US005692372A

United States Patent [19]

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[11] Patent Number: 5,692,372

[45] Date of Patent: Dec. 2, 1997

[54] **AIRCRAFT COMPOUND CYCLE PROPULSION ENGINE**

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[21] Appl. No.: **573,950**

[22] Filed: **Dec. 14, 1995**

[51] **Int. Cl.**[6] **F02K 5/00**

[52] **U.S. Cl.** **60/226.1**; 60/269; 60/598

[58] **Field of Search** 60/226.1, 262, 60/269, 597, 598

[56] **References Cited**

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[57] **ABSTRACT**

A ducted fan aircraft compound cycle engine comprises a core engine which includes a compressor, three rotary internal combustion engines fed by the compressor and a power turbine to receive the combustion products of the rotary and combustion engines. The rotary internal combustion engines drive the compressor and the power turbine drives the fan. The engine combines the thermal efficiency of the rotary internal combustion engine with the compact size and light weight of the gas turbine engines.

9 Claims, 3 Drawing Sheets

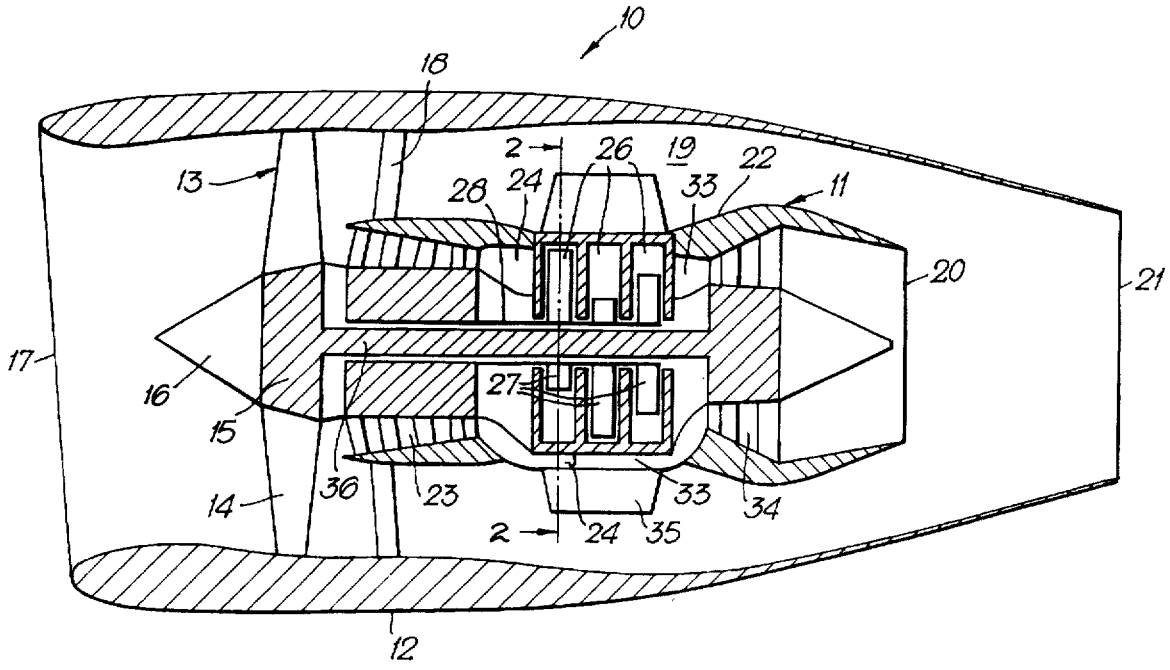


Fig. 1.

