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COUNTRY USSR

REPORT [redacted]

SUBJECT Soviet Technical Manuals for the R11F-300 Turbojet Engine

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THIS IS UNEVALUATED INFORMATION. SOURCE GRADINGS ARE DEFINITIVE. APPRAISAL OF CONTENT IS [redacted]

[redacted] one copy each of the following English 50X1-HUM language manuals [redacted]

a. R11F-300 Engine, Operating Instructions, 200 pages 50X1-HUM and two insets. The text is prefaced with a comment that the drawings specially supplemented to the book are designated with Roman numerals and those contained in the Album of Drawings are designated with Arabic numerals. Unfortunately, the Album of Drawings is not available.

b. R11F-300 Engine, Technical Description, 142 pages. The figures mentioned in the text are not included and probably are found in the Album of Drawings.

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[redacted] Comment: The R11F-300 engine is installed in MIG-21 (FISHBED) aircraft. [redacted] 50X1-HUM

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GROUP 1
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INFORMATION REPORT INFORMATION REPORT

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R11F-300 ENGINE

Operating Instructions

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P11Ф-300 ENGINE

Operating Instructions

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Р11Ф-300 ENGINE

Operating Instructions

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The Book contains 200 pages and 2 insets.

C O N T E N T S

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Attention!

Drawings specially supplemented to this book are designated with Roman numerals; Arabic numerals denote drawings given in the Album of Drawings.

ENGINE OPERATING PRINCIPLE

Air draw in by the compressor is compressed to a pressure of P_c=8.0 kg/sq.cm. and is further delivered into the cannular combustion chamber.

At the combustion chamber inlet the air is divided into two streams: the primary air stream (30% of the entire air) passes through the domes with the swirlers and into the combustion chamber to be used up in the fuel combustion process, fuel being delivered by the HP-21Φ fuel regulating pump via ten main burners installed in the dome portion of the combustion chambers. The secondary air stream (comprising 70% of the air) enters the combustion chambers through special holes provided in the combustion chamber walls, mixes up with the combustion products, and reduces the temperature of the gases, to lessen its detrimental effect on the nozzle diaphragm vanes and turbine blades, and cools the combustion chamber walls.

The secondary air also forms a heat insulating layer between the walls of the combustion chambers and their housing.

All the ten combustion chambers are joined by interconnecting tubes serving for equalizing pressure in the chambers. Interconnecting tubes serve for flame propagation during engine starting.

Two upper tubes located between combustion chambers 1 - 2 and 9 - 10 mount two starting system flame igniters providing for initial delivery and ignition of gasoline.

Hot gases flowing out of the combustion chambers possess high potential and kinetic energy; while passing through the nozzle diaphragm and the turbine blades they impart rotary motion to the turbine.

Power generated by the 1st stage turbine is used up for spinning the high-pressure compressor rotor and for driving the engine accessories mounted on the engine wheel case.

Power developed by the 2nd stage turbine is used for driving the low-pressure compressor rotor. Exhaust gases leave the turbine to be carried via the diffuser into the jet nozzle. The jet nozzle passage area is controlled with the aid of an electro-hydraulic control system.

In the jet nozzle the potential energy of the gases is converted into kinetic energy, the velocity of gas outflow increasing and the temperature and pressure decreasing.

Provision has been made for engine thrust augmentation to accomplish a short-time increase in the engine thrust at take-off from limited area air fields, or during flight, when it is necessary to obtain a rapid increase in speed or altitude of flight because of some tactical considerations.

At augmented rating the fuel via two manifolds and 102 injectors is delivered into the afterburner diffuser by the НР-22Ф fuel regulating pump.

The afterburner fuel is ignited by a special flame igniter and is burnt at the expense of excess oxygen contained in the combustion products issuing from the combustion chambers; fuel thus burnt increases engine thrust by 50%(max).

MAIN TECHNICAL DATA

Р11Ф-300 Engine Specifications

1. General

1. Engine designation Р11Ф-300
2. Engine type . . . . turbo-jet, two-shaft, with afterburner
3. Compressor . . . . axial, 6-stage, two-spool (3+3)
4. Combustion chambers: . . . . individual, straight-flow, accommodated in common housing
   - number . . . . 10 pieces
   - numbering . . . . left-hand, starting from upper left-hand chamber (looking fwd)
5. Turbine . . . . axial, 2-stage, two-shaft; 2nd stage shrouded
6. Jet nozzle . . . . adjustable, variable duty; diameter of flaps varies within 526 - 680 mm

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7. Arrangement of engine accessories . . . . engine lower portion
8. Direction of rotation of rotors . . . counter-clockwise (as viewed from jet nozzle end)
9. Engine overall dimensions:
   - (a) length . . . . 4600 mm
   - (b) diameter of turbine (housing) . . . . 772 mm
   - (c) diameter of afterburner (shroud) . . . . 906 mm
   - (d) maximum height (with accessories) . . . . .1085 mm
10. Dry weight of engine with afterburner . . . . not over 1065^{+2} kg

    Note: Dry weight does not include aircraft accessories and assemblies delivered along with the engine, such as:
    - (a) ГСР-СТ-12000-ВТ starter-generator. . . . . 30 kg
    - (b) ДЦН-13ДТ fuel booster pump. 4.2 kg
    - (c) fuel-oil cooler unit 357 c, complete with brackets and attachment clamps . . . . . .31.1 kg
    - (d) attachment clamps for starter-generator, fuel booster. pump and НП-34-2Т unit . . . .1.7 kg
    - (e) auxiliary drive of hydraulic pump with pump attachment clamp . . . . 4.0 kg
    - (f) hydraulic control unit cooling case . . . . 6.4 kg
    - (g) aircraft brackets used to attach engine. . . . . .3.6 kg
11. Engine weight, as delivered. . . not over 1147.0 kg+2%

    Note: The shipping weight of the engine does not include the weight of the oil inserted for corrosion-preventive treatment, and the weight of the auxiliary parts.

12. Engine mounting on aircraft . . . acc. to Dimensions Dwg
13. Engine is furnished with:
   (a) automatic autonomous starting system providing for push-button starting of engine;
   (b) regulating fuel pump HP-21Φ, which serves for engine control; it maintains low-pressure rotor r.p.m. at a constant level irrespective of altitude and speed of flight, and also meters fuel supplied into the engine at automatic starting, acceleration, and at sustained transient ratings;
   (c) regulating fuel pump HP-22Φ, delivering fuel into the afterburner so that to maintain constant pressure ratio P_2/P_4; it also limits fuel supply depending on pressure P_2 and limits high-pressure rotor r.p.m.;
   (d) compressor intake fairing anti-icing device, providing for normal operation of the engine at any atmospheric conditions;
   (e) afterburner with variable duty jet nozzle and dual main fuel manifold;
   (f) control system incorporating the ПУРТ panel for control of ratings; the panel ensuring engine and jet nozzle control from CUT-OFF to FULL AUGMENTED through the movement of the engine control lever;
   (g) flame igniter oxygen supply system, providing for reliable starting at high altitude.
   (h) system of air bleeding.

Amount of air bled from the compressor at maximum engine speed and at standard atmospheric conditions. . . . . .860 kg/hr

14. Guaranteed service life of engine up to first overhaul . . . . refer to Service Log
   - including operation at maximum and augmented ratings for not more than . . 30%

   Note: When calculating the entire operating life of the engine, running time on the ground is considered to be equal to 20% of the entire operating life. If the engine running time on the ground exceeds 20% of the service life, the subsequent operation should be calculated 1 hr per hr.

2. Jet Nozzle Exhaust Area Diameter Values at Main Engine Ratings

1.	Full augmented rating	680 mm (max.)
2.	Minimum augmented rating	610 mm (min.)
3.	Maximum rating	526 mm (min.)
4.	Normal rating	526 mm (min.)
5.	0.8 normal rating	526 mm (min.)
6.	Idling rating	680 mm (max.)

3. Engine Control

1. Engine control is accomplished by means of the control lever, through the medium of the control unit.

The control unit consists of the HP-21Φ regulating fuel pump and the ПУРТ-1Φ control panel interconnected by means of a link. The control system provides for operating the engine at the following ratings:

(a) idling rating, which is switched on by setting the engine control lever against the idling rating stop;

(b) ratings from idling to maximum, which are switched on by shifting the engine control lever from the idling rating stop to the maximum rating stop;

(c) maximum rating, which is switched on by setting the engine control lever against the maximum rating stop;

(d) minimum augmented rating, which is attained by setting the engine control lever against the minimum augmented rating stop;

(e) partial augmented ratings, which are switched on by moving the engine control lever from the minimum augmented rating stop to the full augmented rating stop;

(f) full augmented rating, which is accomplished by setting the engine control lever against the full augmented rating stop;

(g) engine stopping which is accomplished by setting the engine control lever against the CUT-OFF stop.

2. The jet nozzle of variable-duty type providing for control of augmentation; it is actuated with the aid of three hydraulic cylinders.

Purpose . . . . changing of jet nozzle exhaust area for setting required engine rating

Control system . . . . electro-hydraulic type

Operating fluid . . . . hydraulic fluid АМГ-10Ф , Specifications НП-10-58 , or АМГ-10 , State Standard ГОСТ 6794-53

Hydraulic fluid pressure in system . . 180-215 kg/sq.cm.

4. Starting System

1. Starting system type . . . . automatic, autonomous, electric, with voltage switched over from 24 to 48 V

2. The starting system provides for:
   (a) engine starting or cranking at a temperature of -20 to +50°C, three times in succession, without boost-charging of storage batteries;
   (b) engine starting or cranking at a temperature of -40 to +50°C, five times in succession, using a ground power supply source of the АПА-2МП type, with starter not requiring any cooling in between the operating periods;
   (c) engine starting during flight at any atmospheric conditions at altitudes of up to 12,000 m.(with oxygen supply) and up to 8000 m. (without oxygen supply).

3. Starting system components . . . . . . starter-generator, starting equipment, starting fuel system, flame igniters, oxygen supply system, starting fuel control unit incorporated in НР-21Ф pump, electromagnetic valve controlling fuel feed at starting, starting fuel ignition system, air blow-off valves (2 pieces)

5. Starter-Generator

Type ГСР-СТ-12000ВТ

Purpose . . . . used as starter during engine starting. With engine running, is employed as D.C. generator. Change-over from starter to generator duty is accomplished automatically at $32\%^{+2}_{-1}$ of high-pressure rotor normal rating or by timer action within 44.0±1.2 sec.

Number . . . . 1 piece

Direction of rotation . . . . counter-clockwise

Gear ratio
   at starter duty 2.249
   at generator duty 1.344

6. Starting Equipment (not delivered with engine)

Aircraft power supply source (storage batteries)

Type 15СЦС-45

Number . . . . 2 pieces

Purpose . . . . employed as power source during engine starting

Starting relay box . . . . КПР-15А ; installed on aircraft

Ground power supply source switch box . . КПА-4 (installed on ground power supply source)

Timer

Type . . . . AB7-44-5 (installed on aircraft)

Purpose . . . . provides for successive operation of electric starting equipment within time period of 44.0±1.2 sec.

7. Starting Fuel System

Purpose . . . . during engine starting on ground and in air system provides for gasoline supply into flame igniters and for igniting combustion chambers

Starting fuel used . . . . aviation gasoline Б-70 , State Standard ГОСТ 1012-54

Fuel consumed in one starting. . . . . . not over 0.3 lit.

Components incorporated in starting fuel system:

(a) Starting fuel tank . . . . . 1 piece (mounted on aircraft)

(b) Filter . . . . 1 piece (installed on aircraft)

(c) Starting fuel pump (installed on aircraft)

type . . . . ПНР-10-9М , gear type, driven by electric motor

number . . . . 1 piece

output . . . . 40^{+8} lit.per hour at pressure of $2^{+0.2}$ kg/sq.cm. with V=24V and H=0

pressure adjustment value . . 2±0.2 kg/sq.cm.(with no air pressure supplied into tank and at voltage of 25^{-2} V, as read off aircraft

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voltmeter)

starting fuel tank pressurisation value . . . . 0.4±0.05 kg/sq.cm. (from aircraft compressed air system)

(d) Electromagnetic starting fuel valve

type МКПТ-9

number . . . . 1 piece

(e) Flame igniters

type . . . . external, with low-voltage ignition system ~~and oxygen supply~~

number . . . . 2 pieces

8. Starting Flame Igniter Oxygen Supply System

Purpose . . . . supplies additional amount of oxygen to flame igniters for more effective ignition of main burners when starting engine in flight

Components incorporated in oxygen supply system:

(a) Oxygen bottle . . . . not less than 2 lit. capacity, 1 piece (arranged on aircraft)

(b) Oxygen pressure reducer . . . . . 2130А; outlet pressure amounting to 9 - 10.5 kg/sq.cm.,1 piece (arranged on aircraft)

(c) Electromagnetic oxygen valve . . 1 piece (mounted on aircraft)

(d) Non-return oxygen valve . . . . 1 piece

Oxygen pressure forward of flame igniters . . . . 7 - 9 kg/sq.cm.

Electromagnetic fuel supply valve:

purpose . . . . supplies additional amount of fuel (84±3 lit/hr) for acceleration of starting procedure on ground; fuel is started to be supplied 25 sec. after starting button is pressed; additional fuel supply is discontinued as soon as high-pressure rotor reaches speed amounting to 48%±2 of normal r.p.m.

type ШКПТ-9Ф

number . . . . 1 piece

Starting fuel ignition system . . . . . . low-voltage, employing erosion type surface discharge spark plugs

Air blow-off valves:

purpose . . . . discharges part of air into atmosphere to prevent engine from stalling at starting on ground

type . . . . hydraulic

number . . . . 2 pieces

Permissible gas temperature aft of turbine during starting . . . . not over 650°C

Time required for engine to gain idling speed from the moment starting button is pressed . . . . not over 60 sec.

Afterburner may be turned on within not less than . . . . 90 sec. after pressing the starting button

Notes: 1. ~~During the autonomous starting~~, the time period required for reaching the idling speed may be increased to 80 sec.
2. In case the maximum or augmented speed is reached 90 sec. after pressing the starting button, gas temperature aft of the turbine is allowed to be increased to 720°C (for not more than 5 sec.).

9. Fuel System

1. Grade of fuel

main and afterburner fuels . . . T-1, State Standard ГОСТ 4138-49
T-2, State Standard ГОСТ 8410-57
~~TC-1, State Standard ГОСТ 7149-54~~

2. Fuel booster pump ДЦН13ДТ

Type . . . . centrifugal, with permanent-pressure valve

Direction of rotation . . . . . counter-clockwise

Gear ratio 1.344

Pressure upstream of booster pump . . . . 1.0 - 3.0 kg/sq.cm., abs.

At idling rating . . . . 1.8 - 3.0 kg/sq.cm., abs.

Short-time(with aircraft deenergized) pressure rise upstream of pump:

(a) up to 6000 m.(for TC-1 and T-1) . . . . not less than 0.46 kg/sq.cm., abs.

(b) up to 4000 m.(for T-2). . . . . not less than 0.6 kg/sq.cm., abs.

3. Fuel pressure upstream of high-pressure fuel pumps (main and afterburner ones). . . . . 2.4 - 3.8 kg/sq.cm.

Short-time pressure rise . . . . . . up to 4.0 kg/sq.cm.

At idling rating . . . . not less than 1.4 kg/sq.cm.

4. Main fuel ragulating pump:

Type	HP-21 Ф, plunger, with variable low-pressure rotor speed governor, and with device (ОНД) for limiting fuel pressure increase at acceleration; pump is furnished with hydraulic decelerator, starting fuel control unit, by-pass valve (KC), and distributing valve. Pump rotor is driven by engine high-pressure rotor
Purpose	meters fuel supplied into combustion chambers to provide for maintaining predetermined engine speed at sustained rating and intermediate ratings
Direction of rotation	clockwise
Gear ratio	2.78
Beginning of automatic regulation of engine speed	$85^{-2\%}$ of normal rating, or 9500^{-200} r.p.m.
Maximum fuel consumption (at n_2=11,500 r.p.m.)	not less than 7000^{+200} lit/hr
Minimum fuel consumption (at n_2=10,000 r.p.m.)	$360^{\pm}15$ lit/hr

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5. Afterburner fuel regulating pump:

Type	HP-22 Ф, plunger type with afterburner fuel regulator and barostatic fuel supply limiter; pump is furnished with afterburner valve, high-pressure rotor speed transmitter with limiter, and БУ-4Б control unit
Purpose	meters fuel delivered into afterburner, with P_2''/P_4 ratio permanently maintained; limits fuel delivery depending on compressor outlet pressure (P_2''); limits maximum r.p.m. of highpressure rotor
Direction of rotation	clockwise
Gear ratio	2.57
Maximum fuel consumption (at n_2=11,150 r.p.m.)	Not less than $10,500^{-400}$ lit/hr

6. Pressure of fuel in pilot manifold of engine main fuel system	not over 80 kg/sq.cm.
7. Pressure of afterburner fuel at HP-22 Ф pump outlet	not over 90 kg/sq.cm.

8. Main burner:

Type	centrifugal, two-stage, duplex
Number	10 pieces

9. Starting burner:

Type	centrifugal, single-stage
Number	2 pieces

10. Afterburner fuel injector:

Type . . . . centrifugal, single-stage
Number . . . . .102 pieces
(a) in larger manifold . . . . . .60 pieces
(b) in smaller manifold . . . . . 42 (including 2 starting injectors)

11. Filter at main and afterburner fuel inlet . . . . gauze, having 16,900 meshes per sq.cm.; incorporated in unit 357C

12. Fuel temperature at highpressure pump inlet:

continuous . . . . , not over +80°C
short-time (10 min. per one operating hour) . . . . not over +120°C

10. Lubricating System

1. Type . . . . closed-circuit, autonomous
2. Oil grade used . . . . MK-8, State Standard ГОСТ 6457-53, and 0.6% of MOHOЖ admixture
3. Oil consumption . . . . not over 1.2 lit/hr
4. Pressure in oil line:
(a) at all ratings exclusive of idling rating . . . . . . 3.5 $^{+0.5}$ kg/sq.cm.
(b) at idling rating . . . . . . not less than 1.0 kg/sq.cm.

Note: At altitudes exceeding 10,000 m.oil pressure may drop to 3 kg/sq.cm.

5. Oil temperature at engine inlet . . . not less than +40°C
Oil temperature at engine outlet . . . . not over +140°C

Note: Oil temperature is measured during experimental tests carried out in compliance with a special schedule.

6. Oil pumps:

(a) Oil delivery pump:
Type . . . . gear-type
Number . . . . 1 piece
Direction of rotation . . . . . clockwise
Gear ratio 3.168
Delivery at normal rating with back pressure amounting to 3.5± 0.2 kg/sq.cm. and oil temperature of +60 to 75°C. . . . . not less than 50 lit/min.

(b) Oil pump for scavenging oil from accessory wheel case and from central and rear supports:
Type . . . . gear-type, three-section
Number . . . . 1 piece
Direction of rotation . . . . Clockwise
Gear ratio 3.168
Delivery at normal rating with back pressure amounting to 0.5 - 0.8 kg/sq.cm. and oil temperature of +60 to 75°C . . . . not less than 135 lit/min.

(c) Pump for scavenging oil from front support:
Type . . . . gear-type
Number . . . . 1 piece
Direction of rotation . . . . clockwise
Gear ratio 4.461
Delivery at normal rating with back pressure amounting to 0.5-0.8 kg/sq.cm. and oil temperature of +60 to 75°C. . . . . not less than 12 lit/min.

7. Oil pressure gauge ДИМ-8Т

8. Fuel-oil cooler unit consisting of fuel-cooled oil cooler, low-pressure fuel filter and oil tank:

Type 357С

Purpose . . . . cools oil at any of engine ratings

Oil tank capacity . . . . 16 lit.

Amount of oil inserted in tank . . $12^{\pm}0.5$ lit.

Minimum amount of oil allowing normal operation of engine . . . . 7 lit.

9. Provision has been made in the engine oil system for draining oil from all lower points of the oil cooler and of the engine wheel case, as well as for breathing the engine through the centrifugal breather with barostatic valve ensuring normal operation of the oil system at high altitudes.

10. The engine oil system provides for normal operation of the engine irrespective of interruptions in the oil supply (during inverted flight, etc.) amounting to not more than 17 sec.

11. Ignition System and Electrical Equipment

1. Type of ignition system . . . . electric, low-voltage

2. Booster coil unit:

(a) Booster coils serving combustion chambers КНА-114М

Number . . . . 2 pieces

(b) Booster coils serving afterburner КНА-114М (installed on aircraft)

Number . . . . 1 piece

3. Starting spark plugs: . . . . shielded, surface-discharge

(a) Spark plugs serving combustion chambers СПН-4-3

Number . . . . 2 pieces

(b) Spark plugs serving afterburner . СЭ-21ДБ

Number . . . . 2 pieces (including 1 stand-by spark plug)

4. Generator regulating equipment . . . . РУГ-82 and ДМР-[illegible] (not delivered with engine; installed [illegible] aircraft)

5. Afterburner control unit with relay T, type ТКЕ24ПДТ . . . . КАФ-13Д (not deliv[illegible] ed with engine; [illegible] led on aircraft)

Purpose . . . . causes afterburner [illegible] be turned on and [illegible] off automatically

Number . . . . 1 piece

6. Ratings control panel:

Type ПУРТ-10

Number . . . . 1 piece

7. Variable duty jet nozzle control system:

Type ЭГСУ-1А

Components:

Rheostat transmitter ДР-3А

Regulating rheostat Р-1

Feed-back transmitter ДОС-1А

Pulse delivery box . . . . КВС-1 (installed on aircraft; not deliv[illegible] ed with engine)

Electro-hydraulic switch . . . . . . ГА-164М (installed on aircraft)

8. Control unit:

Type БУ-4Б

Number . . . . 1 piece

Chapter I

OPERATIONAL LIMITATIONS

A. Flight Limitations to Be Observed by Pilot

Rating	Characteristics controlled by pilot on ground and in flight			
	Low-pressure rotor speed (n_1), %	Gas temperature aft of turbine, °C (max)	Pressure of oil delivered into engine, kg/sq.cm.	Time of continuous operation
1	2	3	4	5
FULL AUGMENTED rating	$100^{+1}_{-0.5}$ When afterburner is switched on or off, speed increase (short-time) is not to exceed 106.5	700 With engine gaining idling rating speed within 90 sec. after GROUND STARTING button is pressed: not over 720	3.5 - 4.0	On ground: not over 15 sec. During flight at altitudes up to 10,000 m.: not over 10 min. For altitudes exceeding 10,000 m.: not over 20 min.
MINIMUM AUGMENTED rating	$100^{+1}_{-0.5}$ When afterburner is switched on or off, speed increase (short-time) is not to exceed 106.5	700 With engine gaining idling rating speed within 90 sec. after GROUND STARTING button is pressed: not over 720	3.5 - 4.0	On ground: not over 15 sec. During flight at altitudes up to 10,000 m.: not over 10 min. For altitudes exceeding 10,000 m.: not over 20 min.
MAXIMUM rating	$100^{+1}_{-0.5}$	700 With engine gaining idling rating speed within 90 sec. after GROUND STARTING button is pressed: not over 720	3.5 - 4.0	On ground: not over 1 min. During flight at altitudes up to 10,000 m.: not over 10 min. For altitudes exceeding 10,000 m.: not over 20 min.

1	2	3	4	5
Notes: 1.	The total time of engine continuous operation at maximum and augmented ratings without cooling should not exceed the time period specified for one of these ratings.			
2.	With outside air temperatures above zero, gas temperatures aft of the turbine at the maximum rating may increase to 730°C, when checking the engine on the ground or at take-off. In this case the engine should not be run at the above rating for more than 30 sec.			
NORMAL rating	93±0.7	Not specified	3.5 - 4.0	Not limited either on ground or during flight at any altitude
0.8 NORMAL rating	88±0.7	Not specified	3.5 - 4.0	Not limited either on ground or during flight at any altitude
IDLING rating	According to chart, Fig.1	420	Not less than 1.0	On ground: not over 10 min. In flight at any altitude: not limited.
Engine starting on ground		650		Time required for engine acceleration to idling rating after GROUND STARTING button is pressed:

1	2	3	4	5
				(a) not over 60 sec. if using external power supply source for automatic starting (b) during autonomous automatic starting: not over 80 sec.
Engine spinning: (a) without changing voltage of power supply source (using 24 V system)	n_2 : not less than 10	-	Pointer should start to indicate oil pressure	Not over 45 sec. (according to timer)
(b) with power supply source switched over from 24 to 48 V	n_2 : not less than 15	-	Pointer should read stable oil pressure	Not over 45 sec. (according to timer)

Note: Speed n_2 is developed when the engine is spinned by using a ground power supply source. With the engine spinned by using the aircraft power supply source, speed n_2 should amount to not less than 11.5%.

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<u>Notes</u>: 1. A short-time speed increase should not last for more than 5 sec.
2. Time of engine continuous operation within the range of 95 - 100% is limited in the same manner as when running the engine at the maximum rating.
3. During flight at altitudes exceeding 10,000 m. the pressure of the oil delivered into the engine may decrease to 3.0 kg/sq.cm.
4. During flight at altitudes exceeding 15,000 m. the gas temperature aft of the turbine may increase to 720°C.

Minimum permissible speeds of flight with afterburner on:

(a) up to the altitude of 15,000 m. indicated air speed should not be less than 350 km/hr; at altitudes of 13,000 - 15,000 m. recommended indicated air speed should not be less than 450 km/hr;

(b) at altitudes exceeding 15,000 m. indicated air speed should not be less than 500 km/hr.

<u>Note</u>: In case minimum augmentation is associated with fluctuations in the engine thrust, shift the engine control lever forward until the fluctuation is eliminated.

Engine Acceleration Data

Shift the engine control lever within 1.5 to 2.0 sec.

(a) Time of engine acceleration from idling rating r.p.m.:
- to 99% r.p.m. . . . . according to chart (Fig.II)
- to augmented rating(full, minimum, and intermediate) . . . . not over 20 sec.

(b) Time of engine acceleration from 85% r.p.m. :
- to 99% r.p.m. . . . . 8 - 11 sec.
- to augmented rating (full, minimum and intermediate) . . . . not over 20 sec.

(c) Time of engine acceleration from maximum rating to augmented rating (full, minimum, and intermediate) . . . . not over 9 sec.

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<u>Notes</u>: 1. When accelerating the engine to maximum rating, speed n_1 is allowed to be increased to not over 101.5%.
2. With the engine accelerated to augmented rating, speed n_1 should not be increased to over 106.5%.
3. During engine acceleration to augmented rating a short-time increase in the temperature of gases aft of the turbine should not exceed 720°C.

The time of engine acceleration depends on the speed developed by the engine at the idling rating; the idling rating r.p.m. should be regulated as indicated in the chart (Fig.I).

The maximum permissible r.p.m. of the high-pressure rotor amounts to 103.5%.

Adjustment of the high-pressure rotor speed limiter should be carried out at n_2 amounting to $103.5^{-0.5}$%.

B. <u>Ground Starting Limitations</u>

When checking the engine on the ground, comply with the recommendations presented in the table of limitations for the pilot, taking into consideration the following additional data:

1. Speed n_2 associated with operation of starter (CT) switch of control unit (starter cut off at starting, starting fuel delivery discontinued) . . . . 32^{+2}_{-1}%

2. Speed n_2 associated with operation of control unit switch ВДТ (additional fuel supply at starting cut off, combustion chamber spark plugs deenergized) . . . . 48 ± 2%

3. Speed n_2 associated with operation of control unit switch БОО-1 . . . . 66^{+2}_{-1}%

4. Speed n_2 associated with operation of control unit switch БОО-2 due to decrease in r.p.m. . . . . 60^{+1}_{-2}%

5. Speed n_1 associated with operation of ГЗ switch of НР-21Ф pump hydraulic decelerator (afterburner blocking with respect to speed n_1) . . . . . . 98 ± 1%

6. Operating angle of control panel switch ПК with lever of ПУРТ-1Ф control panel turned from CUT-OUT stop(ГЗ switch gets blocked) . . . . 68-1°

7. Operating angle of control panel switch БФС with turning of control panel lever from CUT-OUT stop(involves setting up of MINIMUM AUGMENTED rating) . . . . 73-1°

8. Operating angle of control panel switch 4, with lever turned from CUT-OUT stop (providing blocking in case two-position system of jet nozzle control is employed) . . . . 100±1°

9. Minimum speed at which low-pressure rotor speed is regulated automatically (for reference) . . . . 85^-2 %

Chapter II

PREPARATION OF ENGINE FOR STARTING

PRIOR TO FLIGHT

1. Filling of Aircraft Main Fuel and Starting Fuel Tanks

Prior to filling the tanks:

1. Check to see that the following servicing facilities are in proper conditon: hoses, fuel dispensing guns, tank plugs, and other equipment exposed to fuel delivered into the tanks; they should be thoroughly protected against dirt.

2. Check the Certificate containing the analysis data of the fuel in question.

The analysis data should conform to the respective State Standard.

Clean aviation gasoline Б-70 (unleaded), State Standard 1012-54, is used as starting fuel.

Fuels T-1 (State Standard 4138-49), TC-1(State Standard 7149-54), or T-2(State Standard 84-10-57) are used as the main fuel.

Fuel should be delivered into the tanks via the refuelling truck filter, type ТФ4-150-200С, and the gauze filter installed in the dispensing gun (10,000 meshes per sq.cm.).

Make sure that the fuel delivered into the tanks does not contain water. For this, prior to filling the tanks, drain 1.5 to 2 lit. of fuel from the refuelling truck settler into a clean glass vessel, after which drop a few crystals of potassium permanganate into the fuel. A characteristic tint will indicate that the fuel contains water.

2. Filling of Engine Oil Tank

For lubrication and cooling of the bearings and of the engine drives use is made of oil MK-8, State Standard 6457-53, with HOHOH admixture.

The oil delivered into the tank should be clean and should conform to the respective State Standard (be sure to look through the Certificate, containing the analysis data of the oil in question).

When filled to capacity (with the engine oil system filled likewise), the oil tank should contain 12±0.5 lit. of oil (the oil level should be checked with the aid of the oil measuring rod).

The oil level should be checked not less than 10 min. after the engine is stopped.

Note : If the engine oil system or the wheel case has been drained due to some reason, refilling of the oil tank should be carried out using the following procedure:
1. Fill the engine oil tank to the normal level.
2. Start the engine and accelerate it to 90% r.p.m. within 30.sec. After the engine has been stopped, check the oil level, and top up the tank, if necessary.

WARNING: Do not add oil into the tank with the engine running, to prevent oil ejection.

3. Preflight Inspection of Engine

Operations to Be Carried Out Directly Prior to Starting

Prior to starting perform the following operations:

(a) Check the main fuel tanks, starting fuel tank, oxygen bottles, and the oil tank to see that they are properly filled; make sure the oil tank filler plug is properly closed and locked.

WARNING: The aircraft is not allowed to be flown unless the engine oil tank and the oxygen supply system are filled to capacity.

(b) Thoroughly inspect the ground forward of the aircraft; remove the ground equipment, clean the area of foreign objects (wire, waste cloth, paper, etc.).

(c) Remove the blanking cover from the aircraft air intake, and inspect the air duct for condition. While doing so, employ an inspection lamp or a flood light.

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(d) Remove the blanking cover and inspect the afterburner for condition; inspect the jet nozzle flaps, the flame arrester, and the divider. When proceeding in this way, use an inspection lamp or a flood light.

(e) Check the engine control lever for smooth travel, by moving it from one extreme position to the other.

(f) Check to see that:

- the aircraft storage batteries are properly charged (as is laid down in the respective Instructions);
- the oxygen equipment (for starting the engine in air) is fully charged and ready for operation;
- switch OXYGEN (ВКЛ) is in the proper position.

WARNING: Upon completion of the operations involved in setting the OXYGEN switch in the CHECKING position, it is necessary to set the switch to the OPERATION position and to lock it subsequently.

(g) Check the engine oxygen supply system for tightness, using the following procedure:

- open for 10 to 15 sec. the oxygen shut-off valve; check the readings of the pressure gauge downstream of the reducing valve;

- check the readings of the pressure gauge 3 or 5 min.later, and compare them to the initial readings. The readings should agree. This will indicate that the system between the shut-off valve and the electromagnetic valve controlling the oxygen supply is airtight.

Chapter III

CHECKING OF ENGINE ON GROUND PRIOR TO FLIGHT

The engine check on the ground is performed once, at the beginning of the flying day, and includes the following procedures:

1. Engine starting.
2. Warming up and checking engine operation during acceleration and deceleration.
3. Engine stopping.

The ground check should be carried out in compliance with the chart (Fig. [illegible]). Augmented rating (indicated by the dotted line on the chart) should be checked when carrying out the regular operation (See Chapter V).

1. Engine Starting

During the engine starting and operation, the maintenance personnel should keep a distance of not less than 15 metres away from the aircraft intake duct and a safe distance from the exhaust gas stream.

WARNING:
1. Do not start the engine, if the engine instruments are out of order.
2. In case some routine maintenance or mounting operations have been carried out on the engine or in the engine compartment, the engine should be started with the access panels open, to allow inspection of the engine in the course of starting.
3. After 5 unsuccessful attempts to start or to crank the engine, proceed as follows:
   (a) discharge fuel from the drain tank, by removing the blanking cover from the drain tank tee-piece;
   (b) check oil level in the tank; if more than two litres are gone, drain oil from the engine accessory wheel case, and add oil into the tank up to the specified level (See Chapter II);
   (c) cool the starter-generator for at least 30 min. The starter-generator may be blown with compressed air for 15 min.;
   (d) engine starting on the ground may be accompanied by a characteristic sound in the region of the two-speed drive which will indicate a slipping of the friction clutch discs (the sound is heard within 10 sec. after pressing the GROUND STARTING button).
4. No attempt to repeat the engine starting or cranking should be made until the high-pressure rotor comes to a standstill.

The engine starting on the ground is accomplished automatically in the following way:

1. Turn on the following switches:
- AFTERBURNER (A3C-15);
- aircraft-ground storage battery (master switch);
- STARTING UNITS (A3C-25);
- CRANKING (BΠ), in the STARTING position;
- PROCESSING (BK), in the OPERATING position, if found turned off;
- pump No.2 (A3C-5);
- engine instruments (A3C-5).

2. Set the engine control lever in the IDLING RATING position.

3. Press the GROUND STARTING button, releasing it in 2 or 3 sec.

This should cause the engine to automatically accelerate to idling rating r.p.m.

WARNING:
1. When starting the engine, do not shift the engine control lever beyond the IDLING RATING stop, as this may result in engine surges accompanied by a sharp rise of the gas temperature aft of the turbine.
2. Set the engine control lever in the IDLING RATING position 10 sec. before pressing the GROUND STARTING button.
3. If the engine starting is accompanied by surges (rumbling) when the engine picks up n_2=18 - 20%, shift the engine control lever for 1 or 2 sec. to the CUT-OUT stop, and then set it again in the IDLING RATING position.
4. To avoid overfilling the drain tank, or overheating the electromagnetic valve controlling additional fuel supply at starting, discontinue the starting procedure by turning off the STARTING UNITS (A3C-25) switch in case the engine fails to accelerate to n_2=18-20%.

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When starting the engine, watch the readings of the tachometer indicators, the pressure gauge indicator, and the gas temperature gauge:

- with speed n_2 = 10 - 15%, the pressure gauge pointer should indicate stable oil pressure;

- the gas temperature rise aft of the turbine should not exceed the permissible value (650°C);

- speed n_2 associated with the end of the starting cycle of the starter-generator during a normal starting should amount to 31^{+2}_{-1} % (speed associated with operation of cam CT).

Check this point by the indications of the pilot lamp ENGINE STARTING (the lamp should go out).

Notes: 1. Normal starting should not be accompanied by torches ejecting from the jet nozzle.
2. In the course of starting, engine acceleration rate may be reduced within the range of 24 to 28%; total starting time not exceeding 60 sec. When the engine is started by using the aircraft storage batteries the starting cycle should not exceed 100 sec.

WARNING: If the above recommendations are not complied with, or in case some troubles become evident in the course of the starting procedure, immediately discontinue starting by setting the engine control lever in the CUT-OUT position and by turning off the STARTING UNITS switch.
If the starting procedure had been interrupted before the STARTING UNITS pilot lamp went out, turn on the STARTING UNITS switch and keep it in the ON position for not less than 45 sec. to allow the starting control equipment to complete cycle of operation.
A repeated attempt to start the engine should not be made until the trouble is located and eliminated.

2. Power Supply Sources

Engine starting on the ground may be accomplished by the use of the aircraft and ground power supply sources.

The aircraft power supply source is comprised of two storage batteries, type 15СЦС-45, rated for a voltage change-over of 24x48 V.

A ground power supply source may be represented by any D.C. supply source having 24 - 30 V across the terminals and rated

for a voltage switch-over of 24x48 V. The АПА-2МП ground starting trolley is best suited for the purpose.

The capacity of the power supply source should not be less than 200 ampere-hours.

3. Warming Up and Checking Engine Operation

1. After the engine has accelerated to the idling r.p.m. run it at this rating for 8 to 10 sec.

Check the readings of the tachometer oil pressure gauge, and the gas temperature gauge.

2. Smoothly shift the engine control lever to the position corresponding to 88 - 90% r.p.m., and run the engine at this rating for 8 to 10 sec.

3. Smoothly shift the engine control lever to the MAXIMUM rating stop and run the engine at this rating for 8 to 10 sec. Check the readings of the tachometer, oil pressure gauge and the gas temperature gauge.

4. Smoothly shift the engine control lever to the FULL AUGMENTED rating stop and make sure the afterburner has been turned on judging by the indication of the respective pilot lamp and by a drop in the gas temperature aft of the turbine; the gas temperature should rise to the initial value after the afterburner is ignited. Run the engine at this rating for 8 to 10 sec., while checking the readings of the tachometer, oil pressure gauge, and the gas temperature gauge.

5. Smoothly move the engine control lever to the MAXIMUM AUGMENTED rating stop. Run the engine at this rating for 5 sec.; watch the readings of the tachometer and gas temperature gauge.

The augmented ratings should be cut off by a smooth movement of the engine control lever to the MAXIMUM rating stop or to a position corresponding to some lower rating. The afterburner disconnection is indicated by the respective pilot lamp, which should go out.

WARNING: 1. To prolong the engine service life, the maximum rating should not be checked for more than 1 min., whereas the augmented rating should be checked for not more than 15 sec.
2. When the afterburner is turned on or off, a short-time speed increase (not exceeding 5 sec.) may be observed, the increase being not in excess of the specified value (See Chapter I).

3. The introduction of the augmented ratings must be smooth, no popping being permissible. A drop in the gas temperature aft of the turbine should be within 20 - 60°C. With the ambient air temperatures above +15°C, the temperature drop may equal 80°C (as compared to the temperature characteristic of the maximum rating).
4. If no fuel ignition takes place after the afterburner has been turned on (the gas temperature aft of the turbine drops below 450°C), cut off the afterburner by shifting the engine control lever to the MAXIMUM rating stop, to avoid excessive fuel consumption.
5. In case afterburner operation is associated with the speed surging or a rise of the gas temperature aft of the turbine in excess of the specified value, cut off the afterburner by shifting the engine control lever to the MAXIMUM rating stop. If surging or the temperature increase persists, move the engine control lever to the CUT-OUT stop. Do not turn on the afterburner until the trouble is located and eliminated.
6. In case the movement of the engine control lever to the MAXIMUM rating stop does not result in the afterburner cut-off, turn off the AFTERBURNER (A3C-15) switch.

Note: Check engine operation at the augmented ratings every 10±2 hours of its operation, or in case operation of the engine at this rating is doubted; carry out the above check every 10 days, in case the aircraft is not flown for periods up to 30 days.

6. Reduce the engine speed to the idling rating r.p.m. by smoothly moving the engine control lever; while doing so check the engine operation by the readings of the tachometer and the gas temperature gauge.

7. Check to see whether the engine responds properly to the movements of the control lever shifted from the IDLING rating position to the MAXIMUM rating position and back.

Notes: 1. The engine r.p.m. should not lag behind the engine control lever smoothly moved within not less than 20 sec. from the idling rating r.p.m. to the maximum rating r.p.m. and back.
2. Fluctuations in the engine speed are allowed within the following range:
(a) ±0.5% for r.p.m. equalling 88%;
(b) ±0.3% for speed ranging from 88% to 100%.

8. Having ascertained that the engine operates normally at sustained and transient ratings, check it for proper acceleration within the following ranges:

(a) from idling rating to maximum rating;

(b) from 85% r.p.m. to maximum rating r.p.m.;

(c) from idling rating to augmented rating (if necessary).

The time required for engine acceleration is determined starting from the moment the engine control lever begins moving, and ending with the moment the engine accelerates to the respective rating r.p.m.

Note: With the engine accelerating up to the augmented rating r.p.m., the end of the acceleration period is indicated by a characteristic noise produced by the afterburner.

9. Having completed the acceleration test and run the engine at the respective rating for 5 sec., reduce the engine speed to 80% by smoothly shifting the engine control lever to the required position, and run the engine at this rating for 8 to 10 sec.

10. After the engine run at 80% r.p.m. is over, check operation of the oxygen supply system employed for starting the engine in the air, proceeding in the following manner:

(a) smoothly shift the engine control lever to the CUT-OUT stop;

(b) as soon as the engine reaches speed of n_1=35 - 40%, set the engine control lever against the IDLING rating stop, and operate the switch STARTING IN AIR (A3C-10) keeping it in the ON position for 10 to 12 sec. After reaching the idling rating r.p.m., accelerate the engine to 80% r.p.m. and run it at this rating for 10 to 15 sec., then stop the engine after running it for 10 to 12 sec. at the idling rating. After the engine comes to a standstill, check to see that the oxygen pressure is equal to zero (as indicated by the low pressure gauge).

4. Engine Stopping

Engine stopping should be accomplished by shifting the control lever to the CUT-OUT position.

If the engine has been run at the r.p.m. exceeding 80%, allow it to cool down while running it at 80% r.p.m. for 10 sec. prior to stopping.

In case the engine has been operated within the range of from the idling rating to 80% r.p.m. (including engine operation after taxiing), the stoppage should be accomplished without cooling it at lower ratings.

Stop the engine using the following procedure:

1. After operating the engine for 10 to 12 sec. at the idling rating, smoothly shift the control lever to the CUT-OUT position.

2. After the high-pressure rotor comes to a standstill, turn off the following switches: master switch A3C-25 and switch AFTERBURNER (A3C-15).

WARNING: To avoid damage to the fuel pumps, never close the fuel shut-off valve until the high-pressure rotor comes to a standstill (exclusive of the cases when fire becomes an immediate danger).

3. While the engine is slowing down, check the rotors aurally for smooth rotation and for absence of foreign noises.

4. After the engine rotor has stopped, fit the blanking cover into the engine air intake duct. Close the engine exhaust port 15 to 30 min. after stopping the engine (depending on the outside air temperature).

5. Add oxygen into the oxygen supply system, as is laid down in Chapter VII (in case the oxygen supply system has been checked on the ground), open the cut-off valve and make sure oxygen low pressure gauge reads pressure.

Notes: 1. As the high-pressure rotor slows down, the two-speed drive dogs should cause noise similar to that produced by a rattle.

2. While the engine is slowing down, check the rotors for ease of rotation by noting the time period elapsing from the moment the engine starts running at the idling rating r.p.m. to the moment the engine comes to a standstill. This time period should amount to 180 sec. for the low-pressure rotor, and to at least 35 sec. for the high-pressure rotor; these values should remain practically unchanged throughout the service life of the engine.
The high-pressure rotor stopping is associated with the disappearance of the noise produced by the dogs of the two-speed drive of the starter-generator.

Should it be necessary to stop the engine in emergency, shift the engine control lever to the CUT-OUT stop.

Stop the engine immediately in the following cases:

1. When a sharp drop is experienced in the pressure of the oil supplied into the engine.
2. When leakage of fuel, oil, or hydraulic fluid shows up in the engine system or in the delivery lines, which is likely to involve fire hazard.
3. If a sharp rise is evidenced in gas temperature aft of the turbine.
4. When flame or sparks are ejected from the jet nozzle.
5. When the engine produces an abnormal noise.
6. When engine operation is accompanied by vibrations.

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Chapter IV

OPERATION OF ENGINE IN FLIGHT

During taxiing and in flight the engine may be operated at any rating within the range of from the idling rating to the FULL AUGMENTED rating, provided the indications of the instruments agree with the values referred to in Chapter I.

The following instruments should be kept under regular observation while in flight:

- tachometer indicators (n_1 and n_2);
- oil pressure gauge indicator;
- gas temperature gauge indicator.

Note: In case one of the tachometers (reading speed n_1 or n_2) fails, the readings of the other tachometer may be used; in this event, the idling rating r.p.m. (for n_2) in landing should amount to not less than 48%.

The instrument readings should conform to the established engine rating.

Should the instrument readings disagree with the permissible range of values, the engine should be operated at a lower rating, providing for proper indications of the instruments.

1. Engine Operation at Take-Off and during Climbing

During the take-off and climbing the engine may be operated at any of the following ratings: MAXIMUM, MINIMUM AUGMENTED, any of the transient augmented ratings, and FULL AUGMENTED.

WARNING: 1. Under emergency conditions (with the engine accelerated to the augmented rating within 90 sec.) at the take-off, gas temperature aft of the turbine may increase to 720°C.
2. Continuous operation of the engine at maximum and augmented ratings is allowed within a specified time period (See Chapter I).

During aircraft acceleration and climbing, speed n_2 will vary depending on the variations in the speed of flight (Mach number), but it should not exceed 103.5% r.p.m.

WARNING: 1. Climbing at a constant Mach number may involve an increase in speed n_2, the increase not exceeding 0.5%.
2. When climbing with the Mach number decreasing, do not allow the Mach number to drop below the specified value (See Chapter I).

At altitudes exceeding 10,000 m. pressure of the oil delivered into the engine is allowed to decrease to 3.0 kg/sq.cm.

Engine control. Any of the engine ratings within the range of from the idling rating to the full augmented rating may be established by shifting the engine control lever to the respective position.

The engine control lever may be shifted at any rate, but not quicker than 1.5 to 2.0 sec. With the engine control lever shifted within the range of from 85% to 100% r.p.m. at a rate exceeding 10 sec., speed n_1 should not lag behind the travel rate of the control lever.

In any of the fixed positions of the engine control lever, variations in the r.p.m. should not exceed the following values:

±0.5% - from idling rating r.p.m. to n_1=88%;
±0.3% - from speed n_1=88% to n_1=100%.

Note: In-flight variations in speed n_1 (taking place within 2 sec.) exceeding the permissible values and resulting in the swinging of the link are not allowed. Eliminate the trouble on the ground (See Chapter XI).

Acceleration and deceleration

Engine acceleration to the maximum rating (including the cases with the engine slowing down) may be accomplished by quickly moving the engine control lever from any effective position (excluding positions below the idling rating stop).

Normal acceleration of the engine during flight and acceleration with the engine slowing down, within the range of from the idling rating to the maximum or augmented rating, as well as engine deceleration within the above range is allowed to an altitude of 15,000 m. at any flight speed specified in the respective instructions (at altitudes of 13,000 to 15,000 m. the recommended indicated speed should not be less than 450 km/hr).

WARNING: In case engine acceleration is accompanied by surging, immediately stop the engine and start it as is laid down in the present Chapter. Further acceleration of the engine in flight is not allowed.
The engine should be controlled by moving the engine control lever in a slow manner.

Engine augmentation. The afterburner may be turned on at altitudes up to 15,000 m., with the indicated air speed amounting to not less than 500 km/hr.

Should it be necessary to turn on the afterburner at altitudes of from 15,000 to 18,000 m., the recommended indicated air speed should exceed 550 km/hr.

The afterburner is switched on in flight by shifting the engine control lever to the FULL AUGMENTED rating position, with a subsequent setting of the control lever in the required position.

The change-over to the augmented ratings (minimum, intermediate and full) on the ground and at the take-off should be accomplished by setting the engine control lever to the respective position.

WARNING: 1. If the afterburner operation is accompanied by an excessive rise in the gas temperature aft of the turbine, turn off the afterburner by setting the engine control lever to the MAXIMUM rating position.
2. In case fuel fails to be ignited after the afterburner is switched on (gas temperature aft of the turbine drops below 450°C within 15 sec.), switch off the afterburner by shifting the engine control lever to the MAXIMUM rating position or to a position corresponding to a still lower rating.

Engine operation at augmented ratings:

- up to 15,000 m. - with the indicated air speed amounting to not less than 350 km/hr (at altitudes of 13,000 to 15,000 m. recommended indicated air speed should not be less than 450 km/hr);
- at altitudes exceeding 15,000 m. - with the indicated air speed amounting to not less than 500 km/hr.

Engine operation at minimum and intermediate augmented ratings is allowed within the entire range of altitudes and speeds referred to above. In case of an unstable engine running at minimum or intermediate augmented ratings, which is manifested by variations in the engine r.p.m., as read by the n_1 and n_2 indicators, as well as by jerks occurring along the aircraft centre line, it is necessary to shift the engine control lever to the FULL AUGMENTED rating stop, until the variations in the speed disappear.

Repeated engagement of afterburner. A repeated engagement of the afterburner within the time period specified for continuous operation should be done after running the engine at the maximum rating for at least 10 sec. A repeated acceleration of the engine to the maximum and augmented ratings, after the specified time period of engine operation at these ratings has expired (See Chapter I), should not be performed earlier than 1 min. after the engine has cooled down while running at the normal or less [illegible] rating.

Afterburner disengagement. The augmented ratings are switched off by shifting the engine control lever within 2 to 3 sec. to the MAXIMUM rating position, within the entire range of permissible altitudes and augmented rating r.p.m.

WARNING: 1. If shifting the engine control lever to the MAXIMUM rating stop or further does not cause the afterburner to be cut off (the afterburner pilot lamp keeps burning for more than 3 sec.), operate the AFTERBURNER switch.
2. If the afterburner switches off spontaneously, (involving a sudden drop in the gas temperature aft of the turbine), immediately shift the engine control lever to the MAXIMUM rating position or to a position corresponding to a still lower rating.

Adjusting engine thrust augmented rating. The adjustment of the engine thrust at the augmented rating is performed by shifting the engine control lever within the range of from MINIMUM AUGMENTED to FULL AUGMENTED.

WARNING: 1. With the engine running at the minimum augmented rating, the gas temperature aft of the turbine may increase by 20°C as compared to the temperature characteristic of the sustained full augmented rating.

2. If engine operation at the MINIMUM AUGMENTED rating is accompanied by variations in speeds n_1 and n_2 and in the engine thrust involving jerks along the aircraft centre line, shift the engine control lever to the FULL AUGMENTED rating stop until the variations in speed disappear.
   When repeatedly shifting the engine control lever to the MINIMUM AUGMENTED rating position, it is necessary to increase the speed of flight.
3. In case the follow-up system controlling the jet nozzle flaps fails in flight, with the engine running at the augmented rating (the engine fails to respond to the movement of the control lever; engine thrust suddenly decreases or increases), operate the EMERGENCY ENGAGEMENT OF TWO-POSITION JET NOZZLE switch. This will cause the follow-up system to be cut off; further control of the engine will be effected with the aid of the two-position system(MAXIMUM rating = AUGMENTED rating).

2. Engine Operation when Accelerating Aircraft at Augmented Rating

With the aircraft accelerated at the augmented rating, engine speed n_2 should not exceed 103.5%.

At high speeds of flight (exceeding M = 1.6) and with the engine running at augmented and maximum ratings (after the afterburner is turned off), speed n_2 may reach the maximum-permissible value of 103.5 - 0.5% (as limited by the limiter of speed n_2). A further increase in the speed of flight will cause speed n_1 to decrease by 2 - 3 %, with speed n_2 remaining constant.

WARNING: 1. With the engine running at a speed preset by the limiter of speed n_2, speeds n_1 and n_2 may vary within ±0.5%.
2. If during the aircraft acceleration speed n_2 is less than 102.4%, and speed n_1 starts decreasing (by 1 or 2%), the limiter of speed n_2 should be adjusted after the flight is over, as is laid down in Chapter X.
3. As the aircraft is being accelerated, the gas temperature aft of the turbine increases; however the gas temperature should not exceed 700°C when the maximum permissible speed of flight is attained.
4. Should speed n_2 exceed 103.5%, it is necessary to subject the afterburner to ground trials as is laid down in Chapter IX; before doing so,

make sure the tachometer indicator gives correct readings.
5. In case the engine speed drops abruptly below 80%, due to surging in the power plant, immediately stop the engine by shifting the control lever to the CUT-OUT stop, after which start the engine as is instructed in the present Chapter.

Gliding. Gliding is allowed at any of the engine ratings, with the r.p.m. equal to, or exceeding, the idling rating r.p.m. (See Fig.IV).

Note: When gliding is performed after an emergency stoppage of the engine, the control lever should be set in the CUT-OUT position.

Engine operation with booster pumps failing. In case the booster pumps of the service tanks fail, the engine will run normally to the following altitudes:

- up to 6000 m., when using fuel T-1 and TC-1;
- up to 4000 m., when using fuel T-2.

WARNING: Do not turn on the afterburner, if the aircraft is deenergized or the service tank booster pumps are out of order.

3. Flight with Zero or Negative G-Factor

Flight with zero or negative G-factor is allowed at any of the engine ratings for not more than 17 sec.

If oil pressure drops to 0 and does not reach the initial value within 17 sec., it is necessary to discontinue the mission and to reduce the engine r.p.m. to the minimum value providing for a contimation of the level flight.

The representative of the engine Manufacturer should be consulted as to further operation of the engine.

4. Engine Operation with Aircraft Going Round

With the aircraft going round, the engine control may be accomplished by shifting the control lever within 1.5 to 2.0 sec. from the idling rating position to the required position (including the position corresponding to the augmented rating).

WARNING: 1. It should be borne in mind that total time of engine acceleration to the maximum rating amounts to 11 - 14 sec., to the augmented rating - not over 20 sec.; therefore, going round should be decided upon in due time.
2. Should one of the tachometer indicator pointers fail, the readings of the other may be made use

of; it should be taken into consideration, that at low altitudes and on the ground (with the engine running at the idling rating) speed n_1 should exceed 32%, whereas speed n_2 should exceed 48%.

5. Engine Starting and Stopping in Flight

A reliable starting of the engine in flight (with the oxygen supply switched on) is ensured to an altitude of 12,000 m. Engine starting with the use of the oxygen supply system should be performed:

- at altitudes of 12,000 to 10,000 m., with the indicated air speed amounting to 520 - 650 km/hr;
- at altitudes below 10,000 m., with the indicated air speed amounting to 450 - 650 km/hr.

Notes: 1. The speed of autorotation at starting should be equal to 15 - 33% of the speed normally developed by the low-pressure rotor.
2. The engine starting without oxygen supply can be performed to an altitude of 8,000 m., with the indicated air speed amounting to 450 - 650 km/hr.

The engine starting in flight should be carried out using the following procedure:

1. Set the engine control lever in the IDLING rating position.

2. Turn on the switch STARTING IN AIR. With the engine picking up speed at a high rate, turn off the STARTING IN AIR switch (not later than 30 sec. after it has been turned on). The attempt at starting should be considered successful if the engine r.p.m. increases to not less than 50%.

Engine stopping in flight. The engine stopping in flight is accomplished by shifting the engine control lever from the initial position to the CUT-OUT stop.

In case of an inadvertent stoppage of the engine in flight, immediately set the engine control lever in the CUT-OUT position, and start the engine, proceeding in the usual manner (provided the aircraft tanks contain fuel).

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Emergency in-flight stopping of engine. The following conditions are cause for immediate stoppage of the engine in flight:

- strong vibration of the engine;
- sharp increase of gas temperature aft of the turbine;
- surging of the power plant accompanied by a sharp decrease of engine r.p.m.

In case of a fire in the engine nacelle, set the engine control lever in the CUT-OUT position, close the fuel shut-off valve, and use the fire-fighting system.

In all other cases of the engine stoppage in flight, no closing of the fuel shut-off valve is required.

6. Trial Flight

A trial flight is performed after the installation of a new engine, as well as after the replacement of the HP-21Ф and HP-22Ф fuel regulating pumps.

The following points should be checked during the trial flight:

1. Engine controllability within the range of from idling rating to maximum rating, at an altitude of 5000 to 8000 m., with indicated air speed amounting to 500 - 600 km/hr (in the airfield region).

2. Engine acceleration from idling rating to maximum rating at an altitude of 5000 to 8000 m. with the indicated air speed amounting to 500 - 600 km/hr (in the airfield region).

3. Engine operation at augmented ratings within the range of from MINIMUM AUGMENTED to FULL AUGMENTED, at an altitude of 10,000 to 16,000 m., with the indicated air speed amounting to 550 - 650 km/hr. The afterburner switching-on at an altitude of 14,000 to 16,000 m. should be accomplished at indicated air speeds within 450 - 500 km/hr.

4. With the aircraft flying at maximum Mach number, check the engine for maximum speed n_2. This speed should amount to within $103.5^{-0.5}$%.

Notes: 1. After the replacement of the HP-21Ф fuel regulating pump carry out the checks enumerated in Points 1, 2, and 3.
2. After the replacement of the HP-22Ф fuel regulating pump, carry out the checks enumerated in Points 3 and 4.

Chapter V

CARE OF ENGINE

1. General

Trouble-free operation of the engine is largerly dependent on timely and thorough fulfilment of all routine maintenance operations. Any defects should be eliminated as soon as they are detected. The routine maintenance operations performed as well as repairs carried out should be registered in the engine Service Log in due time.

WARNING: All mounting, routine maintenance, and other operations on the engine should be performed using the engine tools set carried on the aircraft.

When carrying out some operations on the aircraft, do not place bolts, nuts, cotter pins, safety wire, or other parts on the engine. Having completed the work, check to see that no small parts and foreign objects are left lying on the engine or in the engine compartment. The engine compartment should be thoroughly cleaned of dust, dirt, and oil.

2. Preflight Engine Inspection

Preflight inspection of the engine should be performed as is laid down in Chapter II of the present Instructions.

3. Postflight Engine Inspection

Postflight engine inspection should be carried out in the end of a flying day. Engine readiness for a subsequent operation is dependent on the quality of the inspection in question.

