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Petrie et al.

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[54] **GAS TURBINE ENGINES**

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[52] **U.S. Cl.** **417/405,** 60/39.32, 415/134

[51] **Int. Cl.** **F02c 7/20**

[58] **Field of Search** 60/39.32; 415/79, 115, 131, 415/132, 134, 136; 417/373, 405

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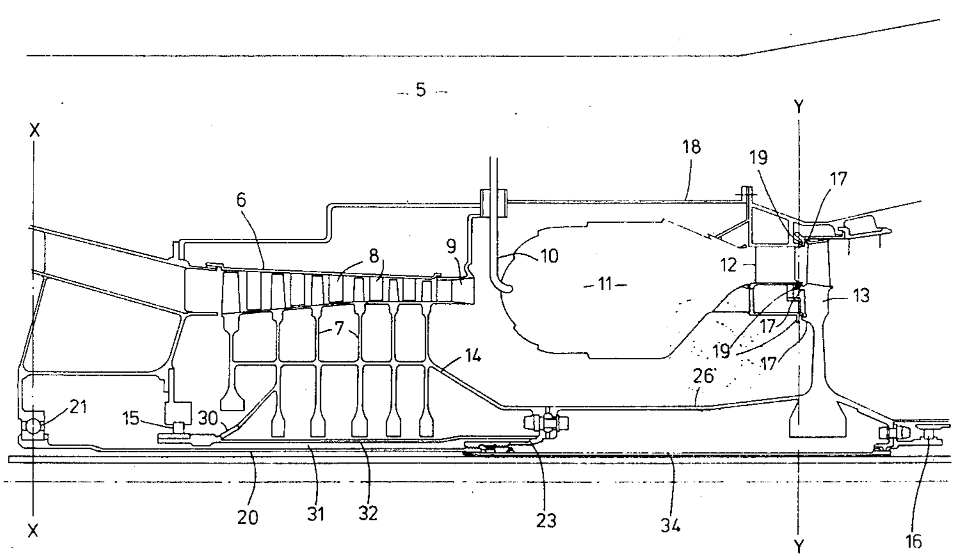
[57] **ABSTRACT**

In order to minimize the variation in the sealing clearance between a turbine rotor and associated static structure at different temperatures of the engine the shaft connecting the turbine with its compressor is supported at its ends in roller bearings. A tubular member is introduced, which is made of a low expansion material, which is located at an upstream datum radial plane and which supports the shaft at a joint close to the turbine rotor. The expansion of the shaft between the upstream roller bearing and the joint does not therefore, affect the position of the turbine rotor.