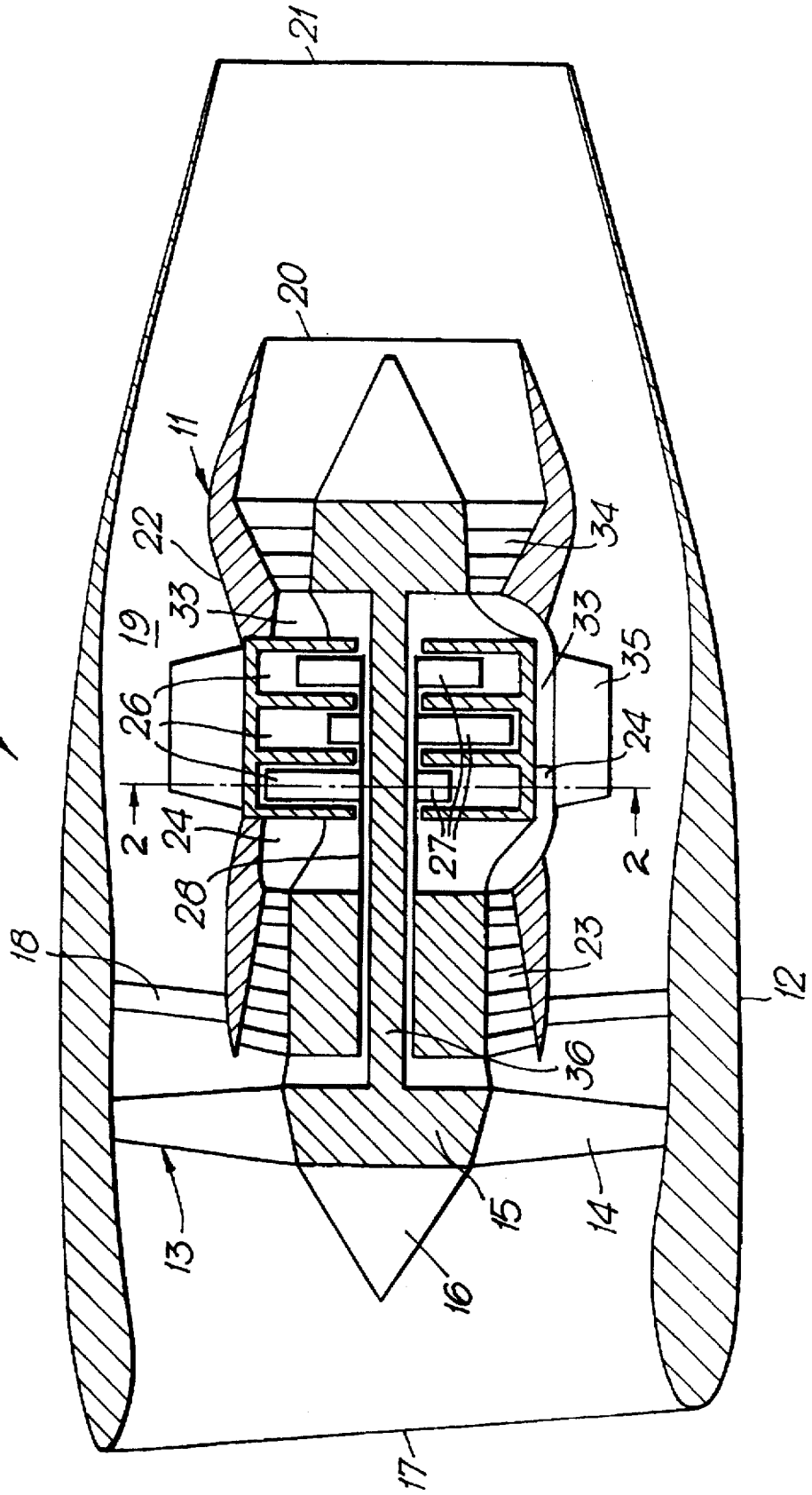
