ref. No. 103). This is how the ignition units are fed when the engine is started only from one storage battery No. 1.

The relay (ref. No. 46C) operates and its contacts 3-2 connect the relays (ref. Nos 173, 183, 333) engaging the major power consumers.

Note: The major power consumers on the aircraft are as follows: the radar station, pump of 1st group of tanks (unit 495A2), generator CPO-8, Series II, heating and filament circuits of rocket missiles P-3C and launching circuits. Thus, when the ground supply is employed, box KUA-6 (ref. No. 303) and the interlocking relays of the ground power source (ref. Nos 113, 26A and 46C) ensure:

(a) connection of the ground power source to the aircraft mains;

(b) simultaneous disconnection of the airborne storage batteries and generator from the aircraft mains;

(c) connection of the major power consumers;

(d) application of power supply to the engine ignition system when the engine is started from one storage battery;

(e) impossibility of connection of the ground power supply sources of wrong polarity.

While starting the engine for 4.1 sec. the positive voltage is fed to the winding of the relay (ref. No. 513) and to the winding of the contactor (ref. No. 373). The relay (ref. No. 513) operates and its contacts 3-2 prepare the circuit switching-over of the ground power sources from 24 to 48 V.

The contactor (ref. No. 273) operates 7.1 sec. later and feeds the voltage drained by the aircraft mains from the ground power source (contactor K_5 in box KUA-6 is on) to the winding of contactors KM_3 and KM_5 in box KUA-6 through contacts 1-3 of the contactor (ref. No. 273) and through contacts 3-2 of the relay (ref. No. 513). Contactors KM_3 and KM_5 operate and close their contacts 1-2.

The ground power sources are connected in series to the aircraft mains (48 V).

Airborne storage batteries 15СНС-45 (ref. No. 103) are connected to and disconnected from the aircraft mains by means of the BATTERY: AIRCRAFT - GROUND switch (ref. No. 143) and the contactors (ref. Nos 193 and 263).

When the BATTERY: AIRCRAFT - GROUND switch (ref. No. 143) is turned on, the negative voltage is fed from storage battery No. 2 (ref. No. 103) to the winding of the contactor (ref. No. 263) through contacts 5-4 of the relay (ref. No. 113). The contactor (ref. No. 263) operates, closes its contacts and feeds the positive voltage from storage battery No. 2 to the power distribution unit busbar through contacts 2-1 of the contactor (ref. No. 273).

At the same time the negative voltage is also fed to the winding of the contactor (ref. No. 193) through contacts 8-7 of the relay (ref. No. 113). The contactor (ref. No. 193) operates, closes its contacts and feeds the positive voltage from storage battery No. 1 to the busbar of the power distribution unit.

Airborne storage batteries No. 1 and No. 2 are connected in parallel with the aircraft mains (24 V).

When the engine is started autonomously (from the airborne storage batteries) the batteries are switched over from the parallel to series connection by means of contactors КП-400Д (ref. Nos 273 and 283) to obtain the voltage of 48 V.

This voltage is applied only to the starter-generator while the aircraft mains is fed only from one storage battery No. 1 (ref. No. 103).

Starter-generator ГСР-СТ-12000ВТ (ref. No. 13) is connected to the aircraft mains through differential reverse-current relay РМР-400Т (ref. No. 23) after the engine is started.

When the generator (ref. No. 13) starts to operate the positive voltage is fed from the generator to the differential reverse-current relay through the wires passed through the hole in the stabilizing transformer.

As soon as generator switch 87К (ref. No. 93) is closed, relay ТКЕ-1Р2АТ in the differential reverse-current relay operates and its contacts feed the voltage to the winding and the contacts of relay ТКЕ-210АТ, as well as to the winding and the contacts of the differential control relay.

When the generator voltage exceeds the voltage in the mains by 0.3-0.7 V, the current in the shunt winding of the differential relay establishes a magnetic flux in the gap directed in accordance with the flux of the permanent magnets.

The relay contacts become closed and the positive voltage is applied to the winding of the differential reverse-current relay contactor. The contactor contacts become closed and the generator is connected to the aircraft mains.

At the moment the contactor contacts become closed, intermediate signalling relay ТКЕ-22ПАТ and additional voltage relay ТКЕ-210АТ operate. Contacts 1-2 of relay ТКЕ-22ПАТ disconnect the shunt winding of the differential control relay from the BATTERY terminal and its contacts 2-3 connect the winding to the positive terminal of starter-generator ГСР-СТ-12000ВТ; contacts 4-5 disconnect the GENERATOR OFF red pilot lamp and contacts 5-6 connect through fuse СП-5 the relay engaging major power consumers in generating mode (ref. Nos 173, 183, 333 and relays in box КРЗ-31М, ref. No. 489).

Voltage relay ТКЕ-210АТ operates and connects the winding of the power contactor after its operation through holding resistor R (ПЭВ-7-39-1).

The contactor connects the generator to the aircraft mains through the shunt of ammeter М-2.

If the power cables running from the generator to the differential reverse-current relay become open, the current will flow through the winding of the differential control relay and establish a magnetic flux in the opposite direction to the flux of the permanent magnets.

The contacts of the differential relay become open and deenergize the contactor winding. In this case the winding of relay ТКБ-22ПДТ in the differential reverse-current relay will become also deenergized and the relay cuts out the major power consumers (cuts out the relays ref. Nos 173, 183, 333 and the relay in the box ref. No. 433) and cuts in the GENERATOR OFF pilot lamp on the light panel.

If the voltage in the generator becomes less than that of the aircraft mains, a reverse current is induced in the series winding of the polarized relay under the action of which the polarized relay operates and deenergizes the winding of the power contactor and then relay ТКБ-22ПДТ in the differential reverse-current relay (ref. No. 23). The contactor contacts return to the initial position (become open) and disconnect the generator from the aircraft mains.

Contacts 4-5 of relay ТКБ-22ПДТ cut in the GENERATOR OFF red pilot lamp on the light panel (ref. No. 10C) and take the power supply from the windings of the relays (ref. Nos 173, 183 and 333) and relay $Б_7$ (in the box ref. No. 433) connecting the major power consumers.

The reverse current that disconnects the generator is equal to 15 - 35 A and the generator voltage at this moment should be not in excess of 8 V.

To keep the generator voltage at the constant level and to damp the oscillations when the load or motor speed is changed, provision is made for voltage regulator РУТ-82 (ref. No. 33) and stabilizing transformer ТС-9Ш (ref. No. 73).

The voltage regulator is provided with an electromagnet, a carbon pile and an adjusting rheostat.

The carbon pile is placed in the circuit of the generator excitation shunt winding and changes its resistance in inverse proportion to the pressure built up by the electric magnet.

The electromagnet has four windings: working (1_1), correcting (1_2), temperature compensating (1_3) and parallel (1_4); the last one is not used aboard the aircraft.

For manual control of the generator voltage within the range of 28 to 30 V extension resistor ВС-20 (ref. No. 253) is connected to voltage regulator РУТ-82.

An increase in the generator voltage causes an increase of current in the electromagnet windings of the carbon-pile regulator and reduction of pressure on the carbon pile.

An increase in the pile resistance causes a reduction of current in the generator excitation shunt winding and therefore a reduction of voltage drop in it.

Transformer ТС-9Ш is a current and voltage transformer simultaneously.

The transformer has three windings but it has no power current winding whose function is performed by power wires passing through the hole in the transformer.

The primary parallel winding is connected in parallel with the generator excitation winding. The secondary winding is connected in series with the working winding of the voltage regulator electromagnet. The e.m.f. induced in it as a result of a change of current in that or the other primary winding prevents the current from changing in the working winding of the carbon voltage regulator electromagnet.

The equalizing winding is designed for parallel operation of several generators (is not used on this type of aircraft).

The transformer is employed when the generator modes are changed (a change in the speed or load).

The transformer serves the purpose of damping automatic oscillations caused by the voltage fluctuations and the fluctuations of the generator load current which are accompanied by sharp "chatters" of the voltage regulator armature and the contactor of the differential reverse-current relay.

Abrupt changes in the generator voltage cause respective changes in the voltage and current of the generator excitation winding. Voltage changes result in the e.m.f. induced in the secondary winding of transformer ТС-9М which affects the current in the working winding of the voltage regulator. The e.m.f. immediately reduces or increases the strength of the electromagnet thus damping the oscillations of the regulator armature.

Abrupt changes in the generator load current also induce the e.m.f. in the secondary winding.

Radio interference of the equipment is reduced by means of two capacitors МБГТ-160-4 (ref. No. 63).

To measure the current consumption in the generator mode provision is made for the socket (ref. No. 153) connected to shunt Ш-2 and the voltage in the circuit is indicated by voltmeter В-1 (ref. No. 163). The voltmeter circuit is protected with a fuse (ref. No. 83).

A.C. Supply Circuit

Generator СГО-8, Series II (ref. No. 503) feeds the A.C. voltage of 115 V at a wobbling frequency from 400 to 900 c.p.s. to the following consumers:

(a) radar station;

(b) rocket missiles Р-3С.

Inverter ПО-750А (ref. No. 523) feeds the A.C. voltage of 115 V at the frequency of 400 c.p.s. to the following consumers:

(a) oil pressure gauge transformer ДИМ-8Т;

(b) ionization fire warning unit НС-2МС;

(c) thyratron interrupter ПТ-56Н of flowmeter РТС-164-4;

(d) automatic radio compass АРК-10;

(e) marker radio receiver МРП-56П;

(f) transformer of unit БУК-2А of the air intake cone control system;

(g) radio station РСИУ;

(h) radio altimeter РВ-УМ.

Inverter ПО-1500ВТ-3Н (ref. No. 533) in the main mode feeds the A.C. voltage of 115 V at the frequency of 400 c.p.s. to radar station Р-1М.

In the emergency mode, i.e. when main inverter ПО-750А (ref. No. 523) is defective, all the consumers are fed from inverter ПО-1500ВТ-3Н (ref. No. 533). To switch them from inverter ПО-750А (ref. No. 523) to inverter ПО-1500ВТ-3Н it is necessary to turn on the EMERG. SWITCH-OVER OF INVERTERS circuit breaker (ref. No. 7Р).

The ground supply of single-phase current at the voltage of 115 V, 400 c.p.s. is applied through contactor ТКД-501АТ (ref. No. 483) when the socket of connector БРА-200АК (ref. No. 123) of the A.C. ground supply is coupled. In this case the supply circuit from generator СГО-8 is broken by contactor ТКД-511АТ (ref. No. 493).

A.C. GRNER.: GROUND A.C. SUPPLY circuit breaker АЗС-5 (ref. No. 45Н) on the right-hand horizontal console serves for turning on the A.C. consumer or the A.C. ground power source.

Inverter ПТ-500И (ref. No. 5Н) feeds three-phase current at the voltage of 36 V, 400 c.p.s. to the fighter directional system МСН, gyro horizon АГД-1 and single-axis roll stabilization autopilot КАП-2.

Inverters ПО-750А, ПО-1500ВТ-3Н and ПТ-500И are started automatically as soon as any of the consumer circuit breakers is turned on.

Inverter ПАГ-1Ф (ref. No. 27Н) feeds three-phase current at the voltage of 36 V, 400 c.p.s. to the stand-by gyro horizon АИ-200.

The inverter is started by turning on АИ-200. GYRO HRANSH. CAGING МСН, КАП circuit breaker АЗС-5 (ref. No. 16Н) installed on the right-hand horizontal electric board.

Inverter ПТ-125И (ref. No. 33Н) feeds three-phase current at the voltage of 36 V A.C., 400 c.p.s. to gyro horizon АГД-1.

The inverter is started by feeding the power supply to terminal 2 of the inverter connector through fuse НН-10 (ref. No. 45Н) and closed contacts 2-3 of the relay (ref. No. 43Н). The relay (ref. No. 43Н) operates after circuit breaker АЗС-10 (ref. No. 32Н) is turned on.

2. ENGINE STARTING SYSTEM, CRANKING AND PROCESSING

General

The engine starting system is designed for starting the engine on the ground and in the air as well as for cranking and processing it.

Operation of the engine starting system is performed by the electric devices given in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	2	3	4	5	6
1	13	Starter-generator	ГСР-СТ-12000ВТ	1	Engine lower portion, frames Nos 26 to 28 along the axis of symmetry
2	53	Starting resistor	СП-0.05 ohm	1	Starting contactor and resistor box; frames Nos 13А and 14, starboard side, lower portion
3	103	Airborne storage battery	15СЦС-45	2	Under cockpit floor, between frames Nos 7Б and 10
4	113	Relay	ТКЕ53ПАТ	1	Relay box, frames Nos 12 and 13, starboard side
5	133	Plug to connect ground power source	ПРА-250ШЛК	1	Fuselage, port side, frames Nos 12 and 13
6	143	BATTERY: AIRCRAFT - GROUND switch	2ВГ-15К	1	Horizontal electric board of right-hand cockpit console

1	2	3	4	5	6
7	193	Contactor	КМ-400Д	1	Contactor box, frames Nos 10 and 11, lower accessories compartment
8	263	Contactor	КМ-400Д	1	Contactor box, frames Nos 10 and 11, lower accessories compartment
9	273	Contactor	КМ-400Д	1	Contactor box, frames Nos 10 and 11, lower accessories compartment
10	283	Contactor	КМ-400Д	1	Contactor box, frames Nos 10 and 11, lower accessories compartment
11	303	Switching box of ground power sources	КПА-6	1	Ground equipment
12	313	Overload circuit breaker	АЗП-1МА, Series III	1	Frames Nos 13 and 13A, lower portion, along the axis of symmetry
13	373	Contactor	КМ-400Д	1	Starting contactor and resistor box, frames Nos 13A and 14, starboard side, lower portion
14	383	Contactor	КМ-400Д	1	Starting contactor and resistor box, frames Nos 13A and 14, starboard side, lower portion
15	513	Relay	ТКЕ53ПДТ	1	Relay box, frames Nos 12 and 13, starboard side
16	1Д	Electromagnet of fuel additional supply valve	ЭМ2	1	Engine
		Fuel dump valve electromagnet	$ЭМ_4$	1	Engine
		Electromagnet of starting fuel valve	$ЭМ_5$	1	Engine
		Electromagnet of air by-pass hydraulic valve control valve	$ЭМ_8$	1	Engine
		Ignition coil unit	КИА-114М	2	Engine
		Creeping discharge plug for igniting main fuel	СНЕ-4-3	2	Engine
		Afterburner fuel plug	СЗ-21Б5	1	Engine

SECRET

1	2	3	4	5	6
		Control unit	EУ-45	1	Engine
17	2Ж	Afterburner automatic control box	КАФ-13Ж, Series III	1	Frames Nos 15A and 16, starboard side, lower portion
18	3Ж	Timer	АВ-7-44-5	1	Frames Nos 13A and 14, starboard side, lower portion
19	4Ж	Starting relay box	КПР-15А	1	Frames Nos 14 and 15A, port side, lower portion
20	6Ж	Hydroelectric valve for controlling jet nozzle flaps	ГА-164М	1	Fuselage tail portion, between frames Nos 32A and 33, starboard side, upper portion
21	9Ж	Afterburner ignition coil	КНА-114М	1	Fuselage tail portion, frames Nos 30 and 31, port side, upper portion
22	10Ж	Fuse	МП-10	1	Frames Nos 14 and 15A, port side, lower portion
23	11Ж	Oxygen supply electropneumatic valve	694400	1	Frame No. 20, well for left wheel of main L.G. leg
24	12Ж	Switch	ВГ-15К	1	Processing box, frames Nos 14 and 15, port side, lower portion
25	14Ж	COLD CRANKING OF ENGINE switch	2ВГ-15К	1	Cockpit, left console
26	15Ж	STARTING button	5К	1	Cockpit, left console
27	17Ж	ENGINE START ACCESSORIES circuit breaker	АЗС-25	1	Cockpit, left console
28	18Ж	IN-FLIGHT RESTARTING circuit breaker	АЗС-10	1	Cockpit, left console
29	19Ж	AUGMENTED MAXIMUM circuit breaker	АЗС-15	1	Cockpit, left console
30	22Ж	ENGINE PROCESSING switch	ЗПШМ-45	1	Processing box, frames Nos 14 and 15, port side, lower portion
31	23Ж	Fuse	МП-5	1	Processing box, frames Nos 14 and 15, port side, lower portion
32	24Ж	Fuse	МП-10	1	Processing box, frames Nos 14 and 15, port side, lower portion
33	25Ж	Fuse	МП-10	1	Processing box, frames Nos 14 and 15, port side, lower portion
34	26Ж	Relay	ТКЕ21ПДТ	1	Relay box, frames Nos 12 and 13, starboard side

1	2	3	4	5	6
35	27Ж	Contactor	КП-50Ж	1	Control and protection box of ignition circuits, frames Nos 8 and 9, port side, lower portion
36	28Ж	Resistor	СП-0.3	1	Control and protection box of ignition circuits, frames Nos 8 and 9, port side, lower portion
37	29Ж	Fuse	ПН-20	1	Control and protection box of ignition circuits, frames Nos 8 and 9, port side, lower portion
38	30Ж	Fuse	ПН-20	1	Control and protection box of ignition circuits, frames Nos 8 and 9, port side, lower portion
39	62Ж	Fuse	ПН-5	1	Power distribution unit busbar, frames Nos 12 and 13, port side
40	66Ж	Relay $Т_1$	ТКЕ22ПДТ	1	Engine rating control box, frames Nos 13А and 14, starboard side, lower portion
41	67Ж	Relay $Т_2$	ТКЕ22ПДТ	1	Engine rating control box, frames Nos 13А and 14, starboard side, lower portion
42	70Ж	Contactor $КР_1$	ТКЕ12ПДТ	1	Engine rating control box, frames Nos 13А and 14, starboard side, lower portion
43	71Ж	Relay $Ф_4$	ТКЕ52ПДТ	1	Engine rating control box, frames Nos 13А and 14, starboard side, lower portion
44	72Ж	STARTING FUEL VALVE PROCESSING switch	ВТ-15К	1	Relay box, frames Nos 14 and 15, port side, lower portion
45	10У	CHECK.LIGHT PANEL, PITCH TRIM. WARNING; SPEEDOGRAPH circuit breaker	АЗС-5	1	Cockpit, rear right-hand electric board
46	5М	SERVICE PUMP circuit breaker	АЗС-5	1	Cockpit, right-hand horizontal electric board
47	6М	Contactor	КМ-50А	1	Power distribution unit, frames Nos 11 and 12, port side
48	7М	Filter	Ф-37ВТ	1	Frames Nos 15А and 16, port side, lower portion

1	2	3	4	5	6
49	8M	Service pump	495A2	1	Frames Nos 18 and 19, port side, lower portion
50	10C	SWITCH IGNITION OFF indicating lamp on light panel T-10V2	CM-30	1	Cockpit, right-hand portion of instrument panel
51	25C	Relay	THE56RAT	1	Cockpit, relay box, frames Nos 6 and 7, starboard side
52	15K	3AM OF HYDR. SYS., FUEL REMAINDER, TANK WARNING circuit breaker	A3C-5	1	Cockpit, right-hand rear electric board

The engine starting system is supplied with current of 24 - 48 V from two storage batteries 15CHC-45.

When generator TCP-CT-12000BT is supplied with the voltage of 24 V (storage batteries are connected in parallel) the engine turbine cannot gain the IDLING conditions.

To ensure reliable starting of the engine, 7.1 sec. after releasing the starting button the storage batteries are automatically switched in series and the starter-generator as well as other starting accessories (starting fuel ignition coil unit, starting fuel valve electromagnet, electromagnet of control valve of air by-pass hydraulic valves) begin to get current of increased voltage.

Note: Supply of the starter-generator with higher voltage increases torque moment in the starter-generator shaft; the engine starts to gain speed progressively.

The starting accessories are switched to the series - connected storage batteries because during starting the storage batteries voltage considerably decreases (approximately 3 times).

Decreased supply voltage (from one storage battery) destroys the ignition coils (sluggish operation of the breaker, electric arcing and caking of the breaker contacts) and leads to improper operation of electromagnets of the following valves: the starting fuel valve, additional fuel supply valve, hydraulic air by-pass control valve and fuel dump valve as a result of which the starting process becomes longer or the engine will not start at all.

With the increase of speed the starter-generator begins to consume less power and the voltage of series - connected storage batteries rises to normal. Relay PH installed in the starting relay box protects the starting accessories from the excess voltage (higher than 29.5 V). When the voltage exceeds 29.5 V the relay switches the starting accessories to one storage battery supply.

Note: Relay PH operates at $24^{+0.5}_{-1.5}$ V, but to make the relay operate at 29.5 V, resistor R_1 is connected into its coil circuit.

Supply of the engine starting electric system with a current of 24 - 48 V ensures:

(a) engine starting from the aircraft storage batteries on the ground;
(b) engine starting from ground power supply source;
(c) engine starting in the air;
(d) engine cold cranking.

Functioning of Electric System

Starting of engine from aircraft storage batteries (autonomous starting) is carried out by the starter-generator that is supplied from the storage batteries (ref. No. 103).

In order to start the engine, it is necessary to turn on the switch (ref. No. 143) and circuit breakers (ref. Nos 17Д, 19Д, 5И and 13К). The engine control lever is set to the IDLING position. Switches of the additional oxygen supply (ref. No. 12Д), engine processing (ref. No. 22Д), dump valve (ref. No. 20Д), starting fuel valve (ref. No. 72Д) are to be set in the operating position. The IN-FLIGHT RESTARTING circuit breaker (ref. No. 18Д) should be turned off.

When switch (ref. No. 143) is on, the contactors (ref. Nos 193 and 263) operate thus connecting the storage batteries (in parallel) to the aircraft mains.

When the circuit breaker (ref. No. 5И) is switched on, the contactor (ref. No. 6И) operates cutting in the service fuel tank pump electric motor (ref. No. 8И) through the filter (ref. No. 7И).

When the circuit breaker (ref. No. 19Д) is switched on, the positive voltage is supplied to the winding of the relay (ref. No. 67Д) through contacts 5-4 (ref. No. 71Д) and 2-1 of the relay (ref. No. 66Д).

The relay (ref. No. 67Д) operates and its contacts 2-1 disconnect the supply circuit of hydroelectric valve terminal 3 (ref. No. 6Л) from the power distribution unit busbar through fuse (ref. No. 62Д) while contacts 5-6 close the supply circuit of hydroelectric valve terminal 2 (ref. No. 6Д) from the circuit breaker (ref. No. 19Д).

The engine nozzle flaps take the augmented rating position.

With the circuit breaker (ref. No. 13К) switched on the power is fed to the engine control instruments: fuel remainder indicators, fuel tank pressure indicators and hydraulic system pressure indicator.

Directly from storage battery No. 1 (ref. No. 103) the power is fed through fuse (ref. No. 30Д), contacts 2-1 of the contactor (ref. No. 77Л) and terminals 35, 38, 24 and 18 of the starting relay box connector (ref. No. 4Д) to the following units respectively:

(a) to contacts 3 of relays P14 and 3;
(b) to contact 2 of relay P10;
(c) to contact 3 of relay P8;
(d) to contact 9 of relay P6 through contacts 1-2 of relay P4;
(e) to contacts 5 of relay P4.

When circuit breaker (ref. No. 17Д) is switched on, the mains power supply is applied to contact 3 of relay Д in the starting relay box (ref. No. 4Д) through terminal 8 of the box connector and contacts 4-5, 2-1 of relay ЖС and through the fuse (ref. No. 10Д) the mains power supply is fed to:

(a) contacts 3 of relays P6 and P7 and contact 6 of relay P5, respectively, through terminals 37 and 29 of the starting relay box connector (ref. No. 4Д);

(b) microswitches 1 and 2, contacts 2 and 5 of relay A_3, contact 3 of relay A_4 through terminal 10 of the connector of the timer (ref. No. 3Д) as well as to the starting button (ref. No. 15Д) through contacts 0-НЗ of microswitch 2 and terminal 7 of the connector of the timer (ref. No. 3Д).

Then, the starting button (ref. No. 15Д) is depressed for 2-3 sec. After pushing the starting button the following devices are switched on:

(a) main fuel ignition coil on the engine (ref. No. 1Д);

SECRET

(b) IGNITION ON indicating lamp on light panel T-10V2 (ref. No. 10C);

(c) electromotor of the timer (ref. No. 3Д);

(d) afterburner fuel ignition coil (ref. No. 9Д).

The above units are energized in the following way: the power from the aircraft mains is fed to relay A_1 (ref. No. 3Д) through the circuit breaker (ref. No. 17Д), fuse (ref. No. 10Д), normally-closed contacts of cam 2 (ref. No. 3Д), the contacts of push-button (ref. No. 15Д) and through contacts 2-1 of relay Г (ref. No. 4Д).

Relay A_1 operates and contacts 9-8 connect relay A_4 and relay P_2 of the overvoltage circuit breaker (ref. No. 313) through contacts 4-5 of relay A_2 and contacts 5-6 connect relay A_3.

Contacts 1-2 of relay P_2 of the circuit breaker (ref. No. 313) exclude operation of relay P_1 (type РЭД-Ч) designed for measuring the overvoltage value and duration and contacts 4-5 open the circuit connecting the generator to the differential reverse-current relay for the whole starting period. This prevents false operation of the circuit breaker in cases of high voltage while starting the engine and protects the aircraft mains from high voltage.

Contacts 3-2 of relay A_4 energize electromotor Д-2Р (ref. No. 3Д) which starts to turn the shaped cams in accordance with the cyclogram.

Having operated relay A_3 closes its contacts 2-3 and 5-6 and feeds the power to the limit switches of cams 3, 4, 5, 6 and 7.

As soon as the starting button is depressed (ref. No. 15Д) the power is fed to the winding of relay 3 through switch (ref. No. 14Д), contacts 4-5 of relay 3В and contacts 4-5 of relay P_5 (ref. No. 4Д). Relay 3 operates and its contacts 3-2 and 5-6 feed the power from storage battery No. 1 (ref. No. 10Б) to ignition coils КИА-114М through fuse (ref. No. 30Д), normally-closed contacts of the contactor (ref. No. 27Д), the fuses (ref. No. 24Д and 25Д) and through the contacts of the processing switch (ref. No. 22Д). This results in aging of spark plugs СНМ-4-3 of the main combustion chambers.

The power is fed to the SWITCH IGNITION OFF lamp (ref. No. 10С), through fuse (ref. No. 23Д), contacts 2-1 of relay КР (ref. No. 2Д) and through contacts 7-8 of relay (ref. No. 25С). The lamp lights up.

The power is fed to afterburner fuel ignition coil КИА-114М (ref. No. 9Д) of the afterburner fuel through contacts 5-4 of relay P_7 (ref. No. 4Д) and through contacts 3-2 of relay P_9 (relay P_9 operates simultaneously with relay 3). Thus the aging of afterburner spark plug СЗ-21Д5 begins.

At the same time the winding of relay P_{14} (ref. No. 4Д) starts to receive current through contacts 4-5 of relay 3В. Relay P_{14} operates and contacts 11-12 prepare the connecting circuit of contactor $КП_4$ (ref. No. 27Д) switching the power supply of the starting accessories from 24 to 48 V, and contacts 9-8 prepare the connecting circuit of relay P_8 (ref. No. 4Д) controlling the fuel dump valve; contacts 9-8 also prepare the connecting circuit of relays P_{11} and P_{16}.

Contacts 11-12 of relay P_{14} disconnect the winding of contactor $КП_4$ (ref. No. 27Д) after limit switch СТ of control unit БУ-4Б has operated (at 32% of high-pressure rotor speed or upon completion of the timer cycle at the 44th second).

In 1.4 seconds the microswitch of cam 1 operates.

Relay A_1 that has been operated by the starting button now is kept through its contacts 9-8.

From this time on the starting button may be released since the timer (ref. No.8Д) will go on to follow up its cycle.

In 1.6 seconds the microswitches of cams 6 and 7 operate.

Microswitch 6 feeds the power to the winding of relays P_8, P_{11} and P_{16} (ref. No. 4Д) through contacts 5-4 of relay P_3 and contacts 9-8 of relay P_{14}. Relay P_8 operates and feeds the power to the winding of relay KP_1 (ref. No. 70Д) through its contacts 3-2.

Having operated relay KP_1 closes its contacts 2-3 and energizes the electromagnet of fuel damp valve 3М4 from the regulated voltage of storage battery No. 1.

Contacts 9-8 of relay P_{14} in the circuit of relay P_8 prevent damp valve 3М4 from switching while cranking the engine.

Relay P_{16} (ref. No. 4Д) operates and opens the connecting circuit of voltage relay $P_Н$.

Relay P_{11} (ref. No. 4Д) operates and its contacts 4-5 open the supply circuit of the winding of relay P_5 (ref. No. 4Д).

During the time period from 1.6 sec. up to 16.6 sec. of the engine starting the winding of relay P_5 that is cut in from the microswitch of cam СТ of unit БУ-4Б is deenergized by open contacts 4-5 of relay P_{11} which prevents spontaneous cessation of the starting cycle of the timer when the microswitch of cam СТ operates accidentally at the 7.1 sec. of starting when the starting fuel is fed into the combustion chamber and contactors $КЛ_1$ and $КЛ_2$ (ref. Nos 273 and 283) are switched to the voltage of 48 V.

The microswitch of cam 7 energizes the winding of relay P_4 which operates and its contacts 5-6 switch on valve 3М8 controlling the air by-pass hydraulic valves while contacts 1-2 open the supply circuit of the electromagnet of valve 3М2 of the additional fuel supply up to 25.6 sec. of starting.

Notes: (a) Fuel damp electromagnetic valve 3М4 serves for abrupt reduction of fuel supply to the main combustion chambers during first 16.6 seconds of starting. After operation the valve sets the minimum fuel supply which results in small or even zero consumption of the main fuel in the engine thus improving the starting conditions of the engine.

(b) Electromagnetic valve 3М8 controlling the air by-pass hydraulic valves is used only for starting the engine on the ground and ensures its reliable starting by widening the range of stable operation of the compressor, which allows to increase the supply of the main fuel to the combustion chamber. It serves for feeding the main fuel during starting to the hydraulic valves which are opened under the pressure of the fuel and release some air from the cavity behind the compressor thus making the starting more easy. The valve is switched on at 1.6 sec. of starting and is switched off by the microswitch of the additional fuel supply cam (at 48% of high-pressure rotor speed).

In 2.0 seconds the microswitch of cam 2 operates and opens the supply circuit of the starting button (ref. No. 15Д) and also cuts in relay Н (ref. No. 4Д) and contactor $К_1$ (ref. No. 383). Since this moment the engine starting begins. Contacts 2-1 of relay Н disconnect the shunting winding of the starter-generator (ref. No. 13) from the voltage regulator (ref. No. 33) and contacts 3-2 connect it to the aircraft mains through contacts 1-2, 5-4 of relay СЗ and through circuit breaker (ref. No. 17Д).

Contacts 5-6 of relay Н (ref. No. 4Д) prepare the switching of relay P_{10}.

Contactor $К_1$ (ref. No. 383) feeds the power from the aircraft mains to terminal СТ of starter-generator (ref. No. 13) through starting resistor $R_д$ = 0.05 ohm (ref. No. 53) which limits the current at the moment when the starter is switched on thus ensuring elimination of gear backlash.

[illegible] simultaneously.

In 4.1 seconds the microswitch of cam 3 operates and cuts in contactor K_2 (ref. No. 373) and relay OP (ref. No. 513).

Contactor (ref. No. 373) shunts the starting resistor (ref. No. 53).

The starter-generator is switched to full voltage of the aircraft mains and intensive engine spinning takes place.

Parallel-connected contacts 4-5 and 7-8 of relay OP (ref. No. 513) remove the voltage from the working winding of the voltage regulator (ref. No. 83) and its contacts 3-2 prepare the connecting circuit of contactor $КП_3$ (ref. No. 303) in КПА-6 for switching over the ground supply source in series so as to obtain 48 V (necessary for starting the engine from the ground power source).

In 7.1 seconds the microswitch of cam 5 operates and feeds the power to the winding of relay P_{10} through cranking switch (ref. No. 14А) and through contacts 5-6 of relay П (ref. No. 4Д).

Relay P_{10} operates and its contacts 5-6 cut in contactors $КП_1$ and $КП_2$ (ref. Nos 273 and 283) while contacts 2-3 connect starting fuel valve ЭМ5. Starting fuel flows to the flame igniters. That is the end of the first aging of plugs which is followed by ignition of the starting fuel.

Contactors $КП_1$ and $КП_2$ (ref. Nos 273 and 283) switch over storage batteries Nos 1 and 2 (ref. No. 103) in series.

After the storage batteries are switched in series, the total voltage of both batteries (48 V) is fed to the starter-generator and the generator goes on to intensively spin the engine turbine.

At the same time the power is fed through contacts 1-2 of relay P_3 (ref. No. 4Д) to the winding of relay P_7.

After operation relay P_7 opens contacts 5-4 breaking the connecting circuit of the afterburner ignition coil. And that is the end of the afterburner spark plug aging. Contacts 3-2 of relay P_7 feed the power to the winding of relay P_6 through the normally-closed contacts of the additional fuel supply limit switch of unit БУ-4Б.

Relay P_6 operates and is self-reset through contacts 3-2, its contacts 9-8 prepare connection of additional fuel electromagnetic valve ЭМ2 while contacts 5-6 by-pass contacts 5-6 of relay P_4 thus feeding the power to electromagnetic valve ЭМ3 controlling the air by-pass hydraulic valves irrespective of relay P_4 (ref. No. 4Д).

At the same time contacts 3-2 of relay P_7 cut in contactor $КП_4$ (ref. No. 27А) through contacts 2-1 of relay P_{12}, contacts 2-1 of relay P_{15}, previously closed contacts 11-12 of relay P_{14} and through contacts 2-1 of relay (ref. No. 26А). Upon connection contactor $КП_4$ (ref. No. 27А) switches the supply circuit of the starting accessories (ignition coils, fuel damp electromagnetic valve ЭМ4, starting fuel electromagnetic valve ЭМ5, additional fuel supply electromagnetic valve ЭМ2, electromagnetic valve controlling air by-pass hydraulic valves ЭМ3) to the higher voltage source (from 24 V to 48 V) through fuse (ref. No. 29А) and resistor (ref. No. 28А). This is necessary to maintain the voltage in the starting accessories, since the voltage in the aircraft mains abruptly drops when the starter-generator is switched from 24 to 48 V. The series resistor (ref. No. 28А) prevents the voltage across the starting accessories from rising above the normal value.

In 12.6 seconds the microswitch of cam 4 operates and feeds the power to the winding of relay ОЗ (ref. No. 4Д). Relay ОЗ operates and is kept in the operating position by the positive voltage of the timer (ref. No. 3А) through its contacts 6-5 and 2-3.

Opening its contacts 4-5 and 2-1 relay OM connects additional resistor R_8 to the circuit of the starter generator shunt winding.

In this case the starter-generator excitation field is weakened and therefore its speed is increased.

In 16.6 seconds the microswitch of cam 6 returns to the initial position and deenergizes relay P_8 whose contacts 3-2 open the supply circuit of fuel dump electromagnetic valve 3M4. At the same time relays P_{11} and P_{16} are also deenergized.

Contacts 4-5 of relay P_{11} prepare the supply circuit of the winding of relay P_5 (ref. No. 4Д).

Relay P_{16} closes contacts 1-2 and connects the winding of voltage relay PH to the supply circuit of the ignition coils through resistor R_1. Resistor R_1 is selected so as to make voltage relay PH operate at 28 to 29 V in the supply circuit. Relay PH is connected to the circuit of the starter-generator shunt winding 0.5 sec. after the connection of the series resistor so as to give enough time for accomplishing all the transients (current and voltage changes in the starting circuit) which are caused by the connection of the series resistor to the circuit of the shunt winding.

As the engine gains the speed, the starter-generator consumes less current and the voltage across terminal CT and the starting accessories is increased. As soon as the voltage rises up to the operating value of voltage relay PH (28 to 29 V), contacts 2-3 of this relay close the supply circuit of the winding of relay P_{12}. Relay P_{12} operates and becomes interlocked through its contacts 2-3 while contacts 2-1 open the supply circuit of the winding of contactor KH-50Д (ref. No. 27Д). The contactor becomes disconnected and its contacts 2-1 cut in the supply circuit of the starting accessories to the lower voltage (from 48 V to 24 V).

In 25.3 seconds the microswitch of cam 4 returns to the initial position and closes the supply circuit of the winding of relay P_{15} in KMP-15A (ref. No. 4Д). Contacts 2-1 of relay P_{15} open the supply circuit of the winding of contactor KH_4 (ref. No. 27Д) and the contactor becomes disconnected if it has not been deenergized before (in case of operation of relays PH and P_{12}). When contactor KH_4 (ref. No. 27Д) becomes deenergized, its contacts 2-1 switch over the supply circuit of the starting accessories to the mains voltage.

In 25.6 seconds the microswitch of cam 7 returns to the initial position and opens the supply circuit of the winding of relay P_4. The relay becomes disconnected and its contacts 5-6 open the supply circuit of electromagnetic valve 3M8 controlling the air by-pass hydraulic valves, but valve 3M8 remains connected through previously closed contacts 5-6 of relay P_6 and contacts 1-2 of relay P_4 close the supply circuit of additional fuel supply electromagnetic valve 3M2 while starting the engine through previously closed contacts 9-8 of relay P_6.

While accelerating the engine up to 32% of the high-pressure rotor speed, limit switch CT of the control unit operates and closes the supply circuit of the winding of relay P_5, through contacts 4-5 of relay P_{11}. Relay P_5 operated and contacts 2-1 open the negative circuit of the winding of relay A_1 of the timer (ref. No. 3Д).

Relay A_1 becomes disconnected and its contacts open the supply circuit of the windings of relays P_9, P_{14}, Э, A_3 and contactor K_1 (ref. No. 383). Relay A_3 in its turn deenergizes the supply circuit of the windings of relays OP (ref. No. 513), P_7, P_{10}, P_{13}, OM in the box of starting relays (ref. No. 4Д) and contactors KH_1, KH_2 (ref. Nos 273 and 283) and K_2 (ref. No. 373).