8 Claims, 4 Drawing Figures



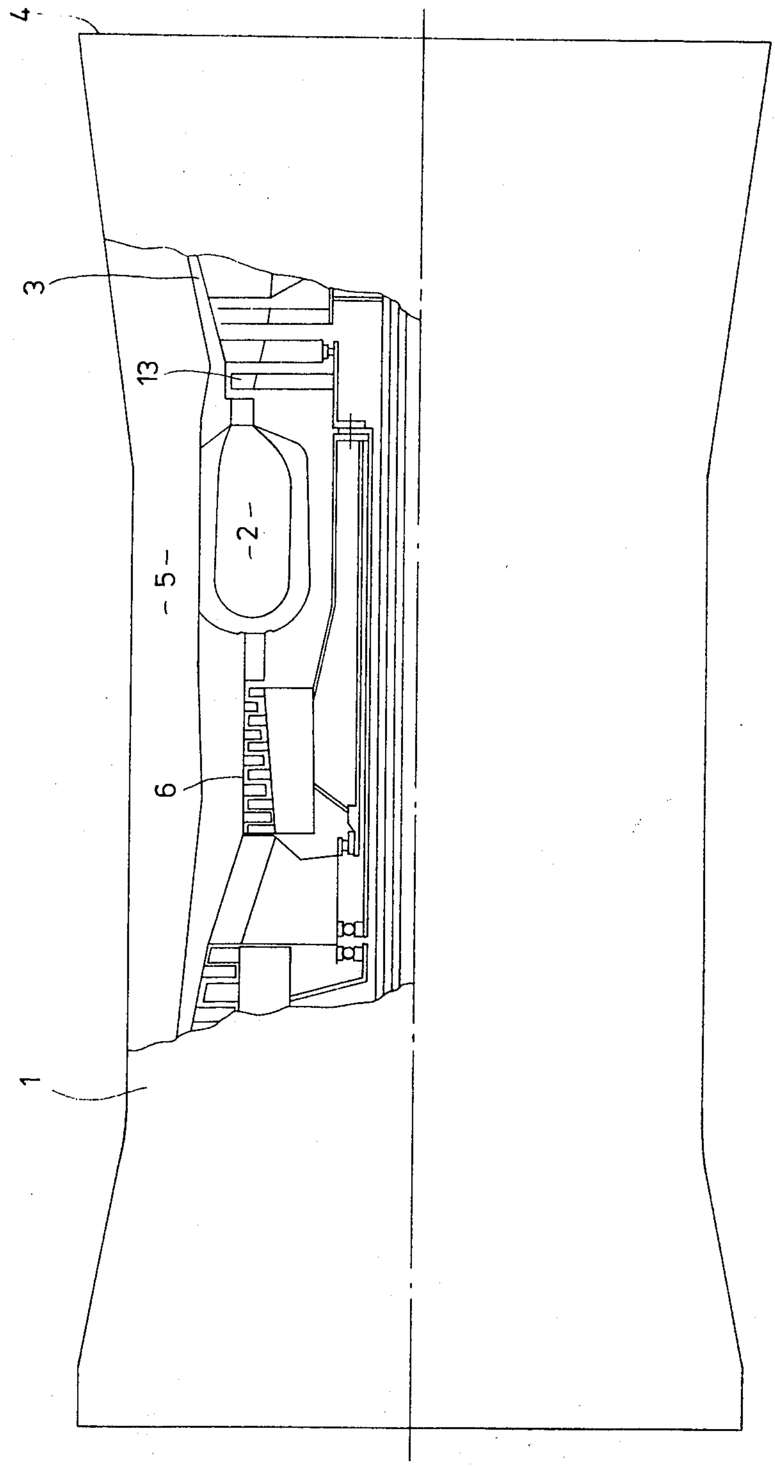


FIG 1

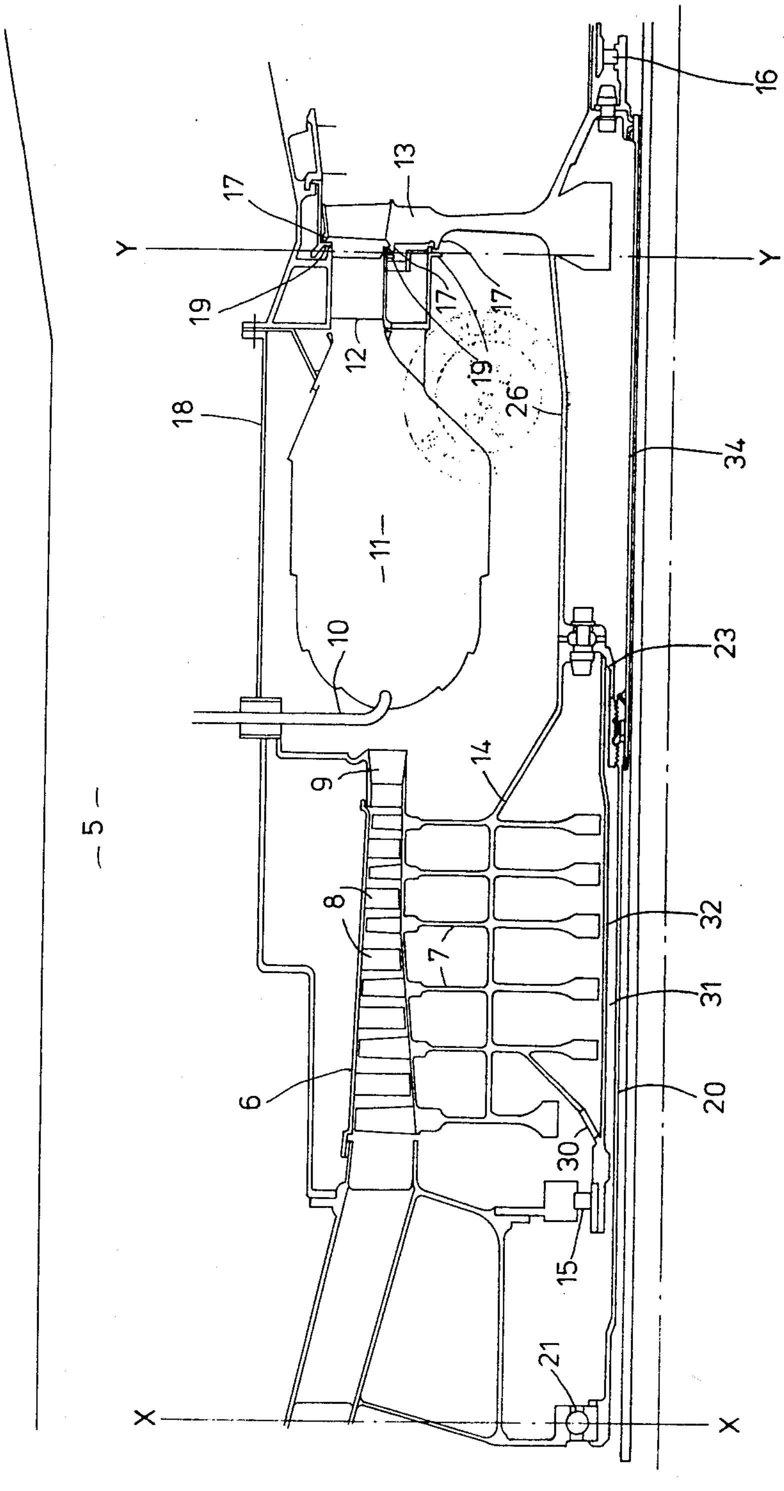