Subject to inspection and checking are the following units and components of the engine:

1. As the engine is being stopped, with the rotor still spinning due to inertia, see that:

(a) the engine does not generate any foreign noises and knocks. Perform the check aurally. In case some noises appear which question engine soundness, listen to engine operation while cranking it once or twice with the aid of the starter-generator. Do not start the engine unless the defect is detected and eliminated;

(b) no smoke issues from the adjustable jet nozzle. Smoke is a sign of a defective drain valve of fuel regulating pump HP-21Ф; fuel or oil leakage into the afterburner may also be the cause of smoking.

2. After the engine comes to a standstill, proceed as follows:

(a) inspect the aircraft intake duct and the blades of the engine compressor stages through a special inspection hole. Dirt and mechanical damage are not allowed (while proceeding in this way, use an inspection lamp or a flood light).

(b) inspect the inner surface of the afterburner and the adjustable jet nozzle flaps. Make sure they do not contain cracks, burns, or warpage (use an inspection lamp or a flood light).

Special care should be taken in inspecting the accessible components of the diffuser (circular flame arrestors, posts, flame igniter, fuel burners, etc.).

3. Inspect visually all accessible units, control links, and lines, to see that they are properly attached and locked. Defective locking should be excluded.

4. Check the fuel and oil lines as well as the hydraulic fluid lines for leakage. Inspect the points where leakage is likely to show up, such as flanges of individual units, the union nuts of the burners, the joints in the pipe lines, manifolds, and housings.

5. Open the oxygen cut-off valve; oxygen pressure, as indicated by the low-pressure gauge, should be within 7 to 9 kg/sq.cm. (in the aircraft cockpit).

Notes: 1. If leakage is detected in the pipe line joints, tighten them as instructed in Section "Replacement of Pipe Lines". The nuts of the flared joints should not be tightened by more than 45°. A repeated tightening of the flared joints is not allowed.
2. If the tightening of the nuts does not stop the leakage, replace the sealing rings.
3. Having tightened the nuts or replaced the sealing

rings, start the engine and check the joints for leakage, with the engine running.

4. In case leakage is detected on the housing of the fuel filter of fuel-oil unit 357C, it is allowed to tighten the nut securing the filter shackle by ¼ to ¾ of a turn.
5. Permissible fuel escape into the vent system, with the engine running:
   (a) from the drive of the ДЦН-13ДТ booster pump - in drops;
   (b) from the drive of the HP-21 Ф pump and of the starting fuel control unit (total) - not over 60 cu.cm/min.
   (c) from the drive and electric contactor of the HP-22 Ф pump (total) - not over 50 cu.cm/min.
6. Make certain the electric mains as well as the instrument and thermo-couple wiring is in good repair and is securely attached.
7. After the engine cools down, inspect the blades and the shrouds of the turbine II stage. If cracks or dents are detected on the turbine blades, consult the representative of the engine Manufacturing plant, prior to taking decision as to the engine further use. When inspecting the engine, it is prohibited to carry out any operations on the aircraft electrical and hydraulic equipment.
8. Check the starting fuel and oil levels; add up if necessary; add up oxygen into the system supplying the flame igniters of the burners.

WARNING: The minimum permissible amount of oil in the tank after flight should be equal to 7 lit. In case the tank contains a smaller amount of oil, consult the representative of the engine Manufacturing plant.

4. Routine Maintenance after First 5±1 Hours of Engine Operation

1. Inspect the engine as is laid down in Section "Postflight Engine Inspection".

2. Check and tighten, if necessary, the bolt securing the solenoid of the HP-22Ф pump.

3. Remove, inspect, and, if necessary, wash the surface of the oil pump unit filter. The oil pump unit filter should be washed using the following procedure:

(a) without removing the filter from the cover, rinse it in a bath containing clean gasoline Б-70 (prior to doing so, fit the filter with rubber stopper C31-131); do not forget to fit

the oil pump unit with blanking cover БН37-317 in place of the cover removed together with the filter. For cleaning the filter gauses use should be made of brush C31-139;

(b) dry the filter, without blowing it with compressed air.

4. Check clearance П in the telescopic joint between the afterburner diffuser and the adjustable jet nozzle (Fig.V); a local increase of clearance П up to 4.5 mm over an arc not exceeding 300 mm is allowed.

5. If clearance П exceeds 4.5 mm, it is necessary to disjoint the aircraft, to bring up a trolley-mounted frame, and to measure clearance B in the telescopic joint, making use of a feeler gauge.

Where clearance B is largest, make a notch (with a pencil) on the diffuser, remove the telescopic ring, and measure the height of the diffuser collar (size H). The difference between sizes H and B should not be less than 1 mm.

6. If the above difference is in excess of 1 mm, install the telescopic ring, remove the frame and couple the aircraft. During further operation of the engine, see that maximum clearance П does not increase in excess of the initial value. If the clearance does increase, carry out the operations detailed in Point 5.

7. In case the difference between sizes H and B is less than 1 mm, check to see which of the components (diffuser or jet nozzle) is deformed. For this, turn the adjustable jet nozzle through 180° and measure clearance B (at the point where the difference between sizes H and B is less than 1 mm and at the opposite side). If maximum clearance B appears to have been turned also through 180°, then the adjustable jet nozzle is deformed.

If the location of maximum clearance B remains the same after turning the adjustable jet nozzle, then diffuser flange Ж is deformed.

8. Straighten the deformed flange (E or Ж) until the required difference between sizes H and B is obtained. Straightening should be performed with the aid of wooden tools (a mall and a dolly).

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5. Periodic Maintenance

1. Every 30±5 days of engine operation inspect and, if necessary, wash the oil pump unit filter, as is laid down in Section "Routine Maintenance after First 5±1 Hours of Engine Operation".

2. Every 10±2 hours of engine operation, check it for proper operation at the augmented rating. While doing so, measure speed n_2 as is detailed in Section "Replacement of НР-22Ф Fuel Regulating Pump". Enter the value of speed n_2 thus obtained into the engine Service Log.

6. Routine Maintenance Performed Every 50±5 Hours of Engine Operation

1. Perform the operations enumerated in Sections "Postflight Engine Inspection" and "Routine Maintenance after First 5±1 Hours of Engine Operation".

2. Inspect the engine control unit for wear of the links and for play in the control system; check to see that the locking devices of the levers of the НР-21Ф pump and ПУРТ-1Ф control panel, as well as of other parts are intact. Treat the control link joints with ЦИАТИМ-201 lubricant.

Check the engine control system for proper operation by shifting the engine control lever within the entire range, from the CUT-OUT stop to the FULL AUGMENTED rating stop and backwards. The engine control lever should move smoothly, without any binding. While proceeding in this way, pay attention to the following:

(a) with the engine control lever set in the CUT-OUT and FULL AUGMENTED rating positions the lever in the aircraft cockpit should stop 1.5 or 2.0 mm short of the respective stops;

(b) with the engine control lever set in the CUT-OUT position the lever of the НР-21Ф fuel regulating pump should snugly contact the respective stop on the pump dial;

(c) with the engine control lever shifted to the IDLING

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rating position the notch on the flag of the НР-21Ф fuel regulating pump should stop between the notches limiting the IDLING rating sector on the pump dial (first and third notches from the CUT-OUT stop);

(d) when the engine control lever is set against the MAXIMUM rating stop figures 69 - 70 of the control panel dial should come up against the notch on the housing, whereas the notch on the flag of the fuel regulating pump should be located beyond the 6th notch on the pump dial;

(e) with the engine control lever set against the MINIMUM AUGMENTED rating position the lever of the ПУРТ-1Ф control panel should be within the MINIMUM AUGMENTED rating sector (73+1° to 78±2°, as indicated on the dial of the control panel), while the notch on the flag of the НР-21Ф fuel regulating pump should be beyond the seventh notch on the dial of the НР-21Ф fuel regulating pump;

Note: The MINIMUM AUGMENTED rating stop has been so adjusted as to allow figures 74 - 75 of the control panel dial to line up with the notch on the housing when the engine control lever is shifted to the MINIMUM AUGMENTED rating stop.

(f) with the engine control lever set against the FULL AUGMENTED rating stop the lever of the НР-21Ф fuel regulating pump should have a clearance between the flag and the stop, amounting to not less than 2 mm; in this case the lever should be located behind the 7th notch on the dial of the НР-21Ф fuel regulating pump whereas the lever of the ПУРТ-1Ф control panel should tightly contact the FULL AUGMENTED rating stop.

3. Start the engine and check the maximum r.p.m.; if necessary, adjust the maximum r.p.m. to 100±0.5 per cent and check engine operation at the AUGMENTED rating.

4. When inspecting the afterburner:

(a) check the ring and the jet nozzle flaps for cracks, warpage, and scores;

(b) check the hydraulic system controlling the jet nozzle flaps (with the engine at standstill);

When checking the hydraulic system proceed in the following manner:

- connect the ground supply source to the aircraft mains;

- turn on the following switches: MASTER SWITCH, AFTERBURNER, PROCESSING (in the I position);

- cut out the blocking system of hydraulic decelerator ГЗ by turning screw Н on the КАФ-13Д afterburner control unit in the BLOCKING CUT-OUT position;

- connect the ground trolley mounting hydraulic pumps. Make sure the pressure in the hydraulic system is within the permissible limits;

- shift the engine control lever from the MAXIMUM rating stop to the FULL AUGMENTED rating stop, and note the time period required for the jet nozzle flaps to shift from the FULL AUGMENTED rating to the MAXIMUM rating position.

The time period should amount to 5.0±1.5 sec.

Notes: 1. The engine control lever movement must take 1.5 to 2.0 sec.
2. When checking the hydraulic system, do not fail to inspect the hydraulic cylinders and the hydraulic system pipe line joints for leakage.
3. If the jet nozzle flap shifting time does not agree with the specified value, perform readjustment, as detailed in Section "Replacement and Adjustment of Hydraulic Cylinder" (Chapter IX).
4. Shifting of the jet nozzle flaps from the MAXIMUM rating to the FULL AUGMENTED rating position and backwards should be observed by the movement of the actuating cylinder attachment ring.
5. The rods should project from the hydraulic cylinders to the same length; the permissible difference should not exceed 7 mm at the intermediate augmented ratings and 1.5 mm at the full augmented rating.

Set screw Н of the afterburner control unit in the BLOCKING CUT IN position; set switches MAIN SWITCH, PROCESSING, AFTERBURNER in the initial position; disconnect the ground power supply source from the aircraft mains, and disconnect the trolleymounted hydraulic pumps.

5. In case the locking devices are found to be damaged or loose, check the nuts of the engine pipe lines for proper tightening. Tighten up the nuts, if necessary.

7. Routine Maintenance after Expiration of Engine Service Life

1. Process the internal surfaces of the engine as recommended in Section "Internal Processing of Engine".

2. Remove the engine from the aircraft. Process the external surfaces of the engine as is laid down in Section "External Processing of Engine".

All defects and troubles encountered in the course of engine operation on the aircraft should be duly entered into the engine Service Log and reflected in the Certificates, which are to be submitted to the Manufacturing plant.

Chapter VI

OPERATION OF ENGINE AT SUBZERO

TEMPERATURES

At subzero temperatures and excessive air humidity the air intake duct tends to be coated with ice, which may involve engine failure.

Ice hazard is especially great during drizzle, rain, or snow fall at ambient air temperatures approaching zero; water on the airfield also favours icing.

When inspecting the engine make sure that the intake duct surfaces have no traces of icing. An ice coat on the engine and air intake duct components should be removed with the aid of hot air, making use of the heating devices available on the airfield.

When warming up the engine under the above conditions, it is necessary to keep the edges of the air intake duct and of the inlet cone under observation. As soon as ice shows up, stop the engine and inspect the air intake duct and the blades of the compressor first stage through the access hole. If the blades are found to be in proper condition, proceed warming up the engine at ratings excluding ice formation.

1. Preparation of Engine for Operation

When the cold season sets in:

1. Check the blanking covers for tight fit over the air intake duct and over the jet nozzle (to prevent snow penetration).

2. At subzero air temperatures storage batteries 15СЦС-45 should be operated in compliance with the respective instructions.

2. Ground Starting, Warming-Up, Checking, and Stopping of Engine

The starting, warming-up, checking and stopping of the engine on the ground should be performed in the usual manner. Besides, the following should be taken into consideration, when starting or stopping the engine in cold weather:

1. With the air temperature dropping below 0°, the idling rating r.p.m. of the cold engine decreases by 2 to 3%. After the engine is warmed up, the idling rating r.p.m. should increase to the normal value.

2. With the air temperature below – 40°C, the engine should be warmed up prior to starting by using hot air provided by ground installations (air temperature should not exceed + 80°C). Special care should be taken when warming up the fuel-oil unit, oil and fuel pipe lines. Hot air should be delivered via the inspection holes of the engine compartment.

Note: Prior to starting the engine at subzero temperatures, check the low-pressure rotor for smooth spinning by turning the rotor manually by the blades of the compressor first stage or by the blades of the turbine rotor.

In case the rotor blades are found to be frozen, warm up the engine with hot air as is instructed in Point 2 of the present Section.

3. After starting the engine and accelerating it to the idling rating r.p.m., as well as during checking and taxiing, the engine should not be run at a r.p.m. below 50% (if ice hazard exists) for more than 5 min. (with air temperatures amounting to 0 – 10°C).

The engine may be operated again at a r.p.m. below 50%, only after it has run at a r.p.m. exceeding 50% for not less than 0.5 min.

Notes: 1. The above limitations have been introduced for prevention of ice formation on the nose bullet and the blades of the compressor first stage (when starting the engine under conditions favouring icing).

2. When running the engine on the ground, keep the aircraft intake duct under observation to prevent ice formation.

4. Special care should be taken to cool down the engine before stopping it, to prevent the parts of the engine hot section from warpage. Prior to stopping the engine, run it at 80% r.p.m. for not less than 1 min.

3. Operation of Engine during Flight

In a cold season the engine should be operated in flight at the same ratings as in other seasons, with the limitations referred to in Chapter 1 of the present Instructions duly taken into consideration.

4. Keeping Engine Ready for Operation

To provide for quick and reliable starting of the engine, the following should be observed:

1. Fit the blanking cover over the engine outlet within 15 to 30 min. (depending on the outside air temperature) after the rotor stops.

Install the blanking cover into the air intake duct immediately after the engine comes to a standstill.

2. Take care to see that the fuel and oil are guarded against water, to avoid ice formation in the oil and fuel systems.

At low outside air temperatures use of main fuel with admixture И (Specifications МХП 1170-49) is permissible. The admixture content should not exceed 0.3% (by weight).

3. With the outside air temperatures below - 40°C, the engine should be warmed up at regular intervals by running it at 88 to 90% r.p.m. for 2 to 3 min.

The engine may be warmed up with the aid of hot air (not over + 80°C).

When using hot air, special care should be taken to thoroughly warm up the fuel-oil unit, as well as the oil and fuel pipe lines. Hot air should be delivered via the inspection holes of the engine compartment.

Chapter VII

ENGINE MOUNTING AND DISMANTLING

MOUNTING OF ENGINE ON AIRCRAFT

1. Engine Transportation

The engine is transported in a special reinforced wooden case, which also contains the following items:

- single set of spare parts;
- aircraft-carried tools.

The case amounts to 3480 mm in length, 1100 mm in width, and 1410 mm in height.

The jet nozzle is packed in an individual case, which is 2800 mm in length, 1150 mm in width, and 1221 mm in height.

The case used for transporting the engine is of a collapsible type. The end wall of the case upper portion is removable, whereas the entire upper portion is capable of sliding on the bottom panel. The upper portion is attached to the bottom panel by means of four bolts. Bolted to the bottom plate is a metal support mounting the engine.

The case for jet nozzle transportation is also a collapsible type. The upper portion of the case slides on the bottom panel. Bolted to the bottom panel is a metal support mounting the jet nozzle. The upper portion is attached to the bottom panel by means of four bolts.

The engine is secured to the support in two planes (Fig.43):

(a) in the plane of the compressor rear casing - to two side brackets;

(b) in the plane of the front flange of the first stage turbine nozzle diaphragm casing - to the brackets located in the middle portion of the engine.

To provide for reliable attachment of the engine to the case during transportation, the bolts holding the support to the bottom panel should be securely tightened whereas the pins supporting the engine should be locked.

The jet nozzle is secured to the support in two zones:

(a) the first zone is represented by the front flange of the jet nozzle; the flange collar engages the half-ring of the case support to be held down by a removable half-ring with the aid of two hinged bolts;

(b) the second zone comprises the afterburner attachment slides which hold the afterburner on two T-shaped pins of the case support.

The case containing the engine should be hoisted with the help of a crane having a capacity of not less than 2 tons.

WARNING: It is strictly prohibited to either tilt or turn over the case.

The case is suspended from the crane on a wire rope passed through four eyes provided on the case upper portion.

Prior to removing the case from a truck or a platform, make certain the upper portion of the case is securely attached to the bottom panel.

Weight of the case with the engine . . . . . 1550±30 kg

Weight of the case with the jet nozzle . . . .650±30 kg

2. Unpacking of New Engine

Unpack the engine proceeding as follows:

1. Remove the four bolts attaching the upper portion to the bottom panel.

2. Detach and remove the end wall of the upper portion; slide the upper portion off the bottom panel.

3. Take out the spare parts and the aircraft-carried tools. Check to see that the seals are intact.

Remove the cover from the engine as is laid down in the Instructions for unpacking the engine.

Attach the hoisting device to bolts 2 and bracket 7 (Fig.43); detach the engine from the bottom panel support; lift the engine and carefully mount it on the trolley with the help of brackets 6 and bolts 8; the trolley will be used for moving the engine into the engine compartment.

When lifting and mounting the engine, see that the engine pipe lines are not damaged, and that the wire ropes of the hoisting device do not contact the engine units and components.

WARNING: When lifting the engine remember that the centre of gravity is located at a distance of 165 mm from the rear casing joint, towards the adjustable jet nozzle.

Unpack the jet nozzle proceeding as follows:

- remove the jet nozzle control unit;
- detach the jet nozzle from the case support;
- fit the straps of the hoist under the jet nozzle body, lift and mount it on a trolley.

3. Preparing Engine for Installation on Aircraft

Prior to be installed in the aircraft the engine and the jet nozzle are subjected to deprocessing in the following manner:

1. Wash all external surfaces of the engine having a coat of processing compound with clean gasoline, using a brush.

2. Thoroughly rub the washed areas with dry cloth.

Notes: 1. Solidified processing compound may be removed with the aid of transformer oil preheated to 80 - 90°C.
2. When deprocessing the engine, see that no oil or gasoline is allowed to find its way into the engine electric equipment.
3. Gasoline or solvents should not be allowed to remain on painted surfaces for more than 2 min.

The deprocessing procedure completed, make an external inspection of the engine.

When inspecting the engine, check the following points:

1. Engine units and assemblies for proper attachment. All units should be securely fastened and locked.

2. The fuel, oil and air pipe lines for proper condition. The pipe lines for proper clearances. The pipe lines should be securely fastened and locked.

The clearances between the pipe lines should amount to not less than 3 mm.

The clearances in the places of rigid attachment (to cases, brackets, flanges, etc.) should not be less than 2 mm.

3. The engine wires for proper condition and attachment. The wires should be securely attached and locked; the plug connectors should be clean.

4. Check the closures in the engine measurement points (See Diagram showing arrangement of measurement points,(Fig.42).

Notes: 1. The places serving for checking engine characteristics on the ground should be fitted with service closures.
2. The places serving for connection of engine instruments should be fitted with shipping closures coated with red paint.

5. Check the seals on the adjustable components in compliance with Appendix No.3.

Should some defects be revealed on the engine, draw up a certificate which should be submitted to the Manufacturing plant.

Do not install the engine on the aircraft unless the cause of the trouble is detected and eliminated.

6. Remove the shipping closures and install on the engine the following equipment:

- tachometer generator (for measuring speed n_1 and n_2);
- oil pressure transmitter;
- НП-34-2Т hydraulic pumps and other units and assemblies enumerated in the aircraft Instructions;

Note: The shipping closures should be removed from the units and the engine just before installing the instruments or connecting the pipe lines.

4. Installation of Engine on Aircraft

Prior to installing the engine in the aircraft, check the engine compartment for proper condition. The engine compartment should be cleaned of dust, dirt, traces of oil and fuel, as well as of foreign objects, such as nuts, bolts, tools, etc. Check the air intake duct surfaces for proper condition.

WARNING: The engine oxygen supply system should be filled with nitrogen as is instructed in the present chapter.

Install the engine in the aircraft in compliance with the recommendations of the aircraft Instructions. Then mount the adjustable jet nozzle.

Secure the telescopic ring on the left-hand side (looking forward). The narrow slot of the telescopic ring receives the

collar of the diffuser flange; the collar of the jet nozzle flange enters into the wide slot of the ring.

Having installed the telescopic joint, measure clearance П (Fig.V) which should not exceed 4.5 mm (over an arc not exceeding 300 mm). Should clearance П be in excess of 4.5 mm, proceed as is laid down in Chapter 5, Section "Routine Maintenance after First 5±1 Hours of Engine Operation"(Points 5, 6, 7, and 8). It is not allowed to leave the adjustable jet nozzle unfastened or without support on the afterburner diffuser.

Perform aircraft jointing as is laid down in the aircraft Instructions, after which install the hydraulic units controlling the adjustable jet nozzle proceeding as instructed in Section "Replacement and Adjustment of Hydraulic Cylinder" (Chapter IX); connect the piping of the hydraulic cylinders to the aircraft pipe lines.

Note: In case there is a necessity to check operation of the afterburner, it is allowed to check the engine on the ground, with the adjustable jet nozzle secured to the frame.

Having secured the engine to the aircraft, connect the aircraft pipe lines to the engine in compliance with the list attached.

WARNING: Prior to connecting the aircraft pipe lines to the engine, see that the delivery pipes and hoses are free of any foreign objects or dirt on the inside and outside.

5. List of Aircraft Pipe Lines Connected to Engine

Nos	Description	Type of joint
	Lubricating system	
1	Engine breathing	Durite sleeve
	Main and starting fuel system	
1	Main fuel supply to ДЦН-13ДТ fuel booster pump	Flange
2	Starting fuel supply to electromagnetic valve	Nipple

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Nos	Description	Type of joint
	System of air bleeding from engine and air release from pressure chamber	
1	Air bleed for aircraft needs (in two points)	Nipple, flange
2	Air bleeding from pressure chamber manifold (in two points)	Flange
3	Air bleeding for shaft cooling	Telescopic
	Hydraulic system	
1	Hydraulic fluid supply to hydraulic cylinders controlling jet nozzle flaps	Fitting
2	Hydraulic fluid outlet from cylinders	Fitting
	Flame igniter oxygen supply system	
1	Supply of low-pressure oxygen to non-return valve	Fitting
	Engine electric system	
1	Plug connector 2ШР60П45НШ2	
2	Connection of wires to starter-generator	Bolt
3	Starter-generator cooling	Telescopic
	Drain system	
1	Hydraulic fluid drain from two hydraulic pumps НП-342Т	Fitting
2	Fuel drain from drive of ДЦН-13ДТ pump	Fitting
3	Fuel drain from electric contactor of НР-22Ф pump	Fitting
4	Fuel drain from combustion chamber housing	Fitting

Nos	Description	Type of joint
5	Fuel drain from diffuser collector at afterburner pipe joint	Fitting
6	Fuel drain from diffuser collector at nozzle diaphragm joint	Fitting
7	Fuel drain from glands incorporated in drives of НР-21Ф and НР-22Ф fuel regulating pumps	Fitting
8	Oil drain from two-speed drive of starter-generator	Fitting
9	Fuel drain from starting fuel control unit, electric contactor, and gland incorporated in drive of НР-21Ф fuel regulating pump	Fitting

Note: All drain (vent) lines, exclusive of that referred to in Point 5, have a common outlet.

6. List of Engine Instruments

1. For checking engine r.p.m. (n_1 and n_2) - ИТЭ - 2 and ДТЭ -1 sets.

2. For checking oil pressure - ДИМ -8Т set.

3. For checking gas temperature aft of the turbine- ТВГ-11Т set.

7. Flushing of Pipe Lines

Having connected the aircraft pipe lines to the engine, flush the pipe lines with the purpose of removing air locks.

Prior to flushing the pipe lines it is necessary to fill the main fuel and starting fuel tanks with fuel as is laid down in Chapter II.

Pipe line flushing is carried out as follows:

1. Flush the main fuel system, for which purpose:

(a) connect the ground power supply source to the aircraft mains;

(b) remove the screw cap from the connection serving for air release from unit 357C, and connect ВИ -535 air release device;

(c) open the fuel shut-off valve, and start the booster pumps.

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Discontinue the fuel delivery as soon as the fuel stream issuing from the device hose becomes free of air bubbles, but not before allowing 8 to 10 litres of fuel to run from the pipe;

(d) the procedure over, stop the booster pumps and reinstall the screw cap after fitting it with a new rubber sealing ring;

(e) employ the same procedure for flushing the HP-21 Φ fuel regulating pump, after connecting device БИ37-535 to air release valve 9 (Fig.24).

2. Deliver fuel into the pipe line carrying starting fuel to the electromagnetic starting valve, for which purpose:

(a) set the storage battery switch in the ON position (B_1);

(b) set the PROCESSING switch (BK) in the K position;

(c) turn on the STARTING UNITS switch (A3C-25);

(d) turn on the STARTING IN AIR switch (3B).

Stop the fuel delivery as soon as the stream of the starting fuel issuing from the aircraft drain cock becomes free of air bubbles.

Note: The oxygen cut-off cock should be closed. Having completed the procedure, set the STARTING IN AIR switch in the initial position and use a piece of cloth to wipe the places showing fuel splashes.

3. Remove air locks from the hydraulic system proceeding as follows:

- connect the trolley-mounted hydraulic pumps;

- cut out the hydraulic decelerator blocking by turning screw H on the afterburner control unit to the BLOCKING CUT-OUT position;

- turn on the AFTERBURNER switch; set the PROCESSING switch in the K position; switch on A3C-15;

- shift the engine control lever 3 to 5 times from the MAXIMUM stop to the FULL AUGMENTED rating stop and backwards. While proceeding in this manner, watch the jet nozzle flap ring. The misalignment of the ring should not exceed the specified limits (proper operation of the ring testifies to the fact that the hydraulic system is free of air locks).

The procedure completed, set all the switches to the initial positions, disconnect the ground power supply source, and the trolley-mounted hydraulic pumps from the aircraft.

8. Deprocessing of Engine

The engine internal deprocessing is accomplished as follows:

1. Drain oil from the engine wheel case and from the oil tank.

2. Use hose БИ37-592 to connect the unions for measuring main and afterburner fuel pressure to the pilot manifold union (alternately).

3. Pour fresh oil into the engine tank, proceeding as recommended in Chapter II.

4. Connect piping for delivery of nitrogen to the union serving for measuring oxygen pressure.

5. Connect the ground power supply source to the aircraft mains.

6. Turn on the following switches:

(a) AFTERBURNER (A3C-15);

(b) STORAGE BATTERY (B_1);

(c) STARTING UNITS (A3C-25);

(d) BY-PASS VALVE (KC);

(e) CRANKING (BП) (in the STARTING position);

(f) PROCESSING (BK) (in the K position).

Note: The STARTING IN AIR switch (A3C-10) should be in the OFF position. The OXYGEN switch (BKП) should be set to OPERATION.

7. Cut off the hydraulic decelerator blocking by turning screw И on the afterburner control unit.

8. Open the fuel shut-off valve.

9. Start the main fuel booster pumps.

10. Set the engine control lever against the FULL AUGMENTED rating stop, press the GROUND STARTING button and release it 1 or 2 sec. later.

To prevent oil from getting into the oxygen system, blow the latter with nitrogen at a pressure of 7 to 9 kg/sq.cm. while cranking the engine.

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As soon as the GROUND STARTING button is pressed, the starter begins spinning the engine rotor. The rotors should spin smoothly, without knocks or binding.

To deprocess the engine, it is necessary to crank the engine 3 or 4 times.

WARNING: After cranking the engine 5 times in succession, it is necessary to allow the starter to cool down for not less than 30 min. prior to cranking the engine again. The starter may be cooled by using compressed air during 15 min.

If some troubles show up during the engine cranking, immediately discontinue the cranking procedure by operating the STARTING UNITS switch.

With the cranking procedure discontinued due to some reason, that is with the starting cycle of the starter-generator discontinued by the action of the STARTING UNITS switch, it is necessary to turn on the switch in question for not less than 45 sec. to allow the starter control equipment to complete the cycle. After this, the engine cranking may be performed in the usual manner. After completing the engine cranking (with the fuel delivered), stop the main fuel booster pumps and crank the engine with the purpose of removing the remaining fuel from the engine.

Engine deprocessing completed, proceed as follows:

1. Turn off the following switches: MASTER SWITCH, STARTING UNITS, AFTERBURNER.

Set the PROCESSING switch in the operating position; turn screw Н on the afterburner control unit to the initial position.

2. Disconnect the ground power supply source from the aircraft mains; detach the nitrogen delivery pipe and hose БН37-592 from the unions used for measuring the fuel pressure. Fit screw caps onto the unions and lock them.

3. Inspect the oil and fuel lines for leakage, and remove oil and fuel splashes from the engine and engine compartment surfaces.

Note: After deprocessing the engine which has been idle for over 30 days, blow the pipe lines delivering oxygen to the flame igniters of the combustion chambers with nitrogen as is instructed in Chapter VII.

9. Engine Cranking

The engine cranking is carried out using the following procedure:

1. Connect the ground power supply source to the aircraft mains, and start the fuel booster pumps (installed on the aircraft).

2. Turn on the following switches:

(a) AFTERBURNER (A3C-15);

(b) STORAGE BATTERY (B_1);

(c) STARTING UNITS (A3C-25) (in the ON position);

(d) CRANKING (ВП) (in the CRANKING position).

Note: When performing the engine cranking with the use of the 24x48 V system, set the CRANKING switch in the STARTING position; set the PROCESSING switch in the К position, and detach the plug connector of the electromagnetic starting valve.

3. The engine control lever should be set in the CUT-OUT position.

4. Press the GROUND STARTING button and release it 1 or 2 sec. later.

This will cause the starter-generator to spin the engine rotor.

In 45 sec. after pressing the GROUND STARTING button, turn off the following switches: MASTER SWITCH, STARTING UNITS, and CRANKING; disconnect the ground power supply source from the aircraft mains and stop the fuel booster pumps.

Note: Limitations to be observed when cranking the engine with the fuel delivery apply to the engine cranking without the fuel delivery as well.

10. Checking Oxygen System of Main Flame Igniters and Charging System with Oxygen

The main flame igniter oxygen supply system should be checked in the following manner:

1. Charge the aircraft oxygen bottle with commercial nitrogen. Deliver the nitrogen via the charging connection until pressure rises to the specified value.

__Note:__ Deliver the nitrogen through a felt filter.

2. Install a pressure gauge with a measurement range of 0 to 10 kg/sq.cm., for checking oxygen pressure downstream of the non-return valve.

3. Connect the ground power supply source to the aircraft mains.

4. Open the cut-off valve of the oxygen bottle.

5. Set the master switch in the GROUND STORAGE BATTERY position; turn on the STARTING UNITS switch.

6. By setting the OXYGEN switch (ВКЦ) in the CHECKING position, measure the pressure downstream of the non-return valve.

7. Remove the pressure gauge and install the service closure.

8. Coat the joints of the non-return valve, aircraft pipe connection as well as the closure with neutral soap foam for checking the joints for tightness.

9. Set the OXYGEN switch (ВКЦ) in the CHECKING position and discharge the nitrogen.

__Notes:__ 1. When discharging the nitrogen, check the joints for tightness. If bubbles show up, tighten up the joint or reassemble it.
2. Nitrogen pressure downstream of the non-return valve should be 7 to 9 kg/sq. cm.

Having blown the system with nitrogen, set all the switches to the initial position, disconnect the ground power supply source from the aircraft mains and charge the oxygen bottle as is laid down in the aircraft Instructions.

11. __First Starting of Engine__

Prior to starting the engine for the first time, observe the following:

1. Check operation of the hydraulic system controlling the jet nozzle, as detailed in Section "Routine Maintenance Performed Every 50±5 Hours of Engine Operation".

2. Adjust time delay values (with regard to the jet nozzle and fuel) of the afterburner control unit, in accordance with the data presented in the engine Service Log.

3. Carry out the operations referred to in Section 1, Chapter III (Engine Starting).

4. Remove caps from the air release needles.

__WARNING:__ 1. The engine should be started with the engine compartment access holes open, to make it possible to check the oil and fuel line joints for leakage.
2. If leakage is detected in some joint, immediately stop the engine and eliminate the leakage. The engine should not be run unless the defect is corrected.
3. In the case of 5 unsuccessful attempts at starting or cranking performed in succession, allow the starter to cool down for not less than 30 min. prior to making another attempt. The starter cooling may be accomplished by using compressed air delivered for 15 min.

When starting the engine, proceed as is laid down in Chapter III.

12. __Engine Ground Check after First Starting__

The checking of the engine on the ground after starting it for the first time should be performed as is instructed in Section 3, Chapter III "Warming Up and Checking Engine Operation", making use of the graph (Fig. III) attached hereto.

__WARNING:__ If variations in the engine r.p.m. are experienced during the engine trial, subject the main fuel pipe line to flushing.

13. __Engine Stopping__

The engine stopping should be accomplished as is laid down in Chapter III.

After the engine comes to a standstill, check the oil level in the tank; add up oil to the specified level, if necessary (See Chapter II); add oxygen into the oxygen supply system as recommended in the present Chapter.

Carry out the operations enumerated in Section "Post-flight Engine Inspection", and inspect the filter of the oil pump unit, as instructed in Section "Routine Maintenance after First 5±1 Hours of Engine Operation" (Chapter V).

14. Trial Flight

Perform the trial flight as instructed in Chapter IV.

DISMANTLING OF ENGINE

1. General Information on Engine Processing

1. The purpose of the engine processing is to preclude corrosion on the engine components and to provide for safe storage and transportation of the engine. Therefore, the processing of the engines temporarily kept away from service should be carried out properly and in due time, making use of corrosion-preventive compounds strictly complying to the respective State Standards, so far as their physical and chemical properties are concerned.

2. A complete processing safeguards the engine against corrosion within the period of 12 months, provided the engine is stored in a closed building and is processed in compliance with the "Processing Instructions" accompanying the engine.

3. The engines in service are subjected to internal processing providing for a three-month storage period.

4. The engines in storage should be inspected visually once a month.

If some corrosion is detected on the external components of the engine, clean the affected areas with fine grain emery cloth (No.180 - 220) moistened with oil, grind with ГОИ paste, wash with clean gasoline, and coat with corrosion-preventive compound.

The processing of the external surfaces or the removal of surface corrosion should not be performed during rain or snow fall.

Apply corrosion-preventive compounds only to clean and dry surfaces having no paint coating.

5. When washing or processing the external surfaces of the engine, as well as when deprocessing the engine, take care to see that gasoline and corrosion-preventive compound do not get on the wires, on the release jet of the HP-21Ф pump starting fuel control unit, on the ГСР-СТ-12000ВТ starter-generator, on the КНА-114 booster coils, or on the adjustment needles.

6. Having performed the engine processing, make a corresponding entry into the engine Service Log.

2. Corrosion-Preventive Compounds

For the internal processing of the fuel and oil systems use should be made of oil MK-8, State Standard 6457-53.

For the external processing of all non-painted components of the engine use neutral petrolatum, State Standard 782-53.

Notes:
1. As a substitute for petrolatum, use may be made of aviation oil MC-20 or MK-22, State Standard 1013-49, with addition of 4 to 10% of ceresine, State Standard 2488-47.
2. All corrosion-preventive compounds should be used only in case they are free of moisture. If the oil intended for processing happens to contain moisture, remove it by heating the oil to a temperature of of 110 to 120°C, until any traces of froth disappear from the oil surface.
3. Prior to processing the engine, check to see whether the corrosion-preventive compounds comply to the respective State Standards.
4. Reclaimed or used compounds should not be employed for processing.

3. Internal Processing of Engine

The internal surfaces of the engine should be processed in accordance with Appendix No.7 of the present Instructions.

4. Dismantling of Engine from Aircraft

Dismantle the engine from the aircraft using the following procedure:

1. Detach all aircraft pipe lines and wires from the engine.
2. Remove the hydraulic unit controlling the jet nozzle.
3. Disjoint the aircraft.
4. Bring the trolley under the adjustable jet nozzle.
5. Remove the telescopic ring and detach the jet nozzle from the afterburner diffuser.

Note: Having removed the jet nozzle, reinstall the hydraulic control unit.

6. Bring the trolley under the engine.

Detach the engine attachment fittings from the aircraft; move the engine out of the engine compartment, attach the hoisting device to the engine and place the engine onto the packing case support.

7. Remove the tachometer generators, oil pressure transmitters, as well as other assemblies and units referred to in the aircraft Instructions. Install the auxiliary and service closures and subject the engine to external processing.

5. External Processing of Engine

The external processing of the engine consists in coating non-painted components of the engine with a thin layer of corrosion-preventive compound.

1. Prior to processing the engine, fit special plugs into all open connections or close them with cellophane film.

2. Wipe the external surfaces of the engine and afterburner with cloth soaked in clean gasoline. Dry the surfaces subject to processing.

3. Coat all external surfaces of the metal non-painted parts as well as the internal surfaces of the afterburner with petrolatum (or with a mixture of aviation oil MC-20 or MK-22 [illegible] to 10% of ceresine).

Apply th[illegible]d with a brush or an atomizer.

For thinning [illegible] corrosion-preventive compound, petrolatum should be preheated to 80 - 90°C, whereas the mixture should be preheated to 60 - 70°C.

4. Wrap the engine in 2 or 3 layers of paraffin paper and fit on a polyvinyl chloride cover.

6. Packing Engine in Shipping Case

Having performed the external processing of the engine, attach the container with the single set of spare parts and the aircraft-carried tools to the case support.

Slide the upper portion of the case over the support, install the end wall of the case, bolt them down to the support and apply the seals.

Chapter VIII

CARE OF ENGINE INSTALLED ON AIRCRAFT DURING

PARKING PERIODS

Up to 30 days. With the aircraft parked for a period of up to 30 days, perform the following operations once every 10 days:

1. Open the access panels, remove the blanking covers from the air intake duct and the adjustable jet nozzle, inspect, where possible, the external components of the engine for corrosion. Treat the areas affected with corrosion as is instructed in Section "External Processing of Engine".

2. Start the engine; check its operation making use of the chart presented in Section "Checking Engine on Ground prior to Flight"; check engine operation at the augmented rating.

3. Stop the engine.

4. Close the access panels, the air intake duct and the jet nozzle.

WARNING: 1. It is prohibited to carry out the operations referred to in Point 1 in the open air during rain or snow fall.
2. During the entire idle period the engine fuel system should be filled with fuel.
3. The aircraft fuel system should be free of air locks, which are likely to cause corrosion of the fuel system unit components.
4. If the engine fuel system has been drained, subject the engine to internal processing within 24 hours after discharging the fuel.

Over 30 days. If the engine idling period exceeds 30 days, perform engine processing for a three-month storage period, as is instructed in Section "Internal Processing of Engine" (Chapter VII).

Chapter IX

REPLACEMENT OF ENGINE UNITS AND ASSEMBLIES

If some defects which cannot be corrected in the field become evident in the course of engine operation, replace the respective assemblies, units, or parts.

When replacing individual parts, assemblies and units, extreme care should be used to prevent foreign objects from finding their way either into the engine or into the units and pipe lines. All holes uncovered during disassembly should be immediately closed with auxiliary closures or cellophane. The units and parts dismantled from the engine should be processed not later than 24 hours after the removal.

The sealing and spring washers, as well as the locks of the dismantled units should be replaced by new ones.

WARNING: When installing the new units and assemblies, pay attention to the arrows, indicating the direction of rotation or fluid flow.

The tightening-up of the nuts (or bolts) of the flanged joints should be performed uniformly in a criss-cross manner. A successive tightening of the nuts(or bolts) is strictly prohibited.

The threaded joints of the units exposed to high temperatures should be liberally coated with chalk paste (a mixture of chalk powder with oil) prior to the installation of the units.

Bolts yielding with difficulty during dismantling operations should be treated with kerosene.

Prior to dismantling the units of the fuel (or oil) system, it is necessary to close the fuel shut-off valve and to drain the fuel (or oil).

The units to be installed on the engine should be subjected to external deprocessing. When deprocessing the external surfaces of the units, the shipping caps and bushes should not be removed.

The shipping caps and bushes must be removed only when installing the units in place.

When turning off the nuts and caps, use another wrench to prevent unscrewing of the connections.

After the replacement of the units or pipe lines of the fuel and hydraulic systems, it is necessary to thoroughly flush the respective units and pipe lines as is recommended in Section "Flushing of Pipe Lines"(Chapter VII).

The flushing procedure over, check the joints for tightness with the engine running.

WARNING: 1. Do not tighten up the joints if the pipe lines are exposed to the pressure of liquid or gas.
2. When replacing the units and assemblies, use the aircraft-carried tools set.

The list of the units and assemblies which may be replaced in the course of engine operation is presented in Appendix No.1.

The list of the parts to be substituted with new ones when replacing the respective units and assemblies is presented in Appendix No.2.

1. Replacement of Pipe Lines

1. The replacement of the pipe lines can be carried out only by the representative of the Manufacturing plant.

2. The pipe lines, fasteners, and locking devices newly installed on the engine should be fabricated at the Manufacturing plant.

2. External Inspection of Pipe Lines Prior to Installation

The pipe lines to be installed on the engine should be subjected to external inspection to see that:

(a) the pipes are plugged and sealed;

(b) the colour of the paint coating is correct;

(c) the nipples on the flared pipes are capable of displacing within 10 to 15 mm along the pipe, and the nuts are capable of the same displacement on the nipple;

(d) the mating surfaces of the pipes are free of burrs, notches or other mechanical damage;

(e) the deflection radius of the low-pressure and high-pressure pipe lines is not less than two diameters of the pipe.

If the pipes do not comply with even one of the above requirements, they should not be installed on the engine.

3. Pipe Lines and Fittings Employed for Oxygen System

The high-pressure and low-pressure oxygen systems employ steel piping of 4x6 and 6x8 mm in diameter; at the Manufacturing plant the piping is subject to special chemical treatment (degreasing and passivation).

Pipe lines to be newly installed on the engine are not subject to degreasing or passivation.

WARNING: If traces of oil are detected on the joints, or if there is a suspicion that some fuel or oil has found its way into the pipe, subject the pipe to degreasing and passivation.

A. Degreasing. Wash in soda-potassium bichromate solution or in hot alkali solution at a temperature of 60 to 70°C. After degreasing wash the pipes first with hot water and then with cold water. Washing should be accomplished by a repeated dipping of the pipe into the water. The inner surfaces of the pipe should be flushed.

B. Passivation. Wash and keep the pipe for 20 min. at a room temperature in a solution of the following composition:

chrome anhydride . . . . . . 150 to 160 gr/lit.

sulfuric acid (commercial) . . 1.5 mgr

After the passivation wash the pipe in hot running water. Dry at a temperature of 70 to 100°C until moisture is completely removed.

1. The inside of the oxygen system components ready for installation should be treated with 10 mgr of clean rectified spirit. The spirit issuing from the components should be applied to filtering paper. No oil stains should be left on the paper after the spirit evaporates. Repeat the above procedure, if some oil stains are detected on the paper.

2. Check the pipe lines for tightness with the aid of pure dry nitrogen. For this treat the joints with a concentrated neutral soap solution. The check completed, remove the remaining soap with a dry piece of cloth, and wipe the respective places dry.

WARNING: 1. Do not blow the pipe lines with compressed air.

2. Any modifications and changes in the construction of the reducing and non-return valves of the oxygen system must not be introduced by the Customer.
3. The pipe line is connected to the instrument union after blowing the pipe line with compressed nitrogen.
4. When disassembling the pipe lines exposed to pressures, reduce the pressure available in the pipe line to zero (as indicated by the pressure gauge) and then disconnect the joint.
5. The pressure gauges employed for checking pressure in the oxygen system should be in proper condition and carry the required seals. The pressure gauges should be guarded against oil and fatty substances; the pressure gauge dials should bear the following inscription: "OXYGEN, OIL IS DANGEROUS".

4. Installation of Pipe Lines on Engine

The preliminary erection of the pipe lines is carried out with the purpose of fitting the pipe to the engine configuration.

The pipe is considered fit for installation if:

(a) the clearances between the pipe line and other lines (at the points of their attachment) agree with the specified values (not less than 3 mm between pipe lines and not less than 1 mm between the pipe lines and other components);

(b) the pipe line is so installed as to cause no stresses, and is fitted into the clips with a negative allowance of not over 1 mm;

(c) the pipe remains in the initial position after the nuts of the joints are turned off.

WARNING: 1. The preliminary erection of the pipe lines should be performed without using the sealing rubber, the necessary clearance providing for the installation of the sealing rubber being taken into consideration when fitting the pipes.
2. The deflection of the pipe from the union and from the clip nest should not exceed 1 mm.

(d) the places with stripped paint coating coinside with the clips (for bonding purposes).

If the pipe is fitted into position with some difficulty (requirements presented in Points a, b, c are not complied with), it is allowed to bend the pipe at the point located at a distance of not less than 75 mm from where the nipple is soldered or welded; no subsequent hydraulic or X-ray tests are required. The bending may be accomplished manually or by using a special tool.

Note: The pipe bending is performed after the pipe is necessarily removed from the engine, the work being entrusted to the representative of the Manufacturing plant only.

When laying the pipes provided with telescopic joints, treat the surfaces to be connected with lubricant HK-50.

The threaded portions of the pipe line joints should be treated with clean oil prior to screwing them on.

When unlocking the pipe line nuts, see that the locking lugs and strips on the nuts and pipes are intact.

Do not use the rubber and copper sealing rings again.

When carrying out the replacement operations, use pipes, fasteners, and locking devices fabricated at the Manufacturing plant only.

The fasteners should be fitted exactly in the same places as before the pipe was replaced.

Prior to the replacement, blow the pipes with compressed air and wash them with clean gasoline (exclusive of the oxygen system pipes).

Do not put the pipes in storage unless they are processed. The pipes should be plugged or closed with cellophane film.

The final erection of the pipe lines should be accomplished in compliance with the following requirements:

(a) the rubber ring should be free of ply separation, scores or cuts;

(b) the rubber ring should be fitted into the recess by means of rod БИ37-28;

(c) the nut should be turned on the union manually until it contacts the collar of the nipple; then the nut should be tightened up with a wrench.

Notes: (a) tighten up the flared joint by using a wrench with a 120 to 160 mm long arm;
(b) when tightening up the joints, hold the unions of the mating components with a wrench;
(c) the flared joints may be tightened up four times, after which the respective pipe should be replaced;
(d) lock the nuts of the pipe lines with brass and steel (where exposed to high temperatures) binding wire having 0.8 or 1.0 mm in diameter.

5. Units Replaced via Access Holes of Engine Compartment

Replacement of ГСР-СТ-12000ВТ Starter-Generator

The starter-generator should be replaced using the following procedure:

1. Remove the cooling air delivery pipe from the starter-generator.
2. Detach the wires from the starter-generator.
3. Release the locks (2 pieces) and back out 2 bolts of the connecting ring, while supporting the starter-generator.
4. Remove the starter-generator from the engine.

A new starter-generator is installed in the order reverse to dismantling.

Check to see whether the starter-generator has occupied the correct position; if the position is correct, the cylindrical pin will enter the hole provided on the flange of the engine wheel case.

Notes: 1. When installing the starter-generator, the quick-disconnect ring should be so arranged as to allow the joint to be set in the horizontal plane.
2. The starter-generator cooling air delivery pipe may be installed at any angle, depending on arrangement of the aircraft pipe lines.
3. The wire attachment block should be located at an angle of 20° below the horizontal plane (at port side, looking forward).

Having replaced the starter-generator, crank and start the engine, after which run the engine for 1 or 2 min. at 88 to 90% r.p.m. to see that the generator is properly loaded.

Replacement of HP-21Φ Fuel Regulating Pump

The replacement of the HP-21Φ fuel regulating pump should be carried out in the following sequence:

1. Unlock and detach control link 7 (Fig.43) from the fuel regulating pump.

2. Remove the low-pressure rotor tachometer generator.

3. Remove the universal joint shaft of the pump centrifugal governor drive, connected to the oil scavenge pump of the front support.

The universal joint shaft is dismantled as follows (Fig.19):

- extract the spring ring;
- remove the plug;
- extract bush 10;
- loosen the straps on the rubber boot;
- take out universal joint shaft 8;
- remove the rubber boot.

WARNING: 1. The installation of the universal joint shaft should be accomplished in the reverse order of dismantling.
2. During reassembly see that the universal joint shaft enters the recess provided in the bush of the HP-21Φ fuel regulating pump and the recess of the drum incorporated in the oil scavenge pump.
3. Check to see that the drum is properly engaged with the pump, for which purpose turn the low-pressure rotor manually. If the engagement is correct, the universal joint shaft will rotate.

4. When coupling the drive of the centrifugal governor of the HP-21Φ fuel regulating pump to the pump scavenging oil from the front support by means of universal joint shaft 8 (Fig.19), see that the hole for bush 10 lines up with the hole for block 9; the permissible error is not to exceed 5.5 mm (check by using appliance БИ 37-189 contained in the group set, Appendix No.5). If the appliance pin enters, the hole provided in the fuel regulating pump, the misalignment of the holes may be considered to be within the permissible range.

The axial displacement of the universal joint shaft should be within 0.8 to 3 mm.

After the HP-21Φ fuel regulating pump has been installed in position, adjust the position of the levers of the ПУРТ-1Φ control panel and of the HP-21Φ fuel regulating pump as is instructed in Section "Adjustment of Engine Controls", Chapter X.

After the replacement of the fuel regulating pump take the following steps:

(a) flush the main fuel system as is laid down in Section "Flushing of Pipe Lines" (Chapter VII);

(b) deprocess the fuel regulating pump as is instructed in Section "Deprocessing of Engine" (Chapter VII);

(c) start the engine in accordance with recommendations presented in Section "Engine Starting" (Chapter III);

Notes: 1. When starting the engine, it is allowed to perform manual regulation of fuel supply.
2. With the engine running, check the fuel system for leakage. No leakage should be allowed.

Adjust the following:

(a) engine maximum r.p.m. as recommended in Chapter X;

(b) r.p.m. associated with the operation of the hydraulic decelerator limit switch, as is laid down in Chapter X;

(c) engine controls and acceleration, as instructed in Chapter X;

(d) engine starting, as is laid down in Chapter X.

Perform the trial flight as instructed in Chapter IV.

Replacement of ПУРТ-10 Control Panel

The replacement of the control panel should be carried out in the following sequence:

(a) detach the plug connectors of the control panel, ДР-3А transmitter, and P-1 rheostat;

(b) disconnect the link from the control panel lever;

(c) unlock and turn out the bolts securing the control panel; remove the control panel from the engine;

(d) remove the ДР-3А transmitter, P-1 rheostat, and the lever from the control panel.

The installation of the new control panel onto the engine should be accomplished in the following manner (Fig.49):

1. Mount the ДР-3А transmitter on the control panel, for which purpose:

(a) remove cover K (Fig.38) where the transmitter is to be connected to the control panel; back out four bolts;

(b) set shaft 10 of the control panel in the zero position (Fig.11);

(c) mount the ДР-3А transmitter onto the control panel, having fitted a gasket under it. Secure the transmitter with bolts 7 and install locks;

(d) attach the transmitter plug connector to fixture БИ37-587;

(e) rotate the panel shaft in the direction of arrow H until the transmitter slide shifts to the soldered portion of the winding;

Note: As soon as the slide reaches the soldered portion, the resistance of the winding stops changing despite the slide movement.

(f) with the control panel shaft in this position, figures 107 - 109 of the dial should line up with the notch provided on the casing.

Fasten the dial in this position by means of screw 2; lock the screws with binding wire;

(g) rotate the control panel shaft in the clockwise direction to line up figures 78 - 80 on the dial with the notch on the casing.

With the shaft in this position, manipulate screw 13 of the transmitter to adjust the initial movement of the transmitter slide in response to the clockwise turn of the control panel shaft (from figure 78).

Notes: 1. When the slide starts moving, the resistance of the transmitter winding changes in response to the shaft turning.
2. Having adjusted the slide, lock screw 13 and register the R value in the transmitter Certificate.

2. Install the lever on the control panel, for which purpose:

(a) turn the shaft in the clockwise direction and line up the dial zero with the notch on the casing;

(b) mount the lever over the splined bush of the panel shaft, at an angle of $53 + 1^{\circ}$ (Fig.40);

Note: The specified angle can be obtained by resetting the lever over the splined bush and by displacing the splined bush over the splines of the control panel shaft.
Measure the angle with the aid of a gauge. Fasten and lock the lever.

(c) turn the shaft in the counter-clockwise direction and line up dial divisions 112 - 113 with the notch on the casing. With the shaft in this position, adjust control panel stop screw 5 (Fig.36) so that the control panel lever flag is tightly pressed against the stop screw.

3. Check to see whether the operating angles of the control panel cams agree with the limitation values presented in Chapter I (perform the check with the engine inoperative, using fixture БИ37-587).

If necessary, adjust the operating angles of the control panel cams, using the following procedure:

(a) slacken screw 12 (Fig.38) of the control panel cam to be adjusted;

(b) turn screw 13 of the respective cam to adjust the required angle of operation;

(c) the adjustment over, tighten screw 12 and lock it together with screw 13.

4. Mount the P-1 rheostat (Fig.49) on the control panel, having removed cover 8 from the latter (Fig.38). Tighten

screws 14 and lock them with binding wire.

5. Install the panel on the engine. Bolt it down and lock. Couple the link to the control panel lever, fasten and lock it. Attach the plug connectors of the control equipment to the ДР-3А transmitter and to the control panel.

Having installed the control panel on the engine, carry out the necessary checks and adjustments:

(a) of the engine controls, as is laid down in Section "Adjustment of Engine Controls", Chapter X;

(b) of the jet nozzle diameter at the MINIMUM AUGMENTED rating and at the FULL AUGMENTED rating, as is instructed in Section "Replacement and Adjustment of Hydraulic Cylinders".

Replacement of ДР-3А Transmitter

The replacement of the ДР-3А transmitter should be carried out using the following procedure:

(a) remove the ПУРТ-1Ф control panel in compliance with the recommendations presented in Section "Replacement of ПУРТ-1Ф Control Panel";

(b) remove ДР-3А transmitter from the control panel.

The installation of the new transmitter and further operations pertaining to checking the engine controls should be conducted in compliance with the instructions presented in Section "Replacement of ПУРТ-1Ф Control Panel".

Replacement of P-1 Rheostat

The replacement of the P-1 rheostat should be performed as follows:

(a) detach the rheostat plug connector;

(b) unlock and remove the screws securing the rheostat. Remove the rheostat from the control panel (See Fig.49).

The installation of the new rheostat should be accomplished in the order reverse to dismantling. Further operations pertaining to checking the engine controls should be carried out as is laid down in Section "Replacement of ПУРТ-1Ф Control Panel".

Replacement of ДОС-1А Feed-Back Transmitter

In case the feed-back transmitter is found to be defective, the hydraulic cylinder should be replaced along with the transmitter. The replacement of the hydraulic cylinder should be effected as instructed in Section "Replacement and Adjustment of Hydraulic Cylinder" (Chapter IX).

Replacement of БУ-4Б Control Unit

The control unit is replaced using the following procedure:

(a) detach the plug connector of the control unit.

Unlock and remove two bolts securing the quick-disconnect joint;

(b) remove the БУ-4Б control unit, taking care to support the shaft connecting pin.

Note: When dismantling the control unit it is allowed to remove the pipe lines and wires interfering with the control unit removal from the engine.

Prior to installing a new control unit, set its shaft in the initial position by rotating it about the axis, until the key accommodated inside the shaft occupies a position diametrically opposed to the hole provided on the face of the control unit (Fig.39). Set the shaft of HP-22Ф pump speed transmitter 30 in the initial position, that is in a position, allowing the notch on the tachometer generator shaft end face to stop against the notch on the flange of the quick-disconnect joint (the shaft should be rotated from the initial position in the clockwise direction, if viewed from the flange side); in this case (See Fig.26) the axis of the grooves provided on the shaft for accommodation of the bush (for the connecting pin) will set at an angle of 90° relative to the reference pin on the flange of the HP-22Ф fuel regulating pump. Proceed with installing the unit:

(a) install the connecting pin into the grooves of the bush on the shaft of the HP-22Ф pump;

(b) install the key into the shaft of the БУ-4Б control unit; the key should engage the groove of the bush of the HP-22Ф pump;

(c) fit two half-rings of the quick-disconnect joint onto the flanges;

(d) secure the rings with two bolts; lock the bolts;

(e) attach the plug connector to the БУ-4Б control unit.

After the installation of the БУ-4Б control unit, check the operation of switches СТ, ВДТ, БФО-1, and БФО-2 with the engine running, watching the indications of the tester pilot lamps and of the pointer of the high-pressure rotor speed indicator.

Note: The operating speed of switches БФО-1 and БФО-2 should be checked while slowly shifting the engine control lever within the range of 50 - 80% r.p.m.

If the operating speed values of switches СТ, ВДТ, БФО-1, and БФО-2 do not agree with the specified values, presented in Chapter I, adjust the switches as follows:

(a) back out screw 15 and hinge off the control unit cover (Fig.39);

(b) unlock screw 8 of the respective cam and slacken it;

(c) by turning screw 9, adjust the switch as is laid down in Chapter I;

Note: One turn of the switch cam screw will change the operating speed by about 3.6% (with regard to the high-pressure rotor speed).

(d) the adjustment over, turn in screw 8, lock it along with screw 9 with wire, and reinstall the control unit cover.

Replacement of ДЦН-13ДТ Fuel Booster Pump

The fuel booster pump should be replaced as follows:

1. Detach the fuel inlet and outlet pipe lines from the pump.

Note: When dismantling the pump it is allowed to remove the piping interfering with the procedure.

2. Unlock and back out 2 coupling bolts of the quick-disconnect joint half-rings.

The installation of a new pump should be carried out in the order reverse to dismantling; gasket 0253112 should be replaced beforehand.

The correct position of the pump is indicated by the cylindrical pin provided on the pump flange; the pin should enter the hole on the flange of the engine wheel case.