Relay P_{14} becomes deenergized and its contacts 11-12 open the supply circuit of the winding of contactor KM_4 (ref. No. 27Д).

Contacts 7-8 of relay OP (ref. No. 51Э) close the supply circuit of the working winding of the voltage regulator (ref. No. 38).

Contactor K_1 (ref. No. 38З) opens the supply circuit of the starting winding of the starter-generator (ref. No. 13). Contacts 2-1 of relay И connect the shunting winding of the starter-generator (ref. No. 13) to the voltage regulator (ref. No. 38) while contacts 5-6 open the supply circuit of the winding of relay P_{10}. When relay P_{10} becomes disconnected, its contacts 2-3 open the supply circuit of starting fuel electromagnetic valve 3М5 thus cutting out the starting fuel supply, while contacts 5-6 open the supply circuit of the windings of contactors KM_1 and KM_2 (ref. Nos 27З and 28З), thus switching the storage batteries from the series to the parallel connection (from 48 V to 24 V) and open the supply circuit of the winding of relay P_6, but relay P_6 will not be disconnected since it is locked through its own contacts 3-2 and additional fuel supply contacts of control unit БУ-45; and therefore additional fuel supply electromagnetic valve 3М2 and electromagnetic valve 3М8 controlling the air by-pass hydraulic valves will remain connected through contacts 9-8 and 5-6 of relay P_6, respectively, till the engine gains the speed equal to 48% of that of high-pressure rotor.

In 42 seconds the microswitch of cam 3 returns to the initial position and opens the supply circuit of the winding of contactor K_2 (ref. No. 37З). The contactor becomes disconnected and introduces the starting resistor (R_s = 0.05 ohm) in the starter line.

In 42.7 seconds the microswitch of cam 2 returns to the initial position and again breaks the supply circuits of the windings of contactor K_1 (ref. No. 38З) and relay И (ref. No. 4Д).

Thus the starting accessories become deenergized except additional fuel supply electromagnetic valve 3М2, electromagnetic valve 3М8 controlling the air by-pass hydraulic valves and the ignition coils which are fed through the contacts of energized relays 3, P_5 and P_6. Thus the plugs of the main combustion chamber are aged once more.

After that the starting cycle is over and the starter-generator starts to operate in the generating mode.

If the engine fails to gain the speed equal to 32% of that of the high-pressure rotor during the time period up to 44 sec. then the starter-generator and the starting accessories are disconnected in the following way.

In 43.4 seconds the microswitch of cam 5 returns to the initial position.

In 44 seconds the microswitch of cam 1 returns to the initial position and opens the supply circuits of the windings of relays A_1, A_3, A_4, P_9, P_{14} and 3 and the above relays in their turn open the supply circuits of windings P_{11}, P_{15}, ИМ, ignition coils and motor Д-2Р of the timer (ref. No. 3Д).

And that is the end of the cycle of the timer (ref. No. 3Д).

As soon as the engine gains the speed equal to 32% of that of the high-pressure rotor, cam СТ in control unit БУ-45 operates and the second aging of the spark plugs of the main combustion chamber begins.

When the idle rating is reached, the engine gains the speed equal to 48% of that of the high-pressure rotor, additional fuel supply cam operates and deenergizes the winding of relay P_6. The relay disconnects additional fuel supply electromagnetic valve 3М2 and valve 3М8 controlling the air by-pass hydraulic valves and deenergizes relay P_5. Relay P_5 disconnects the ignition coils. The aging of pluge СПН-4-3

is over and the IGNITION indicating lamp goes out. That is the end of the starting cycle. All the accessories return to the initial position and become prepared for the next switching.

If the engine has not developed the speed equal to 48% of that of the high-pressure rotor, valves 3M2 and 3M8 as well as the ignition coils remain energized and they should be deenergized by switching off circuit breaker A3C-25 (ref. No. 17A).

The engine starting from the ground supply source applying the 24-48 V system is accomplished with the aid of box KNA-6 (ref. No. 303) included in the set of the ground equipment.

When the power is fed from the ground power source to the socket (ref. No. 133), the relays (ref. Nos 113 and 26A) operate. Contacts 4-5 and 7-8 of the relay (ref. No. 113) disconnect storage batteries No. 1 and No. 2 (ref. No. 103) while contacts 8-9 cut in contactors K_5 and K_6 in box KNA-6 (ref. No. 303) designed for connecting the ground supply sources.

Contacts 1-2 of the relay (ref. No. 113) open the connecting circuit of the differential reverse-current relay (ref. No. 29), i.e. the circuit connecting the generator to the aircraft mains. Contacts 1-2 of the relay (ref. No. 26A) exclude operation of contactor KL_4 (ref. No. 27A) designed for feeding the starting accessories and therefore the starting accessories such as ignition coils, electromagnetic valves 3M2, 3M4, 3M5 and 3M8 on the engine are fed from storage battery No. 1 that is not employed for starting the engine on the ground and which practically has no voltage drop due to small load, i.e. the starting accessories are fed with D.C. voltage.

Relays PA_1 and PA_2 in box KNA-6 (ref. No. 303) are designed for connecting the ground supply sources with wrong polarity.

When the starting button (ref. No. 15A) is depressed the engine starting is provided in the same way as during autonomous starting. The only difference is that in 7.1 seconds after the engine starting the microswitch of cam 5 operates and then contactors KL_1 and KL_2 (ref. Nos 279 and 280) operate as well and only after their operation contactors KL_3 and KL_5 in ground supply box KNA-6 (ref. No. 303) become connected through the contacts of relay OP (ref. No. 513). The ground supply sources become connected in series forming a source of voltage of 48 V.

This voltage is applied only to the starter while the whole aircraft mains and control circuits are fed with the voltage of 24 V.

In 44 seconds the starting system returns to the initial position.

In-flight restarting of the engine is performed by cutting in the circuit breaker A3C-10 (ref. No. 18A) at autorotation r.p.m. with additional oxygen supply of the flame igniters and without switching the starter-generator in the starting mode.

With circuit breaker A3C-10 (ref. No. 18A) turned on relay 9B in the starting relay box (ref. No. 4A) operates and its contacts 3-2 feed the power to the additional oxygen supply electropneumatic valve (ref. No. 11A). Contacts 6-5 of relay 9B feed the power to the winding of relay 3 (ref. No. 4A) through contacts 4-5 of relay P_5 and contacts 9-8 of relay P_5 feed the power to the winding of relay P_{10} (ref. No. 4A).

Relay 3 operates and its contacts 3-2 and 5-6 feed the power to ignition coils CNK-4-8 of the main combustion chamber and to the IGNITION ON indicating lamp on the light panel (ref. No. 10C).

Contacts 2-3 of relay P_{10} feed the power to starting fuel electromagnetic valve 3M5.

Engine cranking. The high-pressure rotor is cranked by the starter-generator without fuel supply, switching on the ignition system but with electromagnetic valve 3M8 controlling the air by-pass hydraulic valves being on from 1.6 sec. to 25.6 sec.

To crank the engine, first lock the engine control lever, set the cranking switch (ref. No. 14A) in the COLD CRANKING OF ENGINE position and then depress the starting button (ref. No. 15A) for 2-3 sec.

As soon as the starting button is depressed, the starting cycle is performed by the timer (ref. No. 3A) in the same way as during autonomous starting, i.e. the starter-generator is started for normal operation to spin the high-pressure rotor. At this time relays 3, P_7, P_{10}, P_{14}, P_{16} (ref. No. 4A) and contactors KM_1 and KM_2 (ref. Nos 273 and 283) are not cut in, i.e. the power is not fed to the ignition coils, starting fuel electromagnetic valve 3M5, fuel damp valve 3M4, additional fuel supply valve 3M2 and the supply sources are not switched from 24 V to 48 V.

The engine cranking may be performed both from the ground supply sources and from the airborne storage batteries.

When it is necessary to crank the engine at lower speed the starting cycle is interrupted by turning on circuit breaker A3C-25 (ref. No. 17A). Prior to the next starting or engine cranking when circuit breaker A3C-25 (ref. No. 17A) is turned on, the cycle is completed by the timer motor (ref. No. 3A) and the timer returns to the initial position without making the contactors and relays operate. This is achieved by means of timer relays A_1 and A_3. At the time when the cycle is completed by the timer the starting button circuit is deenergized by the contacts of the microswitch of cam 2 and in the generating mode of the starter-generator by contacts 1-2 of relay Г (ref. No. 4A). Relays A_1 and A_3 cannot be cut in.

The engine is cranked applying the 24 V system without switching the power sources and the line from 24 V to 48 V.

The circuit feeding the signal for switching over the supply sources and the line energizing the starting accessories from the microswitch of cam 5 of the timer (ref. No. 3A) is broken by the cranking switch (ref. No. 14A).

Engine processing. In the processing duty set the corresponding switches of the engine (ref. No. 22A), the fuel damp valve (ref. No. 20A) and the starting fuel valve (ref. No. 72A) in the PROCESSING position.

With the switches in this position the ignition coils are switched off and all the electromagnetic valves of the engine except fuel damp valve 3M4 and starting fuel valve 3M5 are prepared for processing.

Altitude correction valve 3M-11 (ref. No. 65A) should be disconnected for the whole period of engine processing by setting the switch (ref. No. 63A) in the OPERATING position.

The electric circuit in the processing duty functions in the way similar to that of the autonomous starting.

As soon as the starting button (ref. No. 15A) is depressed, the timer, additional fuel supply electromagnetic valve 3M2, electromagnetic valve 3M6 of 1st carburettor, relay P_3 (ref. No. 4A) and relay KP of afterburner control box (ref. No. 2A) become connected through the inertia fuses (ref. Nos 23A, 24A, 25A), the engine processing switch (ref. No. 22A) and through contacts 7-8 of relay P_5.

Relay P_3 operates and its contacts 1-2 and 4-5 open the supply circuits of the respective windings of relays P_7 and P_8 up to the end of the timer cycle, thus preventing relay P_6 from being connected by contacts 3-2 of relay P_7 and preventing fuel dump electromagnetic valve 3M4 from being energized.

Contacts 3-2 and 9-8 of relay KP operate and energize electromagnetic valves 3M7 of 2nd carburettor and relay Φ_4 (ref. No. 71Ж) which energizes electromagnetic valve 3M1 of the afterburner pump for the timer cycle.

In 1.6 seconds after the starting button is depressed and up to 25.6 sec. electromagnetic valve 3M8 controlling the air by-pass hydraulic valves is on.

Forty four seconds after the beginning of the engine starting the timer finishes its cycle and all the processing accessories become disconnected.

After the engine is processed in compliance with the above cycle, process fuel dump valve 3M4. To do this, close the switch (ref. No. 20Ш), i.e. set it to the PROCESSING position and depress the STARTING button (ref. No. 15Ш).

Note: Starting fuel electromagnetic valve 3M5 is not subjected to processing since the processing liquid interferes with the normal operation of the starting unit of the engine (when the engine is subsequently deprocessed or started).

3. ENGINE MAXIMUM AND AUGMENTED RATING CONTROL SYSTEM

General

The system is designed for switching the engine to the maximum and augmented ratings so as to increase the engine thrust.

This operation of the system is performed by the electric devices listed in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	2	3	4	5	6
1	IЖ	Electromagnet of valve of pump НР-22Ф2	-	1	Engine, frames Nos 26 and 27
2		Limit switch of hydraulic decelerator of pump НР-21Ф	-	1	Engine
3		Control unit	БУ-4Б	1	Engine
4		Engine rating control panel	ПУРТ-1Ф	1	Engine
5		Electromagnet controlling additional release of air pressure P_2^1	-	1	Engine
6		Limit switch of pump НР-22Ф2	-	1	Engine

1	2	3	4	5	6
7		Electromagnets of carburettor valves I and II	-	2	Engine
8	1Д	Rheostat transmitter	РР-3А	1	Engine
9	1Ж	Rheostat	Р-1	1	Engine
10	2Д	Afterburner control box	КАФ-18Д, Series III	1	Starboard lower portion of fuselage, frames Nos 15 and 16
11	5Д	Signal transmission box	КВС-1	1	Fuselage, lower portion, port side, between frames Nos 13А and 14
12	6Д	Hydroelectric valve for controlling jet nozzle flaps	ГА-164М	1	Tail portion of fuselage, between frames Nos 32 and 33, upper starboard portion
13	7Д	Feedback transmitter	ДОС-1А	1	Engine
14	9Д	Afterburner ignition coil	КНА-114М	1	Engine
15	22Д	Switch	ЗПНН-45	1	Relay box, between frames Nos 14 and 15, fuselage, port side
16	23Д	Inertia fuse	ИП-5	1	Relay box, between frames Nos 14 and 15, fuselage, port side
17	16Д	NOZZLE EMERGENCY CONTROL switch	ВГ-15К	1	Cockpit, right-hand console
18	19Д	AUGMENTED MAXIMUM circuit breaker	АЗС-15	1	Electric board, left-hand console
19	62Д	Inertia fuse	ИП-5	1	Power distribution unit, port side, frames Nos 12 and 13
20	65Д	Relay Т	ТКЕ53ПДТ	1	Relay box, frames Nos 13А and 14, starboard side, lower portion
21	66Д	Relay $Т_1$	ТКЕ22ПДТ	1	Relay box, frames Nos 13А and 14, starboard side, lower portion
22	67Д	Relay $Т_2$	ТКЕ22ПДТ	1	Relay box, frames Nos 13А and 14, starboard side, lower portion
23	70Д	Relay $КР_1$	ТКД12ПДТ	1	Relay box, frames Nos 13А and 14, starboard side, lower portion
24	71Д	Relay $Ф_4$	ТКД52ПДТ	1	Relay box, frames Nos 13А and 14, starboard side, lower portion

1	2	3	4	5	6
25	82Д	Relay T_5	ТКЕ21ШДТ	1	Processing box, frames Nos 14 and 15, port side, lower portion
26	83Д	Switch	БГ-15К	1	Processing box, frames Nos 14 and 15, port side, lower portion
27	84Д	Pressure indicator	САДА-0.35	1	Well for left wheel of main landing gear
28	85Д	Electromagnetic valve	ЭМ-11	1	Engine
29	10С	AFTERBURNING indicating lamp	Green	1	Light panel Т-10У2, instrument panel, on the right-hand side

Notes: Relays Z, "y", $Ф_2$, У1, D, H, C, "q", "e", Ф1, КР, $РВ_1$, $РВ_2$, $РВ_3$, $РВ_4$ and slotted controls Б, А, Д, Г, Б, Е and И are housed in afterburner control box КАФ-13Д, Series III.

Maximum Rating

The engine maximum rating is cut in by setting the engine control lever (РУД) to the MAXIMUM stop. However, the rating will be cut in only after operation of the high-thrust rating interlocking elements according to the revolutions of the hydraulic decelerator terminal switch (r.s.) and the afterburner interlocking (БФО), switches i.e. after reaching the prescribed engine speed corresponding to its stable running conditions when cutting in the high-thrust ratings. The cams of switches БФО-1 in control unit БУ-4Б are respectively adjusted to 60 and 65% of the high pressure rotor revolutions and the hydraulic decelerator switch of fuel control pump НР-21Ф to 98% of the low-pressure rotor revolutions.

When the engine control lever (РУД) is shifted forward through 68° against the limb on control panel ПУРТ-1Ф, switch ПК of the panel operates and prepares the circuit of relay Z connecting the relay to afterburner control box КАФ-13Д.

As soon as the engine gains the r.p.m. corresponding to the closed positions of the hydraulic decelerator terminal switch and switch БФО-1 in control unit БУ-4Б, the current is supplied to relay Z. The relay operates and interlocks the hydraulic decelerator terminal switch and switch БФО-1.

When the engine operates from the moment of starting up to the moment when the interlock of БФО-1 is on (65% of high-pressure rotor speed), the jet nozzle flaps are in the AFTERBURNING position and after the interlock is cut in, they assume the MAXIMUM position.

After the maximum rating is cut out, the engine control lever is released from the MAXIMUM stop. In this case, limit switch ПК is opened on control panel ПУРТ-1Ф (in the position below 68° against the limb on the panel), and relay Z becomes disconnected thus unlocking the hydraulic decelerator terminal switch and switch БФО-1. Up to the moment when the interlock of switch БФО-2 is cut out (60% of the high-pressure rotor speed), the jet nozzle flaps are kept in the MAXIMUM position and after the interlock is cut out the flaps assume the AFTERBURNING position.

Functioning of Maximum Rating Electric Circuit

Relay Z in the afterburner control box is supplied from the aircraft mains through the AUGMENTED MAXIMUM circuit breaker (ref. No. 19Д), switch БКО-1 in control unit БУ-45Б, the hydraulic decelerator terminal switch and through switch ПК on control panel ПУРТ-1Ф. The relay operates and its contacts 2-3 interlock the hydraulic decelerator switch and switches БКО.

As soon as switch БКО-1 (at 65% of the high-pressure rotor speed) is turned on, relay $Т_1$ (ref. No. 66Д) becomes connected. The relay operates and its contacts 5-6 lock the relay through the previously closed contacts (at 60% of the high-pressure rotor speed) of switch БКО-2.

At the same time contacts 2-1 of relay $Т_1$ (ref. No. 66Д) become open. Relay $Т_2$ (ref. No. 67Д) is deenergized and its contacts 2-1 become closed while contacts 6-5 open thus feeding the power to winding М (terminal 3) of the hydroelectric valve (ref. No. 6Д) controlling the jet nozzle flaps. The power supply is removed from winding Ф (terminal 2) and the flaps assume the maximum position.

When the maximum rating is switched off and the engine control lever is retracted, limit switch ПК becomes open deenergizing the winding of relay Z and unlocking the hydraulic decelerator switch and switch БКО-1.

However, the winding of relay $Т_1$ (ref. No. 66Д) is still energized through its contacts 5-6 from switch БКО-2. Therefore, relay $Т_1$ (ref. No. 66Д) remains on while relay $Т_2$ (ref. No. 67Д) is disconnected up to the moment when switch БКО-2 is turned off (less than 60% of the high-pressure rotor speed). Winding М of the hydroelectric valve (ref. No. 6Д) controlling the jet nozzle flaps becomes energized and the flaps assume the MAXIMUM position.

After switch БКО-2 is disconnected, the winding of relay $Т_1$ (ref. No. 66Д) becomes deenergized and its contacts 2-1 cut in the winding of relay $Т_2$ (ref. No. 67Д) through the following circuit: AUGMENTED MAXIMUM circuit breaker (ref. No. 19Д), contacts 5-4 of relay $Ф_4$ (ref. No. 71Д), contacts 2-1 of relay $Т_1$ (ref. No. 66Д) and the winding of relay $Т_2$ (ref. No. 67Д).

Relay $Т_2$ (ref. No. 67Д) operates and its contacts 2-1 take the power from terminal 3 of winding М of the hydroelectric valve (ref. No. 6Д) through fuse (ref. No. 62Д) and contacts 5-4 of relay $Ф_2$ in the afterburner control box (ref. No. 2Д) while its contacts 6-5 feed the power to terminal 2 of winding Ф of the valve as a result of which the flaps assume the AFTERBURNING position.

Augmented Rating

The augmented rating is cut in by setting the engine control lever (РУД) to the MINIMUM AFTERBURNING or FULL AFTERBURNING stop as well as in a position between these stops.

In this case switch БКС (interlocking the afterburner operation by the flap position) operates at the 73° against the limb on panel ПУРТ-1Ф cutting in relay $Ф_1$ installed in the afterburner control box.

Relay $Ф_1$ cuts in relays Н and $Ф_2$ in the same box, and relay $Ф_4$ controlling the afterburner fuel.

As soon as relay Н has operated, the electromagnetic valves of the flame igniter carburettors and the afterburner fuel ignition coil are cut in. Relay $Ф_4$ operates and connects electromagnetic valve ЭМ1 of the afterburner fuel regulating pump which allows the working fuel to enter the fuel manifolds of the afterburner chamber and makes the AFTERBURNING indicating lamp light up.

Thus, the flame igniter of the afterburner chamber is started.

After the working pressure of the fuel in the combustion chamber manifolds is obtained, the limit switch of the afterburner pump deenergizes the winding of relay Н thus cutting out both electromagnetic valves of the carburettor and the AFTERBURNER FUEL ignition coil.

Relay $Ф_2$ operates and deenergizes winding Н (terminal 3) of hydroelectric valve ГА-164Ж and energizes relay "е" which in its turn connects the electrohydraulic follow-up system controlling the jet nozzle flaps. In this case, if the engine control lever is set to the MINIMUM AFTERBURNING stop, the follow-up system energizes winding Ф (terminal 2) of hydroelectric valve ГА-164Ж setting the jet nozzle flaps in the MINIMUM AFTERBURNING position.

The electrohydraulic system controlling the jet nozzle flaps is arranged as a D.C. bridge the motor of which includes the winding of high-sensitive polarized relay РПС.

The bridge arms are resistors 4Ф and 7Ф of rheostat Р-1 and the resistance of mismatch transmitters ДР-3А and feedback transmitter ДОС-1А.

When the engine control lever is shifted, its movement is imparted to the slider of transmitter ДР-3А rigidly coupled with the ПУРТ-1Ф unit shaft, which results in bridge unbalancing and appearance of a current in the winding of relay РПС of either direction.

Depending on the direction of the current in the winding, relay РПС closes its right or left pair of contacts connecting relay "а" or "б", respectively, in signal transmission box КВС-1.

As a result, either winding Н or Ф of hydroelectric valve ГА-164Ж is cut in, thus allowing the hydraulic fluid to enter the respective cavity of the actuating cylinders and the jet nozzle flaps either close or open.

As the rod of the hydraulic cylinder is shifted, it pulls the slider of transmitter ДОС-1А which in its turn reduces unbalance of the bridge circuit and the current in the bridge diagonal, i.e. in the winding of relay РПС. When the unbalance of the circuit is eliminated by shifting the slider of rheostat ДОС-1А and reducing the current in the winding of relay РПС down to the value below the level of the sensitivity current, the contacts of the relay return to the neutral position and both windings of electrohydraulic valve ГА-164Ж become deenergized.

The hydraulic system is closed and the jet nozzle flaps remain in the fixed position till the engine control lever (РУД) is shifted anew. Thus, the jet nozzle flaps follow the position of the engine control lever within the performance range of the engine control lever from the minimum to maximum augmentation (from 70° to 108° against the limb of panel ПУРТ-1Ф).

The full augmentation of the engine is achieved by setting the engine control lever to the FULL AFTERBURNING stop.

In this case, the lever on panel ПУРТ-1Ф is set to the 100°-112° position, switch Ф operates and energizes electromagnetic valve ЭМ3 of additional decrease of pressure P_2^1. As soon as the valve becomes energized it stops to decrease air pressure P_2^1 in the pipe line delivering pressure P_2 to the afterburner regulator. As a result, the output of the afterburner pump is increased.

Note: Pressure P_2^1 is the corrected air pressure behind the compressor in the pipe line delivering the static pressure P_2 to the afterburner regulator of pump НР-2Ф2. When the engine operates within the range from the minimum to full augmentation, the delivered static air pressure P_2 is decreased up to air pressure P_2^1 and is applied to the afterburner pump regulator which operates according to the principle of maintaining constant ratio $\frac{P_2}{P_4}$. The air is released through metering needle No. 1

disturbed, the fuel regulating pump changes the fuel supply to the burners either reducing or increasing it till the constant ratio is restored.

Electromagnetic valve 3M3 operates and stops bleeding the air (pressure P_3) through the valve jet. This reduces pressure P_2 delivered to the regulating pump and stops additional fuel bleeding as a result of which the output of the regulating pump is increased at full augmentation. The air bleeding (pressure P_2) through metering needle No. 1 is constant for the given adjustment of the needle at all augmented ratings and serves for obtaining the necessary temperature of the gas before the turbine in the FULL AFTERBURNING rating.

At the partial augmentation ratings the temperature before the turbine is adjusted by the jet of electromagnetic valve of additional decrease of pressure P_2.

To switch on the augmented rating depress the latch on the engine control lever and set it to the MINIMUM AFTERBURNING stop. In this case, switch БКС is disconnected, relay $Ф_1$ is deenergized, the bridge is unbalanced, relay РПС energizes relay "a" and the latter energizes relay T. Relay T energizes winding M of the hydroelectric valve setting the jet nozzle flaps in the MAXIMUM position.

When the augmented rating is cut out abruptly by placing the engine control lever below the MAXIMUM stop, a rise in the low-pressure rotor speed takes place. To avoid such a rise of speed provision is made for an interlock of the afterburner fuel cut-off delay for the period of time required for the flaps to change from the FULL AFTERBURNING to MINIMUM AFTERBURNING position. And only after that the supply of the afterburner fuel is cut out. The interlock is accomplished by means of relay T.

When the augmented rating is cut out abruptly below the MAXIMUM stop, and the speed of the low-pressure rotor drops down to the r.p.m. at which the hydraulic decelerator terminal switch operates, the afterburner fuel delivery is cut off immediately after the operation of the hydraulic decelerator limit switch.

In case of failure of the all-duty jet nozzle control system the two-position system can be employed by turning on the NOZZLE EMERGENCY CONTROL switch. This will make relay B of the afterburner control box operate and disconnect the follow-up system.

In this case, FULL AFTERBURNING, will be cut in only by switch Ч on panel ПУРТ-1Ф (103° against the limb on panel ПУРТ-1Ф), and the interlock of the afterburner fuel cut-off delay does not participate in the operation.

Functioning of Augmented Rating Circuit

When the engine control lever (РУД) is set to the MINIMUM AFTERBURNING stop, switch БКС on panel ПУРТ-1Ф (ref. No. 1Д) operates. The power from the aircraft mains is fed to winding $Ф_1$ in КАФ-13Д (ref. No. 2Д) through the AUGMENTED MAXIMUM circuit breaker (ref. No. 19Д), contacts 2-3 of relay Z, contacts 4-6 of switch БКС and through contacts 4-5 of relay B. Relay $Ф_1$ operates and feeds the power to the winding of relay H through its contacts 2-3 and contacts 1-2 of the afterburner pump limit switch; and to the winding of relay $Ф_2$ through contacts 1-2 of relay C in the afterburner control box and to the winding of relay $Ф_4$ (ref. No. 71Д) through contacts 1-2 of relay "q" and contacts 7-8 of relay КР in the afterburner control box.

Relay H of the box (ref. No. 2Д) operates and its contacts 2-3 and 5-6 feed the power from the aircraft mains to electromagnetic valves 3M6 and 3M7 (ref. No. 1Д) of the carburettors through the AUGMENTED MAXIMUM circuit breaker (ref.

No. 19A) and to the afterburner fuel ignition coil (ref. 9A) through contacts of the switch (ref. No. 22A) and contacts 1-2 of relay P_9 in the starting relay box (ref. No. 4A).

As soon as the fuel pressure in the afterburner combustion chamber manifolds reaches the working level, the afterburner pump limit switch (ref. No. 1A) opens the supply circuit of the winding of relay H and both electromagnetic valves 3M6 and 3M7 (ref. No. 1A) of the carburettors as well as the afterburner ignition coil (ref. No. 9A) become disconnected.

Relay Φ_2 operates and its contacts 5-4 break the supply circuit of winding H (terminal 3) of the hydroelectric valve (ref. No. 6A) and its contacts 2-3 close the supply circuit of the winding of relay "e" through contacts 8-7 of relay B.

Contacts 2-3 of relay Φ_4 (ref. No. 71A) feed the power to the electromagnet of the valve of afterburner pump 3M1 (ref. No. 1A) and the afterburner indicating lamp on the light panel (ref. No. 10C).

Relay "e" operates and its contacts 2-3 feed the power to the bridge follow-up circuit from the AUGMENTED MAXIMUM circuit breaker (ref. No. 19A) through resistor R in the signal transmission box (ref. No. 5A).

This power is fed to transmitter AP-3A through resistors MΦ (positive voltage) and 1Φ (negative voltage) of rheostat P1 (ref. No. 1A) and at the same time to the feedback transmitter (ref. No. 7A).

The all-duty jet nozzle control system starts to operate. Before the augmented rating is cut in the jet nozzle flaps are in the MAXIMUM position. This position of the flaps corresponds to a certain position of the slider of the feedback transmitter (ref. No. 7A) relative to its winding.

When the engine control lever is set in the MINIMUM AFTERBURNING position the bridge circuit is charged with the preset mismatch at which the voltage across the slider of mismatch transmitter AP-3A is lower than that across the slider of feedback transmitter AOC-1A.

Therefore, a mismatch current will flow from the slider of transmitter AOC-1A to that of transmitter AP-3A through the bridge diagonal, i.e. through the winding of the polarized relay.

At this voltage the left pair of contacts Я and И of the polarized relay becomes connected through the winding of relay PHC as a result of which relay "d" in the signal transmission box (ref. No. 5A) operates and makes the following circuit: AUGMENTED MAXIMUM circuit breaker (ref. No. 19A), contacts 2-1 of relay B in the afterburner control box (ref. No. 2A), contacts Я and И of relay PHC, the winding of relay "d".

On closing contacts 3-3 relay "d" feeds the power to winding Φ (terminal 2) of the hydroelectric valve (ref. No. 6A). The hydraulic system starts to open the jet nozzle flaps and the mismatch current in the bridge diagonal will decrease since the slide of the feedback transmitter (ref. No. 7A) is shifted together with the rod of the cylinder so as to reduce the voltage, i.e. to approach the voltage across the slide of the mismatch transmitter. In this case, the mismatch current decreases and becomes less than the operating current of relay PHC. Contacts Я and И of the polarized relay become open thereby deenergizing both windings of the hydroelectric valve. The hydraulic system will be blocked and the flaps will assume the MINIMUM AFTERBURNING position.

When the engine control lever is moved forward up to 70° along the limb on panel HVPT-15 (ref. No. 1A), the flaps remain in the MINIMUM AFTERBURNING position. When the lever is shifted further so as to increase the augmentation (up

to 108° against the limb on panel ПУРТ-1Ф), the follow-up system becomes unbalanced again and the mismatch current will flow from the slider of the feedback transmitter (ref. No. 7Д) to the mismatch transmitter (ref. No. 1Д) through the winding of relay МС. As a result, contacts Я and Л become closed and cut in relay "б" in box (ref. No. 5Д). Relay "б" operates, closes its contacts 3-2 and feeds the voltage to winding Ф of the hydroelectric valve (ref. No. 6Д). The jet nozzle flaps gradually increase their diameter up to the FULL AFTERBURNING position.

When the engine control lever is shifted forward from 108° to 112° along the limb of panel ПУРТ-1Ф, the jet nozzle flaps maintain the FULL AFTERBURNING diameter of the jet nozzle as the slide of the mismatch transmitter moves at this time within the invariable resistance sector.

In this case, at the full augmentation rating (108° and higher against the limb on panel ПУРТ-1Ф the switch (ref. No. 1Д) operates and feeds the power to the winding of electromagnetic valve ЭМ8 of additional decrease of pressure P_2^1. The valve stops bleeding the corrected air pressure P_2^1 behind the compressor through its jet out of the pipe line delivering the pressure to the afterburner regulating pump. As a result, the additional fuel is no longer bleeded at full augmentation and, therefore, the output of the afterburner regulating pump is increased.

When the engine control lever is shifted backward within the sector from 108° to 78° along the limb of panel ПУРТ-1Ф (ref. No. 1Д) so as to reduce the augmentation, the follow-up system becomes so unbalanced that the voltage across the slide of the mismatch transmitter slide is higher than that across the slider of the feedback transmitter (ref. No. 7Д). This causes a current to flow in the winding of the polarized relay in the reverse direction, i.e. from the slider of transmitter ДР-3А to the slider of the feedback transmitter. As a result, contacts Я and П of this relay become closed and they feed the power to the winding of relay "а" in the box (ref. No. 5Д). Relay "а" operates, closes contacts 3-2 and feeds the power from the aircraft mains to the winding of relay Т (ref. No. 65Д) through the AUGMENTED MAXIMUM circuit breaker (ref. No. 19Д).

Relay Т (ref. No. 65Д) operates, closes contacts 2-3 and feeds the power to winding М (terminal 3) of the hydroelectric valve (ref. No. 6Д). The supply circuit of winding Ф (terminal 2) of the hydroelectric valve (ref. No. 6Д) is opened by contacts 3-2 of relay "б". The jet nozzle flaps reduce the diameter to the MINIMUM AFTERBURNING position and remain in this position up to 78° of the limb.

With further movement of the engine control lever backward, i.e. after its release from the MINIMUM AFTERBURNING stop, the augmented rating becomes cut out. In this case, switch БФС on panel ПУРТ-1Ф (ref. No. 1Д) is cut out and its contacts deenergize the winding of relay $Ф_1$; this results in similar unbalancing of the follow-up system. After this, contacts Я and П of the polarized relay and the winding of relay "а" in the box (ref. No. 5Д) become cut in.

Relay "а" energizes the winding of relay Т (ref. No. 65Д) and contacts 2-3 of relay Т feed the power to winding М of the hydroelectric valve (ref. No. 6Д). As a result, the jet nozzle flaps are set from the MINIMUM AFTERBURNING to MAXIMUM position.

At the same time contacts 5-6 and 8-9 of relay Т (ref. No. 65Д) feed the power from the AUGMENTED MAXIMUM circuit breaker (ref. No. 19Д) to relays $Ф_4$ (ref. No. 71Д) and $Ф_2$ (ref. No. 2Д), respectively, through contacts 2-3 of relay 2.

Thus, contacts 2-3 of relay $Ф_4$ will go on to feed the power to the electromagnet of afterburner pump valve ЭМ1 and the AFTERBURNING indicating lamp on the light panel (ref. No. 10С).

When energized relay Φ_2 continues to hold relay "c" of the follow-up system through contacts 2-3.

Relay T (ref. No. 65Ã) will be on till the bridge circuit is balanced, i.e. when the flaps assume the MINIMUM AFTERBURNING position, i.e. the mismatch current approaches zero. When the bridge is balanced, the afterburner fuel supply is stopped since relay "n" in the box (ref. No. 5Ã) is deenergized and its contacts 3-2 open the supply circuit of the winding of relay T (ref. No. 65Ã).

The above connection of relays Φ_4 and Φ_2 for the period of time during which the jet nozzle flaps are moved from the FULL AFTERBURNING to MINIMUM AFTERBURNING position (i.e. a time delay in cutting out afterburner fuel and follow-up system) is necessary only for preventing the rise in the speed of the low-pressure rotor and for excluding the drop of pressure P4 when the engine control lever is abruptly shifted below the MAXIMUM stop (while cutting out the augmented rating).

The engine control circuit provides for a time delay both in the opening of the jet nozzle flaps and in the afterburner fuel supply after the augmented rating is cut in.

The time delay in the opening of the jet nozzle flaps occurs in the MAXIMUM position and serves for excluding the possible drop of pressure P4 when the augmented rating is cut in. It may be set to 0 sec., 0.5 sec., 1 sec., 1.5 sec. and 2 sec.

The time delay in the afterburner fuel supply is necessary to prevent the rise of pressure P4 and it may be set to 0 sec., 1 sec., and 2 sec.

The above time delays are ensured by time relay unit: PB_1, PB_2, PB_3, PB_4 and relays C and "q".

The time delays in the flap opening and fuel supply may be ensured only in case the time relay is deenergized. This is achieved by opening the normally-closed contacts 2-1 of relay Φ_1 while cutting in the augmented rating.

Besides, to obtain the required time delays, slits А, Б, В, Г, Д, Е in the afterburner control box (ref. No. 2Ã) should be set in the respective positions.

Opening its contacts 2-1 relay Φ_1 deenergizes the time relay unit (the winding of relay PB_1) which was energized when the AUGMENTED MAXIMUM circuit breaker (ref. No. 19Ã) was turned on. All time relays PB_1, PB_2, PB_3 and PB_4 in succession open their contacts 2-3 with a time delay of 0.5 sec. thereby deenergizing one another. Therefore, by setting any of slits А, Б, В and Г for the flaps in the closed position, relay C of the box (ref. No. 2Ã) may be deenergized in 0.5 sec., 1 sec., 1.5 sec. or 2 sec., respectively, after the augmented rating is cut in, i.e. after relay Φ_1 is energized.

Relay C becomes deenergized and its contacts 1-2 feed the power to the winding of relay Φ_2, thus setting the jet nozzle flaps in the augmented rating position 0.5 sec., 1 sec., 1.5 sec. or 2 sec. after the afterburner fuel has been delivered. In this case, slits Д and Е should be open.

When slits Д and Е are set in the closed position the same time relay unit may be used for deenergizing relay "q" in the afterburner control box (ref. No. 2Ã) in 1 or 2 seconds, respectively. In this case, slits А, Б, В and Г should be open.

When deenergized, relay "q" through its contacts 1-2 feeds the power to the winding of relay Φ_4 (ref. No. 71Ã), thus feeding the fuel and making AFTERBURNING indicating lamp light up in 1 or 2 sec. after the jet nozzle flaps are open.

The jet nozzle control system is switched from the all-duty augmented rating to the two-position augmented rating (an emergency rating) by means of a special switch (ref. No. 16Ã).

In this case, relay B in the afterburner control box (ref. No. 2Ã) operates.

Contacts 2-1 of relay B remove the power from the contacts of the polarized relay (ref. No. 5Ã), contacts 4-5 disconnect the winding of relay Φ_1 from switch B4C, contacts 5-6 feed the power to the winding of relay Φ_1 from switch 4 on panel IIVPT-1Φ, while contacts 8-9 prepare the circuit designed for setting the jet nozzle flaps in the AFTERBURNING position through contacts 2-3 of relay Φ_2.

Contacts 2-3 of relay "e" disconnect the bridge circuit, thus cutting out the circuit of the all-duty jet nozzle control system.

If the engine control lever is in the FULL AFTERBURNING position (up to 100° against the limb on panel IIVPT-1Φ), the power is fed to winding M (terminal 3) of the hydroelectric valve (ref. No. 6Ã) through fuse IIII-5 (ref. No. 62Ã), contacts 2-1 of relay T_2 (ref. No. 67Ã), contacts 5-4 of relay Φ_2. As a result, the flaps will assume the MAXIMUM position.

The two-position augmented rating is cut in by placing the engine control lever at the FULL AFTERBURNING stop (from 100 to 112° against the limb on panel IIVPT-1Φ).

