Sept. 15, 1970 D. JOHNSON **3,528,250**

BYPASS ENGINE WITH AFTERBURNING AND COMPRESSOR BLEED AIR HEAT EXCHANGER IN BYPASS DUCT

Filed April 16, 1969 2 Sheets-Sheet 1

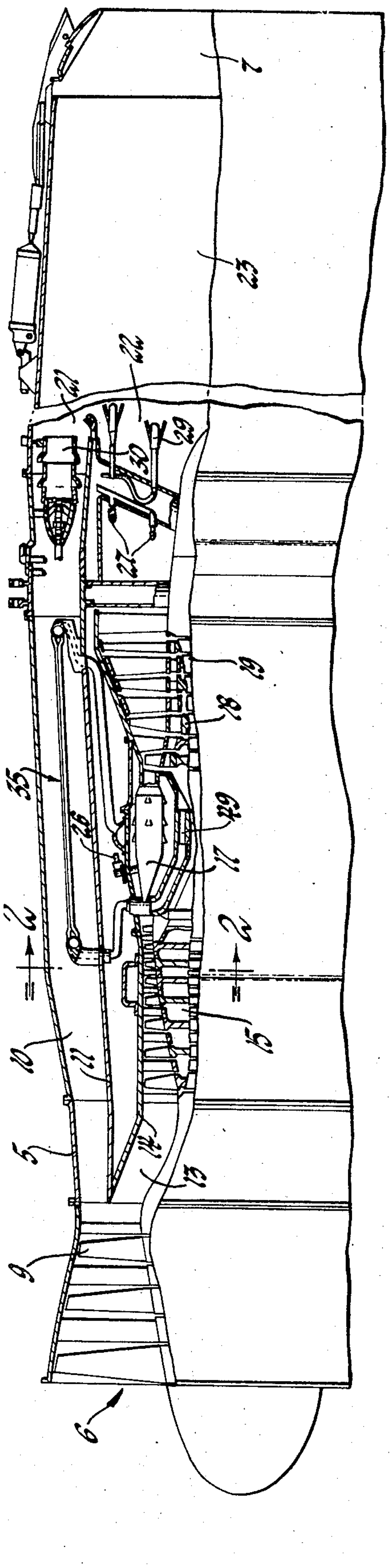

Fig. 1

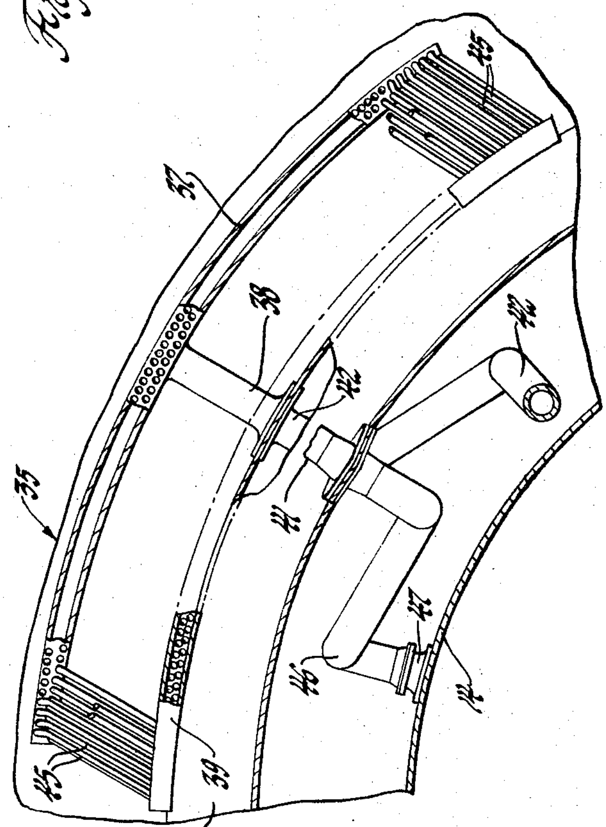

Fig. 2

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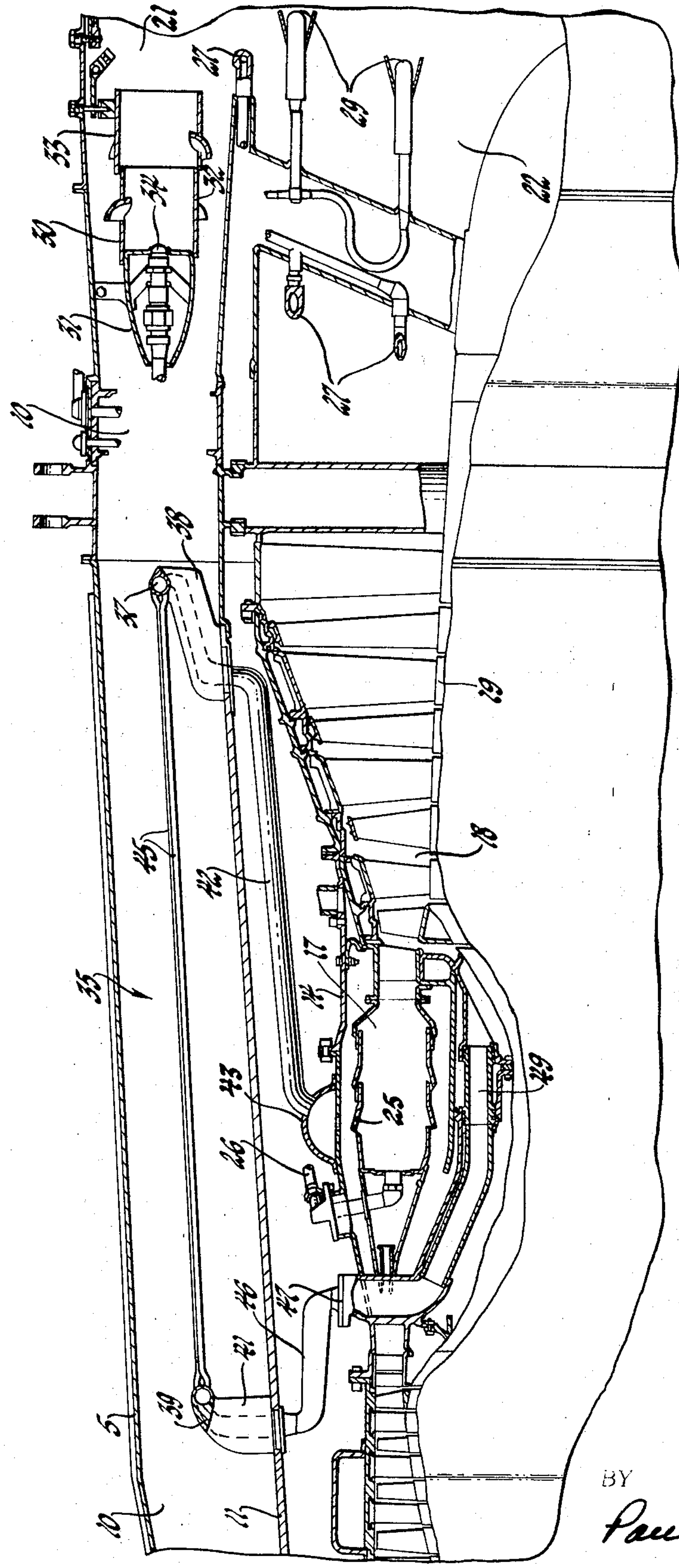

Fig. 3

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BYPASS ENGINE WITH AFTERBURNING AND COMPRESSOR BLEED AIR HEAT EXCHANGER IN BYPASS DUCT

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ABSTRACT OF THE DISCLOSURE

A bypass turbojet engine includes an afterburner for reheating the turbine exhaust and also a burner in the bypass duct. Air flowing to the bypass burner is warmed by heat exchangers mounted in the line of air flow to the burner through which air is circulated from a high pressure stage of the compressor to the turbine for cooling the turbine.

My invention is directed to an improvement of bypass turbojet engines having a duct burner or burners to increase the temperature of the air discharged from the bypass duct. Essentially, my invention provides for improving the combustion in such duct burners, and at the same time improving the efficiency of turbine cooling, by circulating cooling air from the compressor of the engine to the turbine through a heat exchanger or heat exchangers mounted in the path of air flow through the bypass duct to the duct burner or burners.

A typical bypass type jet engine of the sort in which my invention preferably is incorporated comprises a gas turbine engine which drives a fan or low pressure compressor which supplies part of its discharge to the gas turbine engine and the remainder to a bypass duct, which ordinarily is an annular duct surrounding the gas turbine engine. The flow through the bypass duct and the exhaust from the engine are combined and discharged through a jet propulsion nozzle. The thrust in such engines may be increased for takeoff or during high speed flight by afterburning equipment located downstream of the turbine and duct burners serving to heat the air flowing through the bypass duct. The burners operating in the turbine exhaust burn the fuel in quite hot gas which still contains a considerable part, ordinarily the major part, of its oxygen uncombined. The bypass burner, on the other hand, burns fuel in air which, while warmed by the work exerted by the fan, is far cooler than the engine exhaust. There are greater problems of stability and smoothness of combustion in this relatively cool bypass air. This means that a lower gas velocity, larger combustor volume and more turbulent mixing are required in the vicinity of the flameholding elements which results in a larger, heavier burner and increased pressure drop. The increase in pressure drop reduces engine output.