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FIG 2

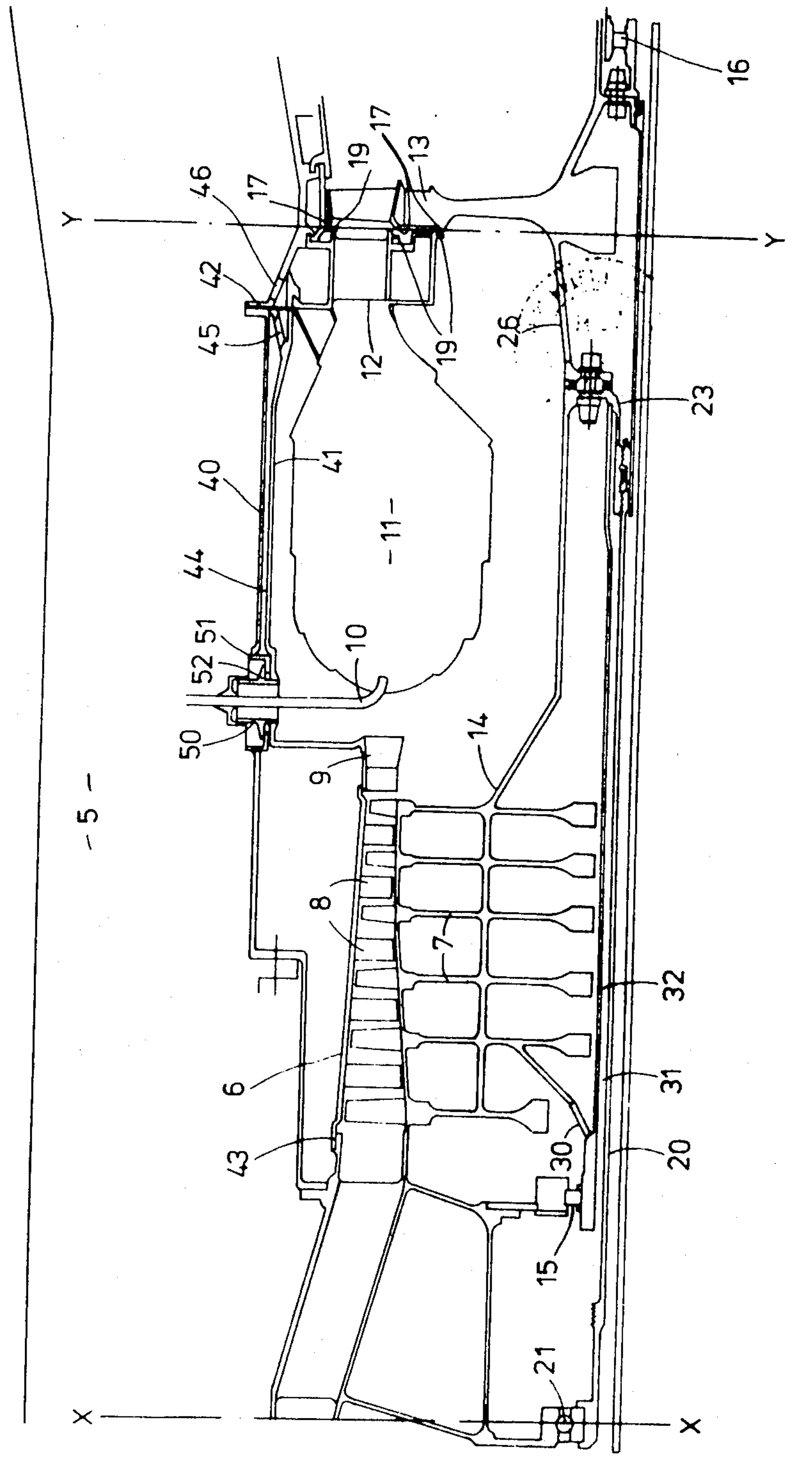
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FIG 3

