March 19, 1963 F. W. W. MORLEY ETAL 3,082,010

LABYRINTH SEALS

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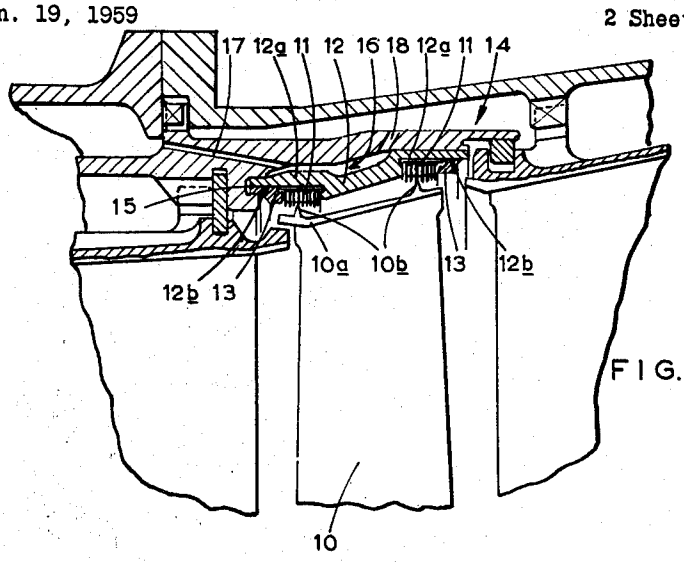

FIG. 1.

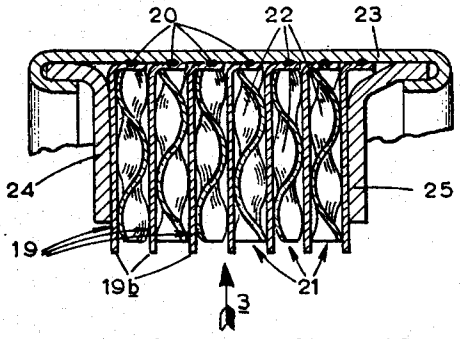

FIG. 2.

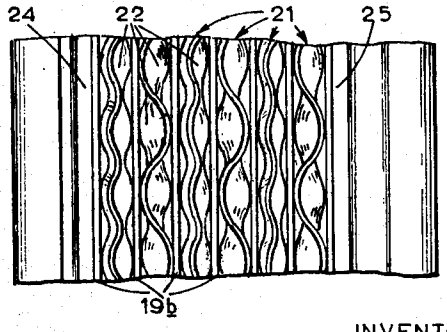

FIG. 3.

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FIG. 4.

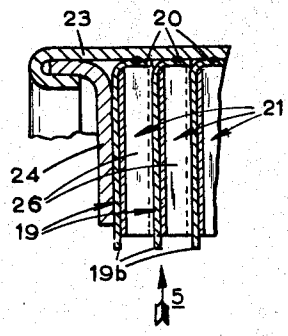


FIG. 6.

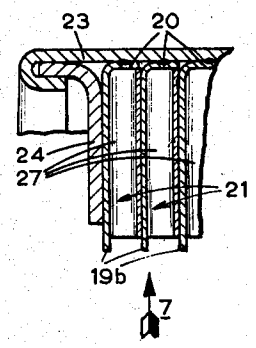


FIG. 5.

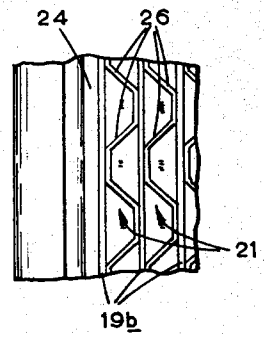


FIG. 7.

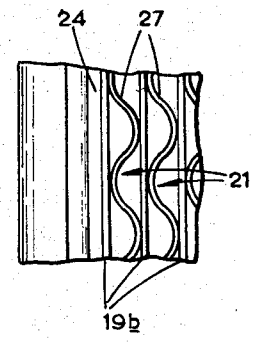
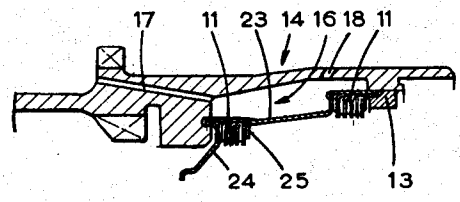


FIG. 8.



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LABYRINTH SEALS

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9 Claims. (Cl. 277—16)

This invention is for improvements in labyrinth seals of the type which are used to prevent leakage of a fluid between a rotating member and an adjacent stationary member.

Such seals frequently consist of a series of annular fins or projections carried by one or both the members the edges of which are in close proximity to the other member or to like fins or one or more projections on the other member.