The afterburner is started in the same succession as was described above:

Relay Φ_1 in afterburner control box (ref. No. 2Ã) is connected through the AUGMENTED MAXIMUM circuit breaker (ref. No. 19Ã), contacts 2-3 of relay "2", switch 4 on panel IIVPT-1Φ of the engine (ref. No. 1Ã) and through contacts 6-5 of relay B in the box (ref. No. 2Ã). Relay Φ_1 closes its contacts 2-3 and feeds the power from the aircraft mains to the winding of relay Φ_2 and relay Φ_4 (ref. No. 71Ã). Relay Φ_2 in the afterburner control box (ref. No. 2Ã) is connected through the contacts of relay C, while relay Φ_4 (ref. No. 71Ã) is connected through contacts 1-2 of relay "q" and contacts 7-8 of relay KP.

Contacts 2-3 of relay Φ_4 cut in the electromagnet of afterburner pump valve 3M1 and the AFTERBURNING indicating lamp on the light panel (ref. No. 10C). After that, the afterburner fuel starts to flow into the combustion chamber.

Relay Φ_2 operates and feeds the power to winding Φ (terminal 2) of the hydroelectric valve (ref. No. 6Ã) through its contacts 2-3 and closed contacts 8-9 of relay B, the supply circuit of winding M (terminal 3) of the hydroelectric valve (ref. No. 6Ã) being opened by contacts 5-4 of relay Φ_2. The flaps will be locked in the FULL AFTERBURNING position.

When the augmented rating is cut out by releasing the engine control lever from the FULL AFTERBURNING position, relays Φ_1, Φ_2, Φ_4 are disconnected. Relay Φ_2 opens its contacts 2-3 and closes contacts 5-4. Winding Φ of the hydroelectric valve (ref. No. 6Ã) becomes deenergized, while winding M becomes energized and as a result, the flaps assume the MAXIMUM position.

Contacts 2-3 of relay Φ_4 deenergize the electromagnet of afterburner pump valve 3M1 and the AFTERBURNING indicating lamp on the light panel (ref. No. 10C). As a result, the afterburner fuel is no longer fed and the indicating lamp goes out.

For the emergency augmented rating provision is also made for a time delay in the opening of the jet nozzle flaps (for 0.5 sec., 1 sec., 1.5 sec., and 2 sec.) and a time delay in the afterburner fuel supply (for 1 sec. and 2 sec.). These time delays are ensured by means of the same time relay unit and slits (jumpers) in the afterburner control box (ref. No. 2Ã).

Operation of Altitude Correction Circuit

To ensure stable operation of the engine during acceleration at high altitudes, provision is made for the altitude correction circuit in the control system. As soon as a certain level of pressure P_1 is reached, warning unit CAIA-0.35 (ref. No. 84Ã)

operates at the engine inlet and ... relay closes its contacts 3-2 and energizes valve ЭМ-11 (ref. No. 85Д). The valve closes and adjusts the fuel supply system for altitude acceleration.

While adjusting the altitude acceleration on the ground the switch (ref. No. 83Д) should be turned on.

Note: During the engine processing valve ЭМ-11 (ref. No. 85Д) should be de-energized for the whole processing cycle.

4. ENGINE CONTROL INSTRUMENTS

General

The engine control instruments are as follows:

(a) electric remote-indicating tachometer МТЭ-2;

(b) exhaust gas temperature gauge ТВГ-190;

(c) electric remote-reading oil-pressure gauge ДИМ-8Т.

The devices employed in the engine control instruments are listed in the Table below:

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	1Д	Electric remote-indicating tachometer transmitter of high- and low-pressure rotors	ДТЭ-1	2	Engine
		Electric remote-reading oil-pressure gauge transmitter	ДДТ-8	1	Engine
2	8Д	Transformer, 115/36 V for ДИМ-8Т	ТР-115/36 V (in set for ДИМ-8Т)	1	Frames Nos 7 and 8, port side, lower portion
3	21Д	Fuse	СП-2	1	Radio relay and fuse box, frames Nos 5 and 6, port side, lower portion
4	7К	Oil pressure indicator	УИ-1-8 (in set for ДИМ-8Т)	1	Cockpit, instrument panel
5	27К	Exhaust gas temperature gauge installed behind turbine	ТВГ-1 (in set for ТВГ-190)	1	Cockpit, instrument panel
6	28К	Junction box for thermocouples	(in set for ТВГ-190)	1	Frames Nos 31 and 31А, port side, upper portion
7	29К	Exhaust gas temperature sensing element	Т-90 (in set for ТВГ-190)	4	On both sides of fuselage in lower and upper portions, frames Nos 30 and 31
8	30К	Two-pointer tachometer indicator	(in set for МТЭ-2)	1	Cockpit, instrument panel

Tachometer МТЭ-2 includes:

(a) indicator;

(b) low-pressure rotor transmitter ДТ3-1;

(c) high-pressure rotor transmitter ДТ3-1.

The tachometer is designed for measuring the speed of the high and low pressure rotors of the engine in per cent relative to the maximum speed.

The speed measurement is based on the principle of converting the rotor speed by the transmitter into three-phase alternating current of the frequency proportionate to the speed of the engine rotor.

The alternating current is fed to the synchronous motor of the instrument. The tachometer transmitter and indicator are three-phase units, a generator and an A.C. motor, respectively, with permanent four-pole magnets employed as their rotors.

The stator windings have the form of three-phase star-connected, four-pole windings. The indicator and transmitters are electrically interconnected and not connected to the aircraft mains.

Exhaust gas temperature gauge ТВТ-190 consists of:

(a) temperature indicator ТВТ-1;

(b) exhaust gas temperature sensing element Т-90;

(c) thermocouple junction box.

The temperature gauge is a thermoelectric set comprising a magneto-electric millivoltmeter and four series-connected thermocouples.

It is designed for remotely measuring the temperature of gases behind the turbine in °C.

The temperature gauge operation is based on the employment of thermoelectric principle.

For normal operation of the temperature gauge it is necessary that the resistance of the external circuit is equal to $R_{\text{total of extnl circuit}} = 2.4 \pm 0.1$ ohms. For this purpose, provision is made for an adjusting resistor made of manganin wire and placed in the connector of the indicator. The resistor is adjusted to $0.24^{+0.03}_{-0.04}$ ohm and the connecting wires of specific length and cross-section insure $R_{\text{total extnl circuit}} = 2.4 \pm 0.2$ ohms.

The components of the temperature gauge are electrically interconnected and are not connected to the aircraft mains.

Electric remote-reading oil pressure gauge ИМИ-8Т consists of:

(a) indicator УИ-1-8;

(b) oil-pressure gauge transmitter ИД-8Т;

(c) transformer 115/36 V.

The pressure gauge is designed for measuring the oil pressure at the engine inlet in kg/sq.cm.

The components of the electric remote-reading pressure gauge are electrically interconnected. Besides, the transformer primary winding (ref. No. 8А) is fed with the voltage of 115 V, 400 c.p.s. from terminal 6 of inverter ПО-750А (ref. No. 523) in regular operation through terminals 10-11 of the relay (ref. No. 32Р) and fuse СП-2 (ref. No. 21А) and in case of emergency, from terminal 9 of inverter ПО-1500ВТ-2Н (ref. No. 503) through fuse СП-2 (ref. No. 21А) and contacts 12-11 of the relay (ref. No. 32Р).

5. ANTI-SURGE SHUTTERS CONTROL SYSTEM

General

The system is designed for preventing the engine surge. Its operation is performed by the devices listed in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	81Д	CONE AND ANTI-SURGE SHUTTERS CONTROL circuit breaker	АЗС-10	1	Rear electric board of right-hand console in cockpit
2	82Д	Mach number setter	МР-1.35	1	Cockpit, frames Nos 10 and 11, starboard side
3	84Д	Switch	ПНПГ-15К	1	Cockpit, left-hand console
4	86Д	Relay	ТКЕ21ПДТ	1	Relay box, frames Nos 7 and 8, port side, lower portion
5	45Д	Hydroelectric valve	ГА-184	1	Well for front wheel, frames Nos 5 and 6, starboard side, lower portion
6	46Д	Limit switch	КС03	1	Tail portion of fuselage, frames Nos 33 and 33А, starboard side, upper portion
7	47Д	Relay	ТКЕ52ПДТ	1	Relay box, frames Nos 7 and 8, port side, lower portion

The shutters may be controlled both manually and automatically. They are opened and closed by means of hydroelectric valve ГА-184 (ref. No. 45Д).

Operation of Electric Circuit

The shutters can be controlled automatically only at flight speeds of M $\geq$ 1.35 when setter МР-1.35 (ref. No. 82Д) operates.

For this purpose, the switch (ref. No. 84Д) is set in the AUTOMATIC position.

At the flight speed corresponding to M $\geq$ 1.35 the mains voltage is fed from terminal Б of the Mach number setter (ref. No. 82Д) to the winding of the relay (ref. No. 47Д) through the circuit breaker (ref. No. 81Д). The relay operates and closes contacts 2-3.

The mains positive voltage is fed to hydroelectric valve ГА-184 (ref. No. 45Д) through the circuit breaker (ref. No. 81Д), the contacts of the switch (ref. No. 84Д), contacts 3-2 of the relay (ref. No. 47Д) and contacts 2-1 of the relay (ref. No. 86Д). The shutters open.

To provide stable operation of the engine, after running the aircraft to a speed corresponding to M $\geq$ 1.35 and cutting in the afterburner, the relay (ref. No. 86Д) operates, contacts 1-2 of the relay (ref. No. 86Д) open and the voltage is no longer supplied to terminal 2 of the connector of the hydroelectric valve (ref. No. 45Д). The shutters close. Provided the afterburner is switched off at these flight speeds, the relay (ref. No. 86Д) releases contacts 2-1 and the hydroelectric valve (ref. No. 45Д) becomes energized. The shutters open.

The shutters also open during pitching of the aircraft if the control stick position corresponds to the stabilizer deflection angle of -20° (big arm) or $+2^{\circ}$ (small arm) at a speed of the aircraft corresponding to M $\geq$ 1.35.

In this case, the hydroelectric valve (ref. No. 45Ж) is supplied from the aircraft mains through the circuit breaker (ref. No. 81Ж), the contacts of the switch (ref. No. 84Ж), closed contacts 3-2 of the relay (ref. No. 47Ж) and closed contacts 1-2 of the microswitch (ref. No. 46Ж).

For manual control of the shutters the switch (ref. No. 84Ж) is set to one of the positions required: OPEN and CLOSED (neutral position of switch).

With the switch in the OPEN position the hydroelectric valve (ref. No. 45Ж) is energized and the shutters open. With the switch in the CLOSED position the supply circuit of the hydroelectric valve (ref. No. 45Ж) becomes open and the shutters close.

The manual opening and closing of the shutters is performed by the pilot irrespective of the aircraft speed corresponding to $M \geq 1.35$.

6. AIR INTAKE CONE CONTROL AND WARNING SYSTEM

General

The system is designed for changing the position of the air intake cone from the fully retracted to the fully extended position both automatically and manually depending on the rating of the engine to obtain the necessary thrust and reliable operation of the engine for all states of flight.

The electric devices ensuring cone control are given in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	2	3	4	5	6
1	81Ж	CONE AND ANTI-SURGE SHUTTERS CONTROL circuit breaker	АЗС-10	1	Rear electric board of right-hand console in cockpit
2	83Ж	CONE CONTROL switch	ВГ-15К	1	Left-hand console in cockpit
3	85Ж	AUTOMATIC - MANUAL switch	ВГ-15К	1	Left-hand console in cockpit
4	87Ж	Cone position indicator	УПЗС-3	1	Instrument panel, upper left-hand electric board
5	88Ж	Transmitter	УПЗС-3	1	Upper accessories compartment, frames Nos 3 and 3А along the axis of symmetry
6	89Ж	Output signal unit	МЛО-ЕВС1	1	Lower accessories compartment, frames Nos 7 and 8, lower portion, along axis of symmetry
7	40Ж	Amplification and switching unit	БУК-2А	1	Lower accessories compartment, frames Nos 7 and 8, port side
8	41Ж	Compressor inlet pressure induction transmitter	МЛО-ВР$_1$	1	Frames Nos 16 and 17, port side, upper portion

9	42Ж	Compressor outlet pressure induction transmitter	НДО-ДР$_2$	1	Frames Nos 16 and 17, port side, upper portion
10	43Ж	Cone control electro-hydraulic unit	АУ-35	1	Frames Nos 5 and 6, port side, lower portion
11	44Ж	Hydroelectric valve	ГА-184	1	Well for front wheel, frames Nos 5 and 6, starboard side, lower portion
12	47Ж	Relay	ТКЕ52ПДТ	1	Relay box, port side, frames Nos 7 and 8, lower portion
13	49Ж	Relay	ТКЕ52ПДТ	1	Relay and fuse box, frames 5 and 6, port side, lower portion
14	50Ж	Fuse	СП-5	1	Relay and fuse box, frames 5 and 6, port side, lower portion
15	51Ж	Limit switch	Ж303	1	Upper accessories compartment, frames Nos 2 and 3, starboard side
16	63Ж	Microswitch	Ж303	1	Frames Nos 33 and 33А, starboard side, upper portion
17	64Ж	Microswitch	Ж303	1	Frames Nos 33 and 33А, starboard side, upper portion
18	80	Right wheel retracted position limit switch	ВК2-200Р	1	Right wing, rib 1
19	18С	CONE EXTENDED indicating lamp	Light panel Т-4У2	1	Instrument panel in cockpit
20	26С	Relay	ТКЕ56ПДТ	1	Relay box, frames Nos 6 and 7, starboard side, in cockpit

The position of the air intake cone may be changed both automatically and manually. As a rule, it is controlled automatically with the manual control system being employed only in emergency cases and for checking the control system on the ground.

<u>When the automatic system is employed</u> the position of the air intake cone is determined by the ratio of static inlet pressure P_1 of the compressor to its outlet pressure P_2.

Static pressures P_1 and P_2 are measured, respectively, by transmitters НДО-ДР$_1$ and НДО-ДР$_2$ and sent out in the form of electric signals proportionate to these pressures. The transmitters are interconnected electrically. When a mismatch signal is available, it is fed to the output signal unit where it is amplified and applied to the control winding of motor ДГ-1А. The motor starts running and through the reduction gear sets the brush of the follow-up potentiometer in such

a position in which the follow-up system becomes electrically balanced. In this case, the mismatch signal is equal to zero.

When the follow-up system is balanced, every certain ratio of pressures $\frac{P_2}{P_1}$ corresponds to a certain position of the brush of outlet potentiometer $П_2$ which determines the value of the output relative resistance proportionate to the pressure ratio of $\frac{P_2}{P_1}$. After that, the mismatch signal is fed to the control winding of magnetic amplifier МУ of the amplification and switching unit.

Depending on the sign the mismatch signal is applied to the winding of the polarized relay of controller АРУ-35. The controller converts the electric signals fed from the amplification and switching unit into hydraulic signals indicating the rate of consumption of the working fluid. The signals are converted by means of the NOZZLE - FLAPPER element of the control system. The polarized relay receives signals of various intensity in accordance with which the flapper is turned narrowing or widening the nozzle.

Shifting of the flapper from the neutral position disturbs the equilibrium of forces acting on the end faces of the distribution slide valve as a result of which the slide valve is shifted by the hydraulic fluid and gives access to one of the cavities of the cone hydraulic cylinder connecting the other cavity with the return line.

When shifted by the hydraulic fluid the piston of the hydraulic cylinder exercises the command aimed at shifting the cone till the moment when the signal is removed from the polarized relay. The piston is mechanically coupled with the shaft of feedback transmitter УПЗС-3 through drive П-1 (drive П-1 transforms the forward motion of the power cylinder rod into rotation of the shaft of transmitter УПЗС-3). When the transmitter shaft is turned, the position of the potentiometer brush is changed as well. The signal is applied to the warning system of cone position indicator УПЗС-3. The warning system is a four-coil ratiometer. In the magnetic field of the coils a movable magnet rotates. Its shaft carries a pointer.

Every position of the potentiometer transmitter corresponds to a certain position of the magnet with the pointer of cone position indicator.

Manual control is accomplished by turning the rack-and-pinion of indicator УПЗС-3. The rack-and-pinion is coupled with the pointer and the potentiometer brush. When turning the rack-and-pinion the brush of the feedback potentiometer changes its position thus sending the signal to the cone to assume the necessary position. Then, the signal is applied to the amplification and switching unit where it is amplified and fed to the control unit. As a result, the cone assumes the required position. Since the rod of the cone control cylinder is mechanically coupled with the feedback potentiometer the follow-up system becomes electrically balanced. The other potentiometer of transmitter УПЗС-3 feeds the signal to the warning system of indicator УПЗС-3. The pointer of the ratiometer coincides with the pointer of the given position of the cone.

The automatic cone control system has a special correction circuit providing for additional extension of the cone depending on the deviation of the stabilizer in all states of flight. The correction is accomplished by means of microswitches (Ж303) of stabilizer angle transmitter ДСУ-2.

The full travelling range of the cone extension is 200 mm. When the cone is extended for 4 to 6 mm the CONE EXTENDED indicating lamp lights up.

Operation of Electric Circuit

As soon as the circuit breaker (ref. No. 31Д) is turned on, the power is fed to the setter (ref. No. 32Д), the switch (ref. No. 33Д) and then to the limit switch (ref. No. 51Д).

When the switch (ref. No. 33Д) is turned on, the mains positive voltage is fed to the switch (ref. No. 35Д), the ratiometer of cone position indicator УПЗС-3 (ref. No. 37Д), the amplification and switching unit (ref. No. 40Д), the control unit (ref. No. 43Д), the hydroelectric valve controlling the position of the cone (ref. No. 44Д) and to the winding of the relay (ref. No. 49Д). The hydroelectric valve operates and connects the control unit (ref. No. 43Д) to the common hydraulic line. Relay (ref. No. 49Д) operates and feeds the voltage of 115 V, 400 c.p.s. to the transformer of the amplification and switching unit (ref. No. 40Д) to energize magnetic amplifier МУ and to the output signal transformer (ref. No. 39Д) to energize (through the rectifier) the amplifier valve anodes, the windings of the induction units of transmitters ИДО-ДР$_1$, ИДО-ДР$_2$ (ref. Nos 41Д and 42Д) and to energize the excitation windings of motor generator М$_1$, type ДГ-1А.

Automatic cone position control is performed as follows:

When the legs of the main landing gear are retracted, the limit switch of the retracted position of the main L.G. right-hand leg (ref. No. 8С) operates and closes its contacts О-ПР. The mains voltage is fed to the winding of relay Р$_2$ of the amplification and switching unit (ref. No. 40Д). Relay Р$_2$ starts magnetic amplifier МУ.

The switch (ref. No. 35Д) is set in the open AUTOMATIC position.

The electrical mismatch signal of compressor inlet static pressure P_1 and compressor outlet static pressure P_2 is fed from transmitters ИДО-ДР$_1$ and ИДО-ДР$_2$ (ref. Nos 41Д and 42Д) to the output signal unit (ref. No. 39Д) where it is amplified and fed to the control winding of motor М$_1$. The motor shifts the potentiometer brush to the position in which the follow-up system is electrically balanced. In this case, the mismatch signal is equal to zero. Every certain ratio of pressures $\frac{P_2}{P_1}$ corresponds to a quite certain angular position of the brush of outlet potentiometer П$_2$ which determines the value of the output relative resistance proportionate to the pressure ratio of $\frac{P_2}{P_1}$. After that, the signal is fed to the control winding of magnetic amplifier МУ of the amplification and switching unit (ref. No. 40Д). Then, the amplified signal is applied to the winding of the polarised relay and depending on the sign of the mismatch signal it controls the distribution slide valve of the control unit. The slide valve gives access for the hydraulic fluid into one of the cavities of the cylinder connecting the other one with the return line. The piston of the cylinder executes the command to shift the cone up to the moment when the signal is removed from the polarized relay.

At the same time when the piston of the hydraulic cylinder (cone) is shifted, the brushes of the potentiometers of transmitter УПЗС-3 (ref. No. 36Д) rotate. Executing the command on shifting the cone the potentiometer of the feedback transmitter brings the control unit to the electrically balanced condition. The other potentiometer of the transmitter on shifting the cone redistributes currents in the ratiometer coils of the cone position indicator (ref. No. 37Д). Any change in currents of the coils causes corresponding changes in the magnetic fluxes of every coil and, therefore, a change in the direction of the resultant magnetic flux.

Every position of the brush on the transmitter potentiometer corresponds to a certain position of the magnet with a pointer in the display unit of indicator УПЗС-3 (ref. No. 37Д).

Additional extension of the cone in accordance with the stabilizer deflection angles is achieved by means of microswitches Nos 1 and 2 (ref. Nos 63Ж and 64Ж).

Microswitch No. 1 (ref. No. 63Ж) is turned on within the following range of the stabilizer deflection angles from 0° to $+13^{\circ}$ and from -12.5° to -28°.

In this case, an additional resistor is placed into the control winding circuit of the magnetic amplifier of the amplification and switching unit (ref. No. 40Д). As a result, the control unit (ref. No. 43Ж) additionally extends the cone for 10 mm.

Microswitch No. 2 (ref. No. 64Ж) is turned on within the range of the stabilizer deflection angles from -12.5° to $+13^{\circ}$ and from -16° to -28°.

In this case, an additional resistor is also placed into the control winding circuit of the magnetic amplifier as a result of which the control unit (ref. No. 43Ж) additionally extends the cone for 15 mm. Within the range of stabilizer deflection angles from -16° to -28° both microswitches are turned on, and the cone is additionally extended for 25 mm. At the deflection angle of the stabilizer equal to -2° only microswitch No. 2 (ref. No. 64Ж) is turned on; the cone is additionally extended for 15 mm. At the deflection angle of the stabilizer equal to 0° both microswitches No. 1 and No. 2 (ref. Nos 63Ж and 64Ж) are turned on and the cone is additionally extended for 25 mm.

Manual cone position control is performed irrespective of the aircraft flight speed by turning the rack-and-pinion on cone position indicator УПЗС-3 (ref. No. 87Ж). The rack-and-pinion is coupled with the brush of the potentiometer and with the pointer making the necessary extension of the cone.

The switch (ref. No. 35Д) is in the closed MANUAL position.

While shifting the potentiometer brush sends the signal to the amplification and switching unit (ref. No. 40Д) where it is amplified and fed to the polarized relay of the control unit (ref. No. 43Ж).

The cone assumes the preset position. The follow-up system becomes electrically balanced. The other potentiometer of indicator УПЗС-3 (ref. No. 38Ж) sends the signal to the signalling system of indicator УПЗС-3 (ref. No. 37Д). The movable pointer of the ratiometer coincides with the pointer of the preset cone position.

When the cone is extended for 4 to 6 mm both with the automatic and manual cone position control, the limit microswitch (ref. No. 51Ж) operates and feeds the power from the aircraft mains to the CONE EXTENDED indicating lamp on the light panel (ref. No. 18С). The lamp lights up.

7. ENGINE FUEL SUPPLY AND WARNING SYSTEM

General

The system is designed for feeding the engine with fuel and warning the crew about fuel consumption. Operation of the system is performed by the devices given in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	2	3	4	5	6
1	183	Relay	ТКЕ53ПД7	1	Relay box, starboard side, frames Nos 12 and 13

1	2	3	4	5	6
2	203	Fuse	НП-50	1	Power distribution unit, port side, frames Nos 12 and 13
3	243	Fuse	НП-30	1	Power distribution unit, port side, frames Nos 12 and 13
4	523	Inverter	НО-750А	1	Front accessories compartment, frames Nos 8 to 10, along the axis of symmetry
5	533	Inverter	НО-1500ВТ-3Н	1	Front accessories compartment, starboard side, upper portion, frames Nos 5 and 6
6	5М	SERVICE PUMP circuit breaker	А3С-5	1	Horizontal, electric board, right-hand console in cockpit
7	6М	Contactor	КМ-50А	1	Power distribution unit, port side, frames Nos 11 and 12
8	7М	Filter	Ф-37ВТ	1	Frames Nos 15А and 16, lower portion, along the axis of symmetry
9	8М	Pump of 2nd tank group (service)	495А2	1	Frames Nos 18 and 19, port side, lower portion
10	9М	PUMP OF 3rd TANK GROUP circuit breaker	А3С-5	1	Horizontal electric board of right-hand console
11	10М	Filter	Ф-37ВТ	1	Frames Nos 21 and 22, starboard side, lower portion
12	11М	Pump of 3rd tank group	495А2	1	Frame No. 21, port side, lower portion
13	12М	Contactor	КМ-50А	1	Power distribution unit, port side, frames Nos 11 and 12
14	14М	PUMP OF 1st TANK GROUP circuit breaker	А3С-5	1	Horizontal electric board of right-hand console
15	15М	Filter	Ф-37ВТ	1	Frames Nos 15А and 16, port side, lower portion
16	16М	Pump of 1st tank group	495А2	1	Frames Nos 15А and 16, port side, lower portion
17	17М	Contactor	КМ-50А	1	Power distribution unit, port side, frames Nos 11 and 12
18	18М	Fuse	НП-50	1	Busbar of power distribution unit, frames Nos 12 and 13
19	1К	Pressure warning unit	СД-3	1	Frames Nos 16 and 17, port side, lower portion

1	2	3	4	5	6
20	3K	Pressure warning unit	СН-3	1	Fuselage, lower portion, frames Nos 20 and 21, port side
21	5K	Pressure warning unit	СН-3	1	Fuselage, port side, frames Nos 15 and 15A, lower portion
22	6K	Fuse	СН-2	1	Radio relay and fuse box, port side, frames Nos 11 and 13, upper portion
23	13K	ЭКН OF HYDR. SYS., FUEL REMAINDER, TANK WARNING circuit breaker	АЗС-5	1	Rear electric board of right-hand console
24	14K	Float-type transmitter	СЭ-1637Н	1	Port side, lower portion, frames Nos 23 and 24
25	15K	Pressure warning unit	СНУ-2-0.35	1	Port side, lower portion, frames Nos 22 and 23
26	16K	Indicating lamp	СМ-30 (green)	1	Cockpit, middle electric board of instrument panel
27	19K	Fuel flowmeter	РТС16А-4	1	Cockpit, instrument panel
28	20K	Thyratron breaker	ПТ-56М	1	Starboard side, frames Nos 11 and 12
29	21K	Flowmeter transmitter	РТС-16А	1	Port side, lower portion, frames Nos 22 and 23
30	10С	Light panel with indicating lamps: SERVICE TANK; 1st TANK GROUP; 3rd TANK GROUP; 450 LIT. FUEL REMAINDER	1-1072	1	Cockpit, instrument panel
31	24С	Relay	ТКЕ56ПАТ	1	Relay box, starboard side in cockpit, frames Nos 6 and 7
32	32Р	Relay	ТКЕ56ПАТ	1	Relay box, frames Nos 5 and 6, port side, lower portion

The aircraft fuel system comprises seven fuselage main fuel tanks, a drop tank and wing tanks.

Operation of Electric System

The pump (ref. No. 16М) of the 1st tank group is cut in by feeding the power from the aircraft mains to terminal 1 of the pump connector through fuse (ref. No. 24З), the closed contacts of the contactor (ref. No. 12М) and the filter (ref. No. 15М). The contactor operates and closes its contacts when circuit breaker АЗС-5 (ref. No. 14М) is turned on and the power is fed from the aircraft mains to the contactor winding through contacts 3-2 of the relay (ref. No. 16З). The relay operates after the ground supply source or the generator is connected to the aircraft mains.

The pump (ref. No. 6M) of the 2nd (service) tank group is cut in by feeding the power from the aircraft mains to terminal 2 of the pump connector through the fuse (ref. No. 203), the contacts of the contactor (ref. No. 6M) and the filter (ref. No. 7M).

The contacts of the contactor (ref. No. 6M) close when the circuit breaker (ref. No. 5M) is turned on and the voltage is fed from the aircraft mains to the contactor winding.

The pump (ref. No. 11M) of the 3rd tank group is cut in by feeding the power from the aircraft mains to terminal 2 of the pump connector through the fuse (ref. No. 18M), the closed contacts of the contactor (ref. No. 17M) and the filter (ref. No. 10M).

The contactor contacts close when the circuit breaker (ref. No. 9M) is turned on and the voltage is fed from the aircraft mains to the contactor winding.

After the fuel has been consumed from the 1st tank group (at a drop of pressure in the fuel line), the contacts of the pressure warning unit transmitter CД-3 (ref. No. 5K) close, and the negative voltage is applied to the 1st tank group indicating lamp (ref. No. 10C). The lamp lights up.

After the fuel has been consumed from the 3rd group of tanks the contacts of transmitter CД-3 (ref. No. 3K) close and the 3rd TANK GROUP indicating lamp (ref. No. 10C) lights up.

After the fuel has been consumed from the fuselage drop tank, the indicating lamp (ref. No. 16K) lights up since the contacts of unit СЖУ2-0.35 (ref. No. 15K) close and the positive voltage is applied from the aircraft mains to the lamp through the circuit breaker (ref. No. 13K).

When the pressure in the fuel line between the engine and the service tank drops below 0.3 kg/sq.cm., the contacts of transmitter CД-3 (ref. No. 1K) close and the positive voltage is fed from the aircraft mains to the SERVICE TANK indicating lamp (ref. No. 10C) through the circuit breaker (ref. No. 13K) and contacts 13-14 of the relay (ref. No. 24C). The lamp lights up.

When the fuel remainder is about 450 litres, the contacts of the float-type transmitter (ref. No.14K) close and the negative voltage is fed to the 450 LIT. FUEL REMAINDER indicating lamp through contacts 16-17 of the relay (ref. No. 24C).

The positive voltage is fed from the circuit breaker (ref. No. 13K) to the lamp. The lamp lights up.

To check the fuel consumed by the engine, provision is made for summation fuel flowmeter РРС16А-4 installed on the aircraft.

The fuel flowmeter allows to check visually the quantity of fuel remaining in the aircraft tanks provided the fuel lines are in proper condition.

The fuelmeter set comprises the transmitter (ref. No. 21K), the indicator (ref. No. 19K) and thyratron breaker ВТ-56М (ref. No. 20K).

The indicator (ref. No. 19K) and the fuel flowmeter transmitter (ref. No. 21K) are electrically connected with the thyratron breaker (ref. No. 20K).

Thyratron breaker ВТ-56М is fed with the voltage of 115 V, 400 c.p.s. from inverter НО-750А (ref. No. 523) through contacts 10-11 of the relay (ref. No. 32P) and fuse СН-2 (ref. No. 6K) and in case of emergency - from inverter НО-1500БТ-3Н (ref. No. 583) through contacts 12-11 of the relay (ref. No. 32P) and fuse СН-2 (ref. No. 6K).

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8. DROP TANK ATTACHMENT, RELEASE AND WARNING SYSTEM (UNDER FUSELAGE)

General

The system is designed for attaching and releasing drop tanks and warning about the presence of the fuel tank under the fuselage.

Operation of the system is performed by the devices listed in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	58Х	DROP TANK RELEASE circuit breaker	АЗС-10	1	Rear electric board of right-hand console in cockpit
2	59Х	DROP TANK SUSPENDED indicating lamp	СМЗН (green)	1	Middle board of instrument panel
3	60Х	DROP TANK RELEASE button	205К	1	Control stick
4	61Х	Attachment lock	ЕА3-56Б (or 369Б)	1	Tank attachment pylon
5	19М	Limit microswitch	А703	1	Tank attachment pylon

Operation of Electric System

When the fuel tank is suspended, contacts 4-3 of the limit microswitch (ref. No. 19М) close and the negative voltage is fed to the indicating lamp (ref. No. 59Х). The mains positive voltage is fed to the indicating lamp (ref. No. 59Б) through the circuit breaker (ref. No. 58Х). The DROP TANK SUSPENDED indicating lamp (ref. No. 59Х) lights up.

To release the drop tank, depress the button (ref. No. 60Х).

In this case, the mains positive voltage is fed to the winding of the electromagnet in the lock release mechanism (ref. No. 61Д) through the circuit breaker (ref. No. 58Х) and the closed contacts of the button (ref. No. 60Х).

The fuel tank is released. Contacts 3-4 of the microswitch (ref. No. 19М) open and break the negative circuit of DROP TANK SUSPENDED indicating lamp (ref. No. 59Х). The lamp goes out.

9. ENGINE SHUT-OFF COCK CONTROL SYSTEM

General

The system is designed to shut off the engine main fuel line.

Operation of the system is performed by the devices listed in the Table below:

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	2	3	4	5	6
1	54Х	SHUT-OFF COCK button	204К	1	Electric board of port side console in cockpit

1	2	3	4	5	6
2	55A	Electropneumatic valve	695000/M	1	Nose section of fuselage, port side, lower portion, frame No. 17
3	29C	FIRE-FIGHTING EQUIPMENT SHUT-OFF COCK circuit breaker	A3C-5	1	Electric board of left-hand console in cockpit

To shut off the engine main fuel line (when disassembling units and in case of emergency) a stop-cock with the electropneumatic valve (ref. No. 55A) is installed in the fuel supply line before the engine.

Operation of Electric System

The electropneumatic valve is cut in by depressing the button (ref. No. 54A). In this case, the power is fed from the aircraft mains to terminal 1 of the connector of the valve (ref. No. 55A) through the circuit breaker (ref. No. 29C) and the closed contacts of the button (ref. No. 54A).

10. FIRE-FIGHTING SYSTEM

General

The fire-fighting system is designed for warning the pilot about fire in the engine compartment and switching on the fire-extinguishing bottle.

The electric devices composing the fire-fighting system are given in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	2	3	4	5	6
1	523	Inverter	NO-750A	1	Front accessories compartment, frames Nos 8 to 10, along the axis of symmetry
2	533	Inverter	NO-1500BT-3M	1	Accessories compartment, port side, upper portion, frames Nos 11 to 13
3	56A	FIRE EXTINGUISHER button	205K	1	Left-hand console in cockpit
4	57A	Fire-extinguishing bottle	20C-2-1C	1	Lower portion of fuselage, frames Nos 19A and 20
5	10C	FIRE indicating lamp (red)	CM-30	1	Light panel T-10Y2, instrument panel, starboard side
6	29C	FIRE-FIGHTING EQUIPMENT SHUT-OFF COCK circuit breaker	A3C-5	1	Electric board of left-hand console
7	30C	Electronic amplifier	MC-2MC	1	Frames Nos 11 and 12, starboard side, upper portion

1	2	3	4	5	6
8	31C	Transmitter	МС-2МС	2	Along aircraft sides, frames Nos 28A and 29
9	33C	Fuse	СП-2	1	Radio relay and fuse box, port side, frames Nos 11 to 13
10	32P	Relay	ТКЕ56ПЕТ	1	Relay box, frames Nos 5 and 6, port side, lower portion

Operation of Electric Circuit

Ionization fire warning unit МС-2МС sends a signal of rise and disappearance of flame in the engine compartment.

A heat-resistant metal tube is used as a warning unit transmitter. The transmitters are installed on special ceramic insulators.

The operating principle of ionization fire warning unit МС-2МС is based on the property of flame to conduct electric currents due to the air ionization accompanying flame reaction.

The warning unit operates only in case a flame appears in the gap between the transmitter and the aircraft structure. The unit does not respond to a temperature rise. Practically it has no delay time and operates instantaneously.

The transformer primary winding of the electronic amplifier of warning unit МС-2МС (ref. No. 30C) is connected to pins 2 and 5 of connector РР20ВБЖ10 and is fed with the voltage of 115 V, 400 c.p.s. from inverter ПО-750А (ref. No. 52B) through contacts 11-10 of the relay (ref. No. 32P) and fuse СП-2 (ref. No. 33C) and in case of emergency - from inverter ПО-1500БТ-3И (ref. No. 52B) through contacts 12-10 of the relay (ref. No. 32P) and fuse СП-2 (ref. No. 33C).

The grid leads of the warning unit double triode are connected to the aircraft framework. The positive rectified stable voltage is applied to the leads of two transmitters (ref. No. 31C) through terminals 1 and 2 of connector РР20ВБЖ6.

In case a flame appears in the gap between the transmitter and the aircraft structure, the air in the gap becomes current-conductive. This is equivalent to the connection of a resistor of 2 kilohms to 5 - 6 megohms between the grid and the anode. A positive potential is applied to the grid. The anode current increases and reaches the value sufficient to operate the relay. The relay operates and feeds the voltage from the aircraft mains to the FIRE indicating lamp on the light panel (ref. No. 10C) through the circuit breaker (ref. No. 29C), the closed contacts of the amplifier relay (ref. No. 30C) and contacts 1-2 of the relay (ref. No. 28C).

To make the fire-extinguishing bottle operate it is necessary to depress the button (ref. No. 56A). In this case, the power is fed from the aircraft mains to the the bottle (ref. No. 57A) through the circuit breaker (ref. No. 29C) and the closed contacts of the button (ref. No. 56A).

The fire is extinguished by feeding mixture 7 from the fire-extinguishing bottle to the engine compartment through special pipe lines.

11. MAIN AND BOOSTER HYDRAULIC LINE PRESSURE MEASUREMENT AND WARNING SYSTEM

General

Electric small-size remote-reading pressure gauge 23ЭМИ-250А is used for measuring the pressure in the aircraft hydraulic system.

The set of the electric pressure gauge includes:

(a) electric pressure transmitter ЭДП-50/250 (ref. No. 12K) in the main hydraulic system;

(b) electric pressure transmitter ЭДП-50/250 (ref. No. 17K) in the booster system;

(c) electric remote-reading indicator У2-250А (ref. No. 11K).

Transmitters ЭДП-50/250 (ref. Nos 12K and 17K) are installed in the right- and left-hand wheel wells, respectively, to the left and right of frame No. 20.

The electric indicator (ref. No. 11K) is mounted on the instrument panel.

The transmitters and the indicator are electrically interconnected. Besides, the indicator (ref. No. 11K) is fed with the mains voltage through the ЭДИ ОР HYDR. SYSTEM, FUEL REMAINDER, TANK WARNING circuit breaker (ref. No. 13K).

