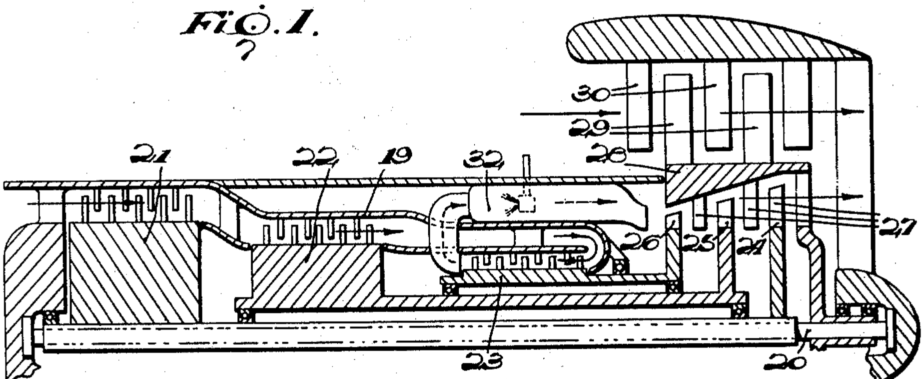
Nov. 4, 1947. F. A. M. HEPPNER 2,430,399

JET AUGMENTER FOR COMBUSTION TURBINE PROPULSION PLANTS

Filed Sept. 11, 1943 3 Sheets-Sheet 1

FIG. 1.



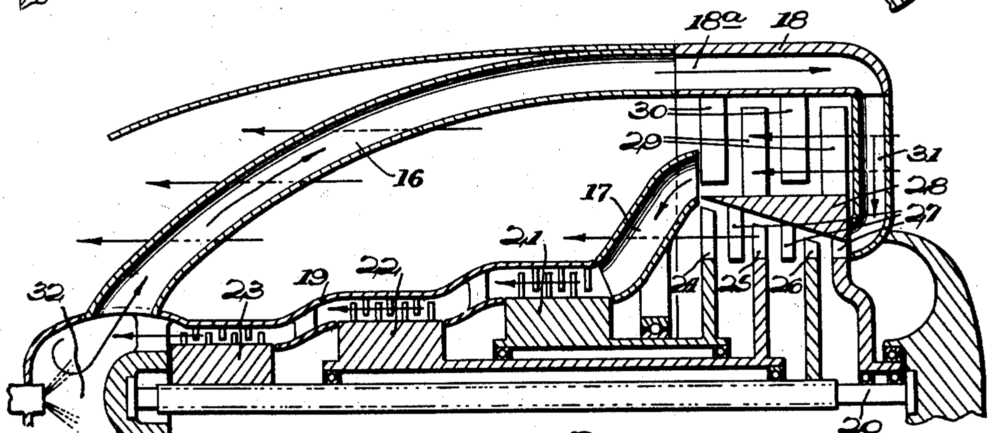


FIG. 2.

18

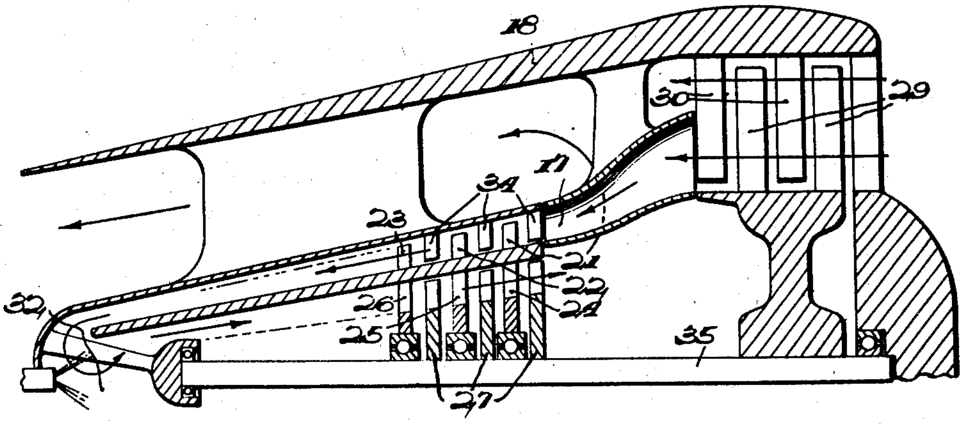


FIG. 3.