After the replacement of the pump, proceed as follows:

(a) flush the main fuel system as is instructed in Section "Flushing of Pipe Lines" (Chapter VII);

(b) start the engine and check the tightness of the pump delivery and suction lines.

Replacement of Non-Return Oxygen Valve

The non-return oxygen valve should be replaced using the following procedure:

(a) unlock and turn off the nuts securing the pipes which deliver oxygen to, and carry it from, the valve; back out the bolts fastening the valve strap;

(b) remove the non-return valve from the engine.

Prior to installing the new non-return oxygen valve, blow it with compressed commercial nitrogen. Do not wash the valve.

Note: The commercial nitrogen should be delivered via a felt filter to remove hard particles and moisture.

The new non-return valve should be installed in the order reverse to valve dismantling. After the valve installation, check the oxygen piping (upstream of flame igniters) for tightness of the joints, using commercial nitrogen at a pressure of 7 - 9 kg/sq.cm.; prior to delivering the nitrogen, treat the joints with the neutral soap solution, as is instructed in Chapter VII.

WARNING: When installing the valve, follow the recommendations presented in Section "Replacement of Pipe Lines".

Replacement of НР-22Ф Pump Regulating Needle

(the needle being marked with one collar made with the electric etcher or with digit 2 and one yellow strip on the housing)

The regulating needle should be replaced in the following manner:

1. With the engine running at the maximum rating r.p.m., measure the air pressure in the pipe line delivering P'_2 to the afterburner governor.

2. Detach the air lines from the regulating needle.

3. Unlock and turn out the bolts securing the strap which

holds the needles to the bracket; remove the regulating needle from the engine.

The new needle should be installed in the reverse order of dismantling.

4. Having installed the new needle, restore the original air pressure in the line delivering P'_2 to the afterburner governor, by manipulating the regulating needle with the engine running at the maximum rating r.p.m.

With the needle turned in the counter-clockwise direction, pressure P'_2 will increase; when the needle is turned through 1 division, the pressure will change by about 0.008 kg/sq.cm.

Notes: 1. The operations presented in Points 1 and 4 should be carried out under the same outside air temperature conditions.
2. If pressure P'_2 has not been measured prior to the removal of the regulating needle, perform the adjustment of augmented rating after the installation of the new needle, as is instructed in Section "Replacement of HP-22Φ Fuel Regulating Pump" of the present Chapter.
3. The needle head should not project above the tightened-up nut by more than 11 to 23 mm.

Replacement of HP-22Φ Pump Barostatic Limiter Needle

(the needle being marked with two collars made with the electric etcher or with digit 1 and a blue strip on the housing)

The replacement of the limiting needle should be carried out in the following manner:

1. With the engine running at the maximum rating r.p.m., measure the air pressure in the line delivering P''_2 to the barostatic limiter of the HP-22Φ fuel regulating pump.

2. Detach the air lines from the barostatic limiter needle.

3. Unlock and turn out the bolt securing the strap which holds the needle to the bracket; remove the needle from the engine.

The installation of a new needle should be accomplished in the reverse order of dismantling.

Having installed the new needle, restore the original air pressure in the line delivering P''_2 to the barostatic limiter of the HP-22Φ pump, by manipulating the needle, with the engine running at the maximum rating r.p.m.

With the needle turned in the counter-clockwise direction, pressure P''_2 increases, and vice versa.

With the needle turned through 1 division, the pressure changes by 0.008 kg/sq.cm.

Notes: 1. If pressure P''_2 has not been measured prior to the removal of the barostatic limiter needle, carry out the adjustment after installing the new needle as is laid down in Section "Replacement of HP-22Φ Fuel Regulating Pump" of the present Chapter.
2. The needle head should not project above the tightened-up nut by more than 11 to 23 mm.

Replacement of Afterburner Spark Plug on Disjointed Aircraft (See Fig.37)

The СЭ-21Д5 spark plug should be replaced using the following procedure:

1. Fasten the adjustable jet nozzle on the support of a special trolley.

2. Unlock and turn off two nuts securing the quick-disconnect joint between the diffuser and the jet nozzle. Extract the bolts, remove the fuel collector and the half-rings, after which move the jet nozzle aside.

3. Unlock and detach the following pipe lines and wires from the diffuser casing:

(a) two pipes delivering fuel to the afterburner fuel manifolds;

(b) pipe connecting P_4 (static) to the HP-22Φ fuel regulating pump;

(c) afterburner wire running to the СЭ-21Д5 spark plug;

(d) pipe delivering carburized mixture to the flame igniter;

(e) pipe delivering air to the flame igniter.

4. Unlock and turn off six nuts holding the fuel collector to the 2-nd stage nozzle diaphragm-to-diffuser joint; remove the fuel collector.

5. Unlock and turn off the nuts of the bolts securing the diffuser; remove the diffuser.

Note: When extracting the bolts holding down the diffuser, mark with chalk the places for installing the following lengthened bolts which serve for fastening the pipe lines on the diffuser:
(a) four bolts securing the brackets;
(b) six bolts for the fuel collector;
(c) one bolt for the bracket mounting the afterburner fuel pipe line.

6. Unlock and turn off the nut holding the busbar to the spark plug.

7. Unlock and turn out the spark plug with the aid of a special wrench (contained in the group set of spare parts).

The installation of the new spark plug, the afterburner diffuser, and the adjustable jet nozzle should be accomplished in the order reverse to dismantling.

Notes: 1. When installing the diffuser, the nuts of the diffuser fastening bolts should be tightened by turning them to an angle of 5 to 15° (from the position where the nuts contact the flange).
2. When fitting the pipe delivering P_4, replace copper gasket 0253132 (1 piece).

Check the diffuser for correct installation by the position of the notch provided on the nozzle diaphragm casing; normally, the notch should line up with the centre dot on the diffuser flange.

In a properly jointed afterburner the wider collar of the adjustable jet nozzle will fit into the wider groove of the half-rings, whereas the narrower collar will enter the respective groove of the joint.

When installing the diffuser pipe lines, lock the nuts of the joints with the aid of wire 1X18H9T, having 0.8 mm in diameter, State Standard ГОСТ 5948-50 (hardened).

After completing the operations pertaining to the replacement of the СЭ-21Д5 afterburner spark plug, check the operation of the engine, with the adjustable jet nozzle fastened to the trolley-mounted frame (at any of the engine ratings).

Prior to turning on the afterburner, check the pipe lines which have been subjected to dismantling and reinstallation for tightness, for which purpose:

(a) deenergize the KHA-114 afterburner booster coil by detaching the low-voltage plug connector;

(b) start the engine, after which shift the engine control lever to the FULL AUGMENTED rating position and keep it therefor 0.5 to 1.0 min.;

(c) if no leakage shows up, attach the plug connector to the booster coil and check the afterburner for proper controllability, as is laid down in Section "Checking of Engine on Ground prior to Flight".

__Replacement and Adjustment of Hydraulic Cylinder__

(to be performed with the hydraulic control unit dismantled)

The replacement of the afterburner hydraulic cylinder should be carried out in the following manner:

1. Remove the hydraulic unit controlling the adjustable jet nozzle, for which purpose:

(a) detach the hydraulic pipe lines from the hydraulic control unit and disconnect the plug connector from the feedback transmitter;

(b) unlock and remove six pins securing links 3 (See Fig.45) to the adjustable jet nozzle casing;

(c) release struts 3 from the eyes and remove the hydraulic control unit (three hydraulic cylinders along with the cooling casings, flap ring 10, and load-carrying ring 4 with six links 3).

2. Remove the casing of the cylinder to be replaced.

3. If possible, measure the projecting portion of the cylinder rod in each of the two positions (MAXIMUM and FULL AUGMENTED) for which purpose:

(a) connect the trolley-mounted hydraulic pumps;

(b) connect the hoses, contained in the aircraft-carried tools set, to the hydraulic control unit and to the aircraft connections;

(c) connect the ground power source to the aircraft mains;

(d) turn on the following switches: AIRCRAFT-GROUND STORAGE BATTERY, AFTERBURNER, PROCESSING (in the K position).

Set screw M on the afterburner control unit in the BLOCKING CUT-OUT position, turn on the switch EMERGENCY ENGAGEMENT OF TWO-POSITION JET NOZZLE;

(e) set the engine control lever in the MAXIMUM rating position and in the FULL AUGMENTED rating position. While proceeding in this manner, measure the projecting portion of the hydraulic cylinder rod.

Should it be found impossible to take the above measurements, make use of the values obtained while measuring the rods of the sound cylinders (taking the mean value).

After carrying out the above measurements, disconnect the ground power supply source from the aircraft mains.

4. Release pressure from the hydraulic system.

5. Unlock and detach the pipe lines from the cylinder to be replaced.

6. Unlock the nut of the bolt holding the hydraulic cylinder to load-carrying ring 4, and hydraulic cylinder fastening pin to flap ring 10.

Extract the bolt and the pin, and remove the hydraulic cylinder.

The installation of a new hydraulic cylinder should be carried out in the order reverse to dismantling.

Adjust the rod travel of the newly-installed cylinder in the MAXIMUM and FULL AUGMENTED rating positions so that it agrees with the respective values obtained on the replaced cylinder (in case the measurements were carried out), or with the rod travel values of the sound cylinders (proceed as instructed in Point 3 of this Section).

Check the hydraulic cylinder rods for synchronous travel, for which purpose shift the engine control lever several times from the MAXIMUM rating stop to the FULL AUGMENTED rating stop.

No difference in the travel values is permissible.

The misalignment of the ring during the rod travel should not exceed 7 mm at intermediate augmented ratings and 1.5 mm at the full augmented rating.

<u>Note</u>: The ring is checked for misalignment by using a rule to measure the projecting portions of the cylinder rods; the difference between the rod projection values (of three hydraulic cylinders) will affect the synchronous travel of the rods.

Should it be necessary, perform the adjustment of the rod travel by manipulating screws 5, springs 4, and the synchronizing valves (Fig.48); prior to carrying out the procedure, slacken nuts 6. The tightening of the screw of the right-hand synchronizing valve spring (See Fig.50) will cause the rods to open the jet nozzle flaps at a higher rate. The tightening of the screw of the left-hand synchronizing valve spring will cause an accelerated closing of the jet nozzle by the cylinder rods.

Check the time period within which the hydraulic cylinder rods shift from the MAXIMUM rating position to the FULL AUGMENTED rating position and backwards, as is instructed in Section "Routine Maintenance Performed Every 50±5 Hours of Engine Operation".

If this time period does not agree with the specified one, carry out the adjustment of the synchronizing valves (Fig.50) with the aid of flow restrictors I, II and III.

An increase in the capacity of left-hand synchronizing valve flow restrictor I will cause the rods to close the flaps within a shorter time period, and vice versa.

An increase in the capacity of right-hand synchronizing valve flow restrictor II will cause the rods to open the flaps within a longer time period, and vice versa.

Having completed the final adjustment of the cylinder rods, install flow restrictor III with a capacity specified in the chart attached, where 0_1 and 0_2 are the capacities of the flow restrictors of the left-hand and right-hand synchronizing valves respectively.

Having completed the above procedure, disconnect the trolley-mounted hydraulic pumps from the hydraulic system; disconnect the ground power supply source from the aircraft mains, turn off the EMERGENCY ENGAGEMENT OF TWO-POSITION NOZZLE switch, and install the hydraulic control unit on the engine in the reverse order of dismantling.

After the installation of the hydraulic control unit, check to see whether the jet nozzle diameters conform to the values presented in the Service Log, proceeding as follows:

1. Connect the trolley-mounted hydraulic pumps to the aircraft.

2. Connect the ground power supply source to the aircraft mains.

3. Set the engine control lever in the MAXIMUM rating position and measure the jet nozzle diameter (see that the 69 - 70° division of the control panel dial lines up with the notch provided on the casing).

4. Shift the engine control lever to the MINIMUM AUGMENTED rating stop and measure the diameter of the jet nozzle (in this case the 74 - 75° division on the control panel dial should line up with the notch on the casing).

5. Shift the engine control lever to the FULL AUGMENTED rating stop and measure the jet nozzle diameter (this should cause the 112 - 113° division on the control panel dial to line up with the notch provided on the casing, whereas the engine control lever should tightly fit against the FULL AUGMENTED rating stop).

Adjust the jet nozzle diameters, if necessary.

__Note:__ The jet nozzle diameters should be first adjusted at the FULL AUGMENTED rating, as changing the jet nozzle diameter at this rating will cause a change in the jet nozzle diameter at the MINIMUM AUGMENTED rating.

The jet nozzle diameter should be adjusted in the following manner:

__Adjustment of Jet Nozzle Diameter at FULL AUGMENTED Rating__

1. Adjust the jet nozzle diameter as follows:

(a) set the engine control lever in the FULL AUGMENTED rating position and turn on the EMERGENCY ENGAGEMENT OF TWO-POSITION JET NOZZLE switch;

(b) release pressure in the hydraulic system;

(c) slacken locking bolts 18 (Fig.47) retaining hydraulic cylinder shanks;

(d) turn the hydraulic cylinder rods to obtain the required jet nozzle diameter.

Turning the hydraulic cylinder rod in the clockwise direction (looking forward) will cause the jet nozzle diameter to increase, and vice versa.

One turn of the rod will change the jet nozzle diameter by about 2 or 3 mm.

__WARNING:__ To avoid causing misalignment of the ring, turn the rods of all the three hydraulic cylinders through the same angle.

Having completed the adjustment procedure, tighten up locking bolts 18.

2. Check the hydraulic cylinder rods for proper projection at the beginning of the FULL AUGMENTED rating sector, proceeding as follows:

Set the engine control lever in a position in which the 107 - 109° division on the control panel dial lines up with the notch on the control panel casing.

__Note:__ When shifting the engine control lever, watch the movement of the hydraulic cylinder rods.

With the engine control lever in this position, the rods of the hydraulic cylinders should set against the mechanical stop.

(a) In case the hydraulic cylinder rods set against the mechanical stop before the engine control lever reaches the specified position, turn screw 10 of the P-1 rheostat (Figs 36, 40) in the clockwise direction to adjust the hydraulic cylinder rods so that they set against the mechanical stop as soon as the engine control lever attains the required position;

(b) If the hydraulic cylinder rods stop as soon as the engine control lever reaches the required position, turn on the EMERGENCY ENGAGEMENT OF TWO-POSITION JET NOZZLE switch. This should not result in changing the hydraulic cylinder rod projection value.

If there is a change in the projection of the hydraulic cylinder rods, turn screw 10 of the P-1 rheostat in the counter-clockwise direction to adjust the rods so as to ensure a full projection of the rods at the given position of the engine control lever.

__Note:__ Having checked and adjusted the full projection of the hydraulic cylinder rods, turn screw 10 in the counter-clockwise direction through 3 or 4° and check to see that the rods do not move when the engine control lever is shifted within the range of the FULL AUGMENTED rating sector.

Adjustment of Jet Nozzle Diameter at MINIMUM AUGMENTED Rating

1. Set the engine control lever in the MINIMUM AUGMENTED rating position.

2. Adjust the jet nozzle diameter to the required value by turning screw 16(Fig.16). Turning the screw in the clockwise direction will cause the jet nozzle diameter to increase, and vice versa.

WARNING: When adjusting the jet nozzle diameter by means of screw 16, see that the axial displacement of the screw should not exceed 2 mm in either direction (as compared to screw projection value Я registered in the Certificate of ДР-3А transmitter).

If the jet nozzle diameter fails to be adjusted by turning screw 16 within the specified range, the adjustment procedure should be carried out as follows:

(a) set screw 16 in the initial position;

(b) turn screw МФ of the P-1 rheostat(Fig.16) to adjust the jet nozzle diameter to the required value.

Turning screw МФ in the clockwise direction causes the jet nozzle diameter to increase, and vice versa.

WARNING:
1. Having adjusted the jet nozzle diameter with the aid of screw МФ, do not fail to check and to adjust the full projection of the hydraulic cylinder rods as is laid down in the present Section, with a subsequent checking and adjustment of the jet nozzle diameter at the MINIMUM AUGMENTED rating by means of screw 16.
2. After checking and adjusting the jet nozzle diameter at the MINIMUM AUGMENTED rating, check to see that the rods do not move when the engine control lever is shifted within the range of the MINIMUM AUGMENTED rating sector.

Adjustment of Jet Nozzle Diameter at MAXIMUM Rating

1. Set the engine control lever in the MAXIMUM rating position.

2. Turn nuts 11 of the hydraulic cylinders to obtain the required diameter of the jet nozzle (Fig.47).

Turning nut 11 in the clockwise direction will decrease the jet nozzle diameter, and vice versa. One complete turn of the nut will change the jet nozzle diameter by 2 or 3 mm.

The adjustment procedure over, lock nuts 11.

WARNING:
1. To avoid misalignment of the jet nozzle ring, turn the nuts of all the three cylinders through the same angle.
   When adjusting the jet nozzle diameter, use the fixture, contained in the 1:20 set; the pressure of the air delivered to the fixture during the adjustment procedure should amount to 4 - 6 kg/sq.cm.
2. Changes in jet nozzle diameter at the maximum rating do not affect the diameter of the jet nozzle at the MINIMUM AUGMENTED and FULL AUGMENTED ratings.

The adjustment procedure over, disconnect the trolley-mounted hydraulic pumps and the ground power supply source from the aircraft; set the switches MASTER SWITCH, AFTERBURNER and PROCESSING in the initial position; set screw Ж on the afterburner control unit in the BLOCKING CUT-IN position and remove the fixture for the measuring jet nozzle diameter (БМ37-575).

No reference has been made in the present Instructions to the replacement of other units and assemblies, the procedure being rather simple since it does not involve engine dismantling.

6. Units Replaced after Dismantling Engine from Aircraft

Replacement of Oil Pump Unit

The oil pump unit should be replaced in the following manner:

1. Remove the ДТЭ-1 high-pressure rotor tachometer generator.

2. Detach the oil inlet and outlet lines.

Note: It is allowed to remove the pipe lines interfering with the oil pump unit dismantling.

3. Release the plate locks and turn out four bolts fastening the oil pump unit.

4. Remove the oil pump unit.

5. Install a new oil pump unit in the following sequence:

- use a depth gauge to measure the distance between the face of the driven gear hub and the face of the dismantled oil pump unit, with an accuracy of 0.1 mm;

- remove the driven gear from the oil pump unit to be replaced;

- install the driven gear on the new oil pump unit;

- measure the distance between the oil pump unit face and the driven gear hub as is recommended above. If the size obtained does not agree with the size of the dismantled unit, ensure the required size to an accuracy of 0.1 mm by replacing calibrated rings No. 0243043 (a set of 12 rings differing in size by 0.1 mm);

- lock the nut fastening the driven gear (lock 0243151).

Further installation of the new oil pump unit should be accomplished in the order reverse to dismantling.

Be sure to fit in a new gaske. (No. 253144).

Having installed the new oil pump unit, check the oil pressure at all ratings up to normal (as indicated by the pressure gauge); after running the engine for 1 or 2 min. at the normal rating, see that no oil leakage shows up on the oil pump unit flange. If the oil pressure does not agree with the specified limits, perform the necessary adjustments as is laid down in Chapter X.

Replacement of Combustion Chamber Flame Igniter

The following procedure should be used for the replacement of the flame igniter:

1. Unlock and turn off the nuts securing the shielded wires; detach the fuel inlet pipes and the oxygen delivery pipes from the flame igniter.

2. Release the plate locks and turn out the flame igniter securing bolts.

Prior to installing a new flame igniter, it should be deprocessed with the aid of clean gasoline applied by a brush. The installation of the new flame igniter should be performed in the reverse order of dismantling.

WARNING: 1. Treat the thread of the flame igniter securing bolts with chalk paste.
2. Install the СПН-4-3 spark plugs into the flame igniter with the help of a torque indicating wrench, to prevent damage to the spark plug thread.

Prior to installing the engine on the aircraft, check the oxygen piping joints for leakage using the following procedure:

- treat the joints of the oxygen system piping subjected to dismantling with neutral soap solution;

- connect the cylinder containing commercial nitrogen to the engine non-return oxygen valve;

- deliver nitrogen into the oxygen system piping and check the joints for tightness.

WARNING: 1. Nitrogen pressure should be within 7 - 9 kg/sq.cm.
2. No bubbling of the soap solution is allowed.

Having checked the oxygen piping joints, disconnect the nitrogen cylinder from the non-return valve and install the engine in the aircraft.

Replacement of Front Support Oil Scavenge Pump

The replacement of the front support oil scavenge pump is carried out in the following manner:

1. Remove the ПУРТ-1Ф control panel, as recommended in the respective Section of the present Chapter; remove the low-pressure tachometer generator.

2. Detach the oil inlet and outlet pipe lines.

Note: It is allowed to remove the pipe lines interfering with the pump dismantling.

3. Remove the universal joint shaft of the HP-21Ф pump centrifugal governor drive as is instructed in Section "Replacement of HP-21Ф Fuel Regulating Pump" below.

4. Back out the bolts securing the half-rings of the pump quick-disconnect joint.

5. Carefully remove the pump; support the pump when removing it to avoid bending the drive coupling shaft.

Install the new pump in the reverse order of dismantling:

Note: When installing the new pump, fit in a new gasket.

Having installed the new pump, start the engine and check the pipe lines subjected to dismantling for leakage.

Replacement of HP-22Ф Fuel Regulating Pump

(the pump is to be replaced complete with the БУ-4Б control unit)

To replace the fuel regulating pump, proceed as follows:

1. Detach the fuel and air lines; detach the plug connectors from the HP-22Ф pump and from the БУ-4Б control unit.

Notes: (a) It is allowed to remove the pipe lines interfering with the pump dismantling.
(b) Do not change the position of the regulating elements of the needles for releasing pressures P'_1 and P''_2.

2. Release the locks of the bolts securing the half-rings of the quick-disconnect joint.

3. Back out the bolts while supporting the HP-22Ф pump.

4. Remove the fuel regulating pump from the engine.

5. Install the new fuel regulating pump in the reverse order of dismantling.

Note: The parting line of the quick-disconnect joint ring should be positioned vertically.

6. Having mounted the fuel regulating pump, install the engine in the aircraft.

Adjustment of Augmented Rating after Replacement of HP-22Ф Fuel Regulating Pump

1. Install instruments for measuring the following characteristics:

(a) $P_{f.p.m.}$ - fuel pressure in the pilot manifold (pressure gauge from 0 to 100 with division value of 0.5 kg/sq.cm.);

(b) $P_{f.a.m.}$ - fuel pressure in the afterburner manifold (pressure gauge from 0 to 100 with division value of 0.5 kg/sq.cm.);

(c) P'_2 - air pressure in the pipe line delivering air to the afterburner fuel control unit (pressure gauge from 0 to 6 with division value of 0.02 kg/sq.cm.);

(d) P''_2 - air pressure in the pipe line delivering air to the barostatic limiter of the HP-22Ф pump (pressure gauge from 0 to 6 with division value of 0.02 kg/sq.cm.);

(e) n_2 - speed of the high-pressure rotor (МСТ-2 tachometer indicator);

(f) P_4 - gas pressure aft of the turbine(pressure gauge from 0 to 6 with division value of 0.02 kg/sq.cm.).

Connect tester ЕМ37-587 (contained in the aircraft-carried 1:20 set) to the main plug connector.

Set zero delays on the afterburner control unit (with regard to fuel ard jet nozzle).

2. Start the engine and check the speed associated with operation of cams СТ and ВДТ as instructed in Chapter III.

3. While smoothly shifting the engine control lever, check the speed associated with operation of the limit switches БФО-1 and БФО-2 (as indicated by the pilot lamp of the tester).

4. With the engine running at the maximum rating, measure characteristics $P_{f.p.m.}$, P'_2, P''_2, n_2, and P_4.

5. Turn on the afterburner and check the afterburner ignition by the indications of the tester pilot lamp.

The afterburner ignition system should operate within 7 to 12 sec. (operation of the electromagnet switching on the HP-22Ф pump and of the afterburner valve limit switch marking off the specified time period).

If the above time period is less than, or exceeds, the permissible limits, perform the necessary adjustment by choosing proper flow restrictor 18 (Fig.26). The flow restrictor of a smaller capacity will cause an increase in the time period within which the afterburner valve opens to its full capacity, and vice versa.

6. With the engine running at the augmented rating, measure the following characteristics: $P_{f.p.m.}$, $P_{f.a.m.}$, P'_2, P''_2, P_4, n_1, and n_2.

The parameters of the augmented rating should be lower than those of the maximum rating:

(a) fuel pressure in the pilot manifold . . by 0.5 – 1.5 kg/sq.cm.

(b) speed n_2 . . . . by 0 – 0.7%

(c) gas temperature aft of the turbine . . by 5 to 15°C

In case the difference between the parameters of the augmented and maximum ratings is less than, or exceeds, the specified values, carry out the adjustment of regulating needle P_2' (marked with one collar made with the electric etcher, or with digit 2 and yellow strip on the housing).

Turning the needle in the counter-clockwise direction will increase the fuel pressure in the pilot and afterburner manifolds, as well as the gas temperature aft of the turbine, and speed n_2, and vice versa.

Notes: 1. If the fuel pressure in the afterburner fuel manifold exceeds 75 kg/sq.cm., the adjustment of the augmented rating should be carried out with the fuel pressure in the afterburner manifold amounting to 65 – 70 kg/sq.cm. In this case, a change in the position of the needle regulating element should be accompanied by a change in the pressure of fuel in the afterburner manifold; pressure P_2' should exceed pressure P_4 by 0.02 kg/sq.cm.

2. During the adjustment procedure pressure P_2'' should exceed pressure P_2' by 0.2 kg/sq.cm.; the final adjustment should be performed in compliance with Point 7.

7. Adjust the needle of the barostatic limiter of the HP-22Φ pump (with speed $n_{1\ ind}$ amounting to 100%) to a pressure determined in accordance with the following formula:

$$P_2'' = \left[\frac{P_2\ stat + \frac{B_o}{736}}{K} - \frac{B_o}{736} \right]^{\pm 0.02} \text{kg/sq.cm.}$$

where K is the coefficient of the ratio between pressures P_2 and P_2'' at an altitude and on the ground:

$$K = \frac{1.30 \times 736}{P_2''\ altitude} = \frac{956.8}{P_2''\ altitude};$$

P_2'' altitude (mm of mercury) is determined from the characteristics of the barostat entered in the Certificate of the HP-22Φ pump (for fuel consumption of Q=3650 lit/hr);

P_2 stat (kg/sq.cm.) is the static pressure of the air aft of the compressor with the engine running at the MAXIMUM rating ($n_{1\ ind}$=100%);

B_o (mm of mercury) is the atmospheric pressure at the moment of adjustment.

Notes: 1. Turning the barostatic limiter needle in the counter-clockwise direction will cause an increase in pressure P_2'', and vice versa. With the needle turned through one division, pressure will change by 0.008 kg/sq.cm.

2. Should it be necessary to adjust the regulating needle (in the course of engine operation), first find the difference between pressures P_2' and P_2'' at 100% r.p.m. and then adjust the regulating needle, with a subsequent adjustment of the barostatic limiter needle for the pressure difference determined.

The adjustment procedures over, remove the instruments and close the respective connections.

After the replacement of the HP-22Φ fuel regulating pump, perform a trial flight and register the n_1 and n_2 r.p.m. values with an accuracy of 0.5%, with the engine running at the sustained FULL AUGMENTED rating (at flying Mach number range of 1.24 – 1.35 and H equal to 11,000 – 13,000 m.).

Notes: 1. Having adjusted the regulating needle, pass over to the adjustment of the barostatic limiter needle, as is laid down in Point 7 of the present Section.

2. When carrying out the adjustment of the augmented rating, make allowance for the tachometer indicator error (in compliance with the respective Certificate).

After the final adjustment of engine operation at the augmented rating, perform a trial flight as instructed in Chapter VII.

The replacement of other units and assemblies (after dismantling the engine from the aircraft) is not delt with in the present Instructions, the replacement procedures not involving any particular difficulties.

Chapter X

ENGINE ADJUSTMENT

The following adjustment procedures may be carried out in the course of engine operation:

1. Adjustment of idling rating r.p.m.
2. Adjustment of oil pressure.
3. Adjustment of engine acceleration.
4. Adjustment of engine starting.
5. Adjustment of maximum r.p.m.
6. Adjustment of the HP-21Ф pump hydraulic decelerator limit switch and of the БУ-4Б control unit limit switches.
7. Adjustment of engine controls.
8. Adjustment of afterburner control unit time delays.
9. Adjustment of high-pressure rotor maximum r.p.m.

The engine delivered to the Customer should have all its adjustment elements locked and sealed.

WARNING: 1. Prior to the engine adjustment, make sure the readings of the measuring instruments are correct.

2. To obtain stable engine characteristics during the adjustment , the positions of the respective adjustment elements should be changed by turning them in. Should it be necessary to turn out an adjustment element through some angle, turn it through the required angle plus 180°. and then turn it in through 180°.

If the adjustment element has some fixed positions (indicated by clicks, etc.), turn out the element so that the number of clicks produced should correspond to the angle of 180°.

Whenever completing the engine adjustment on the aircraft, lock and seal the respective adjustment elements. The list of points subject to locking and sealing is presented in the Appendix.

WARNING: 1. When operating the engine, it is allowed to change the position of the following adjustment elements:

-adjustment screw of the HP-22Ф pump maximum

speed limiter (n_2);
- idling rating r.p.m. adjustment screw (HP-21Φ);
- HP-21Φ pump maximum speed stop (n_1);
- HP-21Φ pump feed-back flow restrictor;
- HP-21Φ pump hydraulic decelerator flow restrictor;
- 1st and 2nd branch pressure increase limiter flow restrictors (HP-21Φ);
- AUGMENTED rating stop of the HP-21Φ pump lever;
- adjustment screw of the HP-21Φ pump hydro-electric contactor;
- HP-21Φ pump starting fuel control unit screw;
- starting fuel control unit air jet;
- HP-22Φ pump afterburner valve flow restrictor;
- oil pump unit reducing valve;
- screws of the БУ-4Б control unit limit switches;
- HP-22Φ pump regulating needle;
- HP-22Φ pump barostatic limiter needle;
- screws HΦ and 1Φ of the P-1 rheostat.

The position of other adjustment elements may be changed only by the representative of the Manufacturing plant.

2. All adjustments performed on the HP-21Φ and HP-22Φ pumps should be duly reflected in the Certificates. All adjustment performed on the engine should be registered in the engine Service Log.

1. Adjustment of Idling Rating R.P.M.

The idling rating r.p.m. should be checked and adjusted after warming up the engine for 1 or 2 min. at 88% r.p.m.

Before the adjustment procedure the notch on the flag of the HP-21Φ pump control lever should be located between the notches provided on the idling rating sector and on the pump dial. Shift the engine control lever in both directions within the range marked off by the idling rating sector notches on the dial of the HP-21Φ pump, to check the idling rating sector for proper setting. If the idling rating r.p.m. associated with the upper notch differs from r.p.m. associated with the lower notch by more than 1.5%, further use of the HP-21Φ fuel regulating pump on the aircraft should be discussed with the representative of the Manufacturing plant.

Should it be necessary, carry out the adjustment of the idling rating r.p.m. in the following manner (Fig.24):

1. Unlock idling rating slide valve screw 11.

50X1-HUM

2. Turn screw 11 so that to cause the idling rating r.p.m. to reach the value referred to in Chapter I.

Notes: 1. With screw 11 turned in the clockwise direction, the idling rating r.p.m. will decrease, and vice versa. One turn of the screw will change the idling rating r.p.m. by 2%.
2. The idling rating r.p.m. should be adjusted in accordance with the chart presented in Fig.I (Fig.VI being duly taken into consideration), with the HП-34-2T and ГСР-СТ-12000ВТ units under load.

3. Lock screw 11.

The above adjustment procedure should be conducted using the following tools and parts:

1. Side cutting pliers C31-204.
2. Pliers C31-225.
3. Safety wire (brass).
4. Locking ring.

2. Adjustment of Oil Pressure

The adjustment of the oil pressure should be performed in case the oil pump unit is replaced or in case the oil pressure drops below the specified level.

Note: If the oil pressure drops by more than 0.5 kg/sq.cm. below the permissible level, further use of the engine should be discussed with the representative of the Manufacturing plant.

The following procedure should be used, when adjusting the oil pressure:

1. Unlock the shank and the union nut of the reducing valve.

2. Turn off the shank union nut by 1 to 1.5 turns, taking care to prevent the reducing valve shank from turning.

3. Adjust oil pressure to the required value by turning the shank.

Notes: 1. Turning the shank in the clockwise direction will cause oil pressure to increase, and vice versa. One complete turn of the shank will change the oil pressure by 1 kg/sq.cm.
2. To provide ease of access to the oil pump unit reducing valve, it is allowed to detach the plug connector of the electromagnetic starting fuel valve.

4. Tighten up the union nut, taking care not to allow turning of the shank; lock the nut and the reducing valve shank.

The above adjustment procedure requires the use of the following tools and parts:

1. Side cutting pliers C31-204.
2. Pliers C31-226.
3. Wrench БИ37-08
4. Wrench БИ37-I3
5. Safety wire.

3. Adjustment of Engine Acceleration

A complete adjustment of the engine acceleration is done at the Manufacturing plant. However, an additional adjustment of the engine acceleration is allowed during engine operation on the aircraft in case the rate of the engine acceleration fails to agree with the specified values presented in Chapter I.

The time of the engine acceleration from the idling rating r.p.m. and from the automatic fuel supply minimum r.p.m. to n_1 =100% is regulated by adjusting the pressure increase limiter and the hydraulic decelerator by choosing proper flow restrictors. An increase in the capacity of the flow restrictors will cause a decrease in the acceleration time, and vice versa.

The time of the engine acceleration from the idling rating r.p.m. to n_1=100% is affected mainly by the adjustment of the pressure increase limiter, whereas the time of the engine acceleration from n_1=85% (automatic fuel supply minimum r.p.m.) to n_1=100% is affected by the adjustment of the hydraulic decelerator.

WARNING: In case the engine accelerating ability is checked immediately after deprocessing or replacement of the HP-21 Ф fuel regulating pump, smoothly accelerate the engine 8 or 10 times to n_1=88 - 90% prior to starting the adjustment procedure; this will deprocess the pressure increase limiter and the hydraulic decelerator.

The engine acceleration is adjusted with the aid of the following elements (Fig.24):

(a) pressure increase limiter 1st branch flow restrictor 27, which affects mainly the first stage of the engine acceleration (from $P_{f.p.m.}$=21 kg/sq.cm. to 27±1 kg/sq.cm., 1st branch);

(b) pressure increase limiter 2nd branch flow restrictor 26, which mainly affects the second stage of the engine acceleration (from $P_{f.p.m.}$=27±1 kg/sq.cm. to 40±2 kg/sq.cm., 2nd branch);

(c) feed-back flow restrictor 15 (incorporated in the regulator), which affects mainly the third stage of engine acceleration (from $P_{f.p.m.}$=40±2 kg/sq.cm. to 100% r.p.m.);

(d) hydraulic decelerator flow restrictor 25 which influences the rate of engine acceleration from n_1=85% to n_1=100%.

In case the engine parameters fail to agree with the specified values, carry out the adjustment proceeding as follows:

1. Connect the pressure gauge (80 - 100 kg/sq.cm.) to the union on the pilot manifold.

2. Measure the fuel pressure in the pilot manifold with the engine running at the idling rating.

The fuel pressure in the pilot manifold should amount to 21±1 kg/sq.cm.

3. Check the time period within which the pressure in the pilot manifold (with regard to the pressure increase limiter 1st branch) increases from $P_{f.p.m.}$=22 kg/sq.cm. to 26 kg/sq.cm.; this time period should be equal to 3.6 sec.

Notes:
1. When proceeding as is laid down in Point 3, shift the engine control lever from a position below the idling rating sector to a position where $P_{f.p.m.}$ = 18 - 19 kg/sq. cm. (Fig.VI).
2. The capacity of the pressure increase limiter 1st branch flow restrictor should not be less than 40 cu.cm /min.
   The capacity range of the flow restrictors used on the aircraft amounts to 40 - 100 cu.cm/min.
3. The initial pressure rise in the pilot fuel manifold should not exceed 2.5 kg/sq.cm.
4. The time of pressure increase should be checked in the following manner:
   - reduce pressure in the pilot fuel manifold to 18 - 19 kg/sq.cm. by slowly moving the engine control lever towards the CUT-OUT stop;
   - smoothly shift the engine control lever to the MAXIMUM rating position, and determine the time of pressure increase with regard to the first branch of the pressure increase limiter.
5. In case the maximum permissible time period is

required for the engine acceleration, and the capacity of the first branch flow restrictor amounts to 40 cu.cm/min., the time of pressure increase (with regard to the 1st branch) may be reduced to 3.0 sec.

4. Check the time of the engine acceleration from the idling rating to 100% r.p.m. which should agree with the data presented in the Chart (Fig.II). The readings should be taken at n_1=99%.

<u>WARNING</u>: If the total time of acceleration fails to agree with the specified data, while the time of the engine acceleration with regard to the 1st branch keeps within the specified range, it is necessary to carry out the adjustment of the engine acceleration time by choosing proper flow restrictors for the 2nd branch of the pressure increase limiter and for the feed-back system.

5. Check the time of the pressure increase in the pilot fuel manifold, with regard to the 2nd branch of the pressure increase limiter, from $P_{f.p.m.}$=28 kg/sq.cm. to $P_{f.p.m.}$ = 40 kg/sq.cm. which should amount to not less than 6.0 sec.

<u>Notes</u>: 1. The change-over from the 1st pressure increase limiter branch to the 2nd branch takes place at $P_{f.p.m.}$=27±1 kg/sq.cm.

To determine the change-over pressure, install a flow restrictor in the 2nd branch with a capacity amounting to 280 - 300 cu.cm/min.

Having determined to the change-over pressure, reinstall the old flow restrictor.

The capacity range of the 2nd branch flow restrictor should be within 70 - 250 cu.cm/min. If the total time of engine acceleration fails to agree with the specified data while the time of the engine acceleration with regard to the 1st and 2nd branches of the pressure increase limiter keeps within the specified range, it is necessary to perform the adjustment of the engine acceleration by replacing the feed-back flow restrictor.

2. When adjusting the time of the engine acceleration with regard to the pressure increase limiter, fit the hydraulic decelerator with a flow restrictor having a capacity of 280 - 300 cu.cm/min. to cut the hydraulic decelerator out of operation.

The adjustment procedure completed, reinstall the old flow restrictor.

The capacity range of the hydraulic decelerator flow restrictors should be within 50 - 90 cu.cm/min.

6. Check the time of the engine acceleration from % r.p.m. to 100% r.p.m.; take also the time readings as soon the engine picks up 99% r.p.m.

The time period should be within 8 to 11 sec. In case the tual time period fails to agree with the specified data, just the engine acceleration by choosing a proper flow restrictor for the hydraulic decelerator.

<u>WARNING</u>: 1. The capacity range for the feed-back flow restrictors should be within 150 - 300 cu.cm/min.
2. When substituting the feed-back flow restrictor by a flow restrictor of a smaller capacity, check the maximum engine r.p.m. in accordance with the recommendations presented in Point 4 of Section "Adjustment of Engine Maximum R.P.M." below.

7. Having completed the adjustment procedure, check the gine acceleration:

(a) from the idling rating r.p.m. to the maximum rating r.p.m.;

(b) from n_1=85% to the maximum rating r.p.m.

The engine acceleration should be checked by quickly (within 1.5 to 2.0 sec.) moving the engine control lever to the quired position.

The time of the engine acceleration should agree with the alues presented in Chapter I.

<u>WARNING</u>: After the replacement of the flow restrictors in the course of the acceleration adjustment procedure, flush the HP-21Φ fuel regulating pump as is laid down in Section "Flushing of Pipe Lines" (Chapter VII).

Having checked the engine acceleration, check the acceleration time margin in the following manner:

- bring the engine speed to maximum and keep the engine unning at this rating for 1 or 2 min.;

- reduce the engine speed to the idling rating r.p.m. and un the engine at this speed for 1 min.; accelerate the engine o 85% r.p.m. and check the time of the engine acceleration o the maximum rating.

In this case the time period should not differ from that easured as indicated in Point 7 (b) by more than 2 sec.

In case the difference is greater, consult the representative of the Manufacturing plant as to further use of the HP-21Φ uel regulating pump.

Note: The difference between the two time periods may exceed 2 sec., provided the time of acceleration is within the specified range (Chapter I).

The acceleration adjustment procedure completed, detach the pressure gauge for measuring fuel pressure in the pilot manifold; fit in the service closure.

WARNING: In case the engine acceleration is accompanied by an excessive increase in the gas temperature aft of the turbine or by surging, shift the engine control lever to the CUT-OUT position, after which locate and correct the trouble.

For carrying out the above adjustment procedure, the following tools and parts are required:

1. Pliers C31-226.
2. Side cutting pliers C31-204.
3. Screw-driver.
4. Safety wire.
5. Rod.
6. Wrench БИ37-10.

4. Adjustment of Engine Starting

The adjustment of the engine starting is carried out in case the starting procedure does not conform to the requirements referred to in Chapter I of the present Instructions.

The adjustment procedure is carried out with the engine started from the ground power supply source.

Starting adjustment elements are as follows:

1. Starting fuel control unit spring screw 3 (Fig.24), affecting the 1st stage of the starting procedure (up to n_2=18 - 21%).

With the screw turned out, the time of the engine acceleration within the 1st stage increases (resulting in a decrease of the gas temperature aft of the turbine), and vice versa.

2. The jet for the air release from the membrane chamber of the starting fuel control unit (Fig.23) which affects the 2nd stage of the starting procedure (at n_2=18 - 21% and above).

A jet of an increased diameter will cause the time of the engine acceleration within the 2nd stage to increase (resulting in a decrease of the gas temperature aft of the turbine), and vice versa.

The engine starting is adjusted in the following sequence:

1. Check pressure of the starting fuel. The starting fuel pressure should be 2±0.2 kg/sq.cm.(with the starting fuel tank not pressurized and with voltage amounting to 25+2 V).

If the pressure value obtained does not agree with the specified pressure range, carry out the necessary adjustment by manipulating the screw of the starting fuel pump reducing valve. With the screw turned in, pressure increases, and vice versa.

2. Check the position of the flag of the HP-210 fuel regulating pump (on the pump dial) when setting the engine control lever in the IDLING rating position. The pump flag should be located between the notches marking off the idling rating sector. Adjust the aircraft link, if necessary.

3. Fit in a pressure gauge (0 - 80 kg/sq.cm.) to measure pressure in the pilot fuel manifold.

4. Start the engine and warm it up at 88 - 90% r.p.m. for 1 or 2 min.

Note: The engine starting may be accomplished with the fuel supply regulated manually.

5. Check the idling rating r.p.m. on the warmed-up engine.

The idling rating r.p.m. should be within the range specified in Chapter I.

If necessary, adjust the idling rating r.p.m. as is laid down in Section "Adjustment of Idling Rating R.P.M." of this Chapter.

6. Check the fuel pressure in the pilot manifold, with the engine running at the idling rating.

The fuel pressure in the pilot manifold should be equal to 21±1 kg/sq.cm.

WARNING: The adjustment of the fuel pressure in the pilot manifold should be performed with the aid of screw P.K.

7. Start the engine automatically 2 or 3 times.

Note: When starting the engine, follow the recommendations of Chapter III.

8. Determine the range between the "cold" and "hot" stalling limits while turning the starting fuel control unit screw out or in; this range should be equal to not less than 1.5 turns

of the screws. This done, set the starting fuel control unit in the intermediate position.

Note: The range between the limits of "cold" and "hot" stalling should be checked only when adjusting the starting procedure after the replacement of the HP-210 fuel regulating pump.

After completing the adjustment procedure, remove the pressure gauge for measuring pressure in the pilot fuel manifold, and plug the respective union; attach the plug connector of the electromagnetic oxygen supply valve.

The above adjustment procedure is carried out by employing the following tools and parts:

1. Pliers C31-226.
2. Side cutting pliers C31-204.
3. Screw-driver БМ37-569.
4. Safety wire.
5. Set of jets 3700188.

5. Adjustment of Engine Maximum R.P.M.

The maximum r.p.m. of the low-pressure rotor should be within the range specified in Chapter I. The maximum r.p.m. should be checked after the engine is warmed up, with the engine control lever in the MAXIMUM rating position.

Notes: 1. Prior to starting the engine, see that the engine controls are set in the correct position (68 - 70°, as read off the control panel dial). See that the notch on the flange of the HP-210 pump is above the 6th notch on the dial.

2. The adjustment of the maximum r.p.m. should be performed by using a reference tachometer indicator capable of giving readings within the range of 90 - 105% r.p.m. with an accuracy of 0.2%.

If a reference tachometer indicator is not available, it is allowed to perform the adjustment making use of the aircraft tachometer indicator; in this case the engine speed should not exceed 100.5%. Allowance should be made for the actual error of the instrument.

The adjustment of the maximum r.p.m. is accomplished by manipulating fuel regulating pump decelerator screw 8 (Fig.24). With the screw turned in, the maximum r.p.m. increases, and vice versa.

The adjustment of the maximum r.p.m. should be carried out as follows:

1. Unlock and turn off the cap of the hydraulic decelerator screw.

2. Unlock hydraulic decelerator screw 8 and manipulate the screw to obtain the required maximum r.p.m.

Notes: 1. One turn of the screw will change speed n_1 by 2.5%.

2. If the slackening of the screw by 2 turns will fail to adjust the maximum r.p.m. to a value of 100±0.5%, the HP-210 fuel regulating pump should be replaced.

3. Check the maximum r.p.m. after the adjustment procedure is over, for which purpose run the engine at n_1=90% and shift the engine control lever two or three times to the MAXIMUM rating stop.

4. Check the HP-210 fuel regulating pump for excessive maximum r.p.m. due to variations in the amount of fuel delivered into the engine; to accomplish this, proceed as follows:

(a) detach the plug connectors from the electromagnetic valve and from the limit switch of the HP-220 pump afterburner valve;

(b) check the difference in the maximum r.p.m. values with the engine control lever set in the MAXIMUM rating position and in the FULL AUGMENTED rating position.

The difference in the maximum r.p.m. values should not exceed 0.5%.

Note: The maximum r.p.m. value in either case should not exceed 100.5%.
If necessary, adjust the maximum r.p.m. with the aid of screw 8.

Should the difference in maximum r.p.m. values be in excess of 0.5%, replace feed-back flow restrictor 15 (Fig.24) by a flow restrictor of a greater capacity (by 20 - 30 cu.cm/min.)

Notes: 1. The maximum permissible capacity of the feed-back flow restrictor is not to exceed 300 cu.cm/min.

2. Having replaced the feed-back flow restrictor, check the engine acceleration from the idling rating r.p.m. to the maximum rating and variations in the r.p.m. at 88 - 100% speed; the variations should not exceed ±0.3%.

5. The adjustment procedure completed, lock and seal screw 8 and the cap.

The following tools are required for carrying out the above adjustment procedure:

1. Wrench БИ 37-509.
2. Pliers 031-226.
3. Side cutting pliers 031-204.
4. Safety wire.

6. Adjustment of Hydraulic Decelerator Limit Switch and of БУ-4Б Control Unit Switches

1. The speed associated with operation of the limit switch of the HP-21Ф pump hydraulic decelerator should be checked with the aid of tester БИ 37-587 (set 1:20) with the engine control lever smoothly shifted within the range of 90% to the maximum r.p.m.

The pilot lamp of tester БИ 37-587 should light up as soon as ~~low-pressure~~ rotor speed n_1 reaches 98±1%.

If the actual rotor speed differs from the specified value, perform the following adjustment:

- remove the cap from hydraulic decelerator switch adjustment screw 1 (Fig.24);
- release the locking nut, taking care to hold the adjustment screw of the hydraulic decelerator switch against turning;
- manipulate adjustment screw 1 to obtain the required speed of operation of the limit switch.

With the screw turned in, the speed increases, and vice versa;

Note: One turn of the screw will change the operating speed of the limit switch by about 3.6%.

- tighten the locking nut while holding the adjustment screw from turning, and install the cap.

2. The operating speed of the cams of the БУ-4Б control unit should be checked and adjusted as is laid down in Section "Replacement of БУ-4Б Control Unit" of Chapter IX.

7. Adjustment of Engine Controls

The adjustment of the engine controls is carried out after the replacement of the HP-21Ф fuel regulating pump or ПУРТ-1Ф control panel.

The adjustment of the engine controls is performed at

the expense of:

(a) changing the length of link 7 (Fig.40);

WARNING: When changing the length of link 7, it is not allowed to expose the row of holes adjacent to the shackle.

(b) changing the position of the link shackle in the groove of HP-21Ф pump lever 2.

Notes: 1. When adjusting the length of link 7 and the position of the shackle in the lever groove, set the levers of the control panel (11) and of the HP-21Ф fuel regulating pump in the CUT-OUT position.
2. The initial distance from the centre of bolt 3 (holding link 7 to the lever of the HP-21Ф pump) to the centre of the pump shaft should be 55 mm.

When adjusting the engine controls, ensure the following arrangement of the levers of the control panel and of the HP-21Ф fuel regulating pump:

(a) with flag 4 of the pump set against the CUT-OUT stop, the zero of the control panel dial should line up with the notch provided on the control panel casing;

(b) with figures 67 - 68 on the control panel dial set against the notch on the control panel casing, the notch on the pump flag should be located against the 6th notch on the pump dial;

(c) with figures 72 - 73 on the control panel dial set against the notch on the control panel casing, the notch on the pump flag should be located beyond the 7th notch on the pump dial;

(d) with flag 13 of the control panel set against the FULL AUGMENTED rating stop, the notch on the pump flag should be located beyond the 7th notch on the pump dial.

The adjustment procedure completed, check the following points:

1. Control panel limit switches for proper operation (making use of tester БИ 37-587, with the engine at standstill).

Make sure that:

(a) lining-up of figures 67 - 68 on the control panel dial with the notch on the control panel casing should cause operation of cam КП;

(b) lining-up of figures 72 - 73 on the control panel dial with the notch on the control panel casing should cause operation of cam БФС;

(c) lining-up of figures 99 - 101 on the control panel dial with the notch on the control panel casing should cause operation of cam 4.

2. The engine control system for proper functioning as is laid down in Section "Routine Maintenance Performed Every 50±5 Hours of Engine Operation".

3. After the replacement of the ПУРТ-1Ф control panel as well as of the ДР-3А transmitter and Р-1 rheostat, check and, if necessary, adjust the jet nozzle so that its diameter should change depending on the travel of the engine control lever; proceed as is instructed in Section "Replacement and Adjustment of Hydraulic Cylinder" (Chapter IX).

8. Adjustment of Time Delays in КАФ-13Д Afterburner Control Unit

The adjustment of time delays is carried out in case the afterburner operation fails to comply with the requirements referred to in Section "Warming Up and Checking Engine Operation" (Chapter III).

Provision is made in the design of the afterburner control unit for time delays (with regard to the jet nozzle and to fuel) ranging from 0 to 2 sec.

To establish the required time delay values, it is necessary to set the slotted screws of the afterburner control unit in the respective positions (Fig.33). To reduce the gas temperature drop aft of the turbine, it is necessary to increase the time delay value with regard to the jet nozzle or to decrease the time delay value with regard to fuel, and vice versa.

Notes: 1. Changes in time delay values should be effected in successive steps equivalent to not more than 1 sec.

2. In case the afterburner cutting-in is accompanied by a double pop, decrease the time delay value with regard to the jet nozzle or increase the time delay value with regard to fuel.

9. Adjustment of High-Pressure Rotor Maximum R.P.M.

The adjustment is carried out in case the maximum r.p.m. (n_2) value during flight fails to agree with the value specified in Chapter I (103.5 - 0.5%).

The adjustment procedure is carried out as follows:

1. Unlock and turn the cap off screw 8 incorporated in the HP-22Ф fuel regulating pump (Fig.26).

2. Manipulate screw 8 to adjust the maximum r.p.m. value as recommended in Chapter I. The tightening of the screw will cause the maximum r.p.m. value to increase, and vice versa. One turn of the screw will change the operating speed of the r.p.m. limitor by 1.7%.

3. The adjustment procedure over, lock screw 8, install the cap and lock it.

Note: Maximum speed n_2 is determined by a drop in speed n_1, with the flight Mach number increasing; in this case speed n_2 should be constant. This r.p.m. value corresponds to the actual maximum r.p.m. value.

4. Perform the trial flight for checking maximum speed n_2.

WARNING: Once every 10±2 hours of engine operation, check the high-pressure rotor r.p.m. (n_2) by flying the aircraft at maximum Mach number. The above check may be omitted, in case the maximum r.p.m. value has been reported to be normal with the aircraft flying at Mach numbers below maximum.

Should it be found that the maximum r.p.m. value fails to agree with the specified value of 103.5 - 0.5%, perform the adjustment procedure as is instructed in the present Section.

Chapter XI

PROBABLE TROUBLES AND METHODS OF THEIR CORRECTION

Cause of trouble	Method of correction
1. Starter-generator fails to properly spin engine (high-pressure rotor r.p.m. is below 10%)	
Insufficient voltage across starter terminals	Check storage batteries for proper change; boost-charge or replace the batteries, if necessary Measure temperature of electrolyte. The temperature should be equal to 25 - 5°C. Heat the storage battery, if necessary Check "storage battery-to-starter" circuit for current leakage Check "storage battery-to-starter" circuit for proper contacts; check resistance of the circuit, which should amount to not more than 0.003 ohm If the above checks fail to detect the trouble, replace the starter-generator
2. Main fuel fails to be ignited in engine	
(a) Starting fuel fails to be supplied into engine	Check: - tank for presence of gasoline; replenish the tank, if necessary - pipe lines for leakage of gasoline. If leakage is detected, tighten up nuts, replace gasket or pipes Flush the gasoline line, as is laid down in Chapter VII of the present Instructions Check electromagnetic starting fuel valve for proper operation, for which purpose: - detach the plug connector of the electromagnetic starting fuel valve - supply voltage to terminals 1 and 2 of the starting valve from D.C. power sources rated at 27 V

Cause of trouble	Method of correction
	- close and open terminals, to make sure (by clicks produced) that the valve operates normally. Replace the valve, if necessary Check voltage across the plug connector of the electromagnetic starting fuel valve. The voltage should amount to not less than 22 V (at the beginning of the starting cycle)
(b) Starting fuel pressure is too low (pressure is less than 1.8 kg/sq.cm., with the tank not pressurized), or too high (pressure exceeds 2 kg/sq.cm., with the tank not pressurized) Pressure should be checked after cutting in tumbler switch STARTING IN AIR	Measure pressure of the starting fuel. Starting fuel pressure should amount to 2±0.2 kg/sq.cm., with starting fuel tank not pressurized If necessary, carry out readjustment, as instructed in Section "Adjustment of Engine Starting" (Chapter X) Measure voltage across the plug connector of ПНР-10-9М starting fuel pump (in case starting fuel pressure is too low). At the beginning of the starting cycle voltage should amount to not less than 18 V
(c) Ignition system is defective	Check storage batteries for proper charge. Boost-charge the batteries, if necessary

Cause of trouble	Method of correction
	Check ignition system wires and connections for proper condition. Measure voltage across booster coil low-voltage plug connector. Voltage should be equal to not less than 12 V Should it be found necessary, replace the booster coils and check the low-voltage circuit
(d) Main fuel fails to be supplied into engine.	Check position of the aircraft fuel system cut-off valve Flush main fuel system as is instructed in Section "Flushing of Pipe Lines" (Chapter VII). Make sure the aircraft booster pump operates normally by checking fuel pressure upstream of HP-21Φ fuel regulating pump. If the defect persists, proceed as follows: - connect a hose to the union for measuring pressure in the pilot manifold - crank the engine after setting the engine control lever in the IDLING rating position. Fuel should run from the hose 16 to 18 sec. after button STARTING is pressed.

