United States Patent

Dee

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[54] **COAXIAL UNIT**

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[52] **U.S. Cl.** **415/79,** 415/170, 415/212, 60/39.16, 60/39.36, 60/39.75

[51] **Int. Cl.** **F01d 1/04,** F01d 5/06, F04d 29/02

[58] **Field of Search** ....415/77, 79, 110, 111, 113, 415/170, 172, 212; 230/122 A, 116 A, 116 B

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[57] **ABSTRACT**

A turbine rotor construction, for example in a gas turbine, has in combination an outer annular member, an inner annular member disposed in coaxial radially spaced relationship to said outer annular member, and first impeller blading means disposed between said outer annular member and sald inner annular member.

4 Claims, 3 Drawing Figures

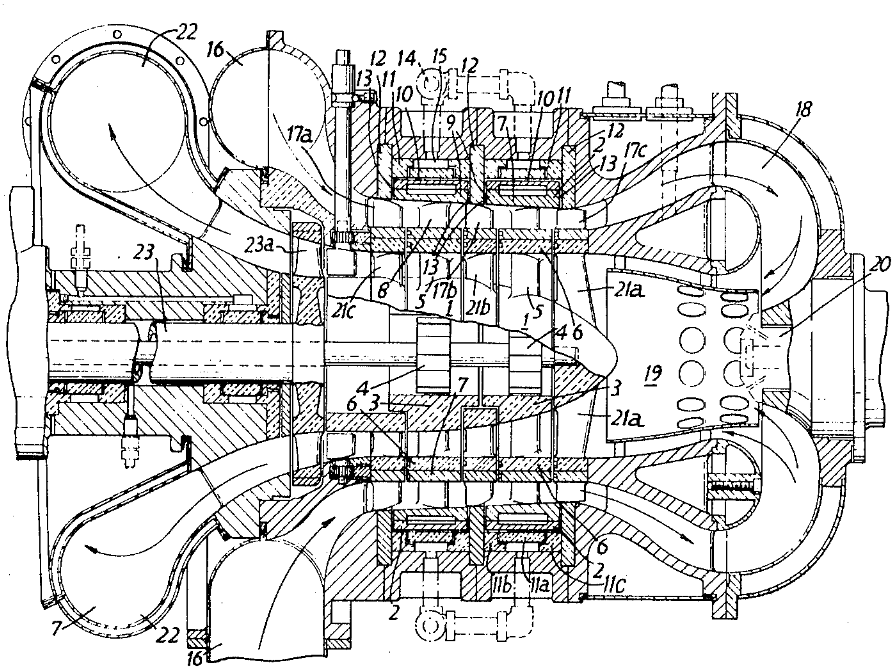
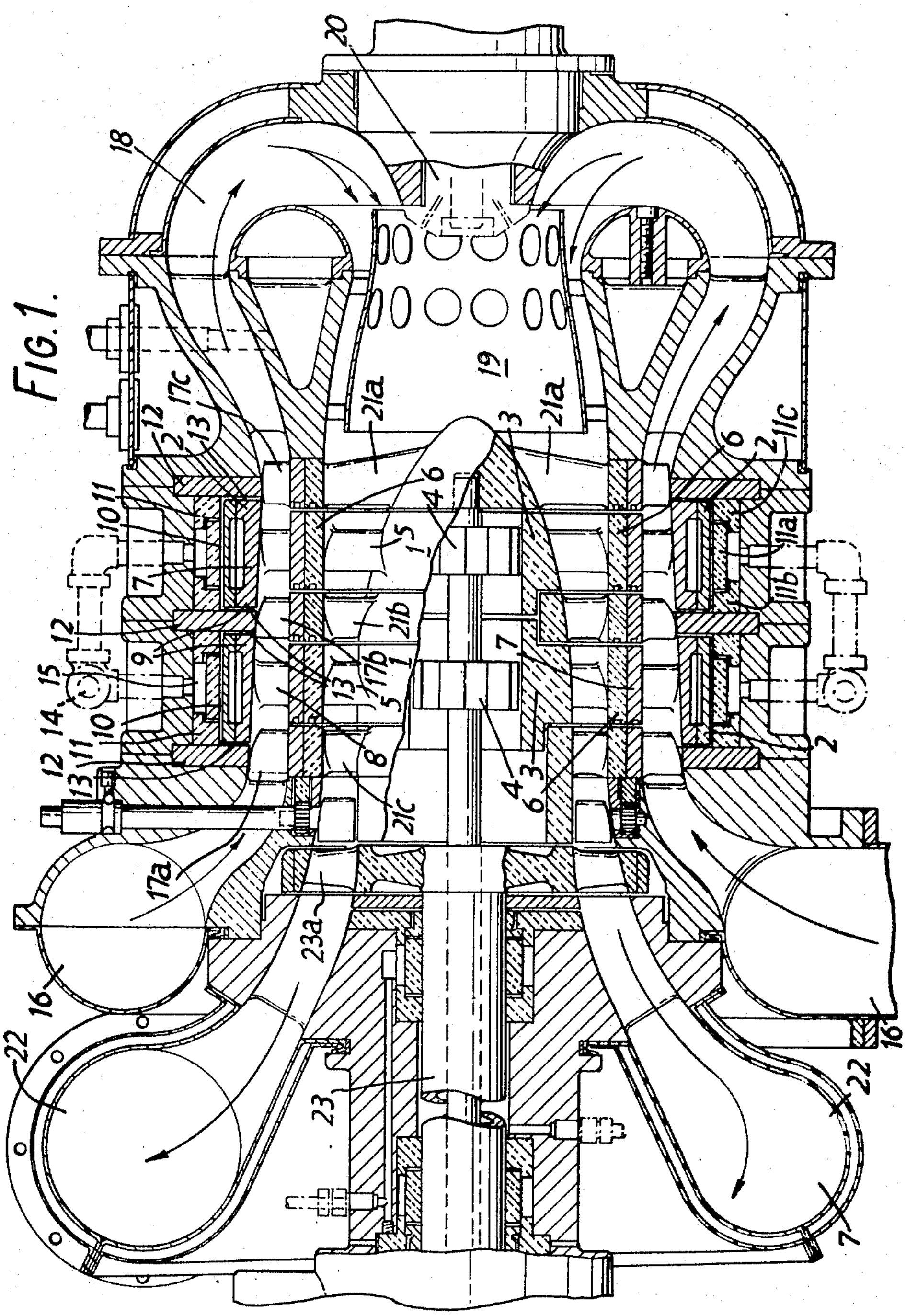