Absence of pressure in the booster and main hydraulic systems is indicated by the devices listed in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	11У	BOOSTER SYS. CUT OUT, HYDR SYS. WARNING circuit breaker	АЗС-5	1	Cockpit, right-hand rear electric board
2	26У	Pressure relay	ГА-135Т	1	Under fin fairing, upper portion, frames Nos 30 and 31
3	27У	Pressure relay	ГА-135Т	1	Under fin fairing, upper portion, frames Nos 31 and 32
4	10С	Light panel with NO PRESSURE IN MAIN SYSTEM and NO PRESSURE IN BOOSTER SYSTEM indicating lamps	ТУ-10У2	1	Instrument panel.
5	26С	Relay	ТКЕ56НДТ	1	Relay box, frames Nos 6 and 7, starboard side, in cockpit
6	27С	Relay	ТКЕ21НДТ	1	Relay box, on left-hand upper electric board of instrument panel

Operation of Electric Circuit

With the pressure drop in the main hydraulic system up to 165 kg/sq.cm. and lower the pressure relay (ref. No. 27У) closes contacts О-НЗ and feeds the negative voltage to the NO PRESSURE IN MAIN SYSTEM indicating lamp (ref. No. 10С) and the positive voltage from busbar А of the rear electric board of the right-hand console through the circuit breaker (ref. No. 11У). The lamp lights up.

With the pressure drop in the booster hydraulic system to 165 kg/sq.cm. and lower the pressure relay (ref. No. 26У) closes contacts О-НЗ. The relay (ref. No. 27С) becomes deenergized. The NO PRESSURE IN BOOSTER SYSTEM indicating lamp (ref. No. 10С) lights up since the positive voltage is fed to it from busbar А of

the rear electric board of the right-hand console through the circuit breaker (ref. No. 11Y) and the negative voltage is applied through contacts 11-10 of the relay (ref. No. 26C) and contacts 2-1 of the relay (ref. No. 27C).

With the pressure rise in the main hydraulic system to 195 kg/sq.cm. and higher the pressure relay (ref. No. 27Y) closes contacts 0-НР and opens contacts 0-НЗ thus removing the negative voltage from the NO PRESSURE IN MAIN SYSTEM indicating lamp (ref. No. 10C). The lamp goes out.

With the pressure rise in the booster hydraulic system to 195 kg/sq.cm. and higher the pressure relay (ref. No. 26Y) opens contacts 0-НЗ and closes contacts 0-НР thus feeding the negative voltage to the winding of the relay (ref. No. 27C), the positive voltage to the winding of the relay (ref. No. 27C) being fed from busbar A of the rear right-hand electric board through the circuit breaker (ref. No. 11Y). The relay operates and opens contacts 1-2 thus removing the negative voltage from the NO PRESSURE IN BOOSTER SYSTEM indicating lamp. The lamp goes out.

12. PUMPING UNIT CONTROL SYSTEM

General

The pumping unit is controlled by the devices given in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	6Y	PUMPING UNIT switch	ВГ-15К	1	Front electric board of right-hand console
2	20Y	Fuse	НП-5	1	Port side, power distribution unit, frames Nos 12 and 13
3	23Y	Fuse	НП-75	1	Port side, power distribution unit, frames Nos 12 and 13
4	24Y	Contactor	КМ-100Б	1	Port side, power distribution unit, frames Nos 12 and 13
5	25Y	Pumping unit	НП-27Т	1	Front fin fairing, frames Nos 32A and 33A
6	26Y	Pressure relay	ГА-135Т	1	Fin fairing, upper portion, frames Nos 30 and 31

To provide landing of the aircraft with the engine inoperative, emergency pumping unit НП-27Т is installed in the booster hydraulic system. The pumping unit is connected to the system automatically when the pressure in the booster hydraulic system drops to 165 kg/sq.cm. and it is disconnected when the pressure increases up to 195 kg/sq.cm.

Operation of Electric System

The pumping unit (ref. No. 25Y) becomes connected when the power is applied from the aircraft mains to terminal 2 of the pumping unit connector through the fuse (ref. No. 23Y) and the closed contacts of the contactor (ref. No. 24Y). The

contactor contacts close when the switch (ref. No. 6Y) is turned on and the pressure in the hydraulic system drops to 165 kg/sq.cm. In this case, contacts 0-НЗ of the pressure relay (ref. No. 26Y) are closed and the power is fed from the aircraft mains to the winding of the contactor (ref. No. 24Y) through the fuse (ref. No. 23Y) and the contacts of the switch (ref. No. 6Y).

With the pressure rise up to 195 kg/sq.cm. the 0-НЗ contacts of the relay (ref. No. 26Y) become open. The contactor (ref. No. 24Y) becomes deenergized and opens the supply circuit of the pumping unit. The pumping unit becomes disconnected.

13. STABILIZER AND AILERON BOOSTERS CONTROL SYSTEM

General

The operation of the system is performed by the devices listed in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	11Y	BOOSTER SYS. CUT OUT, HYDR SYS. WARNING circuit breaker	АЗС-5	1	Rear electric board of right-hand console in cockpit
2	12Y	Button	204К	1	Vertical portion of right-hand console
3	13Y	Switch	ПНГ-15К	1	Left-hand upper electric board of instrument panel
4	14Y	Hydroelectric valve	ГА-190Б	1	Starboard side, lower portion, frames Nos 21 and 22
5	15Y	Hydroelectric valve	ГА-190Б	1	Port side, lower portion, frames Nos 21 and 22
6	16Y	Relay	ТКЕ52ПДТ	1	Processing box, port side, lower portion, frames Nos 14 and 15
7	17Y	Hydroelectric valve	ГА-184	1	Tail portion of fin fairing, frames Nos 32 and 32А
8	22Y	Fuse	НН-10	1	Power distribution unit, port side, frames Nos 12 and 13

Longitudinal and lateral control of the aircraft is provided by the control stick through irreversible boosters fed from the aircraft hydraulic system: the stabilizer is controlled through two-chamber booster БУ-51МС and controller АРУ-3Б, and the ailerons are controlled through two boosters БУ-45А.

Operation of Electric Circuit

The aileron boosters are cut in by setting the switch (ref. No. 13Y) in the ON position.

In this case, the mains voltage is fed to terminal 3 of the connector of the hydroelectric valve (ref. No. 14Y) used for cutting in the aileron booster operat-

ing from the main hydraulic system, through the fuse (ref. No. 22Y) and the contacts of the switch (ref. No. 13Y).

At the same time the mains voltage is also fed to terminal 3 of the connector of the hydroelectric valve (ref. No. 15Y) used for cutting in the aileron booster operating from the booster hydraulic system, through contacts 1-2 of the relay (ref. No. 16Y).

The stabilizer and aileron boosters operating from the booster hydraulic system are cut out by depressing the button (ref. No. 12Y) provided the circuit breaker (ref. No. 11Y) is on. The power is fed to terminal 2 of the connector of the hydroelectric valve (ref. No. 17Y).

The power is also fed to the winding of the relay (ref. No. 16Y). The relay operates and its contacts 1-2 open the supply circuit of terminal 3 of the connector of the hydroelectric valve (ref. No. 15Y) while contacts 6-5 close the supply circuit of terminal 2.

Both aileron boosters are cut out by setting the switch (ref. No. 13Y) in the OFF position. In this case, the supply circuit running to terminals 3 of the connectors of the hydroelectric valves (ref. Nos 14Y and 15Y) becomes open while the supply circuits of terminals 2 become closed.

14. STABILIZER CONTROL SYSTEM

General

The stabilizer control is performed by the devices listed in the table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	2	3	4	5	6
1	1Y	APY AUTOM. CONTROL circuit breaker	АЗС-5	1	Cockpit, rear right-hand electric board
2	2Y	APY MANUAL CONTROL circuit breaker	АЗС-5	1	Cockpit, rear right-hand electric board
3	3Y	AUTOMATIC - MANUAL switch	2ПНГ-15К	1	Left-hand upper electric board of instrument panel
4	4Y	HIGH SPEED - LOW SPEED switch	ПНГ-15К	1	Left-hand upper electric board of instrument panel
5	5Y	Control unit	АРУ-3В, Series II	1	Cockpit, starboard side, behind seat, frames Nos 10 and 11
6	7Y	Arm position indicator	АРУ-3В, Series II	1	Upper left-hand electric board of instrument panel
7	8Y	Switch	ВГ-15К	1	Cockpit, front right-hand electric board
8	9Y	Switch	ПК-4	1	Aircraft control stick
9	10Y	CHECK. LIGHT PANEL, PITCH. TRIM. WARNING; SPEEDOGARO-GRAPH circuit breaker	АЗС-5	1	Cockpit, rear right-hand electric board
10	18Y	Electric mechanism	МП-100М	1	Fin fairing, upper portion, frames Nos 31 and 32

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1	2	3	4	5	6
11	19Y	Actuating mechanism	APY-3B, Series II	1	Frames Nos 29 and 30, upper portion, along axis of symmetry
12	21Y	Fuse	НН-5	1	Power distribution unit, port side, frames Nos 12 and 13
13	18C	Light panel with indicating lamps:	T-4Y2	1	Cockpit, instrument panel
		LANDING STABILIZER;	СН-30 (green)	1	
		TRIM. EFFECT, NEUTRAL	СН-30 (green)	1	
14	26C	Relay	ТКЕ56НД	1	Relay box, frames Nos 6 and 7, in cockpit, starboard side

The aircraft longitudinal control is carried out with the help of the controllable stabilizer through booster БУ-51НС which controls simultaneously both stabilizer halves.

Automatic control equipment APY-3B incorporated in the stabilizer control system automatically changes the transmission ratios from the aircraft control stick to the stabilizer and simultaneously to the artificial feel spring-loaded mechanism.

Regulation law followed by controller APY-3B is a function of the velocity head and flight altitude as determined by the aircraft aerodynamics.

The artificial feel spring-loaded mechanism is incorporated in the stabilizer control system to simulate the action of aerodynamic forces on the control stick.

The artificial feel mechanism simulates the action of forces on the control stick depending on the stick movement and arm position of the APY-3B unit.

Automatic transmission ratio controller APY-3B comprises:

(a) actuating mechanism;

(b) control unit;

(c) arm position indicator.

At low indicated speeds of flight and altitudes over 10,000 m. the inner tube position does not depend on the indicated speed. The control stick force is minimum but the stabilizer deflection is maximum.

At high indicated speeds and altitudes from 0 to 5000 m. the control stick force is maximum but the stabilizer deflection is minimum.

At intermediate altitudes from 5000 to 10,000 m. and higher the automatic equipment operates both according to the velocity head and the flight altitude.

At intermediate altitude (for example, 7500 m.) on reaching the indicated speed less than that of the control limit, the actuating inner tube stops despite the further speed rise.

Regulation law performance by the automatic equipment proceeds not evenly but intermittently by short pulses and is signalized by the arm position indicator of the controller, and at the extreme initial position it is signalized by the green indicating lamp fitted on the instrument panel.

A switch is mounted on the cockpit left-hand console to control automatic equipment APY-3B. When the switch is set in the AUTOMATIC position the actuating mechanism operates automatically from the control unit. With the switch in the MANUAL position the actuating mechanism is switched from the big arm to the small one and back manually by a push-type switch.

The artificial feel spring-loaded mechanism is designed to simulate the action of aerodynamic forces on the control stick in proportion to the stick travel angle, speed and height of flight.

The greater the travel of the stick, the greater is the reduction of the spring and the force imposed on the control stick.

Trimming effect mechanism MH-100M performs the trimmer aerodynamic function by shifting on the pilot's wish the neutral position of the artificial feel mechanism that makes it possible to carry out the aircraft longitudinal balancing in flight according to the forces.

The rotary motion of the electric motor of mechanism MH-100M is transferred into a reciprocal motion of the screw. The screw is retracted or extended depending on the direction of the electric motor rotation and shifts the housing of the artificial feel spring-loaded mechanism the housing being connected with the screw. When the housing of the artificial feel spring-loaded mechanism is shifted for the spring reduction value, the force acting on the control stick is completely removed.

With the screw in the extreme positions the microswitches mounted in the electric mechanism operate and switch off the electric motor in one of the positions.

The mechanism control is performed by a push-type switch on the aircraft control stick. When the switch is set in the DIVING position provided the booster is on and the normal pressure in the hydraulic system is available, the stabilizer leading section deflects upwards (if the control stick is free).

When the screw of electric mechanism MH-100M is in the neutral position the microswitch operates and cuts in the TRIM. EFFECT, NEUTRAL green indicating lamp on the light panel (ref. No. 16C).

Operation of Electric Circuit

The stabilizer booster starts to operate only if sufficient pressure is built up in the booster hydraulic system.

The forces acting upon the control stick are simulated by the artificial feel spring-loaded mechanism. Removal of continuously effecting forces from the stick in the pitching and diving positions of the aircraft is carried out by electric mechanism MH-100M (ref. No. 18Y) by feeding the mains voltage to terminals B or A of the connector of electric mechanism MH-100M (ref. No. 18Y) through the fuse (ref. No. 21Y), the closed contacts of the switch (ref. No. 8Y) and the respective closed contacts of the button (ref. No. 9Y) in the DIVING and PITCHING positions.

At the same time the artificial feel mechanism becomes shifted from the neutral position.

The indicating lamp (ref. No. 16C) showing that the trimming effect mechanism is in the neutral position will light up when the limit switch contacts of electric mechanism MH-100M (ref. No. 18Y) close at the moment corresponding to the position of the stabilizer and electric mechanism MH-100M at the preset balancing speed. The positive voltage is applied to the indicating lamp (ref. No. 16C) as soon as the circuit breaker (ref. No. 10Y) is turned on.

After the circuit breaker (ref. No. 1Y) is turned on and the switch (ref. No. 3Y) is set in the AUTOMATIC position, the power is fed from the aircraft mains through terminal 4 of the connector of the control unit (ref. No. 5Y) to the voltage divider, the contacts of relay PC-3 and to the armature Я of relay PHC.

Relay PHC operates either according to altitude (armature Я closes with contact П) or to speed (armature Я closes with contact К) depending on the mismatch

current of the potentiometric bridge [illegible]

potentiometers and by the feedback potentiometer of the actuating mechanism of the automatic controller APУ-3B (ref. No. 19У); the current flows through windings 1-2, 3-4, 5-6 of relay РПС of the control unit (ref. No. 5У).

Winding 11-12 is a positive feedback element which ensures stable operation of relay РПС.

When contacts Я and П are closed, the mains voltage is fed to the winding of relay РС-3 БП (big arm); when contacts Я and Л are closed the mains voltage is fed to winding МП (small arm) of relays РС-3. The relays will operate and close their contacts thus feeding the voltage from the aircraft mains to the reversing coil of the electric motor of electric mechanism МИ-100М through the circuit breaker (ref. No. 1У).

The microswitches of the extended and retracted positions of the inner tube of the actuating mechanism (ref. No. 19У) are the limit switches of the actuating mechanism extreme positions.

The position of the slide of the stabilizer indicating potentiometer of the actuating mechanism depends on the position of the actuating mechanism inner tube.

The slide takes off the voltage (a part or the whole voltage of the aircraft mains) and feeds it to the arm position indicator (ref. No. 7У) provided the circuit breaker (ref. No. 2У) is turned on.

When the switch (ref. No. 3У) is set in the MANUAL position and the switch (ref. No. 4У) is thrown either to HIGH SPEED or LOW SPEED, the power supply is fed to the corresponding reversing windings of electric motor of electric mechanism МИ-100М of the actuating mechanism (ref. No. 19У).

Thus, the position of the inner tube arm of the actuating mechanism of the automatic controller АРУ-3В (ref. No. 19У) can be manually changed.

At the moment of the BIG ARM the positive circuit of the LANDING STABILIZER indicating lamp on light panel (ref. No. 18С) becomes closed through the contacts of the actuating mechanism microswitch (ref. No. 19У). The lamp (ref. No. 18С) lights up.

15. LANDING GEAR CONTROL AND WARNING SYSTEM

General

The system is designed for extending and retracting the landing gear legs and warning the pilot of their position.

The control and warning system comprises the devices listed in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	2	3	4	5	6
1	2Н	Relay	ТКЕ52ПАТ	1	Relay box, frames Nos 6 and 7, starboard side, in cockpit
2	34Н	L.G. FLAPS circuit breaker	АЗС-5	1	Right-hand rear electric board, in cockpit
3	35Н	L.G. UP - L.G. DOWN switch	ПМП-45	1	Cockpit, left-hand console

1	2	3	4	5	6
4	36M	Hydroelectric valve	PA-142/1	1	Starboard side, lower portion, frame No. 24
5	43M	Microswitch	M703	1	Left-hand wing, rib No. 1
6	2C	L.G. WARNING MAVIG. LIGHTS circuit breaker	A3C-5	1	Right-hand rear electric board in cockpit
7	3C	Limit switch	BK-2-200P	1	Left-hand detachable wing section, between ribs Nos 4 and 5
8	4C	Limit switch	BK-2-200P	1	Left-hand detachable wing section, between ribs Nos 1 and 2
9	5C	Limit switch	BK-2-200P	1	Port side, frame No. 6, nose wheel well
10	6C	Limit switch	BK-2-140P	1	Frame No. 7A, lower portion, along axis of symmetry
11	7C	Limit switch	BK-2-200P	1	Right-hand detachable wing section, between ribs Nos 4 and 5
12	8C	Limit switch	BK-2-200P	1	Right-hand detachable wing section between ribs Nos 1 and 2
13	11C	Flight and landing warning panel	ПЗС-2МК	1	Left-hand console
		Indicating lamps:			
		NOSE WHEEL UP;	red		
		NOSE WHEEL DOWN;	green		
		EXTEND LANDING GEAR;	red		
		RIGHT-HAND WHEEL DOWN;	green		
		RIGHT-HAND WHEEL UP;	red		
		LEFT-HAND WHEEL DOWN;	green		
		LEFT-HAND WHEEL UP	red		
14	12C	Lamp	XC-39	1	L.G. right-hand leg door
15	13C	Lamp	XC-39	1	Nose wheel strut fork
16	14C	Lamp	XC-39	1	L.G. left-hand leg door
17	15C	Relay	ТКЕ53ПАТ	1	Starboard relay box, frames Nos 12 and 13
18	41C	LANDING LIGHTS; L.G. OUTSIDE INDICATING LIGHTS circuit breaker	A3C-10	1	Rear electric board of right-hand console

Operation of Electric Circuit

To extend the landing gear, set the switch (ref. No. 35M) in the L.G. DOWN position.

In this case, the mains voltage is fed to terminal 2 of the connector of the hydroelectric valve (ref. No. 36M) through the closed contacts of the circuit breaker (ref. No. 34M) and the contacts of the switch (ref. No. 35M).

To retract the landing gear set the switch (ref. No. 35M) in the L.G. UP position.

In this case, the power is fed to terminal 3 of the connector of the hydroelectric valve (ref. No. 36M) and the supply circuit of terminal 2 becomes open.

The warning system indicating the positions of the landing gear legs operates as follows:

(a) during take-off the landing gear is extended; contacts O-HP of the limit switches (ref. Nos 3C and 7C) and contacts O-H3 of the switch (ref. No. 5C) are closed, the NOSE WHEEL DOWN, LEFT-HAND WHEEL DOWN and RIGHT-HAND WHEEL DOWN indicating lamps burn on the flight and landing warning panel (ref. No. 11C);

(b) in flight the landing gear is retracted; the LEFT-HAND WHEEL DOWN, RIGHT-HAND WHEEL DOWN and NOSE WHEEL DOWN indicating lamps do not burn any longer since contacts O-HP of the limit switches (ref. Nos 3C and 7C) and contacts O-H3 of the switch (ref. No. 5C) are open while LEFT-HAND WHEEL UP, RIGHT-HAND WHEEL UP and NOSE WHEEL UP indicating lamps burn since contacts O-HP of the limit switches (ref. Nos 4C and 8C) and contacts O-H3 of the limit switch (ref. No. 6C) are closed.

The EXTEND LANDING GEAR indicating lamp does not burn on the flight and landing warning panel (ref. No. 11C) since the negative circuit is broken by contacts 1-2 of the microswitches (ref. Nos 53M and 54M) with the flaps retracted;

Note: When the flaps are extended the EXTEND LANDING GEAR indicating lamp will not burn either since its supply circuit feeding the voltage from the aircraft mains to the lamp through the circuit breaker (ref. No. 2C) and contacts O-H3 of the limit switch (ref. No. 7C) will be broken by contacts 1-2 of the relay (ref. No. 2M) being self-set through contacts 5-6.

(c) during landing the landing gear is extended; the LEFT-HAND WHEEL DOWN, RIGHT-HAND WHEEL DOWN and NOSE WHEEL DOWN indicating lamps burn since the contacts of limit switches O-HP (ref. Nos 3C and 7C) and O-H3 (ref. No. 5C) are closed and the LEFT-HAND WHEEL UP, RIGHT-HAND WHEEL UP and NOSE WHEEL UP indicating lamps do not burn on the flight and landing warning panel (ref. No. 11C).

The EXTEND LANDING GEAR lamp does not burn.

The lamp will light up in case of landing with the flaps extended and the landing gear retracted. In this case, the negative voltage is fed to the lamp through closed contacts 1-2 of the microswitches (ref. Nos 53M and 54M) while the mains positive voltage is fed through circuit breaker (ref. No. 2C), contacts O-H3 of the limit switch (ref. No. 7C) and normally-closed contacts 1-2 of the relay (ref. No. 2M).

Note: The winding of the relay (ref. No. 2M) is deenergized: the negative voltage is fed to the winding through contacts 3-4 of the microswitch (ref. No. 43M) while the positive circuit is opened by contacts O-H3 of the limit switch (ref. No. 4C).

The external indicating lamps (ref. Nos 12C, 13C and 14C) will light up on the extended L.G. legs only when the circuit breaker (ref. No. 2C) is turned on and after the relay (ref. No. 15C) has operated. In this case, contacts 8-9, 5-6 and 2-3 of the relay (ref. No. 15C) close the negative circuits of the external indicating lamps, and the mains positive voltage is fed through contacts O-HP of the limit switches (ref. Nos 3C and 7C) and O-H3 (ref. No. 5C).

16. LANDING GEAR BRAKE AUTOMATIC RELEASE SYSTEM

General

Operation of the landing gear brake automatic release system is accomplished by the devices given in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	1M	Relay	TKE52IIAT	1	Starboard relay box, frames Nos 12 and 13
2	3M	Relay	TKE52IIAT	1	Starboard relay box, frames Nos 12 and 13
3	4M	Inertia transmitter	UA-24/2M-5	1	Nose wheel
4	13M	Electropneumatic valve	UP-53/1-2	1	Frames Nos 6 and 7 under cockpit floor
5	20M	AUT. WHEEL BRAKING circuit breaker	A3C-10	1	Electric board of left-hand console
6	21M	Electropneumatic switch	UP-22	1	Cockpit, behind instrument panel, upper portion
7	22M	Electropneumatic valve	UP-53/1-2	1	L.G. left-hand leg door
8	23M	Electropneumatic valve	UP-53/1-2	1	L.G. right-hand leg door
9	24M	Inertia transmitter	UA-23/2M-13	1	L.G. left-hand wheel
10	25M	Inertia transmitter	UA-23/2M-14	1	L.G. right-hand wheel

In case of an abrupt decrease of angular velocity of the wheels or in case of their side-skidding the electromagnetic valves operate under the effect of the electric pulses sent by the inertia transmitters and relieve the air from the brake chambers thus releasing the wheels.

The electromagnetic valves and inertia transmitters are electrically connected so that in case of an abrupt decrease of angular velocity or in case of side-skidding of one of the main wheels, only one of the main wheels and the nose wheel become released, while in case of side-skidding of the nose wheel only the nose wheel becomes released.

Operation of Electric Circuit

When the brake control lever on the aircraft control stick is depressed, the compressed air from the pneumatic system is delivered to electropneumatic switch UP-22 (ref. No. 21M) and the contacts of the electric circuit become closed.

The mains voltage is fed from the energized circuit breaker (ref. No. 20M) to terminals 1 of the electropneumatic valves (ref. Nos 22M, 23M and 13M) and the windings of the relays (ref. Nos 1M and 3M).

In case of an abrupt decrease of velocity or in case of side-skidding of one or both main wheels the electropneumatic valves (ref. Nos 22M and 23M) operate due to the closing of the negative circuit in one or in both inertia transmitters

(ref. Nos 24M and 25M). The valves relieve the air from the brake chambers thus releasing one or both main wheels.

At the same time when the left-hand wheel is released, the relay (ref. No. 3M) operates since the negative voltage is fed to its winding through the closed contacts of the inertia transmitter (ref. No. 24M).

Contacts 2-3 and 5-6 of the relay (ref. No. 3M) close the negative circuit of terminal 2 of the electropneumatic valve (ref. No. 13M) which operates and releases the nose wheel.

The relay (ref. No. 1M) operates simultaneously with releasing of the right-hand wheel since the negative voltage is fed to its winding through the closed contacts of the inertia transmitter (ref. No. 25M). Contacts 2-3 and 5-6 of the relay (ref. No. 1M) close the negative circuit of terminal 2 of the electropneumatic valve (ref. No. 13M) which operates and releases the nose wheel.

Thus, the nose wheel is always released when the left- or right-hand wheel is released as well as when both landing gear main wheels are released. In case of an abrupt decrease of angular velocity (or in case of side-skidding) of the nose wheel only, the electropneumatic valve (ref. No. 13M) operates and releases only the nose wheel since the contacts of the inertia transmitter (ref. No. 4M) in the negative circuit are closed.

17. AIR BRAKES CONTROL AND WARNING SYSTEM

General

The system is designed for extending and retracting the air brakes and warning the pilot of their position.

Operation of the air brakes control and warning system is performed by the devices listed in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	2	3	4	5	6
1	19M	Microswitch	M703A	1	Frames Nos 17 and 18, lower portion, along axis of symmetry
2	30M	Microswitch	M701	1	Engine control lever
3	31M	Hydroelectric valve	GA-184	1	Fuselage, lower starboard portion, frames Nos 22 and 23
4	32M	Hydroelectric valve	GA-184	1	Fuselage, lower starboard portion, frames Nos 22 and 23
5	33M	AIR BRAKES circuit breaker	A3C-5	1	Rear right-hand electric board
6	2C	L.G. WARNING NAVIG. LIGHTS circuit breaker	A3C-5	1	Rear right-hand electric board
7	9C	Microswitch	M303	1	Port side, frame No. 13, lower portion

1	2	3	4	5	6
8	11C	Flight and landing warning panel: AIR BRAKES EXTENDED indicating lamp (green)	ПНС-2МК СМ-30	1	Left-hand console

The aircraft is provided with three air brakes: two side air brakes and one lower air brake.

They are controlled by means of hydroelectric valves ГА-184 through the microswitch mounted on the engine control lever. When the microswitch is switched off the air brakes are retracted.

As soon as the microswitch is switched on, the voltage is fed to the hydroelectric valves, the air brakes become extended and deflect to a certain angle. The AIR BRAKES EXTENDED indicating lamp lights up on the flight and landing warning panel. The lamp is interlocked by the microswitch controlling the side air brakes.

The extension of the lower air brake is interlocked by the drop tank (the lower air brake may be extended only when the drop tank is jettisoned).

Operation of Electric Circuit

After the circuit breaker (ref. No. 33M) is switched on, the mains voltage is fed to the microswitch (ref. No. 30M). The microswitch feeds the power to terminal 2 of the connector of the hydroelectric valve (ref. No. 32M).

The side air brakes become extended. When the drop tank is jettisoned, contacts 1-2 of the microswitch (ref. No. 19M) become closed and the voltage is fed through them to terminal 2 of the connector of the hydroelectric valve (ref. No. 31M). The lower air brake will also be extended. If the drop tank is not jettisoned, the lower brake will remain retracted.

When the microswitch (ref. No. 30M) is switched off, the supply circuit of terminal 2 of the connector of the hydroelectric valves (ref. Nos 31M and 32M) opens; the air brakes become retracted.

In the extended position of the air brakes the limit switch (ref. No. 9C) operates and closes its contacts 3-4. The closed contacts feed the mains voltage from the circuit breaker (ref. No. 2C) to the AIR BRAKES EXTENDED indicating lamp. The indicating lamp lights up.

When the air brakes are retracted the indicating lamp is dead.

18. FLAP CONTROL AND WARNING SYSTEM

General

The system is designed for extending and retracting the flaps while taking-off and landing.

The devices given in the Table below ensure operation of the system.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	2	3	4	5	6
1	34M	L.G. FLAPS circuit breaker	A3C-5	1	Rear electric board of right-hand console

1	2	3	4	5	6
2	39M	Flap control mechanism	M3 with microswitch Д303	1	Horizontal portion of left-hand console
3	43M	Microswitch	Д303	1	Left-hand detachable section of wing, rear portion of rib No. 1
4	44M	Electrohydraulic valve	ГА-184	1	Lower right-hand portion of fuselage, between frames Nos 23 and 24
5	53M	Microswitch	Д303	1	Flap of starboard wing
6	54M	Microswitch	Д303	1	Flap of port side wing
7	11C	Flight and landing warning panel: FLAPS DOWN indicating lamp СМ-30	ШПС-2МК	1	Left-hand console

Flap control system is of electrohydraulic type. The flaps may be retracted and extended by depressing the respective buttons on the flap control mechanism.

Operation of Electric Circuit

When the EXTENSION button of the flap control mechanism (ref. No. 39M) is depressed, the mains voltage is fed to terminal 2 of the connector of the hydroelectric valve (ref. No. 44M) through the disconnected circuit breaker (ref. No. 34M) and the closed contacts 3-4 of the limit switch controlling the flaps (ref. No. 39M).

The hydroelectric valve operates. The flaps assume the extended position. The FLAPS DOWN indicating lamp on the flight and landing warning panel (ref. No. 11C) lights up since contacts 1-2 of the microswitches (ref. Nos 53M and 54M) are closed feeding the negative voltage to the lamp, the positive voltage being fed to the lamp from the circuit breaker (ref. No. 2C).

When the RETRACTION button is depressed, the power fed from the circuit breaker (ref. No. 34M) is removed from terminal 2 of the connector of the hydroelectric valve (ref. No. 44M) by contacts 3-4 of the limit switch (ref. No. 39M).

The hydroelectric valve operates and retracts the flaps. The FLAPS DOWN indicating lamp on the warning panel (ref. No. 11C) goes out since contacts 1-2 of the microswitches (ref. Nos 53M and 54M) become open thus removing the negative voltage from the lamp.

With the flaps extended and the landing gear not extended the EXTEND LANDING GEAR indicating lamp burns on the flight and landing warning panel. The mains voltage is fed from the circuit breaker (ref. No. 2C) to the lamp through contacts O-НЗ of the limit switches (ref. No. 3C or 7C) and contacts 1-2 of the relay (ref. No. 2M). As soon as the landing gear is extended, contacts O-НЗ of the limit switch (ref. No. 4C) become closed and the mains voltage is fed to the winding of the relay (ref. No. 2M) through the circuit breaker (ref. No. 2C).

The relay (ref. No. 2M) operates, becomes self-reset and its contacts 1-2 break the supply circuit of the EXTEND LANDING GEAR indicating lamp. The lamp goes out.

19. DRAG PARACHUTE CONTROL SYSTEM

General

The system is designed for releasing the parachute in order to shorten the aircraft landing run.

Operation of the system is performed by the devices listed in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	26M	CHUTE RELEASE button	5K	1	Cockpit, left-hand console
2	27M	Electropneumatic valve	695000/M	1	Frames Nos 31-33A, lower portion, on parachute container bracket, along axis of symmetry
3	28M	CHUTE DROPPING button	204K	1	Cockpit, left-hand console
4	29M	Electropneumatic valve	695000/M	1	Frames Nos 31-32A, lower portion, on parachute container bracket along the axis of symmetry
5	40M	DRAG CHUTE circuit breaker	A3C-5	1	Rear electric board of right-hand console

Operation of Electric Circuit

The drag parachute control system is of electropneumatic type.

The drag parachute is released by depressing the button (ref. No. 26M). In this case, the mains voltage is fed from the circuit breaker (ref. No. 40M) to terminal 1 of the connector of the electropneumatic valve (ref. No. 27M).

The electropneumatic valve operates and the air enters the shutters control system. The shutters open.

The parachute falls out of the container and becomes inflated due to its own weight and the air flow.

The parachute is dropped by depressing the CHUTE DROPPING button (ref. No. 28M). In this case, the mains voltage is fed from the circuit breaker (ref. No. 40M) to the terminal 1 of the connector of the electropneumatic valve (ref. No. 29M). The electropneumatic valve (ref. No. 29M) operates and by-passes the air from the air system to the hitching lock cylinder. Thus, the drag parachute is unhooked.

20. CONTROL SYSTEM OF LANDING AND NAVIGATION LIGHTS, INSTRUMENT LIGHTING AND EXTENSION LAMPS

General

The system is designed for illuminating a runway while landing and taxiing, and the instrument dials, cockpit and separate units of the aircraft.

The system comprises the devices given in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	2	3	4	5	6
1	2C	L.G. WARNING NAVIG. LIGHTS circuit breaker	АЗС-5	1	Cockpit, rear right-hand electric board
2	16C	LOW; MIDDLE; FULL switch	ПЗПН-20	1	Cockpit, left-hand console
3	17C	Resistor	ПЭВР-25-15	2	Fuse and resistor box, in cockpit behind pilot's seat, frames Nos 10 and 11, starboard side
4	19C	Port side wing-tip navigation light	БАНО-45 (red)	1	Leading section of port side detachable portion of wing, between tips of ribs Nos 18 and 19
5	20C	Tail light	ХС-39 (white)	1	Fin edge
6	21C	Starboard wing-tip navigation light	БАНО-45 (green)	1	Leading section of starboard detachable portion of wing, between tips of ribs Nos 18 and 19
7	23C	Fuse	СП-2	1	Fuse and resistor box in cockpit behind pilot's seat, frames Nos 10 and 11, starboard
8	28C	Socket	47К	1	Cockpit, right-hand console
9	35C	КИО HEATING, EXTENSION LAMP circuit breaker	АЗС-5	1	Cockpit, rear right-hand electric board
10	36C	Socket	47К	1	Port side wing, L.G. well
11	41C	LANDING LIGHTS, L.G. OUTSIDE INDICATING LIGHTS circuit breaker	АЗС-10	1	Cockpit, rear right-hand electric board
12	42C	LANDING LIGHT, LANDING, RETRACTION, TAXIING switch	ВТ3602014	1	Upper left-hand electric board of instrument panel
13	43C	Landing light	МПРФ-1А	1	Starboard detachable portion of wing, ribs Nos 1 and 2
14	44C	Landing light	МПРФ-1А	1	Port side detachable portion of wing, ribs Nos 1 and 2
15	48C	Relay	ТКД12ПДТ	1	Relay box, starboard, frames Nos 12 and 13
16	49C	Relay	ТКЕ56ПДТ	1	Relay box, starboard, frames Nos 12 and 13

1	2	3	4	5	6
17	50C	Fuse	ПП-30	1	Port side, power distribution unit, frames Nos 12 and 13
18	52C	Fuse	ПП-5	1	Port side, power distribution unit, frames Nos 12 and 13
19	53C	Fuse	СП-2	1	Relay box, in cockpit near frame No. 11, starboard
20	54C	Fuse	СП-2	1	Relay box, in cockpit near frame No. 11, starboard
21	55C	Fuse	СП-1	1	Cockpit, right-hand console
22	57C	Instrument lighting lamps	СМ-37	20	Cockpit, left-hand console
23	58C	Instrument lighting lamps	СМ-37	14	Cockpit, right-hand console and upper boards of instrument panel
24	59C	Instrument lighting lamps	СМ-37	37	Instrument panel
25	60C	Resistor	ПЭВР-30-27	1	Relay box, in cockpit, near frame No. 11, starboard side
26	61C	Resistor	ПЭВР-25-11	2	Relay box, in cockpit, near frame No. 11, starboard side
27	62C	Resistor	ПЭВР-25-11	1	Relay box, in cockpit, near frame No. 11, starboard side
28	63C	Rheostat	РКП-45	1	Cockpit, right-hand console
29	64C	Rheostat	РКП-45	1	Cockpit, right-hand console
30	65C	Switch	ПКР-15К	1	Cockpit, left-hand console
31	66C	INSTRUMENT LIGHTING circuit breaker	АЗС-5	1	Cockpit, rear right-hand electric board
32	67C	Fuse	СП-1	1	Cockpit, right-hand console
33	68C	Fuse	СП-1	1	Cockpit, right-hand console
34	69C	Fuse	СП-1	1	Cockpit, right-hand console

Operation of Electric Circuit

The landing lights (ref. Nos 44C and 43C) are controlled with the help of the switch (ref. No. 42C) and two relays (ref. Nos 48C and 49C).

When the switch (ref. No. 42C) is set in the LANDING position the mains voltage is fed from the energized circuit breaker (ref. No. 41C) to the windings of the relays (ref. Nos 48C and 49C); the relays operate.

From the circuit breaker (ref. No. 41C) the voltage is fed to terminal 2 of the landing lights (ref. Nos 44C and 43C) through terminals 12-11 and 9-8 of the relay (ref. No. 49C); the landing lights are extended.

From fuse HH-30 (ref. No. 50C) the voltage is fed to terminals 4 of the landing lights (ref. Nos 44C and 43C) through terminals 2-3 and 5-6 of the relay (ref. No. 48C). The landing lights go on - FULL LIGHT.

When the switch (ref. No. 42C) is set in the TAXIING position, the mains voltage is fed from the energized circuit breaker (ref. No. 41C) to the winding of the relay (ref. No. 49C). The relay operates and the landing lights are extended.

From fuse HH-30 (ref. No. 50C) the voltage is fed to terminal 5 of the landing lights (ref. Nos 44C and 43C) through terminals 5-4 and 2-1 of the relay (ref. No. 48C) and terminals 18-17 and 15-14 of the relay (ref. No. 49C). The landing lights go on - LOW LIGHT.

When the switch (ref. No. 42C) is set in the RETRACTION position, the voltage from the energized circuit breaker (ref. No. 41C) is fed to terminals 3 of the landing lights (ref. Nos 44C and 43C) through terminals 2-4 and 1-3 of the switch (ref. No. 42C). The landing lights are retracted.

