United States Patent [19]

Penny

[11] **3,875,993**

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[54] **ROTARY REGENERATIVE HEAT EXCHANGER**

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[21] Appl. No.: **320,650**

[30] **Foreign Application Priority Data**

Jan. 8, 1972 United Kingdom 962/72

[52] **U.S. Cl.** **165/9**; 277/83; 277/96; 277/192

[51] **Int. Cl.** **F28d 19/00**

[58] **Field of Search** 165/9; 277/96, 83, 192

[56] **References Cited**

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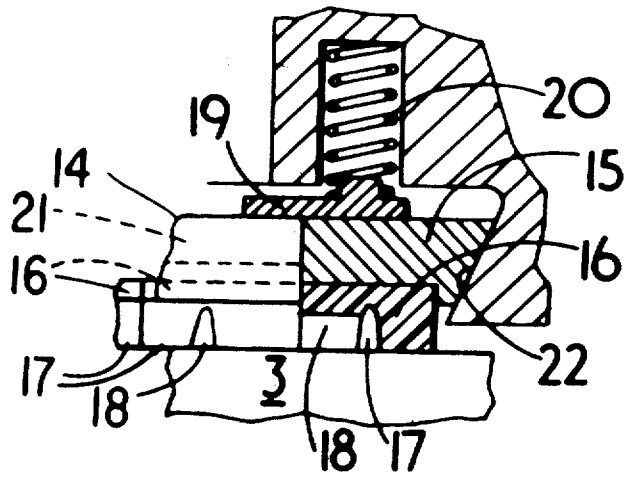
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Primary Examiner—Albert W. Davis, Jr.
Attorney, Agent, or Firm—Hauke, Gifford, Patalidis & Dumont

[57] **ABSTRACT**

A rotary regenerative heat exchanger for a gas turbine engine and comprising a disc-shaped matrix mounted for rotation about its longitudinal axis and non-rotatable seals engaging end faces of the matrix and defining separate flow-paths through the matrix for counterflow streams of compressed air and turbine exhaust gases. The seals are so arranged that the forces due to the pressure of the air and gas streams acting on the matrix are in substantial axial balance and the seal engaging the colder end of the matrix is biased continuously into light rubbing engagement with the adjacent end face of the matrix by a spring and also effects axial movement of the matrix into light rubbing engagement with the corresponding hotter end seal which is not movable axially.