FIG. 1.



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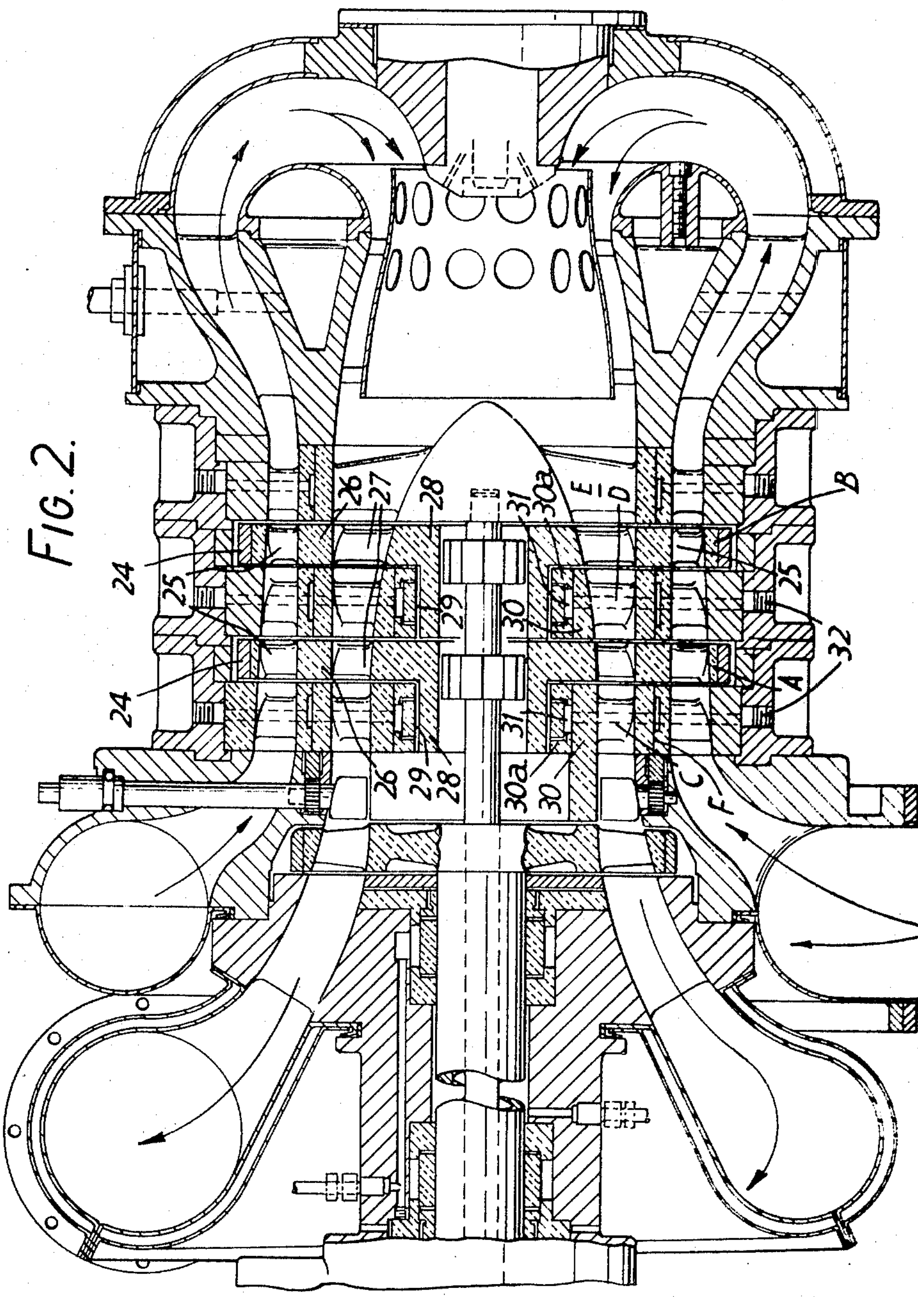

FIG. 2.