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JET AUGMENTER FOR COMBUSTION TURBINE PROPULSION PLANTS

Filed Sept. 11, 1943 3 Sheets-Sheet 2

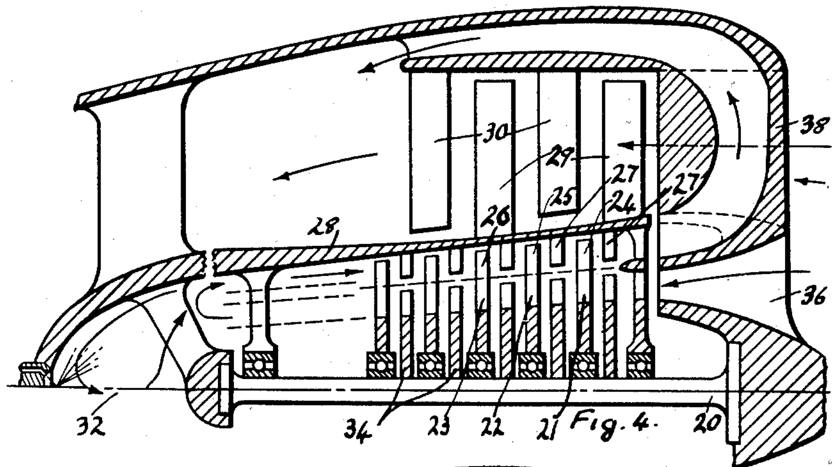

Fig. 4.

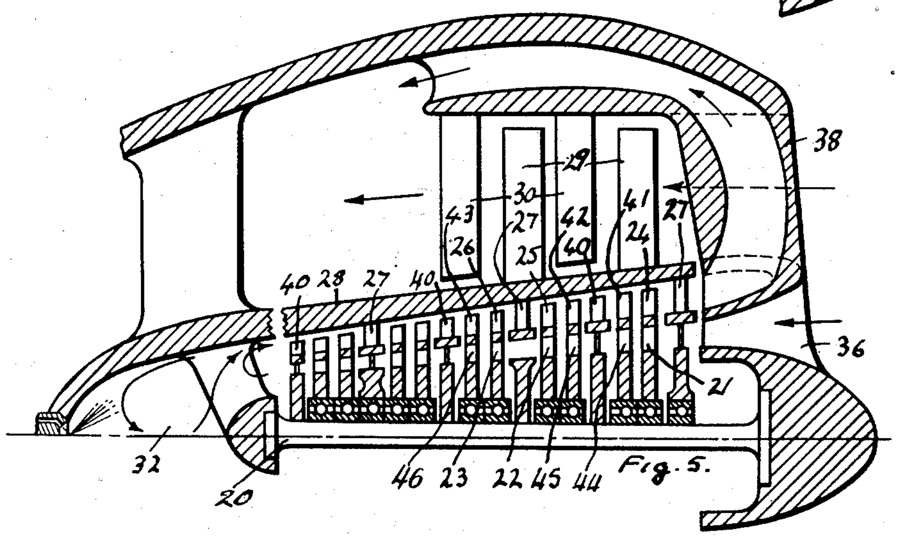

Fig. 5.

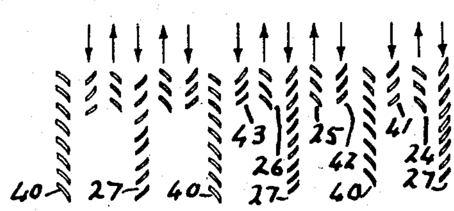

Fig. 5a.