The navigation lights (ref. Nos 19C, 20C and 21C) are switched on by setting the switch (ref. No. 16C) to one of the following positions: LOW, MIDDLE and FULL depending on the luminous intensity required. In this case, the mains voltage is fed from the energized circuit breaker (ref. No. 2C) to the navigation lights through fuse (ref. No. 23C), the contacts of the switch (ref. No. 16C) and through the resistor (ref. No. 17C).

The sockets (ref. Nos 28C and 36C) designed for connecting the extension lamp are fed with the voltage from the energized circuit breaker (ref. No. 35C).

The voltage is applied to the instrument lighting lamps (ref. Nos 58C, 57C and 59C) of the right- and left-hand consoles and instrument panel in the pilot's cockpit by switching on the circuit breaker (ref. No. 66C).

The console lighting lamps (ref. No. 58C) mounted on the right-hand console are fed with the voltage through the fuse (ref. No. 54C), the damping resistor (ref. No. 62C), the brightness control rheostat (ref. No. 64C) and through the fuse (ref. No. 67C).

The console lighting lamps (ref. No. 57C) installed on the left-hand console are fed with the voltage through the same circuit having instead of the fuse (ref. No. 67C) the fuse (ref. No. 55C) connected after the rheostat (ref. No. 64C).

The instrument lighting lamps (ref. No. 59C) installed on the instrument panel are fed with the voltage through the fuse (ref. No. 53C), the damping resistors (ref. No. 61C), the brightness control rheostat (ref. No. 63C) and through the fuses (ref. Nos 68C and 69C).

Note: The switch (ref. No. 65C) is in the OFF position.

In emergency case the instrument lighting lamps on the instrument panel are switched on by the switch (ref. No. 65C) set in the ON position. The power is fed to the lamps (ref. No. 59C) through the fuse (ref. No. 52C), the brightness control rheostat (ref. No. 60C) and through the contacts of the switch (ref. No. 65C).

21. HEATING SYSTEM OF STORAGE BATTERIES, PRESSURIZED HELMET, CLOCK, PITOT-STATIC TUBE ПВД-7 and PITOT TUBE ТП-156М

General

The system is designed for maintaining normal temperature conditions for the storage batteries, preventing the pressurized helmet glasses from sweating, providing the precise escapement of the clock and for de-icing Pitot tubes ПВД-7 and ТП-156М.

Operation of the system is performed by the devices listed in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	34З	Fuse	НП-5	1	Frames Nos 11 and 12, lower portion, port side
2	35С	ККО HEATING, EXTENSION LAMP circuit breaker	АЗС-5	1	Cockpit, rear right-hand electric board
3	7Т	PITOT-STATIC TUBE, CLOCK circuit breaker	АЗС-10	1	Cockpit, middle board of instrument panel
4	8Т	Heating element of clock АЧС	АЧС	1	Instrument panel, clock
5	9Т	Heating element of Pitot-static tube	ПВД-7	1	Pitot-static tube rod end
6	10Т	Heating element of Pitot tube ТП-156М	ТП-156М	1	Fuselage, starboard, between frames Nos 3 and 4
7	11Т	Circuit breaker of Pitot tube ТП-156М	АЗС-10	1	Cockpit, middle board of instrument panel
8	12Т	Relay	ТКЕ52ПДТ	1	Relay box, starboard, frames Nos 12 and 13
9	13Т	Heating slip-cover for storage battery 15СНС-45 with thermal relay Т-50	-	1	Frames Nos 7 to 10 under cockpit floor
10	16Т	Rheostat	РТ-10	1	Cockpit, left-hand console
11	19Т	Heating element for pressurized helmet	-	1	Pressurized helmet
12	20Т	STORAGE BATTERY HEATING switch	ВГ-15К	1	Cockpit, right-hand console
13	21Т	FAST HEATING OF PRESSURIZED HELMET button	5К	1	Cockpit, left-hand console

Operation of Electric Circuit

The heating element (ref. No. 13Т) of storage batteries 15СНС-45 is switched on by setting the switch (ref. No. 20Т) in the ON position.

With the switch set in the ON position the voltage is fed from the ground power supply source to the heating element (ref. No. 13Т) through КПА-6

(ref. No. 303), the fuse (ref. No. 343), the closed contacts of the switch (ref. No. 20T) and contacts 2-3 and 5-6 of the relay (ref. No. 12T).

The relay operates automatically when the contacts of the thermoswitch close with the temperature drop.

Note: The heating slip-cover is furnished with thermal relay T-56 adjusted for breaking the contacts at a temperature of 15° ±2°C.

Pressurized helmet ГШ-4МС of oxygen set КИО-3 is heated by feeding the mains voltage from the energized circuit breaker (ref. No. 35C) to the helmet heating element (ref. No. 19T) either through the rheostat (ref. No. 18T) or through the closed contacts of the button (ref. No. 21T).

The heat control of the helmet element is provided by means of rheostat also used for switching on the mains full power supply and cutting it out. The fast heating of the pressurized helmet is cut in by depressing the respective button. In this case, the full mains power is applied to the helmet heating element.

The heaters of Pitot-static tube ПВД-7, clock АЧС and of Pitot tube ПИ-156М are switched on by turning on the respective circuit breakers (ref. Nos 7T and 11T) which pass the mains power to the heater of Pitot-static tube ПВД-7 (ref. No. 9T), the heater of clock АЧС (ref. No. 8T) and to the heater of Pitot-tube ПИ-156М (ref. No. 10T).

22. COCKPIT HEATING SYSTEM

General

Operation of the system is performed by the devices listed in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	1T	COCKPIT POWER SUPPLY circuit breaker	АЗС-5	1	Rear electric board of right-hand console in cockpit
2	2T	AUTOMATIC-HOT-COLD switch	П3ПН-20	1	Cockpit, left-hand console
3	3T	Thermoregulator	ТРТВК-45М	1	Cockpit, frames Nos 10 and 11, port side
4	4T	Electric air distributor	Unit 525	1	Fuselage, lower portion, frames Nos 21 and 22, along axis of symmetry
5	14T	Relay unit	РН-2 (in set with ТРТВК-45М)	1	Cockpit, frame No. 11, port side

The thermoregulator is designed for maintaining automatically the air temperature in the cockpit within the specified limits.

The air distributor is used for receiving air from the engine compressor and distributing it between the hot and cold air supply lines or delivering it to both lines simultaneously.

The relay unit is designed for switching the power supply circuits of the electric air distributor.

Operation of Electric Circuit

To maintain the air temperature in the cockpit automatically within the specified limits (with the help of a limb), it is necessary to switch on the circuit breaker (ref. No. 1T) and to set the switch (ref. No. 2T) in the AUTOMATIC position.

When the air temperature is below the normal level (as preset on the limb), the bimetallic coil of the thermoregulator (ref. No. 3T) blown by the mains air is strained thus closing the moving contact and the first fixed contact and feeding the negative voltage to the winding of the relay unit (ref. No. 14T) through terminals Б and Д of the connector of the thermoregulator (ref. No. 3T) and terminal В of the connector of the relay unit (ref. No. 14T).

The positive voltage is fed from the circuit breaker (ref. No. 1T) to the relay winding and contacts through the closed contacts of the switch (ref. No. 2T) and terminals Л and Ж of the connector of the relay units (ref. No. 14T). The relay operates and feeds the mains voltage to the electromotor of the electric air distributor (ref. No. 4T) through the closed contacts of relay unit (ref. No. 14T), terminal Б of the connector of relay unit (ref. No. 14T), terminal А of the connector of the electric air distributor (ref. No. 4T), the closed contacts of the limit switch and the reversing winding of the air distributor (ref. No. 4T).

The motor starts to operate and opens the throttle in the hot air supply line.

If the air temperature in the cockpit exceeds the value preset on the limb, the bimetallic coil of the air temperature regulator (ref. No. 3T) strains and closes the moving contact and the second fixed contact thus starting the electromotor of the electric air distributor (ref. No. 4T) through the contacts of the other relay of the unit (ref. No. 14T). The motor turns the throttle in the supply line feeding the cockpit with cooled air.

To decrease the temperature fluctuations, the thermoregulator has an electromagnetic feedback coil both leads of which are connected with the potentiometer of the air distributor (ref. No. 4T). One lead of the potentiometer and the feedback coil is fed with the mains positive voltage while the other one is fed with the negative voltage and the potentiometer slide is connected with the other lead of the feedback coil.

Shifting together with the air distributor throttles, the potentiometer slide changes the voltage in the feedback coil. The lower the position of the slide on the potentiometer the higher is the voltage in the feedback coil and vice versa.

Respectively, the moving contact of the thermoregulator (ref. No. 3T) is attracted to the coil core or repulsed by it thus closing the hot air supply circuit or vice versa.

This is how the air temperature in the cockpit is automatically controlled.

When the air temperature set on the limb of the thermoregulator (ref. No. 3T) does not satisfy the pilot, he sets the switch (ref. No. 2T) in one of the desired positions COLD or HOT.

In this case, the cockpit automatic air temperature control system is switched off, and the mains voltage is directly fed from the switch (ref. No. 2T) to the electromotor of the air distributor (ref. No. 4T) through one of the reversing windings. The electromotor turns the throttles in the cold or hot air supply line, respectively.

As soon as the desired temperature is obtained, cut out the electromotor by the switch (ref. No. 2T).

23. PILOT'S SEAT POSITION CONTROL SYSTEM

General

Operation of the system is performed by the devices listed in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	45M	Fuse	НП-15	1	Power distribution unit, port side, frames Nos 12 and 13
2	46M	SEAT UP-DOWN switch	ПКП-15К	1	Left-hand console in cockpit
3	47M	Limit switch	АВ02-ВК2-141	1	Upper portion of left-hand rail of seat framework
4	48M	Limit switch	АВ02-ВК2-141	1	Upper portion of left-hand rail of seat framework
5	49M	Electromotor	МУ-100АП	1	Lower cross beam of seat framework

The seat position in compliance with the pilot's length is adjusted by shifting the seat pan upwards or downwards along the guide rails of the seat framework. The pan is raised and lowered with the screw driven by electromotor МУ-100АП. The motor is reversible and may turn the screw in one or the other direction.

The upward and downward travel of the pan is limited by means of the limit switch mechanism.

To disconnect the electromotor from the power supply circuits (in case of dismantling the motor) provision is made for connector ШР20ПК4ЕГ8 installed on the lower portion of the right-hand rail of the seat framework.

Operation of Electric Circuit

When the switch (ref. No. 46M) is set in the DOWN position, the power is fed from the aircraft mains to the reversing winding of electromotor (ref. No. 49M) through fuse (ref. No. 45M) and the normally-closed contacts of the limit switch (ref. No. 48M). Electromotor МУ-100АП starts rotating counter-clockwise thus lowering the seat to the position wherein the limit switches (ref. Nos 47M and 48M) operate.

The limit switch (ref. No. 48M) opens the normally-closed contacts thus de-energizing the reversing winding; the motor stops. The limit switch (ref. No. 47M) closes its normally-closed contacts thus preparing the supply circuit of the reversing winding of clockwise rotation.

When the switch (ref. No. 46M) is set in the UP position, the power is fed from the aircraft mains to the reversing winding of the electromotor (ref. No. 49M) through the fuse (ref. No. 45M) and the normally-closed contacts of the limit switch (ref. No. 47M). The electromotor starts to rotate in the clockwise direction thus raising the seat to the position wherein the limit switches (ref. Nos 47M and 48M) operate.

The limit switch (ref. No. 47M) opens the normally-closed contacts thus de-energizing the reversing coil; the motor stops.

The limit switch (ref. No. 48M) closes its normally-closed contacts and prepares the supply circuit of the reversing winding of counter-clockwise rotation.

24. POWER SUPPLY SYSTEM OF SPEEDOBAROGRAPH M2-717

General

The devices included in the system are listed in the Table below:

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	2K	Speedobarograph	M2-717	1	Upper front accessories compartment, frames Nos 4 and 5, starboard
2	4K	Switch	BP-15K	1	Right-hand console
3	10K	Filter for speedobarograph	In set for M2-717	1	Front accessories compartment, frames Nos 4 and 5, starboard
4		CHECK LIGHT PANEL, PITCH TRIM. WARNING; SPEEDOBAROGRAPH circuit breaker	A3C-5	1	Rear right-hand electric board

Small-size speedobarograph M2-717 is designed for making check recordings of speed and altitude. It is installed on all fighters as one of the components of its standard equipment.

Operation of Electric Circuit

The speedobarograph (ref. No. 2K) is put into operation by turning on the circuit breaker (ref. No. 10Y) and switch (ref. No. 4K).

The power supply necessary to energize the speedobarograph is fed to its connector terminal 2 and therefore to the electromotor and timer (ref. No. 2K) from the circuit breaker (ref. No. 10Y) through terminal 2 of the connector of the filter (ref. No. 10K); the electromotor and the timer start to operate.

The electric heating is controlled automatically by means of a bimetallic thermoregulator when the power is fed from the circuit breaker (ref. No. 10Y) through terminal 3 of the connector of filter (ref. No. 10K) to terminal 3 of the speedobarograph (ref. No. 2K).

25. POWER SUPPLY SYSTEM OF CAMERA ATTACHMENT P-115

General

Camera attachment P-115 is designed for taking pictures of the radar indicator screen.

When employed in the intermittent mode the camera attachment takes 1 picture in 2.5 sec. and when operating as a cinecamera it takes 8-10 pictures every second.

These modes are ensured by synchronizer P-111 included in set P-115.

The D.C. consumers in the camera attachment are the electromotors in units P-115 and P-111, as well as the heating and control circuits.

Operation of the camera attachment is performed by the devices listed in the Table below.

Nos	Ref. No. in circuit diagram	Description	Type	Qnty	Installation place
1	8K	CAMERA ATTACHMENT circuit breaker	АЗС-5	1	Horizontal electric board of right-hand console
2	9K	Relay	ТКЕ21ПДТ	1	Relay box in cockpit, between frames Nos 6 and 7, starboard
3	22П	Circuit breaker	АЗС-5	1	Rear electric board of right-hand console
4	13П	Button	204К	1	Aircraft control stick
5	51Ш	Relay	ТКЕ56ПД	1	Relay box in cockpit, frames Nos 6 and 7, starboard
6	173	Relay	ТКД12ПД	1	Relay box in cockpit, upper left-hand board of instrument panel

Operation of Electric Circuit

When the circuit breaker (ref. No. 8K) is turned on, the power is fed to the heating and control circuits of the camera attachment through terminal 1 of connector Ш53. When the HIGH signal is received from the radar station, the camera attachment starts to operate in the intermittent mode.

When the combat launching button is depressed (ref. No. 13П), the positive voltage is fed from the energized circuit breaker (ref. No. 22П) to the relay (ref. No. 9K) through contacts 13-14 of the relay (ref. No. 51Ш).

The relay (ref. No. 9K) operates and its contacts 2-3 feed the positive voltage from the circuit breaker (ref. No. 61P) to terminal 2 of connector Ш53.

As soon as this signal from the relay (ref. No. 9K) and the HIGH signal are received, the camera attachment starts to operate as a cinecamera.

When the combat launching button (ref. No. 13П) is released, the relay (ref. No. 9K) becomes deenergized and removes the positive voltage from terminal 2 of connector Ш53 by contacts 2-3. As a result, the camera attachment starts to operate in the intermittent mode.

With the circuit breaker (ref. No. 8K) turned off the camera attachment stops operating.

C O N T E N T S

САМОЛЕТ

МиГ-21ФЛ

Техническое описание
книга IУ
авиационное оборудование

Ч А С Т Ь I

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AIRCRAFT МиГ-21ФЛ

BOOK IV

PART II

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AIRCRAFT МиГ–21ФЛ

TECHNICAL DESCRIPTION

BOOK IV

ELECTRICAL AND OXYGEN EQUIPMENT AND FLIGHT INSTRUMENTS

PART II

Technical Description of Aircraft MiG-21@I comprises five books:

Book I: Performance Characteristics

Book II: Armament

Book III: Construction

Book IV: Electrical and Oxygen Equipment and Flight Instruments

Book V: Radio Equipment

The second part of Book IV contains description of the oxygen equipment and flight instruments.

In the course of aircraft operation make use of the diagrams, operating and maintenance instructions delivered with the aircraft.

The book includes 76 pages.

Chapter I
GENERAL

The oxygen equipment and flight instruments ensure day and night flights in any weather conditions at all altitudes up to the service ceiling.

They ensure the following:

(a) orientation of the aircraft in space relative to the horizon and heading;

(b) checking the operation of the power plant;

(c) checking the operation of separate systems and units.

Besides, the equipment ensures the necessary living conditions for the pilot during high-altitude flights and at high load factors.

The flight equipment consists of:

(a) flight and navigation instruments;

(b) power plant control instruments;

(c) control instruments of separate systems and units;

(d) flight-and-directional and follow-up systems.

The oxygen equipment includes:

(a) oxygen equipment set (KKO) for providing the pilot with oxygen;

(b) anti-G system (MMV).

The most specific feature of the cockpit of this aircraft is the panoramic arrangement of the instrument panels and control boards (i.e. wherever possible they are turned through 90° with respect to the sighting line) and the illumination of the inscriptions and instruments at night with instrument-lighting lamps.

The arrangement of the equipment provides for proper internal and external observation from the pilot's seat and maximum convenience in using a great number of instruments in flight.

The levers, instruments and warning units are installed within easy reach zones and grouped according to their purpose and simultaneous application. The flight and navigation instruments are mounted on the central and left-hand portions of the instrument panel while the right-hand portion of the panel mounts the power plant (engine and fuel supply system) control instruments. The instrument panel periphery and the consoles carry the control instruments of separate systems and units.

To provide easy reading of instrument indications, the dials of some instruments are divided into coloured sectors indicating different operating conditions:

(a) blue sector means unlimited operation;

(b) yellow sector - caution! Short-time operation;

(c) red sector - operation at this rating is forbidden.

All the levers, buttons and switches that are used in emergency cases are painted red.

The sizes of the cockpit and the arrangement of the oxygen equipment and flight instruments ensure safe ejection of the pilot in case of emergency.

Chapter II

ARRANGEMENT OF EQUIPMENT IN COCKPIT

The pressurized cockpit is located between frames Nos 6 and 11.

All the flight instruments are installed on the instrument panel, left- and right-hand consoles and in places accessible for observation and control.

The instrument panel and middle board are mounted on special brackets in the plane of frame No. 7Б. The left-hand console is mounted along the port side of the cockpit between frames Nos 7Б and 10 and the right-hand console is mounted along the starboard of the cockpit between frames Nos 7Б and 10. The consoles are screwed to a steel tubular framework attached to the cockpit sides.

The instrument panel and middle board are painted black and the left- and right-hand consoles are painted grey.

The white vertical line in the middle of the instrument panel serves for setting the control stick in the neutral position in the roll plane.

1. INSTRUMENT PANEL

The instrument panel is installed in the plane of frame No. 7Б. It mounts the instruments that are more often used by the pilot in flight (they are flight and navigation instruments and engine control instruments). Their arrangement on the panel is shown in Fig. 1.

The instrument panel consists of three stamped panels: two side panels and the middle one. All three panels are installed on the common tubular framework. The framework is suspended through four-leaf rubber dampers from the brackets attached to frame No. 7Б.

The central portion of the panel is easily detachable. After four special nuts are unscrewed the panel may be drawn out and turned inside the cockpit; this gives access to the connectors, hose connections and instruments mounted behind the instrument panel.

If necessary the panel may be removed.

The consoles are attached to the steel framework with screws. The upper boards are rigidly secured through the brackets to the fuselage structure between frames Nos 7 and 7Б to the left and right of the instrument panel. From the rear side the boards are protected with casings.

Under the instrument panel the tubular framework mounts the middle board. Its stamped panel is attached to the framework with four screws. The framework in its turn is rigidly secured to the central control unit.

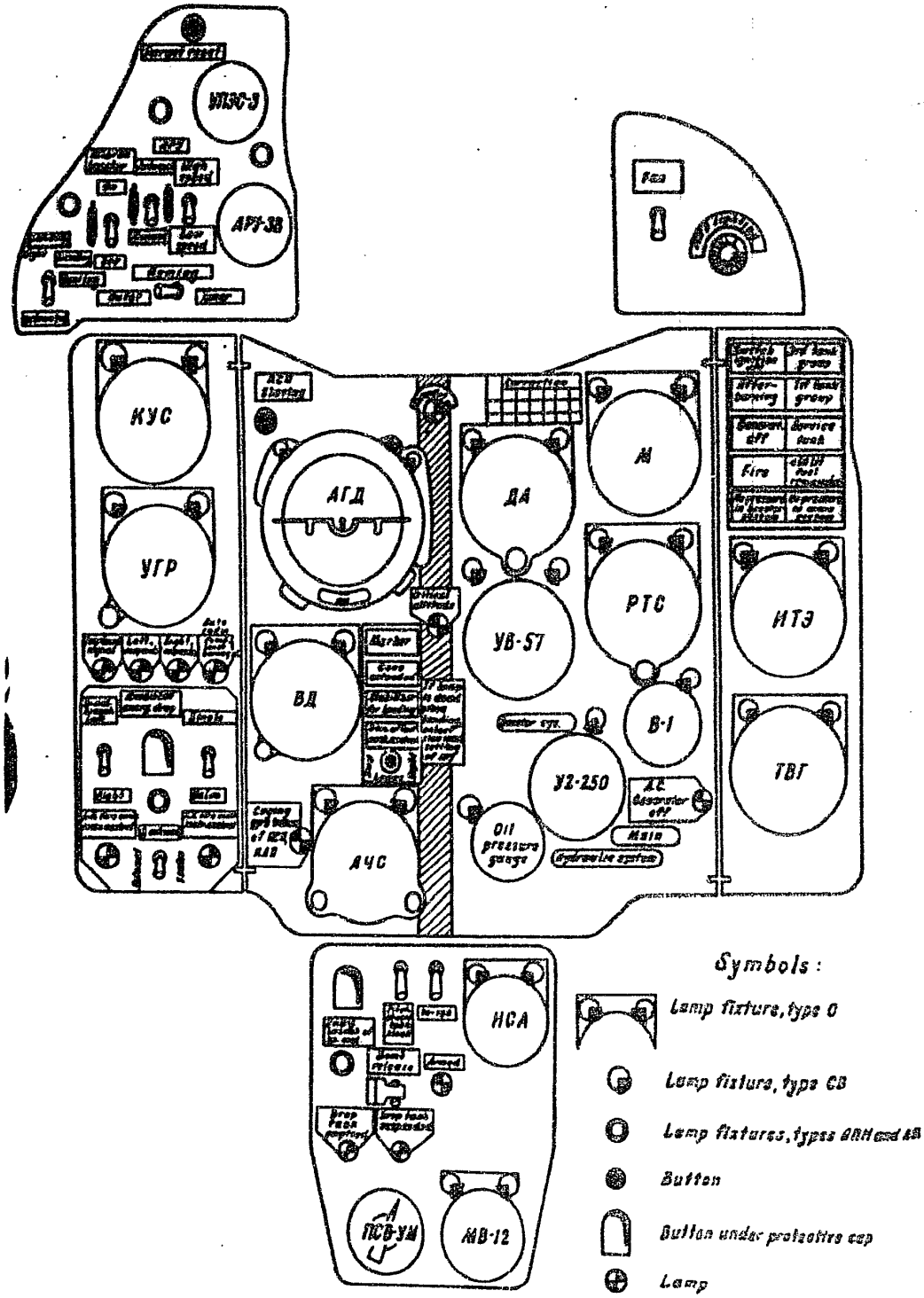

FIG.1. INSTRUMENT PANEL

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There is a clearance between the instrument panel and the middle board to prevent them from contacting.

2. LEFT-HAND CONSOLE

The left-hand console is located along the port side of the cockpit between frames Nos 7Б and 10 (Fig. 2).

The console consists of the vertical and horizontal portions.

The left-hand console mounts the switches, buttons, levers and other devices which are more often used by the pilot in flight. Located within easy reach are: the engine control lever with buttons for switching on the communication radio station and extending the air brakes, the landing gear extension and retraction valve, flaps extension board, oxygen equipment set control units, drag chute dropping and release buttons, seat control switch, navigation instruments control switch, engine control units, etc.

The console includes vertical and horizontal panels, electric boards and control boards.

All the equipment of the panel is mounted on the steel framework rigidly secured to the fuselage structure along the frames (between frames Nos 7Б and 10).

To give an access to oxygen equipment КП-34 and pressure regulator АД-5А, the rear vertical panel is made easily detachable, with spring locks. All the other panels are secured with screws.

In the area where the console neighbours the instrument panel (between frames Nos 8 and 7Б) the vertical panel faces the pilot.

3. RIGHT-HAND CONSOLE

The right-hand console is located along the starboard of the cockpit between frames Nos 7Б and 10 (Fig. 3).

It mounts the devices which are rarely used by the pilot in flight and do not need any special adjustment during their operation (mostly they are switched on and adjusted on the ground).

The console includes the vertical and horizontal portions.

The front portion of the console mounts a group of boards with radio equipment controls and its rear portion carries a group of boards with circuit breakers, switches, fuses and buttons.

The rear electric board is protected with a hinged transparent cover (made of organic glass) so as to prevent the switches and circuit breakers from accidental switching in flight.

As in the case with the left-hand console the panels, boards and circuit breaker boxes are mounted on a tubular steel framework that is rigidly secured to the brackets along frames Nos 7Б, 8, 9 and 10.

All the elements installed on the framework are secured with screws.

In the area where the console neighbours the instrument panel (between frames Nos 8 and 7Б) the vertical panels and radio control boards face the pilot.

4. CONTROL STICK

The control stick (Fig. 4) mounts the following elements:

(a) L.G. wheel brake control lever;

(b) drop tank release button;

(c) firing button;

(d) target lock-on button;
(e) stabilizer trimming effect mechanism control switch;
(f) stabilization-on button of roll stabilization autopilot KAP-2 (black);
(g) stabilization-off button of roll stabilization autopilot KAP-2 (red).

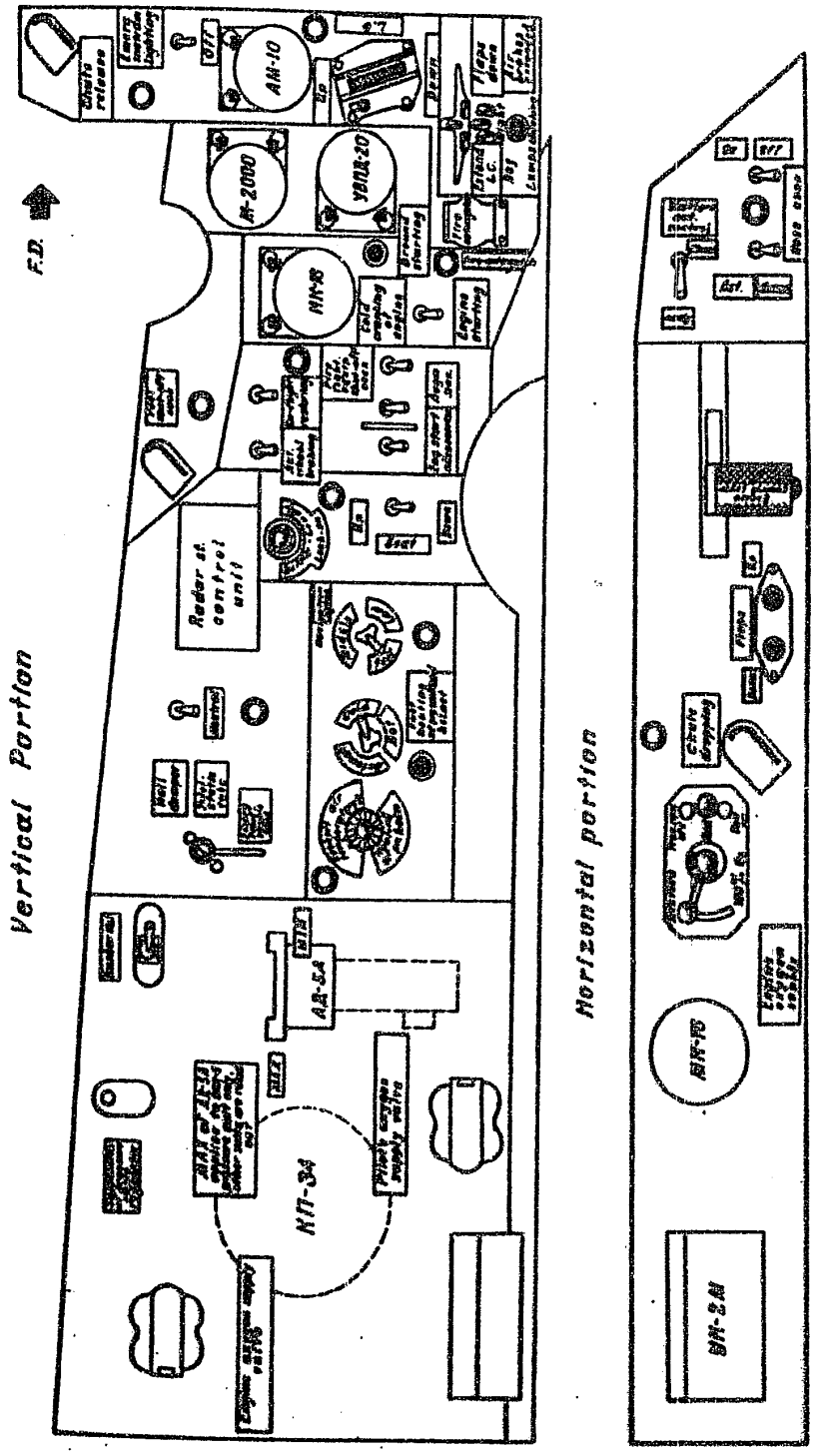

FIG. LEFT-HAND CONSOLE

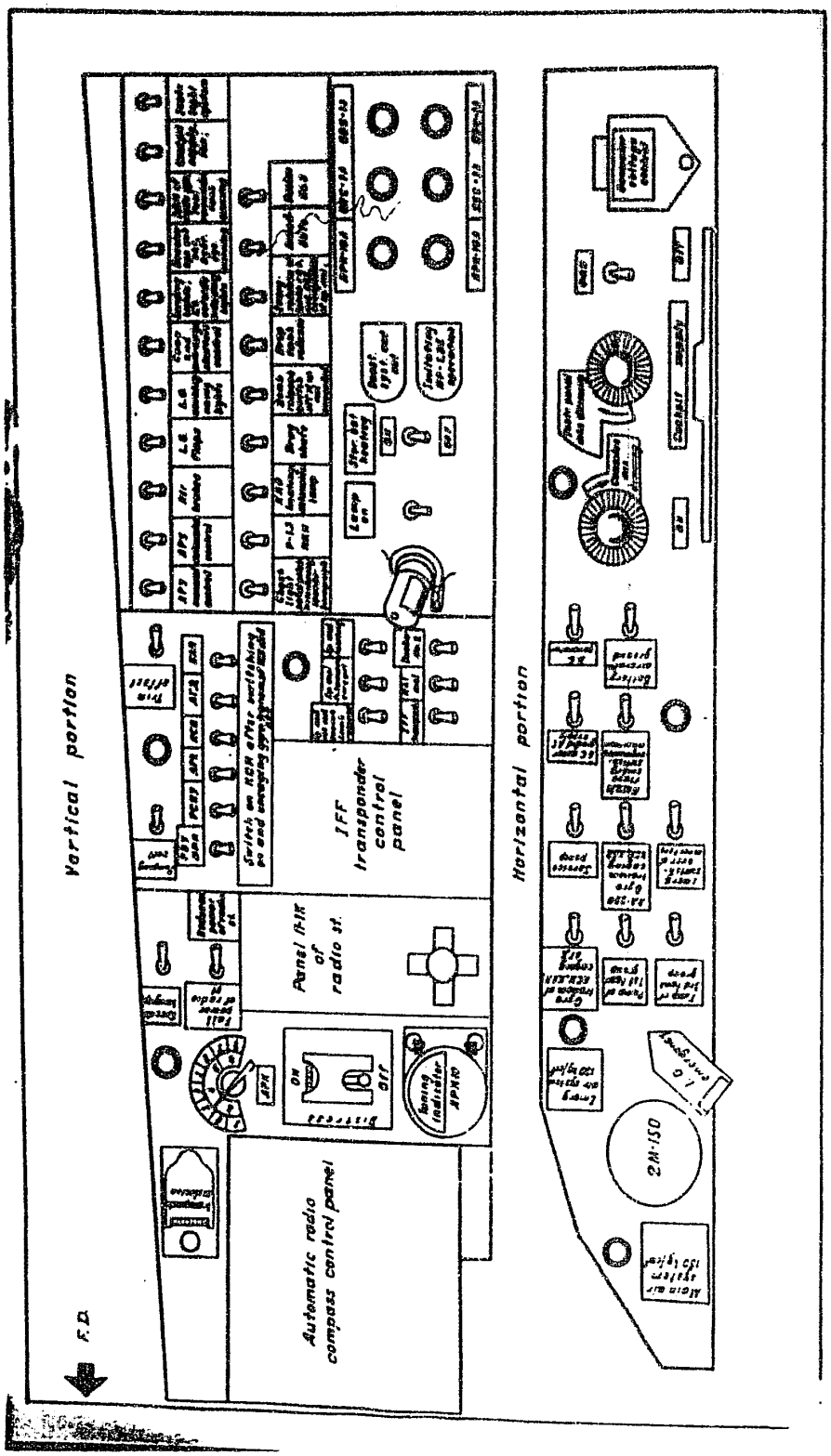

FIG. 9. RIGHT-HAND CONSOLE

Chapter III
INSTRUMENT-LIGHTING SYSTEM

The aircraft cockpit is equipped with instrument-lighting system. All the inscriptions, dials and pointers of the instruments are painted with white enamel.

The instrument dials are illuminated with light fixtures, types C60, C80 and CB. Light fixtures АГН and АГВ are designed for illumination of the gyro horizon indicator.

To illuminate the inscriptions made on the instrument panel and consoles at night, provision is made for illumination units with the light fixtures, types АПН and АПВ (low and high light fixtures) fitted with red light filters and lamps CM-37. The design of the light fixtures is illustrated in Fig. 5.

An illumination unit consists of a transparent cover made of organic glass, 2-3 mm thick, with the inscriptions engraved from the rear side and painted white. The ends of the cover are coated first with white enamel and then with black enamel so as to reduce light losses.

The rear side of the transparent cover is protected with a panel made of organic glass, 1 mm thick. The front side of the cover is also protected with a false panel, 0.5 mm thick, with windows for inscriptions. The panels on which the inscriptions are made are painted black so as to make them quite discernible in the daytime.

The instrument-lighting system is divided into three groups:

Group I - illumination of the instrument panel except the armament board and the middle board; the lights are turned on and adjusted with the help of INSTR. PANEL MIN. DIMMING rheostat РКИ-45 installed on the right-hand console.

Group II - illumination of the left- and right-hand consoles, armament board and upper boards of the instrument panel; the lights are turned on and adjusted by CONSOLES MIN. DIMMING rheostat РКИ-45 installed on the right-hand console.

Group III - emergency illumination of the flight and navigation instruments installed only on the instrument panel, as well as the tachometer indicator, temperature gauge, fuel flowmeter and pressure gauge 23АМИ-250А and integrating ampere-hour meter МСА-К. The lights are turned on by means of the switch installed on the left-hand console in the front upper portion.

Groups I and II are fed through the circuit breakers on the right-hand console and group III is fed through a fuse.

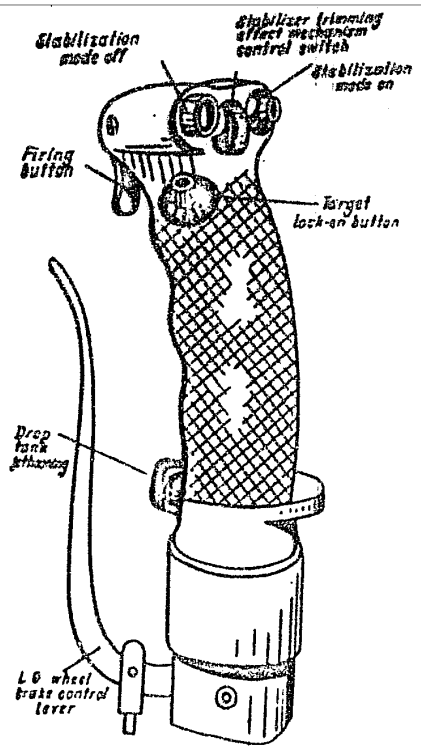

FIG.4. CONTROL STICK

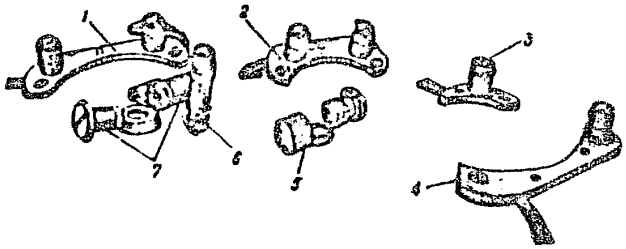

FIG.5. LIGHT FIXTURES

1 – light fixture C80; 2 – light fixture C60; 3 – light fixture AIII; 4 – light fixture AIII; 5 – light fixture AIII, 6 – light fixture, type C8; 7 – light fixture AIII.

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Chapter IV

FLIGHT AND NAVIGATION INSTRUMENTS

The flight and navigation instruments serve to correctly and fully utilize the aircraft performance.

The flight and navigation group of instruments controls the position of the aircraft in space relative to the earth (horizon) and ensures its orientation during day and night flights on a route in any weather conditions at all altitudes up to the service ceiling.

The group includes the following instruments:

(a) two-pointer airspeed indicator КУС-2500-К;
(b) Mach-number indicator М-2.5-К;
(c) two-pointer altimeter ВД-28;
(d) standby gyro horizon АА-200;
(e) accelerometer АМ-10К;
(f) radio altimeter indicator УВ-57 (set РВ-УМ);
(g) aircraft clock АЧС;
(h) gyro horizon АГК-1;
(i) fighter directional system КСМ-2.

