March 20, 1956 P. DESTIVAL 2,738,645

MULTISTAGE TURBOJET ENGINE HAVING AUXILIARY NOZZLES LOCATED IN AN INTERMEDIATE STAGE

Filed June 16, 1950 3 Sheets-Sheet 1

Fig.1.

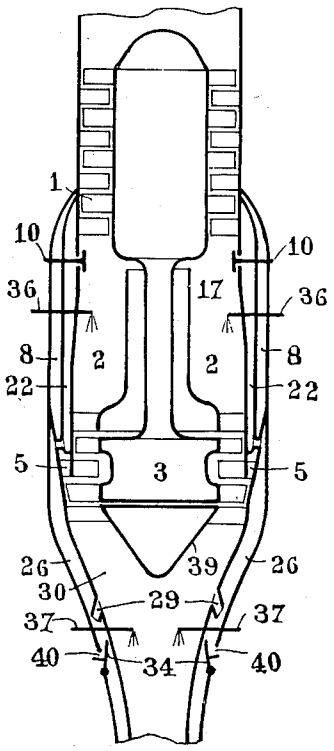

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Fig. 2.

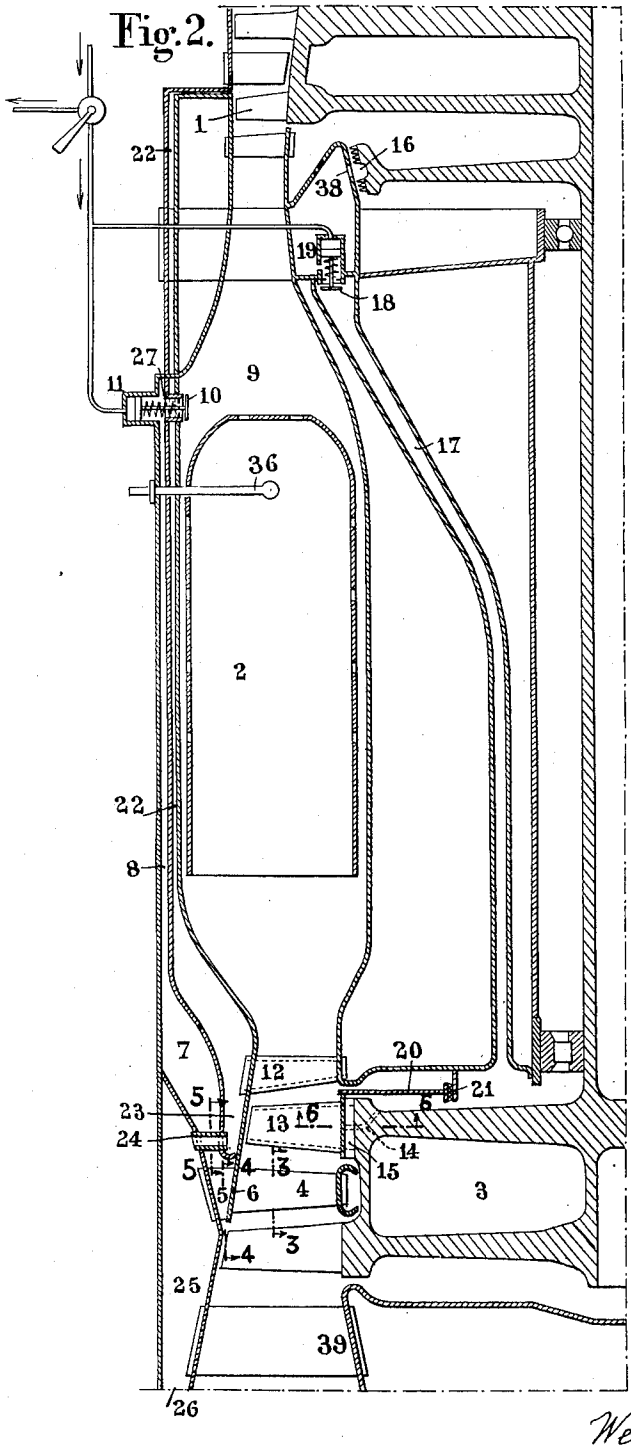


Fig. 5

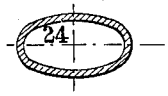
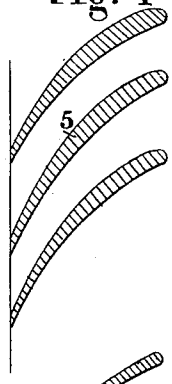


Fig. 4



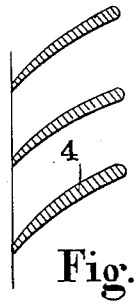


Fig. 3.