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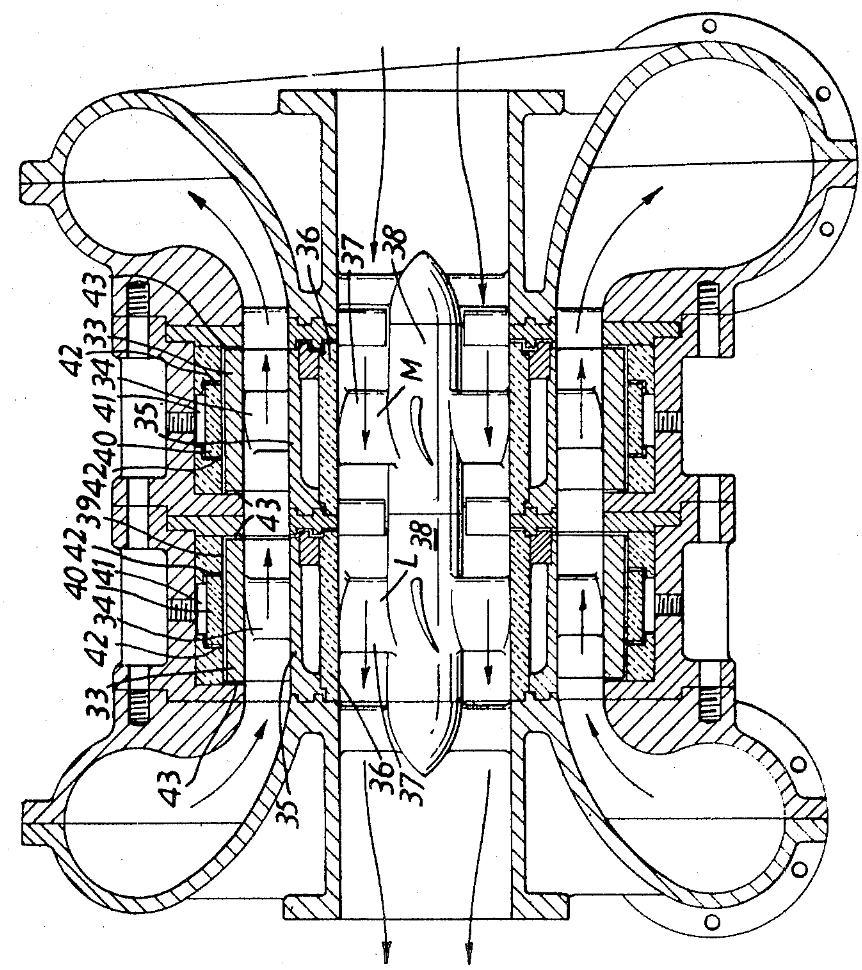

FIG. 3.

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COAXIAL UNIT

This invention relates to turbine devices, such as gas turbines, its object being to provide improvements in rotor construction.

According to the present invention a turbine rotor includes an outer annular member, an inner annular member in coaxial radially spaced relationship to the outer annular member, and first impeller blading situated between the outer and inner annular members. Second impeller blading may be situated within the inner annular member, and/or outside the outer annular member. The outer and/or the inner annular member may be of comparatively elongated tubular form. For example, in the gas turbine, the turbine portion which drives the compressor portion is disposed within the compressor portion and the two are included in a single rotor. This not only reduces the overall axial length of the rotor but also permits a single bearing, or a single set of bearings, to serve for carrying both the driving member and the driven member.

The outer and inner annular members may be secured in coaxial radially spaced relationship by the first impeller blading.

In operation, a turbine rotor as for example in a gas turbine may be subject to relatively high temperatures when driven by products of combustion. It is a major problem in the design and operation of gas turbines that the high temperatures and high centrifugal forces involved result in creep of some materials used in construction of the rotor and blading therefor. This has resulted in the production of special steels and other alloys but the extreme conditions nevertheless still tend to introduce complicating factors in the operation of such gas turbines, and are also related steam turbines.

Although it is well known that certain ceramic materials are able to withstand the elevated operating temperatures encountered they are however of a brittle nature and much more susceptible than metals to rupture under tensile stress conditions. Nevertheless, certain ceramic materials, and in particular silicon nitride, are capable of withstanding high temperatures and have desirable machining properties, with a compression strength of the order of 200/300 meganewtons per square meter.

According to a further feature of the invention, the inner annular element includes ceramic material supported by a radially external enclosure, and in particular the second impeller blading may be made of ceramic material.

The rotating parts are so constructed that the ceramic material is bounded radially externally by rigid support means with the result that, so far as concerns the centrifugal forces exerted during high-speed rotation, the ceramic material operates under compression.

In an advantageous construction of machine including a gas turbine and a compressor driven by the turbine, the gas turbine portion and the compressor portion are arranged coaxially, and in such a construction the external support of the ceramic portions of the rotor may constitute part of the compressor itself, e.g., a generally tubular support for compressor blading. With such a construction the ceramic material, silicon nitride, due to its extremely stable conditions under elevated temperatures, absorbs the generated heat while the outer steel support is maintained at a much lower temperature by the cooler air being pumped through the outer compressor section.