4 Claims, 9 Drawing Figures



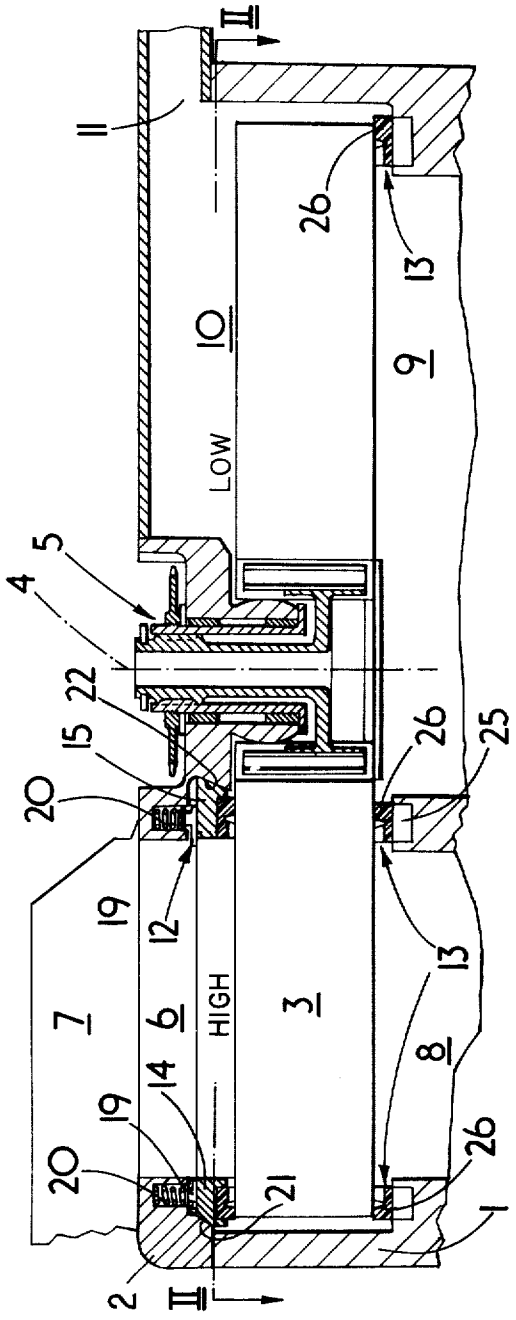

II
II
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II

FIG. 1

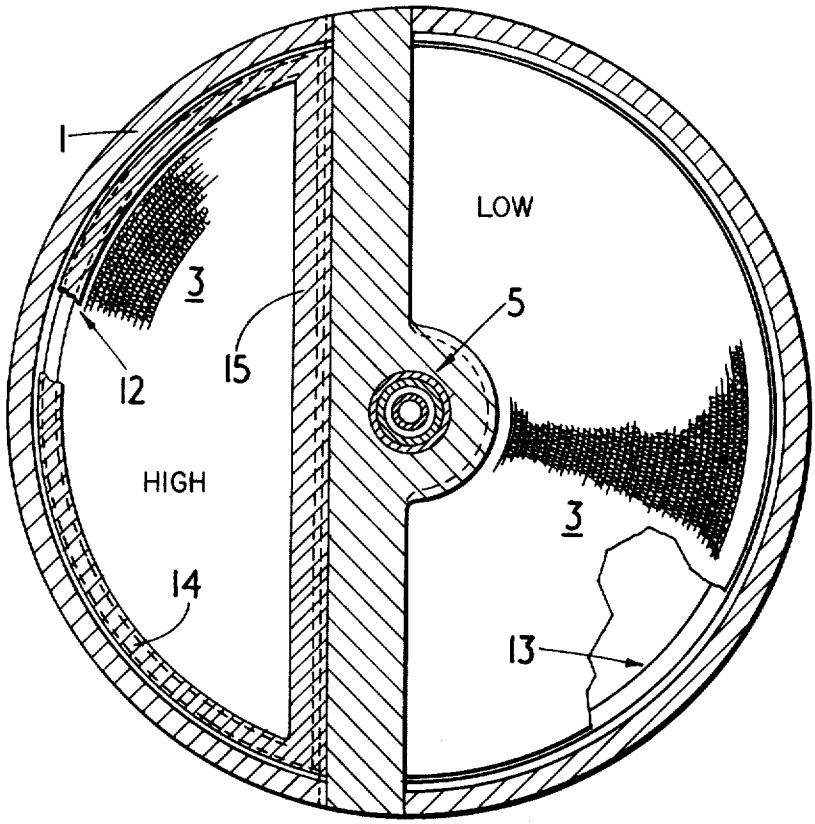


FIG. 2

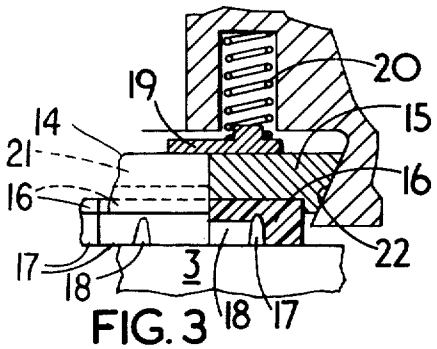


FIG. 3

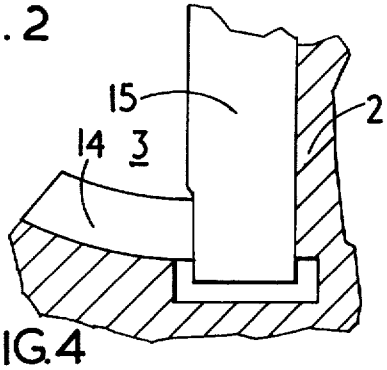


FIG. 4

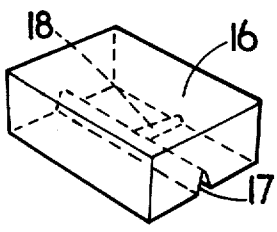


FIG. 6

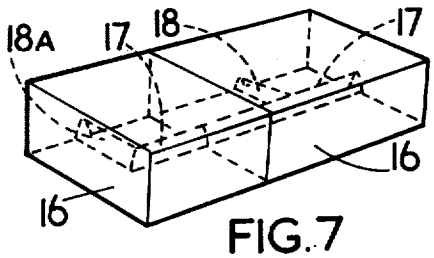


FIG. 7

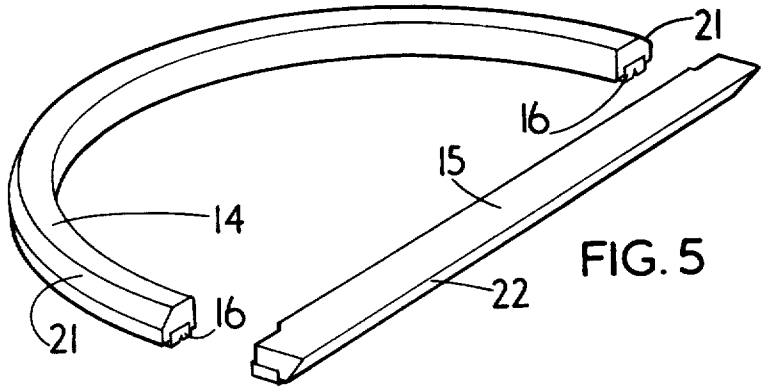


FIG. 5

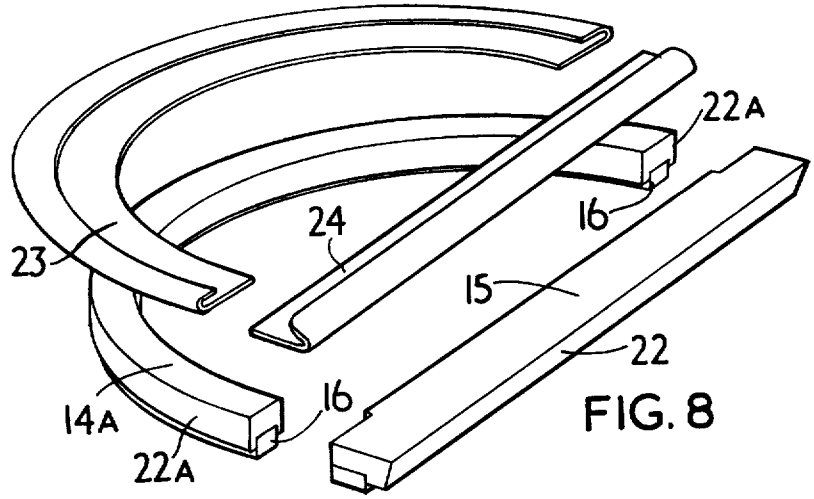


FIG. 8

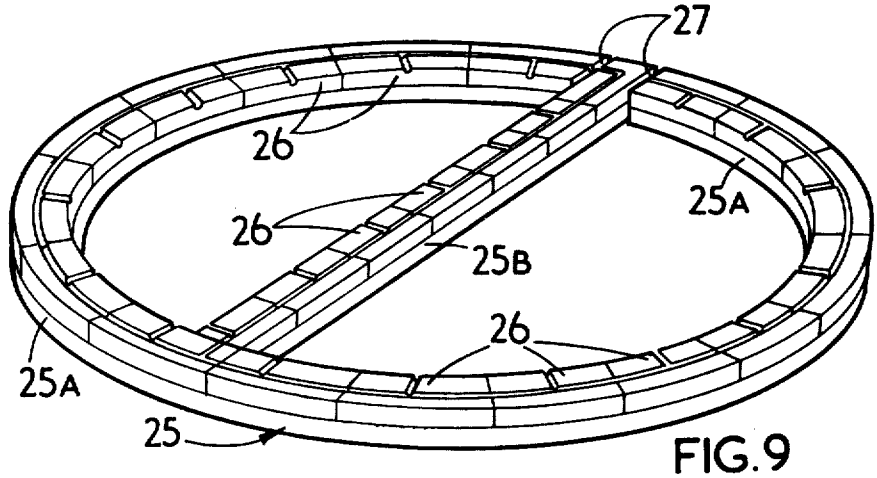


FIG. 9

ROTARY REGENERATIVE HEAT EXCHANGER

BACKGROUND OF THE INVENTION

I. Field of the Invention

The invention relates to a rotary regenerative heat exchanger of the kind comprising a housing containing a disc-shaped matrix rotatable about its longitudinal axis and having a plurality of heat exchange passages extending therethrough between opposite end faces of the matrix and seals defining areas of the end faces through which fluids between which heat exchange is to occur are to be passed in separate streams.