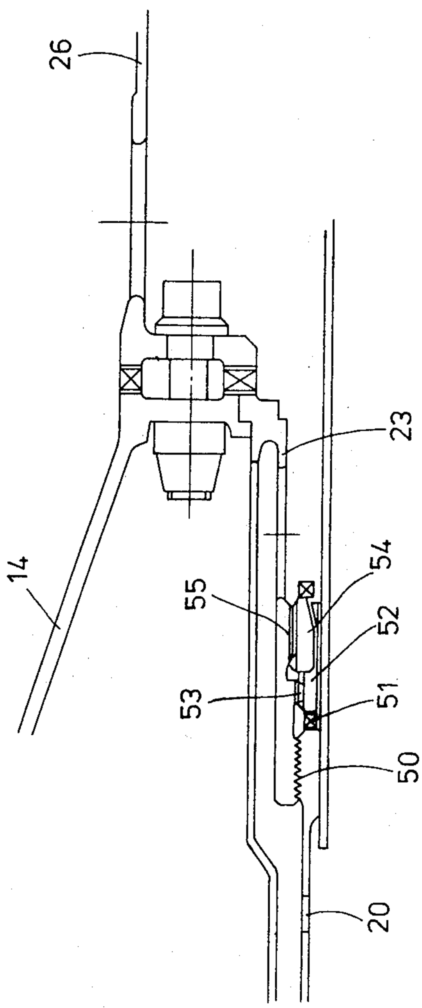

FIG 4

GAS TURBINE ENGINES

The present invention relates to gas turbine engines and has particular reference to the control of sealing clearances between turbine rotors and adjacent static structure.

In high performance gas turbine engines in which high pressures and temperatures are produced in the working fluid, leakage of working fluid through sealing clearances, particularly in the first stage of the turbine, where pressures and temperatures are highest, represents a significant loss in overall engine performance.

The object of the present invention is to provide a construction of gas turbine engine in which a sealing clearance between a rotor member and adjacent static structure is controlled to a low value, particularly at the engine 'design condition'.

According to the present invention a gas turbine engine comprises a rotor member, a shaft to which the rotor member is connected and which is mounted in bearings which allow freedom for axial thermal expansion of the shaft, the rotor member being spaced from a sealing member supported in static structure at a first radial plane of the engine by an axial sealing clearance, the shaft being located in static structure at a second datum radial plane of the engine by means of a member made of a material having a lower coefficient of thermal expansion than the shaft.

