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THE CONTROL SYSTEM OF THE SOVIET TURB[illegible] ENGINE D-30

by

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13. ABSTRACT

In article they have described the operation principles of components of control system of sovietic turbofan engine D-30: the fuel flow control unit NR 30 that retains constant rotational speed of the high pressure compressor in various flight conditions; the centrifugal governor CR IW that limits the low pressure compressor speed and the centrifugal governor CR 2W that controls the bleed valves and the inlet guide vanes of the high pressure compressor [AP1032620]

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CONTROL SYSTEM OF THE SOVIET TURBOFAN ENGINE D-30

[Article by Master Eng Emil Wegrzyn; Technika Lotnicza i Astronautyczna (Aviation and Astronautics Engineering), Polish, Vol 25, No 10-11, 1970, pp 7-10]

The article discusses the functioning of the most important assemblies in the control system of the Soviet coaxial turbofan engine D-30: the NR-30 mechanism for metering fuel output; the excentric CR-1W regulator limiting the rotation speed of the engine's low-pressure assembly; and the excentric CR-2W regulator controlling air outlet and input valves and the vanes of the input control device in the high-pressure compressor.

The basic assembly in the control system of the Soviet coaxial turbofan engine D-30 (designed by the Solov'yev Bureau for the Tu-134 aircraft) is a fuel output metering mechanism which is block-connected with a Vickers type piston pump and which bears the designation NR-30. Auxiliary tasks are performed by the excentric regulators CR-1W and CR-2W.

Fuel Output Metering Mechanism NR-30

Fuel Output Regulation Under Steady Conditions of Engine Work

Under varying flight conditions, the work of the engine is kept steady by:

a differential valve in the range of rotational speeds of the high-pressure assembly which are smaller than the regulated speeds, that is, smaller than 9,700±100 r.p.m.,

an excentric regulator of the pump in the range of regulated rotational speeds.

The differential valve operates on the principle of maintaining a constant fuel pressure difference of 10 kg/cm^2 before and behind the choking

Namely, when the difference becomes greater than 10 kg/cm^2, the fuel pressure in front of the choking valve pushes the differential valve slider to [illegible] connection with the sink of the space enclosed by the pistons of the hydraulic servo system is made. At the same time, the slider connects the high-pressure channel behind the pump with the space under the piston which controls the resistance dial. As a result, the setup of both pistons shifts upward, decreasing the angle of inclination of the resistance dial and thus diminishing the output of fuel from the pump.

When the fuel output decreases, the difference between the pressures in front of and behind the choking valve also decreases. This goes on until this difference reaches the preset value of 10 kg/cm^2. At that moment, the differential valve slider returns to its initial position, thus closing off the inflow of fuel into the space under the piston of the resistance dial and disconnecting the inter-piston space from the sink.

Due to the differential valve, fuel output remains unchanged in spite of the change which occurs in the rotational speed of the high-pressure assembly as a result of changed flight conditions.

After the choking valve is closed, the fuel pressure difference rapidly increases above 10 kg/cm^2, and the differential valve slider slides to the extreme left position. As a result, the resistance dial is set into a position which corresponds to the minimum fuel output, preventing a rise in the fuel pressure which could damage the output regulator.

Within the range of regulated rotational speeds, the fuel output is regulated by the excentric regulator.

The position of the excentric regulator slider is a function of the engine's rotational speed. When this rotational speed is steady, the slider assumes a position in which the whole servo system is in equilibrium. In order to increase the rotational speed of the engine, the load on the spring of the excentric regulator slider must be increased, and this is accomplished by shifting the control lever.

When the rotational speed decreases, the regulator slider loses its equilibrium and slides downward. This position of the slider increases fuel inflow into the space above the upper piston of the servo system and, at the same time, it connects the space under the resistance dial piston with the sink. The setup of both pistons begins to shift downwards, increasing the angle of inclination of the resistance dial and the fuel output as well. By sliding downward, the slider of the upper piston connects, by means of the choke, the space between the pistons with the line of the sink. Under the effect of the lever, the bushing of the regulator slider also begins to move downward, however, with a certain delay with respect to the slider, thus functioning as a typical catch-up system. When the rotational speed of the engine is close to the preset speed, the regulator slider and bushing are in the initial position. The space above the upper piston and the space under the resistance dial piston are supplied with fuel at the same pressure as during the preset rotational speed, while the space between the pistons is connected with the constant-pressure channel by means of the slider of the upper piston. In the space between the pistons, the pressure and the opposite movement of the pistons increase. The slider and bushing of the excentric regulator move upward with the same speed (their mutual position does not change). This upward movement ceases when the slider of the upper servo piston closes off the connection of the inter-piston space with the constant-pressure channel. This takes place when the engine reaches the required rotational speed. Then, the regulator slider and bushing and the upper piston assume their initial position, while the resistance dial piston assumes a position in which the angle of inclination of the resistance dial is increased.