II. Prior Art

A heat exchanger of this kind may be used with a gas turbine engine for effecting heat exchange between hot exhaust gases from a turbine of the engine and compressed air delivered by a compressor of the engine to a combustion chamber for supplying a turbine with hot gases. To provide effective sealing, the seals have to be maintained in rubbing contact with the respective end faces of the matrix despite wearing of the seals or the end faces of the matrix. Hitherto the seals have usually been in the form of internally-pressurised bellows in order to maintain them in sealing engagement with the matrix. Such seals are costly to manufacture.

SUMMARY OF THE PRESENT INVENTION

According to the present invention, a rotary regenerative heat exchanger for use with a gas turbine engine comprises a disc-shaped matrix, mounted for rotation about its longitudinal axis in a housing and having a plurality of heat exchange passages extending therethrough between opposite end faces of the matrix, and non-rotatable seals engaging the end faces of the matrix and defining separate flow-paths through the matrix for counterflow streams of compressed air discharged by a compressor of the engine and exhaust gases discharged from a turbine of the engine, whereby the end face of the matrix which in use receives compressed air from the compressor and from which cooled exhaust gases are discharged is colder in use than the opposite end face of the matrix from which heated compressed air is discharged and which receives exhaust gases from the turbine, the seals engaging the end faces of the matrix being so arranged that the forces due to the pressure of the air and gas streams acting on the matrix are in substantial balance in the axial direction of the matrix and being substantially non-resilient in directions parallel with the axis of the matrix, and the seal engaging the colder end of the matrix and defining the flow thereto of compressed air being biased continuously into light rubbing engagement with the adjacent end face of the matrix by resilient biasing means which also effects through the said colder end seal axial movement of the matrix into light rubbing engagement with the corresponding hotter end seal which is held from axial movement in the matrix housing.

Preferably, the housing has compressed air inlet and outlet ports and an exhaust gas inlet port communicating directly with respective seals, and the cooled exhaust gases leaving the matrix pass into the remainder of the interior of the housing which communicates with an exhaust duct, whereby the peripheral surface of the matrix and the portions of the end faces thereof outside the seals are subjected to the pressure of the exhaust gases. This has the result that the whole of the matrix except the part thereof in registration with the inlet and outlet seals defining the compressed air path is at substantially atmospheric pressure and thereby it is easy to maintain the forces acting on the matrix and the axial direction in substantial balance, except for the axial thrust applied by the aforesaid biasing means, which may conveniently be one or more springs.

BRIEF DESCRIPTION OF THE DRAWINGS

By way of example, a rotary regenerative heat exchanger in accordance with the invention for a gas turbine engine is now described with reference to the accompanying drawings, in which:

FIG. 1 is an axial section through the heat exchanger;

FIG. 2 is a section on the line II—II in FIG. 1;

FIG. 3 is a portion of FIG. 1 to a larger scale and showing one of the seals;

FIG. 4 is a plan view to a slightly larger scale of part of the seal shown in FIG. 3;

FIG. 5 is an exploded perspective view of the seal shown in FIGS. 3 and 4;

FIGS. 6 and 7 are perspective views of bearing blocks used in the seal shown in FIG. 5;

FIG. 8 is an exploded perspective view similar to FIG. 5 of an alternative seal, and