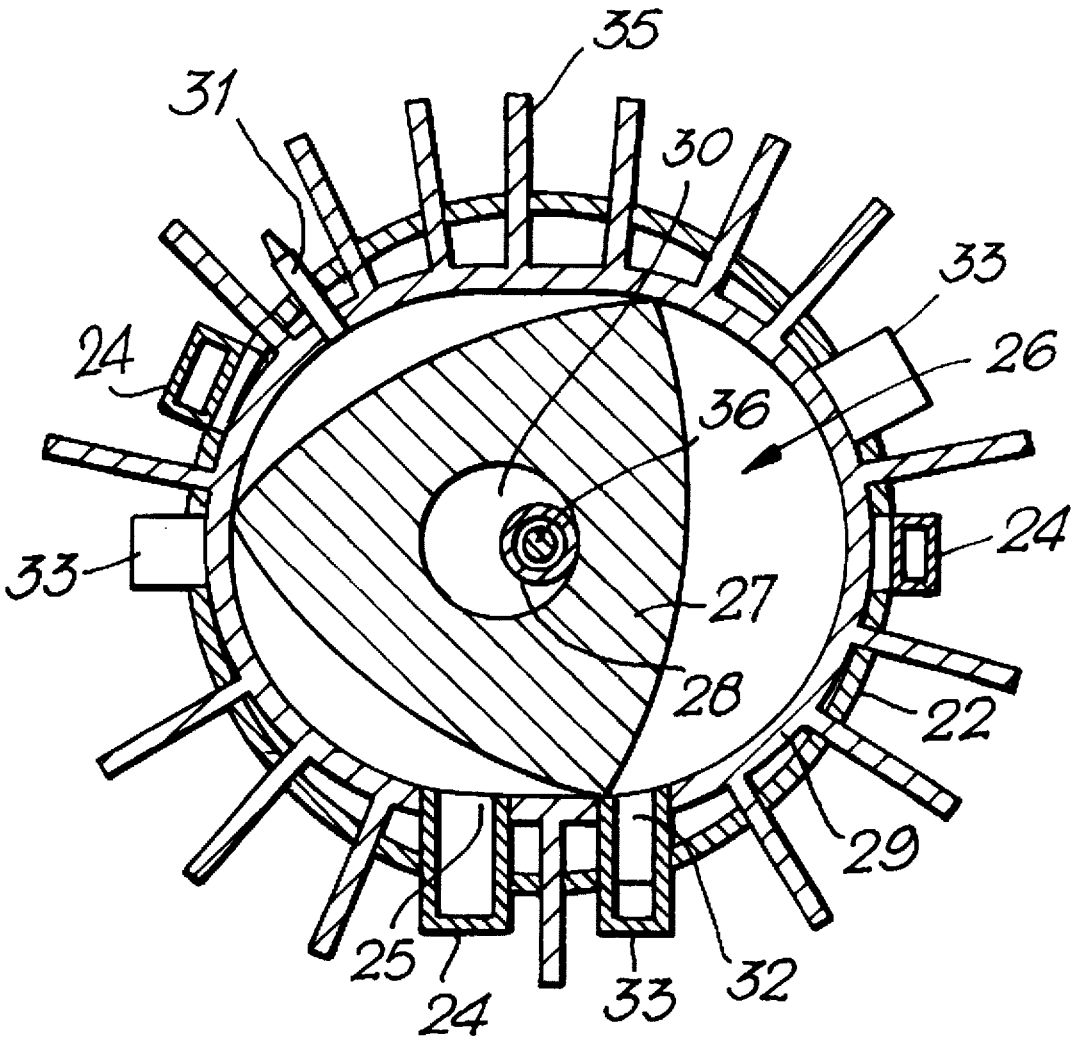

