United States Patent

[11] 3,559,725

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[21] Appl. No. **865,330**
[22] Filed **Oct. 10, 1969**
[45] Patented **Feb. 2, 1971**
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[54] **FOIL SEAL FOR ROTATING HEAT EXCHANGERS OF GAS TURBINE ENGINES**
7 Claims, 4 Drawing Figs.

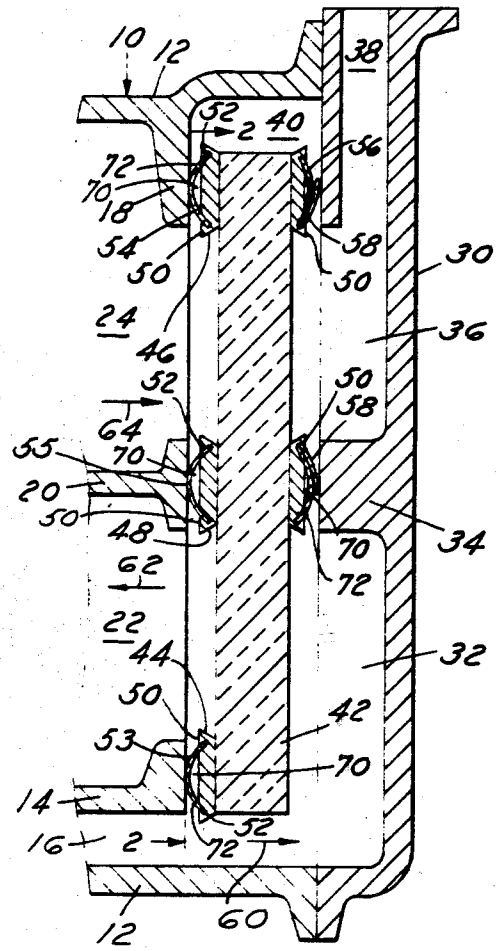
[52] **U.S. Cl.** 165/7, 165/9, 277/81, 277/96
[51] **Int. Cl.** **F28d 19/04**
[50] **Field of Search** 165/9, 7; 277/81, 96

[56] **References Cited**
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3,311,162	3/1967	Chapman et al.	165/9
3,401,740	9/1968	Trudeau	165/9X

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ABSTRACT: A flexible metal foil has its longitudinal edges inserted into slots cut into a shoe rubbing on a rotating regenerator core. The intermediate portion of the foil bows outwardly away from the shoe and bears against the engine housing. Gas pressure is admitted to the space between the foil and the shoe to maintain the foil in contact with the housing and the walls of the slots. The seal readily absorbs thermally induced dimensional changes between the core, shoe, foil and housing.



