United States Patent

Dekeyser

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[45] **June 6, 1972**

[54] **GAS TURBINE WITH ROTARY HEAT EXCHANGERS**

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[73] Assignee: **Bennes Marrel,** Saint-Etienne (Loire), France

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May 22, 1969 France 6915549

[52] **U.S. Cl.** ....**60/39.51 H,** 165/8, 165/9

[51] **Int. Cl.** **F02c 7/10,** F28d 19/04

[58] **Field of Search** ....60/39.51 R, 39.51 H; 165/8, 165/9

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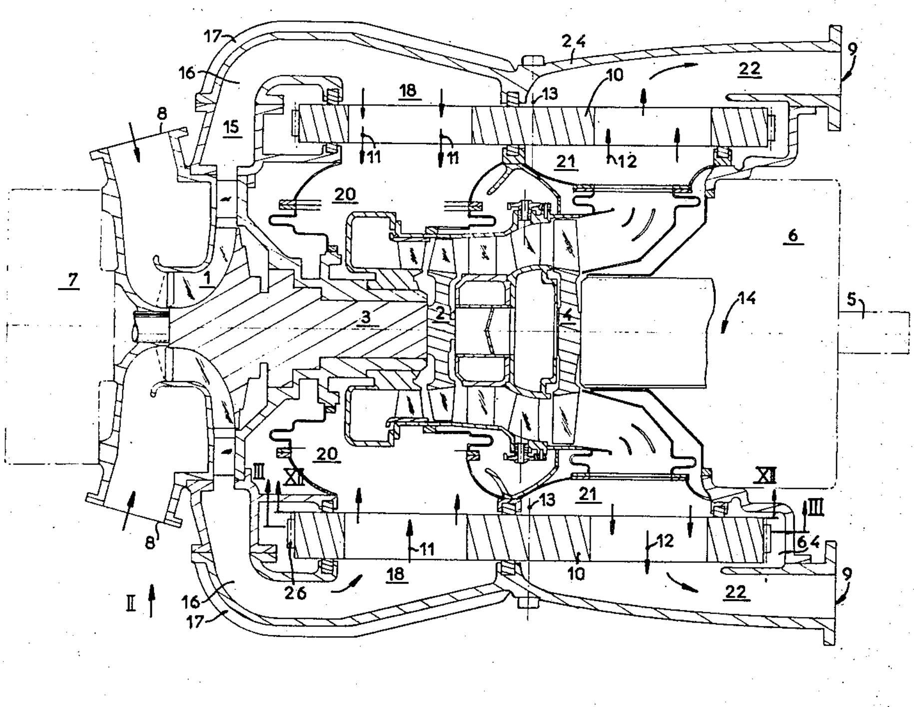
Attorney—Sughrue, Rothwell, Mion, Zinn & Macpeak

[57] **ABSTRACT**

A gas turbine of the type having a pair of rotary heat exchanger discs mounted for rotation about a common axis transverse to the main axis of the turbine on opposite sides thereof is provided with a drive arrangement which will provide for expansion between the disc and an annular drive ring surrounding the disc. The annular drive ring is provided with a plurality of external teeth disposed in meshing engagement with a pinion drivingly connected to the main gear box of the turbine. A plurality of cylindrical rods are mounted in a plurality of equally spaced apart grooves in the circumference of each of the discs. Each cylindrical rod is formed with an arcuate groove in the external surface thereof for the reception of a key member having a convex surface which rests in the arcuate groove and two plain surfaces which define a dihedron, the edge of which is disposed adjacent the internal surface of the annular ring. A pair of wedge members are disposed in engagement with each of the surfaces of the key. The wedges are biased into engagement with the key by means of a spring extending between the wedge and a rib formed on the internal surface of the annular ring.