Cause of trouble	Method of correction
	If no fuel issues from the hose, it is necessary to check fuel delivery of HP-21Ф fuel regulating pump, for which purpose turn the screw of the starting fuel control unit spring all the way in and crank the engine again, with the engine control lever set to the IDLING rating position or further forward. If fuel fails to show up in the hose, replace HP-21Ф fuel regulating pump
3. Starting cycle exceeds specified time period	
(a) Starter-generator fails to spin engine properly	Proceed as is laid down in Section I of this Chapter
(b) Engine controls are out of adjustment: flag of HP-21Ф pump lever stops below idling rating sector when engine control lever is set in IDLING rating position	Adjust aircraft engine control system so that, with engine control lever in IDLING rating position, flag of HP-21Ф pump lever is located between the notches made on the idling rating sector
(c) Insufficient main fuel supply at starting	Perform adjustment of the starting procedure as is instructed in Section "Adjustment of Engine Starting" (Chapter X)
(d) Electromagnetic valve controlling additional fuel supply at starting is defective	Check electromagnetic valve as recommended in Section 2 (Point "a") of the present Chapter. Replace the valve if necessary

Cause of trouble	Method of correction
4. Engine starting is accompanied by rumbling and sharp rise of gas temperature aft of turbine	
(a) Flag of HP-21Ф pump lever stops above the idling rating sector when engine control lever is set in IDLING rating position	Adjust aircraft engine control system so that, with engine control lever in IDLING rating position, flag of HP-21Ф pump lever is located between the notches provided on the idling rating sector
(b) Too much fuel is delivered into engine at starting	Perform adjustment of the starting procedure as is laid down in Section "Adjustment of Engine Starting" (Chapter X)
(c) Air blow-off valves fail to open	Check valves for proper operation and correct the defect
5. Idling rating r.p.m. is too low or too high	
(a) Tachometer indicator is defective or its calibration is disturbed	Recalibrate or replace the tachometer indicator
(b) Engine controls are out of adjustment: with engine control lever set in IDLING rating position, flag of HP-21Ф pump lever is located above or below idling rating sector	Adjust engine controls in compliance with Section 3 (Point "b") of the present Chapter

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Cause of trouble	Method of correction
(c) Fuel delivery is too high or too low at idling rating	Adjust idling rating r.p.m. as is instructed in Section "Adjustment of Idling Rating R.P.M. (Chapter X)
(d) Electromagnetic valve controlling additional fuel supply at starting on ground is out of order	Check electromagnetic valve as instructed in Section 2 (Point "a") of the present Chapter Replace the valve, if necessary
(e) Electromagnetic valve controlling additional fuel supply at starting on ground fails to be deenergized	Detach plug connector of electromagnetic valve and check idling rating r.p.m. If idling rating r.p.m. value agrees with the value presented in Chapter I, it is necessary to check the operating speed of cam ВДТ as is instructed in Chapter IX. If adjustment of idling rating r.p.m. is found to be impossible, replace НР-21Ф fuel regulating pump

6. Low-pressure rotor maximum r.p.m. (n_1) is too low

Cause of trouble	Method of correction
(a) Flag of НР-21Ф pump lever is below notch 6 when engine control lever is set in MAXIMUM rating position	Check engine control levers (in aircraft cockpit) and flags (on levers of НР-21Ф pump and ПУРТ-1Ф control panel) for correct position Should it be found necessary, adjust aircraft link or engine controls

Cause of trouble	Method of correction
(b) Tachometer indicator is defective or its calibration is disturbed	Recalibrate or replace the tachometer indicator
(c) Maximum r.p.m. is insufficient or is out of adjustment	Adjust maximum r.p.m. (n_1) as is laid down in Section "Adjustment of Maximum R.P.M." (Chapter X)
(d) Insufficient fuel supply into engine	Check ДЦН-13ДТ fuel booster pump for proper operation (by fuel pressure upstream of НР-21Ф fuel regulating pump)
(e) High-pressure rotor overspeed governor is out of adjustment	Plug the pipe delivering fuel from НР-21Ф pump to n_2 overspeed governor of НР-22Ф pump, and check maximum r.p.m. Adjust the operating speed of high-pressure rotor overspeed governor as is instructed in Chapter I
(f) Exceptional atmospheric conditions (outside air temperature exceeding 80°C and B_0 below 740 mm of mercury) may cause operation of high-pressure rotor overspeed governor	To check maximum r.p.m., it is necessary to detach plug connector of НР-22Ф pump electromagnetic valve and then to perform the check Adjust, if necessary

Cause of trouble	Method of correction
7. Low-pressure rotor maximum r.p.m. (n_1) is too high	
(a) Tachometer indicator is defective or its calibration is disturbed	Recalibrate or replace the tachometer indicator
(b) Adjustment of maximum r.p.m. is disturbed	Carry out the adjustment procedure as is laid down in Section "Adjustment of Maximum R.P.M. (Chapter X)
8. It takes engine too much time to accelerate from IDLING rating to MAXIMUM rating	
(a) Pressure increase limiter flow restrictors are clogged	Inspect pressure increase limiter flow restrictors and replace them, if necessary. Inspect central fuel filter of НР-21Ф pump. If the filter is clogged, replace the pump
(b) Insufficient fuel supply during acceleration	Check ДЦН-13ДТ fuel booster pump for proper operation (by fuel pressure upstream of НР-21Ф pump
(c) Hydraulic decelerator flow restrictor is clogged	Inspect the hydraulic decelerator flow restrictor and replace it, if necessary

Cause of trouble	Method of correction
9. Engine acceleration is accompanied by rise of gas temperature aft of turbine	
(a) Idling rating r.p.m. is too low	Check and adjust idling rating r.p.m. as is instructed in Section "Adjustment of Idling Rating R.P.M." (Chapter X)
(b) Pressure increase limiter rod binds	Replace НР-21Ф fuel regulating pump
10. Oil pressure is too low	
(a) Oil pressure transmitter is defective, or oil pressure indicator calibration is disturbed	Recalibrate oil pressure transmitter. Replace the transmitter, if required
(b) Tank contains insufficient amount of oil	Check oil level in the tank. Replenish oil, if necessary
(c) Excessive leakage in oil system	Inspect engine oil system piping and its joints Replace defective pipes and gaskets
(d) Oil intake is out of order	Replace the fuel-oil unit
(e) Oil pump unit reducing valve is out of adjustment	Carry out adjustment of oil pump unit reducing valve as is instructed in Section "Adjustment of Oil Pressure" (Chapter X)

Cause of trouble	Method of correction
11. Oil pressure is too high	
(a) Oil pressure indicator is defective or its calibration is disturbed	Recalibrate oil pressure transmitter. Replace the transmitter, if necessary
(b) Oil pump unit reducing valve is out of adjustment	Carry out adjustment of oil pump unit reducing valve as is instructed in Section "Adjustment of Oil Pressure" (Chapter X)
12. Oil consumption is too high	
(a) Leakage in oil system	Inspect engine oil system piping and joints. Replace defective gaskets, if necessary
(b) Ejection of oil out of unloading ports (on the warmed-up engine)	*Note:* Small amount of smoke may issue from the unloading ports, with the engine insufficiently warmed up. Smoking should stop after the engine is warmed up for 5 or 7 minutes at 0.8 per cent of normal rating
(c) Ejection of oil from front compressor labyrinth seal (resulting in oiling of first stage compressor blades)	Check the pipe delivering air into the interlabyrinth space of the front support Check the breather pipe of front support. Replace the pipes, if necessary
(d) Oil drain cocks of fuel-oil unit 357c and of engine wheelcase are leaky	Replace drain cocks
(e) Glands of ГСР-СТ-12000ВТ starter-generator or of the oil pump unit are leaky	Replace starter-generator or oil pump unit

Cause of trouble	Method of correction
13. Oil leakage from tank at parking	
(a) Oil pump unit non-return valve is leaky	Replace oil pump unit. While the oil pump unit is not replaced, drain oil from engine wheelcase and pour it into oil tank prior to starting
(b) Drain cocks of fuel-oil unit 357c and of engine wheelcase are leaky	Replace drain cocks
14. Traces of smoke in air bled from compressor and used for cockpit pressurisation	
(a) Front support breather pipe is clamped	Inspect the pipe and replace it, if necessary
(b) Ejection of oil from front support labyrinth seal	Perform operations of point 12 (c) of the present Chapter
15. Leakage of fuel into oil	
(a) Fuel space of fuel-oil unit 357c is leaky	Check the unit for leakage; replace, if necessary Change oil after eliminating the trouble
(b) Glands of HP-21Ф and HP-22Ф pumps are leaky	Replace HP-21Ф or HP-22Ф pump if some fuel is detected aft of the glands

Cause of trouble	Method of correction
16. Leakage of oil from drain system, with engine running (exceeding permissible limit of 110 cu.cm/min.)	
Leakage of НР-21Ф pump drain valve; excessive leakage through glands and other drain connections of НР-21Ф and НР-22Ф pumps	Locate leakage by successively disconnecting the drain pipes. Replace the defective unit. Notes: 1. Locate leaky joints with the engine running at idling rating 2. Dripping of fuel is allowed from the ДЦН13ДТ fuel booster pump drive
17. Afterburner fails to be cut in	
(a) Ignition system is defective	Check voltage across the plug connector (low voltage) of the afterburner booster coil. Voltage should amount to not less than 12 V. With the engine at standstill, detach the plug connector from electromagnetic valve of НР-22Ф pump. Start the engine, bring it to maximum rating r.p.m. and set engine control lever in FULL AUGMENTED rating position for 5 to 7 sec. Make sure that flame igniter functions properly by observing it from a safe distance. This done, stop the engine. If the flame igniter turns to be inoperative, attach the wire to another spark plug and check flame igniter operation in the same manner.

Cause of trouble	Method of correction
	Should the defect persist, replace the wire running to the spark plug
(b) Fuel fails to be supplied to afterburner (which is detected by measuring pressure of afterburner fuel)	Check the wires running to electromagnetic valve of НР-22Ф pump by measuring voltage across terminals 1 and 2 of plug connector connecting НР-22Ф pump to electric control equipment harness. Voltage should not be less than 22 V. Eliminate defects in the wiring, if any Check to see whether the bolts holding solenoid to НР-22Ф pump are properly tightened. Check the pipe lines delivering air P_2^1 to the governor of НР-22Ф pump Check switch БФС for proper operation as instructed in Section "Adjustment of Engine Controls" (Chapter X). Check limit switches ГЗ for proper operation (by employing tester БИ37-587 contained in 1:20 tools set). In case the above measures are of no help, replace НР-22Ф fuel regulating pump
(c) Fuel-air mixture fails to be delivered to afterburner flame igniter	Check carburettor electromagnetic valves for proper operation, as is instructed in Section II (Point "a") of the present Chapter

Cause of trouble	Method of correction
	Replace the valves, if necessary Check voltage across plug connectors of electromagnetic valves. It should amount to not less than 22 V. Inspect carburettor flow restrictors. Replace flow restrictors, if clogged Note: The new flow restrictors should not differ in their capacity from the old ones by more than ±50 cu.cm/min. (for main system) and by ±10 cu.cm/min. (for pilot system). Inspect the pipes supplying fuel and air to carburettor. Replace the pipes, if necessary
18. With engine control lever set in MAXIMUM rating position, afterburner fails to be cut in	
(a) Control panel switch БФС fails to operate	Check switch БФС for angle of operation. If necessary, readjust the tripping angle of switch БФС as instructed in Section "Replacement of ПУРТ-1Ф Control Panel" (Chapter IX)

Cause of trouble	Method of correction
(b) There is some fault in electric control equipment	Check electric control equipment for proper operation (by employing tester БИ37-587 contained in 1:20 tools set)
19. Variations in engine r.p.m. exceed specified limits	
Feed-back flow restrictor of НР-21Ф fuel regulating pump is clogged or its capacity is insufficient	Inspect the feed-back flow restrictor. Replace the flow restrictor if necessary. Install a flow restrictor of a greater capacity, if the trouble persists
20. Operating speed of high-pressure rotor overspeed governor is too low	
Governor operating speed (n_2) is insufficient or adjustment is disturbed	Carry out adjustment of governor operating speed as is instructed in Section "Adjustment of High Pressure Rotor Maximum R.P.M." (Chapter X)
21. With afterburner cut in, jet nozzle flaps fail to be opened to respective capacity (jet nozzle flaps remain in MAXIMUM rating position, afterburner fuel burns in pulses)	
Wire running to ДОС-1А feed-back transmitter is damaged	Replace the wire
ГА-164М valve is defective	Replace ГА-164М valve

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Cause of trouble	Method of correction
22. With engine operating within range of from FULL AUGMENTED rating to MINIMUM AUGMENTED rating (in flight) sudden drop in thrust is experienced involving bumps along aircraft longitudinal axis	
Spontaneous closing (sticking) of contact A incorporated in PПC relay of KBC-1 pulse delivery box	Turn on switch EMERGENCY ENGAGEMENT OF TWO-POSITION JET NOZZLE. After the flight is completed, replace KBC-1 pulse delivery box
23. With engine running at MINIMUM AUGMENTED rating and partial augmented ratings, FULL AUGMENTED rating is turned on spontaneously	
Spontaneous closing (sticking) of contact "б" incorporated in PПC relay of KBC-1 pulse delivery box	Turn on switch EMERGENCY ENGAGEMENT OF TWO-POSITION JET NOZZLE. Replace KBC-1 pulse delivery box after the flight is over
24. With engine running within range of partial augmented ratings (in flight), thrust does not change in response to shifting of engine control lever	
Wiring of follow-up system resistor bridge is defective	Turn on switch EMERGENCY ENGAGEMENT OF TWO-POSITION JET NOZZLE. The flight over, check the wiring of the follow-up system resistor bridge

Cause of trouble	Method of correction
25. Decrease in gas temperature aft of turbine by more than 20°C when climbing at augmented rating and constant Mach number, with simultaneous reduction in rotor slip factor exceeding 1.5%	
Improper adjustment of governor P_2/P_4= const.	Back out screw 26 (Fig.26) through one turn. After the above adjustment gas temperature aft of turbine at low Mach number and medium altitudes will increase by about 5°C. **Note:** The above adjustment procedure should be performed by the representative of the Manufacturing Plant

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APPENDICES

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Appendix No.1

LIST OF UNITS AND ASSEMBLIES WHICH CAN BE REPLACED IN SERVICE

A. Units and Assemblies Replaced without Dismantling Engine from Aircraft

	Quantity per engine
1. Starter-generator ГСР-СТ-I2000ВТ	1
2. Fuel regulating pump НР-21Ф	1
3. ~~Fuel booster pump ДЦН-13ДТ~~	1
4. Control panel ПУРТ-1Ф	1
5. Feed-back transmitter ДОС-1А	1
6. Rheostat transmitter ДР-3А	1
7. Rheostat Р-1	1
8. Control unit БУ-4Б	1
9. Electromagnetic starting fuel valve МКПТ-9	1
10. Carburettor electromagnetic valve МКПТ-9Ф	2
11. Electromagnetic additional fuel valve МКПТ-9Ф	1
12. Afterburner spark plug СЭ-21Д5 and adapters П-12 (replaced on disjointed aircraft)	2
13. Booster coil КНА-114 (for combustion chamber and afterburner)	2+1
14. Engine wheelcase oil drain valve	1
15. Tachometer generators ДТЭ-1	2
16. Hydraulic pumps НП-34-2Т	2
17. Vent system tank	1
18. Afterburner hydraulic cylinders	3
19. Adjustment needles	2
20. Non-return oxygen valve	1
21. External lines for oil, fuel, instruments, and electric wiring, as well as their attachment fittings	

B. Units and Assemblies Replaced after Dismantling Engine from Aircraft

1. Fuel regulating pump НР-22Ф	1
2. Oil unit	1
3. Deaerator	1

4. Centrifugal breather 1
5. Fuel-oil unit 357C 1
6. Front support oil scavenge pump 1
7. Combustion chamber flame igniters 2
8. Spark plugs СПН-4-3 , for combustion chamber flame igniters 2
9. Air blow-off valves 2
10. External lines for fuel, oil and air systems

Appendix No.2

LIST OF PARTS TO BE REPLACED WHEN REPLACING UNITS AND ASSEMBLIES

Name of unit	Name of part	Dwg No.	Quantity, pc.
1	2	3	4
Fuel booster pump ДЦН-13ДТ	Sealing ring	0250063	2
	Same	0253063	6
	Locking washer	3124509	4
Fuel regulating pump НР-21 Ф	Sealing ring	0250001	6
	Same	0250002	10
	Same	2525152	2
	Same	0250005	2
	Same	0253189	3
	Same	0250040	1
	Locking washer	2525567	2
	Same	0240010	2
Fuel regulating pump НР-22 Ф	Sealing ring	0253063	3
	Same	0250001	2
	Same	0250002	3
	Same	0250006	1
	Same	0253132	2
	Same	0253194	3
Centrifugal breather	Sealing ring	0253179	1
	Same	0250015	1
	Same	0253180	1
	Same	2524578	6
Deaerator	Sealing ring	0258303	1
	Same	0293175	1
	Locking washer	0240010	4
	Same	3124509	2
Adjustment needles	Washer	2524578	1
	Same	0253132	1
Hydraulic cylinder	Locking washer	0243250	59
	Cotter pin	194M51-3x20	3

1	2	3	4
Control panel ПУРТ-1Ф	Cotter pin	194M51-1.5x15	4
Feed-back transmitter ДОС-1А	Sealing ring	0247534	1
Rheostat transmitter ДР-3А	Washer	3124010	4
Afterburner spark plug СЭ-21Д5	Safety wire Graphite grease	d=0.8 Л62	-
Rheostat P-1	Safety wire	d= 0.8 Л62	-
Non-return oxygen valve	Locking washer	0240010	6
Flame igniter	Washer	2524578	8

Appendix No.3

LIST OF ADJUSTMENT ELEMENTS AND POINTS SUBJECT TO LOCKING AND SEALING

Adjustment element	Locked with	Sealed with
1	2	3
A. Fuel regulating pump HP-21Ф		
Idling rating r.p.m. adjustment screw	Wire	Plate seal
Distributing valve adjustment screw	Wire	Plate seal
Automatic fuel supply minimum r.p.m. stop	Wire	Plate seal
AUGMENTED rating stop	Wire	Plate seal
CUT-OUT stop	Wire	Plate seal
Maximum fuel delivery stop	Wire	Plate seal
Maximum r.p.m. stop (n_1)(on hydraulic decelerator)	Wire	Plate seal
Hydraulic decelerator flow restrictor	Wire	Plate seal

1	2	3
Permanent pressure differential valve	Wire	Plate seal
Minimum pressure valve	Wire	Plate seal
Feed-back flow restrictor	Wire	Plate seal
Pressure increase limiter 1st branch flow restrictor	Wire	Plate seal
Pressure increase limiter 2nd branch flow restrictor	Wire	Plate seal
Electro-hydraulic contactor adjustment screw	Wire	Plate seal
Starting fuel control unit screw	Wire	Plate seal
Pump minimum delivery stop	Wire	Plate seal
Pressure increase limiter rod	Wire	Plate seal
Bleeding jet of pipe feeding air to starting fuel control unit	Wire	Plate seal
B. Fuel regulating pump HP-22Ф		
Barostatic limiter spring adjustment screw	Wire	Plate seal
Barostatic limiter aneroid adjustment screw	Wire	Plate seal
Pump maximum delivery stop	Wire	Plate seal
Fuel valve adjustment screw	Wire	Plate seal
Speed (n_2) limiter adjustment screw	Wire	Plate seal
Afterburner valve flow restrictor	Wire	Plate seal
Pump minimum delivery stop	Wire	Plate seal
Afterburner regulator spring adjustment screw	Wire	Plate seal
Servo-piston flow restrictor	Wire	Plate seal
C. Oil pump unit		
Reducing valve	Wire	Plate seal
Oil pump unit filter	Wire	Plate seal
D. Fuel-oil unit 3570		
Oil by-pass valve	Wire	Plate seal
Fuel by-pass valve	Wire	Plate seal
Fuel filter	Wire	Plate seal
Air release valve	Wire	Plate seal

1	2	3
Dip stick plug	Wire	Plate seal
Filler cover	Wire	Plate seal
Oil drain cock	Wire	Plate seal
Fuel drain cock	Wire	Plate seal
E. Control unit БУ-4Б		
Band screws	Wire	Plate seal
F. Fuel booster pump ДЦН-13ДТ		
Closure on suction side cover	Wire	Plate seal
Permanent pressure valve	Wire	Plate seal
Suction side cover	Wire	Plate seal
G. Adjustment needles		
Regulator adjustment needle (P'_2)	Wire	Plate seal
Limiter adjustment needle (P''_2)	Wire	Plate seal
H. Engine controls		
Adjustment link	Wire	No seal
I. Rheostat P-1		
Minimum augmentation adjustment screw MФ	Wire	Plate seal
Full augmentation adjustment screw (1Ф and 2Ф)	Wire	Plate seal

Appendix No.4

LIST OF AIRCRAFT-CARRIED TOOLS
(Figs VII and VIII)

1:1 Set

Tool No.	Description	Size	Quantity
1	2	3	4
БИ37-01	Wrench for mounting booster piping	36x41	1
БИ37-02	Wrench, general-purpose	27x30	1
БИ37-03	Wrench, general-purpose	19x24	1
БИ37-04	Wrench, general-purpose	19x22	1
БИ37-05	Wrench, general-purpose	14x17	1
БИ37-347	Wrench, general-purpose, with sprocket at one end	10x10	1
БИ37-07	Wrench, general-purpose	9x11	1.
БИ37-08	Wrench, general-purpose	5x7	1
БИ37-10	Wrench with sprocket, general-purpose	9x11	1
БИ37-11	Special wrench with sprocket for oil system nuts	27x30	1
БИ37-13	Special wrench with sprocket for high-pressure fuel system nuts and for nuts of afterburner piping	17x19	1
БИ37-574	Special wrench for castellated nuts of booster piping		1
БИ37-188	Wrench with sprocket, general-purpose	9x11	1
БИ37-235	Wrench with sprocket for afterburner piping nuts	22x24	1
БИ37-501	Hinged socket wrench for changeable heads	8x9	1
		8x11	
		8x14	
		8x17	

1	2	3	4
БИ37-505	L-shaped socket wrench for bolts holding down booster piping flanges, for nuts securing oil pump unit filter, and for adjustment of air release needles	7x9	1
БИ37-506	Special wrench for changeable heads	S=9	1
		S=11	
		S=14	
		S=17	
БИ37-507	Special wrench for bolts of pressure chamber outlets	S=11	1
БИ37-509	Wrench for adjustment of HP-22Φ and HP-21Φ fuel regulating pumps	S=4	1
БИ37-515	Socket wrench for bolts of electric wiring blocks	S=9	1
C31-098	Wrench with sprocket, general-purpose	14x17	1
БИ37-185	Changeable head, general-purpose	S=17	1

1	2	3	4
C31-077	Changeable head, general-purpose	S=11	1
C31-078	Changeable head, general-purpose	S=14	1
C31-180	Changeable head, general-purpose	S=9	1
C31-215	Handle bar for hinged socket wrench	L=150	1
400-2	Handle bar for replacement of flow restrictors and for removal of blanking cover from HP-21Φ pump drive cardan shaft	6x1	1
БИ37-605	Screw-driver, general-purpose	L=300	1
БИ37-606	Screw-driver, general-purpose	L=200	1
БИ37-607	Screw-driver, general-purpose	L=150	1
C31-061	Bar for bending locking washer lugs		1
C31-060	Marking tool, general-purpose		1
C37-28	Rod, general-purpose	dia.=3	1
C31-229	Hammer, general-purpose	300 gr	1
C31-206	Pressure gun for washing parts		1
БИ37-317	Blanking cover for oil pump unit housing		1
C31-131	Plug for closing inner holes of filtering elements	dia.=19	1
C31-204	Side cutting pliers for removal of safety wire	L=125	1
C31-226	Combination pliers for safety wire	L=150	1
БИ37-550	Case for aircraft-carried tools		1
БИ37-329	Round-nose pliers		1

1	2	3	4
1 State Standard 2809-45	Spring hook for suspension of tools during work		2
400-1	General-purpose wrench for adjustment of maximum r.p.m., БУ-4Б ,КАФ-13Д , and high-pressure rotor		1
031-139	Brush for washing parts		1
БИ37-592	Hose for elbows of fixture БИ37-590 and 0289914		1
БИ37-590	Elbow for air release		1
0289914	Elbow for processing and deprocessing afterburner manifolds		2

Appendix No.5

LIST OF TOOLS SUPPLIED WITH
EVERY 20 ENGINES

Tool No.	Description	Size	Quantity
1	2	3	4
БИ37-189	Centring bar for checking alignment of holes in НР-21Ф pump centrifugal governor drive and in front support oil scavenge pump drive		1
БИ37-520	Torque wrench rated at 3.0 kg-m, for tightening spark plugs СЭ-21Д5		1
БИ37-310	Handle bar for wrench БИ37-604		1
БИ37-536	Fixture for safety-wiring of nuts in hard-to-get-at places		1
БИ37-604	Special wrench for flame igniter nozzle		1

1	2	3	4
БИ37-570	Socket wrench for flow restrictor of isodrome governor	S=10x10	1
БИ37-408	Screw-driver, special, for replacement of starting fuel control unit jets		1
БИ37-562	Adapter for wrench БИ37-520 , for tightening spark plug СПН4-3 to 6 kg-m		1
Т37-250	Case for aircraft tools		1

Appendix No.6

LIST OF FIXTURES SUPPLIED WITH
EVERY 20 ENGINES

Fixture No.	Description	Quantity
БИ37-575	Fixture for measuring jet nozzle diameter	1
БИ37-587	Electric control equipment tester	1

Appendix No.7

INSTRUCTIONS FOR PROCESSING, STORAGE, AND DEPROCESSING OF ENGINE

(Guarantee Storage Period - 1 Year)

The instructions deal with processing of the engine which is to be put in storage, as well as with the engine deprocessing and storage regulations.

Engines processed in accordance with the given instructions should be stored as is laid down in the instructions, that is, in normal store rooms, with the moisture absorbing silica gel changed in due time in compliance with the indications of the humidity indicators.

I. General

1. Engine processing consists of the following main operations:

(a) internal processing at the test plant;

(b) restoration of paint coating;

(c) external processing;

(d) arrangement of moisture absorbing silica gel inside and outside the engine;

(e) arrangement of humidity indicators;

(f) packing of the engine in a cover of polyvinyl chloride film B-118 and curing of the cover seam;

(g) packing of the engine in the case.

2. When processing the engine for a storage period of not over six months, slush the external non-painted surfaces of the magnesium parts, copper parts and parts of copper alloys, as well as cast iron parts, and parts of carbon and low-alloy steel, including those subjected to oxidizing and phosphatizing.

3. The fuel and oil systems of the engine are processed with the aid of oil MK-8, State Standard 6457-53.

4. Connect the hoses delivering the AMΓ-10 oil from the installation to the unions of the adjustable jet nozzle and start the installation pump. Build up a pressure of up to 80 kg/sq.cm. at the inlet and flush the hydraulic cylinders,

while shifting the jet nozzle flaps from one extreme position to another. Repeat the procedure 3 or 4 times.

The oxygen system pipe line, which has been in use on the engine, is blown with dry, clean nitrogen, plugged, and is then left unprocessed.

5. External processing is accomplished by the use of gun grease, State Standard 3003-51, applied to ferrous metals, and petrolatum, State Standard 782-33, employed for treatment of non-ferrous metals.

Notes: 1. Petrolatum and gun grease may be substituted by aviation oil MC-20 or MK-22, containing 6 to 10% of ceresine.

2. It is strictly prohibited to employ used or reclaimed oils and lubricants for engine processing.

(a) Internal Processing of Engine

1. Check to see that the tank of the processing installation contains the specified amount of oil (40 to 50 lit.).

2. Check the oil against the laboratory Certificate, which is valid for not more than 7 days.

3. Make sure the routine maintenance operations have been performed in due time (washing of tank filters, checking of pressure gauges, etc.).

4. Drain fuel from the fuel filter of fuel-oil unit 357C, and from the ДЦН-13Д fuel booster pump via the drain cocks; remove fuel from the drain tank by extracting the plug.

5. Drain oil from fuel-oil unit 357C and from the front casing wheelcase.

Pour 8 to 10 lit. of fresh oil into the oil tank.

6. Drain used oil from the hydraulic system, fill the system with fresh oil and plug it.

Note: Operations referred to in Points 5 and 6 should not be performed on the engine which have just passed the Acceptance tests, or which have been dismantled from the aircraft due to some trouble, provided the idling period does not exceed 2 weeks.

7. Use a hose to alternately connect the main and afterburner fuel manifolds to the pilot manifold via the unions employed for measuring pressure.

8. Deliver oil to the starting system with the purpose of its processing.

9. Connect the nitrogen delivery pipe line to the union serving for measuring oxygen pressure.

10. Set the following switches in the ON position:

(a) AFTERBURNER (АЗС-15);

(b) STORAGE BATTERY ($Б_1$);

(c) STARTING UNITS (АЗС-25);

(d) BY-PASS VALVE (КС);

(e) CRANKING (ВП), in STARTING position;

(f) PROCESSING (ВК), in К position.

Note: The STARTING IN AIR switch (АЗС-10) should be set in the OFF position. The OXYGEN switch (ВКП) should be locked in the OPERATION position.

11. Adjust oil pressure in the processing system within the operating pressure range at the inlet into the ДЦН-13Д fuel booster pump.

12. Deliver the oil at boost pressure through the valves for air release from the НР-21Ф and НР-22Ф fuel regulating pumps, and through the cap of the fuel-oil unit filter.

13. Set the engine control lever in the maximum rating position.

14. Press the STARTING button and release it in 1 or 2 sec.; with the engine being cranked, blow the oxygen system with nitrogen at a pressure of 7 to 9 kg/sq.cm. When starting the engine, shift the engine control lever repeatedly from the MAXIMUM rating position to the IDLING rating position and back taking care not to retain the lever in the IDLING rating position. With the engine control lever in the MAXIMUM rating position, operate the tumbler switches of by-pass valve КС (on НР-21Ф fuel regulating pump) 1 or 2 times.

15. Open the installation cock and run 4 to 5 lit. of oil through the afterburner manifolds. After the fuel pumps have been drained not less than 30 lit. of oil should be consumed for processing the fuel system. Operations listed in Points 14 and 15 should be repeated 3 or 4 times.

16. Detach the processing pipe line. Plug the hoses of the processing installation. Restore all connections on the engine in accordance with the specified diagram; fit closures onto all open unions.

17. Drain excess oil from the oil tank and from the engine wheelcase.

18. Clean the engine of oil and dust. For this wipe the engine with a rag soaked in gasoline Б-70 (take care to safeguard the wiring and electric equipment against gasoline and oil).

19. Dry the compressor by blowing it with hot air delivered through the compressor front casing intake. The inlet air temperature should be within 110 - 120°C. The air should be delivered for 15 to 20 min.

20. Make a corresponding note in the engine Service Log, with the names of the persons in charge of the engine processing duly indicated.

(b) Processing of Fuel Units Dismantled from Engine

The НР-21Ф and НР-22Ф fuel regulating pumps, as well as the ДЦН-13ДТ fuel booster pump and fuel-oil unit 357С, removed from the engine, should be processed not later than 24 hours after the dismantling procedure. The internal cavities of the units are processed by flushing them with oil МК-8. The НР-21Ф and НР-22Ф fuel regulating pumps should be processed in the following sequence:

1. Drain fuel from the pumps while rotating rotors by the coupling shafts.

2. Plug all fuel outlet holes, exclusive of the hole communicating with the afterburner manifold and the main and pilot manifold unions.

3. Deliver oil at a pressure of 0.5 - 3 kg/sq.cm. to the inlet connection, and run it through the pump at 250 to 800 r.p.m., using 1.5 to 2.0 lit. of oil. The oil should issue in a profuse stream from the pilot manifold union (on the НР-21Ф pump) and from the union delivering fuel to the afterburner manifold (on the НР-22Ф pump). After flushing the НР-22 Ф

pump for the first time, deliver voltage of 24 V to the solenoid-operated valve, and repeat the flushing procedure 2 or 3 times. When flushing the HP-21Φ pump with oil, shift the engine control lever several times from the IDLING rating position to the MAXIMUM rating position.

4. Having completed the flushing procedure, drain excess oil from the unit and install closures. Treat external non-painted surfaces with petrolatum preheated to 60 - 80°C.

5. After processing, pack the unit in a container or wrap it in paraffin paper and turn over to storage.

Make a corresponding entry in the pump Service Log, indicating the date of processing and the name of person in charge.

The internal cavity of the pump is not subject to deprocessing prior to installing the pump on the engine.

II. External Deprocessing and Packing of Engine

1. Make a visual inspection of the engine.

2. The engine should be blown with hot air at a temperature of 110 to 120°C for 15 to 20 min. via the compressor front casing not later than 4 hours after acceptance on arrival.

3. Clean the external surface of the engine of dust, oil and fuel by employing cloth soaked in clean aviation gasoline Б-70; this done, dry the engine in air within 10 to 15 min., or blow it with compressed air.

4. The wires and hoses of the wire harness, the electromagnetic valves, the oxygen pipe line, and the oxygen valve should be cleaned with a piece of dry cloth and wrapped in two layers of paper.

5. All non-painted external surfaces of the magnesium components as well as of the components fabricated of non-ferrous alloys, and also cadmium and zinc-plated parts should be treated with petrolatum preheated to a temperature of 60 to 80°C, using a brush.

6. The non-painted surfaces of the steel components (adjustable jet nozzle, afterburner diffuser, external surface of the rear casing nozzle diaphragm) should be coated with gun grease, preheated to a temperature of 60 to 80°C. The grease should be applied with the aid of a brush or an atomizer.

7. The grease may be preheated to a temperature of 105 to 110°C, if applied by means of an atomizer.

Note: The external surfaces of the engines to be stored within the period of up to 6 months are not subject to greasing; this does not concern the surfaces referred to in Section I (Point 2) of the present Instructions.

8. All ends of safety wires on the engine should be bent inward. All sharp, projecting parts of the engine should be wrapped in 3 or 4 layers of paraffin paper and bound with twine.

9. Prepare the case and the film cover. Treat the inner surface of the cover with a thin layer of petrolatum, using 12 - 15 gr of the lubricant per sq.m. Petrolatum may be diluted with 10 - 15% of hot aviation oil MC-20, if grade УН-2 petrolatum is employed. Leave 300 to 400 mm wide margins along the cover edges untreated. Place the cover onto the case bottom support taking care to put the soft plastic pads over the support rests.

10. Arrange 30 silica gel bags, weighing 300 gr each, on the engine. 6 pieces out of the entire number of the bags should be arranged in the diffuser, 8 pieces - in the front casing. The remaining 16 bags should be arranged on the engine outside as follows:

(a) in the vicinity of the engine accessories . . 6 pieces

(b) on the compressor front casing . . . . . 6 pieces

(c) on the rear compressor casing . . . . . .2 pieces

(d) on the turbine casing . . . . 2 pieces

The silica gel bags should be attached at both ends and placed on top of paraffin paper to keep off grease.

Note: The number and location of the bags on the engine should be indicated in the engine papers. The bags for silica gel should be made of calico lined with mica paper on the inside.

11. Fit the cover on the diffuser. Put a tarpaulin cover or a plywood blanking cover onto the front casing.

12. Wrap the engine with two layers of paraffin paper and bind it with twine.

13. Lift the engine, treat the journals with gun grease, and mount the engine onto the case support. Attach the engine to the support.

14. Place 10 silica gel bags, weighing 300 gr each, on the engine, taking care to see that the bags are distributed uniformly on the entire surface; arrange two humidity indicators on the engine so that they can be easily seen through the cover film and through the inspection ports provided in the case.

Note: Use silica gel having a humidity not exceeding 2%. The silica gel should be transported to the processed engine in a moisture-proof packing, which should be removed just before arranging the silica gel on the engine. The time period between the unpacking of the silica gel and curing of the last seam of the cover should not exceed 1 hour (for handling silica gel see Appendix No.9).

15. Put the film cover on the engine, carefully press the cover around the engine to remove excess air, and cure the seam. Perform the seam curing procedure as is laid down in Appendix No.10.

16. Press together the cover surfaces near the seam and rub them to spread petrolatum applied to the inner surface of the cover.

17. Inspect the cover visually to see that it is intact; suck out the air from under the cover until the latter is slightly pressed to the engine. Any holes detected in the cover should be patched with the film of the same grade, using vinyl perchloride cement.

18. Bind the engine with strips of polyvinyl chloride film where the cover is loose. See that the cover is neither overtightened nor twisted over the engine.

19. All operations pertaining to the arrangement of the silica gel, fitting of the cover, and curing of the seam should follow one another in close succession, without any interruptions, to prevent the silica gel from absorbing moisture out of the surrounding air, with resultant reduction in its activity.

20. Fit the packed engine with a tag (attached by means of cement) which should carry the following data: the date of processing and the storage expiration date, number of silica gel bags, their location on the engine, and the name of the person in charge.

21. Make the following entries into the engine Service Log: the date of processing and the storage expiration date; indicate the number of the silica gel bags, and their location on the engine; make a note as to the necessity of removing the silica gel bags when unpacking the engine.

22. After the engine has been packed in the film cover, install the upper portion of the packing case taking care to see that the film is not damaged and the upper portion is properly aligned.

23. All the operations pertaining to the engine packing in the film cover (curing of the seam, application of patches, etc.) should be carried out in a warm room, at a temperature of not less than +10°C.

24. The time period between the internal processing of the engine and the completion of the external processing procedure and packing should not exceed 120 hours.

III. Storage Premises Specifications

For storage premises specifications see Appendix No.9.

IV. Engine Storage Regulations

1. The engine should be stored in closed premises. Outdoor storage of the engine is not allowed.

2. General requirements to storage locations, as well as engine shipping regulations, and corrosion-preventive measures taken in the course of engine storage, should be as laid down in Appendix 9 dealing with storage of the engine and spare parts in store rooms.

3. Inspection of the indicating silica gel, arranged in the film covers, and replacement of the silica gel in case the indicator acquires pink colour, should be accomplished as follows:

(a) Inspection of Processed Engines for Condition

1. The processed engines should be kept in film covers on case supports; the engines should be so arranged as to allow ease of observation on all sides.

2. Engine inspection should be performed once every month, throughout the entire storage period. Engine inspection consists in checking the condition of the film cover, and the colour of the silica gel contained in the humidity indicators.

3. Blue and blue-violet colour of the silica gel, with some grains having somewhat different tint, which however does not affect the prevailing colour, indicates that the humidity of the air inside the cover is within the permissible range allowing further storage of the engine.

4. In case the indicating silica gel acquires pink or violet-pink colour, replace both the moisture absorbing and indicating silica gel.

5. The engine inspection completed, enter the following data in the engine Service Log: the date of inspection, the condition of the cover, the colour of the silica gel in the humidity indicators; register all operations performed on the engine in the course of storage (replacement of the silica gel, patching of the film cover) and any deviations from the storage specifications. The notes made in the Service Log should be signed by the person in charge of the engine inspection.

(b) Replacement of Silica Gel on Engine

As soon as the silica gel in the humidity indicators acquires pink or violet-pink colour, perform the operation recommended in Appendix No.9.

V. Unpacking and Deprocessing of Engine

Engine unpacking and deprocessing procedure should be carried out in the following sequence:

1. Remove the upper portion of the packing case.

2. Use scissors to clip off the side seam of the cover (remove as narrow strip of the film as possible).

3. Carefully roll the cover down.

4. Remove the humidity indicators, the silica gel bags, the paraffin paper, and the closures from the afterburner diffuser and from the distance ring.

Check the number of the silica gel bags removed from the engine against the number registered in the technical papers. The numbers should agree.

5. Mount the engine onto the trolley.

6. Melt the grease coat on the engine by blowing the latter with warm air at a temperature of 50 to 100° or by heating the engine in a drying chamber at a temperature of 50 to 70°.

7. Wash the engine with clean gasoline until the slushing compound is completely removed. Washing should be accomplished with the aid of a brush; while proceeding in this way, take care to safeguard the wiring, the electrical equipment, and the flexible hoses against gasoline.

8. The washing procedure over, thoroughly rub the engine with dry cloth and make a visual inspection.

9. Fit the closures onto the diffuser, and the front casing, and then have the internal surfaces of the engine deprocessed.

10. Deprocessing of the internal surfaces is performed on the aircraft or on a special stand, as follows:

(a) remove the closures, including those fitted onto the distance ring and the diffuser;

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(b) drain oil from the tank, from the oil cooler, the engine wheelcase; pour 12 $\pm$ 0.5 lit. of fresh oil MK-8 into the oil tank;

(c) disconnect the plug from the receptacle delivering voltage to the booster coil unit;

(d) deliver fuel into the starting system to fill the supply line. Blow the oxygen system pipe line with clean dry nitrogen;

(e) set the power supply switch in the ON position;

(f) turn on switch STARTING IN AIR for 35 to 40 sec.; this should cause gasoline to run from the combustion chamber drain pipe;

(g) connect the plug to the receptacle supplying voltage to the booster coil unit;

(h) deliver main fuel into the pipe lines of the installation and connect the pipe lines to the engine in compliance with the normal diagram;

(i) use a hose to connect the union serving for measuring fuel pressure in the pilot manifold to the union serving to measure pressure in the afterburner manifold (via accessory tee-piece);

(j) set the engine control lever in the idling rating position and accomplish three false startings of the engine, delivering voltage of 48 V from the ground power supply source and keeping the aircraft booster pumps running;

__Note:__ Deliver fuel into the main fuel system to remove air from the fuel pipe line; the air should be discharged via the unions of the НР-22 Ф and НР-21 Ф fuel regulating pumps, as well as through the union of fuel-oil unit 357С.

(k) set the engine control lever in the CUT-OUT position, and crank the engine 2 or 3 times to remove any remaining fuel;

__WARNING:__ Not more than 5 crankings are allowed to be performed in succession.

(l) remove the hose from the union for measuring pressure in the pilot fuel manifold and from the union for measuring pressure in the afterburner fuel manifold. Plug the unions;

(m) inspect the oil and fuel lines, eliminate leakage, and wipe fuel and oil from the engine surfaces.

VI. Materials Employed for Engine Processing and Deprocessing

1. All materials used for engine processing should comply with the respective State Standards and Specifications.

Following below is the list of materials used for engine processing and deprocessing:

1. Aviation oil MK-22 or MC-20	State Standard ГОСТ 1013-49
2. Oil MK-8(with МОНОЖ admixture). .	State Standard ГОСТ 6457-53
3. Petrolatum	State Standard ГОСТ 782-53
4. Gun grease	State Standard ГОСТ 3005-51
5. Oil АМГ-10	State Standard ГОСТ 6794-53
6. Ceresine, grades 80, 75, 67	State Standard ГОСТ 2488-47
7. Polyvinyl chloride film, grade В-118	Standard МХП ТУМ786-57
8. Polyvinyl chloride sheet plastic .	Standard МХП ТУ2024-49
9. Vinyl perchloride resin	Standard ВТУ МХП 1719-48
10. Dichloro-ethane	State Standard ГОСТ 1942-42
11. Calico, bleached, art.42, or coarse linen, bleached, art.55 .	Standard ОСТ 30286-40 НК текстиль (Textile Industry)
Substitutes: Calico, bleached, art.50, or fine linen, bleached, art.56 . . .	Standard ОСТ 30285-40 НК текстиль

12. Cotton thread No.20 or No.30 . . . . State Standard ГОСТ 6309-52
13. Mica paper . . . . State Standard ГОСТ 6500-63
14. Twine . . . . State Standard ГОСТ 5729-51

Substitutes:
Mackey thread No.9 5/6 . . . State Standard ГОСТ 2350-43

15. Moisture absorbing silica gel, grades КСМ and ШСМ (in lumps or granulated). . . State Standard ГОСТ 3956-54
16. Indicating silica gel . . . Standard МХП ТУ1800-50
17. Humidity indicator, standard
18. Paraffin paper . . . . Standard No.305 АМТУ-52
19. Gasoline Б-70 . . . . State Standard ГОСТ 1012-54
20. Sticky tape . . . .
21. Gaseous nitrogen . . . . . Standard ТУ МХП 4280-54

The materials used for engine processing are checked in a laboratory for the following characteristics:

No.	Description	Characteristics checked
1	Aviation oil МК-22, МС-20, and МК-8	(a) Acidity (b) Water-soluble acids and alkalies
2	Petrolatum	(c) Moisture
3	Gun grease	(d) Mechanical admixtures

No.	Description	Characteristics checked
4	Polyvinyl chloride film, grade В-118	Every batch is subject to checking according to Points 3, 4, 5, 6, 7, 8, 9 of Specifications МХП (N785-57)
5	Moisture absorbing silica gel	1. Moisture content 2. Moisture absorbing capacity

Appendix No.8

INSTRUCTIONS FOR STORAGE OF ENGINES AND SPARE PARTS IN STORE ROOMS

The present Instructions deal with the conditions of storage of engines and spare parts (single and group sets, individual parts, etc.); they also contain recommendations on storage of engines and spare parts in the Customer's stores during the guaranteed period.

I. General Requirements to Storage Location

1. The room used for storage of the engines and spare parts should be well heated and ventilated. Relative air humidity should not exceed 70%.

2. The room air temperature should not be below +10 and over +35°C.

Note: Sharp variations in the air temperature and humidity are not allowed.

3. The temperature and relative humidity of the air should be checked twice a day, in the morning and at the end of the working day.

The results obtained should be entered in a special register.

4. The store rooms should have floors of painted wood, concrete, xylolite, or tile. No cement or clay floors are allowed. It is strictly prohibited to keep any materials or engines on floor. The items put in storage should be arranged on special racks or supports.

5. Cleaning of the floors in the store room should be

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accomplished with the aid of moistened sawdust or by using a vacuum cleaner. Sweeping of dry floors or sprinkling them with water is not allowed.

6. The racks should be fabricated of wood having a humidity of not over 18%.

The shelves of the wooden and metal racks should be coated with oil paint and kept clean. The racks should be positioned in a manner providing for a distance of not less than 40 cm. between the shelves and the wall, and a distance of not less than 20 - 25 cm. between the lower shelf and the floor.

7. The racks should be covered with light cloth to protect the materials and units against dust and sun rays.

8. The store room should be safeguarded against gases favouring corrosion (smoke, chlorine, ammonia vapours, etc.).

9. Acids, alkalies, or storage batteries should not be kept in the same room with engines or engine components.

Do not store rubber parts unless properly packed.

10. The store room should be separated from the yard by a vestibule.

Handling of the storage items should be accomplished either in the vestibule or on protected grounds. Any handling operations in the open air are prohibited. Storage of engines and spare parts in the vestibule is not allowed.

11. A special room should be provided adjacent to the vestibule, separated from the store room by a solid partition. In this room the engines are put to assume the room temperature. The same room is used for packing, unpacking, and treatment of the materials and units.

12. The room should be equipped similarly to the store room proper; relative humidity of the air should be within the specified range.

13. Storage of the cases containing engines and spare parts in the open air is not allowed.

14. When transporting the engines and spare parts in open vehicles, care should be taken to protect the packing cases against precipitations (snow, rain, etc.). The storage items should be transported in special closed containers, or under a water-proof tarpaulin cover.

15. The engines put in storage should be kept under regular observation. The dates of engine and spare parts inspections should be recorded in a special register kept in the store room. Besides, every unit should be provided with a tag for registering the date of the last inspection, and the date of the next scheduled inspection and treatment of the unit; the tag should be signed by the person in charge of the unit inspection. All operations pertaining to the treatment of the units should be also registered in the Service Logs (if available).

16. Do not touch the non-protected surfaces of the engines and parts with bare hands. Grip the metal items on painted or otherwise protected places (nickel-plated, painted, etc.). In other cases make use of knitted gloves, oiled waste cloth or thick paper.

II. Storage of Engines and Spare Parts

1. The engines should be kept on the supports, with the upper portion or detachable wall of the case removed.

The supports should be manufactured from wood having a humidity of not over 18%. The support surfaces contacting the engine should be coated with paint and lined with paraffin paper.

2. The spare parts (single sets) for the engine should be kept on supports.

3. The engines and group sets of spare parts may be transported both in special containers and in the containers of the Manufacturing plant. Prior to loading the engines into closed railway cars, make sure the cars are thoroughly cleaned.

4. Cases with engines and group sets of spare parts delivered to storage should be cleaned of dust and dirt outside the building and immediately moved into the room separated from the storage space by a partition. Unpacking should not be done until the engines acquire the temperature of the room (next day). Prior to unpacking the engine, remove the seals from the case wall carrying the number of the engine, take out the technical papers pertaining to the engine unpacking, and the processing Certificate.

__Note:__ Engines to be put to long-term storage are packed in special cases with a detachable wall.

5. After unpacking, thoroughly inspect the engines not fitted with covers; wipe dry the surfaces covered with condensation using a piece of clean cloth and immediately treat the exposed surfaces with lubricant. Use gun grease, State Standard ГОСТ 3005-51, for steel parts, and neutral petrolatum, State Standard ГОСТ 782-53, for parts of non-ferrous metals, as well as for galvanized and cadmium plated parts.

__Note:__ In case petrolatum or gun grease is not available, it is allowed to employ aviation oil MK or MC with addition of 4 to 10% of ceresine.

6. The empty containers should be kept in a location providing protection against atmospheric precipitations.

7. Engines packed in polyvinyl chloride film covers are subject to regular inspections both at the Manufacturing plant and at the Customer's stores.

The inspections should be carried out as follows:

(a) the processed engines should be kept in the film covers on the supports arranged in a manner allowing easy observation of the engines on all sides. Engine storage may be accomplished in the Manufacturer's containers. The silica gel should be observed through the inspection ports provided in the case, or after removing the detachable wall or upper portion of the case;

(b) if silica gel in the humidity indicators acquires pink or violet-pink colour, proceed as is laid down in Appendix No.9;

(c) if the film cover is torn, apply patches as recommended in Appendix No.10.

III. __Steps to Be Taken on Arrival of Group Spare Parts Sets__

When unloading cases with assemblies, especially with those packed in film covers, handle them with due care.

Do not turn over or drop cases containing group sets or individual spare parts.

The group sets of spare parts delivered from the Manufacturing plant are processed for a storage period indicated in the respective technical papers. The parts will be preserved within the specified time period, provided the Manufacturer's corrosion-preventive treatment is left intact. Therefore, it is not recommended to open the cases until the guaranteed storage period expires.

__Note:__ When delivering the group sets of spare parts from the store, do not disturb the Manufacturer's corrosion-preventive treatment for checking the number of the parts. Subject to checking is the number of packs and packets containing small parts (such as nuts, washers, etc.). The contents of the packets should be checked against the labels, on which the type of the parts and their number in the packet should be indicated.

Cases arriving at the same time or within 15 days should be kept in a separate stack, marked with the date of arrival and the date of first processing.

After the specified 6-month period expires, open the cases containing a group set of spare parts, and inspect the parts in the following order:

(a) check to see that there is no corrosion under the layer of the processing compound, without touching the parts with bare hands and breaking the anti-corrosive layer; if no signs of corrosion are detected, wrap the part in the paper and place it in the case.

When performing the inspection, do not take the part out of the paper, but unwrap it and inspect while carefully turning it on the paper;

__Notes:__ 1. Should it be found impossible to check the condition of the surface under the layer of the lubricant, remove the latter by washing the part in gasoline (State Standard ГОСТ 1012-54).

2. Do not use gasoline containing any additions.

(b) some of the parts, that is the parts having traces of corrosion, should be washed in gasoline and inspected through a lens, in case there are some doubts as to their condition.

If traces of corrosion are revealed, eliminate them and reprocess the part. The remaining group sets of spare parts, having the same date of processing, should be deprocessed and inspected.

Deprocessing, inspection and reprocessing should be carried out as follows:

(a) having unpacked the parts, wash them in gasoline to remove the lubricant. Thick slushing compound may be first melted by dipping the part for 2 or 3 min. into mineral oil preheated to a temperature of 70 to 90°. Allow excess lubricant to run down, and wash off any remaining lubricant by using gasoline and a brush;

(b) subjebt the deprocessed parts to inspection, taking care to group the parts into:

1. Parts not affected by corrosion.
2. Parts affected by corrosion.

When inspecting the parts, do not touch them with bare hands;

(c) wash the parts having no traces of corrosion in gasoline, dry them in air for 5 to 10 min., and process the parts as is laid down in the respective Instructions;

<u>Notes:</u> 1. Use gun grease for treatment of steel and cast-iron parts having no protective coatings or solder seams of non-ferrous metals and not contacting the parts of non-ferrous metals.
2. For non-ferrous metal parts, as well as for parts plated with zinc, cadmium, or copper, or soldered with non-ferrous metals or contacting the parts of non-ferrous metals, use of the following neutral lubricants is indicated: petrolatum, or aviation oil MC-20, or MK-22 containing 4 to 10% of ceresine.

(d) small parts are treated by plunging them for 5 to 15 min. into the lubricant preheated to 105 – 110°, until the part is warmed up. A second, thicker layer of lubricant is applied by dipping the part into lubricant, preheated to 60 – 80°.

Large-size parts are coated with lubricant preheated to 60 – 90°, using a brush.

Parts of heat-resisting and stainless steel are treated by plunging them into lubricant preheated to 105 – 110°.

Do not coat with lubricant the painted surfaces of the parts and assemblies.

Parts affected by corrosion should be cleaned, washed with gasoline and processed as is laid down above.

Assemblies, packed in covers of polyvinyl chloride film with the use of moisture-absorbing silica gel, should be opened after one year of storage. After the replacement of the

silica gel, wrap the assemblies in paper, cure the covers, and put the assemblies in storage for one more year.

The curing of the cover seam, application of patches to the film cover, as well as the preparation of the silica gel should be accomplished in accordance with Appendices Nos 10 and 9.

Given below is the list of materials used for processing:

1. Petrolatum . . . . State Standard ГОСТ 782-53
2. Gun grease . . . . State Standard ГОСТ 3005-51
3. Aviation oil MC-20, MK-22 . . . State Standard ГОСТ 1013-49
4. Ceresine, grades 80, 75, 67 . . . State Standard ГОСТ 2488-47
5. Gasoline Б-70 . . . . State Standard ГОСТ 1012-54
6. Moisture-absorbing silica gel, grades KCM and ШСМ (in lumps, or granulated). . . . . State Standard ГОСТ 3956-54
7. Indicating silica gel . . . . . Standard МХПТУ 1800-50
8. Paraffin paper . . . . Standard 305АМТУ-52
9. Wrapping paper . . . . State Standard ГОСТ 2754-44

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Appendix No.9

INSTRUCTIONS FOR CHECKING INDICATING SILICA GEL
AND FOR SILICA GEL RECLAIMING

The present Instructions deal with inspection of the indicating silica gel arranged on the engine under the film cover and its replacement in case it acquires pink colour; the Instructions also contain recommendations on reclaiming moisture-saturated silica gel, grades KCM and ШCM (in lumps, or granulated, State Standard ГОСТ 3956-54).

I. Procedure of Checking Processed Engines for Condition

The processed engines (in the film cover) should be mounted on case supports in a manner allowing easy inspection of the engines on all sides.

The engines should be inspected monthly throughout the storage period. The inspection consists in checking the condition of the cover and the colour of the indicating silica gel contained in the humidity indicators.

Blue and blue-violet colour of the silica gel, with some grains having somewhat different tint, which however does not affect the prevailing colour, indicates that the humidity of the air inside the cover is within the permissible range allowing further storage of the engine.

In case the indicating silica gel acquires pink or violet-pink colour, replace both the moisture-absorbing and indicating silica gel.

The engine inspection completed, enter the following data in the engine Service Log: the date of inspection, the condition of the cover, the colour of the silica gel in the humidity indicators; register all operations performed on the engine in the course of storage (replacement of the silica gel, patching of the film cover) and any deviations from the storage specifications. The notes made in the Service Log should be signed by the person in charge of the engine inspection.

II. Replacement of Silica Gel on Engine

When the silica gel in the humidity indicators acquires pink or violet-pink colour, replace the silica gel arranged on the engine, proceeding as follows:

(a) use scissors to clip off the side seam of the cover (removing a strip as narrow as possible);
(b) carefully roll the cover down;
(c) replace all silica gel bags by new ones;
(d) replace the humidity indicators by those having blue colour;
(e) wrap with paraffin paper the surfaces, which have been exposed during the replacement of the silica gel;
(f) fit the cover onto the engine and cure the seam as is laid down in Appendix No.10;
(g) all operations pertaining to the replacement of the silica gel should follow one another in close succession, as quickly as possible, to prevent a reduction in silica gel activity due to the moisture absorbed.

III. Reclaiming of Silica Gel prior to Use

The drying of the silica gel having a humidity of over 2%, as well as the reclaiming of the silica gel used on the engine as a moisture absorber should be accomplished in the following manner:

1. Spread the moisture-absorbing and the indicating silica gel in a thin layer (not over 30 mm thick) on aluminium or iron pans, and place the pans in a drying cabinet.

2. Dry the moisture-absorbing silica gel at a temperature of 150 to 170°C for three or four hours, stirring it at regular intervals.

3. Dry the indicating silica gel at a temperature of 120+3°C for 1.5 or 2 hours, stirring it at regular intervals.

4. The humidity of the dried silica gel should not exceed 2%.

5. Allow the hot silica gel to slightly cool down before removing it from the drying cabinet. For this, slightly open the cabinet door and reduce the temperature to 40°; then transfer the silica gel into bottles or other containers.

6. Keep the dried silica gel in clean, properly sealed

containers. It may be placed into clean and dry glass bottles with lapped glass stoppers or corks sealed with paraffin or wax.

7. The moisture-absorbing silica gel should be inserted into cloth bags just before being used on the engine. The silica gel should be transported to the engine in sealed polyvinyl chloride film bags.

Note: In case the operations pertaining to silica gel packing and arrangement on the engine, as well as to the engine packing follow one another in close succession, it is allowed to bring the silica gel to the engine in polyvinyl chloride film bags tied with twine.

The silica gel returned from the aircraft Manufacturing plant should be sorted (clean silica gel must be separated from that contaminated with oil and fuel).

The clean silica gel should be passed through metal sieves (State Standard ГОСТ 2851-45) to remove dust and minute particles. Each side of the sieve mesh should correspond to the lower size limit of the respective silica gel grade, that is:

for grade КСМ . . . . . 1.5 mm
for grade ШСМ . . . . . 1.5 mm

The contaminated silica gel should be turned over to a laboratory for checking its ability to absorb water vapours with the purpose of determining whether it can be used for packing the engines.

Treat the moisture-absorbing and indicating silica gel, returned from the Manufacturing plant as is laid down in the present Instructions.

Appendix No.10

INSTRUCTIONS FOR CURING SEAMS AND APPLICATING PATCHES TO POLYVINYL CHLORIDE FILM COVERS

The present Instructions contain recommendations on curing the seams and applicating patches to polyvinyl chloride film covers.

The curing of the seams on the film covers is accomplished by the use of an appliance designed for the purpose. All operations associated with the curing of the film covers should be performed in a heated, clean room, at a temperature of not below 10°C.

No fitter's work should be carried out in the same room.

I. Curing of Cover Seams by Use of Bench Appliance

1. Seam curing should be accomplished on a working bench. The length of the bench should correspond to the length of the cover cut.

The working portion of the bench comprises a straight, planed board, lined with felt and with several layers of parchment paper. Nailed to the board on top of the paper is a wooden lath, serving to guide the curing device along the cover seam.

2. Seam curing comprises the following operations: put two sheets of the film together, and arrange the edges to be cured on the working bench, along the lath, at a distance of 15 to 20 mm from the latter; smooth out folds and wrinkles, after which rub the edges with a piece of cloth soaked in clean aviation gasoline Б-70.

3. Lay an interleaving paper strip (parchment paper or tracing paper), 5 to 6 cm. wide, on the film sheet edges to be cured.

4. The curing device should be uniformly moved along the seam by hand or with the aid of a power drive, at a rate of 45 to 50 m. per hour. When operating the device manually, move it smoothly along the lath, serving as a guide.

5. The quality of the seam is checked visually by the colour of the interleaving paper. The colour of the interleaving paper should be darker than the colour of the film.

6. The temperature of the slider at the given rate of travel should be equal to 250 - 300°C.

7. Excessive pressure on the seam (resulting in film thinning) is relieved by the respective adjustment of the lower component of the slider.

8. The curing procedure completed, carefully tear off the edges of the interleaving paper detached from the seam, and remove the film sheets from the working portion of the bench.

9. Carefully fold the cover cut in two relative to the longer side, with the edges outward, and clip off both butt ends.

10. Bevel all edges of the longitudinal seams, where they meet the transverse seam. The distance from the butt to the base of the bevel should be 35 mm, whereas the distance from the butt to the apex of the bevel should amount to 80 mm.