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Fig.2.



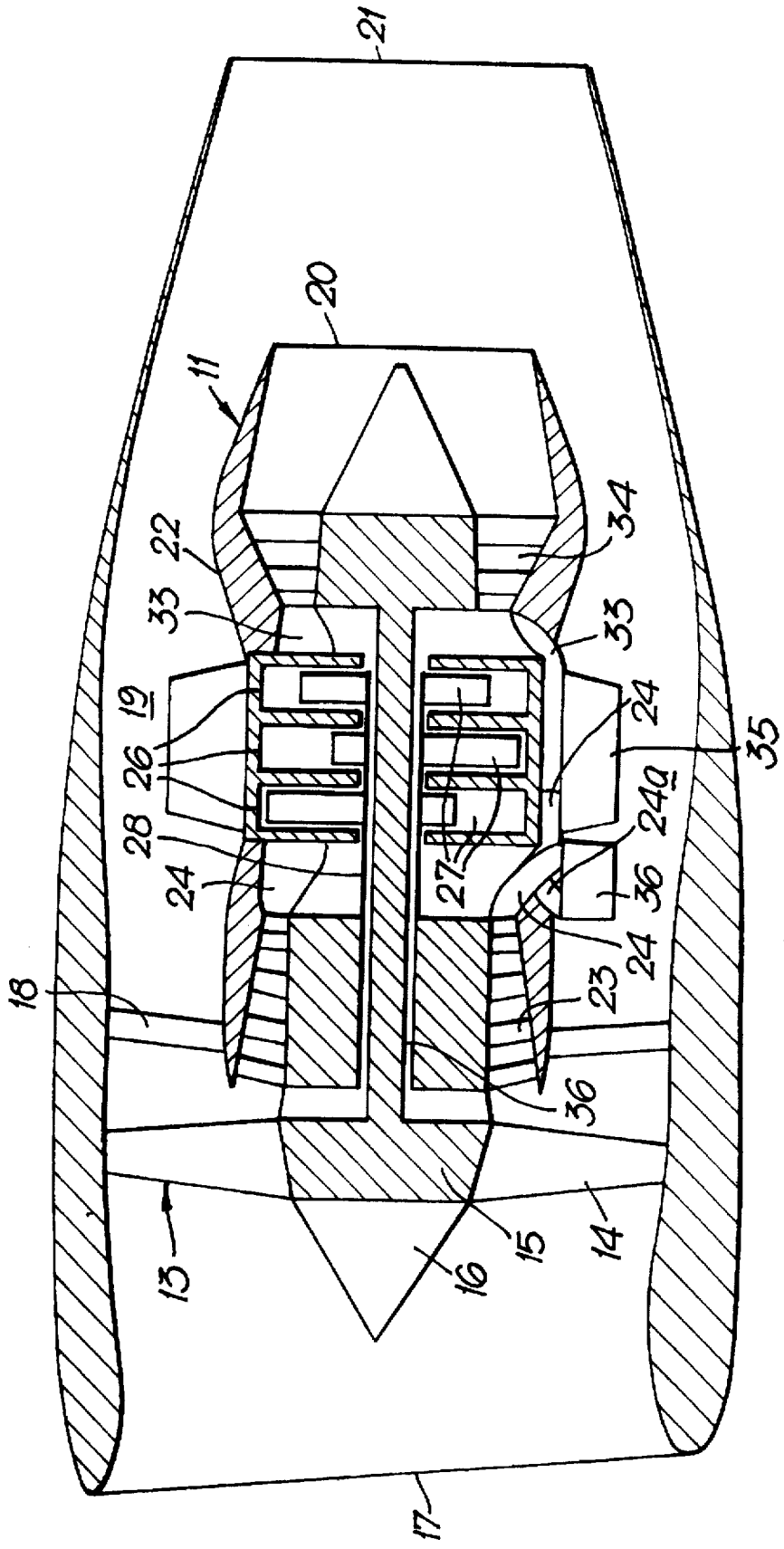

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Fig.3.

AIRCRAFT COMPOUND CYCLE PROPULSION ENGINE

This invention relates to an aircraft compound cycle propulsion engine.

It is well known that internal combustion engines are capable of achieving higher thermal efficiency than gas turbine engines. However, the smaller size and lighter weight of gas turbine engines for a given power output has meant that they are generally used in preference to internal combustion engines in aircraft propulsion.

There have been attempts to combine the advantages of internal combustion and gas turbine engines in so-called compound cycle engines. Such an engine is described in GB2201467A and comprises a propulsive fan which is driven by a reciprocating internal combustion via a drive transmission. A compressor receives a portion of the air compressed by the fan and directs it to the internal combustion engine where it is mixed with fuel and the mixture is combusted within the engine. The resultant exhaust gases are then used to drive a turbine which in turn drives the compressor.

NASA report No TM X-71906 "Preliminary Evaluation of a Turbine/Rotary Combustion Compound Engine for a Subsonic Transport" by Civinskas and Kraft March 1976 describes a similar type of compound cycle engine. In that engine, the conventional combustor of a turbofan engine is replaced by a rotary internal combustion engine. Instead of having two spools within individual shafts, the compressor, rotary engine and turbine are all mounted on a single shaft. The engine's fan is also powered by the shaft via a suitable gearbox.

One of the major drawbacks with compound turbofan engines of the general type described in these two references is that the fan is mechanically linked to the output shaft of the internal combustion engine. This necessitates the use of a gearbox between the fan and the internal combustion engine which is undesirable in view of the weight and power absorption penalties which it provides. A further significant problem in the case of the engine of the NASA reference is that the direct mechanical interconnection of the fan, internal combustion engine, compressor and turbine is likely to give rise to problems of component aerodynamic mismatching under certain engine operating conditions. This could lead in turn to compressor handling problems with the possibility of the compressor surging. A surge usually occurs when the air flow through the compressor stalls and can result in a potentially damaging reversal of the airflow through the compressor.

It is an object of the present invention to provide a compound cycle aircraft engine in which such drawbacks are substantially avoided.