7 Claims, 17 Drawing Figures



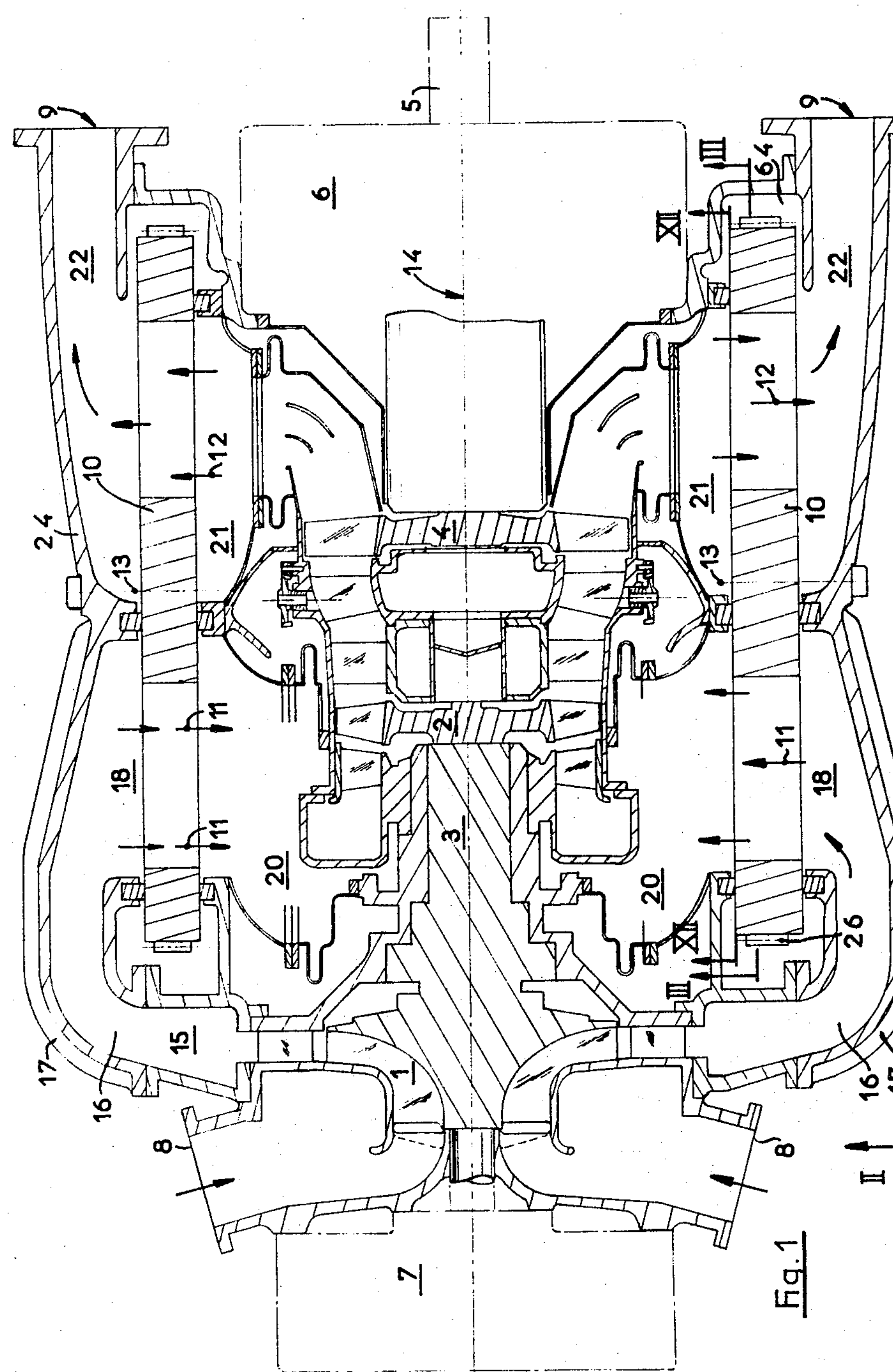

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Fig. 1

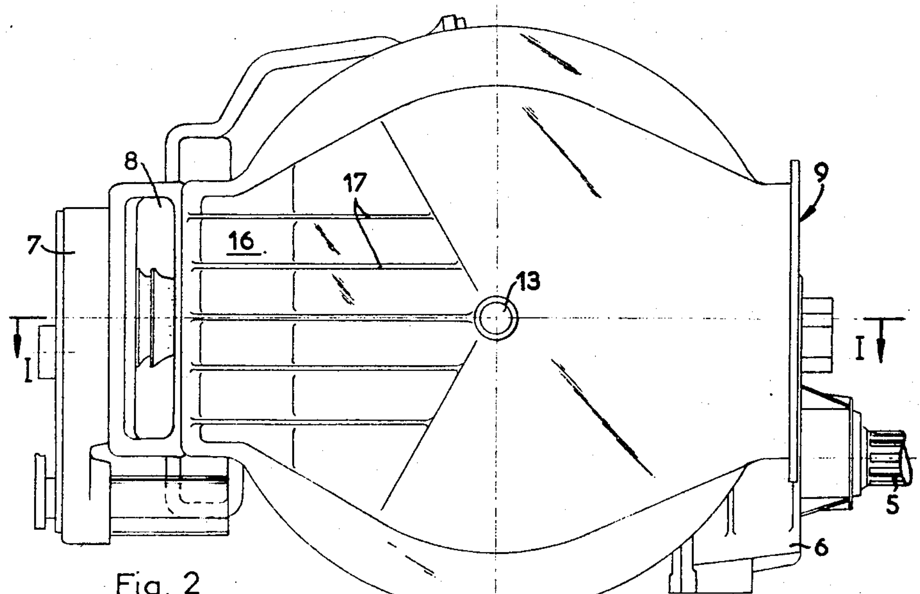
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Fig. 2