According to this invention the sealing member is built up of a plurality of metal annuli initially separate or in spiral form, mounted together as a stack of separate annuli or spiral convolutions on one of the members and axially spaced apart at their peripheral edges by means of a separate spacer piece or pieces located between adjacent annuli or convolutions.

Preferably the annuli are carried by the stator only and co-operate with one or more annular projections on the rotating member, and are of softer metal or one having a lower melting point than these latter projections so that if rubbing occurs it will be these metal annuli which will be worn away.

Thus a tip shroud of a turbine blade of an internal combustion turbine engine may carry one or more annular projections each co-operating with a stack of annuli carried by the surrounding structure to form a gas seal between the tip platform and the surrounding structure.

If the annuli are united in a continuous spiral the spacer can also be in the form of a continuous spiral.

Alternatively if separate annuli are used the separate spacer pieces can each comprise an annulus of thin metal and each abut portions of separate sealing annuli, remote from the sealing portions.

The separate spacer pieces can each comprise an annulus of thin metal provided with a plurality of part spherical dimples.

Alternatively the annulus of this metal is provided with a number of flat sided corrugations.

In a further alternative arrangement the annulus of thin metal can be provided with a number of corrugations of sinusoidal form.

Preferably the corrugations extend in a radial direction. The annuli and separate spacer means may be secured together by mechanical means or by brazing, welding, resin bonding or the like. The metal from which the annuli are formed is preferably of the order of 2 to 6 thousandths of an inch in thickness, but for some applications where high temperatures and/or pressures are experienced a thicker metal may be found desirable.

A method of making the annuli comprises forming a continuous strip to the desired cross-section by extruding, drawing or rolling the strip, winding the formed strip continuously round a mandrel so that the wider surfaces of the strip lie in substantially radial planes to form a spiral of annuli. If separate annuli are employed the wound strip is cut axially of the mandrel so as to form the desired plurality of separate annuli.

Some embodiments of this invention will now be described with reference to the accompanying drawings in which:

FIGURE 1 is a section through part of a turbine rotor assembly of a gas turbine engine, incorporating sealing

means constructed in accordance with the present invention;

FIGURE 2 is a section to a larger scale of one construction of the sealing means,

FIGURE 3 is a developed view in the direction of arrow 3 on FIGURE 2;

FIGURE 4 is a part section, again to a larger scale, of a modification of the construction illustrated in FIGURE 2;

FIGURE 5 is a developed view in the direction of arrow 5 on FIGURE 4;

FIGURE 6 is a view corresponding to FIGURE 4 of another modification of the construction illustrated in FIGURE 2;

FIGURE 7 is a developed view in the direction of arrow 7 on FIGURE 6; and

FIGURE 8 is a part section through a turbine stator assembly to the same scale as FIGURE 1.

In FIGURE 1 is shown part of a turbine rotor of a gas turbine engine, the rotor comprising a row of rotor blades **10**, each blade being provided with a shroud portion **10***a* at its radially outer end, said shroud portions **10***a* each having a pair of axially-spaced outwardly-directed circumferentially-extending ribs **10***b*.

Each of the ribs **10***b* co-operates with one of a pair of axially-spaced sealing members **11** secured to a ring **12** which surrounds the shroud portions **10***a* of the rotor blades **10** and is spaced radially therefrom.

The ring **12** is of substantially frusto-conical form and is provided at each end with an axially-extending portion **12***a* having an inwardly facing annular recess **12***b* in which is received the sealing means **11**, said sealing means **11** being retained against axial movement by retaining ring **13** fitted in and welded to the axially-extending portion **12***a*.

Ring **12** is secured to the surrounding stator structure, indicated generally at **14**, by having the left-hand axially-extending portion **12***a* received in an open-ended axially-facing channel **15** formed in the stator structure **14** and by having the right-hand axially-extending portion **12***a* tackwelded along its edge to the stator structure **14**.

A circumferentially-extending chamber **16**, formed between the ring **12** and the stator structure **14**, is supplied with a flow of cooling air through a series of drilled passages **17** provided in the stator structure **14**, said cooling air flowing out of the chamber **16** through a further series of drilled passages **18**.

One form in which the sealing means **11** may be constructed is shown in FIGURES 2 and 3 and comprises a stack of thin metallic annuli **19** each of which has an axially-thin sealing portion **19***b*. Each annulus **19** is formed from thin metal strip of say,

$$\frac{6''}{1000} \text{ thickness}$$

The annuli **19** are each provided with an axially-directed flange **20** at their outer periphery, and adjacent annuli **19** are spaced axially apart by separate spacer means **21**. Each separate spacer **21** comprises an annulus of thin metal which is provided with a plurality of part spherical depressions or dimples **22**, and each spacer **21** is secured to adjacent annuli **19** by means of spot welds provided in the troughs of a number of the part spherical depressions or dimples **22**. Each spacer **21** is of a less radial depth than the annuli **19** so as to leave the sealing portions **19***b* clear of the spacers **21**.