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JET AUGMENTER FOR COMBUSTION TURBINE PROPULSION PLANTS

Filed Sept. 11, 1943 3 Sheets-Sheet 3

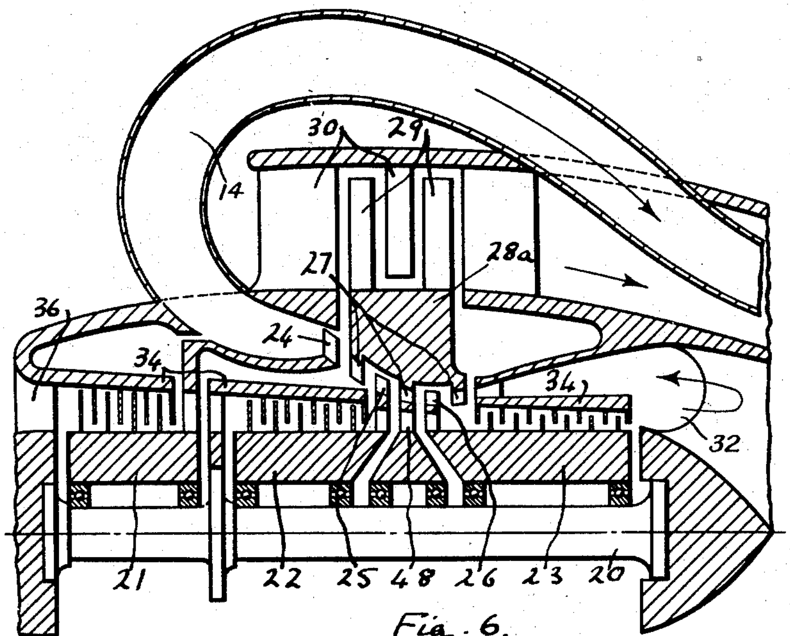

Fig. 6.

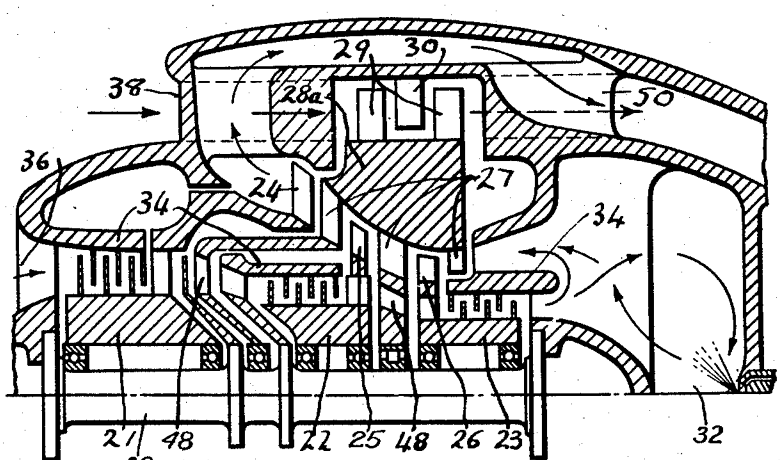

Fig. 7.

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Patented Nov. 4, 1947

2,430,399

UNITED STATES PATENT OFFICE

2,430,399

JET AUGMENTER FOR COMBUSTION TURBINE PROPULSION PLANTS

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Application September 11, 1943, Serial No. 502,035
In Great Britain November 5, 1942

8 Claims. (Cl. 60—35.6)

1

This invention relates to a compound internal-combustion turbine plant for jet-propulsion purposes, a non-compound internal-combustion turbine plant being disclosed in Patent No. 2,416,389, issued February 25, 1947.

The invention consists in a compound plant having independent compressor rotors which are respectively coupled, for rotation in unison therewith, to rotary turbine sections the blades of which coact with blades on a contra-rotating turbine member which drives the rotary portion of a jet-augmenter.