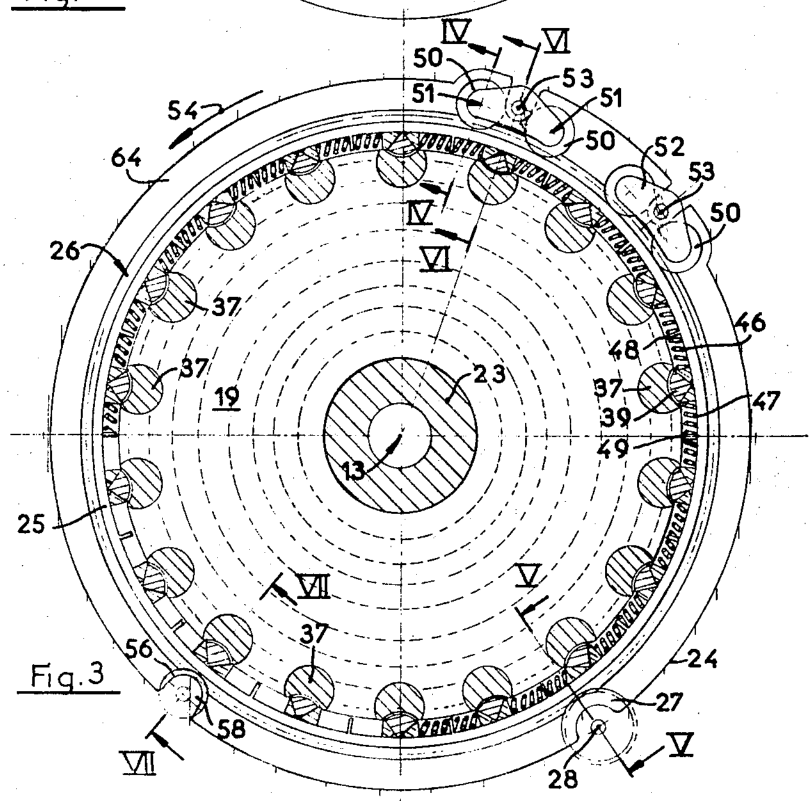
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Fig. 3

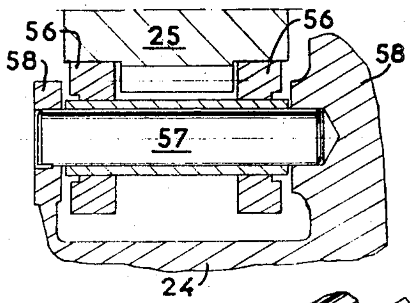


Fig. 7

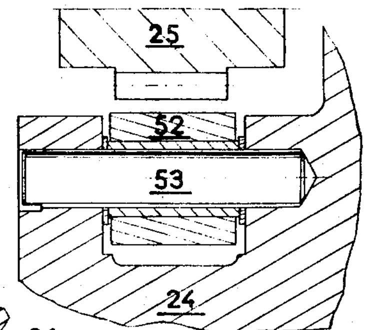


Fig. 6

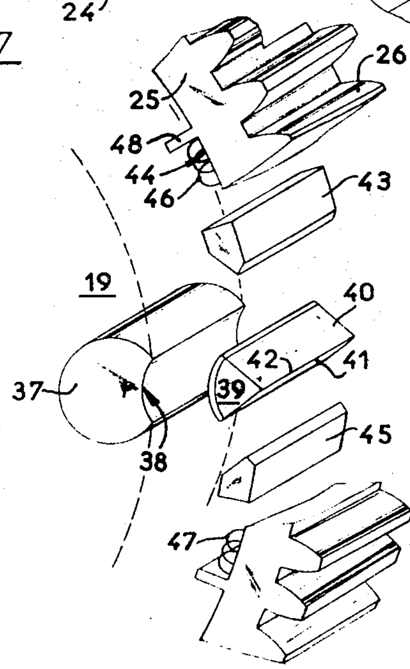


Fig. 8

Fig. 4

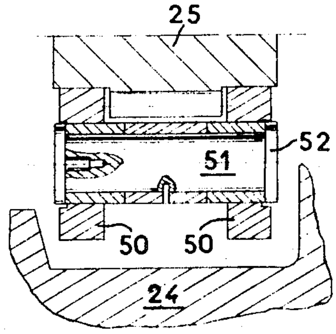
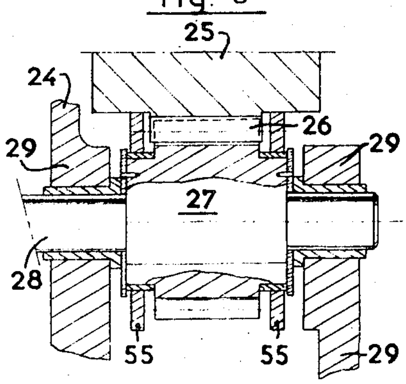