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FIG. 1

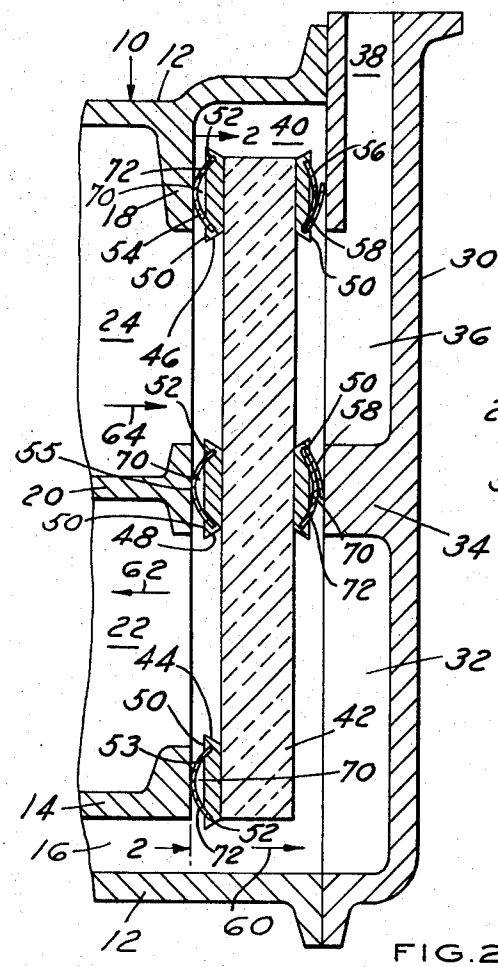


FIG. 3

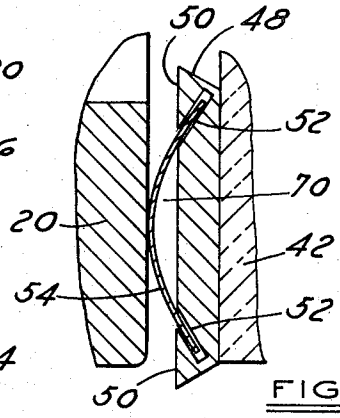


FIG. 4

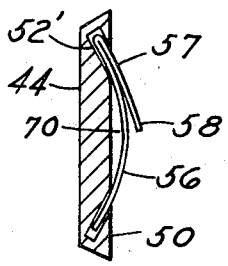
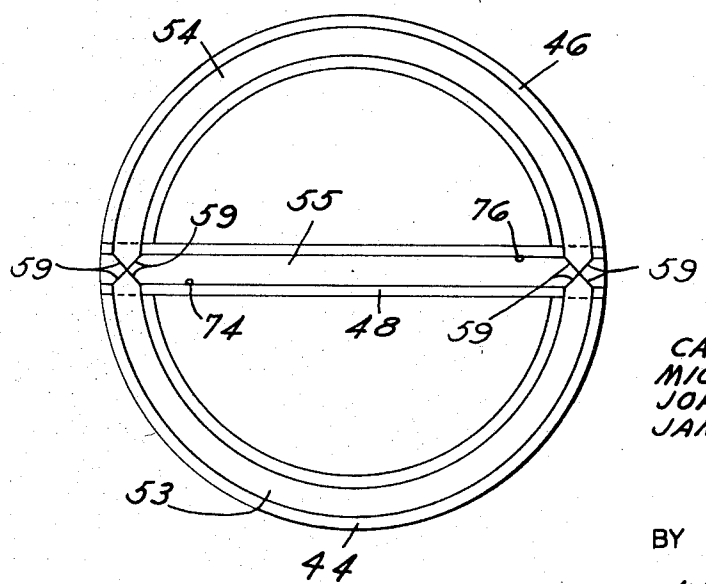


FIG. 2



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FOIL SEAL FOR ROTATING HEAT EXCHANGERS OF GAS TURBINE ENGINES

SUMMARY OF THE INVENTION

Regenerators for gas turbine engines must operate throughout a temperature ranging from room temperature to temperatures exceeding 1,400° F. Dimensional changes produced by differences in thermal expansion throughout this range must be absorbed by the regenerator seals while placing minimum loads on the rotating regenerator. In the past a metal foil has been welded to the shoe sliding against the regenerator so the outer edge of the foil bears against the engine housing. Gas pressure from one of the gas passages is applied to one side of the foil to maintain its outer edge in sealing contact with the housing. Welding such foils to the shoe, however, reduces the flexibility of the foils to the point where thermal distortion of the foil relative to the shoe significantly decreases the sealing effectiveness of the assembly.

This invention provides a seal arrangement that absorbs the effects of differences in thermal expansion between the components of the seal assembly, the housing, and the regenerator core with minimal component and assembly costs. The seal is useful primarily in a gas turbine engine having a regenerator rotating in a housing with sectors of the regenerator being subjected to gas streams of different pressures. A shoe is positioned between the housing and the regenerator at the area to be sealed with one surface of the shoe sliding on the regenerator and the other surface facing the engine housing. The shoe is nonrotatable with respect to the housing and the surface of the shoe facing the housing has a pair of laterally spaced longitudinal slots therein. A resilient foil having a width greater than the lateral distance between the slots has its longitudinal edges inserted into the slots so the intermediate portion of the foil bows resiliently away from the surface of the shoe and into contact with the housing. Foil resiliency maintains the foil in sealing contact with the housing and the shoe and absorbs dimensional changes. The longitudinal freedom of the foil in the slots minimizes foil distortion and insures highly effective sealing throughout the temperature range.

A space preferably is maintained between each foil edge and the bottom of its slot and the foil fits loosely in the slots to permit relative movement toward and away from the bottom of the slots. This movement assists the resiliency of the foil in maintaining the foil in contact with the shoe and the housing despite dimensional changes caused by thermal expansion differences. Gas pressure from the engine compressor can be transmitted into the space defined by the foil and the surface of the shoe where the gas pressure assists in maintaining the intermediate portion of the foil in contact with the housing. The excellent flexibility of the seal assembly also minimizes load variations between the shoe and the rotating regenerator.