It is desirable in certain instances to utilize, as the bearing means for a turbine rotor, one or more fluid bearings. It has been found that ceramic material, and especially silicon nitride, can be used to advantage to form bearing surfaces defining the bearing gap of such fluid bearings, and in particular for reasons of stability in use and relative nonliability to deterioration or galling if the bearing surfaces are accidentally caused to come into physical contact during high-speed running.

The ceramic material is preferably used for the radially outer of the two bearing members between which the bearing gap is defined. If the bearing outer member is stationary it is not subjected to centrifugal tensile forces, and merely undergoes such compression, acting radially, as is exerted through the fluid in the bearing gap.

According to a further feature of the invention, such a rotor construction is supported by one or more fluid bearings. In a first form, the rotor construction is combined with fluid journal bearing means in which the bearing gap is situated radially externally of the outer annular member, and preferably the radially inner boundary of the bearing gap is defined by the outer annular member. This facilitates manufacture and feeding of the or each bearing, and permits a very compact construction of the rotor, both axially and radially.

Such a construction also lends itself to a composite assembly in which each separate unit of a multiunit rotor is on the same axis and each rotating unit is driven at different speeds defined by variation of the driven impeller blade angle, whereby differing compression ratios may be achieved within each unit.

In a second form, the rotor construction is in combination with fluid journal bearing means in which the bearing gap is situated radially within the second impeller blading. A third annular member may be secured in coaxial radially spaced relationship within the inner annular member and define the radially inner boundary of the bearing gap.

In order that the nature of the invention may be readily ascertained, three embodiments of turbine devices incorporating the invention are hereinafter particularly described with reference to the accompanying drawings, wherein:

FIG. 1 is an axial section of a first embodiment of multistage coaxial gas turbine including slot-type fluid bearings;

FIG. 2 is an axial section of a second embodiment of multistage coaxial gas turbine including slot-type fluid bearings;

FIG. 3 is an axial section of a multistage coaxial turbocompressor including slot-type fluid bearings.

Referring to FIG. 1, an automotive gas turbine comprises a pair of axially spaced rotor units each having a ceramic driven turbine member designated generally by reference numeral 1, situated within a steel compressor member designated generally by reference numeral 2. The ceramic material is, for example, silicon nitride.

Each turbine member 1 comprises a hub 3 which has the functions of (a) receiving centrifugally operable starting clutches 4, (b) carrying ceramic driven turbine blades 5, and (c) serving with a ceramic tubular element 6 to define a path for the combustion gases towards an exhaust outlet.

The ceramic tubular element 6 is situated within, and is supported against the effect of radially outwardly acting forces, e.g., centrifugal forces, by a tubular element 7, of the steel compressor member.

The steel compressor member 2 comprises the tubular element 7, compressor blades 8 extending radially of the element 7, and an outer tubular element 9. The cylindrical external surface of element 9 constitutes the inner bounding face of a gap 10 of a fluid bearing. The outer bounding face of that gap is constituted by the cylindrical inner surface of a respective one of a pair of ceramic ring assemblies 11, so that each rotor unit is supported by one of two axially spaced cylindrical fluid bearings. The elements 9 are each situated axially between a pair of annular walls 12, and fluid thrust bearing gaps 13 are defined between each end of each portion and the adjacent annular wall. Each rotor unit is accordingly supported against axial forces, in each direction, by the fluid thrust bearings. The cylindrical journal bearing gaps 10 are fed with fluid under pressure from conduits 14 which communicate with annular plenum chambers 15. The ceramic ring assemblies 11 are each constituted by a cylindrical sleeve 11*a*, and two end members 11*b*, 11*c*. The axial end faces of the sleeve 11*a* are cut back axially to provide a plurality of symmetrical equally angularly spaced parallel-sided recesses, and a plane radial face of the respective end members 11*b*, 11*c* is butted up against each recessed end face so as to provide a plurality of feed slots disposed circumferentially about the bearing surface and providing a communication between the plenum chambers 15 and the fluid bearing gap **10**. Each ceramic ring assembly **11** has two axially spaced circumferential rows of such slots.