Fig. 5



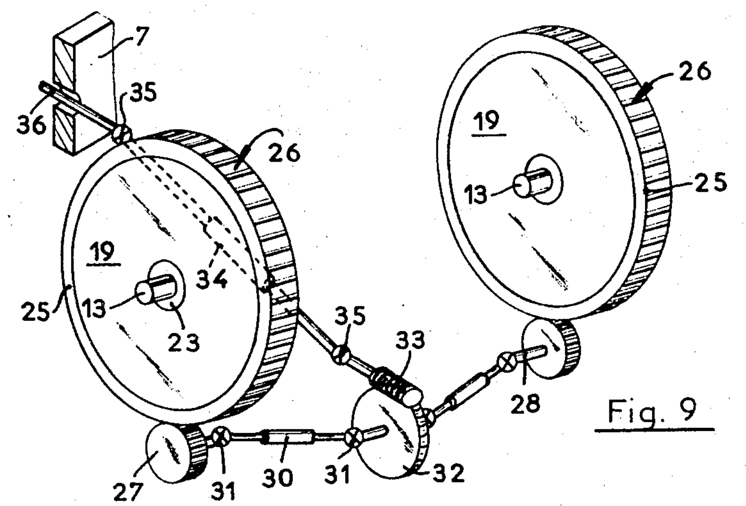

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Fig. 9

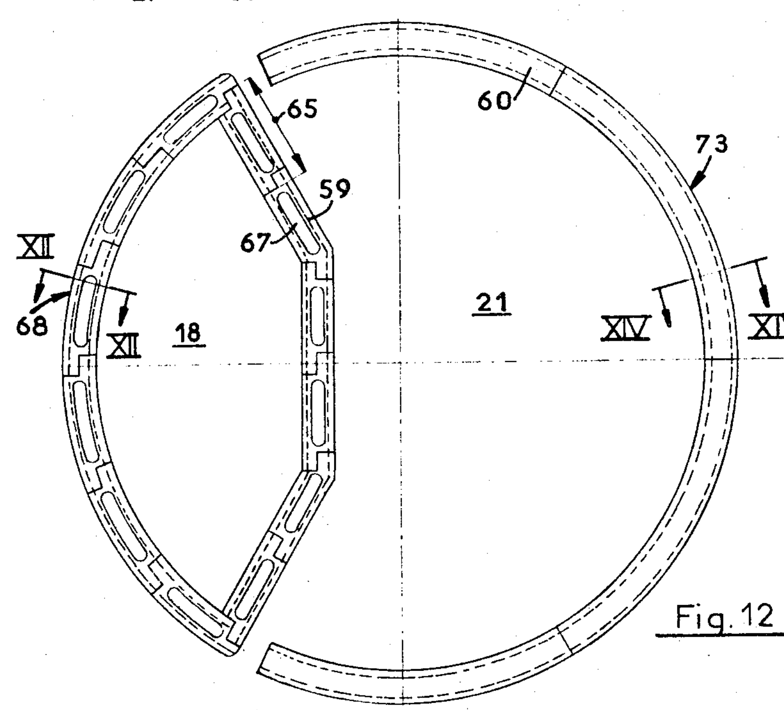
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Fig. 12