According to the present invention, an aircraft compound cycle propulsion engine comprises a propulsive fan and a core engine to power said fan core engine comprising an air compressor downstream of said fan, at least one rotary internal combustion engine configured to receive compressed air from said air compressor, a power turbine positioned to receive and to be powered by the exhaust efflux of said at least one rotary internal combustion engine, a first shaft drivingly interconnecting said power turbine and said propulsive fan, and a second shaft drivingly interconnecting said at least one rotary internal combustion engine and said air compressor.

The present invention will now be described, by way of example, with reference to the accompanying drawings in which:

FIG. 1 is a schematic sectioned side view of a ducted fan compound cycle propulsion engine in accordance with the present invention.

FIG. 2 is a view on section line 2—2 of FIG. 1.

FIG. 3 is a schematic sectioned side view of an alternative ducted fan compound cycle propulsion engine in accordance with the present invention.

With reference to FIG. 1, a ducted fan compound cycle aircraft propulsion engine generally indicated at **10** comprises a core engine **11** enclosed within an elongate annular cowling **12**. The core engine **11** drives a propulsive fan **13** positioned at its upstream end. The fan **13** is of generally conventional construction comprising an annular array of radially extending aerofoil blades **14** mounted on a common hub **15**. A nose cone **16** positioned on the upstream face of the hub **15** ensures a smooth flow of air from the intake **17** of the cowling **12** into the fan **13**.

The fan **13** serves to pressurise air which has entered the cowling **12** through the intake **17**. The pressurised air flow exhausted from the fan **13** is divided into two portions. The larger portion passes over an annular array of guide vanes **18** interposed between the core engine **11** and the cowling **12** before flowing through an annular passage **19** defined between the core engine **11** and the cowling **12**. That air flow then mixes with the hot exhaust efflux issued from the downstream end **20** of the core engine **11** before being exhausted from a nozzle **21** defined by the downstream end of the cowling **12** to provide propulsive thrust.

Although in the present embodiment, the cowling **12** extends downstream of the downstream end **20** of the core engine **11**, it will be appreciated that in certain situations this may not always be necessary. The cowling **12** could be shorter, terminating upstream of the core engine downstream end **20**. Moreover, it may be desirable to dispense with the cowling **12** altogether and replace the fan **13** with a propeller or a so-called propfan. Consequently, the term "fan" as used in the present specification and claims should be construed as embracing both propellers and propfans.

The core engine **11** is cowled to define a smooth radially outer surface **22** which constitutes the radially inner boundary of the annular air passage **19**.

The remaining smaller portion of the pressurised air flow exhausted from the fan **13** is directed into an axial flow compressor **23** which is positioned at the upstream end of the core engine **11**. The compressor **23** is of conventional configuration and comprises axially alternate annular arrays of rotor blades and stator vanes. The pressurised air exhausted from the downstream end of the compressor **23** is directed into three equally circumferentially spaced apart axially extending ducts **24** positioned on the external surface **22** of the core engine **11**. Each duct **24**, which can be seen more easily in FIG. **2**, directs the compressed air into the intake port **25** of one of three similar axially aligned rotary internal combustion engines **26** contained within the core engine **11**.

Each rotary internal combustion engine **26** is of the conventional direct injection stratified charge "Wankel" type and comprises a rotor **27** which rotates eccentrically about, and thereby drives a common hollow shaft **28** within a casing **29**. The rotor **27** has a central hole **30** which is toothed (not shown) to engage corresponding teeth (also not shown) provided on the teeth of an annular member fixed to the wall of the motor housing.

Fuel is introduced into the compressed air flow immediately prior to its entry into the intake **25** by conventional means (not shown). That fuel and air mixture is then further compressed by the rotary motion of the rotors **27** before

being ignited by an igniter **31**. The resultant combustion products then expand, driving the rotor **27**, before being exhausted through an exhaust port **32**. The exhaust port **32** is situated alongside the inlet port **25** and directs the combustion products into an exhaust duct **33**.

There are three exhaust ducts **33**; one being associated with each rotary internal combustion engine **26**. They extend in an axially downstream direction along the external surface **22** of the core engine **11** to terminate at the upstream end of an axial flow power turbine **34**. The exhaust ducts **33** direct the combustion products into the power turbine **34** so that the products expand through, and thereby drive, the turbine **34**. The combustion products are then exhausted from the downstream end **20** of the core engine **11** and, as previously described, mix with and thereby augment the thrust provided by the air flow through the passage **19**.