11. Cure the transverse seam on the working bench following the Instructions given above.

Note: Wrinkles along the transverse seam are allowed, provided the film is free of cracks.

12. Turn out the cover.

13. Use vinyl perchloride cement to attach 200x200 mm polyvinyl chloride strips to transverse-to-longitudinal seam joints (where the bevel is made).

14. Use the same cement to attach soft pads of polyvinyl chloride plastic to both sides of the cover, where the engine rests upon the support.

II. Curing of Last Seam

1. Press the cover around the engine to remove the excess air.

2. Place the edges to be cured on a board which is similar to that used for curing the main seams.

3. Mount the board onto special wooden or metal supports so as to arrange it at the height of the last seam.

4. Rub the edges with a piece of cloth or gauze soaked in clean gasoline Б-70, and smooth out any wrinkles and folds.

5. Cure the seam as is instructed above.

6. Inspect the cover and the seam visually to see that there are no holes. If holes are detected, patch them up using vinyl perchloride cement.

III. Patching up of Cover

1. Any tears on the film cover are mended with the aid of polyvinyl chloride film patches and vinyl perchloride cement (10 - 15% solution of vinyl perchloride resin in dichloro-ethane.). The patch should overlap the edges of the hole by 15 to 20 mm in any direction.

Note: The total number of patches applied to the cover should not exceed 10.

2. Thoroughly rub the patch and the affected area with a piece of cloth soaked in gasoline to remove any grease.

3. Apply the cement with the aid of a brush on the respective side of the patch and on the damaged area to be covered with the patch.

Wait for 1 or 1.5 min. and then apply the patch to the damaged place: thoroughly press the patch to the cover by stroking the patch from the centre towards the edges.

4. The pads of polyvinyl chloride plastic are attached to the cover in a similar manner. To ensure a better bonding between the film and the plastic pad, place a light weight on the pad after stroking it, so that the pad is snugly pressed against the film surface.

IV. Checking of Cover Film and Cured Seams

1. The check is performed by visual inspection. The film is inspected over a port provided in the bench to illuminate the film from below by electric bulbs.

2. The entire film used for manufacturing the cover is subject to inspection. The film should be uniform in its texture, well gelatinized and rolled. Through holes, bulges or rough nonrolled streaks are not allowed.

Minute spots and inclusions visible in the illuminated film by a naked eye are allowed, provided they do not crumble out when the film is bent to 180° at the point of the inclusion.

3. When two sheets of film are attached to each other by employing the curing technique, no wrinkling or cracking of the film should be observed in the vicinity of the seam. Straining the film by hand in the direction perpendicular to the seam should not result in seam lamination.

<u>Note</u>: It is prohibited to strain the cover along the entire seam, to check the seam by straining it with a finger, or to subject the seam to bending stresses.

4. The cured seam should not have any holes located at a distance of 5 mm from the cover surface. In case some defects are detected in the seam (poor bonding or scorching) re-cure the defective place or repeat the seam curing procedure.

<u>Notes</u>: (a) Holes occurring on the cured seam at a distance of over 5 mm from the cover surface are allowed;
(b) Wrinkles in the vicinity of the transverse seam are allowed, provided the film is free of cracks.

5. The film should comply with the requirements of Specifications МХП М786-57. Prior to using the film, make sure it is provided with a fitness Certificate.

Following below is the list of materials used for curing the seams and patching up the covers:

No.	Description	Standard
1	Polyvinyl chloride film, grade B-118	Specifications МХП М786-57
2	Polyvinyl chloride plastic	Specifications МХП 2024-49
3	Pervinyl chloride cement	Specifications МХПКУ 463-56
4	Paper: condenser paper	State Standard ГОСТ 1908-57
	thin parchment paper	State Standard ГОСТ 2995-56

Fifteen per cent solution of pervinyl chloride resin in dichloro-ethane may be used as pervinyl chloride cement (Pervinyl chloride resin, Specifications МХП 1719-48; dichloro-ethane, State Standard ГОСТ 1942-42).

<u>Appendix No. 11</u>

ELECTRICAL CONTROL EQUIPMENT TESTER БМ37-587

(Operating Instructions)

<u>Purpose</u>

(Figs IX, X, and XI)

Tester БМ37-587 is designed for checking the electric control equipment for proper operation, as well as for checking engine rotors r.p.m.

The face panel of the tester mounts the following equipment: a reference tachometer employed for checking the engine r.p.m.; pilot lamps designed for checking operation of the engine limit switches; a milliammeter for checking operation of the ЭПСУ-1А electrohydraulic system; and a resistor knob for detecting defective electric units of the engine. For data on the engine control equipment refer to the respective Operating Instructions.

<u>Checking High-Pressure and Low-Pressure Rotors R.P.M.</u>

To check the engine r.p.m. it is necessary to connect the wires to the master plug connector. The r.p.m. is checked with the engine running. The rotor r.p.m. is read off on the tachometer indicator, mounted on the face panel, with the change-over switch set in a definite position.

The change-over switch has three positions. Setting the switch in either of the extreme positions will allow checking the r.p.m. of one of the rotors, indicated on the switch; in this case, the r.p.m. of the other rotor can be checked in the cockpit.

With the switch set in the middle position, both tachometer indicators in the cockpit will function.

<u>Checking Operation of Limit Switches</u>

For checking the electric control equipment of the engine, the tester wires should be connected to the master plug connector.

The checking procedure should be carried out with the engine running.

The high-pressure rotor r.p.m. are used to check operation of the following limit switches: starter limit switch CT; limit switch ВДТ controlling additional fuel supply and exercising of the spark plugs in the engine combustion chamber; limit switch КП controlling the by-pass valve. Operation of cams БФО-1 and БФО-2 , as well as limit switch КС controlling the relief valve should be likewise checked by the high-pressure rotor r.p.m.

Operation of limit switch ГЗ controlling the hydraulic decelerator should be checked by the low-pressure rotor r.p.m.

Check operating time of limit switch КС.

In the course of engine starting check operation of the following limit switches: CT, ВДТ , КС, and КП.

Pilot lamp ВДТ lights up at the beginning of the starting cycle and goes out as soon as the electromagnetic additional fuel supply valve is cut off.

Pilot lamp CT lights up as soon as the starter is disengaged, and goes out at the same time with pilot lamp ВДТ . If the engine does not develop the r.p.m. associated with operation of limit switch CT, the starter is caused to be disengaged by the timer completing its cycle.

Pilot lamps КС and КП light up at the beginning of the starting cycle; pilot lamp КС burns within a specified period of time, whereas pilot lamp КП is caused to go out at the end of the starting cycle or is deenergized by the action of limit switch ВДТ.

Pilot lamps БФО-1 and БФО-2 are caused to light up by the action of the afterburner r.p.m. interlock circuit.

Pilot lamp ГЗ is caused to light up by the action of the hydraulic decelerator limit switch.

Pilot lamps БФО-1, БФО-2 , and ГЗ keep burning at r.p.m. values exceeding those associated with operation of the respective limit switches.

Pilot lamp Ф3 keeps burning while the afterburner is being ignited.

Pilot lamps ПК, БФС , and 4 are caused to light up by the action of the limit switches incorporated in the control panel (ПУРТ-10). Tumbler switch P_2 RELIEF VALVE should be set in the ON position. Tumbler switch БУ-2.БУ-4Б should be set in the БУ-4Б position.

Checking Operation of ЭГСУ-1А Electrohydraulic Control System

To check the operation of the ЭГСУ-1А electrohydraulic control system, proceed as follows:

- connect the tester wires to the master plug connector;
- connect the ground power supply source to the aircraft mains;
- turn on the following switches: AFTERBURNER, MASTER SWITCH, PROCESSING (in the K position);
- cut out the hydraulic decelerator blocking system (ГЗ) by turning screw Н provided on the КАФ-13Д afterburner control unit to the BLOCKING CUT-OUT position;
- connect the trolley-mounted hydraulic pumps to the aircraft system; make sure the pressure in the hydraulic system is within the specified range.

Shift the engine control lever to the controlled augmented rating sector, and check the ЭГСУ-1А system 2 or 3 sec. after pilot lamp БФС lights up.

Note: It is not allowed to check the electrohydraulic control system earlier than 3 sec. after pilot lamp БФС lights up, since while the engine is being automatically brought to the augmented rating heavy current will be caused to flow through the connected milliammeter.

Whenever the milliammeter pointer overshoots, disconnect the instrument by manipulating switch ЭГСУ CHECKING (ПРОВЕРКА ЭГСУ). Pointer overshooting is likely to be caused by an abrupt shifting of the engine control lever.

By smoothly shifting the engine control lever within the range of the controlled augmented rating sector, determine the operating range of polarized relay КВС, as indicated by the milliammeter, reading the minimum current value.

Operation of polarized relay КВС is indicated by a slight kick of the milliammeter pointer, as well as by a characteristic noise associated with operation of the ГА-164 hydraulic valve located in the vicinity of stabilizer attachment. Operating limits of relay КВС, within the range of 0.5 to 1.0 mA, in both directions, should not differ in current values, which testifies to proper operation of the relay.

With the engine control lever shifted within the MINIMUM AUGMENTED rating sector, the milliammeter pointer should shift within the operating range of relay KBC, without causing a change in the jet nozzle diameter.

With the engine control lever shifted beyond the upper limit of the minimum augmented rating sector, the milliammeter pointer must run beyond the operating range of relay KBC, causing a change in the diameter of the adjustable jet nozzle. The deflection of the milliammeter pointer in either direction from the zero position should well agree with the direction of the travel of the adjustable jet nozzle hydraulic cylinder rods. After the predetermined diameter is attained, the milliammeter pointer should not move beyond the operating range of relay KBC.

With the engine control lever shifted to the FULL AUGMENTED rating position, the milliammeter pointer should run beyond the operating range of relay KBC; accordingly, the rods of the adjustable jet nozzle hydraulic cylinders should be fully extended and should not change their position.

As soon as switch EMERGENCY ENGAGEMENT OF TWO-POSITION JET NOZZLE is turned on, the electrohydraulic system gets cut off; in this case the hydraulic cylinder rods may occupy any of the two positions. With the engine control lever set in the FULL AUGMENTED rating position, the hydraulic cylinder rods should be fully extended, whereas with the engine control lever set within the range of from the CUT-OUT to MAXIMUM rating positions, the hydraulic cylinder rods should rest against the maximum position stops.

Detecting Faulty Electric Units

Tester БМ37-587 accommodates resistors which are equivalent to the resistors incorporated in the electrical equipment of the ЭГСУ-1А system; these resistors serve to simulate the operation of the electrohydraulic system, thus allowing the engine electrical equipment to be cut out. The defective electric units of the engine can be detected by successively disconnecting individual units to simulate their operation with the aid of sound resistors incorporated in tester БМ37-587.

The detection of the faulty units should be performed in the following order.

Disconnect the plug from the ДР-3А rheostat transmitter and connect it to the respective receptacle of the БМ37-587 tester. Make certain, the electrohydraulic system functions properly by varying manually the ДР-3А resistor whose knob is located on the face panel of the tester. In case the electrohydraulic system fails to operate properly, with the rheostat transmitter cut out and substituted by the resistor incorporated in the tester, connect the rheostat transmitter to the engine electric system and check the ДОС-1А feed-back transmitter and rheostat P-1 using the same procedure.

For connection to the receptacle (when checking the feed-back transmitter) extend the tester cable with the aid of a patch cord fitted with two connectors.

For checking the feed-back transmitter, manipulate the resistor of the ДОС-1А unit. To check rheostat P-1, resistors M0 and 10 should be manipulated.

Normal operation of the electrohydraulic system with one of the electric units disconnected and substituted by the resistor incorporated in the tester will indicate abnormal operation of the respective unit.

Appendix No.12

MEASURING ADJUSTABLE JET NOZZLE DIAMETER BY USE OF APPLIANCE БМ37-575

(Fig.XI)

1. Set the master switch and the afterburner switch in the ON position.
2. Set the PROCESSING switch in the K position.
3. Cut out the hydraulic decelerator blocking system (ТЗ) by turning screw M provided on the afterburner control unit in the BLOCKING CUT-OUT position.
4. Connect an air hose delivering a pressure of 4 to 6 kg/sq.cm. to appliance БМ37-575 (the valve of the appliance should be closed).
5. Connect the ground power supply source and the trolley-mounted hydraulic pump to the aircraft mains.

6. Start the hydraulic pump and build up a pressure of 180 to 210 kg/sq.cm. in the hydraulic system.

7. Mount the appliance onto the projecting inner parts of the jet nozzle flaps so that the collars of the appliance rods are pressed against the flap end faces (Fig.XIII).

Open the valve when mounting the appliance on the jet nozzle.

Note: Any air in the hydraulic system is not allowed. To purge the system of the air, manipulate the engine control lever to bring the jet nozzle flaps from the maximum rating position to the augmented rating position, repeating the procedure several times.

8. Measure the jet nozzle diameter at least two times after shifting the engine control lever to the respective position.

Subsequent measurements should be taken after turning the appliance to another position.

Jet nozzle diameter values should be read on the appliance tape. To determine the true diameter value of the jet nozzle, the mean diameter value should be found.

The jet nozzle diameter value corresponding to the given rating is indicated in the engine Service Log. This value should be strictly adhered to, since it has been set in the course of engine adjustment during stand tests.

SUPPLEMENT TO INSTRUCTIONS

No.	Date of publication	Published by	Document No.	Description	Notes

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Fig I. Graph Showing Adjustment of Idling Rating RPM Depending on Variations in Barometric Pressure (B_0)

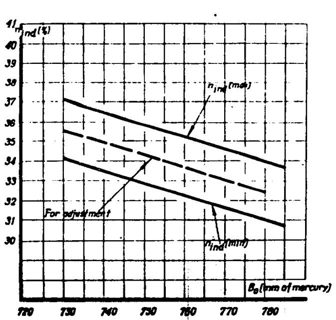
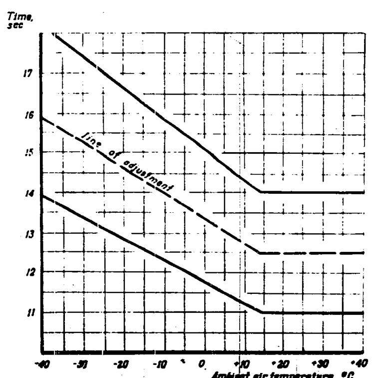


Fig II. Engine Acceleration Time Vs Ambient Air Temperature



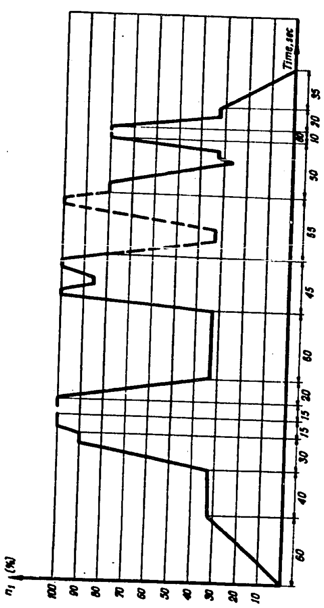


Fig.III. Engine Ground Running Graph

Fig.IV. Idling Rating R.P.M. Vs Altitude of Flight

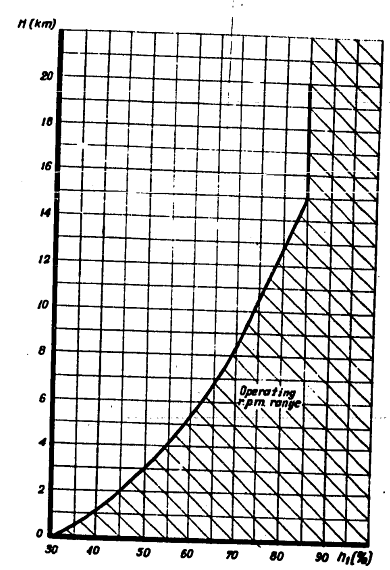


Fig.I. Afterburner Diffuser-to-Adjustable Jet Nozzle Telescopic Joint

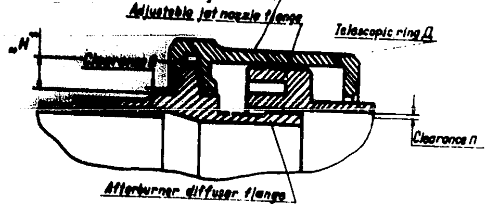
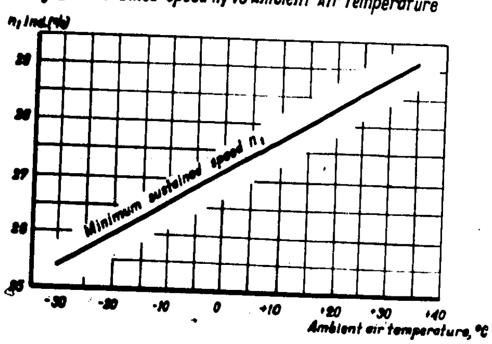
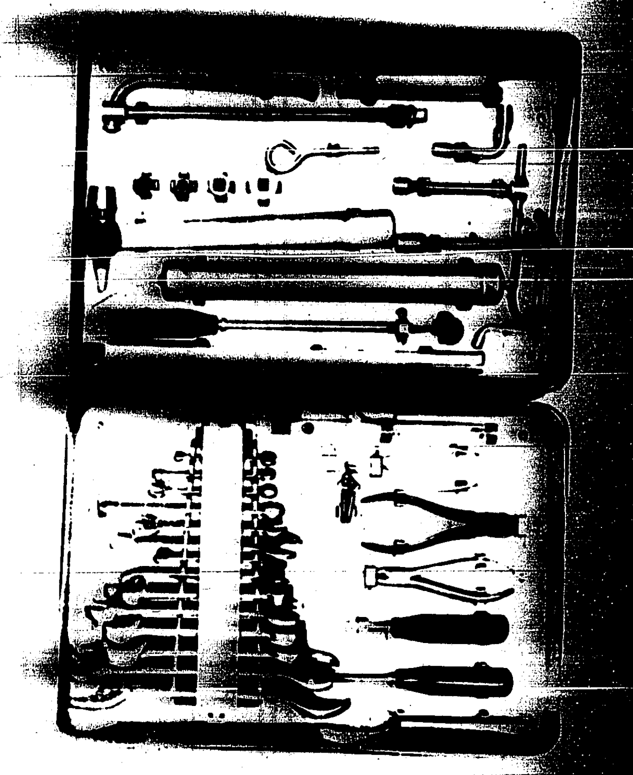


Fig.II. Sustained Speed n_1 Vs Ambient Air Temperature





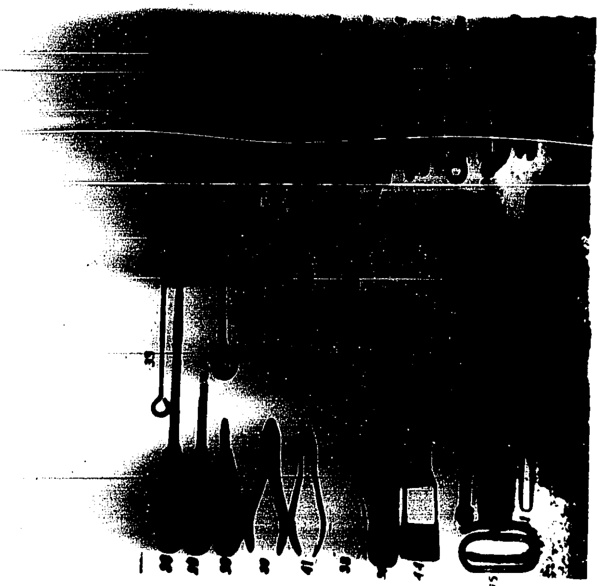


Fig. VIII.

Fig IX. Face Panel of Electric Control Equipment Tester

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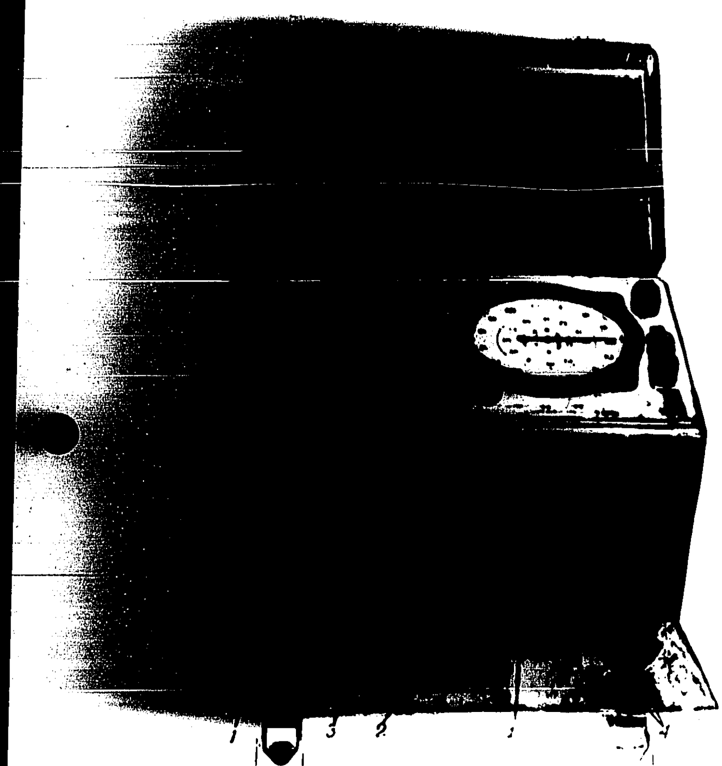


Fig. X. General View of Electric Control Equipment Tester

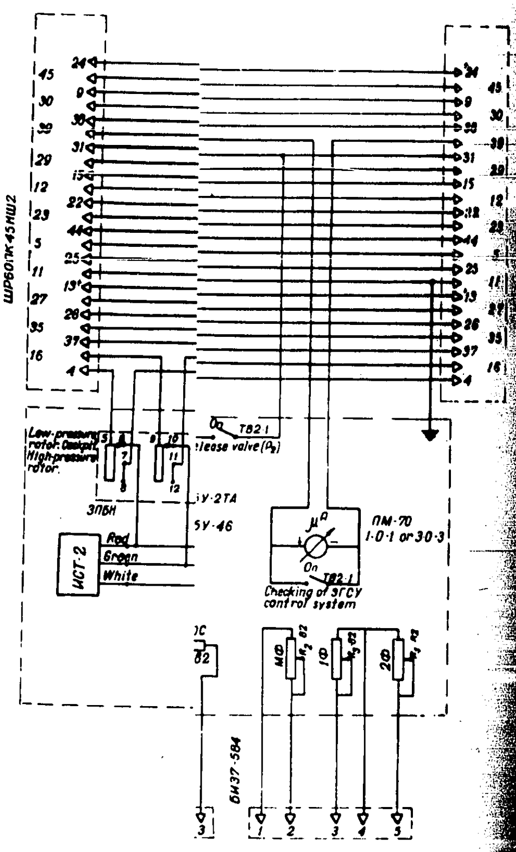
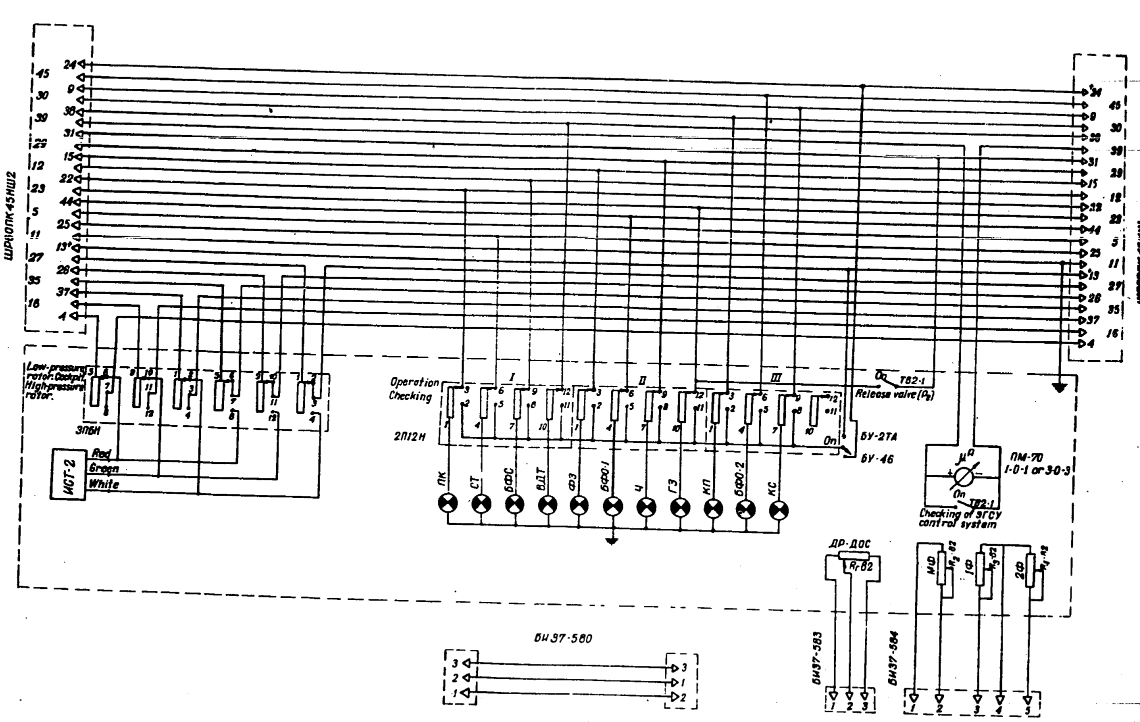


Fig. XI Wiring Diagram of Tester БИ37-587



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e БИ37-575 for Measuring Adjustable Jet Nozzle Diameter

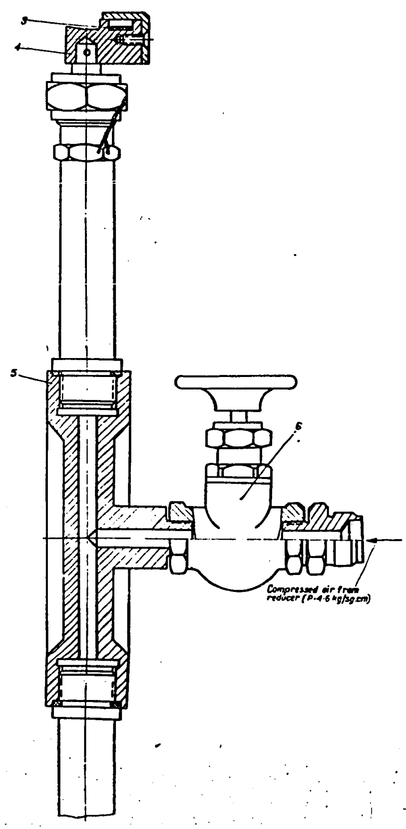

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Fig. III. Mounting of Appliance БИ37-575 When Measuring Jet Nozzle Diameter

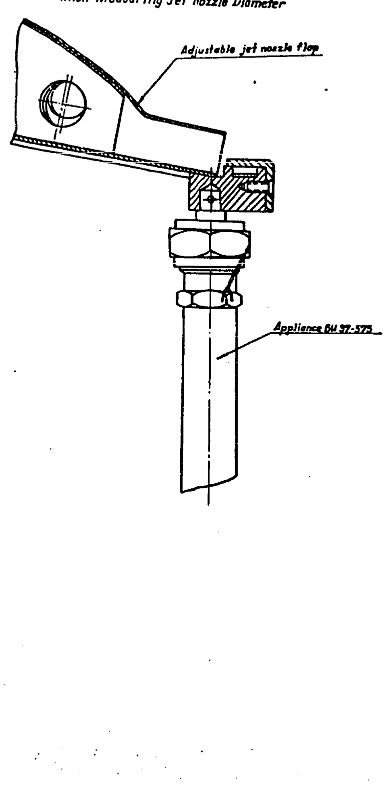

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Fig. XII Applance БИ37-575 for Measuring Adjustable Jet Nozzle Diameter

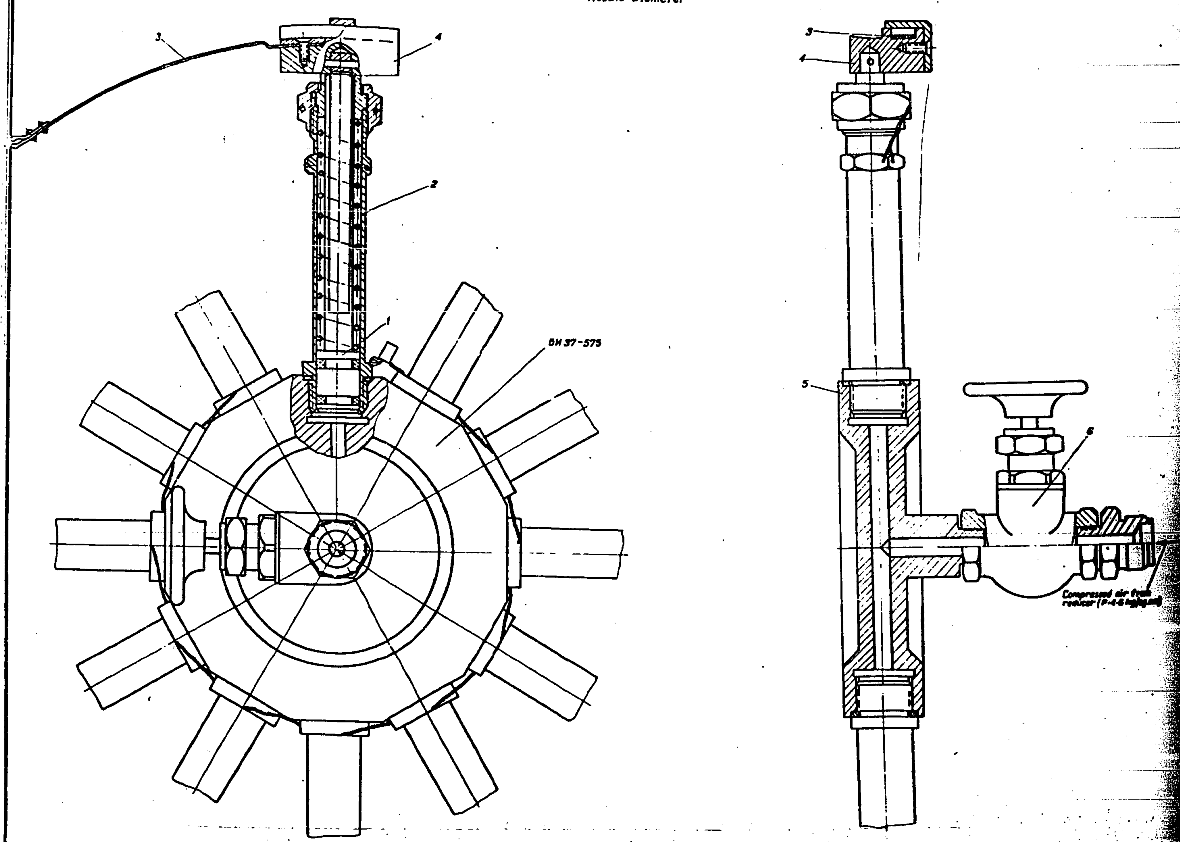
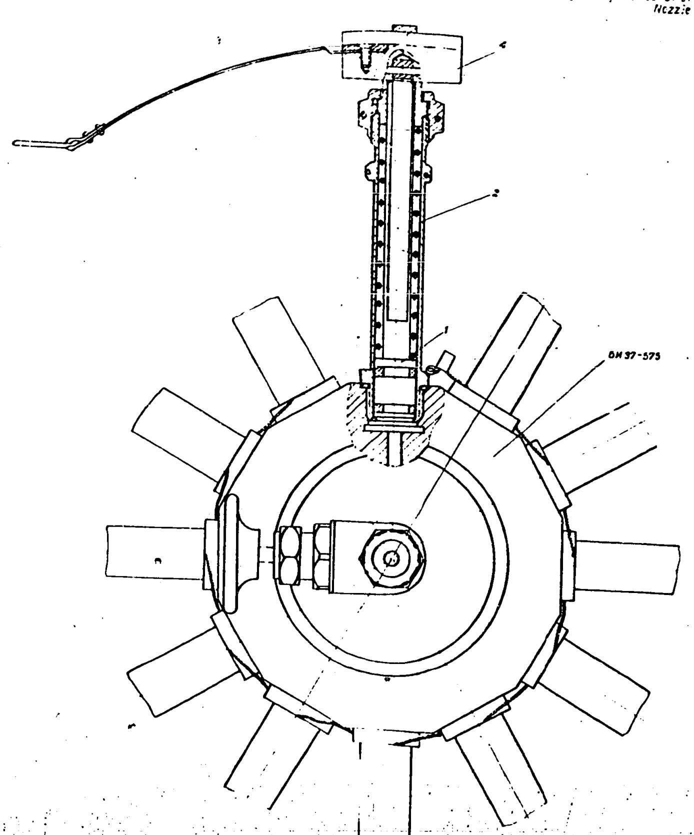


Fig V Apparatus DN 37-575 for Measuring Adjust[illegible]
Nozzle Diameter



SECRET

P11Ф-300 ENGINE

TECHNICAL DESCRIPTION

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NO FOREIGN DISSEM

SECRET
NO FOREIGN DISSEM

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Р11Ф-300 ENGINE

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Book contains 71 sheets

C O N T E N T S

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P11Ф-300 ENGINE SPECIFICATIONS

General Data

1. Engine designation P11Ф-300
2. Engine type .... Turbo-jet, two-shaft, with afterburner
3. Compressor .... Axial, 6-stage, two-spool (3+3)
4. Combustion chambers: .... Individual, straight-flow, accommodated in common housing
   Number .... 10 pieces
   Numbering .... left-hand, starting fro[illegible] upper left-hand chamber (looking fwd)
5. Turbine .... Axial, 2-stage, two-shaft; 2nd stage shrouded
6. Jet nozzle .... Adjustable, variable duty; diameter of throat varies within 526 - 680[illegible]
7. Arrangement of engine accessories .... Lower
8. Direction of rotation of rotors .... Counter-clockwise (as viewed from jet nozzle end)
9. Engine overall dimensions:
   (a) length .... 46[illegible] mm

(b) diameter of turbine casing ... 772 mm

(c) diameter of afterburner on shroud .... 9[illegible]6 mm

(d) maximum height complete with accessories .... 1085 mm

10. Dry weight of engine with afterburner .... Not over 1[illegible]65^{+2} g

Note: Dry weight does not include aircraft accessories and assemblies delivered along with the engine.

11. Engine weight, as delivered ..... Not over 1147.[illegible] kg +2%

Note: The shipping weight of the engine does not include the weight of the oil inserted for corrosion-preventive treatment, and the weight of the auxiliary parts.

12. Engine mounting on aircraft ..... See Chapter X

13. Engine is furnished with:

(a) automatic autonomous starting system providing for push-button starting of engine;

(b) fuel system incorporating main fuel and starting fuel manifolds;

(c) lubricating oil system;

(d) compressor intake fairing anti-icing device providing for normal operation of the engine at any atmospheric conditions;

(e) afterburner with variable duty jet nozzle and dual main fuel manifold;

(f) control system incorporating panel for control of ratings (ПУРТ);

(g) flame igniter oxygen supply system, providing for reliable starting at high altitudes;

(h) system of air bleeding. Amount of air bled from the compressor at maximum engine speed and at standard atmospheric conditions .... 66[illegible] kg/hr

14. Guaranteed service life of engine up to first overhaul .... Refer to Service Log

- including operation at maximum and augmented ratings for not more than .... 3[illegible] hours

Note: When calculating the entire operating life of the engine, engine running time on the ground is considered to be equal to 2[illegible]% of the entire operat[ing] life. If the engine running time on the ground exceeds 2[illegible]% of the service life, the subsequent operation should be calculated 1 hr per hr.

Diameters of Jet Nozzle Exhaust Area at Main Ratings

1. Full augmented rating .... 68[illegible] mm
2. Minimum augmented rating .... 61[illegible]$^{+1[illegible]}$ mm
3. Maximum rating .... 526^{+14} mm
4. Normal rating .... 526^{+14} mm
5. [illegible] normal rating .... 526^{+14} mm
6. Idling rating .... 6[illegible] mm

Engine Control

1. Engine control is accomplished by means of the contro[l] lever, through the medium of the control unit.

The control unit consists of regulating fuel pump HP-2[illegible] and ratings control panel ПУРТ-1[illegible], connected by means of a link. The control system provides for operating the engine at the following ratings:

(a) idling rating, which is switched on by setting the engine control lever against the idling rating stop;

(b) ratings from idling to maximum, which are switched on by shifting the engine control lever from the idling rati[ng] stop to the maximum rating stop;

[redacted]

(c) maximum rating, which is switched on by setting the engine control lever against the maximum rating stop;

(d) minimum augmented rating, which is attained by setting the engine control lever against the minimum augmented rating stop;

(e) partial augmented ratings, which are switched on by moving the engine control lever from the minimum augmented rating stop to the full augmented rating stop;

(f) full augmented rating, which is accomplished by setting the engine control lever against the full augmented rating stop;

(g) engine stopping, which is accomplished by setting the engine control lever against the CUT-OUT (СТОП) stop.

2. The jet nozzle is of variable duty type providing for control of augmentation; it is actuated with the aid of three hydraulic cylinders.

Purpose	Changing of jet nozzle exhaust area for setting required engine rating
Control system	Electro-hydraulic type
Operating fluid	Hydraulic fluid АМГ-10, Specifications НП-10-58, or АМГ-10, State Standard 6794-53
Hydraulic fluid pressure in system	180 - 215 kg/sq.cm.

Starting System

1. Starting system type	Automatic, autonomous, electric, with voltage switched over from 24 to 48 V
2. The starting system provides for:	

(a) engine starting or cranking at a temperature of -20 to +50°C three times in succession, without boost-charging of storage batteries;

(b) engine starting or cranking at a temperature of -40 to +50°C five times in succession, using a ground power supply

source of the АПА-2П type, with starter not requiring any cooling in between the operating periods;

(c) engine starting during flight at any atmospheric conditions, at altitudes of up to 12,000 m. (with oxygen supply) and up to 8000 m. (without oxygen supply).

3. Starting system components	Starter-generator, starting equipment, starting fuel system, flame igniters, oxygen supply system, starting fuel control unit incorporated in pump НР-21Ф, electromagnetic valve controlling fuel feed at starting, starting fuel ignition system, air blow-off valves (2 pieces)

Starter-Generator

Type	ГСР-СТ-12000ВТ
Purpose	Is used as a starter during engine starting. With engine running, is employed as a D.C. generator. Change over from starter to generator duty is accomplished automatically at 32 ±2% of high-pressure rotor normal rating or by timer within 44.0 ±1.2 sec.
Number	1 piece
Direction of rotation	Counter-clockwise
Gear ratio	2.249
At starter duty	2.249
At generator duty	1.344

Starter-generator may be operated as a starter not more than 5 times in succession.

Starting Equipment

(is not delivered with engine)

Aircraft power supply source (storage batteries)

Type	15CЦC-45
Number	2 pieces
Purpose	Is employed as a power source during engine starting
Starting relay box	KПP-15A installed on aircraft (is not supplied along with the engine)
Ground power supply source switch box	KПA-4 (installed on ground power supply source; is not delivered along with the engine)

Timer

Type	ЭВ7-44-5 (installed on aircraft; is not delivered along with the engine)
Purpose	Provides for successive operation of the electric starting equipment within the time period of 44.6 $\pm$1.2 sec.

Starting Fuel System

Purpose	During engine starting on ground and in air system provides for gasoline supply into flame igniters and for igniting combustion chambers
Starting fuel used	Aviation gasoline Б-70, State Standard 1012-54
Fuel consumed in one starting	Not over 0.3 lit.
Components incorporated in starting fuel system:	
(a) Starting fuel tank	1 piece (mounted on aircraft)
(b) Filter	1 piece (installed on aircraft)
(c) Starting fuel pump (installed on aircraft)	

Type	ПНР-10-9M, gear type, driven by elec[illegible] motor
Number	1 piece
Output	40^{+8} lit. per hour at a pressure of [illegible] $2^{+0.2}$ kg/sq.cm., with V = 24 V and H [illegible]
Pressure should be adjusted at	2 $\pm$0.2 kg/sq.cm. (with no air pressure supplied into tank and at voltage of [illegible] 25 -2 V, as read off aircraft voltme[illegible]
Starting fuel tank pressurization value	[illegible].4 $\pm$0.05 kg/sq.cm. (provided by [illegible] turing plant)
(d) Electromagnetic starting fuel valve	
Type	ЭКПТ-9
Number	1 piece
(e) Flame igniters	
Type	External, with low-voltage ignition system and oxygen supply
Number	2 pieces

Flame Igniter Oxygen Supply System

Purpose	To supply additional amount of oxygen to flame igniters for more effective ignition of main burners when start[illegible] engine in flight
Components incorporated in oxygen supply system:	
Oxygen bottle	Not less than 2 lit. capacity (arra[illegible] on aircraft), 1 piece
Oxygen pressure reducer	213[illegible]; outlet pressure amounting to [illegible] 9 - 10.5 kg/sq.cm. (arranged on a[illegible] 1 piece
Electromagnetic oxygen valve	1 piece (mounted on aircraft)
Non-return oxygen valve	1 piece

Oxygen pressure forward of flame igniters	6.5 - 8.5 kg/sq.cm.
Electromagnetic fuel supply valve:	
Purpose	Supplies additional amount of fuel (84 ±3 lit/hr) for acceleration of starting procedure on ground; fuel is started to be supplied within 25 sec. after button STARTING (ЗАПУСК) is pressed; additional fuel supply is discontinued as soon as high-pressure rotor reaches speed amounting to 48% of its normal r.p.m.
Type	МКПТ-9Ф
Number	1 piece
Starting fuel ignition system	Low-voltage, employing erosion-type surface discharge spark plugs
Air blow-off valves:	
Purpose	Discharge part of air into atmosphere to prevent engine from stalling at starting on ground
Type	Hydraulic
Number	2 pieces
4. Permissible gas temperature aft of turbine during starting	Not over 650°C
5. Time required for engine to gain idling speed from the moment starting button is pressed:	Not over 60 sec.

- afterburner may be turned on within not less than 90 sec. after pressing the starting button;

Notes: 1. During autonomous starting, the time period required for reaching the idling speed may be increased to 100 sec.

2. In case the maximum or augmented speed is reached within 90 sec. after pressing the starting button, gas temperature aft of the turbine is allowed to be increased to 720°C (for not more than 5 sec.).

Fuel System

1. Grade of fuel	
(a) main and afterburner	T-1, State Standard 4138-49 T-2, State Standard 8410-57 TC-1, State Standard 7149-54

Note: Engine may operate on fuel T-2 for not more than 50 hours.

2. Fuel booster pump	ДЦН13ДТ
Type	Centrifugal, with permanent-pressure valve
Direction of rotation	Counter-clockwise
Gear ratio	1.344
Pressure upstream of booster pump	1.[illegible] +3.[illegible] kg/sq.cm. abs
At idling rating	1.8 +3.[illegible] kg/sq.cm. abs
Short-time (with aircraft deenergized) pressure upstream of pump (up to 6000 m. for TC-1 and T-1)	Not less than 0.46 kg/sq.cm. abs
(Up to 4000 m. for T-2)	Not less than 0.6 kg/sq.cm. abs
3. Fuel pressure upstream of high-pressure fuel pumps (main and afterburner)	2.4 - 3.8 kg/sq.cm. abs
Short-time pressure rise	Up to 4.0 kg/sq.cm.
At idling rating	Not less than 1.4 kg/sq.cm.
4. Main fuel regulating pump:	
Type	HP-214, plunger, with variable low-pressure rotor speed governor and with device for limiting fu

	pressure increase at acceleration; pump is furnished with hydraulic decelerator, starting fuel control unit, by-pass valve, and distributing valve. Pump rotor is driven by engine high-pressure rotor
Purpose	Meters fuel supplied into combustion chambers to provide for maintaining predetermined engine speed at sustained ratings and intermediate ratings
Direction of rotation	Clockwise
Gear ratio	2.78
Starts regulating engine speed automatically	at 85 -2% of normal rating, or at 9500 - 200 r.p.m.
Maximum fuel output (at Π_2 = 11,500 r.p.m.)	Not less than 7000^{+200} lit/hr
Minimum fuel output (at Π_2 = 10,000 r.p.m.)	360 ±15 lit/hr
5. Afterburner fuel regulating pump:	
Type	HP-22Φ; plunger type with afterburner fuel regulator and barostatic fuel supply limiter; pump is furnished with afterburner valve, high-pressure rotor speed transmitter with limiter, and control unit БУ-4Б
Purpose	Meters fuel delivered into afterburner, with P_2/P_4 ratio maintained at the same value; limits fuel delivery depending on compressor outlet pressure; limits maximum r.p.m. of high-pressure rotor
Direction of rotation	Clockwise
Gear ratio	2.57

Maximum fuel output (at Π_2 = 11,150 r.p.m.)	Not less than 10,500 -400 lit/h[illegible]
6. Pressure of fuel in pilot manifold of engine main fuel system	Not over 80 kg/sq.cm.
7. Pressure of afterburner fuel at HP-22Φ pump outlet	Not over 90 kg/sq.cm.
8. Main burner:	
Type	Centrifugal, two-stage, duplex
Number	10 pieces
9. Starting burner:	
Type	Centrifugal, single-stage
Number	2 pieces
10. Afterburner fuel injector:	
Type	Centrifugal, single-stage
Number	102 pieces
(a) in larger manifold	[illegible] pieces
(b) in smaller manifold	42 (including 2 starting inje[illegible]ors)
11. Filter at main and afterburner fuel inlet	Gauze, having 16,900 meshes pe[illegible] sq.cm.; incorporated in unit[illegible]
12. Fuel temperature at high-pressure pump inlet:	
continuous	Not over +80°C
short-time (10 min. per 1 operating hour)	Not over +120°C

Lubrication System

1. Type	Close-circuit, autonomous
2. Oil grade used	MK-8, State Standard 6457-53
3. Oil consumption	Not over 1.2 lit/hr
4. Pressure in oil line:	
(a) at all ratings (idling rating exclusive)	3.5 +0.5 kg/sq.cm.
(b) at idling rating	Not less than 1.0 kg/sq.cm.

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<u>Note</u>: At altitudes exceeding 10,000 m. oil pressure may drop to 3 kg/sq.cm.

5. Oil temperature at engine inlet	Not less than -40°C
Oil temperature at engine outlet	Not over +140°C

<u>Note</u>: Oil temperature is measured during experimental tests carried out in compliance with a special schedule.

6. Oil pumps:

(a) delivery oil pump:

Type	Gear-type
Number	1 piece
Direction of rotation	Clockwise
Gear ratio	3.168
Delivery at normal rating with back pressure amounting to 3.5 +0.2 kg/sq.cm. and oil temperature of +60 - 75°C	Not less than 50 lit/min.

(b) oil pump for scavenging oil from accessory wheel case and from central and rear supports:

Type	Gear-type, three-section
Number	1 piece
Direction of rotation	Clockwise
Gear ratio	3.168
Delivery at normal rating with back pressure amounting to 0.5 - 0.8 kg/sq.cm. and oil temperature of +60 - 75°C	Not less than 135 lit/min.

(c) pump for scavenging oil from front support:

Type	Gear-type
Number	1 piece

Direction of rotation	Clockwise
Gear ratio	4.461
Delivery at normal rating with back pressure amounting to 0.5 - 0.8 kg/sq.cm. and oil temperature of +60 - 75°C	Not less than 12 lit/min.
7. Oil pressure gauge	ДИМ-8Т

8. Fuel and oil unit consisting of fuel-cooled oil cooler, low-pressure fuel filter and oil tank

Type	357C
Purpose	Cooling of oil at any of engine ratings
Oil tank capacity	16 lit.
Amount of oil inserted in tank	12 ±0.5 lit.
Minimum amount of oil allowing for normal operation of engine	7 lit.

9. Provision has been made in the engine oil system for draining oil from all lower points of the oil cooler and of the engine wheel case, as well as for breathing the engine through the centrifugal breather with barostatic valve, ensuring normal operation of the oil system at high altitudes.

10. The engine oil system provides for normal operation of the engine irrespective of interruptions in oil supply (during inverted flight, etc.) amounting to not more than 17 sec.

<u>Ignition System and Electrical Equipment</u>

1. Type of ignition system	Electric, low-voltage
2. Booster coil unit:	
(a) serving combustion chambers number	KHA-114M
number	2 pieces
(b) serving afterburner	KHA-114M (installed on aircraft)
number	1 piece

3. Starting spark plugs:	Shielded, surface discharge
serving combustion chambers	СПН-4-3
number	2 pieces
serving afterburner	СЗ-21Д5
number	2 pieces (including 1 stand-by)
4. Generator regulating equipment	РУГ-82 and ДМР-400Д (are not delivered with engine; installed on aircraft)
5. Afterburner control unit with relay T, type ТКЕ24ПДТ	КАФ13Д (is not delivered with engine; installed on aircraft)
Purpose	Causes afterburner to be turned on and cut off automatically
Number	1 piece
6. Ratings control panel:	
Type	ПУРТ-1Ф
Number	1 piece
7. Variable duty jet nozzle control system:	
Type	ЗГСУ-1А
Components:	
Rheostatic transmitter	ДР-3А
Regulating rheostat	Р-1
Feed-back transmitter	ДОС-1А
Pulse delivery box	КИС-1 (installed on aircraft; is not delivered with engine)
Electro-hydraulic switch	ГА-164М (installed on aircraft)
8. Control unit:	
Type	БУ-4Б
Number	1 piece

Chapter I

COMPRESSOR

The engine compressor (Fig.6) is an axial, two-spool, six-stage type.

The compressor comprises a stator mounting fixed vanes o[illegible] the guide vane assemblies, and two rotors: a low-pressure rotor and a high-pressure rotor; each of the rotors consists of three stages.

The first four stages of the compressor are supersonic, as regards the relative-velocity of the air entering the ro[illegible] blades; the air at the guide vane assembly inlet has a subso[illegible] velocity.

The rotor blades impart energy to the air, simultaneous[illegible] slowing down its axial velocity; the guide vane assemblies straighten the air stream until it flows in the axial direction, and cause an increase in the axial velocity.

This arrangement provides for satisfactory operation of both the rotors and the guide vane assemblies.

Stator

The compressor stator (Fig.6) consists of distance ri[illegible] front casing 3, casing 6 of second stage guide vane assemb[illegible] middle casing 8, casing 12 of the fourth and fifth stage [illegible] vane assemblies, and rear casing 14. All the casings are th[illegible] walled, light structures fabricated in steel which allows [illegible] the use of welded guide vane assemblies giving reliable per[illegible]formance.

The casings are coupled to each other by means of bol[illegible] passed through flanges. Neither of the casings, exclusive [illegible] the fourth and fifth stages, has a longitudinal joint, which adds to the rigidity of the construction and allows the casings to be made thin-walled (wall thickness amounts to 1.5 - 2 mm). All the vanes of the guide vane assemblies (exclusive of the vanes making the sixth stage) are attached to the casings by means of point welding.

Five straightener vanes 4 of the first stage are somewhat thickened. Passed through one of the straightener vanes is a drive shaft running to the low-pressure rotor speed transmitter, to the oil pump, scavenging oil from the front support of the engine, and to the centrifugal governor of regulating pump HP-21Φ. Two vanes serve for delivering oil to and scavenging it from the front support. Supply of air for heating of the nose bullet and pressurization of the oil labyrinth sealings, as well as breathing are accomplished by the use of the other two thick straightener vanes.

The arrangement of the lines in the front casing is diagrammed in Fig.6.

Front casing 3 accommodates low-pressure rotor front support 2. The front support is made in the form of a housing, cast of magnesium alloy and accommodating pressed-in steel bearing holder and steel nitrated bush contacting sealing rings. The bearing cavity is fitted with a cast cover, also accommodating a pressed-in nitrated steel bush for the front sealing rings. The cast support is secured to the flanges of the vanes of the 1st stage guide vane assembly.

Attached to the flange of front casing 3 is second stage guide vane assembly 5 aligned with regard to the cylindrical surface.

Middle casing 8 serves for arrangement of third guide vane assembly 9 and for forming front pressure chamber 7, reducing axial force acting on the middle support bearing.

The vanes of the fourth and fifth guide vane assemblies are secured in casing 12, which, in contradistinction to the other guide vane assemblies, has a longitudinal joint. The rear flange of the casing is coupled with the aid of fitted

bolts to the front flange of rear casing 14, which is a load-carrying component serving for connection of the compressor to the hot section of the engine; it also connects the low-pressure section to the high-pressure section and comprises one of the main load-carrying structures of the engine. Accommodated in the rear casing are guide vanes 15 of the sixth stage, which are secured by means of trunnions and bolts to the inner and outer walls of the rear casing.

Bearing holder 19 serves for attachment of the holder 13 of middle support and the rear support of the high-pressure rotor. The bearing holder is manufactured from steel and is essentially a light welded construction, reinforced by stiffeners.

The bearing holder accommodates oil supply pipes 17 and oil scavenging pipes 18, as well as air lines comprising two pipes delivering air to the disc of the first stage turbine (via intake 27) and four pipes for outlet of air, bled from the compressor third stage and serving for cooling the turbine bearing holders. This air is diverted to air collector 29 and further is discharged into the atmosphere via pipe 28.

The air lines also comprise eight pipes 16, serving for air discharge from the labyrinth sealings of the rear support to receiver 24, where the air is delivered from the labyrinths of the third and sixth stages, and of two connections 25, through which the air is discharged to the atmosphere.

Bearing holder breathing is accomplished by the use of breather pipe 26.

The lower part of the bearing holder accommodates oil collector 2., which holds oil draining from the rear support.

Low-Pressure Rotor

The low-pressure rotor (Fig.7) consists of shaft 36, three discs, and the blades of the first - third stages, made of stainless steel. First stage disc 34 is aligned with regar to the shaft hole. Discs 37 and 40 of the second and third stages respectively, are coupled by means of radial dowels to form a single unit, which is shrink fitted onto rotor shaft 36. The disc diaphragms are provided with holes serving for protection against pressure drops; the only force acting results from the pressure working against the blades.

The torque from the shaft to the discs is transmitted through splines.

The shaft accommodates slotted bolt 31, which locates first stage disc 34 axially with the aid of nut 32. The same bolt secures spinner 36, installed on the disc of the first stage. The profile surface of the spinner is coated on the outside with organic silicon compound; on the inside the spinner is heated by the air bled from the compressor sixth stage.

The blades are held in the discs by means of locks of a dovetail type. The blades of first stage 35 are held against axial displacement by dowels 33, whereas second stage blades 38 are secured by dowels 39 and ring; third stage blades are fixed by ring 42.

The rear end of the shaft is splined to the second stage turbine shaft. The spherical nut, taking up axial loads, is tightened so that it comes up against the face of the second stage turbine shaft, the necessary clearance being provided between the nut sphere and the low-pressure rotor shaft.

The low-pressure rotor rides in two supports (Fig.6); front support 2 is a roller bearing, located in front casing 3, the rear support being formed by mid support 13 with a radial-thrust bearing arranged in the trunnion of the high-pressure rotor. The bearing takes up axial load, resulting from the difference between the axial forces of the compressor and turbine. The axial load of the low-pressure rotor is transmitted to mid support 13 through the medium of the high-pressure rotor components.

High-Pressure Rotor

The high-pressure rotor (Fig.8) consists of the discs and blades of fourth stage 43, 46, fifth stage 47, 50, and sixth stage 53, 54, and trunnion 51, fabricated in stainless steel.

The discs along with the trunnion form an integral unit. The blades are secured in the discs by means of dovetail lock[s]. All the blades are retained by rings 44, 49, and 55.

The shank of trunnion 51 is splined to the shaft of the first stage turbine and is aligned on the shaft by means of cones and cylindrical surfaces. The cones are tightened by a nut retained by a plate lock.

The cone joint is made as follows. Non-detachable rear cone 22 (Fig.6) is fitted on the turbine shaft with a negati[ve] allowance; front cone 23 is made in the form of a collet.

Pressed on the upper cylindrical portion of trunnion 51 (Fig.8) are fifth stage disc 47 and sixth stage disc 53; the discs are held in place by means of cylindrical dowels 48 and 52. Fourth stage disc 43 is pressed on the ring of fifth sta[ge] disc 47 and is also secured with the aid of cylindrical dow[els]. The high-pressure rotor rigidly connected to the shaft of th[e] first stage turbine, runs in the middle and rear supports of the engine.

The trunnion accommodates the support of the low-pressu[re] rotor, which is essentially mid bearing 10 (Fig.6). Middle support 12 of the high-pressure rotor consists of two radia[l-] thrust ball bearings 11, which take up radial and axial load[s]. Joint operation of both bearings is ensured by proper sele[ction] of calibrated rings and of other components; this allows bo[th] bearings to take up radial and axial loads at the same time. To decrease axial forces acting on the middle support of th[e] engine, provision is made for the rear pressure chamber. The rear support of the high-pressure rotor shaft is represent[ed] by a roller bearing, taking up radial loads only.

Lubrication of the engine supports is accomplished by forced delivery of oil to the bearings via injectors. Sinc[e] oil to the bearing of mid support 10 cannot be delivered in the usual manner, it is supplied from a fixed injector attached to mid support 13, into the oil collecting bushing, at some angle to the engine axis. The bushing is provided with blades, which swirl the oil, thereby causing it to be carried to the bearing (by the action of centrifugal forces) via three injectors. The same forces cause the oil to be fed through the running bearing and further to be discharged along the inner surface of the rotating bushing and via the holes in the trunnions into the oil space of the rotor.

Chapter II

COMBUSTION CHAMBER

The engine is equipped with a cannular combustion chamber system (Fig.9). Ten cylindrical combustion chambers of the straight-flow type are arranged in the circular space between combustion chamber housing 6 (forming the casing of the engine proper), and rotor shaft tube shield 7. The front part of housing 6 and shroud 8 form an annular diffuser whose function is to slow down the air stream at the inlet to the combustion chambers. The combustion chamber proper is comprised of tapered dome 1 with swirler 2 and deflector 9, three-section liner 3, and flame tube 4 with combustion chamber attachment flange 5.

The air coming from the compressor passes through the dif- fuser, and enters the combustion chamber via the swirler and the holes provided in the dome. Deflector 9, having two rows of holes, makes for uniform distribution of the air in the mixture formation zone and provides an air coat serving for cooling down the combustion chamber dome.