The slots preferably extend into the shoe at diverging angles. One longitudinal edge of the foil can be rolled back over itself and the rolled edge inserted into one slot with the projecting edge of the foil terminating against the housing. The projecting edge slopes toward the gas stream having the higher pressure so the pressure differential forces the edge into contact with the housing. This arrangement improves sealing of high pressure differentials and retains the ability to absorb dimensional changes without distorting.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a partial sectional view through a gas turbine engine showing a regenerator installation utilizing the foil sealing arrangement of this invention both on a diameter of the regenerator and at the regenerator periphery. FIG. 2 is a plan view of the seal assembly taken along line 2–2 of FIG. 1. FIG. 3 is an enlarged cross-sectional view of a shoe and foil assembly showing the loose fit of the foil in the shoe. FIG. 4 is an enlarged cross-sectional view showing a foil having one longitudinal edge rolled back over itself with the rolled edge inserted into one of the slots.

DETAILED DESCRIPTION

Referring to FIG. 1, the housing indicated generally by the numeral 10 of a gas turbine engine comprises a substantially oval shaped outer wall 12. The major diameter of outer wall 12 extends vertically in the figure. Spaced a short distance from the lower part of outer wall 12 is a semicircular inner wall 14 that terminates a short distance from the end of outer wall 12. The edges of inner wall 14 intersect outer wall 12 and form an inlet passage 16 therewith as shown more clearly in U.S. Pat. No. 3,401,740.

A ledge 18 is located a short distance from the end of the upper part of outer wall 12 and projects inwardly therefrom. A diametrical wall 20 passes through housing 10 equally spaced between inner wall 14 and the inner lip of ledge 18, thereby dividing the remaining interior of the housing 10 into two semicircular passages 22 and 24. The end of wall 20 lies in the plane of the top of wall 14 and ledge 18.

A cap 30 is fastened to housing 10 by conventional means (not shown) and comprises a chamber 32 communicating with passage 16 and extending over passage 22. A diametrical wall 34 formed on the plane of wall 20 separates chamber 32 from a chamber 36 formed over passage 24. Chamber 36 communicates with an exit passage 38. A ceramic or metal regenerator 42 is mounted rotatably on a spindle (not shown) attached to wall 20 or wall 34 and is driven by appropriate means such as gearing (not shown) attached to its periphery.

Located between regenerator 42 and wall 14 is a C-shaped shoe 44. Shoe 44 surrounds the semicircular periphery of passage 22 and is restrained from rotation by ears (not shown) that engage housing 10. A similar C-shaped shoe 46 is located between regenerator 42 and ledge 18 where it surrounds the semicircular periphery of passage 24. Positioned between regenerator 42 and the end of wall 20 is a straight crossarm shoe 48. Crossarm shoe 48 fits between the open ends of C-shaped shoes 44 and 46 (see FIG. 2). A D-shaped shoe 50 is positioned on the other side of regenerator 42 where it surrounds the opening to chamber 36. Shoes 46, 48 and 50 also are restrained from rotation with regenerator 42 by any appropriate construction.

Each of the shoes has one surface sliding against regenerator 42 and the other surface 50 spaced a short distance from housing 10 or cap 30. (For purposes of the this application, cap 30 is considered to be part of the engine housing.) A pair of longitudinal slots 52 are cut into surface 50 of each shoe as shown more clearly in FIG. 3. Slots 52 preferably are cut into the shoe at diverging angles from each other; in a typical installation each slot makes an angle of about 20° with surface 50.

The longitudinal edges of metal foils 53, 54 and 55 are inserted into slots 52 of respective shoes 44, 46 and 48 so that the intermediate portion of each foil bears against regenerator housing 10 or cap 30. Foils 53, 54 and 55 preferably are made of a spring tempered stainless steel and are sized so that the longitudinal edges fit loosely in slots 52. Each longitudinal edge also is spaced a short distance from the bottom of its slot as shown in FIG. 3.

For shoe 50, a foil of similar material is folded back against itself as at 57 to form a projecting end 58 (see FIG. 4). The folded portion is inserted into an enlarged slot 52′ in shoe 50 and the other edge is inserted into slot 52 of the shoe. Projecting end 58 extends beyond the intermediate portion of foil 56 and the seal assembly is installed in the engine around the opening to chamber 36 with the projecting edge sloping outward and bearing against cap 30 approximately adjacent the highest part of the bow in the foil.

As shown in FIG, 2, foil 55 of the crossarm seal extends radially beyond the intersection points of the foil with foils 53 and 54. The ends of foils 53 and 54 are scalloped as at 59 to fit as tightly as possible against the sides of foil 55. This arrangement permits linear expansion of the crossarm foil and shoe, which are subjected to the highest temperatures. Where such expansion is not a problem as in engines operating at lower temperatures, for example, foil seals 53 and 54 can be com-

bined into a single integral foil seal that circles the entire periphery, and scalloped ends formed on foil **55** fit against the inner wall of the integral foil.