The rotary combustion engines **26** generate heat during their operation which must be dissipated in order to prevent their overheating. This is achieved by a plurality of fins **35** which are integral with the engine casing **29** and radially extend into the annular air flow passage **29**. The air flowing through the passage **19** cools the fins **35** and hence the rotary combustion engines **26**. The rise in temperature of the air flow through the passage **19** resulting from this thermal exchange provides a desirable enhancement of the overall thermodynamic efficiency of the engine **10**. An alternate way of cooling the rotary combustion engines **26** is to pass cooling air derived from the compressor **23** through ducts provided in the casing of the engines **26** and then exhaust that air directly into the power turbine **34**, thereby obviating the need for the fins **35**.

The power turbine **34** is drivingly interconnected with the fan **13** by an axially extending shaft **36** which is concentric with the hollow shaft **28**. Consequently, the power turbine **34** constitutes the sole power source for the fan **13**. In certain circumstances, it may be desirable for the power turbine **34** to drive the fan **13** via a suitable gearbox.

There is not, therefore any direct mechanical interconnection between the rotary combustion engines **26** and the fan **13**. The hollow shaft **28** which is driven by the rotary combustion engines **26**, drivingly interconnects the engines **26** with the axial flow compressor **23**. It will be seen therefore that since the assembly constituted by the rotary combustion engines **26** and the compressor **23** is mechanically independent of the assembly constituted by the power turbine **34** and the fan **13**, there is less likelihood of operational mismatching of the various components of the engine **10**. This leads in turn to the engine **10** operating with greater efficiency that would have been the case if compromises in component matching had been necessary.

Under certain circumstances it may be desirable to enhance the efficiency of the engine **10** still further by the use of an intercooler. Such an intercooler **36** is shown in FIG. **3**. The intercooler **36** is positioned in the air passage **19** so that it is exposed to a portion of the air flowing through the passage **19**. There are three intercoolers **36**, each one associated with one of the air ducts **24** interconnecting the compressor **23** with the rotary combustion engines **26**. Thus air exhausted from the compressor **23** and which has been heated during the compression process is directed through the ducts **24** into the intercoolers **36**. There the air is placed in heat exchange relationship with the relatively cool air flowing through the passage **19**. The cooled air is then directed into the rotary combustion engines **26** through ducts **24***a*. Cooling the air in this manner results in further improvement in the overall efficiency of the engine **10**.

The compound cycle propulsion engine **10** in accordance with the present invention provides a turbofan engine which is light and compact and thereby suitable for aircraft propulsion and which also embodies the thermal efficiency of a rotary combustion engine. Consequently the engine **10** enjoys the weight and size advantage of a conventional gas turbine engine in addition to the low fuel consumption of an Otto cycle engine.

I claim:

1. An aircraft compound cycle propulsion engine comprising a propulsive fan and a core engine to power said fan, said core engine comprising an air compressor downstream of said fan, at least one rotary internal combustion engine configured to receive compressed air from said air compressor, a power turbine positioned to receive and be powered by the exhaust efflux of said at least one rotary internal combustion engine, a first shaft drivingly interconnecting only said power turbine and said propulsive fan, and a second shaft drivingly interconnecting said at least one rotary internal combustion engine and said air compressor.

2. An aircraft compound cycle propulsion engine as claimed in claim **1** wherein said fan is enclosed within a cowling.

3. An aircraft compound cycle propulsion engine as claimed in claim **2** wherein said cowling and said core engine together define an annular air flow duct.

4. An aircraft compound cycle propulsion engine as claimed in claim **1** wherein said core engine includes three of said rotary internal combustion engines.

5. An aircraft compound cycle propulsion engine as claimed in claim **1** wherein said first and second shafts are concentric.

6. An aircraft compound cycle propulsion engine as claimed in any claim **1** wherein said at least one rotary internal combustion engine is provided with cooling fins positioned so as to protrude into the flow path of air exhausted from said fan.

7. An aircraft compound cycle engine as claimed in claim **1** wherein at least one intercooler is positioned in the flow path of air exhausted from said fan, said intercooler being arranged so as to place at least part of the air exhausted from said fan in heat exchange relationship with air exhausted from said compressor prior to said air from said compressor being received by said at least one rotary internal combustion engine.

8. An aircraft compound cycle engine as claimed in claim **1** wherein said compressor is of the axial flow type.

9. An aircraft compound cycle engine as claimed in claim **1** wherein said turbine is of the axial flow type.

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