The air fed into the combustion chamber is divided into the primary and secondary air streams.

The primary air, used up during fuel combustion, enters the combustion chamber through the swirler, as well as through the holes in the dome and in the first section of the liner. While passing through the swirler, the air stream is swirled; the resulting centrifugal forces throw the air against the walls of the dome. As a result, a rarefaction zone is crea[ted] in the centre, due to which hot combustion products flow back towards the burner; this causes increase in the temperature o[f] the fuel and air in the combustion chamber dome which results in a more effective evaporation and mixture formation. The presence of the back currents provides for stable ignition of freshly formed mixture within a wide range of excess air coefficient.

The secondary air, comprising the bulk of the air stream (about 70%), flows into the combustion chamber through several rows of holes provided in the liner. This air gets mixed with the hot gas stream and cools it to the specified temperature. The secondary air is supplied through the holes whose location and diameters allow for distribution of temperatures in the combustion chamber exhaust area with regard to the turbine blade height, which is dictated by the blade strength considerations.

The combustion chamber walls are cooled down by the secondary air, flowing on the outside. This air also passes through the rows of holes 22, provided on the joints between the liner sections, and forms an air coat on the inside, protecting the walls of the combustion chambers against convection heat exchange.

The secondary air forms a heat insulating layer between the combustion chamber walls, external housing 6, and shield 7. For attachment to the engine the combustion chambers are fitted with flange 5. The inner band of the flange carries two lugs, serving to fasten the combustion chambers on common ring 10, which, in its turn, provides for aligning the entire combustion chamber set on turbine nozzle diaphragm 11. The combustion chambers are held against longitudinal displacement by the external collar of flange 5; the collar is clamped between the housing flange and the outer ring of the nozzle diaphragm.

The front part of the combustion chambers rests against burners 13, rigidly secured to the engine casing. The combustion chamber dome has two by-pass holes, accommodating welded bushes 14 and 15. Bush 14 has a special groove and cutouts for attachment of interconnecting tubes 16 and 17; the opposite ends of the tubes enter the bushes of the adjacent combustion

chambers, thereby affording communication between the inner spaces of the chambers. Two interconnecting tubes 17, located in the upper part, between chambers 1 and 2, 9 and 10, are provided with recesses for accommodation of the spherical bushes of flame igniters 21, incorporated in the engine starting system.

The interconnecting tubes serve for propagation of flame in the combustion chambers and for equalizing pressure therein. Swirler 1 providing for swirling of the air stream, is furnished with five curved vanes; the swirler is arranged and expanded in the combustion chamber dome shell. Fitted into the swirler is ring 12 mounting the burner. This arrangement offsets the possible misalignment of the combustion chamber and burner axes and allows axial displacement of the combustion chamber due to thermal expansion.

The combustion chamber dome, three sections of the liner and the flame tube are coupled to each other by means of continuous arc welding. In the zone of the welded seam, the liner sections and the flame tube have slots 19 which serve to reduce thermal stresses appearing at the welded places, and to ensure more tight fit between the welded surfaces.

Some of the holes in the liners are edged with shells 20 to preclude overcooling and resulting cracks due to great thermal stresses.

The combustion chamber ends in the flame tube. Flange 5 is welded to the flame tube. For protection against peening, the flange is plated with copper. All combustion chamber components are fabricated in heat-resisting materials.

To render the material more heat-resisting, the surface of the combustion chamber is coated with special enamel. Combustion chamber housing 6 is fabricated in stainless steel.

The combustion chamber housing has two flanges for mounting the valves serving for air discharge from the compressor into the atmosphere.

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Chapter III

TURBINE

The engine is furnished with a two-stage, axial, reactive turbine (Fig.10).

Each of the turbine stages has its own rotor and nozzle diaphragm(stator).

Outer shaft 47 of the first stage rotor is rigidly connected to the high-pressure compressor and represents the high-pressure rotor.

Inner shaft 48 of the turbine second-stage rotor is coupled to the low-pressure compressor and makes the low-pressure rotor.

First-Stage Nozzle Diaphragm

The nozzle diaphragm of the first stage consists of inner support 1, outer ring 18, radial struts 15 accommodating bolts in their threaded ends, and hollow vanes 19 with flanges cast of alloy.

Inner support 1 is attached to the flange of rear casing 4 with the help of fifteen fitted bolts; it comprises part of the engine inner load-carrying system.

Outer ring 18 is secured together with nozzle diaphragm casing 20 to the rear flange of the combustion chamber and constitutes part of the engine outer load-carrying system.

Struts 15 and the bolts accommodated in their ends, connect concentrically the inner support and the outer ring, and link the inner and outer load-carrying systems of the engine.

Nozzle diaphragm vanes 19 (40 pieces) are mounted on struts 15 and are retained by screws 17; adjustment of the nozzle diaphragm area is accomplished by rearrangement of eccentric blocks 16, having various groups of eccentricity. The outer and inner flanges of the nozzle diaphragm vanes form the tapered profile of the flow path.

Turbine First-Stage Rotor

The high-pressure rotor rests on two supports: the front support is represented by a double-row angular ball bearing, accommodated in the compressor; the rear support is formed by turbine roller bearing 8. The cup of roller bearing 8 with the cage and the rollers is mounted in holder 7, which is drawn to the flange of rear casing 4 by twelve bolts 58.

Roller bearing cone 10 is fastened to bush 11 by means of nut 12 and lock 13.

Connection of turbine first-stage rotor shaft 47 to the high-pressure compressor shaft is accomplished by means of splines; mutual alignment of the shafts is ensured by two cones I and II; angular displacement is prevented by retainer 54 attached to shaft 47 by screw 55.

The rotor of the turbine first stage consists of shaft 47, disc 35, and blades 21.

Dowel-located at the rear end of the shaft are the following components: ring holder 6, shaft bush 11, and inner bearing holder 41.

The disc is connected to the shaft with the aid of an adjusting band and sixteen radial dowels 39.

Blades 21 (61 pieces) are fabricated in heat-resisting alloy. They are secured to the disc with the aid of five-tooth fir-tree locks. The blades are held against displacement by plate locks 14.

The rotor is subjected to dynamic balancing which is accomplished by rearrangement of the blades and installation of balancing bolts 2 and 34.

Apart from this, the high-pressure turbine rotor and the high-pressure compressor rotor are subjected to joint balancing when positioned at a certain angle relative to each other.

Second-Stage Nozzle Diaphragm

The second-stage nozzle diaphragm consists of casing 20, thirty eight vanes 30 cast from alloy and attached to the inner surface of the casing by means of bolts 29 and ring 32.

The outer and inner flanges of the vanes constitute tapered surfaces of the second-stage nozzle diaphragm flow path; the projecting outer flanges make up the shroud of the first-stage turbine; the casing of the nozzle diaphragm constitutes the shroud of the second-stage turbine; the bosses of the inner flanges form two cylindrical surfaces for labyrinth sealings.

Ring 32 ensures stability of the labyrinth cylindrical surfaces. Adjustment of the nozzle diaphragm area within a narrow range can be performed by turning the blades at the expense of the clearances between bolts 29.

Fitted between the end faces of the first and second stage vane flanges are sealing gaskets of asbestos cord, enclosed in thin steel sheathing.

Second-Stage Turbine Rotor

The low-pressure rotor rests on two supports. The front support is represented by a radial thrust ball bearing, accommodated in the shaft; the rear support is constituted by inner roller bearing 25 of the second-stage turbine rotor.

The outer ring of this bearing is mounted in holder 41 pressed into shaft 47 and is secured by nut 26.

The inner ring of the roller bearing is fastened by nut 23 on inner shaft bush 22.

The shaft of the low-pressure compressor and the shaft of the turbine second-stage rotor are coupled by means of splines; axial forces from the low-pressure rotor are trans-

mitted by spherical nut IV, which also serves to prevent longitudinal displacement.

Nut IV is retained by locking bush 51, spring 52, and thrust rings 53.

The rotor of the first-stage turbine consists of inner shaft 48 with disc 36, carrying 64 shrouded blades 31.

Located at the rear end of shaft 48 by means of dowels are: labyrinth ring 44, shaft bush 22, and blanking cover 42. Machined on the shaft, below the bush, are spiral grooves and a circular recess serving for passage of the cooling air whi[ch] prevents heat exchange between shaft 48 and roller bearing 2[5].

The connection of the shaft with the disc is a fork type: the rear end of the shaft is fitted between two machi[ned] lugs of the disc. Twenty radial dowels securing the joint, provide for the necessary strength of the structure.

Blades 31 (64 pieces) are made of heat-resisting alloy. The blades are held in the disc by five-tooth locks of the fir-tree type.

The blades are retained in place by plate locks 33.

The shank section of the blades has a three-knife lug serving as a gas labyrinth.

The shroud provides for damping blade vibrations.

The shroud components are fabricated in heat-resisting alloy and comprise 32 shroud sections 56 and 32 shroud bus[hes]. The shroud sections are fitted into the holes of blades [31] so that each section covers two blades. Mounted into the holes, between two neighbouring sections are shroud bushes. The latter are made tubular to reduce centrifugal forces.

The rotor of the second-stage turbine is balanced by rearranging the blades and by installing balancing bolts 3[?] and 45.

When assembling the turbine unit it is necessary to ensure longitudinal clearances H_1 and H_2. Clearance H_1 i[s ensured] by proper selection of calibrated washer 5[?] prior to insta[l]ling the rotor of the second-stage turbine. Clearance K_2 [is] provided by selecting proper calibrated washer VI, when installing the second-stage rotor; to preserve longitudinal play on the sphere of nut IV, the thickness of calibrated washer VII is so selected as to suit washer VI. Washer VII is secured in nut IV by a retaining ring, whereas washer VI is held on shaft 48 with the aid of thread, cut on the shaft shank and tapped on the inner diameter of washer VI.

Lubrication of Roller Bearings

The roller bearings are lubricated with the help of oil injector M. The rear roller bearing of the first-stage rotor is lubricated directly by the oil spray issuing from three upper holes of the injector. The inner roller bearing is lubricated by the oil flowing due to the centrifugal force from two jets 9. Oil to these jets is fed from the tray formed by shaft bush 11; the tray is continuously filled with oil discharged from two lower holes of jet M.

The oil spaces of the bearings are sealed by rings 5 and 43, ring holders 6 and 22, and by packing bushes.

Turbine Cooling (Fig.10)

The turbine is cooled by the air bled from the air path of the engine.

1. Cooling of the casings and nozzle diaphragm vanes of the first and second stages is accomplished by utilizing the secondary air of the combustion chambers, entering the holes in the combustion chamber housing flange in the direction of arrows"6". Part of this air flows inside the vanes of the first-stage nozzle diaphragm (in the direction of arrows "a"), cools to some extent the nozzle diaphragm casing and the upper flanges of the second-stage nozzle diaphragm vanes (in the direction of arrow "a") and further mixes with the hot gases in the flow path of the turbine. A portion of the air escapes through the clearances between the flanges of the nozzle diaphragm vanes and also mixes up with the hot gases.

2. The turbine discs are cooled by the air bled from the sixth stage of the compressor and delivered along two pipes "h".

3. For cooling the peripheral part of the first-stage disc and for building up pressure both forward of the first-stage disc and in the interdisc space, this air is mixed up with the secondary air of the combustion chambers, supplied via holes y provided in the inner support and in shield 60.

Shield 60 forces the cooling air against the diaphragm surface of the first-stage disc, thereby increasing heat dissipation and preventing adverse circulating air currents in the space forward of the first-stage disc.

From this space part of the air escapes through the gas labyrinth and the fir-tree roots of the blades into the flow path of the engine.

A portion of the air, passing through air labyrinth 59 into space E, is bled via eight pipes "f" into the compressor pressure chamber and further into the atmosphere.

The bulk of the air passes through eight holes r, provided in the diaphragm of the first-stage disc, thereby finding its way into the interdisc space.

After cooling the rear surface of the first-stage disc and the front surface of the second-stage disc, the air is discharged into the flow path of the engine:

(a) through the clearances in the fir-tree roots of the second stage blades (this causes intensive cooling of the second-stage disc rim);

(b) through the clearances in the air-gas labyrinth H, (thereby cooling the shanks of the second-stage blades);

(c) through clearances M in the rear group of the knives of labyrinth 44, via the holes made in this labyrinth and via holes, provided in the shaft and the disc of the second stage.

4. To safeguard bearing 25 against overheating and to reduce heat transfer to the oil from the first-stage disc, provision is made for blowing the central hole in the first-stage disc by the air bled from the third stage of the

compressor. This air flows inside the shaft of the second-stage turbine in the direction of arrows K and via the holes in the front wall of labyrinth ring 44 enters the central hole in the first-stage disc. This air is discharged into the atmosphere through the milled grooves of the shaft, space E and via four pipes I.

For discharging the cooling air into the atmosphere, provision is made in the rear casing of the compressor for two flanges furnished with holes. Part of the cooling air is discharged via the left-hand group of the knives of labyrinth И and is bled aft of the turbine (in the direction of arrow Л through the central hole of the second-stage disc.

Chapter IV

AFTERBURNER

The afterburner comprises two main assemblies: a dif-fuser (Fig.11) and an adjustable jet nozzle (Fig.12). The diffuser serves for slowing down gas flow velocity, which facilitates flame stabilization and favours controlled com-tion of the fuel. An additional amount of fuel burnt in the afterburner allows a short-time augmentation of the engine thrust. The adjustable jet nozzle is used for attaining various operating ratings of the engine.

The diffuser and the adjustable jet nozzle are connected by means of a telescopic ring, which allows the adjustable jet nozzle axis to be somewhat misaligned relative to the diffuser axis. The afterburner is attached to the flange of the second-stage turbine nozzle diaphragm by 76 bolts.

Afterburner Diffuser (Fig.11)

The diffuser casing includes outer wall 1, inner wall and five fairings 3, connecting both walls. Each of the fair-ings is secured to the inner wall of the diffuser with the aid of four bolts, whereas in the outer wall they are held by two pins fitting into bushes; this arrangement allows expansion of the inner wall relative to the outer wall. The fairings are also designed for elimination of gas stream swirling, which is likely to occur aft of the turbine (the section of the fairings is given the shape of aerodynamic profile).

The outer wall mounts five bosses for thermo-couples and a boss for bleeding pressure P_4 supplied to the regulator of pump HP-220. Bolted to the inner wall are flame igniter 17 and the casing of flame holder 8. The casing face acts as a central flame holder.

Secured to the inner wall by five links 4 is also inner circular flame holder 5. The links allow the circular flame holder to freely expand relative to the casing of the flame holder. The inner circular flame holder has five flame propagation ribs, arranged radially relative to the flame holder casing.

Outer flame holder 3 is secured to the outer wall of the diffuser casing with the aid of ten links 7 and is furnished with ten flame propagation ribs, arranged radially relative to inner circular flame holder 1.

Outer manifold 10 is held to the outer flame holder by ten shackles 11.

The manifold mounts 60 fuel injectors, including 40 injectors uniformly spaced on the manifold ring, and 20 injectors located on the pipes branching from the manifold; 10 of these injectors supply fuel to the space before the flame propagation ribs of the outer flame holder, 10 others delivering fuel into the space between the flame propagation ribs.

Inner manifold 12 is secured with the aid of five shackles 13 to the inner flame holder. The manifold ring carries 40 fuel injectors, including 30 injectors uniformly spaced on the manifold ring and 10 injectors arranged on the pipes, branching from the manifold; five of these injectors supply fuel into the interrib space the other five supply fuel to the ribs.

Branching from the inner manifold towards the centre are two pipes carrying starting injectors 21, which deliver fuel to the central zone of the afterburner. The pipes of the starting injectors pass through the slots provided in the flame holder casing.

The pipes conveying fuel to both manifolds project outside through the flanges on the outer wall, accommodating spherical bushes which prevent any loads to be imposed on the manifold fuel supply pipes during assembly or operation.

Hinged attachment of the manifolds (by means of shackles 11 and 13) allows elimination (during assembly) of any manufacturing error; the above arrangement also makes for differences in thermal expansions. The injectors, exclusive of the starting ones, deliver fuel against the gas stream; for this, the injectors are projected forward by 170 mm from the flame holder edges, against the gas stream. The entire fittings and the pipes of the fuel manifolds are soldered with the aid of heat-resisting solder.

Flame igniter 17 is located in the central part of the diffuser and serves for ignition of the afterburner. It consi[sts] of a casing with spark plugs and detachable nozzle 15. The nozzle is held to the flame igniter with the aid of a union nut and a retaining lock.

The ignition of the afterburner is accomplished with the help of a torch which results from combustion of fuel mixture. The fuel mixture is prepared in the carburettors (Fig.21) made in the form of tee-pieces and arranged in series. Air is supplied to the carburettors via a pipe from the compressor sixth stage; fuel metered by the flow restrictors and delivered via the electromagnetic valves from the main and primary fuel manifolds of the engine, is injected into the air stream. From the carburettors the fuel mixture is delivered via pipe 16 (See Fig.11) into the flame igniter, where it is ignited by the spark plugs; the resulting torch is directed to the walls of flame holder casing 8 in three radial jets, projected through the ports of nozzle 15.

An additional amount of air bled from the compressor is carried along pipe 14 and is delivered into the casing of flame igniter 17; then the air passes into the inner cavity of the flame igniter through two rows of holes. This air cools the walls of the flame igniter outlet portion thereby improving the combustion process. The pipes supplying the carburized mixture and the air (16 and 14 respectively) pass inside the fairings. Where the pipes cross the outer wall, they are sealed with the aid of spherical bushes arranged in the flange of the outer wall.

Spark plugs 18 of the СЭ-21Д5 type are turned into the flame igniter casing bosses and are retained by wire 3. Voltage is supplied to the spark plugs via adapters 19 of the П-12А type and busbar 20. The adapter spheres are secured to the outer wall by means of union flanges. The lower ends of the adapters are supported on the inner wall by a bracket, provided with a flange having spherical bushes. The adapters are guarded against turning by locks, fitting into the adapter recesses and fastened to the outer wall flange.

The rear flange of the diffuser casing mounts split ring 22 incorporated in the telescopic connection of the afterburner diffuser with the adjustable jet nozzle. The lower part of the ring carries fuel collector 9 serving for draining of fuel dripping from the telescopic connection.

Adjustable Jet Nozzle

The adjustable jet nozzle (Fig.12) comprises pipe 1 having a progressively decreasing diameter. The pipe is welded from sheet metal. The front part of the pipe is fitted with a flange for attachment to the diffuser by means of a telescopic connection.

The rear portion of the pipe terminates in a flange, mounting thirty six welded lugs 2 for attachment of flaps 3; riveted to the flange are also six brackets 4 serving for attachment of three actuating hydraulic cylinders 6 with ring 7, secured by six posts 5. The brackets are coupled to the posts by means of pins and spherical bushes. Beside two lugs for attachment of the post, each of brackets 4 is provided with two lugs for securing the flaps.

Twenty four flaps capable of turning in the radial plane change the exhaust area of the jet nozzle.

Ring carries three uniformly spaced brackets, each mounting one hydraulic cylinder with two posts secured to spherical supports. Ring 7 serves at the same time for laying the hydraulic cylinder manifolds. The flaps are retained in the required position by load-carrying ring 8, which is connected to the hydraulic cylinder rods by means of three pins with spherical bushes.

The hydraulic cylinder rods displace the ring: with the ring moving forward, the flaps close; when the ring travels backwards, gases issuing from the nozzle force the flaps to open. Riveted to the inner surface of the ring are twenty four profiled knurled copper straps coated with graphite. Through the medium of these straps the ring contacts the outer profiled surfaces of the flaps.

Flaps 3 are of welded construction. They are made up of the outer and inner walls accommodating a rib. At one side the walls form a wing, at the other - a recess. When assembled, the wing of one flap enters the recess of the other.

The inner wall of the flap is enamelled to increase its heat resisting properties, whereas the outer wall is chrome-plated to reduce friction against the copper straps of the ring. Welded to the inner and outer walls in the front part of the flap are two hinges serving for attachment of the flap to the rear flange of the adjustable nozzle casing.

To safeguard the inner skin of the aircraft fuselage against the direct effect of the heat generated by the afterburner, and to provide for a constant flow of cooling air, the afterburner is fitted with two non-split casings 9 and 11. Cooling air passes between the casings and enters the inner cavity of the adjustable jet nozzle flaps, thereby cooling the latter. The casings are fabricated in thin sheet steel reinforced by wire and straps. The casings are aligned by special supports welded to the pipe. Rear casing 9 is secured by twelve bolts to jet nozzle hangers 10 and by four bolts to the pipe supports. The front casing is coupled to the rear one by means of 16 bolts.

The rear casing is provided with six ports giving access to the places where the hydraulic cylinder attachment ports are coupled to the brackets on the rear flange of the pipe. These ports are fitted with covers 12, secured to the casing by two straps and two bolts each.

Inside, the pipe is provided with corrugated anti-vibration screen 13, which guards the pipe against vibration turning. Holes in the screen accommodating bolts 15 are given oval shape, which allows for free thermal expansion of the screen relative to the casing.

Arranged on the outer surface of the pipe is a number of circular shrouds, imparting the necessary rigidity to the most loaded areas (rear flange, hanger zone, etc.); the shrouds also serve to ensure the required stability of the pipe.

Chapter V

ENGINE ACCESSORY DRIVES

Mechanical Diagram (Fig.13)

The engine accessories are driven by the shaft of the high-pressure rotor ($П_2$) and by the shaft of the low-pressure rotor ($П_1$) (Fig.13). The rotary motion of the low-pressure rotor shaft is transmitted through a pair of spur gears, two pairs of bevel gears, and the coupling shaft to the oil scavenging pump and to tachometer generator ДТЭ-1($П_1$). The shaft of the oil scavenging pump drives the regulator of main fuel pump НР-21Ф through a pair of spur gears and a universal shaft. The accessories mounted on the engine wheel case are actuated by the high-pressure rotor through a pair of spur gears with a coupling shaft; one of the gears is fitted on the rotor shaft, the other being accommodated in the drive housing. The coupling shaft rotation is transmitted to the wheel case bevel gears.

The accessories mounted on the engine wheel case include: main regulating fuel pump НР-21Ф, afterburner regulating fuel pump НР-22Ф, two hydraulic pumps НП-34-2Т, centrifugal breather, fuel booster pump [illegible], starter-generator ГСР-СТ-12000ВТ, oil unit, tachometer generator ДТЭ-1 ($П_2$), and deaerator.

The starter-generator drive incorporates the following units: a two-speed drive transmitting the torque from the starter to the high-pressure rotor shaft and having a gear ratio of 2.249; after the engine has been started, the torque is transmitted to the generator, with the gear ratio amounting to 1.344.

Table
Engine Accessory Drive Gear Ratios

Name of accessory unit	Type	Gear ratio	Direction of rotation	Location
1	2	3	4	5
Starter-generator	ГСР-СТ-12000ВТ	1.344 2.249	Counter-clockwise	Engine wheel case
Fuel pump	HP-21Ф	2.778	Clockwise	Wheel case
Fuel pump	HP-22Ф	2.572	Clockwise	Same
Hydraulic pumps	НП-34-2Т	3.008 3.0[illegible]4	Counter-clockwise	Same
Fuel booster pump	ДЦН13-ДТ	1.344	Counter-clockwise	Wheel case
Oil unit	-	3.175	Clockwise	Same
Deaerator	-	2.[illegible]83	Same	Same
Centrifugal breather	-	[illegible].856	Same	Same
High-pressure rotor (n_2) tachometer-generator (installed by aircraft Manufacturer)	ДТЭ-1	4.571	Same	Oil unit

1	2	3	4	5
Low-pressure rotor (n_1) tachometer-generator (installed by aircraft Manufacturer)	ДТЭ-1	4.461	Counter-clockwise	Pump scavenging oil from front support
Pump scavenging oil from front support	-	4.461	Same	Front casing

Notes: 1. Direction of rotation is given as viewed from the drive side.

2. Gear ratio is presented as a result of $\frac{n\ driving}{n\ driven}$.

Engine Wheel Case

The engine wheel case (Fig.14) is arranged in the lower part of the engine and is secured by six bolts to the bracket of the combustion chamber housing. The wheel case is driven by the high-pressure rotor through a pair of bevel gears and a coupling shaft. The driving bevel gear is fitted on the rotor shaft and is held in position by a key and a nut. The driven gear runs in the drive housing in two bearings, a radial thrust ball bearing and a roller bearing minus the inner cone. The coupling shaft of the wheel case drive splines the driven gear to driving bevel gear 33, mounted directly in the wheel case on two supports: a radial thrust ball bearing and a roller bearing. The driving bevel gear imparts rotary motion to driven gear 34 coupled with the aid of fitted bolts to the spur gear of the accessory drive, which is made integral with the drive shaft.

Apart from the bevel gear, the shaft mounts two spur gears 8 and 9 which transmit the torque to the drive gears of regulating pumps HP-21Ф and HP-22Ф; gear 27 actuates starter-generator ГСР-СТ-12000ВТ, fuel booster pump ДЦН13-ДТ, and hydraulic pumps НП-34-2т. The driven gears of the fuel pumps are mounted in the engine wheel case on two narrow-type ball bearings and have inner splines for connection to the pump shanks. Engaged with the driven gear of regulating pump НР-21Ф is deaerator drive gear 18. Two-speed drive gear 30 is fitted into a splined bush, accommodating the coupling shaft driving bevel gear 15 of the oil pump. Gear 26 driving fuel booster pump ДЦН13-ДТ is fitted on the splines of bevel gear 6 driving the centrifugal breather.

Through the medium of inner splines and coupling shafts 23 and 29, the bevel gear driving the centrifugal breather, and the splined bush of the oil pump drive, transmit the torque to two-speed drive, booster pump ДЦН13-ДТ and to gears 25, 22, 21 and 47 driving hydraulic pumps НП-34-2Т mounted on ball bearings in the adapters and housing.

Driven bevel gear 4 of the centrifugal breather drive is enclosed in the engine wheel case; it is mounted on two narrow-type ball bearings and serves for transmitting rotary motion to the centrifugal breather through the medium of inner splines and coupling shaft 3. Oil pump drive gear 13 is splined to the oil delivery pump shaft and is held in place by a nut.

Two-Speed Drive

Two-speed drive 42 comprises a transmission consisting of a housing and a cover, fabricated in magnesium alloy МЛ5, four spur gears 35, 38, 39, and 49, two free-wheeling clutches 36 and 37, and disc friction clutch 41. Free-wheeling clutch 37 is mounted on the shaft of the driven gear(used for engaging the starter); ratchet clutch 36 is coupled to intermediate gear 35 with the aid of dowels; the friction clutch is designed for limiting the starter torque during engine starting.

With the starter-generator operating as a starter, the torque is transmitted via the ratchet clutch and the intermediate gears, as well as via the gears of the engine wheel case and the central drive to the compressor high-pressure rotor shaft. In this case the free-wheeling roller clutch is disengaged due to the difference in the speeds of the clutch ring and the carrier with the rollers, which has a lower speed; therefore, no wedging of the rollers (engagement of the clutch) can take place.

After the engine has been started, the starter-generator begins running as a generator, that is, the torque in this case is transmitted from the engine shaft to the generator, the ratchet clutch being disengaged due to the fact that the carrier with the dogs outruns ratchet gear 39 thereby causing the centrifugal forces to disengage the dogs from the gear ratchet. Simultaneously, the free-wheeling roller clutch comes into engagement, as the carrier with the rollers starts running at a higher speed than the ring, and the rollers get wedged; in this case, rotary motion is transmitted to the generator directly, without involving the intermediate gears of the two-speed reduction unit.

Attachment of regulating fuel pumps НР-21Ф, НР-22Ф, booster pump ДЦН13-ДТ, hydraulic pump НП-34-2Т starter-generator ГСР-СТ-12000ВТ to the engine wheel case is accomplished by the use of quick-disconnect clamps 11, 24, 19, and 14, comprising a strap consisting of two halves, clamped on the tapers of the intermediate parts by means of bolts. Other units are secured by bolts and studs.

The location of the units, their direction of rotation, and gear ratios are referred to in the respective Table.

Chapter VI

LUBRICATING SYSTEM

Lubricating System Circuit

The P11Ф-300 engine is provided with a close-circuit autonomous lubricating system (Fig.15), which makes any additional connections on the aircraft unnecessary. All units of the lubricating system are installed on the engine. Oil tank 5, fuel-cooled oil cooler, and the fuel filter have been combined into one fuel and oil unit 357C. Delivery pump 7, three scavenging pumps 23, 24, and 25, fine oil filter 10, reducing valve 11, and non-return valve 14 likewise constitute a single oil unit.

With the engine running, oil from service tank 5 is supplied by delivery pump 7 into the high-pressure line via filter 10 and non-return valve 14. Pressure in the high-pressure line is maintained at the required level by reducing valve 11. The function of the non-return valve is to prevent oil flow from the tank into the engine, with the aircraft parked. Removal of air locks which are likely to be formed when the oil tank is being filled, or when the engine is running (in the line leading from the oil tank to the delivery pump) is accomplished through the pipe conveying oil to the front support. In this case oil flow from the tank (on the ground) is precluded, the oil level in the tank being lower than the oil level in the front support.

Along the lines running in the engine wheel case and inside the engine, oil is delivered to low-pressure and high-pressure rotor shaft supports 1, 16, 17, 32, and 33 to the bearings and bevel gears of engine wheel case drive 18, to the bearings and gears of engine wheel case 27, as well as to the gears of scavenging pumps 23, 24, and 25. The amount of oil carried to the engine components depends on the clear openings of the jets, installed in the delivery lines. The jet capacity values are given in Fig.15.

On its way to the middle and rear supports the oil is passed through safety filters 15 and 31, located forward of the respective jets; this arrangement prevents the jet ducts from being clogged with scale, likely to be encountered in the steel pipe lines.

Used oil saturated with air is drained into the oil sumps, whence it is scavenged by four gear-type pumps; oil from the middle and intermediate supports of the compressor being scavenged by pump 24; from the rear support and the inner support of the turbine - by pump 23, from the engine wheel case - by pump 25; and from the front support - by pump 2 arranged in the lower part of the front casing. The intakes of the scavenging lines running from the middle and rear supports and from the engine wheel case are fitted with protective filters.

Oil scavenged from the front support is delivered to the engine wheel case. Oil scavenged by the three other pumps flows in a single stream into deaerator 28. The air separated therein passes through the centrifugal valve and into the engine wheel case, whereas the oil is carried through fuel-cooled oil cooler 3, back into the oil tank.

The cavities of the front casing bearing holder, the engine wheel case, and of the oil tank are interconnected by the breather line and communicate with the atmosphere via centrifugal breather 30. The centrifugal breather separates air from the oil particles and directs oil along the duct into the engine wheel case.

To prevent oil escape from the oil cavities of the engine, provision is made on the shaft of the compressor and the turbine for special sealings. The front casing is sealed on both sides with the aid of flexible rings and labyrinths. The space between the rings and the labyrinths is pressurized with air bled from the sixth stage of the compressor. The inner space of the rotor shaft enclosing the middle and rear supports is sealed on the compressor and the turbine sides with flexible cast iron rings and labyrinths. Apart from the sealing rings a double labyrinth is fitted on the turbine side.

To provide the necessary pressure forward of the rings, the space between the rings and the labyrinths of the middle support is connected by a duct to the rear pressure chamber of the compressor. Connected to the pressure chamber by means of eight pipes is also the space between the labyrinths of the rear support. Pressure in the pressure chamber of the compressor is adjusted during stand tests by installing the respective diaphragm on the outlet ports."

Located under the outlet connection of the cooling air space is a diaphragm serving for adjustment of pressure in the space between the labyrinth and the sealing rings of the rear support.

The oil system is checked for proper functioning with the help of delivery line pressure transmitter 6 and inlet oil temperature transmitter 9.

Oil can be discharged from the engine via two cocks: cock 26 is located on the oil tank, and cock 29 - on the engine wheel case.

CONSTRUCTION OF ENGINE ACCESSORIES

Oil Unit

The oil unit (Fig.10) consists of a cast magnesium housing, enclosing the following units: (a) three-stage scavenging pump 2, oil filter 3, reducing valve 6, and non-return valve [illegible], (b) delivery pump 1, mounted on the flange, serving for attachment of the housing to the engine wheel case. The cover of the scavenging pump mounts the drive of the high-pressure rotor tachometer generator.

The delivery pump comprises a housing and a cover fabricated in aluminum alloy, two pumping gears, fixed bronze

shaft, and driving shaft whose end carries a bevel gear, transmitting the torque from the engine wheel case drive to the oil unit. Rotation from the delivery pump shaft is transmitted by coupling shaft 10 to the driving shaft of the scavenging pump and via a pair of bevel gears to the tachometer generator drive. The delivery pump is secured to the oil unit housing by four bolts 13.

Scavenging pump 2 consists of three stages, each stage comprising an aluminum housing and two pumping gears. The housings and the covers are held to the housing of the oil unit by four bolts 11. The joints are sealed by rubber rings. All three stages have a common driven gear shaft, manufactured from bronze, and a common driving shaft, the scavenging gear being made integral with the shaft; two other gears are keyed to the shaft.

To improve the suction ability of the pumps, their outlet cavities are supplied with oil from the pressure line via pipe 9; fitted at the pipe inlet, is non-return valve 12, preventing oil flow from the tank, when the aircraft is parked.

The driving shafts of the scavenging and delivery pumps are fitted with sealing cups, precluding oil leakage from the tank when the aircraft is parked. During engine operation the cups are relieved of the oil pressure due to ports communicating with the suction cavity.

Oil filter 3 consists of 17 sections, fitted on a cylindrical frame and clamped with the help of a calibrated ring. Each of the sections consists of corrugated diaphragms, two frame grids, two fine gauzes and inner and outer holders. The filter frame along with the sections is held by a flexible ring to the filter cover, the entire unit being studded to the oil unit housing.

Oil from the delivery pump flows via the ducts in the housing into the oil filter cavity whence it is passed via the gauzes inside the filter and further into the pressure line. In case the gauzes are clogged, the oil flows through safety valve 4, by-passing the filter.

Non-return valve 5 is a mushroom spring-loaded type; it yields to a pressure of 0.3 - 0.45 kg/sq.cm.

Reducing plate-type valve 6 maintains the predetermined pressure of 3.5 - 4 kg/sq.cm.; the valve is adjusted with the aid of a screw, brought outside.

Deaerator

The deaerator (Fig.17) mounted on the engine wheel case is composed of magnesium housing 5, aluminum cover 3, aluminum rotor (centrifuge) 4, oil deflector 2, centrifugal valve 6, and central shaft 1, mounted in two ball bearings. The end of the shaft is splined for connection to the engine wheel case drive. The oil-air mixture from the scavenging pumps is delivered to the rotor (centrifuge) of the deaerator, where the centrifugal forces separate air from the oil. The air escapes into the engine wheel case via the shaft and centrifugal valve 6, whereas the oil via the circular clearance of the rotor flows along the pipe into the oil tank cooler. The centrifugal valve, enclosed in the shaft prevents oil flow into the engine wheel case when the engine runs at a low speed.

Centrifugal Breather

The centrifugal breather (Fig.18) is designed for separating oil from the air finding its way into the oil space of the compressor rear casing end for maintaining pressure in this space at a constant level irrespective of altitude.

Air mixed with oil enters through the flange of the engine wheel case into breather housing 1 and comes across breather rotor 2, which is actuated by the coupling shaft having splines 3. The breather rotor rides in two radial ball bearings, mounted in housing 1 and in distance piece 4 provided with duct 5, conveying oil from the engine wheel case to the ball bearing. The ball bearing, installed at the breather inlet is lubricated by the emulsion flowing through it. The oil

settling on the breather rotor is carried by thread 6 into collector 7 and is further turned into the engine wheel case via duct 8.

To prevent oil threw, the breather rotor trunnion is provided with slinger ring 19 and two sealing rings 9, installed back of the bearing.

The air separated from the oil passes through eight oval ports between the vanes and into the breather rotor; further, the air enters breather cover 11 via pipe 10, and into connection 13 via sylphon chamber cavity 18; from the connection the air is discharged into the atmosphere. Sylphon chamber cavity 14 is made air-tight, and is capable of preserving a constant pressure, the sylphon proper inside the chamber being precompressed to offset thermal expansion.

As the aircraft climbs, the absolute pressure in cavity 18 drops, causing the pressure differential at the sylphon to increase, as a result of which sylphon cover 15 bars air outlet from pipe 10. This causes plate-type valve 16 to operate; the valve is loaded with spring 17 adjusted to a constant excess pressure in the oil cavities of the engine.

In this case, the air from the rotor escapes through holes 12 (overcoming the force of spring 17 of valve 16) and enters connection 13 whence it is discharged into the atmosphere via the aircraft breather line.

Front Support Oil Pump

The oil pump of the front support (Fig.19) includes a scavenging gear-type pump and two drives: to the low-pressure rotor tachometer generator, and to the centrifugal governor of the fuel pump. The scavenging pump and the drives are accommodated in aluminum housing 4 fitted with two aluminum covers 2 and 7. Cover 2 serves as a support for the trunnions of the pumping gears. It also mounts adapter 1 with a thread for receiving the tachometer generator. Cover 7 acts as a support for the shafts of the drive gears. The housing is provided with a flange, serving for attachment to the front casing (in its lower part) with the aid of a quick-disconnect clamp.

The pump drive is actuated by the shaft of the low-pressure rotor through the medium of a spur gear, made integral with the rotor shaft, an intermediate gear, a pair of bevel gears accommodated in the front support casing, and coupling shaft 5 passing through the vane of the first guide vane assembly. In the drive proper, rotary motion is transmitted from the coupling shaft to driving gear 3 of the scavenging pump by a pair of bevel gears and to the techometer generator through the medium of the inner square, provided in the trunnion of the pump gear.

Spur gear 6 dowelled to the driving bevel gear, imparts rotation to the hollow shaft of the governor drive accommodating bush 10 coupled to the shaft with the aid of end face grooves. Connected to the bush is cardan shaft 8; the connection is accomplished by means of spherical bronze retainer 9, which is a sliding fit on the shaft end. The shaft can be extracted through the hole provided in the drive housing; to take out the shaft, the plug and bush 10 should be removed first. These parts are sealed with rubber rings; the rotating shafts of the drives are sealed by rubber cups. The cardan shaft is enclosed in a corrugated rubber tube, clamped at the ends with straps.

Oil from the front support flows inside one of the guide vanes and along the outer pipe to enter the scavenging pump, whence it is delivered via an outer pipe into the engine wheel case. Some oil scavenged from the front support housing is utilized for lubrication of the drive gears and their ball bearings.

Chapter VII

ENGINE FUEL SYSTEM AND AUTOMATIC EQUIPMENT

The function of the engine fuel system and automatic equipment is to supply and regulate the amount of fuel fed into the combustion chambers and into the afterburner, depending on the engine rating; the fuel control units are also designed for engine starting and afterburner ignition, as well as for control of the engine and the jet nozzle flaps.

The fuel system and the automatic equipment include (Fig.21):

(1) main fuel tank (aircraft);
(2) fuel booster pumps (aircraft);
(3) fuel flow meter (aircraft);
(4) fuel shut-off cock (aircraft);
(5) fuel pump ДЦН13-ДТ with permanent pressure valve;
(6) fuel and oil unit with fuel filter;
(7) main fuel regulating pump НР-21Ф;
(8) main fuel manifold;
(9) primary fuel manifold;
(10) combustion chamber burners;
(11) afterburner fuel regulating pump НР-22Ф;
(12) regulating needle No.1 - adjusting (P'_2);
(13) regulating needle No.2 - limiting (P''_2);
(14) afterburner inner manifold;
(15) afterburner outer manifold;
(16) afterburner ignition system electromagnetic valves;
(17) afterburner ignition flow restrictors;
(18) afterburner carburettors;
(19) afterburner flame igniter;
(20) starting fuel tank (aircraft);

(21) starting fuel filter (aircraft);

(22) starting fuel pump (aircraft);

(23) starting fuel electromagnetic valve;

(24) electromagnetic valve controlling additional fuel at starting;

(25) combustion chamber flame igniters;

(26) oxygen bottle (aircraft);

(27) oxygen shut-off cock (aircraft);

(28) oxygen pressure reducer (aircraft);

(29) electromagnetic oxygen valve (aircraft);

(30) non-return oxygen valve;

(31) electromagnetic air blow-off control valve;

(32) valves for compressor air blow-off at starting;

(33) control unit БУ-4Б;

(34) ratings control panel ПУРТ-1Ф;

(35) rheostatic transmitter ДР-3А;

(36) regulating rheostat Р-1;

(37) electro-hydraulic switch ГА-164М;

(38) hydraulic cylinders for control of jet nozzle;

(39) feed-back transmitter ДОС-1А;

(40) synchronizing valves;

(41) pulse delivery box (КБС, aircraft).

The starting system, the operation of the hydraulic cylinders controlling the jet nozzle flaps and of the automatic equipment is given in Chapters IX, X, and XI.

Fuel supply and regulation at sustained ratings and at starting and acceleration, as well as regulation of fuel delivery at augmented rating is accomplished by main fuel regulating pump НР-21Ф and by afterburner fuel regulating pump НР-22Ф.

Fuel is supplied to the engine as follows:

Fuel from tanks 1 flows via fuel booster pumps 2 and 3, the fuel and oil unit, and filter 6 to fuel regulating pumps НР-21Ф and НР-22Ф (7 and 11 respectively) and further to the engine burners. Combustion chamber duplex burners 10 are arranged in two fuel manifolds: manifold 9 accommodates the primary ducts, manifold 8 - main ducts. Fuel distribution

between the primary and main manifolds is the function of the distribution valve of fuel regulating pump НР-21Ф.

With the afterburner turned on, fuel regulating pump НР-22Ф delivers the amount of fuel required for the normal operation of the afterburner into the diffuser injectors, which are combined into two manifolds 14 and 15.

Ignition of the afterburner is accomplished by the use of flame igniter 19, employing carburized fuel mixture. The carburized mixture is supplied into the flame igniter as follows:

As soon as voltage is delivered to electromagnetic valves 16 fuel starts flowing from the primary and main manifolds into carburetors 18 to form a mixture with air supplied from the combustion chamber; further, the resulting fuel-air mixture is carried into the flame igniter furnished with spark plugs designed for ignition of the mixture; the amount of fuel necessary for ignition of the afterburner is metered by flow restrictors 17. Predetermined gas temperature forward of the turbine (at augmented rating) is regulated by regulating needle No.1 (12), whereas the predetermined travel range with regard to the afterburner fuel limiter is adjusted by regulating needle No.2 (13).

Control unit БУ-4Б (33) mounted on fuel regulating pump НР-22Ф performs the following functions (depending on the speed of the high-pressure rotor): disconnects the electric starter, causes the main spark plugs to be switched on for "exercising" (cam СТ), cuts off additional fuel supply, closes the air blow-off valves, and switches off the main plugs after "exercising" is over (cam ВДТ); the control unit also shifts the jet nozzle flaps from the FULL AUGMENTATION to the MAXIMUM position (cam БФО-1) and vice versa (cam БФО-2) to provide for engine starting and idling rating with the jet nozzle flaps set in the AUGMENTATION position.

To control the jet nozzle flaps in any of their positions at augmented rating, provision has been made for an electro-hydraulic control system (ЭГСУ-1А), including ratings control panel ПУРТ-1Ф (34), mechanically connected to the lever of regulating pump HP-21Ф; rheostatic ratings transmitter ДР-3А (35) and regulating rheostat Р-1 (36), mounted on control panel ПУРТ-1Ф; rheostatic feed-back transmitter ДОС-1А (39), installed in one of the hydraulic cylinders (38), controlling the jet nozzle, and electro-hydraulic switch ГА-164М(37) controlling the pulse delivery box (41). Synchronous operation of the two other control cylinders and of the master hydraulic cylinder (with transmitter ДОС-1А) is ensured by the synchronizing valves (40).

When the control lever is turned, the cams accommodated in the control panel perform the following functions:

Cam ПК blocks contacts of БФО-1 and Г3 when the afterburner is turned on (in case the speed of the high-pressure and low-pressure rotors drops to the respective r.p.m.).

Cam БФС switches on the afterburner (provides for ignition of fuel in the fuel igniter, delivery of afterburner fuel, and energizing of the electro-hydraulic system controlling the jet nozzle flaps).

Cam 4 provides for emergency, two-position control of the jet nozzle (when the electro-hydraulic system fails to operate in response to operation of a special toggle switch).

Cam Ф is not included in the circuit (being a stand-by one).

Transmitter ДР-3А provides for augmented rating (when the control lever is turned) by operating switch ГА-164М, thereby causing the jet nozzle flaps to be opened or partially closed.

Transmitter ДОС-1А takes care of the proper adjustment of transmitter ДР-3А and sets switch ГА-164М in the neutral position as soon as the hydraulic cylinder piston occupies the predetermined position, thereby ensuring a hydraulic lock.

Rheostat Р-1 serves for stand adjustment of the jet nozzle control system; rheostat МФ is designed to regulate jet nozzle area at minimum augmentation; the function of rheostat 1Ф is to provide for similar afterburner regulating range depending on the angle of turn of the control lever;

rheostat 2Ф is not included in the circuit (being a stand-by one).

Fuel Regulating Pump HP-21Ф

Fuel regulating pump HP-21Ф (Fig.23) represents the main unit of the fuel system, ensuring fuel delivery and automatic regulation of fuel amount supplied into the engine at any of the ratings.

The fuel regulating pump comprises the following main components:

- plunger pump;
- stop-cock and throttling valve (made as a single unit);
- hydraulic decelerator (Г3);
- centrifugal regulator of low-pressure rotor speed;
- throttling valve permanent pressure differential valve (КПП);
- distributing valve (РК);
- fuel pressure increase limiter (ОНД);
- starting fuel control unit (А3);
- drain valve;
- minimum pressure valve (disengaged) (КМД);
- thermocompensator of speed governor;
- fuel by-pass valve (КС);
- permanent pressure valve (КПД).

Pump Operation (Fig.23)

The operating principle of the pump is as follows. When pump rotor 63 is spinning, the pump plungers move reciprocally in their guiding wells arranged in the rotor, due to the inclined position of swash plate 66; the plungers draw fuel through the suction port of ported member 69 while the rotor turns through 180° and deliver fuel through the pressure port of the ported member into the high-pressure line while the rotor completes the revolution.

Further, the fuel at high pressure flows to throttling valve 2 via the duct.

To adjust the passage area with the throttling valve set in the IDLING RATING (МАЛЫЙ ГАЗ) position, provision is made for idling rating slide valve 3 enclosed in the throttling valve by-pass duct. When fully closed, the throttling valve acts as a stop-cock.

In case the automatic fuel metering system fails, the throttling cock may serve for emergency manual metering of delivered fuel.

Having passed throttling valve 2 and idling rating slide valve 3 fuel flows to distributing valve 6 via duct 4.

On the diagram the distributing valve is shown in its closed position. With the engine running, the valve opens and distributes fuel into the ducts of the burners. At relatively low pressures amounting to about 11 kg/sq.cm., the distributing valve only starts functioning; as a result, the profiled passage area of duct 9, conveying fuel to the primary manifold opens only partially; as the pressure builds up, the passage area of the duct gradually increases.

With the pressure building up to about 16 kg/sq.cm., duct 7 starts opening, its passage area gradually increasing thereby allowing a greater amount of fuel to be carried to the main fuel manifold. Thus, the construction of the distributing valve provides for the necessary changes in the pressure and fuel consumption by the fuel manifolds depending on the fuel pressure upstream of the distributing valve, in accordance with the engine rating.

Regulating Fuel Pump Operation when Regulating Fuel Delivery at Predetermined Engine Rating

Fuel delivery by the pump depends on the position of swash plate 66, whose angle of inclination affects the plunger travel, as well as on the pump r.p.m.

With the engine r.p.m. exceeding the value, which will be further termed as "automatic fuel supply minimum r.p.m. (НАР)", fuel delivery is controlled by the speed governor, which ensures (at any of the engine ratings) a practically permanent engine r.p.m. at any altitudes and speeds of flight, by changing the position of swash plate 66.

With the engine r.p.m. below the automatic fuel supply minimum r.p.m., fuel delivery is controlled by the throttling valve and permanent pressure differential valve 12, which maintains permanent pressure differential at the throttling valve, amounting to about 10 kg/sq.cm.

Thus, fuel consumption at a constant rate is ensured with the throttling valve in the same position, that is, sustained engine r.p.m. is provided at unchangeable flight conditions. The required engine r.p.m. can be attained by changing manually the passage area of the throttling valve.

Adjustment of the speed governor to the predetermined rating, with the engine running at r.p.m., exceeding the automatic fuel supply minimum r.p.m., and regulation of fuel consumption by means of changing the position of the throttling valve at lower r.p.m. is accomplished by manipulating common control lever 47, linked to the control lever located in the pilot's cockpit (through the medium of the lever on the ratings control panel).

Operation of Automatic Speed Governor

The main components of the automatic speed governor are as follows: low-pressure rotor centrifugal speed transmitter 36, centrifugal governor slide valve 41, centrifugal governor spring 45, swash plate piston 61, feed-back piston 58, feed-back slide valve 37, coupled to feed-back bush 43 through the medium of the lever, valve 14 maintaining permanent fuel pressure at the regulator inlet (in duct 13), and feed-back flow restrictor 57.

Permanent pressure valve 14 serves to ensure that the conditions of operation of the regulator servo-mechanisms are the same at any of the ratings, and that they are not changed due to the changes in the pressure of fuel at the pump outlet (in line 67).

As soon as the pressure in duct 13 increases, the valve overcomes the force of the spring and reduces the passage area. Fuel pressure in duct 13 drops to the predetermined value.

The valve spring maintains fuel pressure in duct 13 at about 15 kg/sq.cm.

In the centrifugal governor, the force acting on slide valve 41 is offset at the centrifugal transmitter side by the force of spring 45. The tension of spring 45 depends on the position of control lever 47. The bands of slide valve 41 are so arranged relative to the ports of feed-back bush 43, that the fuel delivered at a constant pressure via duct 13, creates a pressure differential in cavities 70 and 44, which is necessary to keep the servo-piston and the swash plate in the balanced position (on the diagram the governor is shown in its balanced position). In this case, duct 53 is closed by feed-back slide valve bands 37, and interpiston chamber 59 communicates neither with fuel supply duct 13, nor with the ducts provided in the feed-back slide valve, and serving for fuel drain into the low-pressure cavity.

With a reduction in the predetermined r.p.m., slide valve 41 will move to the right due to disturbance of balance between the force of centrifugal governor spring 45 and the force of the centrifugal weights. This will cause changes in the passage areas, both in the ducts leading from duct 13 to cavities 44 and 70 and in the ducts serving for fuel drain. An increase in the passage area of the duct carrying fuel into cavity 70 is accompanied by a simultaneous decrease in the passage area of the duct serving for fuel drain. The passage areas of duct 44 change in the reverse order, that is, the inlet passage area decreases while the drain passage area

increases. These events cause a change in the pressure differential at pistons 61 and 58, which results in displacement of the swash plate causing an increase in fuel delivery.

Suppose the capacity of interpiston chamber 59 does not change during operation of the governor; then, pistons 61 and 58 will move as a single unit. In this case, a reduction in the r.p.m. (due to a change in the flight conditions, for example) will cause both pistons to travel to the left thereby increasing fuel delivery rate, until the entire system comes to a state of balance again. In this new balanced position centrifugal governor slide valve 41 will practically occupy the initial position relative to the ports of feed-back bush 43, due to displacement of feed-back piston 58 and feed-back bush 43, connected to the former through the medium of feed-back slide valve 37 and feed-back lever 38.

If an increase is experienced in the predetermined r.p.m., the regulating procedure will be the same but will be performed in the reverse order.

With the centrifugal governor operating in the above manner, a stable regulation would be attained, but no initial r.p.m. would be regained at the required degree of accuracy.

To provide for stable regulation and to maintain predetermined engine r.p.m., at a constant level with great accuracy at any flight conditions, pistons 61 and 58 in the centrifugal governor of regulating fuel pump HP-21Ф are connected through the medium of chamber 59, capable of changing its capacity. The actual regulating procedure in the system of pump [illegible]-21Ф occurs as follows.

At any changes in the predetermined engine r.p.m., both pistons 61 and 58 first move as a single unit, that is in the manner described above; then, due to displacement of feed-back slide valve 37 from the neutral position, interpiston chamber 59 is connected via flow restrictor 57 either with fuel delivery duct 13 or with the low-pressure cavity. The former event will take place in case the predetermined engine r.p.m. increases, the latter – in the case the predetermined engine r.p.m. increases. In both cases a gradual change in the capacity of chamber 59 will be experienced.

At the end of the regulating procedure the feed-back piston will return to its initial position, in which interpiston chamber 59 will be disconnected by slide valve 37 both from duct 13 and from the low-pressure cavity. As feed-back piston 58 is connected by lever 38 to feed-back bush 43, the end of the regulating procedure (state of balance) at any positions of piston 61 will always be associated with the same position of feed-back bush 43 and slide valve 41 relative to the bush ports, and, consequently, with the permanent r.p.m. Therefore, the governor ensures a reasonable amount of stability at a great degree of regulation accuracy.

The changes in the tension of spring 45 due to variations in the temperature of fuel are neutralized by a special device - thermal compensator 52. Absence of the thermal compensator will result in changing the tension of spring 45 due to variations in the fuel temperature (with the hydraulic decelerator being in the same position) involving changes in the length of the individual parts. In this case a reduction in fuel temperature will result in an increased engine speed, and vice versa. Thermal compensator 52 is essentially a set of bimetallic plates, installed in the linkage affecting the tension of the governor slide valve spring.

Variations in the fuel temperature cause the bimetallic plates to deflect, thus changing the spring tension, which provides for a constant engine r.p.m. at a given rating.

<u>Regulation of Fuel Supply at Engine r.p.m. below Automatic Fuel Supply Minimum r.p.m.</u>

Governor transmitter spring 45 starts changing its tension as soon as the control lever is set in a definite position, in which decelerator rod piston 51 starts moving, thereby setting the speed governor in operation and causing fuel supply to be regulated automatically.

At engine r.p.m. below automatic fuel supply minimum r.p.m., the tension of the transmitter spring is maintained at a constant level, and is always in excess of the force developed by the centrifugal weights.

As a result, slide valve 41 is displaced to the right, which would cause swash plate piston 61 to move all the way to the left, thereby setting the swash plate in a position involving maximum fuel delivery.

To control fuel delivery at engine ratings which are below the automatic fuel supply minimum r.p.m., permanent pressure differential valve 12 is provided, whose function is to maintain permanent pressure differential at the throttling valve of the pump. From the right valve 12 is acted upon by fuel pressure upstream of the throttling valve. At the other side the valve is affected by fuel pressure downstream of the throttling valve and by the force of the spring.

By adjusting the tension of the spring, a pressure differential value is obtained, which causes the valve to travel to the left. If the pressure differential at the throttling valve happens to exceed the predetermined value, the valve will move to the left, thereby allowing fuel return from the interpiston chamber and supplying high pressure under the swash plate piston. Due to a pressure drop in the interpiston chamber and pressure increase under the swash plate piston, the latter will move to the right thereby reducing the angle of inclination of the swash plate. The pump delivery will decrease, causing the pressure differential at the throttling valve to reduce to the predetermined value, as a result the valve will partially close the ducts running to the interpiston chamber and under the swash plate piston to provide for a pressure differential at the swash plate piston required for maintaining it in the predetermined position.

At all engine r.p.m. values exceeding the automatic fuel supply minimum r.p.m., the pressure differential at the throttling valve is lower than the predetermined value, provided by the tension of the slide valve spring, due to a larger

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passage area opened by throttling valve 2; as a result, the valve is put out of operation by the action of spring 12.

When the engine is cut off, with the shaft and the pump rotor still rotating and the throttling valve closed, pressure differential at the throttling valve tends to grow. To provide an outlet for the fuel, valve 12 is furnished with drain holes which are opened as soon as the pressure differential at the valve reaches 15 kg/sq.cm., thereby allowing fuel drainage into the booster system.

As valve 12 moves all the way to the left, high pressure is fed under the swash plate piston, due to which the swash plate sets against the minimum delivery stop.

Operation of Regulating Fuel Pump during Engine Acceleration

To provide for normal, that is quick enough engine shifting from one rating to another involving quick movement of the engine control lever (within 1.5 to 2 sec.) not accompanied by flame throw-out or surge, the pump is fitted with special devices, i.e. a pressure increase limiter (ОНД) and a hydraulic decelerator.

The hydraulic decelerator provides for:

(a) smooth acceleration of the engine to a given rating from r.p.m. equal to, or exceeding the automatic fuel supply minimum r.p.m.;

(b) extra travel of the engine control lever after gaining the maximum r.p.m. necessary for starting the afterburner;

(c) electric blocking allowing cutting in of limit switch 4 at the predetermined speed of the low-pressure rotor;

(d) possibility of regulating the maximum r.p.m. value (by means of screw 54) and the automatic fuel supply minimum r.p.m. value (by means of screw 39).

The pressure increase limiter provides for engine acceleration from idling rating or from the r.p.m. value which is below the automatic fuel supply minimum r.p.m. value (in the

latter case the termination of the acceleration period may be associated with the operation of the hydraulic decelerator).

Fuel Pressure Variations with Acceleration Controlled by Pressure Increase Limiter and by Hydraulic Decelerator

The normal acceleration of the engine is ensured due to limiting the rate of increase of fuel pressure upstream of the distributing valve (or in the primary manifold) in conformity with the predetermined program of permissible excess fuel rates with regard to the engine r.p.m.

Fig. [illegible] illustrates the nature of fuel pressure changes in the primary manifold with the engine accelerated on the ground.

Operation of Fuel Pressure Increase Limiter

The pressure increase limiter consists of the following main parts: slide valve 25, spring 22, flow restrictors 26 and 30, and piston 23.

The major component of the pressure increase limiter is represented by slide valve 25, which, during engine acceleration, controls the position of swash plate 66 by changing pressure differential at the swash plate piston with the aid of ducts 28 and 29.