In one embodiment of the invention the rotor member is a turbine rotor and the shaft drivingly connects the turbine rotor to a compressor, the member which locates the shaft is a tubular member which is located by means of a ball bearing in said static structure upstream of the compressor.

In this way the rearward movement of the turbine rotor from the radial plane of the ball bearing can be reduced to a value more nearly equal to the growth of the static structure axially between the two planes and the increase in sealing clearance between cold and hot conditions of the engine can be reduced.

Part of the engine casing to which the said static structure is attached may also be made from the low expansion material to reduce the axial growth of the casing.

The position of the connection between the tubular member and the shaft must be calculated from the lengths and temperatures of the shaft, the tubular member and the casing.

In order to be able to predict the said temperatures the various components are arranged to be washed by air bled from the compressor in known quantities and at known temperatures.

The tubular member is additionally made as thin as possible to ensure a quick response to changes in temperature.

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

FIG. 1 illustrates diagrammatically a gas turbine engine to which the invention is applicable.

FIG. 2 is a detailed sectional view of part of the gas turbine engine of FIG. 1 constructed according to this invention showing only the high pressure system.

FIG. 3 is an alternative construction for the engine of FIG. 1.

FIG. 4 shows in detail the joint between the shaft and tubular member of the engine.

Referring now to FIG. 1, there is illustrated in a diagrammatic way, a by-pass gas turbine engine which includes compressor means **1**, combustion equipment **2**, turbine means **3**, and a propulsion nozzle **4**, all in flow series. The engine illustrated is a three shaft engine in which the compressor means comprises low, intermediate, and high pressure compressors driven respectively by low, intermediate, and high pressure turbines each mounted on separate shafts. Since the invention has been applied only to the high pressure system of the engine, only this system is illustrated in detail. This is not meant to be restrictive on the scope of the invention, however, because the invention could be applied to either the intermediate or the low pressure systems, but less is to be gained in performance where the parts of the engine are not subject to the high differential thermal expansions, and high pressures, of the high pressure system.

Part of the air compressed by the low pressure compressor passes into a by-pass duct **5**, by-passing the intermediate pressure and high pressure systems, and is mixed with the efflux from the low pressure turbine before passing to atmosphere through the propulsion nozzle **4**.

Referring now to FIG. 2 there is shown the high pressure system of a gas turbine engine to which the invention particularly relates.

The high pressure compressor **6**, comprising six rotor stages **7** and six stator stages **8**, supplies high pressure air via a diffuser **9**, to the combustion equipment **2**. Fuel, supplied via burners **10**, is burned in the combustion chamber **11** and the hot gases produced by combustion pass through a ring of nozzle guide vanes **12**, to the rotor of the high pressure turbine **13**. From the high pressure turbine **13** the gases pass to the remaining turbine stages of the engine which are not illustrated.

The high pressure turbine and compressor are drivingly interconnected by a shaft **14** which is supported at its ends in roller bearings **15** and **16** respectively. The roller bearings allow for axial growth of the turbine, compressor and shaft assembly due to thermal expansion.

The turbine rotor **13** carries axially extending sealing ribs **17** which seal against radial faces of sealing members **19** attached to the nozzle guide vanes **12**, which are supported from the engine casing **18**.

In addition to the shaft **14** the turbine and compressor assembly include a tubular member **20** which is located at its upstream end in a ball bearing **21** at the plane XX, thus providing a common datum from which expansion of the tubular member and the engine casing can be measured.

The member **20** is attached to the shaft **14** at a position between the compressor and the turbine by a coupling member **23** and serves to locate the shaft relative to plane XX. Thus the turbine expands rearwards, and the compressor forwards, relative to the coupling.

To reduce the rearward movement of the turbine relative to the plane XX, the member **20** is made from a material having a lower coefficient of thermal expansion than those of the shaft **14** and casing **18**.

Since the tubular member is anchored by ball bearing **21** the relative expansion between the member **20** and the engine casing **18** at the plane XX is zero. The movement of the turbine rotor **13** rearwards from plane XX is the sum of the expansions of the tubular member **20**, the coupling member **23** and the rear portion **26** of the shaft **14**. The movement of the casing between planes XX and YY is the sum of the expansions of the various parts of the casing **18** between those planes.