Operation of the above mentioned instruments is based on the following principles:

(a) gyroscopic principle (ability of a gyroscope to keep the position of the spinning axis unchanged and be precessed under the action of the torque applied to the spinning axis); this principle is utilized in the gyro horizon, the turn and bank indicator and in the gyro unit of the fighter directional system;

(b) aneroid principle (deformation of a welded diaphragm capsule due to a change in the atmospheric pressure); the principle is utilized in the altimeter, the instruments used for introduction of altitude corrections and in altitude transmitters;

(c) manometric principle (deformation of the elastic diaphragm capsule due to delivery of impact pressure into it); this principle is utilized in the speed indicator, Mach-number indicator, controller АРУ, Mach-number transmitter, vertical-velocity indicator, etc.;

(d) mechanical principle (deflection of weights, deflection of the pendulum due to the inertia forces in turning flight); the principle is used in the accelerometer, slip indicator, etc.;

(e) magnetic principle (interaction of permanent magnets with the Earth's magnetic field); the principle is employed in the fighter directional system.

Besides, the flight and navigation instruments make use of the remote-indicating electric systems the signals of which are transmitted through selsyns and of the balance bridge principle.

1. TWO-POINTER AIRSPEED INDICATOR KVC-2500-K

The two-pointer airspeed indicator (Fig. 6) is designed for measuring the indicated airspeed of the aircraft (by means of the wide pointer) within the range from 200 to 1600 km/hr and the true airspeed (as indicated with the narrow pointer) within the range from 400 to 2500 km/hr at the flight altitudes from 0 to 25 km.

The sensitive element of the instrument is the diaphragm assembly measuring the difference between the total and static pressures in flight. The inner chamber of the diaphragm assembly is connected with the total pressure connection while its airtight case communicates with the air static system. Besides, the indicator case houses an aneroid cell that introduces a measurement error correction for the air density while determining the true air speed.

The rear wall of the instrument is provided with two connections having indexes C (static) and Д (dynamic) for connecting the instrument to the respective lines of the Pitot-static tube system. The indicator is installed on the instrument panel.

2. MACH-NUMBER INDICATOR

Mach-number indicator M-2.5-K (Fig. 7) is designed for measuring the ratio of the true airspeed to the sonic velocity (at the given altitude):

$$M = \frac{v}{a}$$

where, v - the speed of aircraft flight in m/sec.,
a - the sonic velocity in m/sec.

The sensitive element of the instrument is the diaphragm capsule which measures the difference between the total and static pressures, counting for an air density measurement error correction. The correction table is attached to the panel near the instrument.

The rear wall of the airtight case is provided with two connections with indexes C (static) and Д (dynamic) which serve for connecting the instrument to the static and total-head pressure lines of the Pitot-static tube system.

3. TWO-POINTER ALTIMETER BД-28

Two-pointer altimeter BД-28 (Fig. 8) with the dial range from 0 to 28,000 m. is intended for determining the relative altitude of aircraft flight relative to the take-off and landing site or any other point in which the barometric pressure is known.

The sensitive element of the altimeter is an aneroid capsule. When the aircraft climbs, the static (atmospheric) pressure drops and the elastic diaphragms of the aneroid expand (and vice versa, when the aircraft descends the diaphragms converge). These variations in pressure are transferred through the multiplying gear mechanism to the altimeter pointers. The larger dial indicates the altitudes within the range from 0 to 1000 m. while the smaller dial indicates the altitudes within the range from 0 to 28 km. The airtight case is connected with the static line of the Pitot-static tube system through connection C on the instrument rear wall.

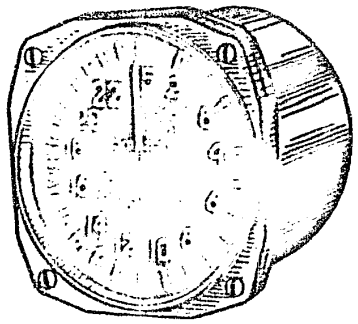

FIG. 6. TWO-POINTER AIRSPEED INDICATOR [illegible]

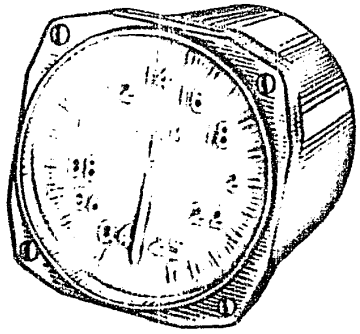

FIG. 7. MACHMETER [illegible]

The lower face part of the altimeter has a window with a movable dial of barometric pressure corrections in mm of mercury. The dial is turned by means of a rack-and-pinion.

4. STANDBY GYRO HORIZON

Combined instrument AA-200 (Fig. 9) is comprised of three independent instruments: vertical-velocity indicator, turn indicator and slip indicator.

The instrument is designed for:

(a) measuring the vertical speed at which an aircraft is gaining or loosing altitude (its sensitive element is the diaphragm capsule placed in the airtight case communicating with the atmosphere through capillary holes);

(b) indicating the turn of the aircraft about its vertical axis or for making a correct turn with the bank of 45^0 (its sensitive element is a rate gyroscope whose spinning axis is parallel to the aircraft pitch axis);

(c) indicating the side slip (its sensitive element is the ball in the conv glass pipe filled with damping liquid).

In cases of failure of gyro horizon AGK the standby instrument may be used instead of it.

The connection with index C (static) on the instrument case serves for connecting the instrument to the Pitot-static tube system.

The power supply necessary to energize the gyro motor of the turn indicator taken from inverter PAP-14 producing three-phase current of 36 V, 400 c.p.s.

5. ACCELEROMETER AM-10K

Accelerometer AM-10K (Fig. 10) is an instrument which indicates the positive and negative accelerations acting upon the aircraft at a direct angle with respect to the wing surface. Such accelerations occur in the aircraft while executing aerobatics manoeuvres and especially when entering and pulling up from a dive.

The accelerations indicate how many times the stress in the framework materi is increased in comparison with the stress during level flight when the weight of an airplane is equal to one pull of gravity. The accelerometer does not measure the accelerations relative to the roll and pitch axes.

The measurement unit is the gravity acceleration equal to 1 g (981 m/sec^2). The instrument is designed to measure acceleration within a range from -5 to +10 When the aircraft is on the ground, the instrument pointer reads +1 g and during its flight in the null-gravity condition the pointer comes to read zero.

The rear panel of the instrument has a cage. After a new instrument has been installed it should be uncaged. To do this, unscrew the plug, drive out the cage with a screw-driver as far as it will go and then, screw on the plug in its place.

During operation protect the instrument from axial shock overloads.

6. AIRCRAFT CLOCK AMC
(Fig. 11)

The clock is designed to show the present time in hours, minutes and seconds measure the time of flight in hours and minutes and to measure short periods of time up to one hour in minutes and seconds.

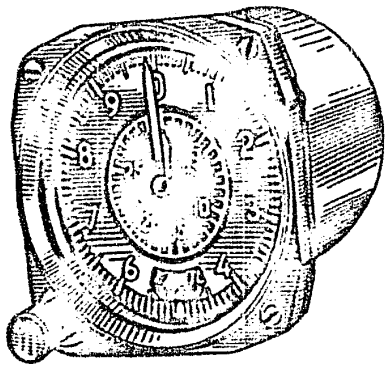

FIG.8. TWO-POINTER ALTIMETER RI-23

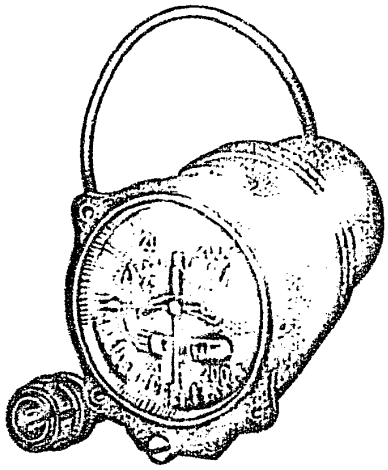

FIG.9. STANDBY GYRO HORIZON

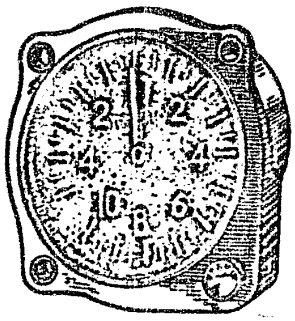

FIG. 10. ACCELEROMETER AN-1CX

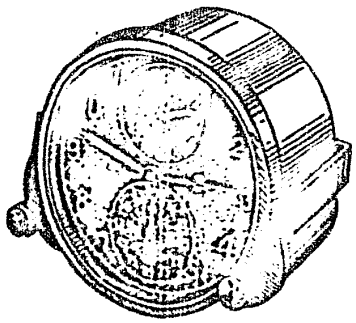

FIG. 11. AIRCRAFT CLOCK AN-

The clock is provided with an electric heater and a thermoregulator keeping the temperature inside the clock at the level of +20°C ±5°C at low ambient air temperature.

The heater ensures normal operation of the clock at a temperature below +15°C. It is fed with D.C. voltage of 27 V ±10%.

The thermoregulator cuts out the heater when the ambient air temperature rises above +25°C, thus protecting the mechanism from overheating with the heater being connected to the circuit. The heater is cut in by the PITOT-STATIC TUBE, CLOCK circuit breaker.

The clock is actuated by a standard spiral spring. When fully wound the spring keeps the clock running for 72 hours without rewinding. To ensure the required precision of the clock, it should be wound once in 48 hours.

The clock is mounted on the instrument panel with the aid of a clasp secured to the rear part of the case with two nuts.

Chapter V

SUPPLY SYSTEM OF ANEROID-AND-DIAPHRAGM ACTUATED INSTRUMENTS

The supply system of the aneroid-and-diaphragm actuated instruments is designed to supply the aneroids and diaphragm assemblies of the navigation instruments with the static (atmospheric) and total-head (dynamic) pressures. Its key diagram is shown in Fig. 12.

The necessary pressure is fed from Pitot-static tube ПВД-7. The tube is mounted on a special rod in the fuselage upper nose section, i.e. in the zone of undisturbed air flow. The end of the tube is provided with a total-head-pressure intake and its upper and bottom sides have three groups of 1 mm static-pressure holes (ten holes in a group). The rear end has connections marked C_1, C_2, C_3 (static) and П (total) which serve for connecting the tube with the respective supply lines.

Besides, the rear end has a wire bundle for connecting the Pitot-static tube heater to the aircraft mains. The heater is cut in by turning on the PITOT-STATIC TUBE, CLOCK circuit breaker installed in the cockpit. Its power consumption is about 6 A. All the elements (wire bundle, rubberized hoses) running from the tube are passed through the tube rod.

During operation see to it that the tube surface is free from scores, burrs and dents. Any minor defect on its surface interferes with the normal air flow which causes redistribution of air pressure in the static pressure intake zones thus introducing errors in the instrument readings.

In addition to the main Pitot-static tube the aircraft has emergency Pitot tube ТП-156М installed in the upper right portion of the fuselage between frames Nos 4 and 5. The Pitot tube can be connected to the Pitot-static tube line by the cock installed on the left-hand console in the cockpit.

The emergency Pitot tube is also electrically heated by the heater the switching of which is provided by PITOT-TUBE circuit breaker installed in the cockpit.

The supply lines are made of metal tubes and those sections of the line feeding the pressure to the instruments under the instrument panel are made of rubber hoses.

Some instruments use only static pressure (they are altimeter, cabin altimeter, vertical velocity indicator, altitude transmitters, etc.), others utilize both static and total-head pressures (airspeed indicator, Mach-number indicator, computer of controller АРУ-3В, etc.).

To protect the static and total-head pressure lines from moisture provision is made for drain arrangements.

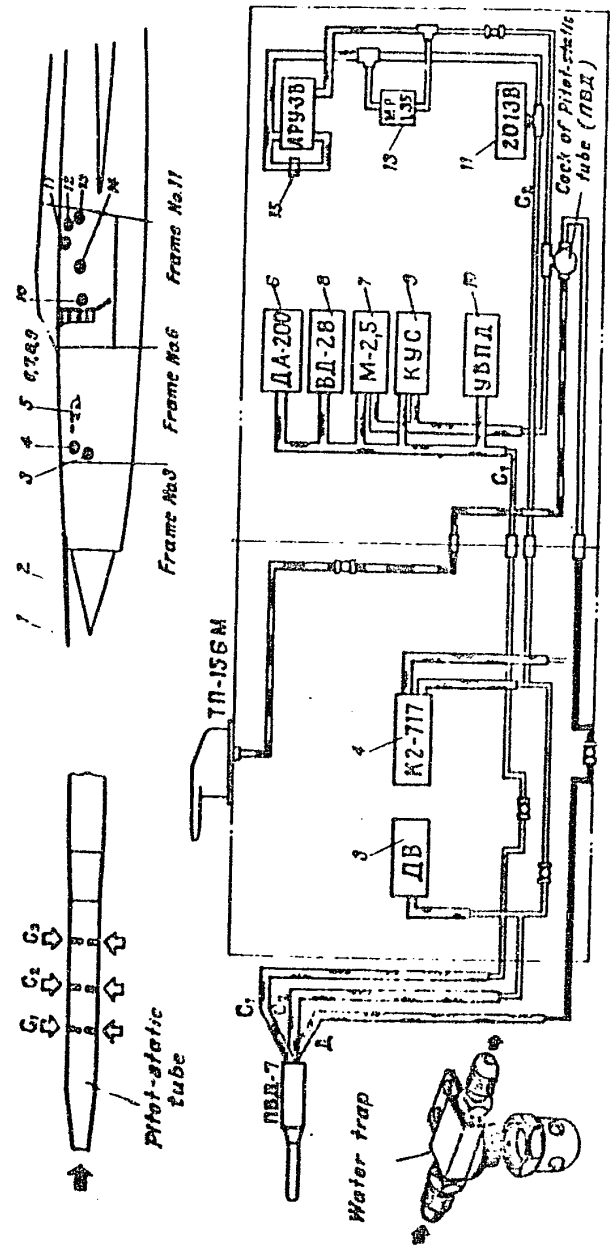

FIG.12. SUPPLY SYSTEM OF AEROID-AND-DIAPHRAGM ACTUATED INSTRUMENTS

1 – Pitot-static tube; 2 – rod; 3 – altitude transmitter ТП; 4 – speedohengraph КЗ-717; 5 – emergency Pitot tube ТП-156М; 6 – standby gyro horizon; 7 – Mach-number indicator; 8 – altitude indicator; 9 – speed indicator; 10 – cabin altimeter; 11 – cabin pressure controller; 12 – control unit of controller АУУ-ЭП; 13 – Mach-number warning unit МР-1,35; 14 – valve to switch over pressure supply from Pitot-static tube to Pitot tube; 15 – split connection for ground check of controller УУ-ЭП.

Such arrangements usually include moisture traps for the main and emergency Pitot tubes installed in the well of the front L.G. strut and one more moisture trap is installed in the total-head pressure line of controller AFV on frame No. 11 in the cockpit.

Prior to starting the engine drain all the moisture from the traps. The design of the trap is illustrated in Fig. 12.

In the static pressure supply line of controller AFV provision is made for a connector to check the unit on the ground.

The total-head pressure supply line is painted black and the static pressure one is painted grey.

The line tubes are attached to the fuselage structure by means of blocks arranged in groups.

The system is checked for air tightness and serviceability of instruments in compliance with the operating instructions.

Chapter VI
ENGINE INSTRUMENTS

The instruments are designed for checking the r.p.m. of the turbo-jet engine, the temperature of the exhaust gasses at the turbine outlet, the fuel consumption and the pressure of oil in the turbo-jet engine.

The light panel provides signalling of proper operation of the fuel pumps of the tank groups, warns about fire, remaining emergency fuel level, cutting in of the augmented rating, etc.

The group includes:

(a) electrical remote-indicating tachometer MT3-2;

(b) exhaust-gas temperature gauge TBT-190;

(c) fuel flowmeter PTC16A-4;

(d) electrical remote-indicating induction pressure gauge AKM-67K;

(e) light panel T-10Y2.

All the above mentioned instruments are electrically connected with their transmitters.

1. TACHOMETER MT3-2

Electrical remote-indicating tachometer MT3-2 is designed for continuous measurement of the r.p.m. of the high and low pressure rotors (Fig. 13).

The instrument is a dual magnetic induction tachometers.

The set includes two transmitting generators MT3-1 producing A.C. three-phase current whose frequency is proportionate to the r.p.m. of the turbo-jet engine shafts and dual indicator MT3-2, a magnetic induction instrument the readings of which are proportional to the frequency of the supplied current.

The dual indicator consists of two similar units mounted in one case.

The dial of the indicator has two pointers mounted on one shaft (for the low pressure rotor and high pressure one).

Readings are red from the dial graduated in per cent of the maximum speed; 100% corresponds to the MAXIMUM rating. The dial is divided into equal divisions from 0 to 110%.

The indicator is installed on the right side of the instrument panel. It is secured to the panel by four screws with self-locking nuts in the flange of the indicator.

The transmitters are mounted on the turbo-jet engine.

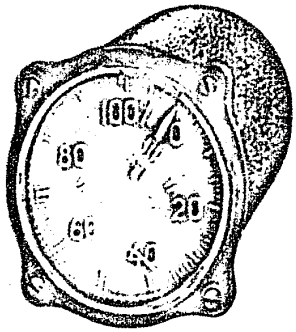

FIG.13. TACHOMETER ITT-2

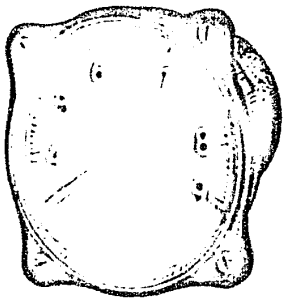

FIG.14. INDICATOR TIP-1

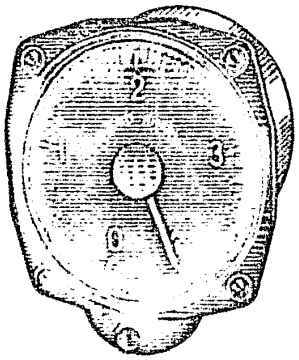

FIG.15. FUEL FLOWMETER FIC16A-1

The transmitters are connected with the indicator through bundle wires feeding a three-phase current from the transmitters to the indicator.

2. EXHAUST-GAS TEMPERATURE GAUGE ТВГ-190

Temperature gauge ТВГ-190 (Fig. 14) is designed for measuring average temperature of the exhaust gases at the turbine outlet.

The set consists of electromagnetic millivoltmeter ТВГ-1 (indicator), four series-connected thermocouples Т-90 and a junction box.

The dial of indicator ТВГ-1 is graduated within the range from 300°C to 900°C with a division value of 1°C and the operating range being from 450° to 750°C.

The temperature gauge operates on a thermoelectrical principle when the e.m.f. (current) is created as a result of heating a junction of two different metals.

The indicator is mounted on the instrument panel and is attached to it by four screws with self-locking nuts in the instrument flange.

The indicator dial has coloured marks limiting the working range of the dial.

Four series-connected thermocouples Т-90 (transmitters) are mounted at the outlet of the turbo-jet engine between frames Nos 30 and 31. The thermocouples are connected with the indicator through a wire bundle (having certain ohmic resistance) through a junction box installed in the upper portion of the fuselage between frames Nos 30 and 31.

During service period special attention should be paid to the quality of the wire insulation and their resistance. The mating part of the indicator connector is provided with an adjustment resistor. Temperature gauge ТВГ-190 is not connected to the aircraft mains therefore it starts to operate as soon as the turbo-jet engine is started.

3. FUEL FLOWMETER РТС16А-4

Summation fuel flowmeter РТС-16А-4 measures the amount of fuel delivered to the engine through a transmitter. The flowmeter indicator shows the fuel remainder in the aircraft tanks provided the fuel supply lines are in good operating condition.

The indicator dial is graduated in litres from 0 to 4000 lit. with the dial division being equal to 100 lit. Before the flight the indicator pointer must be set by means of a rack-and-pinion against the division corresponding to the amount of fuel filled into all tanks of the aircraft. To obtain the amount of fuel in weight units (in kilograms) it is necessary to multiply the measured volume in litres by rated fuel density (i.e. by its specific gravity).

The flowmeter set consists of:

(a) indicator РТС16А-4 (Fig. 15);

(b) induction transmitter РТС16А;

(c) thyratron breaker ПТ-56М.

The indicator is installed on the instrument panel in the cockpit and is attached to it by four screws with self-locking nuts in the instrument flange.

The pulse induction transmitter is mounted in the line feeding the fuel from the service tank to the turbo-jet engine - in the lower portion of the line between frames Nos 20 and 22.

The thyratron breaker is installed in the upper right-hand portion of the fuselage between frames Nos 11 and 12.

The instrument operates on 115 V, 400 c.p.s. from inverter ПО-750А.

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4. OIL PRESSURE GAUGE MM-8TK

Electrical remote-indicating induction pressure gauge MM-8TK is designed for measuring the oil pressure in the turbo-jet engine lubrication system.

Its set includes:

(a) indicator MM1-8K (Fig. 16);

(b) transformer TP-115/36;

(c) induction transmitter MAT-8;

(d) connecting cable.

The pressure gauge can measure the pressure within the range from 0 to 8 kg/sq.cm. with the 8 kg/sq.cm. The indicator is respectively graduated from 0 to 8 kg/sq.cm. with the division value being equal to 0.5 kg/sq.cm. In addition to it the indicator dial has several coloured marks within the following ranges: 0-2.5 red, 2.5-3 yellow, 3-4 blue and 4-8 red.

The indicator is installed on the instrument panel and the transmitter on the turbo-jet engine. Transmitters and indicators of different sets are interchangeable.

The pressure gauge is supplied with the voltage of 36 V, 400 c.p.s. From inverter PO-750A the voltage of 115 V, 400 c.p.s. is applied to the primary winding of transformer TP-115/36 the secondary winding of which generates the voltage of 36 V, 400 c.p.s.

5. LIGHT PANEL T-10V2

Light panel T-10V2 (Fig. 17) is designed to indicate that:

(a) power supply is fed to the turbo-jet engine ignition coils. The SWITCH IGNITION OFF indicating lamp under a red light filter goes out after the ignition is switched off with the starting of the turbo-jet engine;

(b) engine is operating at the augmented rating. The AFTERBURNING green indicating lamp lights up after the electromagnetic valve of the afterburner fuel pump has operated and goes out as the fuel flow into the afterburner is discontinued;

(c) generator PCP is OFF. The GENERATOR OFF red indicating lamp lights up as soon as the turbo-jet engine has stopped or the generator has failed;

(d) temperature in the vicinity of the turbo-jet engine afterburner has risen above the normal level. The FIRE red indicating lamp lights up as soon as the signal is received from ionization warning unit MC-2MC;

(e) pressure in the main and booster hydraulic systems has dropped. Two yellow indicating lamps with inscriptions NO PRESSURE IN BOOSTER SYSTEM and NO PRESSURE IN MAIN SYSTEM light up as soon as the pressure has dropped below 165^{+10}_{-5} kg/sq.cm. and go out if the pressure rise exceeds 12 kg/sq.cm.;

(f) fuel remainder in the tanks is below the normal level. The 450 LIT. REMAINDER red indicating lamp lights up from float-type transmitter CO-1637H when the remaining fuel is below the level of 450 lit.;

(g) pump of the service tank has failed. The SERVICE TANK red indicating lamp lights up from pressure warning unit CA-3 if the fuel pressure has dropped at the pump outlet (either the pump is defective or no fuel is left in the tank);

(h) pressure has dropped at the pump outlet of the 1st group of tanks. The 1st TANK GROUP green indicating lamp lights up from pressure warning unit CA-3 in case of failure of the pump or if no fuel is left in this group of tanks;

(i) pressure has dropped at the pump outlet of the 3rd group of tanks. The 3rd TANK GROUP green indicating lamp lights up from pressure warning unit CA-3 in the cases similar to those of the above mentioned lamp.

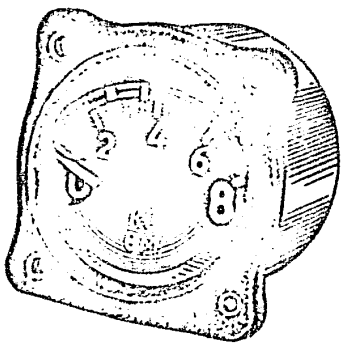


FIG.16. INDICATOR [illegible]

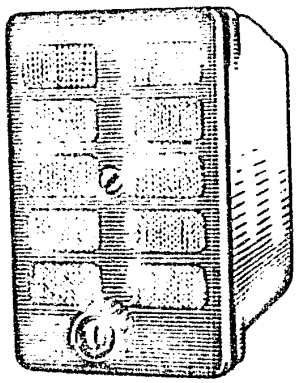


FIG.17. LIGHT PANEL T-[illegible]

The transmitters are not included into the set of the panel. The general view of the panel is given in Fig. 17.

To replace a defective lamp, type CM-30, proceed as follows:

(a) drive out two overset screws (in the upper and lower portions);

(b) remove the panel;

(c) holding the bulb depress the lamp, turn it to the left and remove the lamp;

(d) insert a new lamp;

(e) depress the checking button and if the lamps are sound install the front panel in its place. After that, depress the checking button once more.

Chapter VII

INSTRUMENTS FOR CHECKING SEPARATE SYSTEMS AND ACCESSORIES

This group of instruments is designed for checking: the position of the main landing gear, cabin altitude and differential pressure, capacity of the storage battery, pressure in the hydraulic and air systems, voltage in the aircraft mains and warning system.

The group consists of the following instruments:

1. L.G. light panel ППС-2МК.
2. Cabin altimeter УВДА-20.
3. Integrating ampere-hour meter ИСА-К.
4. Hydraulic pressure gauge 23ДИМ-250А.
5. Air pressure gauge 2М-150.
6. Air pressure gauge МВ-12.
7. Light panel Т-4У2.
8. Voltmeter В-1.

1. L.G. LIGHT PANEL ППС-2МК

The L.G. light panel (Fig. 18) is designed to indicate the position of the landing gear, flaps and air brakes as well as to warn the pilot about the necessity to extend the landing gear while landing.

The panel is installed between the left-hand console and the instrument panel.

Every position of the left, front and right legs of the landing gear is checked by means of a separate lamp.

Three red lamps within the contour of the miniature aircraft silhouette indicate that the landing gear is retracted. The lamps burn when the landing gear is retracted. Three green lamps under the aircraft contour indicate that the landing gear is extended. They burn with the fully extended landing gear. If all lamps under the aircraft silhouette are green except one which is red it means that all the legs are extended but one to which the red lamp corresponds. The same thing will happen when all legs are retracted but one which remains extended to which the green lamp corresponds.

The panel has three inscriptions:

(a) EXTEND L.G. indicating lamp under a red light filter reminding the pilot about the necessity to extend the landing gear burns due to operation of the limit switches when the flaps are being extended;

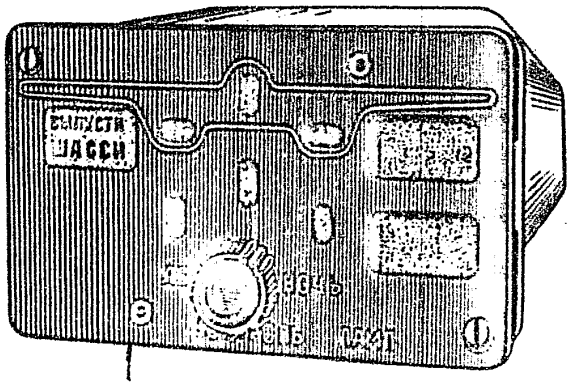


FIG.18. L.G. LIGHT PANEL IRC-2NK

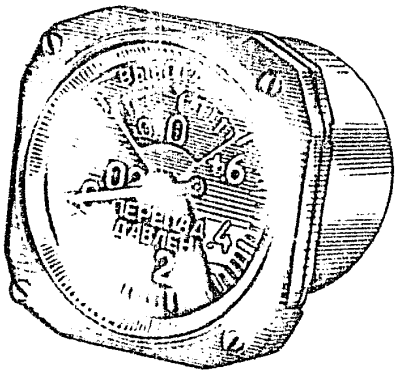


FIG.19. CABIN ALTIMETER TYPE I-23

(b) FLAPS DOWN - indicating lamp under a green light filter burns due to operation of the limit switches when the flaps are already extended;

(c) AIR BRAKES EXTENDED indicating lamp under a green light filter burns due to operation of the limit switches when the air brakes are in the extended position.

Besides, the face of the panel mounts a lamp checking button and a DAY-NIGHT shutter used for adjusting the light intensity of the lamps. The panel employs lamps, type CM-30.

To replace a defective lamp, repeat the operations prescribed for the light panel T-10T2.

2. CABIN ALTIMETER УВПД-20

Cabin altimeter УВПД-20 (Fig. 19) is designed for measuring the altitude in the pressurized cabin and the pressure difference between the pressure in the pressurized cabin and that of the atmosphere surrounding the aircraft.

The cabin altimeter is a combined instrument consisting of a cabin altitude indicator and a differential pressure gauge which are housed in one airtight case and operate independently. The sensitive element of the cabin altitude indicator is the aneroid capsule and that of the pressure gauge is the manometric diaphragm capsule (or the differential pressure gauge).

The face side of the instrument has two dials one of which is movable.

By the lower fixed dial and the pointer the differential pressure is indicated from -0.04 to +0.6 kg/sq.cm. (the division value being equal to 0.02 kg/sq.cm.).

The movable dial is observed through a window in the fixed dial and the altitude ranging from 0 to 20 km. is indicated against a stationary index with the division value being equal to 0.5 km.

The rear wall of the case has two connections. One of them is marked by C and connected to the static pressure line of the Pitot-static tube system while the other one is marked by A and is left open in the cockpit.

The instrument is installed on the left-hand console and is attached to the console by four screws with self-locking nuts in the instrument flange.

During operation regularly check the instrument and the static pressure hose for proper attachment.

3. INTEGRATING AMPERE-HOUR METER НСА-К

The integrating ampere-hour meter (Fig. 20) is designed for use with the aircraft electrical equipment and serves for indicating the capacity of one of the storage batteries.

The set includes: meter НСА-К and external shunt ННС. The shunt is connected in series with the negative circuit of the storage battery.

After a new storage battery is installed in the aircraft, the pointer is set against the initial capacity value by depressing and turning the rack-and-pinion with a special screw-driver.

Do not shift the pointer with the rack-and-pinion during operation till the storage battery is replaced.

The ampere-hour meter operates within the range from 3 to 1000 A. The guaranteed accuracy of the meter during one charge-discharge cycle is:

(a) 3% or better at the ambient air temperature of 20 ±10°C;

(b) 5% or better through the whole temperature range.

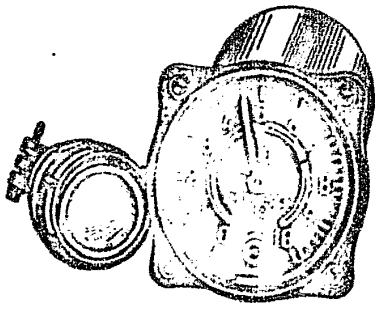


FIG.20. INTEGRATING AMPERE-HOUR METER

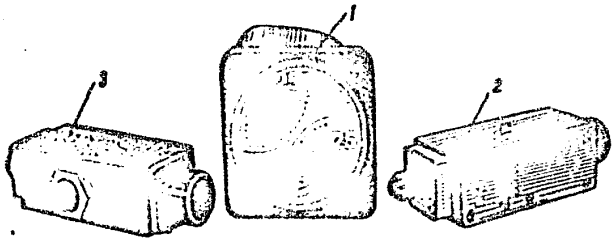


FIG.21. SET OF HYDRAULIC PRESSURE GAUGE 22.3404-3804
1 – two-pointer indicator 22.3404; 2, 3 – transmitters 22.3450/250.

The resistance of a pair of wires connecting the meter with the external shunt should not exceed 0.08 ohm.

The meters and shunts from different sets of equipment are respectively interchangeable.

Do not disassemble the meter during operation. In case of failure replace it by a new one.

4. HYDRAULIC PRESSURE GAUGE 23ИМ-250А

Electrical remote-indicating pressure gauge 23ИМ-250А (Fig. 21) is designed for measuring the pressure of the hydraulic mixture in the booster and main hydraulic systems of the aircraft.

The set includes:

(a) two-pointer indicator У2-250А;

(b) two transmitters ЭИП-50/250.

The indicator has two dials graduated from 50 to 250 kg/sq.cm. with the division value being equal to 10 kg/sq.cm. Besides, the dial has the coloured marks made within the following limits:

blue marks from 50 to 210 kg/sq.cm. and

red marks from 210 to 250 kg/sq.cm.

The indicator is installed on the instrument panel.

The potentiometric transmitters are installed in the main hydraulic line (in the right-hand well of the landing gear) and booster hydraulic line (in the left-hand well of the landing gear).

The transmitter is attached to the aircraft structure through a special threaded cylindrical bone and a fastening nut.

5. AIR PRESSURE GAUGE 2М-150

Double air pressure gauge 2М-150 is designed to measure the air pressure in the main and emergency air supply systems (Fig. 22). The pressure gauge can indicate the air pressure within the range from 0 to 150 kg/sq.cm.

The instrument consists of two separate mechanisms and two sensitive elements.

The operating principle of the pressure gauge is based on the elastic properties of the tubular spring when the pressure applied to it.

As soon as the pressure is applied to the connections, the tubular springs will become deformed. The motion will be transmitted through the links and sectors with pipes to the axles carrying the pointers. The deflection of the pointers depends on the amount of the pressure applied to the tubular spring.

The two-side dial is graduated from 0 to 150 kg/sq.cm. with the division value equal to 10 kg/sq.cm.

The pressure gauge is mounted on the horizontal portion of the right-hand console by means of a yoke and a coupling screw. The yoke is soldered to the console structure.

6. AIR PRESSURE GAUGE МВ-12

Air pressure gauge МВ-12 (Fig. 21) is designed for measuring the control air pressure in the braking system of the main landing gear when the braking lever on the aircraft control stick is depressed.

The air pressure gauge is mounted on the front board by means of a ring.

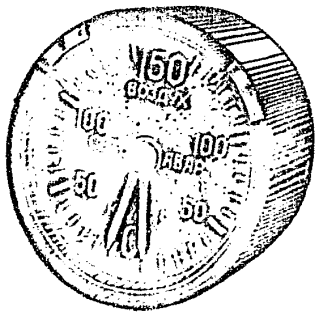


FIG.22. AIR PRESSURE GAUGE 2H-150

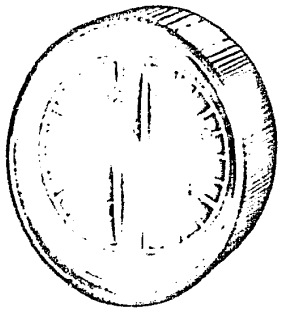
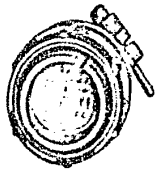


FIG.23. AIR PRESSURE GAUGE HB-12



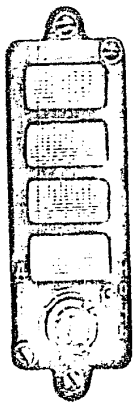


FIG.24. LIGHT PANEL T-432

The ring together with the instrument is secured to the board panel with three screws. The rear wall of the air pressure gauge has two connections supplying the pressure from the pipe lines. Operation of the pressure gauge is based on the elastic properties of the tubular spring to become deformed under the effect of the pressure created in its inner cavity. Deformation of the tubular spring is transmitted through a guide and gear train to a pointer which indicates on a dial the pressure in the air system to be checked.

Air pressure gauge MB-12 combines two separate pressure gauges mounted in one case.

Each pressure gauge has its own sensitive element, gear train, pointer and a dial. Both dials of the instrument are graduated from 0 to 12 kg/sq.cm. with the division value equal to 1 kg/sq.cm. With the foot-operated pedals in the neutral position (when the braking lever on the aircraft control stick is depressed),both pointers should read the same value.

7. LIGHT PANEL T-4V2

Light panel T-4V2 is installed on the instrument panel (Fig. 24). It includes four indicating lamps which operate from the respective transmitters as follows:

(a) when the aircraft flies over the marker radio station the MARKER indicating lamp under a red light filter lights up;

(b) when the cone is extended the CONE EXTENDED indicating lamp under a green light filter lights up;

(c) when the actuating mechanism of controller AFV-3B (big arm) is set for landing,the STABILIZER FOR LANDING indicating lamp under a green light filter lights up;

(d) when the trimming effect mechanism is in the neutral position,the TRIM. EFFECT MECH. NEUTRAL indicating lamp under a green light filter lights up.

The light panel is secured by two screws with self-locking nuts in the ears of the case. As soon as one of the transmitters operates the corresponding circuit becomes closed and a respective lamp lights up illuminating the indicating inscription.

The panel is connected to the transmitters through a relay which permits to check the serviceability of the lamps and at the same time to disconnect the transmitters from the panel. To do this, depress the LAMPS checking button on the face side of the panel.

The lamps, type CM-30, are replaced in the same way as those in light panel T-10V2.

8. VOLTMETER B-1

Voltmeter B-1 (Fig. 25) is designed to indicate the voltage in the aircraft mains. Its dial is graduated from 0 to 30 V with the division value equal to 1 V. The instrument indicates the voltage in the aircraft mains when the power supply switch on the right-hand console is turned on to feed the mains either from the airborne or ground supply source. The instrument is attached to the lower portion of the instrument panel with four screws.

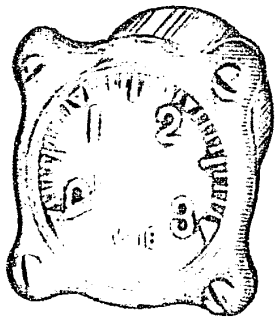


FIG.35. VOLTMETER B-1

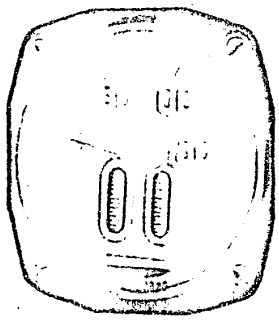


FIG.36. OXYGEN FLOW INDICATOR IIK-1BM

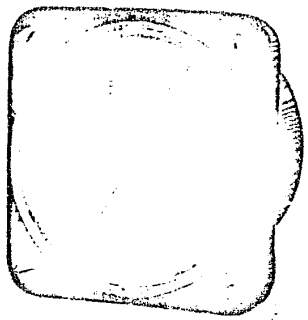


FIG.37. PRESSURE GAUGE M-200A

9. OXYGEN FLOW INDICATOR MK-18M

The oxygen flow indicator consists of an oxygen pressure gauge and an indicator mounted in one case (Fig. 26).