Preferably the turbine and compressor are of the axial flow type, the turbine preferably being radially outwardly of the compressor, in which case the said turbine member can be arranged to be in the form of a shell to surround the compressor or a portion thereof, and to carry the rotary jet-augmenter blades externally. Conveniently, too, the flow through the compressor is in the opposite direction to that through the turbine.

In the drawings,

Figs. 1, 2 and 3 are respectively diagrammatic views showing different arrangements of the compressor, turbine and augmenter that may be employed in the present invention;

Figs. 4 and 5 are axial sections through the compressor, turbine and augmenter of two other embodiments of the present invention;

Fig. 5*a* is a diagram to illustrate the blading and direction of rotation of the embodiment of Fig. 5;

Figs. 6 and 7 are axial sections through the compressor, turbine and augmenter of yet other embodiments of the present invention.

As far as possible like reference numerals are applied throughout the various figures to denote similar parts.

In the construction of Figure 1 there is a stationary shaft **20** on which are journalled independent rotors **21**, **22** and **23** of a compressor the stationary, coacting, bladed portions of which are carried by a shell **19**. The rotors are mechanically coupled to turbine sections **24**, **25** and **26**, respectively. The three turbine sections have blades which coact with blades **27** on a counter-rotating turbine shell **28** carrying externally jet-augmenter blades **29** which coact with stationary augmenter blades **30**.

The compressor flow is indicated by the arrows—i. e., through the first and second sections in one direction and then through the third section in the opposite direction, the flow again reversing to pass through the combustion chamber **32** (comprising in this case a plurality of single chambers arranged in a circle round the axis of the plant) before entering the turbine.

2

As will be well understood, the exhaust of the turbine and the exhaust of the augmenter, as indicated by the arrows, unite to form the propulsion jet.

In the construction of Figure 2 there is again a stationary shaft **20** upon which are mounted the rotors **21**, **22** and **23** of three compressor sections, and a shell **19** on which are carried the stationary, coacting blades. The compressor rotors are mechanically coupled to turbine sections **24**, **25** and **26** the blades of all of which coact with blade rows **27** on a contra-rotating turbine shell **28** which carries externally jet-augmenter blade rows **29** coacting with stationary augmenter blade rows **30** carried by shell **19**.

Part of the air compressed by the augmenter is delivered to the first compressor section **21** through a plurality of tubular members **17** and thence to the second and third sections, as indicated by the arrows, after which combustion is effected in the combustion chamber, indicated at **32** at the tail-end of the plant, the burning gases then travelling with reversed flow, as shown by the arrows, through a plurality of curved pipes **16**, connecting passages **18***a* formed in the annular shell **18**, and pipes **31** to the inlet of the turbine, whilst the exhaust of the latter and the remainder of the air compressed in the augmenter constitute the propulsion jet.

In the construction of Figure 3 there is a series of independent rotary compressor sections of which only three are shown in full lines, being marked **21**, **22** and **23**, and these are mechanically coupled with turbine sections **24**, **25** and **26**, respectively. The coacting compressor blade rows **34** are stationary, whilst the coacting turbine blade rows **27** are fast with the shaft **35** and rotate in the direction opposite to that in which the turbine sections **24**—**26** rotate. The shaft **35** carries rotary jet-augmenter blades **29** which coact with stationary augmenter blades **30**.

It will be observed that the compressor in this case is arranged to be radially outwardly of the turbine, air for the compressor being taken in from the jet-augmenter through the tubular member **17** and, on leaving the compressor, being reversed in the combustion chamber, indicated at **32** at the tail-end of the plant, before entering the turbine. The exhaust from the turbine is again reversed in flow, as indicated by the arrows, to join the remainder of the air compressed by the augmenter and to constitute the propulsion jet.

In the construction of Figure 4 there is again a stationary shaft **20** upon which are mounted a number of independent rotary compressor portions of which three are marked **21**, **22** and **23**. These are respectively coupled with turbine sections **24**, **25** and **26** the blades of which coact with contra-rotating turbine blade rows **27** on a shell **28**. The latter carries externally rows of jet-augmenter blades **29** coacting with stationary augmenter blades **30**. Stationary compressor blades **34** are mounted on the shaft **20**.