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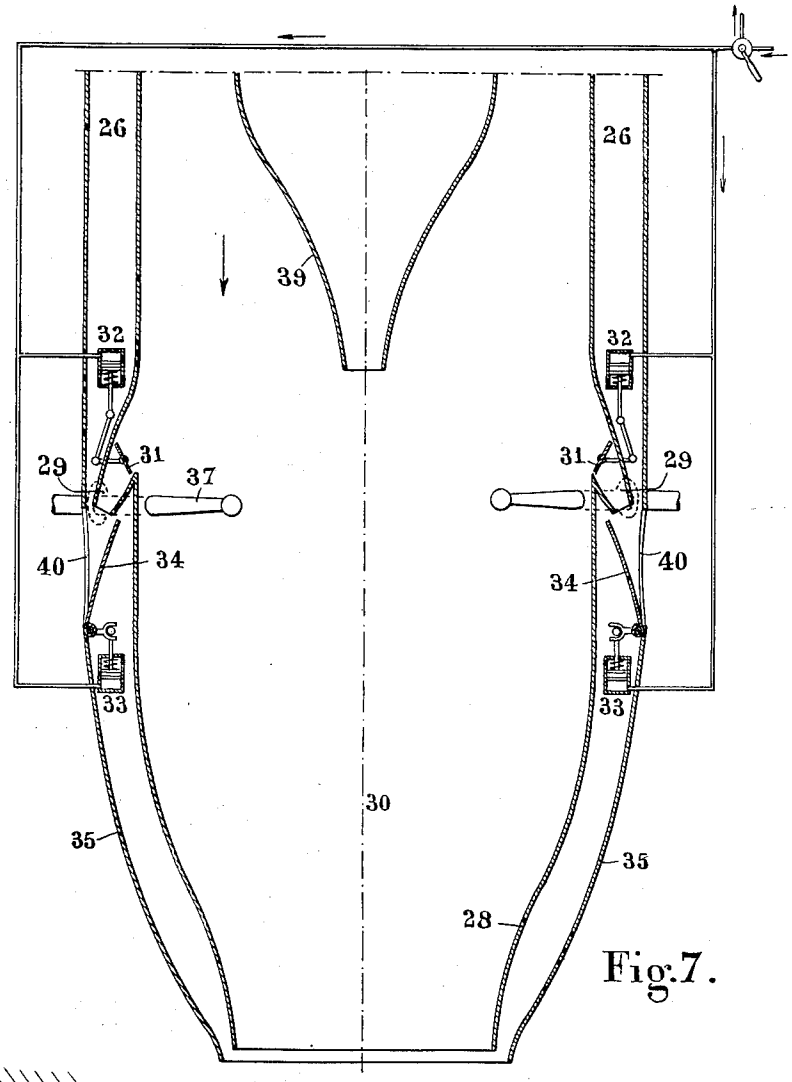

Fig.7.

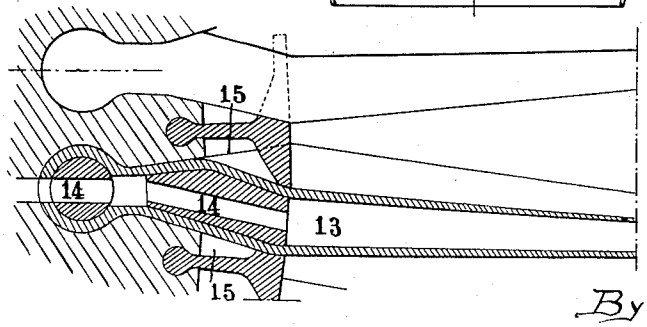

Fig.6.

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MULTISTAGE TURBOJET ENGINE HAVING AUXILIARY NOZZLES LOCATED IN AN INTERMEDIATE STAGE

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Application June 16, 1950, Serial No. 168,474

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5 Claims. (Cl. 60—35.6)

Many means have already been proposed to momentarily confer a superpower upon turbojet engines, to be used in taking-off, climbing, fighting, and so on. Most of these means (generally the very ones that are most effective) involve the use of a jet with an adjustable discharge section, whereby of course the engine is more easily started and brought to normal operation. However, the means necessary to secure such a control of the jet section are heavy in weight and elaborate in design, notably where gas-reheating (or post-combustion) is provided, which is one amongst the conventional engine superpowering means, since such a control mechanism must be effectively protected against the action of the very high temperature of the reheated gases. Besides, in some cases, the turbojet engine is so arranged on the plane that the accommodation of a variable-section jet is not possible.