Methods of forming such slots and constructions of fluid bearings incorporating them are set out in detail in the following applications and patents of the same inventor:

i. copending U.S. Pat. application Ser. No. 557,231 dated 13th June 1966, now U.S. Pat. No. 3,510,175;

ii. granted U.S. Pat. No. 3,410,616

iii. copending U.S. Pat. application Ser. No. 710,258 dated 4th Mar. 1968, now U.S. Pat. No. 3,570,176;

iv. copending U.S. Pat. application Ser. No. 635,741 dated 3rd May 1967, now U.S. Pat. No. 3,437,387;

v. copending U.S. Pat. application Ser. No. 737,005 dated 14th June 1968, now U.S. Pat. No. 3,533,644;

vi. copending United Kingdom Pat. application Ser. No. 48,068/67 dated 23rd Oct. 1967;

vii. copending U.S. Pat. application Ser. No. 792,220 dated 14th Jan. 1969.

The thrust bearing gaps **13** are all fed with fluid by bleed from the ends of the respective journal bearing gaps **10**.

In operation, air is drawn in through an intake **16** and passes through stationary guide blades **17***a* to impinge on the compressor blades **8** of one unit of the rotor. Thereafter it passes through second stationary guide blades **17***b* to impinge on the compressor blades **8** of the other unit of the rotor. Thereafter, the air passes through third stationary guide blades **17***c* and through passages **18** which return it into a combustion chamber **19** fed with fuel through a nozzle assembly **20**. The combustion gases then pass through first stationary guide blades **21***a*, then through the blades **5** of a unit of the rotor, then through second stationary guide blades **21***b*, then through the blades **5** of the other unit of the rotor, and then through third stationary guide blades **21***c* to pass eventually to exhaust through an outlet **22**.

An output shaft **23** serves for power takeoff from the separately driven turbine **23***a*.

In this embodiment, the "outer annular member" mentioned herein refers to the two outer tubular elements **9** each defining the inner boundary of a journal bearing gap. The "inner annular members" refers to the assembly of the ceramic tubular element **6** situated within the steel tubular element **7**. The "first impeller blading" refers to the rotating compressor blades **8**. The "second impeller blading" refers to the rotating driven turbine blades **5**.

Referring now to FIG. **2**, there is shown a somewhat similar multistage gas turbine which is distinguished essentially from that of FIG. **1** by the fact that the two units of the rotor are carried each by one of a pair of fluid journal bearings which, instead of being situated about the outside of the "outer annular member," are situated within the rotor itself.

The rotor has two axially spaced rotating units A and B. These units each consists of a steel outer shell **24**, a ceramic annulus and ceramic compressor blades **25** situated within and supported by the steel shell, an inner ceramic annulus **26**, ceramic driven turbine blades **27**, and a ceramic hub **28**. The two units A and B are each disposed between respective pairs of stationary blade assemblies C, D and E.

Journal fluid bearings for each of the units have cylindrical bearing gaps **29** each defined between an outer cylindrical surface of the hub **28**, and an inner cylindrical surface of a stationary body **30**. In each body **30** there is provided a ceramic ring assembly **30***a* as described in relation to FIG. **1**, for feeding fluid to the journal bearing gap **29** through slots. Each body **30** includes a plenum chamber **31** fed through conduits **32**. Each body **30** includes a plenum chamber **31** fed through conduits **32**. It will be seen that "the outer annular members" refers to the steel shell **24** and the ceramic material within it; the "inner annular members" refers to the ceramic annulus **26**; the "first impeller blading" refers to the compressor blades **25**; the "second impeller blading" refers to the ceramic driven blades **27**. The fluid journal bearing gaps **29** are defined between bearing members (hub **28**, body **30**) which are situated radially within the turbine blades **27**. The "third annular member" refers to the body **30**, with ceramic ring assembly **30***a* therein, which is secured in coaxial radially spaced relationship within the "inner annular member" and which defines the radially outer boundary of the bearing gap.