In this construction the air for the compressor is taken in at **36**, and after traversing the compressor it is reversed in the combustion chamber, indicated at **32**, before being passed to the turbine.

The outlet from the turbine is passed through passages formed in stationary, intake vanes **38** of the augmenter, the latter being hollow, and in due course, as indicated by the arrows, it mingles with the delivery from the augmenter to constitute the propulsion jet.

The construction of Figure 5 has much in common with that of Figure 4, except that, in Figure 5, in addition to the contra-rotating shell **28** there is also contra-rotation between adjacent combined turbine and compressor blade rows. The blading and direction of rotation are illustrated in Figure 5*a*.

Thus, it will be observed that there are compressor portions such as those marked **21**, **22** and **23** respectively coupled with turbine portions such as those marked **24**, **25** and **26**, which all rotate in one direction, being journalled upon the stationary shaft **20**, and coacting with these turbine portions are blades **27** on a counter-rotating shell **28** which carries externally the rows of augmenter blades **29** coacting with the stationary augmenter blade rows **30**. In addition, there are stationary turbine blade rows **40** and there are other turbine blade rows such as those marked **41**, **42** and **43** respectively coupled to compressor sections such as those marked **44**, **45** and **46** rotating in the same direction as the shell **28**.

Air for the compressor is taken in at **36**, being reversed in the combustion chamber, indicated at **32** at the tail-end of the plant, before being delivered to the turbine. The exhaust from the latter is again led through stationary intake vanes **38**, of the augmenter, which are hollow, as indicated by the arrows, and in due course it mingles with the delivery from the augmenter, to constitute the propulsion jet.

In the construction of Figure 6 there are again rotary compressor sections **21**, **22** and **23** journalled upon a stationary shaft **20** and respectively coupled to turbine portions **24**, **25** and **26** the blades of which coact with turbine blade rows **27** carried by a short shell **28*a*** driving rotary augmenter blades **29** coacting with stationary augmenter blades **30**, and in this case one of the turbine blade rows **27** is fast with the row **48** of compressor blades which is journalled upon the shaft **20** and rotates in the opposite direction to the compressor sections **21**, **22** and **23**. The stationary compressor blades are indicated at **34**.

Air for the compressor is introduced at **36** and is reversed in the combustion chamber, indicated at **32** at the tail-end of the plant, before being delivered to the turbine whilst the exhaust from the latter is again reversed in flow by passage **14** and mingles with the augmenter air to constitute the propulsion jet.

Substantially the same arrangement is disclosed in Figure 7, except that there are two rows **27** of counter-rotating turbine blades which are respectively coupled to two rows **48** of compressor blades. Furthermore, in this case the exhaust from the turbine is taken through passages formed in stationary intake vanes **38**, of the augmenter, which are hollow, and finally passed through similar passages formed in stationary outlet vanes **50** of the augmenter to join the air of the latter and constitute the propulsion jet. This serves for equalizing the temperatures of the augmenter air and the turbine exhaust, and thereby increases the sound speed limit of the mixture in the nozzle. The pressures of the two fluids when mixing should be substantially the same, in order to avoid shock, and a small difference in the speeds will cause only negligible losses and in many cases may be advisable. If the augmenter blades are steep ones, i. e., at negative incidence for the designed speed, satisfactory operation will be obtained when climbing.

The constructions of Figures 6 and 7 have much in common with that disclosed in the specification accompanying my co-pending patent application Serial No. 500,694, filed August 31, 1943.

The plant is short, light and very compact with substantially no unused space. It provides for good auxiliary drives and the turbine is short and efficient, whilst few labyrinths only are required. The stressing is good and excellent mixing of the turbine exhaust and augmenter air can be obtained.