The coupling member **23**, and its method of connection to the shaft and the tubular member **20**, is shown in more detail in FIG. **4**.

The member **20** is provided at its end with an external buttress thread **50** and with axially extending dogs **51**. The thread **50** engages with an internal thread on the coupling member **23**, and the dogs **51** engage with corresponding dogs on a locking sleeve **52**. The sleeve **52** has radially extending splines **53** on its radially outer surface which engage with corresponding internal splines on the coupling member **23**. The whole joint is held tight by a nut **54**, which engages with further internal threads **55** on the coupling member **20**.

The coupling member **20** is made from the same material as the shaft, or a material with a similar coefficient of expansion, so that the joint between the coupling member and the shaft can be a conventional curvic coupling. By joining the coupling member **23** and the tubular member **20** in the above-described manner, the effects of differential thermal expansion, which may loosen the threaded joint **50** between the coupling member and the shaft, are taken care of by the splines **53** and the dogs **51**. Additionally the threaded joint **50** can be used to initially adjust the sealing clearance between the turbine rotor and the adjacent static structure when the engine is being built.

Other arrangements of splines and dogs on the coupling member could clearly be used to produce an expansion-compensated joint between member **20** and shaft **14**.

An alternative method of joining the low expansion tubular member to the relatively high expansion shaft is to weld the coupling member **23** directly onto the end of the tubular member **20**. This is preferably done by friction welding to avoid difficulties which can arise in conventional welding due to the different properties of the two materials. A further alternative would be to friction weld a piece of the same material as the coupling member **23** onto the end of the member **20**. This piece would have an external buttress thread **50** as above, and in this case, differential thermal expansion across the thread would be eliminated while retaining the adjusting feature.

A similar differential thermal expansion problem exists at the other end of the tubular member where it is connected to the outer race of the ball bearing. In the embodiment illustrated the member **20** is welded to the bearing race, but clearly an expansion compensated joint similar to that described could also be used at this point.

The position of the joint between tubular member and the shaft can be calculated to give the desired sealing clearance at any one design condition of the engine provided that the temperatures of the shaft **14**, tubular member **20**, and casing **18** can be assessed to a reasonable degree of accuracy.

In order to assist in determining the temperature of the tubular member **20** in the FIG. **2** embodiment, air is bled from a source in the compressor, the temperature of which is accurately known, and is fed through apertures **30** in the shaft **14** into an annular space **31** between the tubular member **20** and an additional sealing tube **32**, to wash the outer surface of the tubular member. The internal surface of the tubular member **20** is washed by a mixture of cooling air and oil, supplied through an oil tube **34**, which has been used to cool the rear bearings, and the temperature of which can also be closely predicted.

The tubular member **20** is made as thin as is practically possible to give it a fast response rate.

The temperature of the casing **18** can be predicted quite accurately since the temperatures of the by-pass air and combustion chamber cooling air on its opposite sides do not vary widely.

The tubular member **20** is made from a material sold under the trade name of E.P.C. 10 by Henry Wiggin & Co. Ltd. and which is basically a Nickel Cobalt Iron alloy with a coefficient of expansion of between 0.000004 and 0.000005 per degree Centigrade.

The material of the shaft is a high temperature nickel base alloy sold under the trade name of WASPALLOY, and the outer casing **18** is made largely of titanium in the cooler regions surrounding the H.P. compressor, and of a high temperature nickel base alloy around the combustion chamber and turbine.

With this combination of materials and the arrangement shown in FIG. **2** the sealing clearance between the sealing ribs **17** and the nozzle guide vane can be maintained in the range 0.010 to 0.020 ins. at the design condition of the engine.

This clearance can be reduced further for the addition of a weight penalty by the arrangement shown in FIG. **3** which shows a modification to the same engine. Identical parts are given the same reference numerals as in FIG. **3** and are not described in detail.

In this arrangement the tubular member is present as described in FIG. **2**, but in addition, the portion of the outer casing which surrounds the combustion chamber is made double-walled, and the outer wall is made from the low expansion material E.P.C. 10.