When the rotational speed increases, the whole system operates in a manner analogous to the above, however, the motion of all the above-mentioned parts proceeds in the opposite direction, while the space between the pistons is connected, not with the constant-pressure channel, but with the sink.

Regulation of Fuel Output During Acceleration

During acceleration of the engine, the fuel output is regulated by the following assemblies:

the hydraulic delayer which operates within the range of regulated rotational speed,

the pressure rise limiter which operates within a range from the idle gear to rotational speeds smaller than the starting speeds.

When, within the range of regulated rotational speeds, the control lever is shifted forward, then, by means of a cog wheel, this lever pushes the bushing of the sliding hydraulic delayer upward. The sliding bushing closes the fuel sink opening in the cylinder of the delayer piston, with the result that the fuel coming from the constant-pressure channel flows into the space under the piston. The piston and its cylinder shift upward with a speed determined by the capacity of two hydraulic dampers. As a result, the lever, whose one end is connected with the cylinder and the other with the spring of the excentric regulator slider, begins to exert force on the regulator spring. The spring adjusts the excentric regulator to the new work conditions (the slider moves forward). The delayer piston stops shifting when the sink opening in the cylinder opens, that is, when the piston has shifted by the same distance as did the sliding bushing.

When the engine's rotational speed decreases, the hydraulic delayer piston shifts down with a speed determined by the capacity of the upper hydraulic damper, which is adjusted so that the flame in the combustion chamber of the engine would not go out.

When the control lever is smoothly shifted forward of the position corresponding to the idle gear, the fuel pressure in front of the dividing valve rapidly increases. As a result, the slider of the pressure rise