Each annulus **19** is secured to a ring **23** by having its axially directed flange **20** welded or brazed thereto and the assembly of annuli **19** and spacer means **21** is clamped between two L-section rings **24** and **25** which are secured to the ring **23**.

FIGURES 4 and 5 show a modification of the construc-

tion just described with reference to FIGURES 2 and 3. In this modified construction the annuli of thin metal which form the separate spacer means **21** are each provided with a number of radially-extending flat sided corrugations **26**, seen more clearly in FIGURE 5. The flat side of each corrugation **26** being welding to the annulus **19** against which it abuts.

A further modification of the spacer means **21** is illustrated in FIGURES 6 and 7. The separate spacer means **21** are each provided with a number of radially-extending corrugations **27** which are of sinusoidal form and are sucured to adjacent annuli **19** by a weld provided in the trough of each corrugation.

The ring **23** and the two end rings **24** and **25** may form the main structural parts of a pre-fabricated sheet metal ring structure illustrated in FIG. 8.

The pre-fabricated sheet metal structure is retained in the stator structure **14** in a manner similar to that of ring **12** and as described with reference to FIGURE 1.

By having the sealing means **11** constructed of thin metal strips of the order of

$$\frac{6''}{1000} \text{ thickness}$$

the clearance between the sealing portion **19***b* and the rotatable ribs **10***b* of the shroud portion **10***a* is not so critical as with previously known types of seals. If the ribs **10***b* come into rubbing contact with the sealing portions **19***b* during operation, part of the sealing portions **19***b* will melt due to the heat set up by friction and the ribs **10***b* will therefore cut their own path in the sealing portions **19***b*.

It will be appreciated that if the two parts of the sealing means **11** do rub together no damage will be done to the ribs **10***b*. If the annuli **19** become damaged to a degree which entails their replacement, then the tack-welds securing the ring **12** to the stator structure **14** can be machined away and the ring **12** may then be withdrawn from the stator structure **14** so that the damaged stack of annuli **19** can be replaced by a new stack.

In each of the arrangements described the separate annuli could be replaced by a continuous strip of spiral form so that the sealing member is built up of continuous convolutions separated by a continuous, spiral spacer piece.

We claim:

1. In apparatus comprising a rotor member and a stator member, in combination; a labyrinth seal and a confronting rib one within the other, said seal being carried by one of said members and comprising a stack of thin strip metal annuli having circular peripheral edges, a plurality of distance pieces formed separately from and interleaved with said annuli to space the latter axially apart and strengthen them, said distance pieces being of less radial depth than said annuli to leave said peripheral sealing edges clear, and at least one relatively sharp continuous rib carried by the other of said members and arranged in substantial sealing relationship with said annuli, said rib being sized to cut its own path in the annuli if rubbing therebetween occurs.

2. A seal as claimed in claim 1 in which the distance pieces are themselves strip metal annuli each lying between two adjacent sealing annuli and deformed so as to contact and hold apart said sealing annuli.

3. A seal as claimed in claim 1 in which the sealing annuli are of a metal strip of a thickness between 2 and 6 thousandths of an inch.

4. In apparatus comprising a rotor and a stator, in combination; a labyrinth seal carried by the stator and comprising a stack of annuli of thin metal strip having circular peripheral sealing edges, a plurality of distance pieces formed separately from and interleaved with said annuli to space the latter axially apart and strengthen them, said distance pieces being of less radial depth than said annuli to leave said peripheral sealing edges clear, and at least one relatively sharp rib carried by the rotor and arranged in substantial sealing relationship with said annuli, said rib being capable of cutting its own path in the annuli if rubbing therebetween occurs.

5. A seal as claimed in claim 4 in which the sealing annuli are of a softer metal than that of the rib on the rotor.

6. A seal as claimed in claim 4 in which the sealing annuli are of a metal having a lower melting point than that of the rib on the rotor.

7. In apparatus comprising a rotor member and a stator member, in combination; a labyrinth seal carried by one of said members and comprising a channel-shaped ring, a stack of annuli of thin metal strip mounted therein, said annuli having circular peripheral sealing edges, a plurality of independent distance pieces interleaved with said annuli to space the latter axially apart and strengthen them, said distance pieces being of less radial depth than said annuli to leave said peripheral sealing edges clear, and at least one rib carried by the other of said members and arranged in substantial sealing relationship with said annuli, said rib being harder than said annuli for cutting its own path in the annuli if rubbing therebetween occurs.

8. A seal as claimed in claim 7 in which the sealing annuli are bent to form flanges which abut laterally against and are integrally fixed to the bottom of the ring channel.

9. A seal as claimed in claim 7 in which the ring is mounted in the stator and there are means for applying cooling fluid to the base of the ring on the opposite side to the stack of annuli so as to cool the latter.

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