FIG. 9 is a perspective view to a larger scale of the other seal shown in FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2, the heat exchanger comprises abutting housing parts 1 and 2 defining a chamber containing a matrix in the form of a disc-like rotor 3 having axially extending heat exchange passages therein extending between opposed end faces of the matrix. The matrix is mounted for rotation about a central axis 4 by a shaft shown generally by arrow 5, the matrix being supported in a floating bearing. The housing part 2 defines an inlet port 6 connected by a duct 7 to the outlet of the compressor of the engine and the housing part 1 defines a port 8 opposite the port 6 and leading to the combustion chamber (not shown) of the engine. Hot gases from the combustion chamber are expanded through a turbine or turbines of the engine and are returned to the housing through a port 9 in the housing part 1. The hot gases leave the housing through a port 10 in the housing part 2 and an exhaust duct 11 formed in the housing part 2. The compressed air and hot exhaust gases pass through the heat exchange passages of the matrix 3 in counterflow in separate streams, the hot gases giving up heat to the matrix which therefore heats the compressed air. Thus the end face adjacent the ports 6 and 10 is colder than the end face adjacent the ports 8 and 9. A substantially D-shaped seal shown generally by arrows 12 and shown in detail in FIGS. 3 to 5 engages the colder end face of the matrix and contains an area of the colder end face through which the compressed air flows to the matrix 3. A seal shown generally by arrows 13 and shown in more detail in FIG. 9 defines two substantially D-shaped separate areas side-by-side of the hotter end face through which compressed air flows through the port 8 and hot expanded gases flow into the housing through port 9. Thus except for the portions of the matrix in registration with the ports 6 and 8, the whole of the remainder of the end faces and the interior of the matrix and the peripheral surface thereof is subjected to a fluid pressure of substantially atmospheric pres-

sure. This is contrary to rotary regenerative heat exchangers previously known and each having a disc-like matrix in which the whole of the matrix except for the portion in registration with the hot gas ports is at substantially compressor delivery pressure. One advantage of this difference is that in the present heat exchanger the seals need not be in the form of internally, pressurized bellows. The seals instead conveniently comprise backing members carrying or engaged by a plurality of sealing blocks arranged end-to-end along the peripheral length of the backing members. Such a seal forms the subject of in my co-pending application Ser. No. 317,823 and is described more fully therein. Each backing member may be made, for example, of mild steel and the sealing blocks may be blocks of sintered material, such as nickel oxide or may be mild steel blocks coated with a deposit of sintered material, for example by using a flame gun. The backing members may also be coated with a layer of sintered material. Referring to FIGS. **1** to **7**, the colder end seal **12** comprises a substantially C-shaped backing member **14** which is abutted by a straight bar-like backing member **15** to form the D-shaped seal which encloses the portion of the upper end face of the matrix **3**. In operation there is a considerably higher pressure within the seal than outside it. The backing members **14** and **15** have on their faces adjacent the end face of the matrix a longitudinally-extending recess in which the aforesaid sealing blocks **16** are located. Each of the sealing blocks has in its sealing face a longitudinally-extending groove **17** communicating to one side thereof with a transverse groove **18**. When the sealing blocks **16** are assembled end-to-end in the longitudinal recesses in the backing members **14** and **15**, the longitudinally-extending grooves **17** abut end-to-end and thus form a continuous groove extending longitudinally of each portion of the seal. The transverse grooves **18A** of the blocks **16** at the ends of the backing member **15** communicate with the longitudinal grooves **17** of the end blocks of the backing member **14** when the backing member **15** is abutted against the ends of the backing member **14**, thereby forming a continuous groove extending around the whole of the seal. The transverse grooves **18** extend inwardly of the seal and thus the compressed air within the seal is applied all around the seal as far laterally thereof as the longitudinal grooves **17**. Therefore only that portion of the bearing face, adjacent the end face of the matrix of each sealing block that is laterally outside the grooves **17** and **18A** acts as a sealing surface. Thus only the laterally-outer portion of the bearing face forms an effective sealing surface. This improves sealing efficiency because there is a greater likelihood of only a portion of the bearing surface forming a perfect of nearly perfect seal with the abutting end surface of the matrix. Furthermore the lateral position of the longitudinal grooves in the sealing block is so selected as to give an effective sealing area necessary to ensure that the opposed axially-directed forces due to the compressed air and hot gas pressures are substantially cancelled.