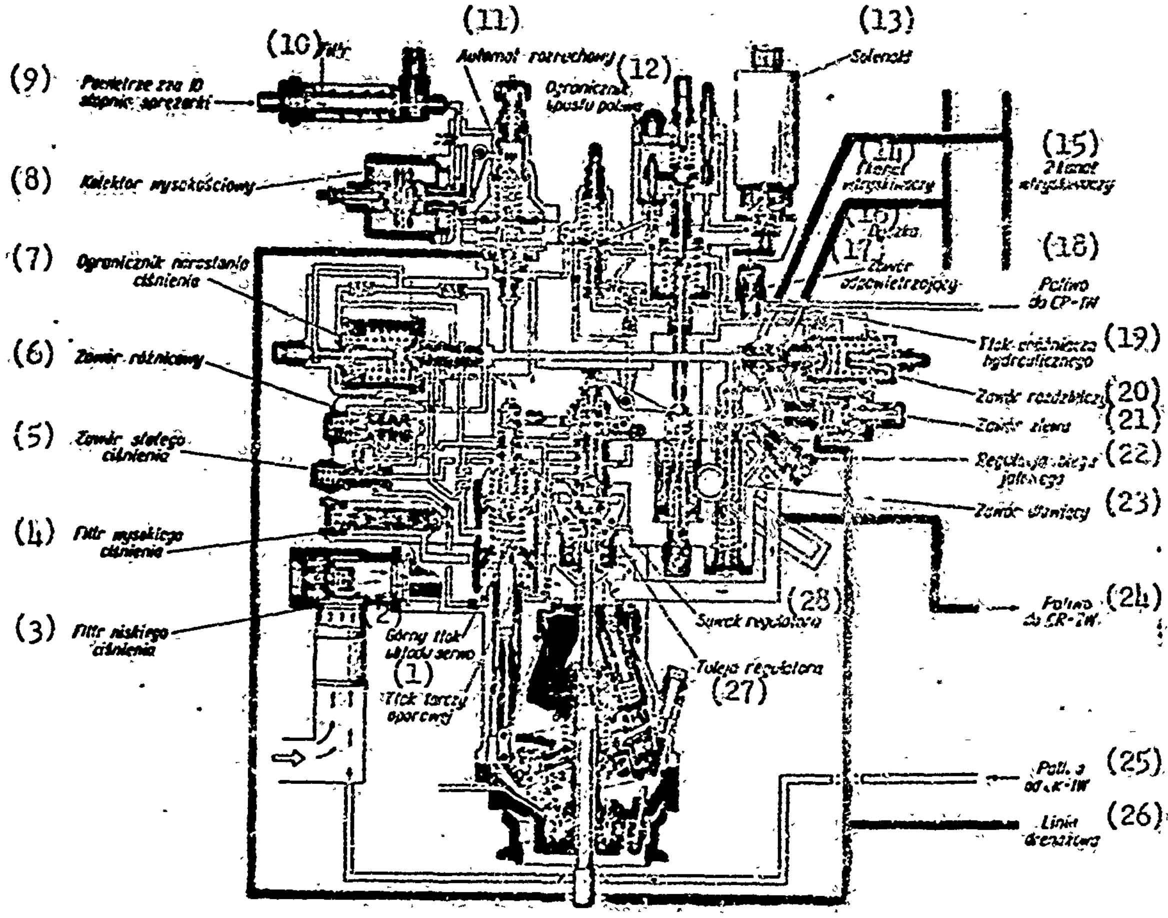

Figure 1. Outline of the Fuel Output Regulator NR-30

Key:

1. Resistance dial piston
2. Upper piston of servo system
3. Low-pressure filter
4. High-pressure filter
5. Constant-pressure valve
6. Differential valve
7. Pressure rise limiter
8. Altitude collector
9. 10-stage compressor air
10. Filter
11. Starting mechanism
12. Fuel outlet limiter
13. Solenoid
14. First channel of injectors
15. Second channel of injectors
16. Jet cone
17. Deaerating valve
18. Fuel to CR-1W
19. Piston of hydraulic delayer
20. Dividing valve
21. Sink valve
22. Regulation of idle run
23. Choking valve
24. Fuel to CR-2W
25. Fuel to CR-1W
26. Drainage line
27. Regulator bushing
28. Regulator slider.

limiter moves to the left and closes the channel of fuel outflow from the space on the left side of the limiter piston, whither the fuel is conducted from the area in front of the dividing valve through a system of two hydraulic dampers. The piston overcomes the resistance of the spring, begins to move to the right, and stretches the spring for as long as the fuel pressure in front of the dividing valve increases. In this way, the pressure rise limiter exerts no effect on the change in the fuel output.

When the control lever is suddenly shifted forward, the fuel pressure under the piston of the resistance dial rapidly falls. The simultaneous, rapid rise in the pressure in front of the dividing valve shifts the limiter slider to the left so that the space between the pistons of the hydraulic servo system is connected with the sink, while fuel from the area in front of the dividing valve is conducted, through an oblique opening, into the space under the piston of the resistance dial. In this way, the piston of the resistance dial remains in the initial position for a certain period. During that time, fuel flows from the constant pressure channel, through two hydraulic dampers, into the space under the piston of the hydraulic delayer, with the result that the piston and its cylinder move upward with a definite speed. The lever exerts force on the spring of the excentric regulator slider, and the spring resets the regulator so that fuel flows from the const- -pressure channel into the space above the upper piston of the servo sys..., while the space under the piston of the resistance dial is connected with the sink. While the limiter piston is moving to the right, the opening in its cylinder is opened, and additional fuel which bypasses one damper flows into the space on the left side of the piston and causes it to move even more. This closes the oblique opening in the bushing of the limiter slider and turns off the inflow of fuel from the area in front of the dividing valve into the space under the piston of the resistance dial. As a result, the fuel output from the pump is increased, and all assemblies are in a position corresponding to a greater rotational speed.

Starting the Engine

When the engine is not working, the resistance dial of the piston pump is positioned at a maximum angle. In view of this, in the first moment of starting, the amount of fuel delivered would be too large in proportion to the amount of air. This would suddenly raise the temperature above the permitted level. The action of the automatic starting mechanism consists of adjusting the fuel supply to the air supply. In the first phase of starting, the inflow of air is small, while the fuel pressure in front of the dividing valve rapidly increases, and therefore the slider of the automatic starter is raised, allowing a portion of the fuel to flow into the sink. As the rotational speed increases, the air pressure behind the compressor rises. This pressure acts on a membrane which directly controls the slider of the automatic starter. When the rotational speed reaches 6,000 rpm, the membrane-controlled slider completely closes off the route to the sink.