The outer wall **40** is made relatively thin, since it takes little loading, and expands rearwardly from the common datum XX. The inner wall **41**, however, is the equivalent of the casing wall **18** surrounding the combustion chamber in FIG. **2**. It is made strong enough to support the compressor **6** and to contain the pressure inside the engine. It is anchored from a flange **42** at its downstream end so that it will expand axially in an upstream direction and it supports the compressor **6** by a sliding joint **43** at its upstream end.

The annular space **44** between the walls **40** and **41** is supplied with air bled from the compressor, the temperature and flow rate of which are known fairly accurately. The air is exhausted into the by-pass passage **5** through apertures **45** in the inner wall **41** and apertures **46** in the engine casing downstream of the flange. Alternatively this air may be used for cooling of hot components of the turbine further downstream.

The use of the low expansion material in the outer wall reduces the amount of expansion of the casing and since the temperature and quantity of the air flow on both sides of the wall **40** are known, the temperature of the wall and hence its expansion can be calculated more easily.

At the same time the rearward movement of the turbine rotor is also reduced by moving the position at which the tube **20** meets the shaft **14** rearwards. This also helps to make the rearward movement of the turbine more predictable because of the greater length of low expansion material.

With an engine arrangement as shown in FIG. **2** the sealing clearance can be maintained in the range 0.005 ins. to 0.015 ins.

The whole or any part of the casing between datum XX and flange **42** may be made from a material of lower coefficient of thermal expansion than the inner wall. Due to the predictably low temperature of the outer wall which is washed on both sides by relatively cool air at known temperatures, it may not be necessary to use the very low expansion material E.P.C. **10** for the outer wall. It may be possible, therefore, to use more titanium, which is lighter, and thus save some of the weight penalty incurred by the use of the double-walled casing. This will depend on the expansion of the tubular member **20** and the temperature of the outer wall. Clearly, the use of the double wall for cooling the outer wall, in combination with the tubular member **20** is E.P.C. 10 material allows greater choice of materials for the outer wall, and other combinations of materials may be found which will give the required strength and sealing clearance.

The apertures in the casing through which the burners **10** pass must be sealed in a manner which allows for relative thermal expansion between the inner and outer casings.

A sleeve **50** screws into a threaded aperture in the inner casing, and a cup **51** is disposed between a shoulder **52** on the sleeve, and the inner casing. The cup can slide axially relative to the sleeve, and radially relatively to the outer casing.

I claim:

1. A gas turbine engine having a rotor member, a shaft, means for connecting the shaft and the rotor member, bearings for supporting the shaft with freedom for axial thermal expansion of the shaft, means for supporting a sealing member in static structure at a first radial plane of the engine, the rotor member being spaced from the sealing member by an axial sealing clearance, means for locating the shaft in static structure at a radial datum plane of the engine, said means comprising a member made of a material having a lower coefficient of thermal expansion than the shaft, means for connecting said member to the shaft and means for locating said member in static structure of the engine at said radial datum plane.

2. A gas turbine engine according to claim **1** and in which the rotor member is a turbine rotor, the shaft connects the turbine rotor to a compressor of the engine and the member which locates the shaft is a tubular member.

3. A gas turbine engine according to claim **1** and in which the member is located at said radial datum plane of the engine by means of a ball bearing.

4. A gas turbine engine according to claim **2** and in which the radial datum plane of the engine is upstream of the compressor to which said shaft is connected.

5. A gas turbine engine according to claim **1** and in which means are provided for bleeding air from a compressor of the engine and for passing said air over at least one surface of the member to control the temperature thereof.

6. A gas turbine engine according to claim **1** and in which the static structure comprises a casing of the engine and at least a portion of said casing between the first and second radial planes is made of a material having a lower coefficient of thermal expansion than the remainder of the casing between said planes.

7. A gas turbine engine according to claim **6** and in which at least a portion of the casing comprises an inner wall and an outer wall radially spaced therefrom, the outer wall supporting the sealing member and being made from said material, means being provided for supplying cooling air bled from a compressor of the engine to the space between the two walls.

8. A gas turbine engine according to claim **1** and in which the material having the relatively low thermal expansion is a nickel-cobalt-iron alloy with a coefficient of thermal expansion within the range 0.000004 to 0.000005 per degree Centigrade.

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