The general theory of the multi-compound engine requires that most of the useful energy shall be taken out mechanically, i. e., that the main part of the propulsive effort (as regards a jet-propulsion plant) shall be provided by a jet-augmenter. In the latter the incoming air is slowed down and its pressure, by a ram effect, is increased. After compression in the augmenter the air is expanded in the jet nozzle. When an aircraft with such an engine is climbing, however, the ram effect is negligible and the overall pressure ratio in the augmenter drops considerably and the jet diameter tends to become too small. This effect would be worse if the jet were supersonic with a diverging nozzle because the jet would then be reduced to the smallest cross-section of the nozzle and no expansion in the diverging part of the nozzle could take place, inasmuch as owing to the lack of ram pressure the overall pressure ratio in the augmenter would have dropped. But whereas sound speed is the limit for the speed of the jet of an augmenter engine, taking into consideration both climbing and the possibility of regulation, a comparatively high jet speed is desirable to give the augmenter air the maximum amount of overall acceleration whereby to avoid too great a percentage of intake losses. As stated, however, by mixing the hot gases of the turbine exhaust with the augmenter air the sound speed limit in the nozzle is increased.

The above conditions require a large slowly-rotating augmenter and by driving this from a contra-rotating turbine shell such as **28** or **28*a*** the turbine can have high relative speed without excessive stresses. The necessary reaction torque is preferably provided by the reaction of the whole compressor, and for a very high compression ratio this is just enough. From design considerations this point is very satisfactory with regard to the "non-stall" condition of a regulation compound engine. In general, the sound speed and performance conditions appear to exclude the satisfactory use of small-diameter engines because of restriction to mass flow.

It is, therefore, important to keep the overall length short, rather than to reduce the diameter of the plant, and, as regards head resistance, it should be noted that all the resistance is skin friction only and that no form drag can develop.

What I claim as my invention and desire to secure by Letters Patent of the United States is:

1. A compound internal-combustion turbine plant for jet propulsion purposes including a plurality of independent compressor sections through which the fluid flows in series, a combustion chamber communicating with the end compressor section of said series, a plurality of turbine sections arranged in series and communicating with the outlet of said chamber, said turbine sections being respectively coupled to said compressorr sections to drive the same, a turbine member rotating in the direction opposite to said turbine sections, blades coacting with all of said turbine sections carried by said member, a jet augmenter including blades driven by said member, a jet duct, means for conveying fluid from the end turbine section of said series to said jet duct, and means for conveying fluid from said augmenter to said duct.

2. A turbine plant according to claim 1 in which the turbine member is a rotatable shell and the blades driven thereby are mounted externally thereon.

3. A turbine plant according to claim 1 in which the compressor sections and the turbine sections are arranged for axial flow of the fluid therethrough and in which the turbine sections and the compressor sections are arranged at different radii with one surrounding the other.

4. A compound internal-combustion engine plant for jet propulsion purposes including a plurality of independent compressor sections through which the fluid flows axially in series, a combustion chamber communicating with the end compressor section of the series, a plurality of turbine sections arranged in series for axial flow of the fluid therethrough and communicating with the outlet of said chamber, said turbine sections being respectively coupled to said compressor sections to drive the same, said turbine sections being disposed radially outwardly of said compressor sections, a shell rotating in the direction opposite to said turbine sections, blades carried internally by said shell and coacting with blades of all of said turbine sections, a jet augmenter including blades carried externally by said shell, a jet duct, means for conveying fluid from the end turbine section of said series to said jet duct, and means for conveying fluid from said augmenter to said duct.

5. A turbine plant according to claim 4 in which the means for conveying fluid from the end turbine section to the jet duct reverses the direction of flow of the fluid.

6. A turbine plant according to claim 4 in which the means for conveying fluid from the end turbine section to the jet duct reverses the direction of flow of the fluid and passes around said augmenter.

7. A turbine plant according to claim 4 in which the augmenter includes stationary vanes having passages therein and the means for conveying fluid from the end turbine section to the jet duct includes the passages through said stationary vanes.

8. A turbine plant according to claim 4 having between two of said compressor sections a further compressor section which is mechanically coupled to said shell.

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