During engine operation, relatively cool air from the engine compressor passes through passage **16** in the direction of arrow **60** into chamber **32**. The compressed air from passage **16** contacts the entire periphery of regenerator via chamber **40** for cooling purposes. Air from chamber **32** passes through the lower sector of regenerator **42** and through passage **22** in the direction of arrow **62**. Passage **22** conducts the air to the engine combustion chamber and thence to the turbine wheels (not shown).

Relatively hot combustion gases from the engine turbine wheels pass through passage **24** in the direction of arrow **64**, through the upper sector or regenerator **42** and through chamber **36** to exit **38**. The rotating regenerator transfers heat from the gases leaving passage **24** to the gases entering passage **22** in the conventional manner. Foils **54** flex and move in and out of slots **52** to absorb dimensional changes caused by thermal expansion differences between the housing, foil, shoes, and regenerator. Projecting edge **58** assists in maintaining proper sealing between the substantially atmospheric pressure in chamber **36** and the much higher pressure in chamber **32** since the pressure differential between chambers **32** and **36** acts on projecting end **58** to urge end **58** into contact with cap **30** and also urge the folded portion **57** into contact with the walls of slot **52'**.

Compressed air from passage **16** can be applied to the space **70** between the foils and the shoes to urge the foils into contact with the engine housing. Such air assists in maintaining sealing contact between the foil edges and the walls of the slots also. The air can be admitted into space **70** by small holes **72** in the peripheral foils and by similar holes in the sides of the crossarm foil. Cooling of the crossarm foil can be achieved by small holes **74** on one end communicating with passage **22** and similar holes **76** at the other end communicating with passage **24**. The relatively cool air from passage **22** then flows through space **70** to remove heat from the foil and shoe and exits into passage **24**. A similar arrangement can be used on the peripheral seals if necessary.

Thus this invention provides a seal for a gas turbine regenerator that eliminates distortion caused by differences in thermal expansion between the seal components, the engine housing, and the regenerator. The seal requires a minimum of components and none of the components has any highly critical manufacturing tolerances. Assembly of the seal and its installation into the engine are relatively straightforward. If desired, the double inserted foil can be used only on the crossarm seals where the highest amount of thermal expansion and distortion are encountered, and conventional welded seals can be used on the peripheral shoes.

We claim:

1. In a gas turbine engine having a regenerator rotating in a housing with sectors of said regenerator being subjected to gas streams of differing pressures, a sealing means for said regenerator comprising:

a shoe positioned between said housing and said regenerator with one surface of said shoe sliding against said regenerator and the other surface facing said housing, said shoe being nonrotatable with respect to said housing, the surface of said shoe facing said housing having a pair of laterally spaced longitudinal slots therein; and

flexible foil means having its longitudinal portions inserted into said slots so the intermediate portion of said foil means bows resiliently away from the surface of said shoe, said intermediate portion of said foil means contacting said housing to provide a seal between said housing and said regenerator, said foil means absorbing changes in the spacing between the housing and the shoe.

2. The engine of claim **1** in which the slots extend into the shoe at diverging angles and the longitudinal portions of said foil means fit loosely in said slots.

3. The engine of claim **2** comprising means for transmitting the gas pressure of one of said sectors into the space defined by the foil means and the surface of the shoe, said gas pressure assisting in maintaining the intermediate portion of the foil means in contact with the housing.

4. The engine of claim **3** comprising openings in said seals for flowing relatively cool gas from a gas stream of higher pressure through the space defined by the foil means and the surface of a shoe to a gas stream of lower pressure, said gas removing heat from the foil and the shoe to reduce the operating temperature thereof.

5. The engine of claim **4** in which one longitudinal edge of said foil means is folded back over itself to project outwardly, said folded edge being inserted into an enlarged slot in said shoe, the end of said folded edge bearing against said housing approximately adjacent the highest point of the bow of the foil means.

6. The engine of claim **1** comprising openings in said seals for flowing relatively cool gas from a gas stream of higher pressure through the space defined by the foil means and the surface of a shoe to a gas stream of lower pressure, said gas removing heat from the foil and the shoe to reduce the operating temperature thereof.

7. The engine of claim **1** in which one longitudinal edge of said foil means is folded back over itself to project outwardly, said folded edge being inserted into an enlarged slot in said shoe, the end of said folded edge bearing against said housing approximately adjacent the highest point of the bow of the foil means.