During flight at altitude, activation of the engine is facilitated by the altitude corrector which, by means of a set of aneroid containers, a pusher, a lever, and springs, reduces the action of the membrane on the slider of the automatic starter, thus making it possible for the fuel to flow out into the sink at a lower pressure.

Fuel Output Regulation in Accordance with Gas Temperature

To eliminate the danger of the gas temperature rising above the permitted level, the temperature limiter PRT-35 was applied. The task of this assembly consists of reducing the fuel input into the engine whenever the temperature of the gases rises above the permitted level. The PRT-35 assembly is composed of:

12 thermocouples which measure the temperature of the gases behind the turbine and which also function as the transmitter of the assembly,
an electric amplifier URT-19A-2T
a solenoid EMT-243
a temperature limiter OT
a rotational speed decrease limiter MOR.

From the constant-pressure channel, the fuel flows through a calibrated jet cone, under the membrane of the temperature limiter, and then into the jet cone of the solenoid valve. From the space under the piston of the hydraulic delayer, the fuel flows through a hydraulic damper and into the OT slider. The URT-19A-2T amplifier transmitter is adjusted to the maximum temperature of gases in an ideal atmosphere.

When the gas temperature becomes very close to the temperature to which the amplifier transmitter is adjusted, an appropriate electric impulse is transmitted to the solenoid which, by means of a valve, begins to reduce the outflow of fuel from underneath the membrane of the temperature limiter. As a result, the pressure under the membrane increases. Overcoming the resistance of the spring, the membrane moves upward jointly with the slider attached to it. When the gases reach the preset temperature, the OT slider opens the fuel path from the space under the hydraulic delayer piston to the sink. By means of the lever, the hydraulic delayer resets the excentric regulator so that the pump puts less fuel out, and thus the temperature of the gases decreases.

Since the excentric regulator of the pump operates within the range of regulated rotational speeds, the PRT-35 assembly can regulate the fuel output only in this range.

In order to prevent a fall in the rotational speed of the engine below 10,500 rpm, which could happen when electric installations fail, the MOR limiter of rotational speed decrease was applied. At a rotational speed of 10,500 rpm, the MOR slider closes the fuel flow path from the space under the hydraulic delayer piston to the sink. From that moment on, the hydraulic delayer no longer resets the excentric regulator so as to reduce fuel output.

Excentric Regulator CR-1W

The excentric CR-1W regulator limits the rotational speed of the low-pressure system.

On the side of the regulator slider, fuel from the space under the piston of the HR-30 hydraulic delayer is conducted through the hydraulic damper. The slider is acted upon by excentric weights from below and by a spring from above. When the steady rotational speed of the low-pressure system is smaller than the maximum permitted, the slider is in a position which cuts off fuel inflow into it. The moment the maximum rotational speed is exceeded, due to an increased effect of the weights, the slider rises opening the fuel path to the sink line. In this way, the space under the piston of the hydraulic delayer is connected with the sink, and the fuel pressure in that space falls. The piston and the cylinder of the hydraulic delayer move downward and therefore, by means of the lever, the excentric regulator is reset so that the fuel output from the pump is reduced. The rotational speed of the high-pressure system and then of the low-pressure system decreases.

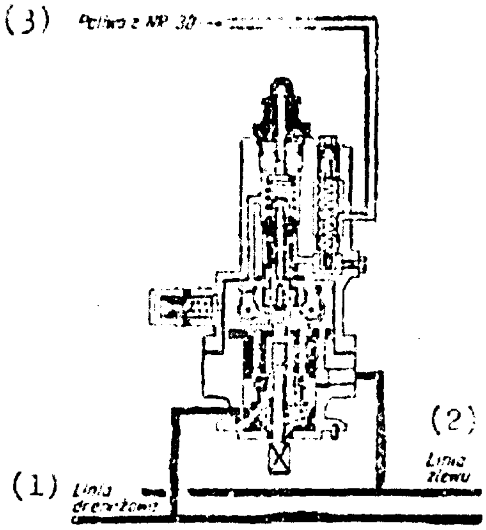

Figure 2. Outline of the Excentric CR-1W Regulator

Key:
1. Drainage line
2. Sink line
3. Fuel from HR-30

Excentric Regulator CR-2W

The excentric CR-2W regulator is designed to perform the following tasks:

opening and closing air outlet valves behind the fourth and fifth stages of the high-pressure compressor;

controlling valves [illegible] air from behind the fifth and 10th stages of the high-pressure compressor flows into the cockpit's aircondi- tioner;

disconnecting generator starters after completion of the activation of the engine:

resetting the vanes of the WNA input control device of the high-pressure compressor from an angle of 0° to an angle of -10° and vice versa.