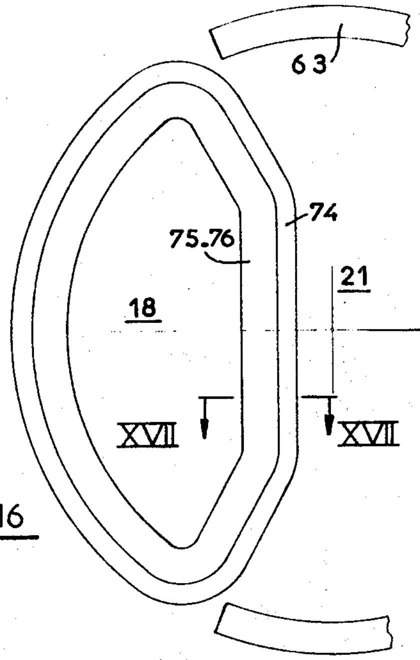

Fig.16

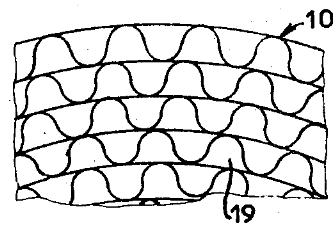

Fig.10

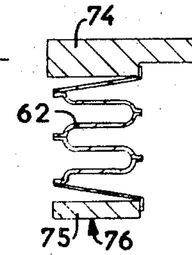

Fig.17

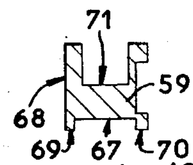

Fig. 13

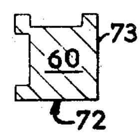

Fig. 14

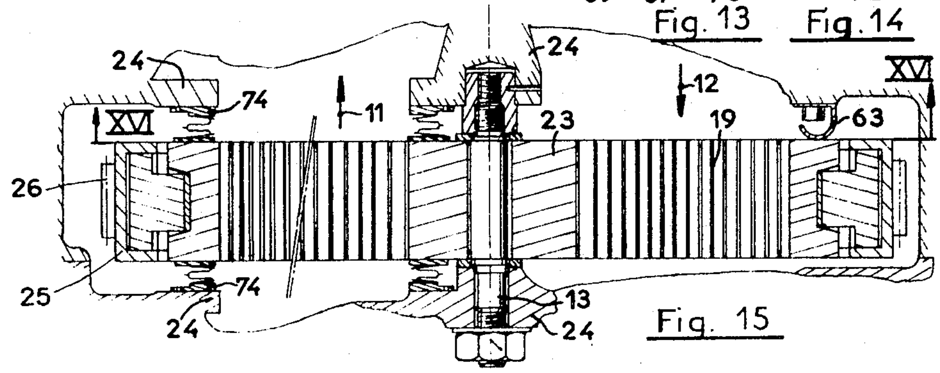

Fig. 15

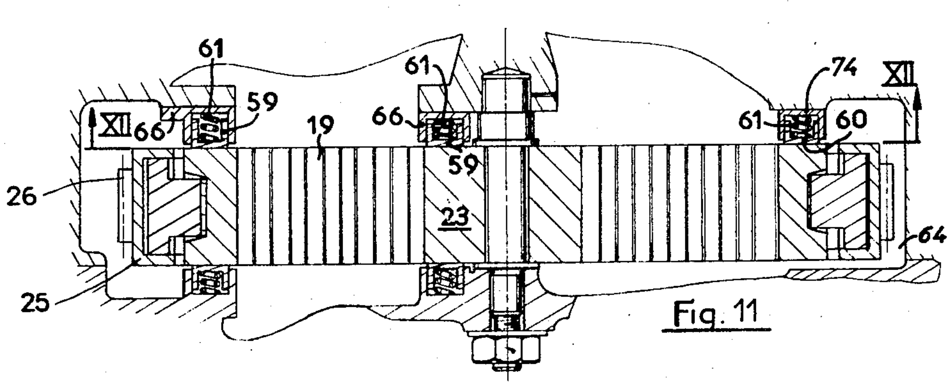

Fig. 11

GAS TURBINE WITH ROTARY HEAT EXCHANGERS

The present invention relates to a gas turbine provided with rotating heat exchangers.

This gas turbine is particularly designed to be used on vehicles, for example on lorries, and its construction is of the type already described in U.S. Pat. No. 3,609,966 granted Oct. 5, 1970.

This U.S. Pat. No. 3,609,966 described a gas turbine in which it was proposed to improve the construction by incorporating therein rotating heat exchangers. These exchangers permitting the partial recovery of the latent heat of the gas escaping from the turbine have the essential task of increasing very substantially the thermodynamic output of the cycle, thus substantially diminishing the specific consumption of the machine. They also present diverse other advantages which are:

Lowering by more than half of the temperature of the gas at the turbine outlet;

Reduction of the noise level at the exhaust (outlet);

Reduction in the section of the outlet casing for the exhaust gas in consequence of the reduction in volumetric flow;

Reduction in cost and bulk of the silencers as a result of the three above advantages.

In the turbine of the invention, the rotating exchangers are formed of a known porous material, with a ceramic or devitrified glass, of the kind which is sold under the commercial name "CERCOR". Such a material has a practically negligible or even very slightly negative coefficient of expansion which permits it to be subjected without damage to substantial thermal shocks.

A gas turbine according to the invention comprises a compressor which admits fresh atmospheric air and compresses it in a manifold feeding combustion chambers, while downstream of the low pressure rotor of the turbine the exhaust gases are ejected to the exterior by an exhaust manifold, and it is characterized in that the passage of the relatively fresh air between the manifold and the combustion chambers is effected through a passageway wherein the air flows in counter-current relative to the hot gases of the adjacent exhaust manifold, a known porous disc being disposed athwart the two passageways so as to rotate around a theoretical axis parallel to the general direction of the two flows of fresh air and hot gas, while a sealing system is provided between this rotating disc and the fixed parts of the passageways to avoid short-circuiting of the gas from one to the other, the rotation of the exchanger disc being assured by the intermediary of a toothed metallic annulus within which it is mounted with means permitting free play for expansion, this annulus being disposed at the exterior of the sealing systems so as to be entrained by a pinion driven by the gearbox of the turbine.

Another feature of the invention consists in distributing on the periphery of the porous disc, cylindrical pins in each of which is cut an external arcuate groove in which is supported the convex back of an immovable element or key also having two plane faces forming a dihedron whose edge is near the internal face of the metallic annulus, while there is mounted in opposition on the faces of the same key two wedges urged one towards the other by springs, each supported on one of the radial ribs distributed transversely on the internal face of the annulus, each rib being disposed an equal distance between the two keys. This arrangement permits free play of expansions between the disc of the annulus.

To ensure the mounting of the rotating annulus, there is provided a series of exterior rollers connected in pairs on a lever pivotal around a fixed axis, these rollers being disposed mainly in the direction of force exercised on the annulus by the driving pinion. In addition it is advantageous to provide two other series of external rollers adapted to ensure guiding of the annulus when it is at rest or when the turbine rotates with very small load.