It will be appreciated that due to the elimination of axial fluid loading on the matrix, the amount of water between the upper cold end seal and the matrix is small but some wear does occur and to compensate automatically for this the backing members **14** and **15** of the seal **12** are engaged by pads **19** urged downwardly by springs **20** spaced apart peripherally of the seal, only two of the springs and pads being shown in FIG. **1**. As the seal **12** is urged towards the matrix by the springs **20** and the pads **19** as wear occurs, provision must be made to hold the backing member **15** in abutment with the backing member **14** to ensure complete sealing. This is performed by forming oblique peripherally outer faces all around the backing members as shown at **21** and **22**. These oblique faces slide against complementary faces formed on the housing part **2**. The angle of inclination of the oblique faces is such that as wear does occur, the spring forces will cause the backing members to slide as one along the inclined faces of the housing part **2** and thereby maintain a constant peripheral length for the seal and also hold the member **15** in abutting engagement with the member **14**. To avoid leakage around the ends of the backing member **15** sealing pads or spring strips such as sealing members **23** and **24** described hereinafter with reference to FIG. **7** must overlie the region of abutment between the members.

Instead of providing both the backing members **14** and **15** with oblique faces **21**, only one of the members need have an oblique face. For example the outer peripheral face of the C-shaped backing member **14** may be substantially parallel to the axis of rotation **4** of the matrix; but spring strips would have to be provided to overlap the backing members to prevent leakage past them. FIG. **8** shows an alternative cold end seal in which the C-shaped backing member **14A** has a peripheral surface **22A** parallel with the axis of rotation of the matrix and the bar-like backing member **15** is the same as in FIG. **5** and has an oblique outer peripheral face **22** to maintain the backing member **15** in abutment with the backing member **14A**. The two backing members **14A** and **15** are on assembly of the heat exchanger covered by bent spring strip sealing members **23, 24** of substantially the same plan shape as the backing members **14A** and **15** respectively and engaged by the springs **20** and pads **19** if direct contact between the springs and the sealing members **23** and **24** is not possible. The end portion of the sealing members **23** and **24** are overlapped to prevent leakage around the sealing members at these two places.

The lower or hot end seal **13** is shown in FIG. **9** and comprises a mild steel backing member **25** and grooved sealing blocks **26** facing upwardly from the backing member **25** for engagement with the lower end face of the matrix. The sealing blocks are similar to the blocks **16** shown in FIG. **6**. The seal **13** defines a D-shaped passage, for compressed air to be led from the matrix to a combustion chamber, in substantial axial alignment with the seal **12** and also a D-shaped passage for leading expanded gases from the turbine or turbines of the gas turbine engine through the matrix to the exhaust port **10**. The backing member **25** is split at positions **27** to permit the curved or C-shaped parts **25A** and a transverse bar-like part **25B** to expand and contract individually and thereby to avoid distortion of the seal. Alternatively two separate D-shaped seals similar to those shown in FIGS. **5** or **8** may be employed each seal having its own bar-like backing member or a backing member common to both seals. The backing member **25** of the seal **13** or the backing members of each seal, where two separate seals are employed, are located in grooves in the housing part **1** and as the backing members are non-circular, rotation of the seal **13** by the matrix will not occur. To prevent leakage at the

junction or junctions between the bar-like part and the C-shaped parts of the backing members additional sealing pads or strips may be required between the locating groove in the housing part **1** and the backing members. The sealing blocks **26** are grooved similarly to the sealing blocks **16** of FIGS. **6** and **7** to provide a continuous peripherally-extending groove around the seal to define the lateral extent of leakage of compressed air past part of the seal from the region **8** and of exhaust gas from the region **9** and hence to determine the effective flow areas of the matrix defined by the seal **13.**

The seal **13** is not movable axially in the housing. The matrix **3** rests on the seal but is permitted axial movement by virtue of the driving shaft arrangement. The seal **12** is held by the force of the springs **20** against the adjacent end face of the matrix **3.** As the axially directed forces acting on the matrix **3** due to the air and gas pressures are substantially eliminated, the only axial force necessary to maintain sealing by the seals **12** and **13** is applied by the springs **20.** By suitable dimensioning of the sealing blocks **16** and **26** and the grooves **17** and **18A** therein, the wear between the seal **13** and the matrix may be substantially eliminated and the wear between the seal **12** and the matrix can be reduced to a small amount. The positioning of the longitudinal grooves **17** in the sealing blocks **16** and **26** laterally thereof determines the effective area of the matrix end faces on which the air pressures within the regions **6** and **8** are applied and the effective area of the matrix end faces within the region **9** and outside the regions **6,** 8 and **9** on which the gas pressures within the region **9** and within the region **10** and the whole of the interior of the housing, except for the regions **6, 8** and **9** are applied. Hence the resultant axial force on the matrix due to the air and gas pressures can be eliminated.