Separate thrust bearings are provided on the inner annular member at F and fed from the supply conduit **32**.

Referring now to FIG. **3**, there is shown a multistage coaxial turbocompressor having a rotor constituted by two coupled axially spaced rotor units L, M. Each unit comprises a steel outer cylindrical tubular member **33** within which are situated compressor blades **34** on an inner steel tubular element **35**. Within the latter is positioned a ceramic assembly consisting of a ceramic tubular element **36**, supported against radial forces by the steel element **35**, and ceramic driven blades **37** mounted on a ceramic hub **38**.

Each unit L, M is supported by an external fluid bearing. The bearing gap **39** has as its inner boundary the outer surface of the steel member **33**, and as its inner boundary the inner surface of a ceramic ring assembly **40**. The assembly **40** is a three piece assembly similar to the assembly **11***a*, **11***b*, **11***c* described in relation to FIG. **1**. Fluid is fed to the gap **39** from plenum chambers **41** through slots **42** arranged in two circumferential rows for each unit. Between the ends of each steel member **33** and the adjacent stationary radial wall of the stator there are defined end-thrust bearing gaps **43** which are fed with fluid by bleed from the end of the associated journal bearing gaps **39**.

In this construction, the "outer annular member" refers to the steel member **33**; the "inner annular member" refers to the assembly of the ceramic element **36** and the steel element **35**; the "first impeller blading" refers to the blades **34**; the "-second impeller blading" refers to the blades **37**.

I claim:

1. In a turbine, the combination of an annular stator member, and a rotor member disposed in radially spaced relationship within said stator member and defining therewith a fluid journal bearing gap, said rotor member including:

i. an outer tubular member made of a metal selected to withstand tensile stresses resulting from centrifugal force as the rotor is rotated

ii. a first inner tubular member made of ceramic material and disposed in contact within and supported radially by said outer tubular member, and

iii. first ceramic impeller blading disposed within and carried by said first inner tubular member

iv. a second tubular inner member made of ceramic material and disposed coaxially in radially spaced relationship within said first inner tubular member

v. second ceramic impeller blading disposed within and carried by said second tubular inner member.

2. The combination of claim **1** wherein said annular stator member is of ceramic material.

3. A turbine comprising: a rotor construction which comprises in combination a tubular outer member, a tubular inner member disposed in coaxial spaced relationship within said tubular outer member, and outer impeller blading disposed between said outer tubular member and said inner tubular member, said outer tubular member and said inner tubular member and said impeller blading being made of a metal selected to withstand tensile stresses resulting from centrifugal force occuring as the rotor is rotated, a tubular ceramic member disposed in contact within and supported radially by said inner tubular member, and ceramic inner impeller blading disposed within and carried by said tubular ceramic member; and an annular stator member disposed in radially spaced relationship about said tubular outer member and defining therewith a fluid journal bearing gap, said annular stator member being made of ceramic material.

4. A turbine rotor construction with comprises in combination a tubular outer member made of a metal selected to withstand tensile stresses resulting from centrifugal force occuring as the rotor is rotated, an outer tubular ceramic member disposed in contact within and supported radially by said tubular outer member, a tubular ceramic inner member disposed in coaxial spaced relationship within said tubular ceramic outer member, ceramic outer blading carried between said inner and outer ceramic tubular members, ceramic inner impeller blading disposed within and carried by said inner tubular ceramic member, and a ceramic hub disposed within and integral with said inner impeller blading, said hub having an external cylindrical surface, and an annular stator member disposed in radially spaced relationship about said external cylindrical surface of said hub and defining therewith a fluid journal bearing gap, said annular stator member being made of ceramic material.

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