In a first variation, the porous disc has at its center a hub provided with an axle whose ends are maintained in fixed bearings. On the opposed lateral faces of this disc are supported two thin friction plates both defining the contour of the transverse section of the air admittance conduit, each of these thin plates being maintained against the disc by a metallic bellows which is supported on fixed parts of the gearcase of the turbine. These plates and bellows define a fixed sector on the rotating disc. On the remainder of the two lateral faces of the disc are supported two metallic joints flexibly mounted in opposition to complete the circumference of each of these faces.

According to another variation, sealing is assured, not with the aid of bellows, but by the intermediary of metallic sectors or rubbing shoes disposed end-to-end and maintained against the opposed faces of the disc, each with the aid of springs supported of the fixed parts of the gearcase.

According to a preferred form of the invention there are used in the turbine two rotating exchanger discs located vertically on both sides of the turbine, their horizontal axes being aligned. This permits particularly the provision in the front (forward) part of the turbine a double skin to the interior of which flows the relatively fresh admittance air. This arrangement is advantageous for a gas turbine designed for use on a lorry since it permits having an external body of relatively low temperature.

The annexed drawing gives by way of example a better understanding of the features of the invention.

FIG. 1 is a horizontal section along X—X (FIG. 2) of a gas turbine according to the invention;

FIG. 2 is a side view in the direction of the arrow II (FIG. 1);

FIG. 3 is a section on III—III (FIG. 2) showing the driving arrangement of the refractory disc of an exchanger by its peripheral metallic annulus;

FIGS. 4, 5, 6, 7 are section on the lines IV—IV, V—V, VI—VI, VII—VII (FIG. 3);

FIG. 8 is an exploded perspective view of the connecting system of a refractory disc and its driving annulus;

FIG. 9 illustrates the kinematic linkage which drives the two rotating exchangers;

FIG. 10 is a fragmentary side view illustrating schematically, to an enlarged scale, the cellular structure of a porous exchanger disc;

FIG. 11 is a part section showing to an enlarged scale a detail of FIG. 1;

FIG. 12 is a schematic plan view on XII—XII (FIGS. 1 and 11) showing the disposition of the segmental fluid tight system disposed between the air admission conduit and the gas exhaust conduit;

FIGS. 13 and 14 are sections on XIII—XIII and XIV—XIV (FIG. 12);

FIG. 15 corresponds to FIG. 11 showing a modified bellows fluid tight system for the rotating discs;

FIG. 16 is a section on XVI—XVI (FIG. 15) showing the mounting of the air tight system on one of the faces of a rotating disc;

FIG. 17 is a section on XVII—XVII (FIG. 16).

There is shown in FIGS. 1 and 2 a gas turbine according to the invention. This turbine comprises a centrifugal compressor **1** and a high pressure bladed rotor **2** keyed on the same shaft **3** while a low pressure bladed rotor **4** constitutes the power rotor which drives the motor output shaft **5** through the intermediary of a reduction gear **6**. At the front, the shaft **3** of the prime mover assembly drives the elements of a gearbox **7**. The admission of atmospheric air is effected through lateral ports **8** and the exhaust gases are forced to atmosphere via two ports **9** directed towards the rear.

The principal features of the invention consist in the interpositioning of two rotating heat exchangers **10** in the paths of air admitted under pressure by the compressor **1** (arrows **11**) and the gases exhausted towards the ports **9** (arrows **12**). Each exchanger is constituted by a disc rotatable around a transverse horizontal axis **13** perpendicular to the longitudinal axis **14** of the turbine. The two exchangers are disposed in vertical planes on both sides of the turbine and their axes **13** are aligned. For the sake of simplicity, only one of the exchangers **10** will be described, the other being identical.

The air extracted from the external atmosphere is forced through the ports **8** by the compressor **1** into an annular manifold **15**. This relatively fresh air has for example a pressure of the order of 4 atmospheres. Two passageways **16** provided with external reinforcing ribs **17** channel the air from both sides of the manifold **15**. Each passageway extends along the exterior of the turbine body and terminates after an elbow formation in a passageway **18** parallel with the axes **13**, where the air flows towards the central axis **14** as indicated by the arrows **11**. Thus flow is effected through the porous mass of disc **19** of each exchanger **10** (FIG. **10**). Then the air collects in a single annular chamber **20** which sends it into the combustion chambers of known type (not shown). The passageways **16** form a double casing traversed internally by the entry air, which allows for an external body of relatively low temperature.

Downstream of the low pressure turbine **4** the exhaust gases are received in two diametrically opposed passageways at both sides of the axis **14**. In each passageway **21**, the exhaust gas traverses the porous mass of the disc **19** of the corresponding exchanger **10** in a direction parallel to the axes **13** (arrows **12**). After this traversal, the gases are received in an exhaust manifold **22** which directs them towards the rear for ejection through the corresponding exhaust ports **9**.

The rotation of the two discs **19** of the exchangers **10** is controlled by the output of the gearbox **7** of the turbine through the intermediary of a geartrain which will be described in detail later, particularly with reference to FIG. **9**. It is to be noted that the flow of air (arrows **11**) is counter-current to that of the exhaust gases (arrows **12**) in two parallel and adjacent passageways **18** and **21**.