The NR-30 pump pumps the fuel into the fuel filter of the CR-2W regulator. Then, the fuel flows through the main and left implementing sliders into hydraulic flapjacks. From the constant-pressure valve, the fuel flows to the slider of the excentric transmitter and, laterally, to two control sliders. Under a pressure of $p = f(n^2)$, the fuel is conducted from the slider of the excentric transmitter to two control sliders and one implementing slider.

The sequence of the functions performed by the CR-2W regulator is as follows:

During Activation of the Engine

1. After the high-pressure system has reached a rotational speed of 7-8%, due to the pressure of the fuel coming from the excentric transmitter, air outlet valves behind the fourth and fifth stages of the high-pressure compressor open.

2. After the rotational speed has reached 8.5-12.5%, the air inlet valves are reset to draw air from behind the 10th stage, while the WNA vanes are set at an angle of -10°.

3. After the rotational speed has reached 37-40%, fuel pressure $p = f(n^2)$ raises the slider which disconnects the generator starters; from the constant-pressure channel, the fuel flows under the membrane of the microdisconnector which turns the starters off.

During Acceleration

1. When the rotation speed has reached 77-79%, the fuel pressure from the excentric transmitter shifts the right control slider upward, and the fuel flows from the constant-pressure channel to the left control slider.

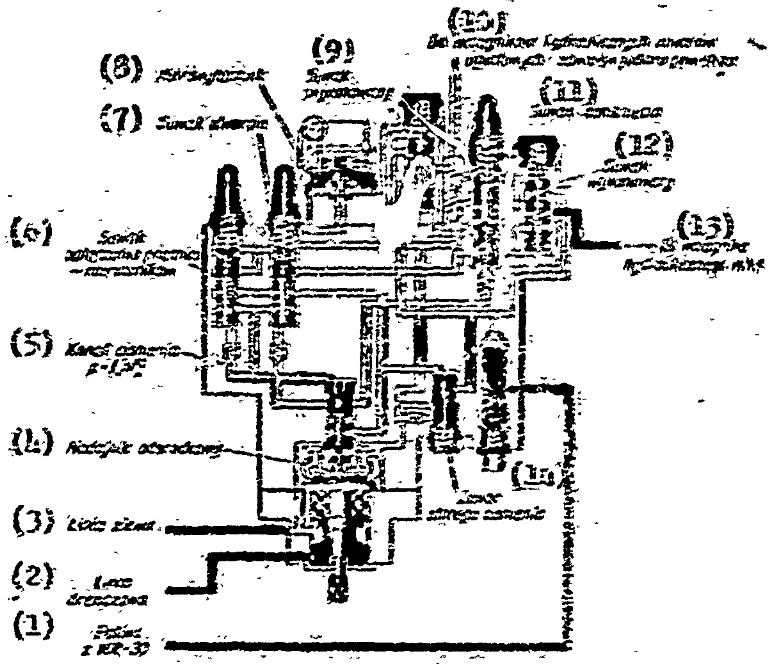

Figure 3. Outline of the Excentric CR-2W Regulator

Key:

1. Fnel from WR-30
2. Drainage line
3. Sink line
4. Excentric transmitter
5. Pressure $p=f(n^2)$ channel
6. Slider disconnecting generator starters
7. Opening slider
8. Microdisconnector
9. Implementing slider
10. To hydraulic flapjacks of air inlet and outlet valves
11. Closing slider
12. Implementing slider
13. To hydraulic WNA flapjack
14. Constant-pressure valve.

2. When the rotational speed has reached 79.5-81.5%, the left control slider is shifted upward, and the fuel flows from the constant-pressure channel under both implementing sliders. As a result, the implementing sliders move upward, and the left implementing slider connects the hydraulic flapjack channels with the sink, while the right slider lets the fuel flow from the pump to the WNA vane control flapjack. The air outlet valves behind the fourth and Iiftn stages of the compressor are closed. Air inlet valves are reset to draw air from behand the fifth stage, while the WNA vanes are set at an angle of 0°.

During deceleration of the rotational speed, the CR-2W operations are performed in the reverse sequence.