From the left, slide valve 25 is acted upon by the fuel pressure upstream of the distributing valve, the right side of the valve being exposed to the booster pressure of fuel and to the force of spring 22. The tension of spring 22 depends on the position of piston 23. The pressure increase limiter comes to a standstill when a state of balance is established. In this case the sum total of the booster pressure of fuel and the pressure of spring 22 is equal to the pressure value of the fuel upstream of the distributing valve, and ducts 28 and 29 are closed.

The position of piston 23 at a state of balance is dependent on the position of slide valve edge 27, controlling pressure in cavity 24.

At another state of balance, piston 23 moves to a new position, in which new pressure value upstream of the distributing valve is balanced by the modified force of spring [illegible]. A change in the position of the piston at another state of balance is brought about by the displacement of slide valve edge 27, which regulates fuel by-pass from cavity 24 to the return line, which determines the position of the piston. In this case ducts 28 and 29 remain closed all the time.

During engine acceleration, fuel pressure upstream of the distributing valve increases due to quick opening of the throttling valve whereas slide valve 25 moves to the right. Slide valve edge 27 bars fuel by-pass from cavity 24; simultaneously, the slide valve edges partially open ducts [illegible] and 29, and the inclination of swash plate 56 is so controlled that fuel pressure upstream of the distributing valve cannot exceed the value preset by spring 22. Fuel drain from cavity 24 being discontinued, piston 23 will be forced by the fuel entering through flow restrictors 26 and 3[illegible] to move thereby tightening spring 22 which will result in gradual increase of fuel pressure upstream of the distributing valve.

The rate of pressure increase, and, consequently, fuel consumption by the engine depends on the rate of travel of piston 23, which in its turn is dependent on the resistance of flow restrictor 26 and 3[illegible], delivering fuel to cavity 24 from the permanent pressure duct. The initial displacement of slide valve 25, when shifting the engine control lever from the balanced state position to the position at which the slide valve edges are controlled through the medium of ducts [illegible] and 29, results in the initial rise of fuel pressure in the primary manifold [illegible] kg/sq.cm.

During engine acceleration, piston 23 moves thereby opening the groove provided in the rod. This causes flow restrictor 26 to be choked with resulting drop in resistance; piston 23

starts moving at a higher rate, which results in a higher rate of fuel pressure increase. This provides for the required fuel-to-time characteristics.

In its further travel piston 23 abuts against slide valve 25 through the medium of the spring seat. The slide valve edges will close ducts 28 and 29, and the slide valve will move to a position allowing control of fuel by-pass from cavity 24 by edge 27. As the rate of fuel pressure increase in cavity 24 may be very high, the piston being at a standstill, any rate of fuel pressure increase upstream of the distributing valve will not be dependent on the pressure increase limiter, as the latter is put out of operation. Spring [illegible] serves for returning the piston to the initial position when the engine r.p.m. decreases.

The engine acceleration characteristic curve consists of three sections differing from one another by the rate of fuel pressure increase upstream of the distributing valve (Fig.A).

First section (first branch) a-1:

Flow restrictors [illegible] and 3[illegible] are connected in series. The rates of the piston travel and of fuel pressure increase are the least and are mainly governed by the resistance of flow restrictor 26.

Second section (second branch) - 1-2:

Flow restrictor 26 is choked. The rates of the piston travel and of fuel pressure increase are higher than at the first section, and depend mainly on the resistance of flow restrictor 3[illegible].

Third section (third branch) - 2-b:

Piston 23 comes against the spring abutment plate of slide valve [illegible] and is not capable of further increasing the tension of spring [illegible]. Under the increasing fuel pressure upstream of the distributing valve, slide valve 25 is not capable of opening ducts 28 and 29, being unable to overcome the pressure applied to the piston from cavity 24, with the by-pass not closed by edge 27.

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The rate of fuel pressure increase is dependent on the rate at which swash plate 66 changes its angle of inclination, which is a function of the resistance value of feed-back flow restrictor 57.

This section is characterized by the greatest rate of fuel pressure increase.

The total acceleration time depends on the balanced state position from which the engine control lever is shifted forward. The higher the pressure upstream of the distributing valve, the greater the distance covered by piston 23; consequently, it will take less time for the piston to complete its travel and for the pressure to reach the predetermined value.

With the engine r.p.m. changed slowly enough by manipulating the engine control lever, the slide valve of the pressure increase limiter does not interfere with the operation of the permanent pressure differential valve (at engine r.p.m. values below the automatic fuel supply minimum r.p.m. value), or of the speed governor (at engine r.p.m. values exceeding the automatic fuel supply minimum r.p.m. value), fuel supply being controlled by the above units, since the rate of fuel pressure changing upstream of the distributing valve agrees with the rate of changing the tension of spring 22, and ducts 28 and 29 remain closed by slide valve 21 all the time.

Operation of Hydraulic Decelerator

Motion is transmitted from the engine control lever to centrifugal governor spring 4[illegible] by the hydraulic decelerator; adjustment of the governor for the predetermined r.p.m. depends on the tension of the spring. Hydraulic decelerator cavity [illegible] is connected via flow restrictor 56 with duct 13 (down-stream of the permanent pressure valve), and via hole 49 in the decelerator rod to the return line.

In the balanced position of the decelerator piston the inflow of fuel through flow restrictor 56 into cavity 5[illegible] is

equal to fuel outflow through hole 49 in the decelerator rod partially closed by bush 48; this results in a balance of the forces acting on the hydraulic decelerator piston.

As soon as hole 49 is completely closed by the edge of bush 48, fuel outflow from cavity 5[illegible] stops, and the piston will slowly move against the force of the spring towards adjustment screw 54, its speed depending on the capacity of the flow restrictor.

With the rod hole open, the piston will be forced by the spring to abruptly shift towards automatic fuel supply minimum r.p.m. stop screw 39, thereby forcing fuel to return via hole 49.

When accelerating the engine from the r.p.m. exceeding the automatic fuel supply minimum r.p.m. value, the engine control lever is shifted within 1.5 to 2 sec. to a position, corresponding to the maximum r.p.m. or to some intermediate r.p.m. value.

In this case bush 48 will close hole 49. The piston with the rod will slowly move towards adjustment screw 54 and will operate lever 46, thereby smoothly readjusting centrifugal governor spring 4[illegible] to a new rating. The decelerator piston will move until a state of balance is reestablished between the forces acting on the piston; this will be associated with a definite position of rod hole 49 relative to the operating edge of decelerator bush 48. Thus, at the engine ratings involving automatic fuel supply, each position of the decelerator bush (or the engine control lever) will be associated with a specific spring tension value, hence with a specific engine rating.

Throughout the engine acceleration period, the actual r.p.m. values are somewhat lower than the values provided for by the governor; governor slide valve 41 in this case is displaced to the right from its balanced position, while piston 61 [illegible] 11 changes the angle of inclination of the swash plate thereby increasing the fuel supply rate and providing for the normal acceleration of the engine.

With the engine accelerated from the r.p.m. values which are below the automatic fuel supply minimum r.p.m. value starting from the idling rating, the decelerator piston may come to a balanced position before the completion of the engine acceleration.

In this case the rate of engine acceleration is dependent on the action of the pressure increase limiter.

Engine acceleration from the r.p.m. values below the automatic fuel supply minimum r.p.m. value cannot be accomplished in a shorter time period than acceleration from the automatic fuel supply minimum r.p.m. value, since at a high rate of r.p.m. increase, the termination of the acceleration period will depend on the action of the hydraulic decelerator.

Operation of Starting Fuel Control Unit

The starting fuel control unit is designed for automatic starting of the engine.

Automatic starting is accomplished with engine control lever 47 set at the idling rating sector.

In the course of starting the starting fuel control unit by-passes (from the line upstream of the distributing valve) excess fuel delivered by the pump to the return line.

At the beginning of the starting procedure, when air pressure aft of the compressor (P_2) is too low, fuel pressure upstream of distributing valve 6 (and, consequently, fuel consumption) is determined by the tension of starting fuel control unit spring 19. As soon as fuel pressure increases, valve 18 opens thereby by-passing excess fuel.

As engine speed grows, air pressure increase in the diaphragm chamber (the chamber is supplied with air at pressure P_2 corrected by the air discharge jet) causes the starting fuel control unit to by-pass less fuel, which results in higher rate of fuel flow through the burners.

At an engine r.p.m. approaching or higher than the idling rating, air pressure in the chamber will increase to a value

causing the valve to close completely. Then, the rate of fuel flow through the burners will become equal to the rate of fuel flow through idling rating slide valve 3.

Limiting of High-Pressure Rotor Maximum r.p.m.

Provision is made in fuel regulating pump HP-21Ф for limiting maximum r.p.m. of the high-pressure rotor, which is accomplished as follows.

Fuel regulating pump HP-22Ф accommodates the high-pressure rotor speed transmitter, which by-passes fuel from the cavity between jet [illegible] and the decelerator flow restrictor as soon as the high-pressure rotor reaches the maximum permissible r.p.m. value; this results in a pressure reduction in decelerator piston cavity [illegible], which causes piston 51 to move to the right thereby readjusting the tension of governor spring 45 and decreasing the speed of the low-pressure rotor (the transmitter slide valve spring being slackened). A decrease in the r.p.m. of the low-pressure rotor will cause a reduction in the speed of the high-pressure rotor.

By-Pass Valve

The main fuel by-pass valve serves for cutting off fuel supply into the combustion chambers during engine starting within 16.6 sec. after the engine starts to be spinned; the valve may also be used for by-passing fuel when firing rocket missiles.

When voltage is supplied from a special automatic system to the winding of solenoid of by-pass valve 31, the valve slide will move to the left for a period of [illegible].3 ±[illegible].5 sec. thereby connecting the spring chamber of permanent pressure differencial valve 1[illegible] with low-pressure cavity 34. Pressure in the spring chamber will drop, excess pressure of fuel upstream of the valve will move the latter to the left, and the front edge of the valve will connect the cavity of the swash plate piston with high-pressure cavity 62, whereas the groove of valve 12 will connect interpiston chamber 59 with low-pressure cavity 34. Due to the difference between the pressures, the piston will set swash plate 66 in a position providing for a lower rate of fuel delivery.

Simultaneously, high pressure will be discharged into the booster cavity via the inner duct of valve 12.

At the same time (with the valve slide moving to the left) slide valve edge will connect decelerator cavity 50 with low-pressure cavity 34.

The decelerator spring will force the rod to move all the way to the right, thereby reducing the tension of spring 45 through the medium of lever 46. The force developed by the centrifugal weights will displace slide valve 41 to the left, causing the slide valve to connect cavity 70 with low pressure; this will provide for more effective by-passing of the main fuel. Fuel drop upstream of the distributing valve will readjust spring 22 of the pressure increase limiter thereby causing the fuel to be delivered at a lower rate. After the solenoid has been energized, the by-pass valve slide and permanent pressure differential valve 12 will move to the initial position, and the rate of fuel supply will be reestablished as required for engine acceleration, provided by the pressure increase limiter or the hydraulic decelerator depending on the reduction of speed of the low-pressure rotor within the operating period of the by-pass valve.

Drain Valve

The function of the drain valve is to direct fuel from the fuel manifolds into the drainage tank after the engine has been stopped to preclude fuel combustion in the burners.

With the engine stopped, throttling valve 2 is set in the CUT-OUT (СТОП) position; fuel pressure upstream of the distributing valve drops to the drain pressure value, as a drain hole is opened by the rear edge of the valve, due to which a

reduction is experienced in the pressure of fuel delivered to drain valve piston 1 via duct 4; as a result, the valve is forced by the spring to move down, thereby connecting the main and primary fuel manifolds with the drainage tank.

At any other position of the throttling valve, fuel pressure in duct 4 causes the valve to be locked in the upper position; in this case the main and primary fuel manifolds are cut off the drainage tank.

Fuel Regulating Pump HP-22Ф

Fuel regulating pump HP-22Ф (Fig.25) delivers fuel into the afterburner and automatically regulates fuel flow rate at any of the afterburner ratings. The fuel regulating pump consists of the following main units:

- plunger pump;
- afterburner regulator;
- barostatic fuel consumption limiter;
- afterburner valve;
- fuel valve;
- permanent pressure valve;
- afterburner control solenoid;
- electric contactor;
- by-pass valve;
- high-pressure rotor speed transmitter and maximum speed limiter with thermal compensator;
- cut-off valve.

Pump Operation

Fuel is directed through filter 58 and via the duct to ported member 59, having suction port 60 and delivery port 61.

While the pump rotor actuated through the medium of shaft 66 is spinning, plungers 63 forced by the springs against the face of swash plate 65 move reciprocally in their guiding wells, thereby drawing fuel through suction port 60 while the rotor turns through 180° and delivering it through delivery port 61 into high-pressure cavity 62 while the rotor completes the revolution.

Fuel supply rate is dependent on the angle of inclination of swash plate 65, as well as on the rotor speed and the pressure in cavity 62. The greater the angle of inclination of the swash plate, the higher the fuel delivery rate, plungers 63 being capable of longer travel.

The swash plate is displaced by servo-piston 55, whose rod is hinged to the swash plate bearing housing.

Servo-piston 55 is controlled by the afterburner regulator, which tends to maintain the P_2/P_4 ratio at a constant value, in the event the ratio between pressures $P_2' = \frac{P_2}{K}$ and P_4 is disturbed, the afterburner regulator changes the rate of fuel flow to the afterburner injectors.

P_2' - corrected pressure aft of the compressor;

P_4 - static pressure aft of the turbine;

K - constant value - reduction factor.

The reduction factor is a constant value for the given adjustment of regulating needle No.1 (Ref.No.12, Fig.21).

Fuel delivery control, with afterburner valve 71 open (Fig.25) is accomplished as follows:

Servo-piston cavities 49 and 56 are connected with high-pressure cavity 62, cavity 56 being connected via the duct, and cavity 49 through jet 11 and flow restrictor 57. Besides, provision is made for the ducts running from cavity 62 via filter 10 and jet 11 to afterburner regulator valve 36, limiter valve 21, and to afterburner valve groove 68. With limiter valve 21 closed and afterburner valve groove 68 cut off, changes in fuel by-pass through valve 36 take place depending on the pressure difference between P_2' and P_4.

In case afterburner regulator valve 36 is closed and no fuel is by-passed, the pressures in cavities 49 and 56 are equal. Under the force of the springs and the pressures acting on the servo-piston, the latter sets the swash plate at a maximum

angle of inclination which corresponds to the maximum pump delivery. The maximum angle of inclination of swash plate 65 is adjusted with the help of maximum delivery screw 64.

As soon as valve 36 is open (due to an increase of pressure P_4, for example) pressure in cavity 49 will start decreasing due to fuel outflow and the presence of jet 11.

Excess pressure of fuel applied from the side of cavity 56 will cause the piston to overcome the force of the spring and to move towards cavity 49, thereby setting the swash plate at a less angle of inclination, which will result in reduced pump delivery. Fuel consumption rate will keep changing until pressure P_4 in the afterburner nearly approaches the value of pressure P_2', and the system (engine-regulating pump) comes to a state of balance. In this case, forces acting on the piston from the left (the swash plate and pressure in cavity 56) and from the right (the spring and pressure in cavity 49) will be equal.

Consequently, fuel by-pass from cavity 49 via valve 36 serves for regulating fuel delivery by the pump. The rate of fuel by-pass from cavity 49 is automatically controlled due to changing of the clearance between the jet and afterburner regulator valve 36, maintaining pressures P_2' and P_4 at about the same level at any altitude and speed of flight.

The afterburner regulator serves for automatic regulation of afterburner fuel consumption, at various altitudes and speeds of flight.

The afterburner regulator has three cavities 29, 31, and 3[illegible].

Cavities 3[illegible] and 31 are divided by an air-tight, flexible metal partition, sealing lever 33. Cavities 31 and 29 are partitioned by membrane [illegible]. The lever is supported by an axle incorporating ball bearings. The balance of lever 33, and, consequently, the balance of the entire system depends on the following factors: the force of spring 27 and valve spring 39 (which provide for lever balance with the pump at a standstill); pressure in duct 28 between afterburner valve 36 and limiter valve 21, and pressure difference between P_2' and P_4.

Regulation of fuel consumption with the aircraft climbing, is accomplished as follows: pressure P_2 (aft of the compressor) and, consequently, pressure P_2' starts dropping, which results in excess pressure P_4 acting on the membrane. The excess pressure applied to the membrane displaces the lever and partially opens valve 36, which increases the rate of fuel by-pass from servo-piston cavity 49, with resulting displacement of the servo-piston and a reduction in the fuel delivery.

Fuel will be delivered into the engine afterburner at a lower rate, causing pressure P_4 to drop. The rate of fuel supply will be decreasing until there is no practical difference between pressures P_2' and P_4.

Afterburner operation in accordance with the law providing for constant ratio P_2/P_4 is dependent on equality of pressures P_2' and P_4.

For adjustment of afterburner operation with regard to varying altitudes provision is made for spring 39, located under valve 36. Slackening of spring screw 40 will cause temperature T_4 aft of the turbine to decrease, whereas tightening of the screw will result in temperature increase at higher altitudes.

The barostatic fuel consumption limiter serves for limiting fuel consumption in case of an unsuccessful attempt at afterburner ignition, for precluding the possibility of the afterburner going out at high altitudes, as well as for ensuring afterburner fuel supply regulation, in case the afterburner regulator fails; the limiter also serves to control afterburner fuel consumption depending on air pressure aft of the compressor (P_2) that is depending mainly on the altitude and speed of flight. To provide for normal operation of aneroid 22, high pressure P_2 is reduced to pressure P_2' in regulating needle No.2 (Ref.No.13, Fig.21). The degree of pressure reduction $\Pi = P_2/P_2'$ is constant at all engine ratings irrespective of altitude and speed of flight.

The aneroid transmitter along with profiled fuel valve 9 limits fuel consumption depending on the changes in altitude

and speed of flight, in compliance with a definite altitude characteristic, which provides for somewhat higher than required rate of afterburner fuel consumption, not to interfere with the operation of regulator P_2/P_4.

The limiter has two cavities 18 and P_2' divided by an airtight flexible metal partition, sealing lever 24. The lever rests on an axle mounting ball bearings. The balance of lever 24, and, consequently, the balance of the entire system, depends on the following factors: tension of valve spring 16; pressure in duct 23 between the afterburner valve 36 and limiter valve 21; pressure applied to transmitter retainer 25 from cavity 62 and from aneroid 22. A change in any of the above forces will invariably cause changes in all other forces tending to maintain the balance. Practically, only two forces in the limiter are related to each other as simple dependents: pressure P_2', (affecting the force of aneroid 22) and pressure in cavity 62 (affecting the force acting on transmitter 25).

With air pressure reducing in cavity P_2', aneroid 22 increases its pressure on the end of lever 24, thereby relieving the valve which causes an increase of fuel by-pass from cavity 49 of the servo-piston via valve 21, and displacement of the servo-piston towards lower rate of fuel supply. This will change fuel pressure in the system and upstream of transmitter retainer 25.

As a result, a new state of balance will be established in the limiter, which will cause it to maintain a new reduced pressure in cavity 62.

Changing of pressure in cavity 62 with relation to altitudes and speed of flight is determined by the characteristics of aneroid 22, by the diameter of pressure transmitter piston (retainer) 2 , projecting beyond the diaphragm, and by changes in the length of the arm from the contact point of the rod of eccentric 19 with lever adjustment screw 20 to the axle at the point of lever attachment. Damper 26, located in the path of fuel flow from cavity 62 to limiter transmitter 25, eliminates fuel pulsation likely to occur in the system.

The nature of changes in maximum rate of fuel delivery into the afterburner within the range limited by the pressure in cavity 62 depends on the profile (affecting the passage area) of fuel valve 9, as well as on the tension and rigidity of spring 4. As the pressure in cavity 62 is the function of pressure P_2, the general characteristic of maximum rate of fuel delivery into the afterburner system within the range limited by pressure P_2 is dependent on the adjustment of the limiter and of the fuel valve.

Adjustment of the limiter is performed by manipulating adjustment screw 15 of spring 16 and screw 2 of spring 4 of fuel valve 9. With the afterburner regulator in the balanced state, limiter valve 21 is partially closed.

Control of fuel delivery into the afterburner is accomplished by opening and closing afterburner valve 71 coupled to the piston.

Afterburner valve 71 is operated by solenoid 34, which, when energized, closes valve 37, thereby causing fuel from duct 17 to be delivered into cavity 67 via flow restrictor 12; as a result, the piston and valve 71 will be opened to full capacity and the spring will be compressed. At the beginning of the afterburner valve travel, groove 68 gets closed, and fuel is not allowed to be drained from spring cavity 49 of the servo-piston. Servo-piston 55 starts displacing the swash plate towards a higher rate of fuel delivery. With the voltage cut off, valve 37 opens (by the action of the spring located under the valve) and the strong spring of valve 71 forces fuel from cavity 67 to the return, (that is, into the booster pressure cavity) thereby closing afterburner valve 71.

The nature of changes in fuel delivery while the afterburner valve is being opened, depends on the variations in the passage area of the valve and on the changes in fuel pressure in cavity 62.

The rate of pressure increase in cavity 62 is dependent on the swash plate servo-piston rate of travel, which is the function of the capacity of flow restrictor 57, whereas the rate of travel of the afterburner valve is determined by the capacity of flow restrictor 12. At the end of the travel the

piston of valve 71 (at full augmentation) works against rod 69 of engine blocking device electric contactor 70, thereby breaking the circuit supplying voltage to the electromagnetic valves controlling fuel delivery into the afterburner flame igniter.

When the piston moves in the reverse direction, the spring returns rod 69, and consequently, electric contactor 70 in the initial position.

To ensure that the afterburner valve moves at a constant rate, permanent pressure valve 13 is provided. This valve maintains a permanent pressure in the duct aft of the valve, irrespective of changes in fuel pressure upstream of the valve (that is, downstream of filter 10). As soon as pressure in duct 17 increases, valve 13 will be displaced towards the spring, causing the holes provided on the side surface of the valve to be partially or fully closed; thus a fuel pressure of about 11 kg/sq.cm. will be maintained in duct 17.

Fuel valve 9 serves to ensure a predetermined afterburner fuel consumption, when the limiter is set in operation.

With afterburner valve 71 open (it is shown in the diagram in its closed position), fuel from cavity 62 will be delivered to the fuel valve after passing through the afterburner valve passage area.

Fuel valve 9 consists of a slide and a guiding bush having profiled ports. The passage area in the fuel valve assembly is dependent on the position of the slide relative to the bush ports. The position of the slide is determined by the fuel pressure value upstream of the valve, by the tension of the spring, and by the booster pressure in valve spring chamber 3.

As pressure builds up upstream of valve 9, the valve passage area increases. Screw 2 serves for adjusting the initial tension of the spring. Jet 1, connecting valve spring chamber 3 to the return, serves for damping the valve (eliminating possible pulsation of the fuel).

The function of by-pass valve 6 provided on the valve is to ensure a minimum fuel consumption, when the afterburner is turned on and afterburner regulator 36 is open (the angle of inclination of the swash plate being minimum). At a low pressure of fuel in duct 8, downstream of afterburner valve 71, by-pass duct 6 is fully open thereby directing excess fuel delivered by the pump to the inlet of main regulating fuel pump HP-21Φ. As soon as the pressure increases, duct 6 gets partially closed which causes a reduction in the amount of fuel by-passed. When fuel pressure in duct 8 reaches the maximum value, duct 7 is open, which drains the fuel thereby limiting maximum fuel pressure in the pump.

By-pass valve 5 upstream of the afterburner valve is designed: for relieving excessive pressure resulting from disengagement of the afterburner valve; for maintaining pressure in the pump required for the normal operation of the servo-piston with the afterburner turned off; for by-passing fuel with the purpose of cooling the pump when the afterburner is turned off.

With the afterburner turned on, valve 5 is closed, the force of its spring exceeding the pressure differential at valve 71. When the afterburner is turned off, pressure in cavity 62 will decrease at the expense of fuel by-pass via valve 5, and will depend on the tension of the valve spring, since the valve spring chamber will be connected with the return via the groove provided on the afterburner valve.

The speed transmitter serves the blocking devices of the engine responding to the r.p.m. values of the engine high-pressure rotor.

The speed transmitter comprises a centrifugal governor, consisting of centrifugal weights 41 and pendulum 42, a servo-piston with rod 53, speed transmitter shaft 47, and rack 44.

With the rotor speed increasing, the centrifugal force of the weights builds up causing pendulum 42 to come out of the state of balance, thereby allowing fuel from cavity 17, downstream of the permanent pressure valve, to flow into

cavity 52 of servo-piston 53, whereas servo-piston cavity 54 is caused to be connected to the return duct.

The servo-piston starts moving thereby increasing the tension of spring 43 through the medium of the gear and rack 44, until the state of balance is reestablished, that is until the force of spring 43 equals the force developed by centrifugal weights 41. This will cause speed transmitter shaft 47 to change its angle. With the speed reducing, the order of the above events will be reversed.

At the end of the travel of servo-piston 53, corresponding to the maximum permissible r.p.m. value of the high-pressure rotor, groove 48 on the servo-piston rack will line up with the edge of high-pressure rotor maximum speed limiter slide valve 50, causing fuel from duct 51 to be by-passed to the return line. Fuel to duct 51 is delivered from the cavity of the hydraulic decelerator of main regulating fuel pump HP-21Φ.

The cut-off valve serves for preventing fuel from finding its way into the afterburner fuel manifolds at drain pressure when the afterburner is turned off. When the afterburner is switched on, pressure in cavity 3 increases, thereby causing fuel to open the valve and to flow into the fuel manifolds.

Combustion Chamber Burners

The engine is provided with 1? two-stage, duplex centrifugal burners, arranged in two manifolds - the main manifold and the primary manifold.

The burner construction is illustrated in Fig.27. The burner consists of steel stamped body 3 incorporating a pressed-in distance sleeve; tightly pressed against the lapped face of the sleeve are two sprayers 6 and 7, clamped by nut 5 and sealed by copper ring 8 and ring 9. Nut 5 is retained on the burner body by lock 4. Fitted into the inlet connections of the burners with slight interference are gauze filters 1 and 2. The burner is rigidly secured to the flange of the combustion chamber casing by two bolts; the cylindrical surface of nut 5 enters into the hole of the combustion chamber spherical ring.

Fuel is fed into the burners via two ducts: I stage primary duct 11 (idling rating duct) and II stage main duct 1. Each of the ducts has its own sprayer (6 for the I stage, and 7 for the II stage). Each of the sprayers is furnished with tangential grooves for whirling fuel, and a whirl chamber. The dimensions of the grooves, the whirl chamber, as well as of the passage area of the sprayer are so selected as to provide for the required quality of fuel atomization within the entire range of the required fuel consumption values at the permissible pressures.

When fuel pressure upstream of the distributing valve of pump HP-21Φ is about 16 kg/sq.cm. (during engine starting), fuel is delivered into the combustion chamber only via the primary duct of the burners; as pressure upstream of the distributing valve builds up, the main duct gets open, and fuel flows into the combustion chamber via two ducts, the rate of fuel flow through the main duct increasing with the engine speed.

The profile of the distributing valve and properly selected hydraulic characteristics of the burner sprayers provide for the required changes in fuel consumption depending on pressure upstream of the distributing valve.

<u>Regulating Needle (Fig.28)</u>

The engine is equipped with two regulating needles (Fig.28) incorporated in the afterburner control equipment.

Regulating needle No.1 (contained in the regulator) serves for reducing air pressure from P_2 to P_4, which in the afterburner regulator P_2/P_4 (pump HP-22Φ) equals pressure P_4.

Regulating needle No.2 (limiting) is designed for reducing air pressure from pressure P_2 to pressure P_2 which is supplied into the barostatic fuel consumption limiter.

The operation of the regulating needle is based on the principle of maintaining a constant ratio between air pressure P_2 at the inlet to the chamber limited by two jets, and air pressure P_4 (or P_2) inside the chamber, irrespective of the changes in the inlet pressure (provided $P_2/P_H \neq 5$), in case air keeps flowing from the outlet jet at sonic velocity irrespective of the engine rating, and from the inlet jet - at subsonic velocity (which provides for preserving the constant reduction coefficient). Adjustment of the regulating needle for the predetermined pressure ratio value is carried out by changing the passage area of the inlet jet with the aid of the tapered needle.

Needle casing 7 is made in the form of a cylindrical chamber welded from steel; the inlet end of the chamber encloses an [illegible] cylindrical jet having a sharp edge; this jet provides only for subsonic flow velocity, with pressure ratio [illegible] = 1.36. The outlet end accommodates a constant capacity jet having inner configuration approaching a convergent-divergent type of nozzle. This jet provides for supersonic velocity of air outflow into the atmosphere, with pressure ratio [illegible] 1.[illegible] - 1.8.

Turned into the casing is needle 4, whose tapered portion enters the inlet jet, thereby allowing regulation of its passage area. The needle threads are treated with molybdenum disulfide for protection against burning.

The needle is retained in a definite position by locking nut 2; to eliminate any air leakage through the threads, cap 1 is fitted back of the locking nut. Mounted on the needle in front of the locking nut is washer 3, which rotates together with the needle, and carries [illegible] allowing needle turning to be easily registered.

With the needle turned [illegible], pressures P_4 or P_2 [illegible] (on the ground). The face of the needle [illegible] for needle turning.

[illegible] is delivered [illegible] connection to the inlet [illegible] chamber and is discharged into the atmosphere through the outlet jet. The required pressure P_2 for needle No.1 or P_2^1 for needle No.2 is established in chamber 8 due to displacement of needle 4 in the inlet jet; further, the pressure is supplied via the connection to the afterburner regulator or to the barostatic fuel consumption limiter accommodated in regulating fuel pump НР-22Ф.

Enclosed in the chamber aft of the inlet jet is a deflector, which breaks the inlet air stream, thereby preventing a straight air flow, which is likely to affect the static operation of the outlet jet.

Engine Controls

The engine controls (Fig.40) are designed for changing the engine ratings. The controls comprise regulating fuel pump НР-21Ф (1) and ratings control panel ПУРТ-1Ф (10) with rheostatic transmitter ДР-3А (15) and regulating rheostat unit Р-1 (12).

The regulating fuel pump is attached to the engine wheel case by means of a quickly detachable strap. The pump dial has the following notches:

(a) notch 2 - IDLING RATING, located between notches 1 and 3, limiting the idling rating sector;

(b) notch 4 - AUTOMATIC FUEL SUPPLY MINIMUM R.P.M.;

(c) notch 5 - NORMAL;

(d) notch 6 - MAXIMUM;

(e) notch 7 - ADDITIONAL.

Control panel ПУРТ-1Ф with rheostatic transmitter ДР-3А and regulating rheostat unit Р-1 is secured by means of two bolts to the box of master connector 9, which in its turn is attached to the compressor casing with the aid of bracket 8 and bolts.

The levers of the regulating fuel pump НР-21Ф and of the control panel ПУРТ-1Ф are connected to each other by link 7 which can be adjusted as to its length. The aircraft control system is connected to control panel lever 11.

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When shifted from CUT-OUT stop 5 located on the regulating fuel pump, to the FULL AUGMENTATION stop 14 located on the control panel, levers 11 and 2 are moved through the following positions: CUT-OUT (СТОП), IDLING RATING (МАЛЫЙ ГАЗ), AUTOMATIC FUEL SUPPLY MINIMUM R.P.M. (ОБОРОТЫ НАР), NORMAL (НОМИНАЛ), MAXIMUM (МАКСИМАЛ) (hydraulic decelerator contact gets blocked), MINIMUM AUGMENTATION (МИНИМАЛЬНЫЙ ФОРСАЖ), JET NOZZLE AREA STARTS CHANGING (НАЧАЛО ИЗМЕНЕНИЯ СЕЧЕНИЯ СОПЛА), END OF JET NOZZLE AREA CHANGING (ОКОНЧАНИЕ ИЗМЕНЕНИЯ СЕЧЕНИЯ СОПЛА), and FULL AUGMENTATION (ПОЛНЫЙ ФОРСАЖ). When moved from the CUT-OUT stop to the MAXIMUM position, lever 11 of the control panel does not cause any changes in the electric circuit, that is it performs an idling travel.

In this case control of the engine is accomplished by regulating fuel pump НР-21Ф alone, which changes the engine r.p.m.; at the engine ratings starting from the CUT-OUT up to the r.p.m. amounting to 65% of the normal speed of the high-pressure rotor (up to the operation of cam БФО-1) the jet nozzle shutters are open to the FULL AUGMENTATION position, whereas after operation of cam БФО-1 the jet nozzle shutters close to the MAXIMUM rating position (to the minimum area).

Setting of the levers in the MAXIMUM position will cause operation of control panel cam ПК, which will block contacts ТЗ and БФО-1 (after operation of special relay Z incorporated in the automatic equipment).

From the MINIMUM position to the FULL AUGMENTATION stop regulating fuel pump lever 2 is capable of extra travel, which does not involve any changes in the engine maximum r.p.m., but causes operation of the control panel cams and provides for functioning of the follow-up system controlling the jet nozzle. Setting of lever 11 in the MINIMUM AUGMENTATION position, causes operation of control panel cam БФС, which turns on the afterburner (provides for afterburner ignition, fuel supply, and for opening of the shutters). When lever 11 is moved from the JET NOZZLE AREA STARTS CHANGING position to the FULL AUGMENTATION position, the slide of jet nozzle follow-up control system rheostatic transmitter ДР-3А changes its position, thereby displacing the rods of the jet nozzle control cylinders, which results in changing of the jet nozzle area. With lever 11 set in the END OF JET NOZZLE AREA CHANGING position, the rheostatic transmitter slide will come to the end of the rheostat, and further turning of lever 11 will not cause changing of the jet nozzle area. The angle between the positions JET NOZZLE AREA STARTS CHANGING and END OF JET NOZZLE AREA CHANGING comprises the afterburner regulation range.

The angle between the positions MAXIMUM and MINIMUM AUGMENTATION makes up the MAXIMUM sector, the angle between the positions MINIMUM AUGMENTATION and JET NOZZLE AREA STARTS CHANGING is the MINIMUM AUGMENTATION sector, and the angle between the positions END OF JET NOZZLE AREA CHANGING and FULL AUGMENTATION represents the FULL AUGMENTATION sector. Shifting of levers 11 and 2 within the range of these angles does not affect the respective engine ratings.

With levers 11 and 2 moving from the FULL AUGMENTATION position to the CUT-OUT position, the engine ratings change in the reverse sequence, the reverse opening of the jet nozzle shutters from the MAXIMUM position to the FULL AUGMENTATION position taking place at the engine rating amounting to 60% of the high-pressure rotor normal speed (when operation of cam БФО-2 occurs).

Emergency Control of Jet Nozzle

When switch EMERGENCY CONTROL OF 2-POSITION JET NOZZLE is turned on, the follow-up system is disconnected, thereby transforming the all-duty jet nozzle into a two-position nozzle. When levers 11 and 2 are turned from the CUT-OUT stop to the MAXIMUM position, engine speed reaches the maximum value.

The jet nozzle shutters, depending on the speed of the high-pressure rotor (operation of cams БФО-1, БФО-2) will

occupy the position, corresponding to the FULL AUGMENTATION or MAXIMUM rating. In this case, the angle between the position MAXIMUM and the position AFTERBURNER SWITCHING IN EMERGENCY CONTROL OF JET NOZZLE (CAM 4) will represent the MAXIMUM sector. With lever 11 set in the AFTERBURNER SWITCHING IN EMERGENCY CONTROL OF JET NOZZLE (CAM 4) position, cam 4 of the control panel will operate, thereby causing the jet nozzle to open to the FULL AUGMENTATION position; besides the afterburner will be ignited and the fuel will be duly supplied. Further movement of the lever to control lever step 14 (FULL AUGMENTATION) will not affect the engine operation, this range of the lever travel representing the FULL AUGMENTATION sector. With the lever moved in the reverse direction, the engine ratings change in the reverse sequence.

Drain and Dump Systems

The drain system is designed to prevent overfilling of the drain cavities with fuel, leaking through the sealings installed in the drives of the fuel equipment units arranged on the engine (Fig.22).

Fuel drainage is accomplished as follows.

Fuel is drained from the drive of fuel regulating pumps НР-21Ф and НР-22Ф, from fuel booster pump ДЦН13-ДТ, electric contactor of fuel regulating pump НР-22Ф and electric contactor of the starting fuel control unit, as well as from the drive of the speed transmitter of fuel regulating pump НР-21Ф into the aircraft drain system.

Apart from this, the bottom section of the engine has the following drain points:

(a) drainage from the front fuel collector (on the engine wheel case);

(b) drainage from the rear fuel collector (located on the rear flange of the combustion chamber housing).

Fuel drainage from the rear fuel collector is necessary to prevent uncontrolled burning of the fuel outside the engine combustion chambers.

Fuel from these points is directed into the aircraft drain system via individual pipes.

Note: Hydraulic fluid from two hydraulic pumps HП-34/2 and oil from the two-speed drive of the generator are drained to the front fuel collector.

The dump system serves for draining fuel from the main and primary fuel manifolds, as well as for draining fuel from the fuel and oil lines and cavities after the engine is stopped.

Fuel from the manifolds is drained through the drain valve of fuel regulating pump HP-21Φ, into the drain tank. From the drain tank the fuel is forced beyond the end face of the jet nozzle by the air, delivered from the compressor when another attempt at starting is made.

To drain fuel from the fuel lines of the engine, from the filter, and the oil cooler of unit 357C, provision is made for a drain cock, mounted on the fuel and oil unit.

Oil drainage from the oil tank and from the fuel-cooled oil cooler is accomplished via the drain cock, installed on unit 357C.

Drainage from the engine wheel case is through the drain cock mounted on the engine wheel case.

Chapter VIII

STARTING SYSTEM

The engine starting system includes:
- air blow-off system,
- starting fuel system,
- oxygen feed system.

Functioning of the above systems in conjunction with the automatic fuel control units is provided for by the engine automatic control equipment.

Starting Fuel System

The starting fuel system (Fig.29) functions only at engine starting, and includes the following units:
- starting fuel tank 1 (installed on the aircraft);
- filter 3 (installed on the aircraft);
- starting fuel pump 4 (installed on the aircraft);
- electromagnetic valve 2 (installed on the aircraft);
- starting fuel manifold 24;
- two flame igniters 9.

Oxygen Feed System

The oxygen feed system is switched on only when starting the engine in the air. It provides an excess amount of oxygen for ignition of the engine combustion chambers, and consists of the following components:
- oxygen bottle 5;
- oxygen pressure reducer 6;

- electromagnetic oxygen valve 7;
- non-return oxygen valve 8;
- service jets 23 incorporated in the oxygen connections of the flame igniters and limiting oxygen consumption to within 0.9 +1.1 gm/sec.per one flame igniter, with oxygen pressure upstream of the flame igniter amounting to 6.5 - 9.5 kg/sq.cm.

Air Blow-Off System

The air blow-off system functions only during engine starting on the ground; it provides for reliable starting by widening the range of compressor sustained operation, which allows for delivery of main fuel into the combustion chamber at a higher rate (as compared to engine starting without air blow-off).

The compressor air blow-off system comprises the following components (Fig.29):

- electromagnetic valve 33;
- left air blow-off valve 32;
- right air blow-off valve 31;
- non-return valve 30;
- air blow-off system pipe lines.

Air Blow-Off Valves (Fig.31)

The engine is equipped with two air blow-off valves mounted on the flanges of the combustion chamber casing, the left valve being located between the 2nd and 3rd and the right - between the 8th and 9th combustion chambers.

The blow-off valve consists of body 1, cover 2, piston 3, valve 4, and spring 5. Left valve piston 3 is provided with a 0.5 mm dia. aperture to provide a flow path in the system of fuel supply, when the blow-off valves are being closed. Cover 2 accommodates a fuel supply connection; valve body 1 incorporates connection 7 for directing fuel into the drain system,

and connection 8 for conveying fuel to the dump system. [illegible] air blow-off ports on the valves are protected by gauze [illegible] preventing foreign objects from getting into the engine com[illegible] bustion chamber.

Flame Igniters (Fig.30)

The engine is provided with two flame igniters, in[illegible] in the upper connecting tubes, between 1 - 2 and 9 - 10 [illegible] tion chambers. The flame igniter consists of body 1, [illegible] the body bosses mount bushes, serving as casings for one spark plug СПН-4-3 and for special plug 8.

To safeguard the spark plug against direct fuel spray [illegible] the spark plug and the special plug are inserted into the [illegible] bushes to a depth of 3.5 to 4 mm and are blown with air supplied through holes 7. The other bosses of body 1 mount starting fuel burner 3 and connection 4 accommodating a jet serving for oxygen supply; the connection also encloses a [illegible] filter, protecting the non-return oxygen valve from hard particles occurring in the products of combustion.

Each of the flame igniters carries spark plug СПН-4-3 in a boss located in the vicinity of the oxygen supply connection.

Operation of Starting System

Operation of the starting control units and of the [illegible] electric equipment is described in Chapter Electric Equi[illegible]

Sequence of Starting Equipment Connection

When the engine is started on the ground, the oxygen [illegible] system is not employed; the starting system operating sequence is as follows.

The engine control lever is set at the IDLING RATING stop, after which button STARTING is pressed. This will cau[illegible] connection of electromagnetic by-pass valve incorporated in fuel regulating pump HP-21Ф; the ignition system and electromagnetic valve 33 supplying fuel from regulating fuel pump HP-21Ф into air blow-off valves 31 and 32 will be likewise switched on. The starting fuel system starts to function; starting fuel pump 4 draws gasoline from starting fuel tank 1 via fuel filter 3, and feeds fuel to electromagnetic starting fuel valve 2.

The starter-generator starts spinning the engine. By-pass valve incorporated in fuel regulating pump HP-21Ф opens the ducts, which set the pump swash plate in a position providing for minimum fuel supply, which results in low or even zero rate of fuel flow into the engine. Fuel from pump HP-21Ф flows into the cavity above pistons 34 and 35 of valves 31 and 32 thereby providing for compressor air blow-off into the atmosphere.

Fuel dripping through the clearances of pistons 34 and 35 and through a 0.5-mm jet installed in piston 35 is directed to the booster line via non-return valve 3 ; a small portion of the fuel is passed into engine drain tank through the rod clearances.

Then electromagnetic starting fuel pump 2 is switched on, and gasoline flows via the starting fuel manifold pipes into the flame igniter burners (Fig.29), where it mixes up with air, coming through four holes 5 (Fig.30) provided in the fuel flow path. The mixture is ignited by the electric discharge, taking place on the surface of spark plug 2.

Within 16 sec., the timer cam disconnects electromagnetic fuel by-pass valve incorporated in fuel pump HP-21Ф, thereby causing fuel drain from the cavities to be discontinued; the pump swash plate is set at a certain angle maintained by the permanent pressure differential valve, and fuel supply into the engine now depends on the setting of the starting fuel control unit.

The torch thus formed in the flame igniter will propagate via by-pass pipes 1, 2, 1 , and 9 through the combustion

chambers, where it ignites the fuel-air mixture formed by the atomized fuel supplied by the main fuel burners, and by the air stream delivered by the compressor.

After igniting four combustion chambers, flame will propagate throughout the entire number of the combustion chambers.

At the very beginning of engine starting, hot gases flowing towards the turbine help spinning the engine. At subsequent stages of the starting procedure, the hot gases cause the engine to be accelerated to the idling rating r.p.m. Fuel consumption at idling rating is controlled by the idling rating slide valve of fuel regulating pump HP-21Ф. The amount of fuel flowing through the idling rating slide valve is dependent on the pressure difference between cavities A and Б, amounting to 1 kg/sq.cm. and on the section of slot 27, which is adjusted by idling rating slide valve 12.

During engine acceleration, when the pump swash plate is set in a position providing for the maximum fuel supply, the main fuel delivered by regulating fuel pump HP-21Ф flows into cavity Б (Fig.29) upstream of distributing valve 14 and starting fuel control unit 18, the amount of fuel directed into cavity Б, starting from engine speed of 1000 - 1200 rpm being already equal to the amount, consumed by the engine at idling rating. Fuel from cavity Б can flow either into the engine via distributing valve 14, or be drained via starting fuel control unit 18. The amount of fuel delivered into the engine depends on the difference between the amount of fuel consumed by the engine at idling rating and the rate of fuel drain through the starting fuel control unit. The rate of fuel drain through the starting fuel control unit depends on two adjustable components: spring 16 and air jet 21. Changing of the spring tension with the aid of screw 26 will affect the constant component of the pressure applied to the membrane; whereas reduction or increase in the diameter of jet 21 will cause respective changes in pressure P_2 representing the variable component of the pressure applied to the membrane, whose characteristics change in proportion to the characteristics of pressure P_2 aft of the compressor. Air jet 22 at the starting fuel control unit inlet is adjusted to 1.5 +0.2 mm.

At the initial stage of the starting procedure, when pressure aft of the compressor is still low, the major portion of the fuel is drained, the remaining amount of fuel supplied into the engine being sufficient for starting engine spinning. When the high-pressure rotor picks up speed amounting to 30% of its normal r.p.m., pressure P_2 aft of the compressor reaches the value, at which the starting fuel control unit is closed; as a result, the engine is supplied with an amount of fuel required for maintaining idling rating.

The appropriate fuel-to-air consumption ratio at the engine is dependent on the setting of the fuel control unit incorporated in fuel regulating pump НР-21Ф. When the high-pressure rotor reaches a speed amounting to 32^{+2}_{-1}% of its normal r.p.m., the ignition is switched off at 44.3 sec. by the action of the timer cam simultaneously with disconnection of the starter accomplished by cam СТ of control unit БУ-4Б.

To increase the rate of engine acceleration to idling speed, the starting fuel system is equipped with an electromagnetic valve controlling additional fuel supply which is switched on by the timer cam at 25 sec.

After being switched on, the valve connects cavity A, forward of the idling rating slide valve, to cavity Б, forward of the distributing valve, via jet 26; as the permanent pressure differential valve of fuel regulating pump НР-21Ф maintains a pressure of 10 kg/sq.cm. between cavities A and Б, fuel will flow into cavity Б at a rate of 84 ±3 lit/hr., by-passing the idling rating slide valve, which will cause quick acceleration of the engine to idling rating. When the high-pressure rotor picks up speed amounting to 48 ±2% of its normal r.p.m., cam ВДТ of control unit БУ-4Б switches off the electromagnetic additional fuel supply valve thereby cutting off fuel supply not controlled by the idling rating slide valve and by electromagnetic valve 33; fuel delivery

from regulating fuel pump НР-21Ф is discontinued, and air blow-off valves 31 and 32 are closed by air pressure P_2 [illegible] of the compressor and by the action of the valve spring. As soon as the air by-pass valves are closed, fuel trapped under pistons 34 and 35 is by-passed through a 0.5-dia. hole in piston 3?, and non-return valve 3? gets closed. The engine starts running at a sustained idling rating.

Engine Starting in Air

With the engine started in air, the starter-generator [illegible] does not participate in engine spinning; in this case engine spinning is due to auto-rotation.

The starting panel, the timer, and the electromagnetic valves controlling additional fuel supply, and the air by-pass valves are cut off. Compressor air by-pass valves are closed.

Due to the fact that no additional fuel is supplied [illegible] the engine, more favourable conditions are created for engine starting in air.

Set the engine control lever in the IDLING RATING position.

Turn on switch STARTING IN AIR, and keep it in the on position until the combustion chambers are ignited.

The engine should automatically accelerate to the idling rating r.p.m.

With the above switch turned on, voltage is supplied to the ignition system, the starting fuel pump electric motor [illegible], electromagnetic starting fuel valve ?, and electromagnetic oxygen valve ?.

The starting fuel system and the ignition system function in the same way as on the ground.

The oxygen feed system provides for reliable ignition of the starting fuel, which results in a vigorous torch facilitating the ignition of the combustion chambers. Oxygen is delivered from bottle ? via cut-off valve 2? into the oxygen pressure reducer, which brings the oxygen pressure from 25 - [illegible] 1?? kg/sq.cm. down to 9 - 1? kg/sq.cm.; further oxygen [illegible] via electromagnetic oxygen valve 7 into non-return oxygen valve 8 and into 0.8-mm jet 23; then oxygen is fed into the flame igniter, where it is atomized while passing through the apertures in oxygen connection 4 (Fig.30).

Pressure downstream of non-return oxygen valve 8 should be maintained within 6.5 - 8.5 kg/sq.cm., to prevent oxygen consumption rate in excess of 1.1 gm/sec., which is likely to cause a temperature rise in the flame igniters in excess of the specified value.

Chapter IX

JET NOZZLE FLAPS CONTROL SYSTEM

The jet nozzle flaps are controlled by the follow-up electro-hydraulic system, whose servo-components are represented by actuating hydraulic cylinders.

The flap control system provides for smooth changing of the jet nozzle exhaust area diameter, depending on the position of the engine control lever.

The main components of the jet nozzle shutters control system include:

1. Actuating elements.
2. Synchronizing devices.
3. Hydraulic fluid pipe lines.
4. Cooling system.
5. Electro-hydraulic control system (for respective description see Chapter Electrical Equipment).

Actuating Elements

The actuating elements (Fig.4) of the flap control system include:

- flap ring 13;
- hydraulic cylinders 6;
- load-carrying ring assembly.

All actuating elements are combined into a single assembly which is mounted on the jet nozzle shutter flange.

Hydraulic cylinder. For actuating the flap ring and retaining it in a predetermined position, use is made of three actuating hydraulic cylinders.

The hydraulic cylinder (Fig.47) consists of liner 4 and piston 5 made integral with the rod. The rod passes through rubber sealing rings 16 accommodated in cylinder cover 9. The cylinder cover is turned onto liner 4, the threads being soldered for sealing purposes. The cover and the liner comprise an integral assembly.

The other end of the liner is sealed by shank 1, clamped by union nut 3. The shank is held in a definite position relative to the liner by key 15, and is sealed by rubber rings 14.

Piston 5 is sealed by rubber rings 7 fitted with fluoro-plastic gaskets at their sides.

Adjustment of the piston travel is carried out with the aid of changeable spacer shims 8, thrust nut 11 serving for adjustment of the MAXIMUM position, and rod shank 12 serving for adjustment of the AUGMENTATION position.

Load-carrying ring. Load-carrying ring 4 (Fig.45) is fitted with brackets 2 for mounting the hydraulic cylinder shanks. The load-carrying ring is fabricated in sheet steel and has a channel-shaped section. The effort from the hydraulic cylinder is transmitted through the medium of shank 9 to ring 1?, sliding over the shutters.

Reactive forces are transmitted by the hydraulic cylinder shanks to the load-carrying ring, which is rigidly connected to the flange of the jet pipe by means of six links 3.

Synchronizing Devices

The synchronizing devices serve to ensure that the movement of the hydraulic cylinder rods is uniform and takes place within a specified time period. The synchronizing devices include synchronizing and additional valves.

Synchronizing valves (Fig.48) provide for synchronous travel of the pistons, that is for the same rate of travel at any given moment irrespective of the forces acting on the rods. Due to this, no misalignment results during flap ring

displacement. The rate of piston travel is controlled by changing the rate of hydraulic fluid flow from the hydraulic cylinders.

The synchronizing valves maintain a permanent pressure differential at flow restrictor 2 irrespective of the pressure value at the valve inlet and outlet. As soon as the piston starts moving at a higher rate, the hydraulic fluid outflow from the cylinders will increase, which will result in increased pressure upstream of flow restrictor 2 and in cavity Б. Pressure downstream of the flow restrictor will remain practically unchanged; as pressure increase in cavity Б will cause displacement of slide valve 3, which will partly close the hole in the liner thereby causing a reduction in the hydraulic fluid flow rate. The initial pressure value upstream of the flow restrictor will be reestablished.

Permanent pressure differential at the permanent jet (permanent resistance of flow restrictor 2) provides for permanent hydraulic fluid consumption through flow restrictor 2. Any pressure changes in the return line will not tell on the hydraulic fluid consumption through the throttling valve, the pressure differential remaining the same.

If the hydraulic fluid flows via the valve in the reverse direction, flow restrictor 2 is pressed off the seat and the valve allows unrestricted flow of the fuel.

Additional Valve

The kinematics of the jet nozzle control system do not provide for self-braking. The exhaust gas flow produced by the running engine generates a force which tends to bring the pistons to the augmented position. To equalize this force at the moment of flap opening, provision is made for an additional flow restricting device, which is installed at the hydraulic cylinder inlet, and whose function is to bring down hydraulic fluid pressure. The restricting effect is provided by the flow restrictor incorporated in additional valve 9, and by rigid attachment of the flow restrictor in synchronizing valve 13 (Fig.44). The capacity of the flow restrictor in the additional valve is adjusted after choosing proper flow restrictors for valves 13 and 13 (See Graph).

Hydraulic Fluid Lines (Fig.46)

Load-carrying ring 26 accommodates two manifolds 16. Each of the collectors has a connection for inlet of hydraulic fluid and three connections for delivery of the hydraulic fluid to the hydraulic cylinders. Joined to the hydraulic fluid inlet connections are the pipes of the aircraft hydraulic system. Secured to connections 7 are synchronizing valves 3 and pipes 6. The manifolds and the pipes are wound with heat insulating tape and are clamped by blocks to load-carrying ring 26.

Cooling System

The system for cooling the hydraulic cylinders and pipe lines (Fig.46) comprises the aircraft air intakes, delivery connections and casings.

The casing consists of two stamped parts. Lower part 12 is point-welded on the inner radius of load-carrying ring 26, and forms a seat for the cylinder and pipes. The link passes through a narrow slot in visor 9, which reduces air leakage. Walls 2 form annular air duct 1 around cylinder 10. Upper casing part 13 is secured to the lower part. The end faces of both parts are tightly pressed against ring 26, and are held by screws to brackets 8. The casings have ports 14 and 24 for connection of the aircraft air delivery pipes.

The air stream is divided in the casing. Part of the air flows along cylinder 10 and escapes through duct 11 at the end of the casing; the remaining portion of the air cools the cavity accommodating pipes 6 and passes into ring 26 via hole 2[illegible].

Ring 26 and casing 17 form a duct, enclosing manifold 16. After cooling the pipes, the air escapes through holes 21.

Operation of Jet Nozzle Flap Control System

(Fig.44)

With the engine control lever moved forward, voltage is delivered to electromagnet I of unit ГА-164М (three-position valve with electromagnet control). The unit opens ball valve 2. Duct 3 is connected to the pressure cavity, as a result of which valve 4 opens, while piston 5 opens valve 7 through the medium of pusher 6. Thus, operating pressure is supplied into cylinder cavity 11, whereas cavity 12 is connected to the return line. Synchronizing valves 13 installed at the return, maintain hydraulic fluid flow from each of the cylinders at a constant rate; therefore the pistons travel at the same rate (synchronously). The ring releases the flaps, and the jet nozzle is open by the action of the gas stream. The action of the forces generated by the gas stream is off-set by additional valve 9 which reduces pressure in cavity 11.

When the jet nozzle diameter reaches a certain value, electromagnet I of the ГА-164М switch cuts off the power supply. Valves 2 and 4 are closed by the action of the springs, piston 5 returns in the intermediate position, pusher 6 releases valve 7, which also closes. The cylinder cavities thus being locked, the pistons are retained in the predetermined position.

With the engine control lever moved backwards, voltage is delivered to electromagnet 8 of the ГА-164М switch. Further operation of the hydraulic system occurs as described above, the only difference being in that the operating pressure is supplied into the cavities which have been connected to the return lines.

Chapter X

ENGINE MOUNTING IN AIRCRAFT

The P11-300 engine is secured with the aid of brackets arranged in two attachment stations of the engine (Fig.43). The main attachment station is represented by the casing of the compressor sixth-stage guide vane assembly, located at the centre of gravity of the engine (Section BB).

Upper bracket 3 fitted with a spherical ring is designed for attachment of the aircraft pin, and serves for transmitting the engine thrust. The aircraft pin is so fitted into the bracket as to provide at least a 3-mm clearance between the casing and the pin, to allow thermal expansion of the engine (the clearance is illustrated on the diagram). Two side brackets 4 with eyes for connection of the aircraft struts, are designed to take up the engine weight and the overloads involved in aircraft manoeuvres.

The auxiliary attachment station arranged on the combustion chamber rear flange (Section ГГ) incorporates two brackets 7 which assume part of engine weight and overload that may appear.

Apart from the above brackets, the engine has bolts 1, arranged on the compressor front casing-to-distance ring joint flange; the bolts serve for coupling the brackets to the guiding rollers employed for mounting the engine into the engine compartment.

Bolts 2 located on the flange of the front and middle compressor casings serve for lifting the engine.

Brackets 6 provided on the main attachment station of the engine serve as thrust pieces for the engine mounted on the trolley.

Bolts 8 located on the rear flange of the combustion chamber housing (section through ГГ) serve for attachment of brackets used for production purposes.

The afterburner-to-engine joint is of a telescopic type. The afterburner is equipped with slides 9, which move over the rollers of the aircraft brackets.

Chapter XI

ENGINE ELECTRICAL EQUIPMENT

The engine electrical equipment includes the power supply sources, the starting units, the units providing for engine augmentation, the blocking devices, and the measuring instruments.

Power Supply Sources

The main power supply source is represented by starter-generator ГСР-СТ-12000ВТ rated at 12,000 W.

In generator duty the starter-generator operates as a shunt-wound generator in conjunction with voltage regulator РУТ-82, reverse current cut-out relay ДМР-400Д, and transformer ТС-9М. The equipment is provided for the following purposes:

(a) for stabilizing voltage delivered into the aircraft mains at various engine r.p.m.;

(b) for protection of the storage batteries against discharge current during parking or with the engine running at low speed;

(c) for reducing voltage variations due to variations in engine speed.

Engine Starting Units

1. Starter-generator with starting equipment.
2. Two booster coils КПА-114 with two erosion type spark plugs СПН-4-3.
3. Electric motor МУ-102А driving starting fuel pump ПНР-10-9М with electromagnetic valve МКПТ-9.
4. Electromagnetic valve МКПТ-9Ф controlling additional supply of main fuel.
5. Electromagnetic oxygen feed valve.
6. Electromagnetic valve МКПТ-9 controlling air blow-off valves.

1. Starter-Generator with Starting Equipment

Engine starting is accomplished with the help of starter-generator ГСР-СТ-12000ВТ, which operates as a starter during engine starting, and changes over to generator duty, after the engine has been started.

(a) Starter duty. With voltage across the starter terminals amounting to 19.3 V, at compound excitation and brake power equal to 2.5 kg-m, the unit should develop a speed of at least 1400 r.p.m.