The oxygen pressure gauge is mounted in the upper portion of the case. Its measurement range is from 0 to 150 kg/sq.cm. and the division value of the dial is 10 kg/sq.cm.

The pressure gauge serves for checking the amount of oxygen aboard the aircraft.

The indicator mechanism is mounted in the lower portion of the instrument case.

During inhalation the leaves move apart and the slots become open. During exhalation the leaves are returned to the initial position with the help of a spring. While breathing the leaves periodically move apart and then come together. In case of a permanent flow of oxygen the leaves do not come together and the slots remain open.

The dial divisions, figures, pointer and leaves are painted white.

10. PRESSURE GAUGE M-2000K

The surplus pressure gauge (Fig. 27) is designed for checking the surplus pressure built up by oxygen regulator KM-34 in the inhalation system.

The pressure gauge is housed in a plastic case. Its dial is graduated from 0 to 20 and figured in every two divisions which corresponds to the measurement range from 0 to 2000 mm of water (the pressure gauge readings should be multiplied by 100).

The dial divisions, pointer and figures are painted white. The pressure gauge is installed on the left-hand console in the cockpit.

Chapter VIII

FLIGHT-AND-DIRECTIONAL AND FOLLOW-UP SYSTEMS

This group of systems includes:

1. Remote-indicating gyro horizon АГД-1 which serves for indicating gyro horizon while flying an aircraft.

2. Fighter directional system КСИ which indicates the aircraft heading and radio bearings; the heading is red from the gyroscope corrected by the magnetic heading.

3. Roll stabilization autopilot КАП-2 which improves roll control of the aircraft in the stabilization and damping modes.

4. Automatic transmission ratio controller АРУ-3В (Series II) which improves pitch control of the aircraft at different speeds and altitudes of flight and provides uniform flight control irrespective of the speed and altitude of flight.

5. Cone position indicator УПЗС-3 which indicates the extension of the cone in per cent. It is a potentiometric follow-up system.

All the above mentioned systems are designed to make the pilot's duties easier and to improve the flight and tactical capabilities of the aircraft. The systems employ transmitters based on the following operating principles: gyroscopic, barometric, electrical, radio and manometric. For precise transmission of mechanical motions use is made in the systems of the remote selsyn and potentiometric follow-up drives.

The aircraft has two gyro transmitters. One of them is installed between frames Nos 3 and 4, starboard, and is used only for the gyro horizon indicator.

The other one is used for the directional system, autopilot and radar station. It is installed on the horizontal stiffener between frames Nos 3 and 4, port side.

The corresponding switching and indicating elements of both gyro units are installed in the cockpit.

1. GYRO HORIZON АГД-1

a. General

Remote-indicating gyro horizon АГД-1 is designed for creating artificial horizon when flying the aircraft in adverse weather conditions both in the daytime and at night when the natural horizon is not seen.

The instrument consists of a gyro transmitter and indicator interconnected through an electrical selsyn follow-up system.

It indicates the pitch and roll angles within the range from 0 to 360° and the presence of aircraft side slip testified by the ball of the inclinometer.

The gyro horizon operates on the principle of free gyroscope to keep the main axis (spinning axis) in a permanent position in space but not with respect to the Earth's axis.

The sensitive element of gyro horizon AFA-1 is a free gyroscope mounted in a gimbal frame with an additional roll follow-up frame. The main element of the gyroscope (its spinning axis) is perpendicular to the Earth's surface.

This position of the spinning axis is ensured by employing a liquid level switch which in accordance with the gravity force effects the erection motors of the gimbal frames thus keeping the spinning axis of the gyroscope in a position perpendicular to the Earth's surface.

In case of longitudinal tangential or transverse normal accelerations the liquid will assume the position in the direction counteracting the gravity and acceleration, i.e. it will be accumulated in one side and therefore the erection motors will follow up the liquid displacement making the spinning axis deflect from the vertical position.

To prevent such a drift of the gyroscope provision is made in the gyro horizon for the disconnection of the erection system:

(a) the pitch erection system is disconnected by the liquid accelerometer after the horizontal acceleration of 1.67 m/sec^2 is achieved (and the system becomes connected again after the acceleration drops down to 1.05 m/sec^2);

(b) the roll erection system is cut out by erection cutout BK-53PB when the aircraft is turned at the angular velocity of more than 0.1-0.3 degree per sec.

The gyro horizon indicator (Fig. 28) comprises a follow-up system reproducing roll and pitch angles in accordance with the electrical signals produced by the gyro transmitter.

In addition to the indicator the roll and pitch signals produced by the gyro transmitter may be fed to other systems such as autopilot, directional system, etc.

To set the frames of the gyro transmitter in the operating position and therefore the spinning axis of the gyroscope in the position perpendicular to the Earth's surface, provision is made in it for an automatic electromechanical caging device.

B. Operating Principle

The key diagram of the gyro transmitter and indicator is given in Fig. 29.

The gyro transmitter is a free gyroscope. It consists of a gyro unit 16 installed in gimbal frames 20 and 25 which are mounted in follow-up frame 22. The follow-up frame through follow-up motor 14 sets all the time the outer axle of gimbal frame 20 in a position perpendicular to gyroscope spinning axis 19.

The resetting of the position of the follow-up frame is performed by the signals from induction transmitter 13 whose armature is mounted on the gyro unit shaft and its stator is mounted on the gimbal frame. When the outer axle of the gimbal frame deflects from the position perpendicular to the gyroscope spinning axis, the induction transmitter transmits A.C. signals through switching unit K_1 to the amplifier input. These signals are amplified and sent out to motor-generator 14 which resets frame 22 through the reduction gear and thus the perpendicular position of the gimbal frame outer axle and that of the gyroscope spinning axis is restored. The resetting speed is much higher than the possible speed of change of the aircraft bank.

As a result, at any evolutions of the aircraft the position of the gyroscope spinning axis does not coincide with that of the gimbal frame axle and therefore the gyro unit becomes nontumbling.

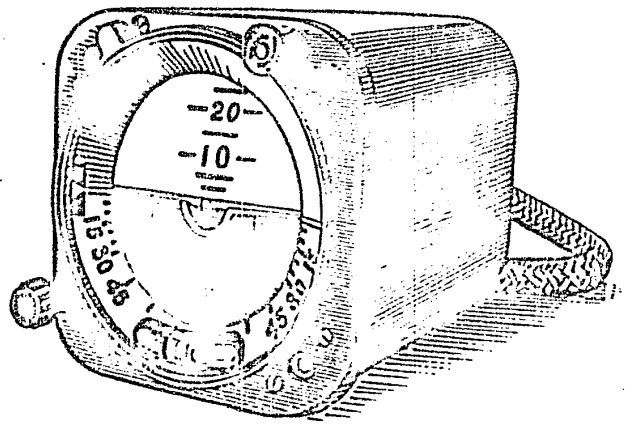


FIG.15. GYRO HORIZON INDICATOR

To damp the oscillations of follow-up frame 22 during its resetting the tacho signal of the motor-generator (i.e. the voltage proportional to the rotation speed of the follow-up frame) is fed to the amplifier of the negative feedback channel where it is summed with the signal of the induction transmitter. At aircraft pitch angles greater than 90° the correct direction of resetting of the follow-up frame by motor-generator 14 is ensured by switching over the phase of the control signal of the induction transmitter by switching unit 17. The switching unit is mounted on the outer axle of the gimbal frame.

Owing to the switching unit the follow-up frame has two operating positions in relation to the gyroscope spinning axis - the main one in which it is set by the remote caging device and the other one turned through 180°. The follow-up frame follows the gyroscope spinning axis normally in both positions of the frame.

The vertical positions of the gyroscope spinning axis is controlled by liquid level switch II mounted on the lower surface of the gyro unit. The switch activates two erection motors: longitudinal erection motor 21 mounted on the inner axle of the gimbal frame and lateral erection motor 18 mounted on the outer axle of the gimbal frame. The roll and pitch signals are generated by flat selsyns. The pitch selsyn transmitter (Cт) is installed on the outer axle of the gimbal frame and the roll selsyn transmitter (Cк) - on the axle of the follow-up frame.

In the inverted position of the follow-up frame the zero position of the pitch and roll selsyn rotors relative to the stator is changed through 180°.

Besides, the direction of turn of the pitch selsyn rotor relative to the stator is changed for the reverse.

To ensure correct readings of the horizon indicator in the inverted position of the follow-up frame of the gyro transmitter two phases of the roll and pitch selsyn transmitters are switched over. The switching signal is produced by switching unit $K_2$27 which starts the roll switching relay in the gyro transmitter; at this moment the miniature aircraft on the indicator turns through 180° and starts the pitch switching relay in the gyro transmitter and the relay in the indicator. At the same time the card starts to follow up the pitch in the reverse direction.

C. Caging

To spend as little time as possible when preparing gyro horizon АГД-1 for operation, the gyro transmitter is provided with an electromechanic caging device.

When starting the gyro transmitter the caging device operates automatically and the plane of follow-up frame 22 is set in a position parallel to the instrument base whereas the gyroscope spinning axis is set in a position perpendicular to the base which results in automatic uncaging.

The caging device includes the following elements: (Fig. 29):

(a) D.C. motor 6 with a reduction gear and friction clutch 7;

(b) cams 12, 15, 26 and 29;

(c) return spring 30;

(d) pusher 24 and rod 28;

(e) roller 31.

The caging is performed as follows (provided the gyro unit, the gimbal and follow-up frames are in an arbitrary position).

When the power is fed to the cage motor 6, the latter starts to operate and through the reduction gear rotates outlet gear 11. The bush of gear 11 has a stud that slides along the helical groove of rod 10 and pushes it forward.

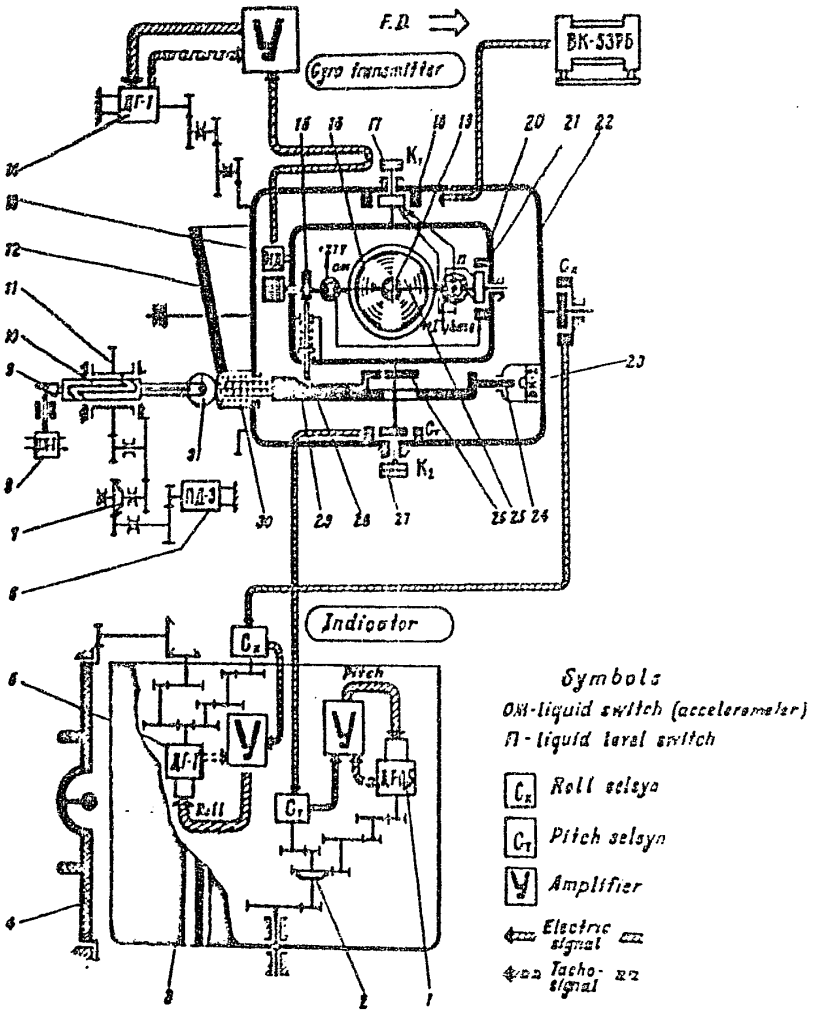


FIG. 29. KEY DIAGRAM OF GYRO HORIZON

1 – pitch follow-up motor; 2, 7 – friction clutch; 3 – cord; 4 – miniature aircraft; 5 – roll follow-up motor; 6 – cage motor; 8 – limit switch; 9 – cam; 10 – cage rod; 11 – outlet gear; 12, 15, 26, 29 – cams; 13 – induction transmitter; 14 – follow-up frame motor; 16 – gyro unit; 17, 27 – switching units; 18 – lateral erection motor; 19 – gyroscope spinning axis; 20 – outer gimbal frame; 21 – longitudinal erection motor; 22 – roll follow-up frame; 23 – limit switch; 24 – pusher; 25 – inner gimbal frame; 28 – rod; 30 – return spring; 31 – roller.

Cage rod 10 can move reciprocatingly without rotating in the bush of the outlet gear. With the movement of rod 10 roller 31 rolls down along the helical groove of cam 12 thus turning follow-up frame 22 to the horizontal position. When the rod moves further along cam 26, the plane of gimbal frame 20 is also turned to the horizontal position.

After that, gyroscope spinning axis 19 is set with the help of cams 15, 29 and rod 28 in a position perpendicular to the plane of the gimbal frame. The gyro unit is ready for starting.

The complete caging of the instrument takes place during one turn of the outlet gear. During this time period the guide stud shifts to the magnitude of one step of the helical groove of rod 10 after which it finds itself in the longitudinal groove and under the effect of spring 30 and the spring inside the rod becomes thrown back. At this moment the power supply is removed from motor 6 and the 36 V three-phase, 400 c.p.s. supply of the gyro motor and erection system is cut in.

The indicating lamp must burn on the indicator during caging. The caging process lasts about 15 seconds. Limit switches KB-1 and KB-2 provide the automatic succession of switching on and off the D.C. and A.C. voltages in the gyro horizon starting and signalling system.

After the gyro unit is started the signals from the roll and pitch selsyn transmitters of the gyro transmitter are fed to the selsyn receivers of the indicator follow-up system (See Fig. 29 where the signals are shown by means of arrows). The outer appearance of the remote-indicating indicator is shown in Fig. 28. The indicator shows the aircraft roll and pitch angles measured by the gyro transmitter.

The gyro horizon consists of two roll and pitch follow-up systems which provide the shifting of the movable elements of indication, i.e. a card and a miniature aircraft. See the key diagram of the indicator in the lower portion of Fig. 29.

The pitch follow-up system consists of a selsyn receiver (Cт) connected to the selsyn transmitter of the gyro transmitter, motor-generator МГ-0.5, reduction gear and amplifier.

The system operates as follows. In case of a mismatch between the selsyn receiver and selsyn transmitter the mismatch signal from the indicator selsyn receiver rotor is fed to the amplifier. The output voltage of the amplifier makes motor-generator МГ-0.5 rotate imparting the rotation through the reduction gear to card 3 and the selsyn receiver rotor thus placing it in a position corresponding to that of the gyro transmitter selsyn rotor.

From motor-generator МГ-0.5 the tacho signal as a negative feedback is applied to the amplifier where it is summed with the signal of the selsyn receiver rotor thus providing the damping of oscillations of the pitch follow-up system. Thus, the card is always set in the position corresponding to the turn angle of the selsyn of the gyro transmitter, i.e. the horizon indicator reproduces the pitch angles.

The maximum speed of the card performance is not less than 80° per second. The possibility is foreseen for adjusting the position of the pitch (card) scale horizon within ±12° due to the turn of the selsyn stator (Cт) with the help of the centering rack-and-pinion.

The rack-and-pinion is coupled with the centering index located on the left side of the indicator front panel.

The roll follow-up system consists of similar elements and operates like the pitch follow-up system. The transmission ratio from motor generator 5 (МГ-1) to the roll selsyn and the miniature aircraft is the same. The maximum performance rate of the miniature aircraft is not less than 360° per second.

The roll indication system has no manual erection system. All weak signals from the transmitters are fed to the executive and follow-up mechanisms through the transistorized electronic amplifiers.

D. Arrangement of Gyro Horizon Units in Aircraft

The arrangement of gyro horizon units in the aircraft is shown in Fig. 30. The indicator is mounted in the centre of the instrument panel in the cockpit. The gyro transmitter is mounted on a special panel in the front accessories compartment between frames Nos 3 and 4 on the right side as viewed in the direction of flight. The gyro transmitter is so mounted that it may be adjusted in the vertical and horizontal planes.

While mounting the gyro horizon after its removal observe the following rules:

(a) the gyro transmitter should be installed with the help of a level; the arrow on its case should coincide with the direction of flight; the notches and arrows on the attachment plate and special frame of the gyro transmitter should coincide; the longitudinal axis of the gyro transmitter should be strictly parallel to the longitudinal axis of the aircraft during level flight;

(b) the plane of the indicator scale on the instrument panel should be perpendicular to the longitudinal axis of the aircraft and the ball in the slip indicator should be in the middle position.

Inaccurate installation of the gyro horizon results in additional error in the roll and pitch angle readings which in its turn interferes with the navigation of the aircraft in adverse weather conditions and at night.

E. Starting and Operation of Gyro Horizon

The gyro horizon is fed from the aircraft mains with the D.C. voltage of +27 V and from inverter ПТ-125Ш with the A.C. three-phase voltage of 36 V, 400 c.p.s. The D.C. voltage is fed to the switching units, transistorized amplifiers, caging drive and indicating lamp. The A.C. voltage is fed to the gyro motor, selsyn follow-up systems and erection motors. Prior to starting the gyro horizon it is necessary first to switch on the АА-200, GYRO TRANSM. CAGING КСН, КАП circuit breaker on the horizontal portion of the right-hand console. In this case, the indicating lamp on the indicator lights up. After that, turn on the АГД circuit breaker on the vertical portion of the right-hand console. In this case, the power will be fed to the starting relay of inverter ПТ-125Ш and to motor ПД-3 of the cage drive. The cage operates automatically for 15 sec. and during this time do not press the caging button on the indicator.

During the caging cycle a red lamp is on. As soon as the lamp goes out it means that the caging cycle is over (all the gyro transmitter frames are in the operating position) and the A.C. power is fed for starting the gyro motor and the erection devices.

During 1 to 1.5 min. the gyromotor gains the speed of 22,000 to 23,000 r.p.m. and after this the gyro horizon is ready for operation.

Do not use the caging button on the indicator while starting the gyro horizon during normal operation on the ground and in flight. If the pilot has noted that the gyro transmitter makes errors which can be caused only by a casual interruption in the power supply to the set, it is necessary to make the aircraft enter level flight and push for an instant the CAGE IN LEVEL FLIGHT ONLY button on the indicator. In this case, a red lamp should light up on the indicator which should go out as soon as the cage cycle is over and the gyro horizon is again ready for use.

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Notes: 1. During caging, the gyroscope of gyro horizon АГИ-1 assumes the vertical position not relative to the Earth's surface but to the vertical axis of the aircraft. After caging the gyroscope is set in the vertical position relative to the Earth's surface by the liquid level switch at a rate of:
2° per min. for pitch and
4° per min. for roll.
Thus the gyro horizon gives readings with normal accuracy not immediately after caging but some time later the length of which depends on the degree of accuracy at which the aircraft was kept in the horizontal position during caging.

2. Do not use the caging button at pitch angles greater than ±4° since after caging the longitudinal erection mechanism may be disconnected.

3. The gyro transmitter of the fighter directional system and roll stabilization autopilot is fed from inverter АТ-500П. It is switched on by the GYRO TRANSM. OF КСИ, КАП; CAGING АГИ circuit breaker when the АА-200. GYRO TRANSM. CAGING КСИ, КАП circuit breaker is on. In this case, the CAGING OF GYRO TRANSM. OF КСИ, КАП indicating lamp (on the instrument panel) should go out in 15 sec.

4. When the button on the indicator is depressed for a short period of time, both gyro transmitters become caged (during 15 sec. both red lamps are on).

If the second or third phase of the A.C. voltage is open, an indicating lamp will light up on the indicator and the gyro motor power supply will be cut off.

F. Basic Specifications

1. Operational readiness after switching on power supply (at roll and pitch angles of the aircraft, while on the ground, up to ±4°):

at temperatures from +50 to -30°C ..... 1 min.

at temperatures from -30 to -60°C ..... 1.5 min.

2. Duration of gyro transmitter caging cycle (caging - uncaging) is not in excess of 15 sec.

3. Operating angles within which the readings are correct:

roll angles ..... 360°

pitch angles ..... 360°

(except for the zone from 85 to 95° while pitching and from 265 to 275° while diving).

4. Accuracy of maintaining the vertical position by the gyro transmitter gyroscope with the erection system cut in on a fixed base:

roll angles ..... ±0.25°

pitch angles ..... ±0.2°

5. Errors in the readings of the roll angles after the performance of up to 360° turns should not exceed ±3° (in rare cases up to 5-6° are possible). Errors in the readings of the roll and pitch angles after performing any aerobatics should not exceed ±5°.

6. Erection rate of the gyro transmitter gyroscope:

roll ..... 2 to 8° per min.

pitch ..... 1 to 3° per min.

7. Rate of turn at which the signal of erection cutout ВК-53РЗ cuts out the roll erection of the gyro transmitter ..... 0.1 to 0.3° per sec.

8. Horizontal component of aircraft fore-and-aft acceleration at which the pitch erection is practically cut out ..... 1.67 m/sec^2

and cut in ..... 1.05 m/sec^2

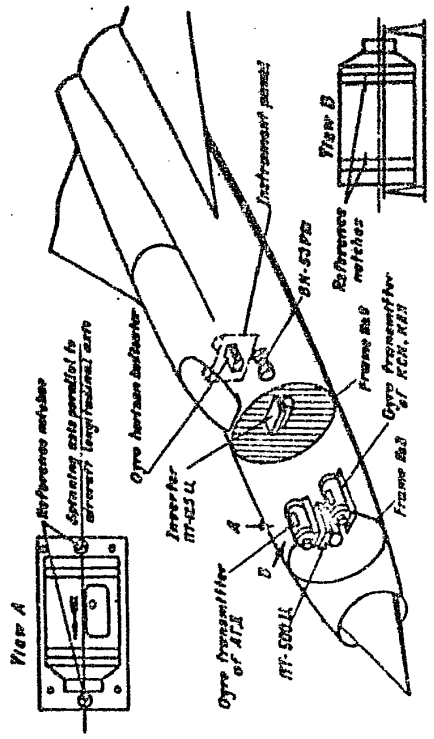

FIG. 10. ARRANGEMENT OF GYRO HORIZON UNITS IN AIRCRAFT

9. After take-off errors ..... not more than 3°

10. The maximum resetting speed of the follow-up frame of the gyro transmitter ..... not less than 360° per sec.

11. Error in the readings of the roll and pitch angles on the horizon indicator:

at 0° ..... ±1°

up to ±30° ..... ±1.5°

above ±30° ..... ±2.5°

12. Sensitivity of horizon indicator to changes in roll and pitch angles ..... not worse than 0.3°

13. Current consumed:

(a) from 36 V, 400 c.p.s. A.C. power supply source (inverter PT-125M): 1.6 A for the first and third phases and not more than 1.2 A for the second phase;

(b) from D.C. power supply source (aircraft mains ±27 V): not more than 0.75 A.

Note: When erection cutout BK-53PM is switched on, the current consumption increases by 0.4 A in every phase.

14. Operating temperature range ..... from +15° to -60°

15. Safe operating altitude ..... 20,000 m.

16. Weight of gyro horizon units:

gyro transmitter ..... 7 kg

horizon indicator ..... 2.6 kg

2. FIGHTER DIRECTIONAL SYSTEM

A. General

The fighter directional system is designed for determining the magnetic heading of the aircraft flight, bearings and relative bearings of the radio stations during joint operation with the automatic radio compass.

The directional system combines magnetic, gyroscopic and radio methods of measurement of the aircraft heading.

It ensures:

(a) required accuracy in determining the heading (of not less than ±2° in the straight-and-level flight);

(b) high accuracy in the heading readings during unsteady flight.

The directional system is employed in two modes of operation: directional gyro and magnetic slaving.

The main mode of operation of the directional system is the directional gyro (when the heading is received from gyro unit GA-2) and the magnetic slaving is an auxiliary one used for initial correction of the directional gyro readings on the ground (prior to the take-off) or in the straight-and-level flight.

The high accuracy in determining the course under conditions of unsteady flight with large roll angles is achieved by using a vibration-proof gyroscope in the directional system with stabilization of the axle of the gyroscope outer gimbal frame by means of additional roll and pitch follow-up frames in compliance with the signals of the gyro horizon transmitter.

Besides, provision is also made in the directional system for making corrections for the gyro drift due to daily rotation of the Earth depending on the latitude of flight in the northern or southern hemisphere.

B. Units and Devices of Fighter Directional System

The set of fighter directional system includes:

1. Gyro unit ГА-2.
2. Heading indicator УГР-4У.
3. Induction transmitter ИД-2.
4. Slaving mechanism МС-1.
5. Erecting mechanism КМ-3.
6. Control panel ПУ-3.
7. Amplifier У-12.
8. Amplifier У-18.
9. Relay unit БР-4.
10. Slaving button БК.
11. Set of connecting cables.

C. Purpose of Separate Units

1. Gyro unit ГА-2 is designed for using the directional system in the directional gyro mode and for sending the heading signals to heading indicator УГР-4У through slaving mechanism МС-1.

The sensitive element of the gyro unit is free gyroscope. Its spinning axis is horizontal and the motor generator rotor rotates at a speed of 22,000 to 23,000 r.p.m.

2. Heading indicator УГР-4У is designed for indicating:

(a) magnetic heading;

(b) radio station magnetic bearing;

(c) radio station relative bearing.

3. Induction transmitter ИД-2 is designed for correcting the heading taken off gyro unit ГА-2 in compliance with the magnetic heading through slaving mechanism МС-1. The sensitive element of the transmitter includes three magnetic probes located in an equilateral triangle pattern.

Each magnetic probe consists of two permalloy cores with magnetizing and signal windings. The platform with the magnetic probes is installed in a gimbal frame.

4. Slaving mechanism МС-1 is designed for:

(a) initial slaving of the heading signals taken off gyro unit ГА-2 in accordance with the magnetic heading;

(b) correction of the heading signals when the mechanism is employed in directional gyro mode (i.e. introduction of latitude correction for the gyroscope drift due to the daily rotation of the Earth).

The mechanism consists of a differential selsyn, reduction gear with an electromagnetic clutch, follow-up motor ДИД-0.5 and tachogenerator of ДИД-0.5

5. Erecting mechanism КМ-3 is designed for:

(a) following up the electric signals of induction transmitter ИД-2;

(b) for eliminating quadrantal and instrument errors.

The mechanism includes two selsyns (СП-1 and СП-2), motor ДИД-0.5 and a cam device.

6. Control panel ПУ-3 is designed for:

(a) ensuring operation of the directional system in the magnetic slaving and directional gyro modes as well as in the northern and southern hemispheres;

(b) introducing latitude correction for the gyroscope drift due to the daily rotation of the Earth;

(c) controlling the rate of following up the latitude correction and the feedback value.

The panel consists of a supply transformer, N-S switch, latitude potentiometer, correction potentiometers and a relay used for switching over the system from the directional gyro to magnetic slaving (when the button is depressed).

Note: The N-S switch should be locked with wire KO-0.5K in the N position when the aircraft is used in the northern hemisphere and in the S position when the aircraft is used in the southern hemisphere.

7. Amplifier У-12 is designed for amplifying the signals in the erecting and slaving mechanism channels.

The erecting mechanism channel amplifies the induction transmitter signal taken off selsyn receiver СП-1 and transmits it to motor ДИД-0.5 of the follow-up system of erecting mechanism КМ-3.

The slaving mechanism channel amplifies the signal transmitted from erecting mechanism КМ-3 to slaving mechanism МС-1 and the latitude correction signal taken off control panel ПУ-3. In addition to all these units the amplifier includes a rectifier.

8. Amplifier У-18 is designed for amplification of the signals taken off the gyro horizon transmitter passing through the roll and pitch channels, as well as for sending them to the motors resetting the additional follow-up frames of gyro unit ГА-2.

9. Relay unit БР-4 serves to ensure operation of the directional system when the aircraft performs aerobatics and to eliminate 180° error in heading readings when performing a half-loop.

10. Push button 5K is designed for feeding the voltage of +27 V to the relay in control panel ПУ-3 thus switching on the directional system for operation in the magnetic slaving mode. Besides, this voltage is also fed to the electromagnetic clutch from slaving mechanism МС-1 so as to increase the rate of slaving.

D. Modes of Operation of Directional System

Directional Gyro Operation

The principal unit of the fighter directional system is gyro unit ГА-2 that is a free gyroscope (the spinning axis is in the horizontal position). Two additional follow-up frames stabilize the shaft of the outer gimbal frame in the vertical position.

The additional frames are reset by the correction motors by the roll and pitch signals taken off the gyro horizon transmitter through amplifier У-18.

The aircraft heading signals are taken off the selsyn transmitter of gyro unit ГА-2 and fed to the differential selsyn receiver in the slaving mechanism. From the differential selsyn the signals are fed to the heading indicator where the rotating dial is reset. The heading is read off the dial clockwise between the rotating dial is reset. The heading is read off the dial clockwise between index C on the rotating dial and the upper index of the fixed dial. Besides, from the differential selsyn the signals are fed to the stator of selsyn receiver СП-2 in erecting mechanism КМ-3.

Gyroscope of gyro unit ГА-2 has no azimuth correction system. The gyroscope spinning axis assumes arbitrary position relative to the magnetic meridian in the horizontal plane. The spinning axis is kept in the horizontal plane by a reversive correction motor mounted on the shaft of the outer gimbal frame which applies

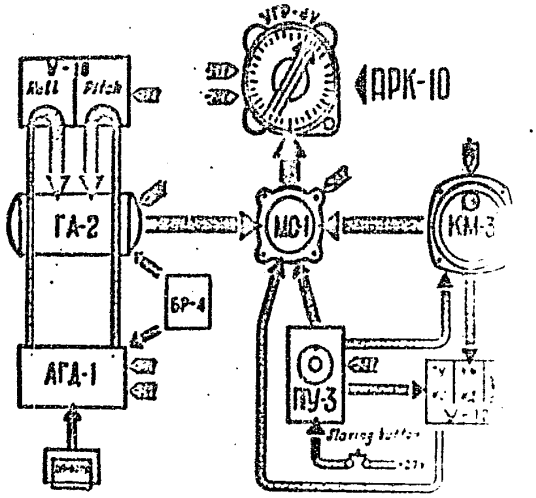

FIG. 11. BLOCK DIAGRAM OF DIRECTIONAL [illegible]

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the torque to the gyroscope spinning axis (if it has drifted away from the horizontal plane) thus setting the axis again in the horizontal plane.

During operation of the directional system in addition to the signals taken off gyro unit ГА-2 the signals from the potentiometer in the control panel are also fed to the erecting mechanism. These signals serve for introducing (by additionally turning the rotor of the differential selsyn through the reduction gear with a gear ratio of $\frac{1}{4.6 \cdot 10^6}$) a latitude correction for the drift of the gyroscope spinning axis due to the daily rotation of the Earth. Besides, the control panel has adjusting potentiometers regulating the rate of correction and the feedback value; the potentiometers are also connected with slaving mechanism МС-1.

Magnetic Slaving

The magnetic slaving is started by depressing the slaving button on the instrument panel. The button is kept depressed till the rotating dial stops and then the button is released.

In case of maximum mismatch between the induction transmitter and the indicator readings the slaving time does not exceed 23 sec.

With the button depressed, the latitude correction is cut out and the power is fed to the relay on control panel ПУ-3 and the electromagnetic clutch of slaving mechanism МС-1. In this case the signals are fed to follow-up motor АМА-0.5 in slaving mechanism МС-1 from the rotor of selsyn СП-2 in erecting mechanism ЭМ-3 through the closed contacts of the relay in control panel ПУ-3 and through the slaving mechanism channel in amplifier У-12. The motor additionally turns the rotor of the differential selsyn through the reduction gear (when the electromagnetic clutch is cut in the gear ratio is $\frac{1}{2500}$) thus reducing the mismatch between the stator and rotor of selsyn СП-2 in the erecting mechanism to zero. The rotor of the differential selsyn is connected both with heading indicator УГР-4У and with the stator of selsyn СП-2 in erecting mechanism ЭМ-3.

At the same time when the rotor of the differential selsyn is additionally turned, the mismatch signal will be fed to the heading indicator making it recet and the rotating dial will be set in a new (matched) position.

As soon as the slaving button is released, the erecting mechanism becomes switched off, the latitude correction is cut in and the heading is again taken off gyro unit ГА-2 corrected by the magnetic heading.

B. Arrangement of Units in Aircraft

The units of the directional system are arranged in the aircraft as follows (Fig. 32):

1. The front accessories compartment between frames Nos 3 and 6, starboard, houses:

(a) gyro unit ГА-2;
(b) slaving mechanism МС-1;
(c) control panel ПУ-3;
(d) amplifier У-18;
(e) relay unit РП-4;
(f) gyro transmitter of the fighter directional system, roll stabilization autopilot (it is not included into the set of fighter directional system);

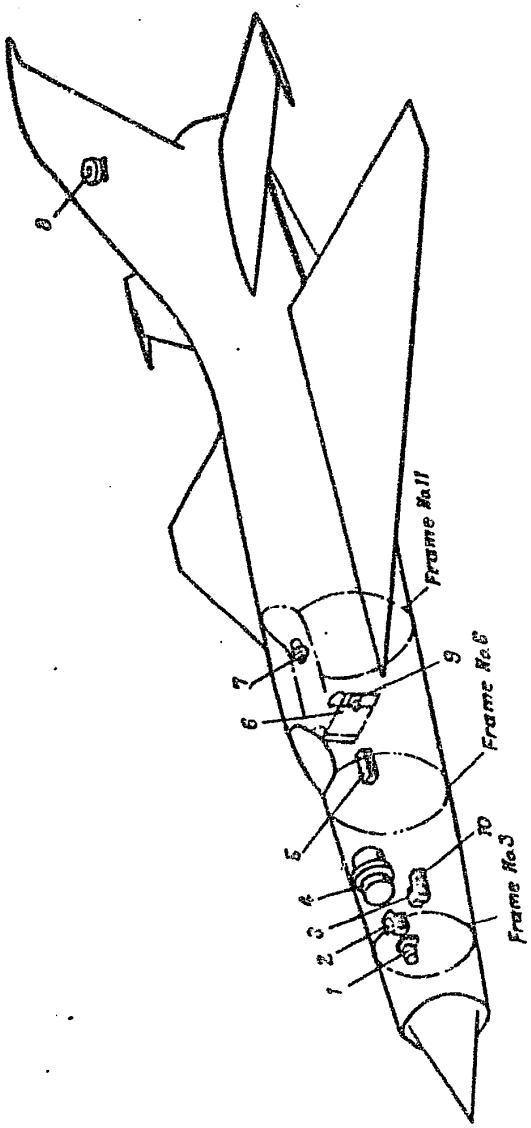

FIG.32. ARRANGEMENT OF DIRECTIONAL SYSTEM COMPONENTS IN AIRCRAFT

1 – slaving mechanism; 2 – control panel; 3 – relay unit; 4 – gyro unit ГА-2; 5 – amplifier У12; 6 – slaving transmitter; 7 – erecting mechanism; 8 – induction transmitter; 9 – heading indicator; 10 – amplifier У-18.

(g) inverter ПТ-500Ш (it is not included into the set of fighter directional system).

2. Mounted in the cockpit are:

behind the instrument panel:

amplifier У-12;

on the instrument panel:

(a) heading indicator УГР-4У;

(b) slaving button;

near frame No. 11, starboard:

erecting mechanism КМ-3.

3. Induction transmitter ИД-2 is mounted in the middle portion of the fin.

F. Installation and Operating Instructions

When mounting the directional system observe the following:

See to it that no iron or magnetic objects are placed near the induction transmitter, the arrow on its case should be directed towards the aircraft nose.

Gyro unit ГА-2 is mounted on its shock absorbers and its lower plate should be placed on a strictly horizontal panel when the aircraft is in the line of flight with the arrow on the case directed towards the aircraft nose.

Incorrect installation of the gyro unit and especially of the induction transmitter results in greater errors in the heading readings on indicator УГР-4У which interferes with the pilot's normal orientation. The induction transmitter and the gyro unit are checked (set) when the aircraft is in level flight by the levels on these units.

When mounting the induction transmitter see to it that the reference notches coincide.

In case of failure of gyro unit ГА-2 the rotating dial will come to a rest in an indefinite position. In this case, when the slaving button is depressed, the dial will come to a rest in a position corresponding to the magnetic heading indicated by the induction transmitter.

To check the serviceability of the induction transmitter depress the slaving button on the instrument panel and bring a permanent magnet on a pole to it making the dial turn.

The induction transmitter is provided with a deviation compensator to eliminate the magnetic deviation. In this case, the deviation is eliminated also when the slaving button is depressed. After the directional system is started, it is necessary to slave the directional gyro with the magnetic compass prior to taxiing to the start line. The heading indicator is shown in Fig. 33.

The directional gyro (magnetic slaving) heading readings are red off the rotating dial between index N (North) and the fixed index in the clockwise direction.

The magnetic bearing of the radio station is read off between index N and the tip of the radio compass pointer. The relative bearing of the radio station is red off the fixed dial between the course index and the tip of the pointer.