My invention is related to means for superpowering turbojet engines with the aid of which a considerable power increase can be obtained even with a fixed-section jet at the same time as the starting of the engine is facilitated. Where it is possible to use a variable-section jet the advantages of the device according to my invention are added to the effects normally obtained. My invention is characterized thereby that the superpower is obtained by materially increasing the temperature of the gases ahead of the turbine, that is, beyond the limit at which normally surging will occur, combined with a reheating of the gases, and this, without the necessity of varying the section of the jet; the reheating is so controlled that the pressure behind the turbine is raised sufficiently to keep the rotational speed of the rotor at the desired level; means are provided whereby part of the gases can be shunted to a set of separate nozzles in order to prevent surging in the compressor and to keep the latter in the neighborhood of its point of maximum efficiency while a complementary blade- and disc-cooling system is set into action momentarily for the time the engine is superpowered.

In known turbojet engines the ratio of compression is so chosen that the temperature corresponding to economic operation is substantially below the limit attainable with existing refractory materials. It follows that the temperature admissible in superpower working conditions is decidedly higher than that which generally is chosen for cruising speed operation, and that it can be raised to a still higher level by using means to effectively cool the fixed as well as the movable blades and discs, even if this involves the consumption of considerable amounts of air which is not heated up by the combustion, since according to my invention the said means are only meant for use in superpower working conditions.

At any given speed any appreciable increase in the temperature of the gases ahead of the turbine is attended with a decrease in the weight of gases delivered per unit of time, which may lead to surging in the compressor if the latter is designed to work at maximum efficiency

at cruising speeds as it rationally must be. This is why part of the gases must be diverted in order to keep the flow at about the same level as when the engine is working at normal power. According to my invention, such a diversion is effected with the aid of a set of separate nozzles in order that the energy in the gases diverted shall be utilized integrally. Where the turbine comprises a plurality of stages it is advisable, for convenience in achieving such a diversion, to tap the air from a point behind the compressor which is ahead of the combustion chamber and to lead it to a set of separate nozzles provided at an intermediate stage of the turbine; in this manner the decrease in the temperature of the air thus diverted will be compensated by the increased drop of its pressure and the said air will hit the movable blades at the proper angle. The air diverted will flow through the control valve at a moderate temperature and consequently the design of such a valve is attended with no particular difficulty. Preferably, the nozzles are arranged as a ring or in sectors about the normal stator of the desired stage.

It is well known that at idling speed of the turbojet engine the compressor will operate at a point close to the surging point, which sometimes makes acceleration difficult. The provision of auxiliary nozzles according to my invention removes this difficulty since owing to its being used at a substantially unchanged temperature ahead of the turbine the compressor is enabled to work at a lower point of its characteristic.

In order to keep the rotational speed of the turbine constant, which generally is required for rotor strength considerations, it is necessary that any increase in the temperature of the gases ahead of the turbine should be attended with an increase in the pressure behind the same in order that the power developed by said turbine shall be kept at the same level as in normal working conditions. With this end in view, the fixed section jet is provided with reheating means of any known kind whereby the temperature and consequently the pressure of the gases can be restored to the desired value while the weight of gases delivered per unit of time is held substantially to the same level. The operation of the reheating means is set under the control of an automatic regulator of known kind.

Known engine superpowering means consist in injecting water, preferably admixed with alcohol, either at the inlet of the compressor or into the combustion chamber. These means notably where the water is injected at the inlet of the combustion chamber, result likewise in raising the point of working of the compressor on the characteristic curve; however, they make it necessary to decrease the section of the jet. Consequently, these means of superpowering an engine by water injection may usefully be resorted to, owing to the provision of means to deviate part of the gas flow and to reheat the remainder of it according to my invention, in the case of a fixed section jet, and this, either with or without a correlative momentary elevation of the temperature ahead of the turbine.

It may happen that the reheating effect required remains behind the full capacity of the reheating means. It is then possible for the mere time the engine is superpowered to use complementary tappings whereby part of the gases are led from a point located preferably between the turbine and the reheating means to complementary jets which in cruising flight are completely shut off from the outside. The operation of these complementary jets is set under the control of an automatic regulating device of known kind.