The starter-generator is connected into the aircraft mains in parallel with the aircraft storage batteries, providing for autonomous starting of the engine.

(b) Generator duty:

power (at 30 V) .... 12,000 W
rated voltage .... 28.5 V
rated load current .... 400 A
operating speed range .... 4200 - 9000 r.p.m.
operating duty .... continuous

The starter-generator has two excitation windings: a shunt winding and a series winding. Within 12.6 sec. a series winding is connected into the shunt winding circuit to increase the follow-up speed.

As soon as the starter-generator starts delivering voltage, the series winding gets disconnected.

The starting system circuit diagram is presented in Fig.32.

The starting equipment includes: starting box КПР-15А, two change-over contactors КП-400Д, four contactors КМ-400Д, one contactor КП-50Д, starting resistor rated for 0.5 ohm, ground power supply source selector box КПА-4, one relay ТКЕ53ПДТ, one relay ТКЕ52ПДТ, two relays ТКЕ21ПДТ, one relay ТКЕ24ПДТ, resistor R·q = 0.3 ohm, and timer АВ-7-44-5.

All of the above equipment is installed on the aircraft in places easily accessible for mounting and servicing, exclusive of ground power supply source selector box КПА-4, which is contained in the set of the ground power supply source.

Starting box КПР-15А encloses: two relays ТКД12ПД1У, one relay ТКД12ПКТ, three relays ТКЕ52ПКТ, one relay ТКЕ53ПКТ, four relays ТКЕ21ПД1У, one resistor rated for 3 ohms, one relay ТКЕ22ПД1У, one relay ТКЕ22ПКТ, one relay ТКЕ21ПКТ, one relay ТНЕ201Д, one relay ТВЕ101В, resistor of the ПЭВ-7-36-1 type, two relays ТКЕ52ПД1У, and two relays ТКЕ54ПД1У.

The starting box has a plug connector for connection to the control circuits. Timer АВ-7-44-5 consists of electric motor Д-2Р with an electromagnetic brake coupling and a centrifugal speed governor, reduction gear, seven profiled cams, seven limit microswitches ПДФ, two relays ТКЕ53ПДТ, one relay ТКЕ52ПДТ, and one relay ТКЕ21ПД.

The operating time of the switches (from the moment button STARTING is pressed) and the time within which the switches return in the initial position (as measured from the end of the starting cycle) is indicated in the starting system diagram (See Fig.32).

2. Booster Coil with Spark Plugs

The ignition system of the combustion chambers comprises two booster coils КВИ-114 and two surface discharge erosion type spark plugs СПН-4-3 (Fig.37).

The peculiar feature of this system consists in that the discharge on the spark plug takes place between electrodes 13

and 14, across the operating surface of insulator 11, coated with the electrode metal. This metal coating turns out when the ignition system functions in parallel with fuel delivery, the process being the more intensive during engine starting on the ground. Therefore, with the engine started on the ground, the ignition system is switched on 7.1 sec. before delivery of the starting fuel. This provides for "exercising" the spark plug, as a result of which the operating surface of the insulator gets coated with the electrode metal due to the action of the spark discharges causing erosion of the electrodes. Besides, the spark plugs are exercised at the end of the starting cycle, from the moment of the operation of microswitch СТ up to the moment when operation of microswitch [illegible] of the БУ-4Б control unit occurs, that is until the engine reaches the idling rating r.p.m. The ignition system employing surface discharge spark plugs has the following advantages:

(a) rated flash-over voltage of 1500 V, resulting in reduced dielectric losses. Insulation of the electrical wiring becomes more reliable, which allows for engine starting at higher altitudes;

(b) the inductive component value of the secondary current increases providing for more effective ignition of fuel;

(c) the system is capable of normal operation irrespective of heavy carbon deposits on the spark plug insulator;

(d) the flash-over sparking voltage of the spark plug is practically independent of the pressure in the flame igniter (at least up to 5 kg/sq.cm.). The spark plugs (Fig.37) are a non-sectional shielded type, having ceramic insulation.

Booster coil КВИ-114 consists of a frame, high-voltage winding, low-voltage winding, interrupter, two high-voltage capacitors, one low-voltage capacitor, one plug connector of the [illegible] type, and one high-voltage lead.

The primary low-voltage winding of the induction coil is supplied with voltage from a D.C. power source via the interrupter. Connected in parallel with the interrupter is a capacitor.

Due to the presence of the interrupter (vibrating at a frequency of about 400 - 800 c.p.s.) pulsating voltage is induced in the secondary high-voltage winding, which is sufficient for formation of discharges on the plugs.

The secondary winding of the induction coil has one high-voltage lead running to the plug, the other lead running to the minus via the capacitor.

Booster coil КНА-114 provides for reliable spark formation, with power source voltage across the terminals of the booster coil unit amounting to 12 - 29.7 V. During operation of the booster coil the voltage should not be lower than, or exceed the specified limit.

The resistance of the line supplying voltage to the booster coil should not exceed 0.15 ohm.

3. ПНР-10-9М Starting Pump Electric Motor МУ-102А, Electromagnetic Valve МКПТ-9

Starting fuel pump ПНР-10-9М is driven by electric motor МУ-102А, having series excitation. The current consumed at rated power and voltage of 27 V amounts to 6 A.

Electric motor МУ-102А operates in parallel with the ignition system booster coils. Connection to the electric motor is accomplished by the use of a plug connector.

Starting fuel pump ПНР-10-9М is installed on the aircraft.

Incorporated in the fuel pipe line running from the starting fuel pump to the starting fuel manifold, is electromagnetic starting fuel valve МКПТ-9, which is engaged within 7.1 sec. after button STARTING is pressed.

With the voltage amounting to 27 V, the valve consumes current of 3.5 A.

4. Electromagnetic Additional Fuel Supply Valve МКПТ-9Ф

The valve is designed to feed an additional amount of main fuel into the primary manifold, when the engine is being started on the ground, which causes the engine to accelerate to the idling rating r.p.m. at a higher rate.

The electromagnetic valve is engaged within 25.6 sec. and is cut off as soon as the high-pressure rotor reaches a speed amounting to 48 ±1% of its normal r.p.m.

The electromagnet is supplied with voltage from a D.C. power source; with the voltage amounting to 27 V, the electromagnet consumes current not exceeding 3.5 A.

5. Electromagnetic Oxygen Supply Valve

The valve is designed for delivery of oxygen into the flame igniters of the combustion chambers when starting the engine during flight.

The electromagnet is supplied with voltage from a D.C. power source; at a voltage amounting to 27 V, the electromagnet consumes current of 3.5 A.

6. Electromagnetic Valve МКПТ-9 Controlling Hydraulic Air Blow-Off Valves

The valve serves for supplying main fuel (during engine starting) to the hydraulic valves, which open under the pressure of fuel and allow a portion of the air to be discharged into the atmosphere, thereby facilitating engine starting. The valve is engaged within 1.6 sec. after button STARTING has been pressed, and is cut off by cam ВДТ.

The electromagnet is supplied with voltage from a D.C. power source; with voltage amounting to 27 V, the electromagnet consumes current not exceeding 3.5 A.

Electromagnetic Fuel By-Pass Valve

The valve participates in the operation of the starting system from the 1st up to the 16th sec. Besides, the valve is connected into the circuit when the engine is being processed. At voltage amounting to 27 V the valve consumes current of 1.2 A.

Electric Units Providing for Engine Augmentation

With the afterburner turned on, the following electric units take part in the engine operation:

- control panel ПУРТ-1Ф;
- control unit БУ-4Б;
- booster coil КПА-114 with one spark plug СЭ-21Д5;
- electromagnet of fuel pump НР-22Ф;
- electro-hydraulic switch ГА-164М;
- electromagnetic fuel by-pass valve;
- limit switch of НР-22Ф pump fuel valve;
- Ist electromagnetic valve of carburettor МКПТ-9Ф and IInd electromagnetic valve of carburettor МКПТ-9Ф;
- limit switch of НР-21Ф regulating fuel pump hydraulic decelerator;
- afterburner control box КАФ-13Д;
- pulse delivery box КВС-1;
- rheostatic transmitter ДР-3А;
- feed-back transmitter ДОС-1А;
- rheostat Р-1;
- units decelerating and restoring the engine speed.

Engine Control Panel ПУРТ-1Ф

(Fig. 36)

Engine control panel ПУРТ-1Ф serves for closing and opening the electric circuits in the engine control system.

The control panel consists of the following main [illegible] casing 1, cam mechanism, four limit switches, dial 14, [illegible] connector 16, and lever.

As the drive shaft rotates, the limit switches [illegible] close or open the circuits, depending on the adjustment [illegible] the cam mechanism.

Dial 14 is mounted on splined bush 4 and is graduated [illegible] to 18[illegible] in both directions. With the lever set in the [illegible] position (58° from the horizontal axis of the control [illegible] the zero division of the scale should line up with the [illegible] provided on the boss of stop screw 5. Splined bush 4 has thrust pin 3, which abuts against stop screw 5 whenever [illegible] lever is turned through an angle of 113^{-1}. The cam mechanism allows for individual adjustment of each limit switch. [illegible]ed cams 6 are in constant touch with the roller mounted on axle 11. This axle is secured to shaped nut 9, which is [illegible] by spring 15. With the shaft rotating, the profiled cam rigidly secured to the shaft presses off the roller, thus transmitting the motion to the limit switch button through the medium of the shaped nut. The travel of the limit switch button is adjusted with the aid of the adjusting mechanism consisting of screw 1[illegible], spring 1[illegible], clamp 17, and shaped [illegible]

To adjust the cams for proper operating angles, remove cover 8 and loosen locking screw 1[illegible]. The position of profiled cam 6 relative to shaft [illegible] is changed by turning adjusting screw 13. Accuracy of adjustment is within $\pm 1^{\circ}$. The limit switches are adjusted for the following operating angles:

cam БФС – [illegible]° – 1°

cam ПК – 6[illegible]° – 1°

cam Ф – 6[illegible]° – 1°

cam 4 – 1[illegible]° ±1°

cam Ф is not connected into the system and does not take part in operation.

Control Unit БУ-4Б (Fig. 31)

Control unit БУ-4Б is mounted on regulating fuel pump HP-22Ф. The control unit comprises cast casing 1, enclosing four profiled cams 2, four rockers 10, and four limit switches 13.

The casing is provided with a flange for receiving the quick-disconnect ring of regulating fuel pump HP-22Ф.

Shaft 3 mounting cams 2 is coupled to the shaft of the speed transmitter of regulating fuel pump HP-22Ф. Cams 2 are fastened to shaft 3 with the aid of adjustment screws 8 and are locked by special screws 9. Rockers 10 are arranged on shaft 12 and are always pressed against the profiled cams by springs 11. For ease of mounting and adjustment of the profiled cams, the unit casing is fitted with removable covers 7 and 14. Mounting wires 4 running from the micro-switches are led into steel flexible hose 5 and terminate in plug connector 2РТ32П10ВШ1.

The limit switches in the control unit are labelled as СТ, БФО-1, ВДТ, and БФО-2.

Limit switch СТ is designed to disconnect the starter depending on the engine r.p.m. and to cut in booster coil КНА-114 with the purpose of exercising spark plugs СПН-4-3.

Limit switch БФО-2 delivers pulses causing the jet nozzle flaps to open from the MAXIMUM to the FULL AUGMENTATION position, whenever the engine speed is reduced below 60% of the high-pressure rotor speed.

Limit switch ВДТ serves to disconnect the electromagnetic valve controlling additional fuel supply as well as to discontinue spark plug exercising and to close the air blow-off valves (by deenergizing the electromagnetic valve).

Limit switch БФО-1 provides for blocking engine ratings depending on the speed of the high-pressure rotor, and serves for closing the jet nozzle flaps from the FULL AUGMENTATION position to the MAXIMUM position, as soon as the engine

reaches a speed amounting to 65% of the r.p.m. normally developed by the high-pressure rotor.

Booster Coil КНА-114 with the Spark Plug СЭ-21П5

In their design booster coil КНА-114 and spark plug СЭ-21П5 do not differ from those described earlier and used for ignition of the combustion chambers. Supply of high voltage from the booster coil to the spark plug is accomplished with the aid of adapter insulator П-12А and a current-carrying bus-bar connected to the spark plug and to the adapter.

Electromagnet of Fuel Regulating Pump HP-22Ф

The electromagnet (when energized) provides for fuel flow into the afterburner fuel manifold.

The electromagnet is supplied with voltage from a D.C. power source; at a voltage amounting to 27 V, the electromagnet consumes current not exceeding 0.35 A. The electromagnet winding is led to the plug connector.

Electro-Hydraulic Switch ГА-164М

The ГА-164М switch is essentially a solenoid-controlled valve serving for remote control of the jet nozzle actuating cylinders. The switch is installed on the aircraft.

Supply voltage amounts to 27 V, current - to 0.3 A.

Operating duty of the electromagnet - continuous.

Afterburner Electromagnetic Valves

Two electromagnetic valves provide for fuel supply from the main and primary manifolds into the combustors. The electromagnetic valves are cut in together with booster coil КНА-114 and are cut off by the limit switch of fuel regulating pump HP-22Ф (with the afterburner valve fully open).

With voltage amounting to 27 V, each of the electromagnetic valves consumes current not exceeding 3.5 A.

Limit Switch of HP-22Ф Fuel Pump Valve

The limit switch provides for cutting off afterburner booster coil КНА-114 and the electromagnetic valves of the carburettor, when the valve of the fuel regulating pump HP-22Ф is set in its furthermost position (corresponding to the fully open position of the afterburner valve).

Limit Switch of HP-21Ф Pump Hydraulic Decelerator

The function of the limit switch is to cut off the afterburner depending on the minimum permissible speed of the low-pressure rotor.

Afterburner Control Box КАФ-1ЗД with Additional Relay T

The afterburner control box accommodates four relays TBE101B, one relay ТКЕ53ПДТ, two relays ТКЕ21ПДТ, three relays ТКЕ52ПДТ, one relay ТКЕ14ПД1, and four relays ТКЕ12ПД1.

Pulse Delivery Box ПБС-1

The pulse delivery box is designed for delivery of pulses causing connection and disconnection of the servo-units (ГА-164М), when the bridge circuit of the follow-up circuit becomes unbalanced.

Arranged inside the box on shock absorbers is a polarized relay, responding to the direction and magnitude of the current causing bridge unbalancing. As soon as the unbalancing current reaches the magnitude sufficient for energizing the polarized relay, the latter delivers pulses to intermediate relay "a"

or "б", enclosed in the same box. Relays "a" and "б" deliver voltage to the electromagnets of electro-hydraulic switch ГА-164М, thereby causing the jet nozzle flaps to be opened or closed. The pulse delivery box is installed on the

Rheostatic Transmitter ДР-3А (Fig.34)

Rheostatic transmitter ДР-3А, is rigidly connected to the shaft of control panel ПУРТ-1Ф and comprises the pair of the bridge arms in the system of regulation. The rheostatic transmitter consists of the following main units: casing 14, drive shaft 17, sector 16, return spring 7, with contact device 12, holder 13 with resistor 4, cover 6, and others.

Shaft 15 mounting a gear, contact busbar 12, and is engaged with sector 16 through the medium of the

Return spring 7 is fitted into the hole provided in the casing, the other end being inserted into the sector hole.

While the lever of control panel ПУРТ-1Ф is on its forward travel, transmitter drive shaft 17 is running idle (it not engaged with the sector) until the lug on bush 10 rigidly connected to the shaft comes up against dowel 8 of sector 16.

Further rotation will cause the lug of bush 5 rotating together with the shaft, to actuate sector dowel 8, thereby transmitting rotary motion via the gearing to shaft 15, mounting the contact device sliding on resistor 4 and contact ring 1.

With shaft 17 rotating in the reverse direction the sectors are caused by return spring 7 to move backwards stop 11 rigidly secured to shaft 15 comes up against adjustment screw 3.

Feed-Back Transmitter ДОС-1А (Fig.35)

The feed-back transmitter comprises a second pair of the bridge arms and is designed to effect feed-back in the regulation system.

The feed-back transmitter consists of the following main units and parts: tube enclosing wire-wound resistor 4, slide 2 with contact device, fairlead 1, etc.

The resistor wire wound on a core is enclosed together with busbar 6 in a metal tube and is connected to the fairlead. The ends of the resistor are soldered to tips 3.

Slide 2 with contact springs 5 is essentially an insulator enclosed in a casing. One end of contact spring 5 slides along the resistor, the other - along current-carrying busbar 6.

Rheostat P-1 (Fig.36)

Rheostat P-1 consists of 3 adjustable resistors manufactured as separate units. The resistors are mounted in cast aluminum casing 1, which acts as a cover for control panel ПУРТ-1Ф.

The adjustable resistors serve for regulating the diameters of the jet nozzle flaps: screw 6 serves for adjustment of jet nozzle diameter at minimum augmentation, screw 5 - for adjustment of jet nozzle diameter at I stage full augmentation, and screw 4 - for adjustment of jet nozzle diameter at II stage full augmentation.

To adjust diameter of the jet nozzle, remove cover [illegible] of rheostat P-1 and adjust the jet nozzle diameter at the respective rating by manipulating the adjustment screw.

Units Decelerating and Restoring Engine Speed

Electromagnetic fuel by-pass valve (See Section Electric Units Providing for Engine Augmentation).

Electromagnetic starting fuel valve (See Section Engine Starting Units).

Electromagnetic oxygen supply valve (See Section Engine Starting Units).

Electromagnetic additional fuel supply valve (See Section Engine Starting Units).

Measuring Instruments

The engine is fitted with the following instruments: Two tachometer generators ДТЭ-1, miniature oil pressure gauge transmitter, transmitter of exhaust gas temperature gauge ТВГ-11Т. All of the above instruments are installed by the Manufacturing Plant.

The tachometer generator ДТЭ-1, when operating in conjunction with double-dial indicator ИТЭ-2, serves for measuring engine speed in percentage of the maximum r.p.m. The operating principle of the tachometer generator is based on transforming the engine rotor r.p.m. into three-phase alternating current with frequency proportional to the engine rotor r.p.m.

Alternating current is fed to the synchronous motor of the tachometer indicator. The tachometer generator is a three-phase A.C. machine employing a permanent four-pole magnet as a rotor.

The alloy used for the manufacture of the generator rotor, possesses high induction and considerable coercive force; its magnetic properties are almost not affected by vibration.

The stator has a four-pole, three-phase winding employing 0.27-mm copper wire. Each of the phases has four coils. The phases are star-connected.

The engine is equipped with two tachometer generators, for the low-pressure and high-pressure rotors respectively.

Double-dial indicator ИТЭ-2 indicates the speed of the engine rotor within 0 to 105%.

Indicator error at engine speed amounting to 1? - 60% of the maximum r.p.m. is equal to 1%. At engine speed amounting to 60 - 105% of the maximum r.p.m., the indicator error is equal to 0.5%.

100 per cent speed of the high-pressure rotor amounts to 11,425 r.p.m.

100 per cent speed of the low-pressure rotor amounts to 11,150 r.p.m.

The miniature oil pressure gauge is designed for measuring oil pressure at the engine inlet.

Exhaust gas temperature gauge TBГ-11T is essentially a thermoelectric set, consisting of a moving coil millivoltmeter and four thermo-couples connected in series.

The temperature gauge is designed for remote measurement of gas temperature aft of the turbine (exceeding 300°C).

The operation of temperature gauge TBГ-11T is based on the thermoelectric principle.

With the gas temperature aft of the turbine exceeding 300°C, thermoelectromotive force is generated in the thermo-couple circuit, whose magnitude depends on the material of the thermoelectrodes making up the thermo-couple, and on the temperature difference between the operating end (hot junction) and the free ends (cold junction).

The magnitude of the thermoelectromotive force is read on the indicating millivoltmeter graduated in degrees C.

In temperature gauge TBГ-11T all of the thermo-couples are connected in series thereby forming a thermo-battery, with total thermoelectromotive force corresponding to the mean temperature of gases in four points aft of the turbine.

The thermo-electrodes of the thermo-couple employed in the temperature gauge are fabricated in materials capable of producing thermoelectromotive force when the temperature of the hot junction rises to 300°C or over; therefore, the temperature of the thermo-couple free ends, varying within -60 to +50°C has no notable effect on the magnitude of thermoelectromotive force.

Variations in the ambient air temperature tell on [illegible] resistance of the indicator loop. To eliminate the [illegible] error, provision is made for a silit resistor accom[illegible] in the indicator and having a negative temperature [illegible]

Operation of Electrical Equipment

The electric equipment provides for the following[illegible]

1. Automatic starting of the engine:

(a) autonomous engine starting, with the use of [illegible] 48-V system;

(b) engine starting from ground power supply sour[illegible] with the use of 24- or 48-V system.

2. Manual regulation of fuel supply during autono[illegible] starting and when starting the engine from ground pow[illegible] sources.

3. Engine starting in air.

4. Engine cranking.

5. Switching in the maximum rating.

6. Switching in the augmented rating and regulatin[illegible] the jet nozzle flaps.

7. Voltage supply to the aircraft and engine load[illegible] boost-charging of the aircraft storage batteries (with [illegible] engine being at a standstill).

8. Engine processing.

Presented in Figs 32 and 33 are the starting system circuit diagram and the engine ratings control diagram. [illegible] provide for the normal operation of the electrical equ[illegible] the following devices should be turned on.

1. Master switch B_1, (connecting storage batteries [illegible] and AK_2 into the aircraft mains).

2. Circuit breakers A3C-25 (STARTING UNITS) suppl[illegible] voltage from the aircraft mains to the servo-circuits [illegible] to the starting system control circuits.

3. Circuit breakers A3C-15(AFTERBURNER [illegible] CUT-OFF) supplying voltage to the afterburner control circuits (See Fig.33).

Autonomous Engine Starting

Automatic autonomous starting of the engine is accomplished by the use of two storage batteries 15СЦС-45 which are switched over from parallel to series connection in the course of the starting procedure (using 24x48-V system).

When master switch B_1 is turned on, voltage is supplied to contactors K_3 and K_4. The winding of contactor K_4 is permanently connected to the positive terminal of storage battery AK_2; connection to the battery negative terminal being accomplished via contacts 7-8 of relay A and switch B_1.

The winding of contactor K_3 is permanently connected to the positive terminal of storage battery AK_1; connection to the battery negative terminal (led to the aircraft frame) is accomplished via contacts 5-4 of relay A and switch B_1.

The positive terminal of storage battery AK_1 is permanently connected to the aircraft mains via contactor K_3.

The negative terminal is permanently connected to the aircraft frame.

The positive terminal of storage battery AK_2 is connected to the aircraft mains via contactors K_4 and $КП_1$, whereas the negative terminal is led to the aircraft frame via contactor $КП_2$. Thus, both storage batteries are connected to the aircraft mains in parallel.

Engine starting is accomplished as follows:

1. Set the engine control lever in the IDLING RATING position.

2. Press button STARTING and release it in 2 or 3 sec.

With button STARTING pressed, voltage via circuit breaker A3C-25, time-lag safety fuse ИП-10, closed contacts of cam 2, and relay Г, blocking button STARTING when the starter-generator delivers voltage to the aircraft mains, flows to time

relay РВ, which prepares relay P_{16} for operation; voltage is also delivered via the closed contacts of relay P_{11} to relay A_1 of timer АВП-44-5; contacts 9-8 of the relay cause voltage to be delivered to relay A_4, whereas relay A_3 is energized via contacts 5-6.

Contacts 3-2 of relay A_4 cause voltage to be delivered to motor Д-2Р of the timer, which will start turning program cams 1, 2, 3, 4, 5, 6, and 7 thereby switching over the respective micro-switches at time periods, indicated in the cyclogram (Fig.32). Timer relay A_3 prepares the circuits for connection of a number of relays and contactors.

As soon as button STARTING is pressed, relay P_9 gets energized via cranking switch ВП; contacts 3-2 of the relay will cause voltage to be delivered to afterburner booster coil КНА-114 (thus causing spark plug СЭ-21Д5 to be exercised); contacts 2-1 of the above relay will cut the coil off [cut off at edge] ratings control circuit during engine starting.

Via closed contacts 4-5 of relay ЗВ and closed contacts 4-5 of relay P_5 the pulse is delivered to relay З whose contacts 3-2, 5-6 connected to the positive terminal of storage battery AK_1 will connect main fuel manifold booster coils КНА-114 via closed contacts of contactor КП4, two time-lag safety fuses ИП-10, and switch ВК. Pilot lamp IGNITION will light up at the moment voltage is delivered to spark plugs СПН-4-3. At the same moment voltage will be delivered to relay P_{14} via contacts 4-5 of relay ЗВ; contacts 3-2, 5-6 of relay P_{14} will cut-in the motor of the ПНР-10-9М pump, while contacts 11-12 will make up the circuit for connection of contactor $КП_4$ switching over the starting equipment power supply from 24 to 48 V; contacts 9-8 will make up the circuit for relay P_8. Contacts 11-12 of relay P_{14} disconnect the winding of contactor $КП_4$ depending on the operation of control unit limit switch СП (when the engine reaches speed amounting to 32% of the high-pressure rotor normal r.p.m.) or at the end of the timer cycle (at 44 sec.).

Relay P_{16} energized via contacts 3-2 of relay PL will open the circuit of voltage relay PH.

In 1.4 sec. the 1st cam will operate.

Relay P_1 energized when button STARTING was pressed is now kept picked up due to its contacts 9-8. At this moment button STARTING may be released, the timer having automatically operated throughout its cycle.

Cam 6 will operate in 1.6 sec. thereby delivering voltage via closed contacts 5-4 of relay P_3 and contacts 9-8 of relay P_{14} to the winding of relay P_8 whose contacts 3-2 will cause voltage to be supplied to fuel by-pass valve ЭМ4 (See ratings control circuit, Fig.33).

Contacts 9-8 of relay P_{14} in the circuit of relay P_8 will keep fuel by-pass valve ЭМ4 deenergized during cold engine cranking.

Cam 7 will also operate in 1.6 sec. thereby energizing relay P_4, whose contacts 5-6 will energize valve ЭМ8 controlling hydraulic air blow-off valves; contacts 1-2 of the relay will break the circuit delivering voltage to additional fuel supply valve ЭМ2 (up to 25.6 sec.).

Cam 2 will operate in 1.9 sec. thereby breaking the circuit of button STARTING and energizing relays BΓ, Ш, and contactor K_1. At this moment the engine starting cycle begins. Contacts 2-1 of relay Ш disconnect the shunt winding from voltage regulator РУГ-82; contacts 2-3 will connect the winding to circuit breaker АЗС-25 via contacts 1-2, 5-4 of relay ОШ; at the same time, a circuit will be formed by contacts 5-6 for energizing relay P_{16}.

Contactor K_1 will connect terminal СГ of the starter-generator to the aircraft mains via starting resistor [illegible] = 0.05 ohm, which limits current magnitude at the moment of the starter connection to provide for impact-free elimination of the gear clearances. Thus the series excitation winding is connected into the aircraft mains by contactor K_1, the shunt winding being connected by relay Ш.

Relay BΓ keeps reverse current cut-out relay ДМР[illegible] deenergized during engine starting.

Cam 3 operates in 4.1 sec. thereby connecting con[illegible] and relay [illegible].

Contactor [illegible] shunts starting resistor [illegible], thereby pr[illegible]ing for delivery of full voltage from the aircraft mains [illegible] the starter-generator. This causes the engine to spin inten[illegible]sively.

Contacts 4-5 and 7-8 of relay [illegible] (connected in paral[illegible]) cut voltage off the operating winding of regulator РУГ-82[illegible] contacts 3-2 of the same relay make up the circuit for con[illegible]tactor $КП_3$.

Cam 5 will operate in 7.1 sec. thereby energizing [illegible] via cranking switch ВП, contactors $КП_1$ and $КП_2$, closed contacts 1-2 of relay P_3; relay P_{17} is energized via contacts 5-6 of relay Ш.

The normally open contacts of contactors $КП_1$ and [illegible] will connect the negative terminal of storage battery [illegible] the positive terminal of storage battery AK_1.

Thus the batteries are connected in series, the resul[illegible]ing voltage of both the storage batteries being deliver[illegible] to terminal СГ of the starter-generator. This causes the speed of the starter-generator to increase, which results [illegible] more intensive spinning of the engine.

Contacts 5-4 of relay P_7 break the circuit deliver[illegible] voltage to the afterburner booster coil.

This cuts voltage off spark plug СЭ-21Д5.

Besides, contacts 3-2 of relay P_7 will cause voltage [illegible] be delivered to relay P_6 via terminals 4-5 of control unit [illegible] limit switch ВАТ; the relay will be kept energized by its contacts 3-2. Contacts 9-8 of relay P_6 will make up the circuit for electromagnetic additional fuel supply valve ЭМ[illegible] whereas contacts 5-4 will block contacts 5-6 of relay P_4[illegible]

At the same time, contacts 5-6 of relay P_7 will cause voltage to be delivered to contactor $КП_4$ via contacts 2-[illegible] of relay P_{12}, contacts 2-1 of relay P_{15}, closed contacts [illegible] of relay P_{14}, contacts 11-1[illegible] of relay [illegible] normally open contacts of contactor КП4 will cause increased voltage (48 V) to be delivered via safety fuse ИП-20 and series resistor to the starting units (booster coil КНА-114, motor of pump ПНР-10-9М, electromagnetic starting fuel valve ЭМ5, additional fuel supply valve ЭМ2, air blow-off valve ЭМ8, and fuel by-pass valve ЭМ-4. This is done to maintain the voltage delivered to the starting units at the required level, since supply of 48 V to the starter-generator causes a sharp voltage drop in the aircraft mains.

The series resistor $R_Д$ limits increase of voltage delivered to the starting units.

Contacts 2-3 of relay P_1 cause voltage to be delivered to starting fuel valve ЭМ5.

Starting fuel starts flowing into the flame igniters, the first period of spark plug exercising being thus terminated.

Cam 4 operates in 12.6 sec. thereby delivering voltage to relay ОШ and relay P_{11} which is kept energized by its contacts 6-5. Relay ОШ opens its contacts 4-5, 2-1 thereby connecting series resistor $R_Ш$ into the circuit of the starter-generator shunt winding.

This weakens the magnetic field of starter-generator excitation, which results in increased speed.

Relay P_{11} opens its contacts 1-2, thereby deenergizing timing relay PB, which opens contacts 3-2 with a time lag of 0.5 sec.; this causes the winding of relay P_{16} to be disconnected at 13.1 sec. Relay P_{16} closes contacts 1-2 thereby connecting the winding of voltage relay PH via resistor R_H to the circuit delivering voltage to booster coils КНА-114.

Resistor R_H is so selected as to allow voltage relay to pick up as soon as voltage in the supply circuit reaches 28 - 29 V.

Relay PH is connected .5 sec. after partial compounding to allow the transitory processes (changes taking place in current and voltage of the starter circuit) associated with

partial compounding of the starter-generator, to be terminated[illegible]

At 16.6 sec. cam 6 breaks the contact and deenergizes relay P_8 whose contacts 3-2 open the supply circuit of electro[illegible]magnetic fuel by-pass valve ЭМ4.

As the engine is being accelerated, current consumed by the starter-generator decreases, which causes voltage on terminal CГ and on the starting units to grow. Should the voltage increase to the value at which voltage relay PH (28-29) picks up, contacts 2-3 of this relay will cause vol[illegible] to be delivered to the winding of relay P_{12} whose contacts [illegible] will keep the relay energized, whereas contacts 2-1 will [illegible] the supply circuit of contactor КП4. Deenergized contactor [illegible] will cause voltage to be delivered to the starting units [illegible] the aircraft mains.

At 25.6 sec. cam 7 breaks the contact, thereby deenergiz[illegible]ing the winding of relay P_4. Relay P_4 will open its contac[illegible] in the circuit supplying voltage to electromagnetic air blo[illegible] off valve ЭМ8, though the valve will remain energized due [illegible] the action of contacts 5-6 of relay P_6.

At the same time, relay P_4 will close its contacts 1-2 thereby delivering pulse via closed contacts 9-8 of relay P_6 which will cause electromagnetic additional fuel supply valve ЭМ2 to be energized.

At 25.6 sec. cam 4 will operate thereby energizing relay P_{15}. Contacts 2-1 of the relay will break the supply circuit of contactor $КП_4$, thus disconnecting the contactor and causing voltage to be delivered to the starting units [illegible] the aircraft mains.

As soon as the engine reaches a speed amounting to 32[illegible] of the normal high-pressure rotor r.p.m., control unit limit switch CT will operate thereby closing terminals 4-5 and energizing relay P_5.

Contacts 2-1 of relay P_5 will cut the minus off the wind[illegible]ing of relay A_1, while relay A_1 (being deenergized) opens [illegible] contacts 2-3, 5-6, and 9-8, thereby deenergizing the windings of relays P_9, P_{14}, P_{16}, PH, БГ, Ш, and A_3, as well as the winding of contactor K_1. Relay A_3, in its turn, will deenerg[illegible] the windings of relays P, P_1, P_7, $P_{1?}$, OШ, P_{11}, and the windings of contactors K_2, $KП_1$, and $KП_2$.

Besides, contacts 11-12 of relay P_{14} will break the supply circuit of contactor КП4. Thus, the starting units, exclusive of electromagnetic additional fuel supply valve ЭМ2, air blow-off valve ЭМ8, and booster coils КНИ-114, become de-energized.

The starting cycle of the starter-generator thus comes to an end, and the latter starts operating as a generator. Booster coils КНИ-114 will be connected to the aircraft mains by contacts 5-6 of relay P_5, to effect repeated exercising of spark plugs СПН-4-3.

In case the engine fails to accelerate to a speed amounting to 32% of the normal high-pressure rotor r.p.m. within 44 sec., the starter-generator and the starting units are disconnected in the following sequence.

At 42 sec. cam 3 will break the contact and deenergize the windings of relays P and K_2. Relay P will close the circuit of the operating winding of voltage regulator РУГ-82, while contactor K_2 will connect starting resistor into the starter line circuit.

At 42.7 sec. cam 2 will break its contacts thereby de-energizing the windings of relays ВГ, K_1, and Ш. Contactor K_1 will disconnect the starter-generator. Relay Ш will connect the shunt winding to voltage regulator РУГ-82 and deenergize relay $P_{1?}$, thereby causing electromagnetic valve ЭМ5 to discontinue starting fuel supply.

Relay ВГ will cause voltage to be delivered to reverse current cut-out relay ДМР-400Д.

Then, cam 5 comes to the initial position (at 43.4 sec.) thereby deenergizing the windings of contactors $KП_1$ and $KП_2$ and relay P_7. Contactors $KП_1$ and $KП_2$ will switch over storage batteries AK_1 and AK_2 from series to parallel connection (from 48 V to 24 V).

Relay P_7 will open its contacts 3-2; nevertheless,

electromagnetic valves ЭМ2 and ЭМ8 will remain energi[illegible] to the action of contacts 3-2 of relay P_6.

At 44 sec. cam 1 will come to the initial positi[illegible] by deenergizing the windings of relays P_1, P_4, P_3, [illegible] and 3, which, in their turn, will deenergize relays [illegible] and OШ, the electric motor of starting fuel pump ПНР[illegible] booster coils КНИ-114, and timer motor Д-2Р. The time[illegible] to an end of its cycle. When the engine reaches a speed [illegible] ing to 32% of the normal high-pressure rotor r.p.m., [illegible] operates), the spark plugs are supplied with voltage [illegible]

When the engine reaches a speed amounting to 45% [illegible] normal high-pressure rotor r.p.m., cam ВДТ operates, [illegible] by breaking the winding of relay P_6, which, when deene[illegible] will cut off electromagnetic valves ЭМ2, ЭМ8, and will [illegible] energize relay P_5. The latter will disconnect booster [illegible] КНИ-114. Voltage will not be supplied to spark plugs [illegible] any more. Pilot lamp [illegible] will go out. This will [illegible] end of the starting cycle. All starting units will come [illegible] the initial position and will be ready for further ope[illegible]

In case the engine fails to be accelerated to a s[illegible] amounting to 45% of the normal high-pressure rotor r.p[illegible] electromagnetic valves ЭМ2 and ЭМ8 remain energized [illegible] should be switched off by manipulating circuit breaker [illegible] АЗС-25.

Engine Starting by Use of Ground Power Sources

Engine starting on the ground involves the use of [illegible] ground power supply source (24 - 48-V system); starting [illegible] accomplished with the aid of box КПА-4 installed on the [illegible] power source.

With voltage delivered to the ground receptacle, [illegible] will pick up and energize contactors K_3 and K_4, thereby [illegible] connecting storage batteries AK_1 and AK_2 from the air[illegible] mains.

After button [illegible] is pressed, engine starting procedure will be the same as in the case of the autono[illegible]

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starting. The only difference consists in that operation of cam 5 within 7.1 sec. after button STARTING has been pressed, will cause voltage to be delivered to contactors $КП_1$ and $КП_2$; only after that will contactor КП3, arranged on the ground power supply source, be energized via contacts 3-2 of relay СР. The ground power supply sources will be connected in series; as a result, voltage of 48 V will be delivered to the starter, the aircraft mains and all control circuits being supplied with 24 V.

Besides, the winding of contactor $КП_4$ is deenergized during starting, and the starting units are supplied with voltage from aircraft storage battery $Б_1$ which does not take part in the starting procedure. Due to a small load connected to the battery there is practically no voltage drop; as a result, the starting units are supplied with voltage of permanent magnitude.

In 44 sec. the starting system returns in the initial position.

The components of the starting system operate in the following sequence.

With voltage delivered to the ground power receptacle, relay A and contactors K_5 and K_6 get energized by being connected to the plus terminal of box КПА-4, the minus being supplied via the normally closed contacts of relays РД-1 and РД-2, terminal 6 of the receptacle incorporated in box КПА-4, contacts 5, 6 of relay A, and master switch B_1. The ground power supply sources are connected in parallel; operation of cam 5 causes the power sources to be connected in series.

As a result, contactors $КП_1$ and $КП_2$ will operate, contactor $КП_3$ being then supplied with voltage via contactor $КП_1$, contacts 3, 2 of relay СР, and terminal 4 of the receptacle incorporated in box КПА-4.

Relay A opens its contacts 1-11, and the winding of contactor $КП_4$ is caused to be deenergized throughout the starting period.

Further events will take place in the same sequence as in the case of autonomous engine starting.

Engine Starting with Manual Control of Fuel Delivery

Engine starting should be accomplished using the following procedure:

1. Press button STARTING and keep it pressed for 2 to 3 sec. The starting system will operate in the same manner as in the case of autonomous starting.

2. Manipulate the engine control lever in a smooth slow manner to start main fuel supply into the engine; accelerate the engine to idling rating r.p.m. Watch pilot lamp IGNITION to go out to see that the starting cycle has come to an end automatically.

Starting Engine in Air

Engine starting in air is accomplished at autorotation speed, with oxygen supply turned on, and the starter-generator not taking part in the starting cycle.

Engine starting should be accomplished as follows:

1. Shift the engine control lever to the IDLING RATING stop.

2. Turn on switch 3B STARTING IN AIR (circuit breaker A3C-10). This causes relay 3B to be energized.

Via circuit breakers A3C-25 and A3C-10 voltage is delivered from the aircraft mains to the windings of relay 3 and P_{14} (via contacts 6, 1 of relay 3B), and to relay P_{10} (via contacts 4, 5 of relay 3B), contacts 3-2 of relay 3B will cause voltage to be delivered to electromagnetic oxygen supply valve ЭМКГ.

Contacts 3, 4 and 5, 6 of relay 3 will deliver voltage to booster coils КПН-114, whereas contacts 3-2 and 5-6 of relay P_{14} will cause voltage to be delivered to starting fuel pump ПНР-10-9М, as described in section Autonomous Starting of Engine.

Pilot lamp IGNITION will light up.

Contacts 2-3 of relay P_1 will energize electromagnetic starting fuel pump ЭМ5.

Engine Cranking

The engine is cranked by the starter-generator, with no fuel supply or ignition system switched on. Engine cranking involves operation of electromagnetic valve ЭМ-3 controlling air blow-off valves (within the time period starting from 1.6 sec. up to 25.6 sec.).

To crank the engine proceed as follows.

1. Set engine cranking switch in the ON position.
2. Press button STARTING and keep it pressed for 2 to 3 sec. The engine control lever should be set against the CUT-OUT stop.

With the button pressed, the timer will proceed throughout the starting cycle exactly in the same manner as in the case of engine starting on the ground. The starter-generator will be spinning the high-pressure rotor until the starting cycle is completed.

Should it be necessary to spin the engine to less r.p.m., the starting cycle is discontinued by switching off circuit breaker АЗС-25. Before subsequent engine starting or cranking the timer motor will complete the starting cycle after circuit breaker АЗС-25 is switched on.

If button STARTING is pressed by mistake before the starting cycle is completed by the timer, neither voltage delivery to the starter nor to the ignition system will result, since no voltage will be delivered to relay A_1 and relay A_3 of the timer; hence, the switches of cams 3, 4, 5, 6, 7 and the circuit of cam 2 will remain deenergized.

Engine cranking is accomplished by the use of the 24-V system; no provision is made for switching over the power

supply sources and the supply circuit of the starting [illegible] from 24 to 48 V.

Switch CRANKING being set in the OFF position prevents pulse delivery from the 5th cam of the timer, thereby [illegible] allowing the power supply sources to be switched over [illegible] to 48 V; the supply circuit of the starting units is [illegible] open by the cranking switch.

Operation of Electrical Equipment with Maximum Rating Switched On

Maximum rating is switched on by shifting the engine control lever to the MAXIMUM stop.

As soon as the engine control lever is set against [illegible] MAXIMUM stop, limit switch ПК of control panel ПУРТ-10 [illegible] gizes relay Z, which closes its contacts 2-3 thereby [illegible] switches ГЗ and БФО-1.

Throughout engine operation from the starting moment [illegible] the moment switch БФО-1 is blocked, the jet nozzle flaps remain in the FULL AUGMENTATION position; as soon as the switch is blocked, the jet nozzle flaps are shifted in [illegible] MAXIMUM position.

Relay Z is energized from the aircraft mains via [illegible] breaker АЗС-15, pin 24 of the engine plug connector, the contacts of limit switch БФО-1 of control unit БУ-4Б, pins 13 and 44 of the engine plug connector, the contacts [illegible] hydraulic decelerator limit switch ГЗ, pins 23 and 6 of the engine plug connector, limit switch ПК of the control panel ПУРТ-10, pin 22 of the engine plug connector, and pin 14 of the plug connector incorporated in the afterburner control box.

To turn off the maximum rating, the engine control [illegible] is removed from the MAXIMUM stop. This causes limit switch [illegible] of the control panel to be open; as a result relay Z will [illegible] deenergized. Contacts 2-3 of the relay will drop out, [illegible] unblocking limit switches ГЗ and БФО-1.

The jet nozzle flaps remain in the MAXIMUM rating position up to the moment limit switch БКС-2 is blocked, then they are shifted to the FULL AUGMENTATION position.

Augmented Rating

Augmented rating is turned on by setting the engine control lever in the MINIMUM AUGMENTATION position, FULL AUGMENTATION position or somewhere between these positions.

This causes operation of control panel limit switch БКС, which energizes relay $Φ_1$. This relay cuts in two carburettor valves and afterburner booster coil КНА-114. Ignition of the afterburner flame igniter takes place.

The electromagnetic valve of regulating fuel pump НР-22Ф is energized at the same time, which allows fuel to flow into the fuel manifolds of the afterburner. With the engine control lever set in the MINIMUM AUGMENTATION position, the jet nozzle flaps are shifted to the MINIMUM AUGMENTATION position, the winding of electro-hydraulic switch ГА-164М (М) being de-energized, and the winding of switch ГА-164М (Ф) being supplied with voltage.

As soon as the afterburner is turned on, the electro-hydraulic follow-up system controlling the jet nozzle flaps starts functioning. This system comprises a D.C. bridge circuit; connected into the diagonal of this bridge circuit is the winding of highly-sensitive polarized relay РПС.

The slide of rheostatic transmitter ДР-3А moves in unison with the engine control lever, which disturbes the balance of the bridge circuit and results in appearance of current in the winding of relay РПС. Depending on the direction of the current, relay РПС closes either the left or the right pair of the contacts, thereby cutting in switch ГА-164М (М) or ГА-164М (Ф), and causing the jet nozzle flaps either to partially close or open.

The slide will move relative to the resistor of rheostat ДОС-1А simultaneously with the hydraulic cylinder rod. This

will result in less disbalance of the bridge circuit and [illegible] reduction of current flowing in the diagonal of the bridge, that is in the winding of relay РПС. As soon as the circuit disbalance is eliminated by the action of the rheostat, and the current in the winding of relay РПС becomes less than the pick-up current, the contacts of relay РПС will set in the neutral position. Both windings of electro-hydraulic switch ГА-164М will be deenergized.

The hydraulic system being locked, the jet nozzle flaps will remain fixed until the engine control lever is shifted to a new position. Thus, the jet nozzle flaps follow up the engine control lever within the zone of afterburner regulation.

Full augmentation is switched on by setting the engine control lever in the FULL AUGMENTATION position.

While the engine control lever is being smoothly moved, the afterburner is switched off by control panel limit switch БКС. By this moment the jet nozzle flaps will have come to the MINIMUM AUGMENTATION position.

In case the afterburner is abruptly turned off with the engine control lever set below the MAXIMUM stop, a sharp [illegible] is experienced in the low-pressure rotor speed. To reduce this speed increase, provision is made for relay T, which delays disconnection of afterburner fuel supply while the jet nozzle flaps are being shifted from the FULL AUGMENTATION to the MINIMUM AUGMENTATION position. Afterburner fuel supply is cut off only after the jet nozzle flaps have occupied the required position.

In case afterburner cutting off is associated with a drop in high-pressure rotor speed, which becomes equal to the speed of operation of limit switch Г3, afterburner fuel supply is discontinued after operation of limit switch Г3. In case variable duty system of jet nozzle control fails, the pilot should pass over to the two-position control system by manipulating switch EMERGENCY CONTROL OF TWO-POSITION JET NOZZLE, which will cut off the follow-up system.

In this case full augmentation will be controlled only by switch 4 of the control panel, whereas the blocking system providing for delay in disconnection of afterburner fuel supply will be cut out.

Operation of Electric Equipment with Afterburner Switched On

When the engine control lever is set against the MINIMUM AUGMENTATION stop, switch БФС will operate thereby supplying voltage to the winding of relay $Ф_1$ via circuit breaker АЗС-15, 24th terminal of the engine plug connector, limit switch БФО-1, 13th and 44th terminals of the engine plug connector, limit switch ГЗ, terminals 23 and 16 of the engine plug connector, switch БФС of control panel ПУРТ-1Ф, terminal 12 of the engine plug connector, terminal 11 of afterburner control unit КАФ-13Д, and contacts 4-5 of relay В.

Contacts 2-3 of relay $Ф_1$ will cause voltage to be delivered to relay Н (via terminal 2 of the afterburner control unit, terminal 20 of engine plug connector, limit switch of pump НР-21Ф, terminal 15 of the engine plug connector, and terminal 26 of the afterburner control unit), to relay $Ф_2$ (via contacts 1-2 of relay С or Д, and switches controlling time delay (В, Д, or Г), to the electromagnetic valve of pump НР-22Ф ЭМ1 and to the afterburner pilot lamp (via contacts 1-2 of relay С or Д, time delay control switches А, Б, or Е, contacts 7-8 of relay КТ, terminal 4 of the afterburner control unit, and terminal 8 of the engine plug connector).

Relay Н will close its contacts 5-6, thereby causing voltage to be delivered to carburettor electric valve ЭМ6 (via terminals 9 of the afterburner control unit and terminal 32 of the engine plug connector) and to afterburner booster coil КНА-114 (via terminal 9 of the afterburner control unit, the processing switch, and contacts 1-2 of relay $Р_9$). Contacts 2-3 of the same relay will cause voltage to be fed to the 2nd carburettor electric valve ЭМ7 (via terminal 27 of

afterburner control unit and terminal 17 of the engine [illegible] connector).

As soon as pressure in the afterburner fuel [illegible] builds up to the specified value, the limit switch [illegible] НР-22Ф (КН, НР-22Ф) will cut off carburettor valves [illegible] and ЭМ7, and afterburner booster coil КНА-114.

Relay $Ф_2$ will open its contacts 5-4 thereby de[illegible] the winding of electro-hydraulic switch ГА-164М (ЭМ) [illegible] tacts 2-3 of the same relay will cause voltage to be [illegible] the winding of relay [illegible] via contacts 8-7 of relay В, [illegible] will close its contacts 5-6 thereby causing voltage [illegible] to the bridge follow-up circuit via terminal 4 of box [illegible] series resistor R, terminal 8 of box РПС-1, terminal [illegible] afterburner control unit, contacts 5-6 of relay [illegible] of the afterburner control unit. This causes variable [illegible] nozzle control system to be set in operation. At the [illegible] voltage is supplied to terminal 2 of feed-back trans[illegible] ДОС-1А and to terminal 1 of the engine plug connector [illegible] to switching on the afterburner, the jet nozzle flaps [illegible] the MAXIMUM rating position.

This position of the jet nozzle flaps is associated [illegible] a certain position of the feed-back transmitter slide [illegible] to its winding.

With the engine control lever set in the [illegible] TION position, the balance of the bridge circuit gets [illegible] turbed, that is, voltage across the slide of rheostat [illegible] (terminal 2 of ДР-5А) will be lower, than across the [illegible] the feed-back transmitter (terminal 2 of ДОС-1А). [illegible] unbalancing current will flow along the diagonal. The [illegible] will flow from terminal 1 of feed-back transmitter ДОС-1А [illegible] terminal 2 of rheostat ДР-5А via terminal 6 of box [illegible] the winding of relay РНС, terminal 7 of box [illegible]-1, ter[illegible] of the engine plug connector.

With the current flowing in this direction via the [illegible] ing of relay РНС, the left pair of contacts of the pola[illegible] relay will close, thereby causing voltage to be fed to [illegible] (via terminal 6 of the afterburner control unit, contacts 2-1 of relay B, terminal 22 of the afterburner control unit, and terminal 5 of box KBC-1).

Relay б will close its contacts 3-2, thereby causing voltage to be supplied to the winding of electro-hydraulic switch ГА-164М (Ф) via terminals 4 and 3 of box КРС-1. The hydraulic system will start opening the jet nozzle flaps, and the unbalancing current in the bridge circuit diagonal will start diminishing, since the slide of feed-back transmitter ДОС-1А will move in unison with the cylinder rod relative to fixed resistor ДОС-1А, thereby causing a reduction in voltage across terminal 1 of the feed-back transmitter.

When voltage across terminal 1 approximates voltage across terminal 2 of rheostatic transmitter ДР-3А, the unbalancing current in the winding of relay РПС will drop to a value which is below voltage causing relay РПС to operate. The left and right pairs of contacts of relay РПС will be open thereby causing both windings of hydraulic switch ГА-164М to be de-energized. The hydraulic system will be locked, and the jet nozzle flaps will be fixed in the MINIMUM AUGMENTATION position.

Further movement of the engine control lever towards increased augmentation will actuate the follow-up system and the jet nozzle flaps will shift to a new position which corresponds to the engine control lever position.

With the movement of the engine control lever towards decreased augmentation will cause voltage across terminal 2 of rheostatic transmitter ДР-3А to increase in excess of the voltage across terminal 1 of the feed-back transmitter, as a result of which unbalancing current will flow from terminal 2 of the rheostatic transmitter to terminal 1 of the feed-back transmitter via the winding of relay РПС. In this case, the right pair of contacts of relay РПС will close thereby causing voltage to be fed to relay "a". Relay "a" will deliver voltage to relay T via terminal 4 of box КРС-1, its contacts 3-2, and terminal 1 of box КРС-1. Relay T will energize the wind-

ing of electro-hydraulic switch ГА-164М (М). The hydraulic system will start closing the jet nozzle flaps until the unbalancing current drops below the pick-up current of relay [illegible]. The jet nozzle flaps will be set in a position corresponding to the new position of the engine control lever.

Provision is made in the engine control circuit for delaying the opening of the jet nozzle flaps and afterburner fuel supply, when the afterburner is turned on.

Jet nozzle flaps opening may be delayed by 0 sec., 1 sec., and 2 sec. Within this period of time the flaps remain in the MAXIMUM position.

Fuel supply may be delayed by 0 sec., 1 sec., and 2 sec.

The above delays are provided for by time relays PB_1, PB_2, PB_3, PB_4, as well as relays "c" and "д". The delays in jet nozzle opening and in supply of afterburner fuel involve deenergizing of the time relays, which is accomplished by opening normally closed contacts 2, 1 of relay $Ф_1$, when the afterburner is turned on.

Besides, to ensure the required delays, it is necessary to set jumpers A, Б, В, Г, Д, and E of the afterburner control unit КАФ-13Д in the respective positions (arrangement of the jumpers is illustrated in the ratings control circuit diagram, Fig.33).

By opening its contacts 2, 1, relay $Ф_1$ will deenergize the time relay unit, which has been energized by switching on circuit breaker АЗС-15. Time relays PB_1, PB_2, PB_3, and PB_4 will open their contacts within 0.5 sec., thereby causing relay C to be deenergized in 1 sec. and relay Д - in 2 sec.

By closing their contacts 1-2 via respective jumpers, relays C and Д provide for the necessary delays in opening of the jet nozzle flaps and in supply of the afterburner fuel.

With the afterburner turned off, relay $Ф_1$ drops out, [illegible] causes the bridge circuit to be unbalanced; relay РПС will energize relay "a". Contacts 3, 2 of relay "a" will cause current to be fed to relay T. Contacts 2, 3 of relay T will cause voltage to be supplied to the winding of electro-hydraulic switch ГА-164М (М) via ИП-5 and contacts 2, 3 of relay T; contacts 5, 6 and 8, 9 of the relay will cause voltage to be delivered to the electromagnet of ИГ-229 (ЭМ1) pump valve, and to the winding of relay Φ_2 (via circuit breaker АЗС-15), to terminal 13 of the engine master plug connector, to limit switch БФО-1, to terminal 24 of the engine master plug connector, to contacts 8, 9 of relay T, to terminal 3? of afterburner control unit КАФ-13Д connected to the winding of relay Φ_2, and to contacts 5, 6 of relay T, to terminal 8 of the engine master plug connector, and to the electromagnet of valve ЭМ1.

Relay T will be kept deenergized until the bridge circuit is balanced again, which will take place when the jet nozzle flaps are set in the MINIMUM AUGMENTATION position, that is, when the unbalancing current drops to zero. As soon as the bridge circuit gets balanced, afterburner fuel supply is discontinued, as contacts 3, 2 of deenergized relay [illegible] open the supply circuit of relay T.

The following events will take place when passing over to the two-position system of jet nozzle control: the winding of relay B will be energized by manipulating switch EMERGENCY CONTROL OF TWO-POSITION JET NOZZLE.

Contacts 2, 1 of relay B will deenergize the contacts of relay PHC, whereas contacts 8, 7 will deenergize the winding of relay L. Contacts 5, 6 of relay L will deenergize the bridge circuit. Thus, the entire system controlling the variable-duty jet nozzle will become deenergized. Contacts 4, 5 of relay B will disconnect the winding of relay Φ_1 from voltage supply via switch БУС of the control panel, whereas contacts 6, 5 will cause voltage to be supplied via switch 4 of the control panel.

With the use of the two-position jet nozzle control system, the afterburner is turned on by setting the engine control lever in the FULL AUGMENTATION position. Afterburner ignition will proceed in the same manner as has been described above. The winding of hydraulic switch ГА-164М (Ф) is kept energized

throughout the afterburner operation, while the [illegible] flaps are set in the FULL AUGMENTATION position. [illegible] is energized via terminal 6 of the afterburner con[illegible] contacts 2-3 of relay Φ_2, contacts 8-9 of relay [illegible] terminal 15 of the afterburner control unit. With the [illegible] burner cut off, contacts 2, 3 will open and contac[illegible] relay Φ_2 will close. The winding of switch ГА-164[illegible] deenergized, voltage being delivered to the winding [illegible] switch ГА-164М(М); the jet nozzle flaps will shift [illegible] MAXIMUM position.

Engine Processing

The sequence of the electrical equipment opera[illegible] engine processing is similar, in the main, to the [illegible] electrical equipment operation during autonomous engin[illegible]ing.

Processing switch ВХ is set in the K position[illegible] switch K (see Fig.33) is turned off. This causes the [illegible] coil to be cut off; at the same time, all engine elec[illegible] magnetic valves, exclusive of fuel by-pass valve ЭМ[illegible] prepared for processing.

During the processing procedure, electromagnetic [illegible]tional fuel supply valve ЭМ2 is kept energized with[illegible] period starting from zero up to 44th sec., whereas [illegible] off valve ЭМ8 is kept energized within the period [illegible] from 1.9 sec. up to 25.6 sec.

As soon as button STARTING is pressed, voltage is [illegible]vered to relay P_3 via safety fuse ИП-20, the normally [illegible] contacts of relay $КП_4$, contacts 3-2, 5-6 of relay [illegible] nel [illegible] of box КПР-15А, safety fuse ИП-10, the con[illegible] switch ВК, terminal [illegible] of box КПР-15А; electromagnetic [illegible]tional fuel supply valve ЭМ2 is energized via contact[illegible] of relay P_6.

Valve ЭМ2 will be kept energized until the [illegible] [illegible] cycle, since contacts 1-2 of relay P_3 will deener[illegible] relay P_7 thereby preventing relay P_6 from being energ[illegible]

Contacts 5-4 of relay P_3 will open the circuit of relay P_C thereby preventing voltage from being supplied to electromagnetic fuel by-pass valve $ЭМ_4$.

At the same time, 1st carburettor electromagnetic valve ЭМ6 will be supplied with voltage via safety fuse ИП-10 and the contacts of switch ВК (See Fig.33); the winding of relay КР will be energized via terminal 18 of box КАФ-13Д.

Contacts 3-2 and 9-8 of relay КР will cause voltage to be fed to electromagnetic valves ЭМ7 and ЭМ1 while the timer completes its cycle.

After the engine has been processed in accordance with the above cycle, it is necessary to process fuel by-pass valve $ЭМ_4$.

For this, turn on switch К, and press button STARTING.

SECRET
NO FOREIGN DISSEM

[redacted]

50X1-HUM

R11F-300 ENGINE

Technical Description

SECRET
NO FOREIGN DISSEM