The exhaust gases traversing the exchangers (arrows **12**) give up heat to the material of the discs **19**. The calories thus received are transmitted by the rotation of the discs **19** to the incoming air flow from the compressor **1** (arrows **11**) for delivery to the combustion chambers.

FIGS. **3** to **8** show details of the driving and guiding systems for the rotating exchangers.

Each disc **19** has a hub **23** which is journalled on an axle **13** fast with a stator **24** of the turbine. This disc **19** is rotated through the intermediary of a metallic ring **25** provided with external teeth **26**; with these teeth meshes a pinion **27** fast on an axle **28** which rotates in bearings in the stator **24**. The two axles **28** are transversely aligned at both sides of the turbine, and each of them is connected by a transmission with a sliding sleeve **30** and Cardan joints **31** to a central tangent ring **32** with which meshes a worm **33**. The latter is disposed longitudinally relative to the turbine and is connected by a transmission with sliding sleeve **34** and Cardan joints **35** to one of the output shafts **36** of the gearbox **7**. Thus this shaft **36** is driven through the intermediary of an appropriate reduction at the output of the prime mover group **1,2,3** of the turbine.

The material constituting each disc **19** has a coefficient of expansion which is practically negligible, even slightly negative. This property is advantageous since the disc **19** is subjected in use to substantial thermal shocks. Consequently, relative play occurs between the disc **19** and the metallic ring **25** driving it. This play evolves as a function of the prevailing conditions of rotation of the turbine. To take account of it there is adopted the following mounting.

On the periphery of the disc **19** there are provided transverse cylindrical grooves (18 in the example of FIG. 3) in each of which engages a cylindrical metallic rod **37**. This rod **37** is cut to provide a cylindrical concave groove **38** whereof the generatrices are parallel to the axis **13**. This concave groove **38** serves as a seat for the cylindrical face of a key **39** which has additionally two inclined convergent faces **40** and **41**; these faces define a dihedron whereof the edge **42**, parallel to the axis **13**, is adjacent the internal surface of the metallic ring **25** (FIGS. **3** and **8**). A metallic wedge **43** is inserted between the inclined face **40** and the internal surface **44** of the ring **25**. Similarly, a wedge **45** is disposed between the inclined face **41** and the internal surface of the ring **25**. The wedges **43** and **45** rest on a face of and each of them is urged against, the oscillating key **39** by a compression spring **46** or **47**. The spring **46** of the wedge **45** is supported on a transverse rib **48** which extends from the internal face of the ring **25**. Similarly, the spring **47** is supported on another rib **49** of the same ring **25**. Thus, the ring **25** comprises regularly spaced ribs such as **48** and **49** whereof the number is equal to that of the rods **37**. Each rib **48** or **49** is disposed between two rods **37**.

This method of connection between the disc **19** and the ring **25** presents in the radial sense a certain flexibility which is incompatible with the loads supported by the ring, that is to say for example the reaction due to the tangential force at the right of the driving pinion **27**. It is, therefore, necessary to provide supplementary external elements to ensure support of the ring. To this end, there are employed double rollers **50** (FIGS. 3 and 4) each supported by an axle **51**. The double rollers **50** are grouped in pairs, that is to say there are two axles **51** mounted on the ends of a swinging arm **52** which is articulated at its center on an axle **53** carried by the stator **24**. In the example of FIG. 3, there are four double rollers **50** grouped on two axles of articulation **53** in the direction of the force acting on the ring **25** when it rotates in the direction of the arrow **54** under the action of the driving pinion **27**.

Two other series of rollers are provided to ensure guiding of the ring when it is at rest or when the turbine rotates under conditions of very light load. It is a matter on the one hand of lateral rollers **55** mounted on both sides of the pinion **27** (FIG. 5) for rolling on the periphery of the ring outside the teeth **26** and on the other hand of rollers **56** mounted in the same manner on an axle **57** disposed in fixed bearings **58** of the stator **24** (FIG. 7).

The sealing system used on the plane faces of each disc **19** to avoid short-circuiting of gas between passageways **18** and **21** (FIG. **1**) can be realized in two different ways. A first variation (FIGS. **1**, **12**, **13**, **14**) uses metallic segments **59** or **60** loaded by springs **61**. A second variation (FIGS. **15**, **16** and **17**) uses a system of bellows **62** and sealing lips **63**, the elements **62** and **63** being wholly metallic.