What I claim as my invention and desire to secure by Letters Patent of the United States is:

1. A rotary regenerative heat exchanger for a gas turbine engine having a compressor and a turbine, the heat exchanger comprising a housing having air inlet and outlet ports for a stream of compressed air discharged by said compressor and exhaust gas inlet and outlet ports for a stream of exhaust gases discharged from said turbine, a disc-shaped matrix mounted for rotation about its longitudinal axis in the housing and having a plurality of heat exchange passages extending therethrough between opposite end faces of the matrix and non-rotatable seals engaging the end faces of the matrix and defining separate flow-paths through the matrix for said streams of compressed air and exhaust gases in counterflow directions, said seal defining the flow-path for said stream of compressed air into the matrix being of substantially 'D'-shape in plan and including an arcuate portion and a bar-like portion bridging the ends of the arcuate portion and thereby completing the 'D'-shape of the seal, the longitudinal edge of the bar-like portion of said seal being inclined inwardly of said seal in the direction towards the sealing face of said seal and engaging a complementarily inclined face of the housing, the air inlet and outlet ports and the gas inlet port communicating directly with said seals and the cooled exhaust gas leaving the matrix passing into the remainder of the interior of the housing which communicates with the gas outlet port, said seals enclosing effective sealing areas to which the respective pressures of said air and gas streams are applied, the resultant algebraic sum of the products of said sealing areas and said air and gas pressures being substantially zero in the axial direction, the heat exchanger also including resilient biasing means by which said seal defining the flow-path into the matrix for said stream of compressed air is biased continuously into light rubbing engagement with the adjacent end face of the matrix, said resilient biasing means also effecting through said seal, defining the flow-path for said stream of compressed air into the matrix, axial movement of the matrix into light rubbing engagement with said seal at the opposite end face of said matrix which is held from axial movement in the matrix housing, the resilient biasing means holding the two portions of said seal defining the flow-path for said stream of compressed air into the matrix in continuous abutment, in use, despite bodily movement of the whole seal in the axial direction of the matrix, whereby as said seal defining the flow-path for said stream of compressed air into the matrix is moved bodily with the matrix in the axial direction thereof under the action of said resilient biasing means, said bar-like portion is maintained in abutment with said arcuate portion by wedging action between the inclined longitudinal edge of said bar-like portion and said complementarily inclined face of the housing.

2. A heat exchanger as claimed in claim **1** in which the outer peripheral edge of said arcuate portion of the seal defining the flow-path for said stream of compressed air into the matrix is inclined inwardly of the seal in the direction away from the sealing face of the seal and is engageable with a complementarily-shaped face of the housing, the angle of inclination of the outer peripheral edge to the longitudinal axis of the arcuate portion of the seal being substantially the same as the angle of inclination of the inclined longitudinal edge of said bar-like portion to a line parallel to the axis of rotation of the matrix.

3. A heat exchanger as claimed in claim **1** in which each seal is formed with a longitudinal groove in the face thereof engaging the adjacent end face of the matrix and with a leakage path communicating with said longitudinal groove and extending inwardly of the seal in one direction only to the flow-path defined inside the seal, whereby fluid will leak between the seal and the end surface of the matrix which it engages to one side only of said longitudinal groove providing an effective sealing surface.

4. A heat exchanger as claimed in claim **3** in which the seal comprises a backing member extending longitudinally of the seal and a plurality of separate sealing blocks arranged end-to-end in said backing member, each said sealing block having a longitudinally-extending groove therein which co-operates with a similar groove in each adjacent said sealing block to form said longitudinal groove of the seal.

* * * * *