I have concluded that it is feasible to heat a core of air going to the duct burner by a heat exchanger so located as to concentrate the heat output in the line of flow to the burner. If such heat exchangers are employed to cool air which is bled from the engine compressor to cool the turbine, such cooling increases the effectiveness of the cooling air and thereby decreases the amount of air which must be so used, thereby increasing the efficiency of the engine.

In a typical bypass engine, I calculate that it is feasible to increase the temperature of the core of air reaching the duct burner by approximately 100° F. by transferring heat from the turbine cooling air. This increase in temperature can be expected to give approximately fifteen percent improvement in stability of combustion in the

duct burners. In this case, the combustion stability index is related to ease of starting. In an engine of the reheat type, the duct burner is not used at all times. It is used at takeoff and at high speed or supersonic flight. During subsonic flight, such as holding during a landing, the reheat system is not used. Thus, it is extremely important that the system ignite reliably every time it is called upon.

The principal objects of my invention are to improve the efficiency and reliability of bypass turbojet engines incorporating thrust augmenting burners, to improve the efficiency of cooling of gas turbine engines, and to improve the operation of bypass duct air heating burners of jet engines. A further object is to provide heat exchanger and burner structure particularly suitable to accomplish the objects above stated.

The nature of my invention and the advantages thereof will be apparent to those skilled in the art from the succeeding detailed description of the preferred embodiment of the invention. This description, it is to be understood, is for the purpose of explaining the principles of the invention and is not presented in a limiting sense, since many modifications of structure may be made within the scope of the invention.

The preferred embodiment of the invention is illustrated in the drawings, in which FIG. 1 is a sectional view of a bypass turbojet engine with afterburner, illustrating particularly the air flow paths through the engine.

FIG. 2 is a fragmentary sectional view to a greater scale, taken on a plane transverse to the axis of the engine as indicated by the line 2—2 in FIG. 1.

FIG. 3 is an enlarged view of a portion of FIG. 1, illustrating the heat exchanger and duct burner more clearly.

Referring first to FIG. 1, the ducted fan turbojet engine includes an outer casing **5** extending from an annular air inlet **6** to a variable jet propulsion nozzle **7**. A three-stage low pressure compressor or fan **9** is mounted at the inlet end of the outer casing, part of the discharge of this compressor being supplied to a bypass duct **10** defined between the casing **5** and an inner wall **11**. The remainder of the low pressure compressor output is fed into an annular engine duct **13** defined by the engine outer case **14** and the usual interior walls (not identified). The engine case **14** encloses a high pressure compressor **15**, combustion apparatus **17**, a high pressure turbine **18**, and a low pressure turbine **19**. The two turbines might be combined into a single turbine, but this is not preferred. The bypass duct terminates in an annular outlet **21** and the engine duct terminates in an annular outlet **22** within the bypass outlet. The flows through the bypass duct and through the turbine are combined in an afterburner **23** in which combustion takes place and in which the gases are mixed before being exhausted through the nozzle **7**.

The internal structure of the rotating machinery such as the rotors of the compressors and turbines and the bearings and shafting are not illustrated, since the structure of these is entirely immaterial to my invention. The engine as so far described may be considered to be conventional.

Referring now to FIGS. 2 and 3, the combustion apparatus **17** includes an annular combustion liner which includes a number of fuel nozzles supplied through lines partially shown as **26**. Air for the combustion apparatus is supplied from the compressor **15** and the discharge from the combustion apparatus flows through the blading of turbines **18** and **19**. Fuel is sprayed into the turbine exhaust from annular manifolds **27** and the flame is retained in the afterburner by vaporizing flameholders **29**.

Heating of the bypass air is accomplished by an annular bypass burner **30** mounted in the duct **10** adjacent the outlet **21**. This burner may be of any suitable type and, as illustrated, comprises an annular dome or inlet cone **31** providing an inlet for primary combustion air and generally cylindrical combustion space defining walls **32** and **33** having suitable air inlets. Fuel nozzles **34** inject fuel for combustion within the burner **30**. It will be noted that this burner is mounted approximately at the mean radius of the bypass duct **10**. The bypass burner **30** and the afterburner combustion arrangements represented by manifolds **27** and vaporizing flameholders **29** may be of any suitable known type and detailed description thereof is unnecessary.