G. Power Supply and Starting of Directional System

The directional system is fed from the aircraft mains with the D.C. voltage of 27 V and from inverter ПТ-500Ш with the voltage of 36 V, 400 c.p.s.

The A.C. and D.C. voltages are intended for feeding gyro motor of ГА-2, selsyn

The A.C. and D.C. voltages are intended for feeding gyro motor of ГА-2, selsyn and electro-follow-up systems, erection electromotors, induction transmitter ИД-2 and electronic amplifiers.

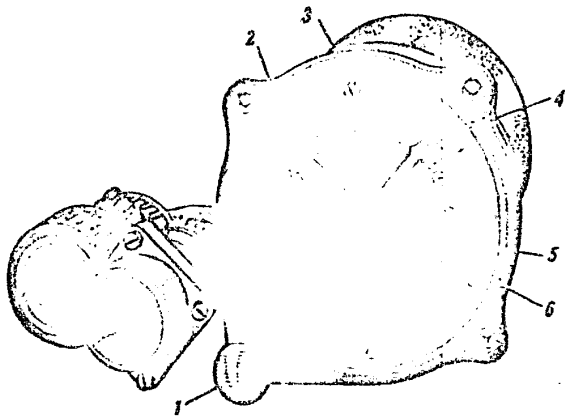

FIG. 33. HEADING INDICATOR
1 – rack-and-pinion; 2 – course setter pointer; 3 – course index; 4 – radio compass pointer; 5 – rotating dial of directional gyro; 6 – fixed dial of radio bearings.

To start the directional system, proceed as follows. First, turn on the АА-200, GYRO TRANSM. CAGING КСН, КАП circuit breaker thus feeding the power for switching on inverter ПТ-500Ш and making the CAGING OF GYRO TRANSM. КСН, КАП red indicating lamp light up on the instrument panel.

After that, turn on the GYRO TRANSM. OF КСН, КАП; CAGING АГД circuit breaker on the horizontal portion of the right-hand console. In this case, the caging cycle will be performed automatically for 15 sec. and then, the red lamp on the instrument panel should go out.

As soon as the lamp has gone out, the КСН circuit breaker may be turned on on the right-hand console and 1.5 - 2 minutes later the directional system is ready for operation.

Note: There is the following inscription on the right-hand console: SWITCH ON КСН AFTER SWITCHING ON AND UNCAGING GYRO TRANSM. OF КСН AND КАП (i.e. after the red lamp on the instrument panel is dead).
The system operates reliably provided the correct sequence of switching is strictly observed.

This sequence of switching is caused by the fact that during caging the pitch and roll selsyn transmitters of the gyro transmitter will send the selsyn signals to gyro unit ГА-2 for resetting the additional follow-up frames. Before caging the frames of the gyro horizon transmitter may assume any arbitrary position. During caging the frames quickly (during 15 sec.) assume the operating position. This may cause failure of the follow-up frames of gyro unit ГА-2.

H. Basic Specifications

1. Time required to prepare the system for operation after the power supply is cut in is:

1.5 min. at a temperature from +50 to -30°C;

2 min. at a temperature from -30 to -60°C.

2. Magnetic heading error in the level flight is not more than ±2°.

3. Additional error due to the drift of gyroscope axis in azimuth in the directional gyro mode does not exceed ±2° for 30 min.

4. Roll and pitch operating angles - from 0 to 360°.

Note: At pitch angles of 90 ±5° and 270 ±5° there is a zone of indefinite heading readings which is determined by characteristics of the gyro horizon vertical.

5. Ambient air temperature range - from +50° to -60°.

6. Service altitude - 25,000 m.

7. Power supply:

D.C. - +27 V ±10%;

A.C. - 36 V ±5%, 400 c.p.s. ±2%.

8. Power consumption in the steady mode:

D.C. - 40 watts;

A.C. - 130 VA.

9. Starting current:

D.C. - 1.8 A;

A.C. - 9 A.

10. Fighter directional system units withstand landing accelerations of 4 g.

3. ROLL STABILIZATION AUTOPILOT KAP-2

A. General

The roll stabilization automatic pilot, type KAP-2, is installed in ' ...ileron control system and serves for improving the aircraft roll stabili... controllability behaviour.

The autopilot is employed in two modes:

1. Roll damping during manual control of the aircraft.

2. Stabilization during the automatic bringing of the aircraft ... angle, zero roll angle stabilization and roll angle control in res... control stick application.

The functions performed by the autopilot are as follows:

(a) aircraft roll damping in combination with the aircraf... (damping mode);

(b) automatic bringing of the aircraft to zero roll an... initial roll angle (including the inverted position of the ...craft control stick is set in the neutral position in ro...

(c) zero roll angle stabilization with the control ... position in roll (stabilization mode);

(d) control of the aircraft roll angle within ... response to the control stick application within ... tion in roll (stabilization mode).

B. Units and Devices of

The autopilot set includes:

1. Servo unit PAV-107.
2. Relay and amplifier unit PUS-1
3. Roll rate gyro DUS-K.
4. Transmission ratio corrector
5. Interference filter FP-11
6. Relay box KP-1A.
7. Phase-sensitive rect...
8. Gyro transmitter of ... not included into the aut...
9. Check connector.

1. Servo uni... relay and ampli... in an extendab... under the co...

2. Rel...

(a) f... gyro, ph... flexible f... electron...

(b) for ...

(c) for ... pilot;

(d) for ...

...to the actuatin...

...utopilot;

...the operation of the auto-

...nits of the autopilot.

The unit is installed between frames Nos 8 and 7, in the lower starboard portion in the direction of flight (in the storage battery compartment).

3. Roll rate gyro RUS-K serves to measure the aircraft roll rate relative to the longitudinal axis and convert it into electrical signals proportional to the roll rate to be measured.

The sensitive element of the unit is a rate gyroscope.

All the mechanism is housed in a pressurized case filled with special fluid of required viscosity. The fluid damps the gyroscope oscillations and partially eliminates the friction in the gyro unit frame bearings by reducing the weight of the parts placed into the fluid. The gyro motor in its turn is mounted in the airtight cylindrical unit with axle shafts filled with gaseous hydrogen.

The roll rate gyro is mounted between frames Nos 12 and 13 in the middle portion, in the direction of flight.

4. Transmission ratio corrector KPH-2 is designed for automatically changing the transmission ratio of the autopilot in accordance with the signal received from the roll rate gyro depending on the head velocity and flight altitude. The corrector is a potentiometer secured to the body of the actuating mechanism of controller APU-3B. The potentiometer brush is rigidly connected with the board of the actuating mechanism which travels in compliance with a certain law depending on the altitude and flight speed.

5. Interference filter FP-110 is intended for suppressing radio frequency interference (20 to 150 Mc/s) generated by the autopilot in the D.C. circuit.

The filter is installed between frames Nos 8 and 9, in the starboard lower portion, in the direction of flight.

6. Relay box KP-1A is designed for switching the control signals.

The box is installed between frames Nos 7 and 8 in the port lower portion, near roll rate gyro RUS-K, in the direction of flight.

7. The phase-sensitive rectifier FFB is designed for converting three-phase A.C. signals coming from the gyro horizon selsyn transmitter into roll D.C. signals within the range of 360°. The rectifier is installed in the cockpit behind the instrument panel, port side.

8. The check connector is intended for ground checking of the autopilot. It is installed between frames Nos 5 and 6 in the wall of the L.G. nose wheel.

The red lamp on the instrument panel indicates whether the autopilot is on or off. The buttons designed for switching on and off the stabilization mode of the autopilot are mounted on the control stick. The circuit breaker is located on the right-hand console.

The ROLL DAMPER switch is mounted on the left-hand console.

D. Autopilot Operation

The interaction of autopilot units is shown in Fig. 34.

In the stabilization mode servo unit RAU-107 deflects the ailerons through ±3.5° maximum in any position. The aileron deflection by virtue of the control stick amounts to ±20° when the servo unit rod is set in neutral position.

Thus, when operating the autopilot it is only 27.5 per cent of the aileron complete deflection that is utilized. This is done to ensure the safety of flight with the autopilot used.

In case the servo unit rod shifts by itself all the way to the stop the pilot can counteract the resulting roll by shifting the control stick in the opposite direction approximately through one third of its travel length.

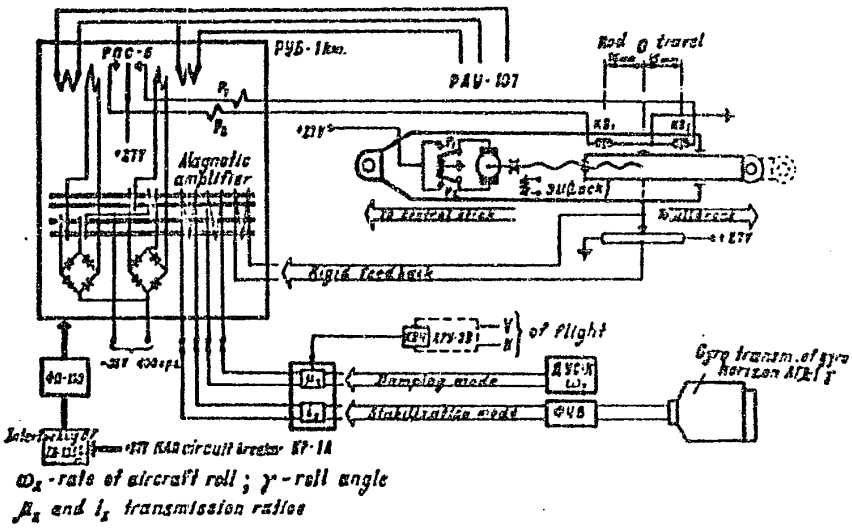

FIG.34. AUTOPILOT BLOCK DIAGRAM

When used in the damping mode the autopilot damps aircraft roll oscillations at the stable roll angle or at the transition from one roll angle to another in response to the aircraft rate of roll.

In damping, the aircraft piloting by means of the control stick is appreciably facilitated since the number of control stick applications required to control the roll is reduced to the minimum. Besides, the autopilot somewhat reduces the aircraft rate of roll, i.e. the deflection of the control stick causes the reverse response on the part of the autopilot and the aileron is deflected through a smaller angle. Owing to this the aircraft roll sensitivity is reduced with a deflection of the control stick and this in its turn results in lower roll response of the aircraft.

When the autopilot is employed in the stabilization mode (with the control stick set in the neutral position in roll) it ensures:

(a) roll-free flight of the aircraft, with no pilot's action required;

(b) bringing of the aircraft to zero roll angle from any initial roll angle (even from the inverted flight);

(c) piloting of the aircraft in roll in response to the control stick application.

Within the roll angles ranging from ± 30 to 40° the present roll angle signal is linearly generated by the gyro transmitter of gyro horizon АГА-1, i.e. the signal value is proportional to the roll. At roll angles greater than 40° the roll angle signal retains a constant value and sign till the angle of 140° ($180^\circ - 40^\circ$) is reached after which the signal value is again decreased in a linear manner to the roll angle of 180°. When the roll angle of 180° (in case of an inverted flight) is passed the sign of the signal is reversed while the signal value increases and becomes maximum at the roll angle of $180^\circ + 40^\circ$. Further on, both the constant value and sign are kept constant till the roll angle of 320° ($360^\circ - 40^\circ$) is reached.

The polarity (sign) of the roll angle signal is also reversed in case the aircraft passes a pitch angle of 90°. Thus, once the roll angle signal is taken off the gyro transmitter of gyro horizon АГА-1, it becomes possible to bring the aircraft to zero roll angle from any initial roll angle including the case when the aircraft performs an inverted flight and when pitch angles are big and range from 70 to 80°.

When applying the control stick transversally through ± 50 to 70 mm from the neutral position with the autopilot operated for stabilization the pilot can change the roll angle within the range of $\pm 40^\circ$, thus piloting the aircraft in response to the control stick application. In case the aircraft control stick is transversally moved through more than ± 50 - 70 mm the aircraft will be piloted in an ordinary way in response to the angular rate, i.e. this time there will be utilized the full travel of the rod of servo unit РАУ-107 which will be operated as a rigid control rod.

B. Power Supply Circuit

As soon as the circuit breaker on the right-hand console is turned on, the power is fed from the aircraft mains to the interference filter, phase-sensitive rectifier and to the winding of the starting relay of inverter ПТ-500Ш.

The relay operates and starts inverter ПТ-500Ш from which the voltage of 36 V, three-phase, 400 c.p.s. is applied to the phase-sensitive rectifier and to the roll rate gyro.

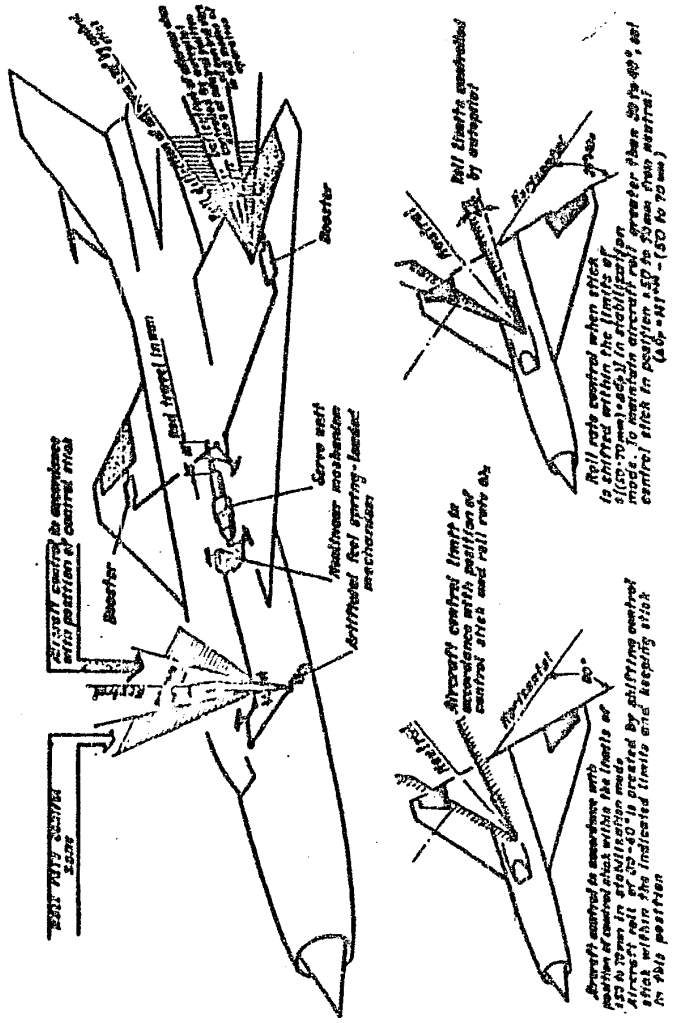

FIG. 15. OPERATION OF AUTOPILOT

The other units of the autopilot are electrically interconnected although they are not directly connected to the aircraft mains.

3. Basic Specifications

1. Maximum travel of the servo unit rod is ±15 mm from the zero position.
2. Servo unit collapsing force is 1600 kg.
3. Roll angle measurement range of the phase-sensitive rectifier is 360°
4. Power supply: 127 V D.C. from the aircraft mains and 36 V, three-phase 400 c.p.s. A.C. from inverter PT-500M.
5. Power consumption:

D.C. - up to 300 W;
three-phase A.C. - up to 0.5 [illegible]

4. AUTOMATIC TRANSMISSION RATIO CONTROLLER APV-3B

The unit, type APV-3B, serves for an automatic change (according to preassigned nonlinear law) of transmission ratios from the control stick to the stabilizer and simultaneously to the artificial feel spring-loaded mechanism. The regulation law performed by automatic transmission ratio controller APV-3B is a function of velocity head and flight altitude and is determined by the aircraft aerodynamics and pilot's physical capabilities.

This unit provides a comparatively uniform technique of aircraft piloting at various speeds and altitudes. This is achieved by increasing the control stick force and stick travel by one grade of the stabilizer deflection with the increase of the indicated speed and decrease of the flight altitude and correspondingly by decreasing the force and travel of the control stick by one grade of the stabilizer deflection with decrease of the indicated speed and increase of the flight altitude.

At altitudes ranging from H=4500 m. to H=10,000 m. the unit operates both in the function of velocity head and flight altitude.

At altitudes less than 4500 m. the unit operates only in the function of velocity head, that is at indicated speeds more than 1000 km/hr the pointer must be on the right limit stop - the small arm of controller APV-3B, whereas at indicated speeds less than 500 km/hr the pointer must be on the left limit stop - the big arm of controller APV-3B.

At an altitude of 10,000 m. and higher the unit retains the constant values of transmission ratio corresponding to the big arm position regardless of the change of velocity head and flight altitude. With the velocity heads corresponding to take-off, landing and flying the traffic pattern in the vicinity of an aerodrome the automatic elements are in the take-off and landing positions, the pointer being on the left limit stop which corresponds to the big arm of the actuating mechanism of controller APV-3B regardless of the flight altitude.

The key diagram of the automatic controller, the arm position indicator and regulation law are shown in Fig. 30.

Controller APV-3B operates independently taking the total-head pressure and static pressure from Pitot-static tube PVA-7 and does not require any action on the part of the pilot at normal operation. In case of failure of the control unit the pilot may control manually the actuating mechanism of controller APV-3B by switching on the electromotor of the mechanism actuating rod drive.

The electric mechanism is controlled by two switches located on the upper left-hand board of the instrument panel. The switches are provided with the following

lowing inscriptions: HIGH SPEED LOW SPEED; AUTOMATIC; MANUAL, AFV. When controlling the electric mechanism manually the second switch must be in the MANUAL position.

Operation of the actuating mechanism is checked by the STABILIZER FOR LANDING indicating lamp on light panel T-4V2 and by the indicator with the dial marked in km/hr and kilometres of flight altitude actually performed by the mechanism actuating rod (Fig. 37).

The arm position indicator is a voltmeter calibrated in speed and altitude units.

In operating conditions readings of the arm position indicator and flight instruments of speed and altitude may not coincide because of the difference in the atmospheric conditions and standard readings and also due to the supply voltage fluctuations from the nominal value of 27 V ±0.5 to 27 V ±10%.

One should bear in mind that the arm position indicator serves to inform the pilot about proper operation of the automatic transmission ratio controller AFV-35.

5. CONE POSITION INDICATOR UPZS-3

Cone position indicator UPZS-3 is installed on the left-hand board above the instrument panel (Fig. 38).

In addition to the indicator, the set includes transmitter UPZS-3 that is mounted near frame No. 3 over the cone extension cylinder. The transmitter is mechanically coupled with the cone (through a flexible cable).

Set UPZS-3 is intended for:

(a) indicating the position of the air intake cone;

(b) generating feedback signals to the amplification and switching unit and to the cone position manual control system.

The indicator has two pointers, a dial and a rack-and-pinion.

The narrow pointer (in the indication system) indicates the present position of the cone. The wide pointer (in the feedback system) is a selective pointer that is set with the help of a rack-and-pinion.

Readings are read from the dial calibrated in per cent from 0 to 100%. The initial position of the cone corresponds to zero reading of the dial.

The indicator case houses two electrically independent systems: a cone position indicating system and a feedback system.

The indicating system is a four-coil ratiometer operating from a four-lead potentiometer installed in the transmitter. The moving magnet of the ratiometer whose axle carries the narrow pointer is turned in the magnetic field of the coils located at an angle of 90°. Turning of the transmitter axle makes the current carrying brush of the four-lead potentiometer change its position thus redistributing the currents in the ratiometer coils. As a result, the magnet (and therefore the pointer) will come to a rest in the direction of the resultant magnetic field.

Each position of the ratiometer magnet corresponds to a certain position of the transmitter potentiometer brush.

The feedback system is a bridge circuit comprising a transmitter potentiometer which operates in combination with the potentiometer employed in the manual control signals or with the potentiometer of the indicator employed in the manual control system of the air intake cone.

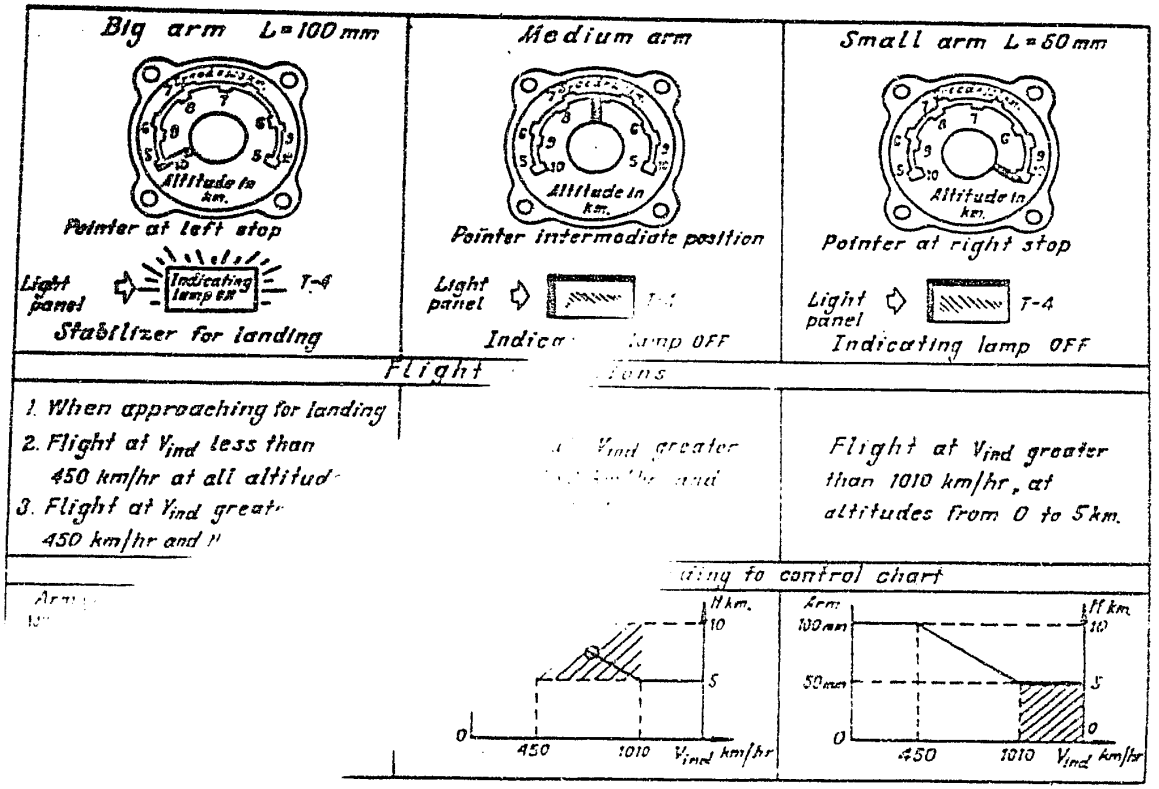

FIG. 32. INDICATIONS OF ARM POSITION INDICATOR OF CONTROLLER APV-3B

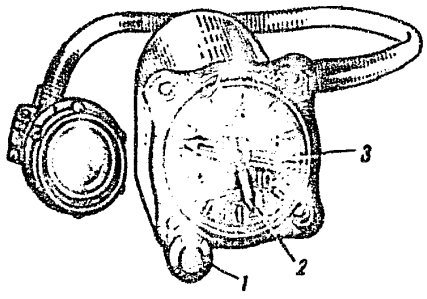

FIG. 18. CONE POSITION INDICATOR УПЗС-3
1 – rack-and-pinion; 2 – follow-up pointer; 3 – selective pointer.

The set is electrically connected with the amplification and switching unit from which the signals are fed to the cone actuating mechanism.

Set УПЗС-3 is fed from the aircraft mains with the voltage of +27 V.

Chapter IX

OXYGEN EQUIPMENT

1. GENERAL

The aircraft mounts a set of oxygen equipment, type KKO-3, with excessive oxygen pressure in the breathing system and in the high-altitude pressure suit pneumatic system which is automatically adjusted depending on the flight altitude. The set is intended to provide proper vital conditions for the pilot and preserve his efficiency and safety during high-altitude and high-speed flights and during ejection (Fig. 19).

Oxygen equipment set KKO-3 is designed for supplying one pilot with oxygen in the following conditions:

(a) during a long period of time - when flying in the pressurized cockpit at altitudes up to the service ceiling and when flying in the depressurized cockpit at altitudes up to 12 km.;

(b) during a short period of time (from 5 to 10 min.) - when the cockpit has been depressurized at altitudes from 12 km. up to the service ceiling and the set is used as an emergency oxygen feeding system while descending down to the safety altitude;

(c) during a short period of time - when the pilot is ejected from the aircraft at the altitudes up to the service ceiling with simultaneous automatic switching over to the oxygen feeding from the parachute oxygen apparatus;

(d) when used in set with high-altitude pressure suit BAK-4 and an anti-G device the oxygen set enables the pilot to withstand the overload of up to 8 g;

(e) pressurized helmet ГШ-4МС protects the face from the air flow during ejection at the indicated speed of 1200 km/hr.

Oxygen equipment set includes the aircraft oxygen equipment and pilot's individual outfit.

The aircraft oxygen equipment comprises:

(a) oxygen regulator КИ-34;
(b) remote control ДУ-2;
(c) oxygen reducer КР-26А;
(d) oxygen valve КВ-2МС;
(e) oxygen indicator КИ-18М;
(f) excessive pressure gauge М-2000К;
(g) set of inboard oxygen hoses КШ-26;
(h) seamen connector ОРМ-2;
(i) pressure ratio regulator РСА-3М with hose bundle;
(j) spherical oxygen bottles;

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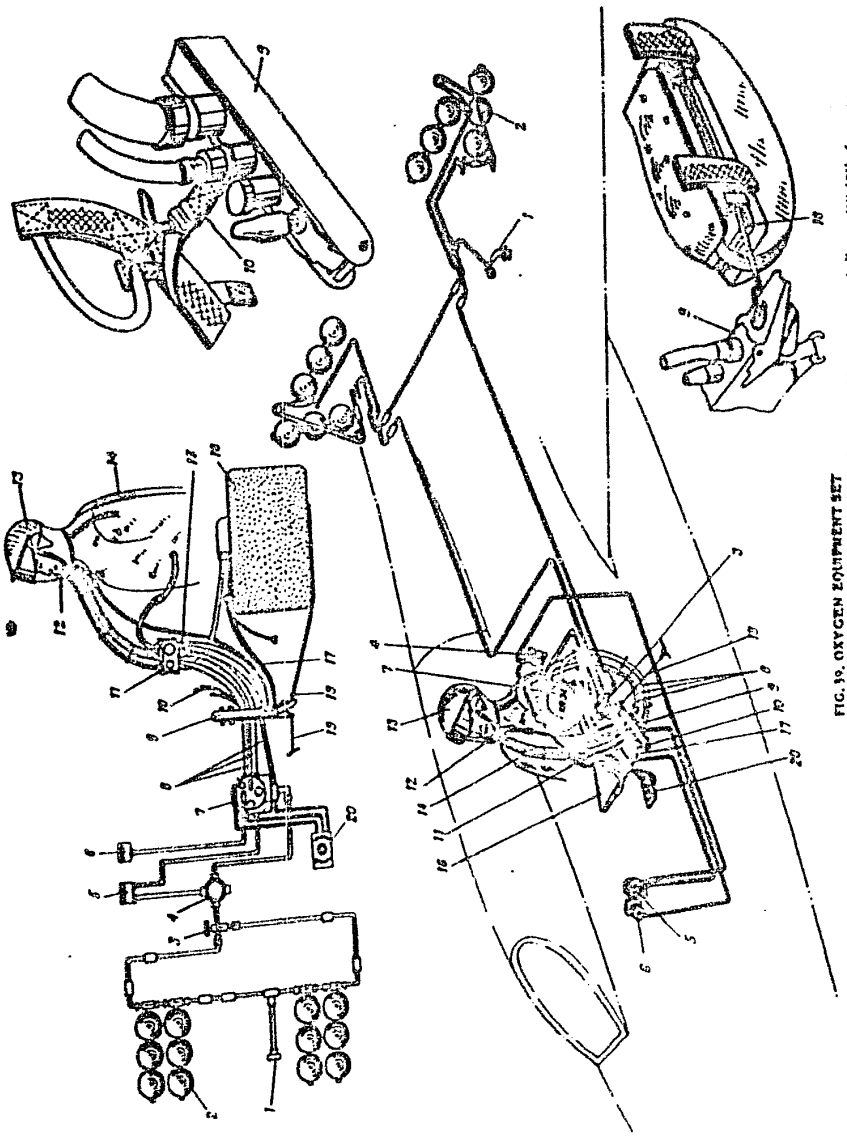

FIG. 39. OXYGEN EQUIPMENT SET

1 – charging connection, 2 – regulator handle, 3 – oxygen valve KD-24C; 4 – oxygen reducer KP-26A; 5 – oxygen indicator IK-18V; 6 – pressure gage M-20GK; 7 – oxygen regulator KD-2B; 9 – common connector OPK-2; 10 – harness; 11 – pressure ratio regulator [illegible]; 12 – antiblackout; 13 – pressurized helmet PSh-4NC; 14 – high-altitude pressure suit; 15 – rope handle for opening [illegible]; 16 – parachute breathing apparatus KD-2N; 17 – cabin mechanism of apparatus KD-2N; 18 – shock absorber; 19 – rope of emergency disjunction connector OPK-2; 20 – remote control ZU-2.

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(k) inboard oxygen accessories.

The pilot's individual outfit includes:

(a) high-altitude pressure suit BKK-4;

(b) pressurized helmet ГШ-4МС;

(c) parachute oxygen breathing apparatus КП-27М.

The aircraft oxygen equipment lines and the pilot's individual outfit are connected through common connector ОРК-2 installed to the left side of the seat pan and through hoses with bayonet joints.

The aircraft oxygen reserve is kept in four spherical 2-lit. bottles under the pressure of 150 kg/sq.cm.

The bottles are divided into two groups. Each bottle is fitted with a tee-piece; non-return valves are pressed into the tee-piece. The non-return valves let the oxygen flow only in one direction. In case of failure of one of the bottle groups the valves prevent the oxygen from flowing out of the operable group of bottles.

The system is charged with oxygen through the charging connection installed in the landing gear well of the port wing.

To check the operation of the oxygen feeding system and to indicate the amount of oxygen aboard the aircraft, provision is made for oxygen indicator КИ-16М and excessive pressure gauge М-2000К installed on the left-hand console in the cockpit.

CAUTION! When operating the oxygen supply system remember that mixture of grease and oil with oxygen is explosion-hazardous.

1. When mounting, checking and charging the oxygen equipment keep it clean; use of lubricants for threaded joints is strictly prohibited.

2. To bleed the oxygen from the oxygen bottles disconnect the pipe line from the H.P. connection of reducer КР-26А; do not allow the oxygen to be flown through the reducer.

3. Do not tighten up the pipe line joints when valve КВ-2МС is open and the system is charged.

4. Do not use dirty tools and oiled waste.

To work with the oxygen equipment, special chrome-plated tools, clean and degreased are used which are kept in a special kit.

5. Operator's hands and overalls should be clean. Prior to mounting, checking and charging the oxygen equipment the operator should wash his hands with soap.

2. INTERACTION OF COMPONENTS OF OXYGEN EQUIPMENT SET КИО-3 IN CASE OF EMERGENCY ESCAPE IN AIR AND ON GROUND

A. In Case of Emergency Escape in Air

At the moment of escape when the seat ejection mechanism has operated, the seat together with the pilot slides along the guides upward.

In this case, the connector emergency uncoupling rope whose one end is attached to frame 10 and the other end to the emergency lever of the lower portion becomes strained, turns the lever and opens the lock of connector ОРК-2.

The lock breaks down into three parts: the lower part with a set of inboard oxygen hoses КИ-26 remains on the aircraft, the middle part (body) is rigidly secured to the seat pan and the upper part with a hose bundle and pressure ratio regulator РКК-3М remains on the parachute suspension system. After the escape this part is pulled up to the left hip of the pilot by means of a strip and a shock absorber.

At the moment of disjointing connector OPK-2 the non-return valves located on its upper portion become closed under the action of springs and prevent the leakage of oxygen from the parachute breathing apparatus KI-27M into atmosphere.

The hook on the lower portion of connector OPK-2 engages the ear of the rope of emergency switching-on of parachute breathing apparatus KI-27M.

When the seat slides upwards, the rope of emergency switching-on whose hook is connected with the lower portion of connector OPK-2 extracts the safety pin out of the mechanism which switches on parachute breathing apparatus KI-27M.

As soon as the oxygen breathing apparatus is switched on, the oxygen from its bottles is delivered to the bladders of high-altitude suit BKK-4 through ratio regulator PCA-3M. The oxygen creates pressure on the pilot's body and then under the excessive pressure it flows into the breathing system, thus preventing the pilot's lungs from uncompensated pressure.

The ratio of the pressure in the suit bladders to that in the breathing system is adjusted automatically by pressure ratio regulator PCA-3M in accordance with the altitudes.

If the oxygen supply from parachute breathing apparatus KI-27M is insufficient at altitudes below 10 km., the non-return valve of the breathing system located in the upper portion of connector OPK-2 provides sucking of the air from the atmosphere to create the required gas mixture.

B. In Case of Emergency Escape during Water Landing or on Ground

For cases when it is necessary to quickly disconnect the oxygen supply line of the pilot's individual outfit from the inboard equipment during water landing or in emergency case on the ground provision is made for a group connector installed on pressure ratio regulator PCA-3M.

The group connector becomes uncoupled after the pin is extracted from the joints of the pressure ratio regulator body and the connector strip. The valve located in the strip of the emergency group connector in the pressure suit bladder supply line becomes shut off and insulates the suit bladders from the atmosphere and from water in case of water landing.

Chapter X

ANTI-G SYSTEM

PURPOSE, OPERATING PRINCIPLE AND INSTALLATION OF SYSTEM IN AIRCRAFT

The anti-G device is intended for increasing the ability of the pilot's organism to withstand the overloads.

The operating principle of the anti-G device consists in the following: since the pressure suit tightly fits the lower half of the pilot's body, the inertial blood shift in the abdominal cavity and lower extremities vessels is reduced thus improving the blood circulation in the cerebrum and, consequently, the pilot's efficiency.

The anti-G device consists of:

(a) pressure regulator;

(b) filter;

(c) anti-G suit bladders.

Pressure regulator AA-5A automatically regulates the air pressure in the anti-G suit bladders depending on the overload value.

The unit is mounted in the cockpit near frame No. 9, port side.

Its filter serves for cleaning the air, supplied from the engine compressor to pressure regulator AA-5A of mechanical impurities.

The filter is mounted in the cockpit near frame No. 10, port side.

The anti-G suit bladders are part and parcel of the high-altitude pressure suit.

During vertical accelerations equal to 2 g the piston of pressure regulator will compress, due to inertia, the spring of the pressure regulator and sliding downwards it will open access for the air from the pressure regulator through the rubberized hose, ocnnon connector OPN-2 and the coupling of the quick-release joint into the anti-G suit bladders.

The greater the acceleration the greater is the travel of the piston downwards and the greater are the cross-sections through which the air is delivered into the suit bladders.

When the accelerations are removed, the piston will assume the extreme upper position allowing the air to bleed into the cockpit through the pressure regulator.

When the accelerations amount to 10 g the air flows into the cockpit through the safety valve.

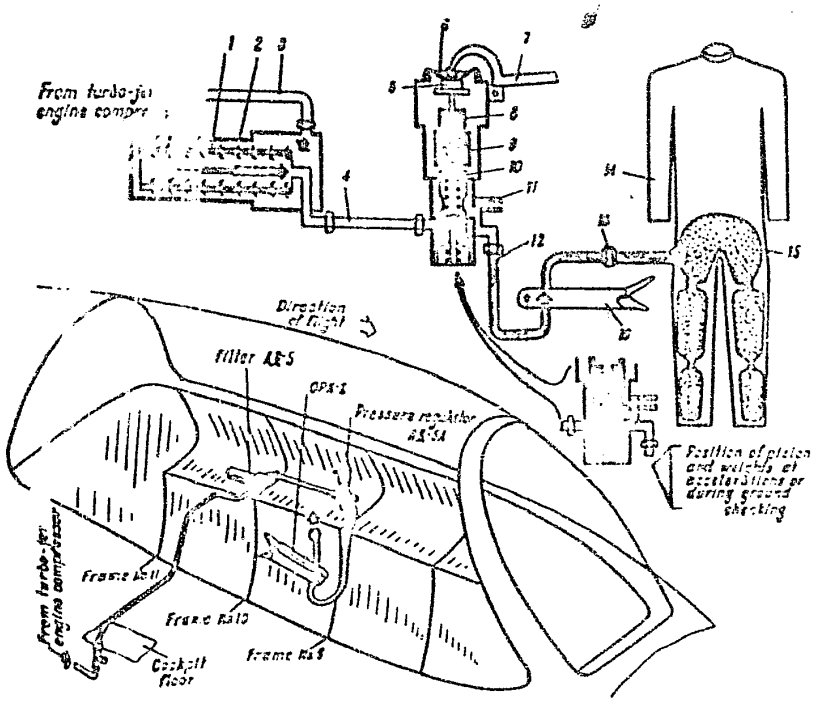

FIG. 42. ANTI-G SYSTEM

1 – paper filter AE-5; 2 – filter AE-5; 3 – air supply pipe line from engine compressor to filter AE-5; 4 – air supply pipe line from filter AE-5 to pressure regulator AE-5A; 5 – pressure regulator checking button; 6 – rubber cap; 7 – lever for checking operation of pressure regulator and switching on head on the HIGH or HIGH position; 8, 9 – weights actuated by levers; 10 – gasket; 11 – safety valve rated for 625 to 670 mm of mercury; 12 – armoured conduit; 13 – coupling of quick-release joint with pilot's high-altitude pressure suit; 14 – high-altitude pressure suit; 15 – rubber bladders; 16 – common connector OPE-2.

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Pressure regulator AI-5i can build up two stages of pr
when the pressure regulator head is in the MIN. position and
the pressure regulator head is in the MAX. position.

When the pressure regulator is used in set with high-alt
suit [redacted]-4, its head is set in the MAX. position.

For ground checking of serviceability of the pressure regulat
there is a button controlled by the pressure regulator checking le

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