Examples of arrangements suitable for a turbojet with

means according to the invention is hereinafter described with reference to the appended drawings in which:

Figure 1 shows the turbojet diagrammatically in axial section,

Figure 2 is an axial half-section showing a central part of Figure 1 on a larger scale and with more details.

Figure 3 is a sectional view of the normal guide vane set of the second turbine stage taken on line 3—3 in Figure 2,

Figure 4 is a sectional view of the complementary nozzles taken on line 4—4 in Figure 2,

Figure 5 is a sectional view of a cooling air vent taken on line 5—5 in Figure 2,

Figure 6 is an enlarged sectional view taken on line 6—6 in Figure 2, and showing how the hollow blades of the first turbine stage are rooted in the disc,

Figure 7 is an axial section showing a lower part of Figure 1 on a larger scale and with more details.

Referring now to Fig. 1 of the drawings, 1 designates the last stage of the axial compressor, 2 the combustion chamber and 3 the 2-stage turbine. Complementing the set of guide blades in the second stage of the turbine, which are shaped as shown in cross-sectional view in Fig. 3, are a set of complementary nozzles 5 distributed in a ring or by sectors around the guide blade set. The blades delimiting said complementary nozzles 5 may be, as better shown in Fig. 2 extensions of the normal guide blades 4, from which they are separated by a partition 6 welded thereto. However, if the nozzle angle has to be different in the normal and the complementary sets of blades, the latter should likewise be different in depth. As shown the complementary blades are deeper than the normal guide blades while the nozzle angle is smaller; the shape of these blades is visible in Fig. 4 which is a section taken on line 4—4 in Fig. 2.

Generally, the span of the auxiliary or complementary blades should be comparatively small since they are not expected to expand more than a rather small fraction of the whole flow and since they are fed with air which is not heated up and which is delivered at the delivery pressure of the compressor. The gas stream through the turbine may then be given such a direction that the operation of the guide blade set 4 shall not be affected materially by the presence of the complementary nozzles since what is important is to obtain maximum efficiency in normal working conditions. In superpower working conditions, i. e. with the complementary nozzles in operation, the gas streams issuing from the guide set 4 will be slightly deflected inwards at the periphery of the blade set.

The air is supplied to the complementary nozzles through an annular feeder 7 and a duct 8 from a chamber 9 located ahead of the combustion chamber. The air supply is controlled by means of such valves as shown at 10 which are actuated by power relays 11 where the engine is superpowered by an increase in the temperature of the combustion gases consequent to a controlled increase in the discharge of the injectors 36.

The fixed blades 12 and 4 may be made either of refractory materials capable of resisting the very high temperatures that will occur in superpower working conditions or of ordinary refractory materials. In the last-mentioned case they should be cooled, that is, protected against overheating, by internal air circulation according to known methods. In the example described it has been assumed that the fixed blades are made of a material capable of resisting very high temperatures. As to the movable blades and more particularly the ones pertaining to the first stage, they should be cooled effectively in superpower working conditions in view of the high temperatures to be dealt with. The same is true of the disc rim. For that purpose a device may be used for instance such as the one shown in Fig. 2 in which the hollow blade 13 is cooled by air discharged from a channel 14, while the rim is cooled by means of channels 15 at right angles to the latter. In the example described here the air for the cooling of the blades 13 and of the channels 15 is tapped from between the joint, for example a labyrinth joint 16, of the compressor through a port 38 and led through channels 17 to the front face of the first turbine disc. Contingently, valves 18 actuated by means of a power relay 19 may be provided whereby air is only supplied to the blades 13 and the channels 15 when the engine is working in superpower conditions. It is also possible to provide for a moderate air supply in normal working conditions and an increased air supply in superpower working conditions. The space assigned to the cooling air is sealed from the one assigned to the hot high pressure gases with the aid of a joint 21, one element of which is carried by a ring plate 20 rigid with the disc.

Generally, it will only be necessary to provide for an extra cooling in superpower working conditions for the first stage of the turbine.

The provision of auxiliary nozzles as illustrated in the example described is not exclusive of the conventional cooling of the outside of the turbine barrel. The air required therefor is tapped through a channel 22 from an intermediate stage of the compressor. It will cool the turbine barrel at 23 and flow through vents 24, of which Fig. 5 is a cross sectional view taken on line 4—4 of Fig. 2, into a chamber 25 where it is still able to cool the hind portion of the barrel before it flows through the annular passage 26 to the outlet of the turbojet engine. Where the channel 22 is annular the same is bridged by ducts 27 through which the air supplied to the auxiliary nozzles can flow.