The engine also includes a heat exchanger means comprising an annular array of heat exchange units **35** each including an arcuate inlet manifold **37** supported from the inner wall **11** by a hollow strut **38** and an arcuate outlet manifold **39** supported from the inner wall on a hollow strut **41**. There are preferably six such heat exchargers, each occupying substantially 60° of the circumference of duct **10**. Struts **38** are connected by compressed air lines **42** to a bleed air manifold **43** downstream from compressor **15**. Thus, compressed air is supplied from the compressor through line **42** and strut **38** to the manifold **37**. Manifold **37** is connected to manifold **39** by a relatively large number (about 150 in this embodiment) of generally parallel heat exchange tubes **45** preferably arranged in two closely adjacent rows, the tubes being disposed approximately on the mean radius of the duct **10**, which diverges rearwardly of the engine. Thus the hot compressed air is conducted through these tubes **45** to manifold **39** and strut **41**, and from strut **41** through an air tube **46**, a fitting **47**, and an air tube **49** into the turbine where it is circulated through the hot parts of the turbine by any suitable cooling arrangement, many of which are known in the art, and which need not be described here since the cooling circuit within the turbine is immaterial to my invention.

The air flowing in the bypass duct **10** flows along the tubes **45** in countercurrent relation to the compressed air and a considerable heating of the bypass air adjacent the mid-radius of the duct takes place. In a typical installation, this heating may amount to about 100° F. The warmer core of air enters the forward entrance of the burner **30** thus providing a more favorable environment for the combustion of fuel sprayed from each nozzle **34**. The improvement of combustion is considerably more marked when the heating of the air is concentrated as far as feasible in the air which enters the duct burner for primary combustion. If the entire body of air flowing through the bypass duct is heated, the temperature rise will be much less and, therefore, the beneficial effect on combustion will be less.

The burners would not necessarily be annular and, if separate can-type burners are distributed around the axis of the engine, a heat exchanger **35** should be located as far as feasible in the direct line of flow to the primary air entrance of each such combustion can. In the example described, the turbine cooling air will be cooled about 300° F. by heat exchange with the air in the bypass duct. This gives a very substantial increase in the cooling power of the air and permits a substantial reduction in the amount of air bled from the compressor for cooling purposes.

References herein to the low pressure compressor are intended to be generic to compressors and fans of single or plural stages.

It will be clear to those skilled in the art from the foregoing that the principles of my invention are adapted to significantly improve the operation and economy of ducted fan engines. The detailed description of the pre-

ferred embodiment of the invention is illustrative only, and various modifications may be made within the scope of the invention.

I claim:

1. A bypass type jet engine comprising, in combination, a low pressure compressor, an engine duct and a bypass duct supplied by the low pressure compressor, a high pressure compressor, combustion apparatus, and turbine means coupled to drive the compressors disposed in the engine duct, a jet nozzle supplied through the said ducts, a duct burner supplied with air through the bypass duct, a heat exchanger mounted in the bypass duct in the line of air flow to the said duct burner, means for bleeding hot compressed air from the high pressure compressor and circulating it through the heat exchanger to the turbine means for cooling the turbine means, so that the cooling air is cooled and the bypass air flow to the said burner is heated, thus improving combustion stability in the said burner.

2. An engine as defined in claim **1** in which the bypass duct is annular and surrounds the engine duct.

3. An engine as defined in claim **2** in which the heat exchanger and duct burner are mounted substantially at the mid-radius of the bypass duct.

4. An engine as defined in claim **3** in which the heat exchanger comprises numerous tubes extending longitudinally of the bypass duct.

5. A bypass type jet engine comprising, in combination, a low pressure compressor, an engine duct and a bypass duct supplied by the low pressure compressor, a high pressure compressor, combustion apparatus, and turbine means coupled to drive the compressors disposed in the engine duct, an afterburner and a jet nozzle supplied through the said ducts, the afterburner including a duct burner supplied with air through the bypass duct, a heat exchanger mounted in the bpass duct in the line of air flow to the said duct burner, and means for bleeding hot compressed air from the high pressure compressor and circulating it through the heat exchanger to the turbine means for cooling the turbine means, so that the cooling air is cooled and the bypass air flow to the said burner is heated thus improving combustion stability in the said burner.

6. An engine as defined in claim **5** in which the bypass duct is annular and surrounds the engine duct.

7. An engine as defined in claim **6** in which the heat exchanger and duct burner are mounted substantially at the mid-radius of the bypass duct.

8. An engine as defined in claim **7** in which the heat exchanger comprises numerous tubes extending longitudinally of the bypass duct.

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DOUGLAS HART, Primary Examiner

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60—262, 266, 39.66