The first variation (FIGS. **1** and **11** to **14**) permits the application on each of the two faces of a disc **19** of a series of flanges or friction segments **59** placed end-to-end to define a closed shape around the section of the fresh air passage (that is to say around the section of the passageway **18**). The remainder of the circumference is provided with friction segments also placed end-to-end to retain the exhaust gases and avoid particularly any penetration by them into the annular chamber **64** (FIGS. **1**, **3** and **11**) where are located the teeth,pinions and rollers **26**, **27**, **50** and **56**. Each segment **59** has a length **65** intentionally reduced in order to compensate for possible deformations. It slides in a runway **66** connected to the stator **24**. A cut-out **67** is formed in the face of each segment **59** which is in frictional contact with the disc **19**. The cut-out **67** forms an expansion chamber which limits the importance of a gas leakage as a result of possible deformation. The friction faces **68,69** and **70** of each segment **59** are covered with a layer of chromium oxide and titanium oxide to facilitate sliding and avoid wear. At their ends the segments **59** are cut in bayonet fashion which permits them to be engaged end-to-end to avoid leakages.

Each segment **59** is grooved on its face opposite to the disc **19** to form a recess **71** which receives the power spring **61**.

The system functions like an autoclave by the action of the pressure on the faces of the segments which are opposite the faces **68**, **69** and **70** receiving the deposit.

The segments **60** are formed on a similar principle but with a simpler structure. They comprise a face **72** which rubs on the disc **19** and a lateral face **73** receiving the pressure against the corresponding support segments **74**. The rubbing faces **72** and **73** are also covered with a layer of chromium oxide and titanium oxide.

In the variation shown in FIGS. **15** to **17**, the sealing around the fresh air passageway **18** is ensured by a continuous metallic bellows **62** secured between two metal plates **74** and **75**.

The plate **75** is thin which gives to the assembly **62, 75** a flexibility capable of compensating for deformations due to relative expansions resulting from the practically negligible coefficient of expansion of the disc **19**. The rubbing face **76** of the thin plate **75** is provided with an anti-wear deposit which can also be based on chromium oxide and titanium oxide. Each plate **74** is supported on the fixed stator **24** on both sides of the disc **19** (FIG. **15**). On the remainder of the periphery of the disc there is mounted on the face upstream of the flow of exhaust gases (arrows **12**) a plate joint **63** having a flexible lip which rubs on the adjacent face of the disc **19**.

It will be noted that in the two variations (FIGS. **11** and **15**), the sealing is realized in a most simple manner between the entry and the exit of gas where the pressure differential is sufficiently slight while the temperature of the exhaust gases (manifolds **22**) is relatively low.

I claim:

1. A gas turbine comprising a stator, compressor means and rotor means disposed for rotation about a common axis in said stator, a pair of porous heat exchanger discs mounted for rotation about an axis transverse to said common axis on opposite sides thereof, inlet passage means directing compressed air from said compressor means radially inwardly toward said common axis through said discs, exhaust passage means directing exhaust gases radially outwardly away from said common axis through said discs, sealing means between said rotatable discs and said stator, and means for rotating each of said discs comprising a metallic annular member having external teeth disposed about each of said discs and drivingly engaged therewith by connecting means permitting free play for relative expansions, each of said annular members being disposed outwardly of said sealing means, drive means for driving said annular member including a pinion disposed in meshing engagement therewith, said connecting means including a plurality of cylindrical rods disposed in a plurality of cylindrical grooves found in the periphery of said discs parallel to the axes thereof, an arcuate groove formed in the external periphery of each rod parallel to the axis thereof, key means having a convex surface disposed in each arcuate groove and two plane surfaces forming a dihedron the edge of which is disposed adjacent the internal face of said annular members, a pair of opposed wedges disposed in engagement with said plane surfaces of each key means, a plurality of radially inwardly extending ribs on said annular member each of which is equally spaced between each of said key means and spring means disposed between said ribs and each of said wedges.

2. A gas turbine according to claim 1 further comprising a series of external rollers connected in pairs on a lever pivotal about a fixed axis, said rollers being disposed mainly in the direction of the force exercised on the annular member by the driving pinion.

3. A gas turbine according to claim 2 further comprising two other series of exterior rollers adapted to ensure guiding of the annular member when it is at rest and when the turbine rotates under low load.

4. A gas turbine according to claim 1 wherein each porous disc comprises at its center a hub provided with an axle of rotation the ends of which are supported in fixed bearings.

5. A gas turbine according to claim 1 wherein two thin friction plates are supported on the opposed lateral faces of the discs, said two thin friction plates defining between them the contour of the transverse section of the passageway for admitting air, each of these thin plates being supported against the disc by a metallic bellows which is supported on the fixed part of the stator of the turbine, these plates and bellows defining a closed shape along a fixed sector of the rotating disc, the remainder of the disc being provided on at least one of its two lateral or side faces with a metal joint with a flexible lip which completes the circumference.

6. A gas turbine according to claim 1 characterized in that said sealing means is comprised of metallic friction shoes placed end-to-end to define a closed shape around the passageway for entry air, these shoes being maintained against the faces of the disc by means of springs acting on fixed parts of the stator while in addition the remainder of the surface of the disc is provided on one face at least with sealing shoes placed end-to-end and also urged by springs supported by the stator.

7. A gas turbine according to claim 1 wherein the fore part of the stator of the turbine is comprised of a double thickness skin between which flows the relatively fresh air being admitted.

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