28 in Fig. 7 designates a fixed-section jet having an annular inlet 26 formed around a tail cone 39 located behind the turbine 3. 29 are complementary jets to be uncovered where the capacity of the gas superheating device (post-combustion by means of injectors 37) of any known kind arranged in the section 30 of the normal jet exceeds what is required for raising the temperature ahead of the turbine or by the injection of water into the combustion chamber 2. The said complementary jets 29 are controlled each by a throttle valve 31 actuated by a power relay 32. Before said jets are put into action, flaps 34 controlling apertures 40 of the fairing 35 are swung open by means of power relays 33. Said flaps 34 are useful to keep the fairing perfectly smooth in normal working conditions, in which case they close the apertures 40.

The provisions according to my invention are applicable irrespective of whether the turbojet engine is equipped with an axial or a centrifugal compressor. Some of them are also applicable to turbo propellers and more generally to all combustion gas turbines designed to be superpowered momentarily by means of an injection of water (or of a water-alcohol mixture) into the combustion chamber or ahead of the compresser or by raising the temperature ahead of the turbine, or by any combination of the said means.

What I claim is:

1. A turbojet engine comprising a compressor, a plurality of combustion chambers in operative connection with said compressor, a multistage combustion gas turbine provided with runner blade sets and guide blade sets, means to drive said compressor by said turbine, an annular feeder including a duct, air intake valves for connecting said duct to the delivery side of the compressor ahead of the combustion chambers, power relays actuating said valves, said duct leading from the said side of the compressor to an intermediate stage of said turbine, said annular feeder being behind said duct, complementary nozzles behind said feeder and located concentrically at the periphery of the guide blades of said intermediate stage of said turbine, a fixed section jet behind the turbine which is provided with reheating means to increase the pressure of the gas behind the turbine,

the power of the engine being increased by an increase of the temperature of the gas at the turbine inlet above the limit at which surging normally occurs in the compressor, while simultaneously said surging is avoided by diverting air through said duct, and the rotational speed of the turbine is kept at a substantially constant value by said reheating means.

2. A turbojet engine comprising a compressor, a plurality of combustion chambers in operative connection with said compressor, a multistage combustion gas turbine provided with runner blade sets and guide blade sets, means to drive said compressor by said turbine, an annular feeder including a duct, air intake valves for connecting said duct to the delivery side of the compressor ahead of the combustion chambers, power relays actuating said valves, said duct leading from the said side of the compressor to an intermediate stage of said turbine for diverting air from the compressor, said feeder being behind said duct and bounded by a cylindrical wall which is coaxial with the housing wall of an inner cylindrical housing enclosing said guide blades and runner blades, complementary nozzles behind said feeder and located concentrically at the periphery of the guide blades of said intermediate stage of said turbine, said complementary nozzles being constituted by the prolongations of said cylindrical wall and said housing wall and by fixed blades which are set at a suitable angle relative to the direction of the flow of said air diverted from the compressor to cause said air to expand in the space between said cylindrical wall, said housing wall and said fixed blades, a fixed section jet behind the turbine which is provided with reheating means to increase the pressure of the gas behind the turbine, the power of the engine being increased by an increase of the temperature of the gas at the turbine inlet above the limit at which surging normally occurs in the compressor, while simultaneously said surging is avoided by diverting air through said duct, and the rotational speed of the turbine is kept at a substantially constant value by said reheating means.

3. A turbojet engine comprising a compressor, a plurality of combustion chambers in operative connection with said compressor, a multistage combustion gas turbine provided with runner blade sets and guide blade sets, means to drive said compressor by said turbine, an annular feeder including a duct, air intake valves for connecting said duct to the delivery side of the compressor ahead of the combustion chambers, power relays actuating said valves, said duct leading from the said side of the compressor to an intermediate stage of said turbine, said annular feeder being behind said duct, complementary nozzles behind said feeder and located concentrically at the periphery of the guide blades of said intermediate stage of said turbine, a fixed section jet dicharging into the atmosphere as reaction propulsion jet, said fixed section jet being located behind the turbine which is provided with reheating means and with complementary jets extending from it between the turbine outlet and the reheating means, said complementary jets discharging into the atmosphere as reaction propulsion jets.

4. An engine as in claim 3 wherein the complementary jets are arranged around said fixed jet between the outlet of the turbine and zone of action of said reheating means, throttle valves are provided to control the flow through said complementary jets and means are provided to actuate said throttle valves.

5. An engine as in claim 4 wherein channels are provided to cool the turbine and means are provided to control the cooling air flow to said channels.

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