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SEAL MEANS FOR A ROTARY HEAT EXCHANGER

Filed June 24, 1959

2 Sheets-Sheet 1

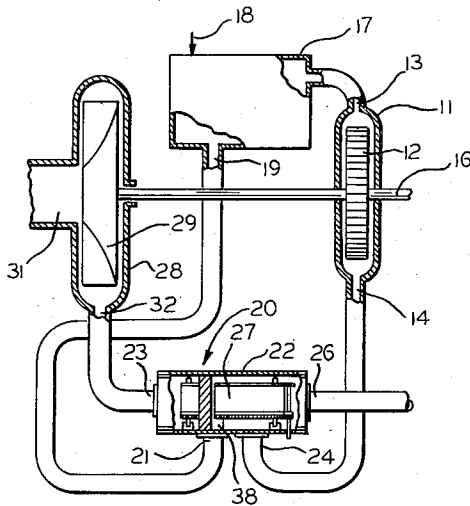


FIG. 1

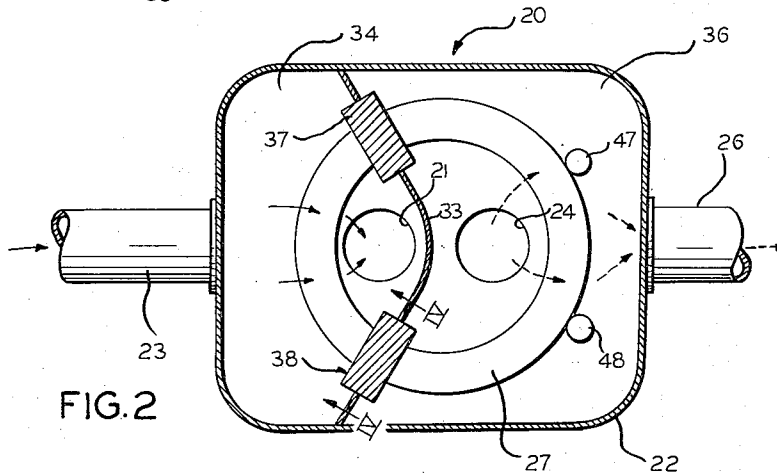


FIG. 2

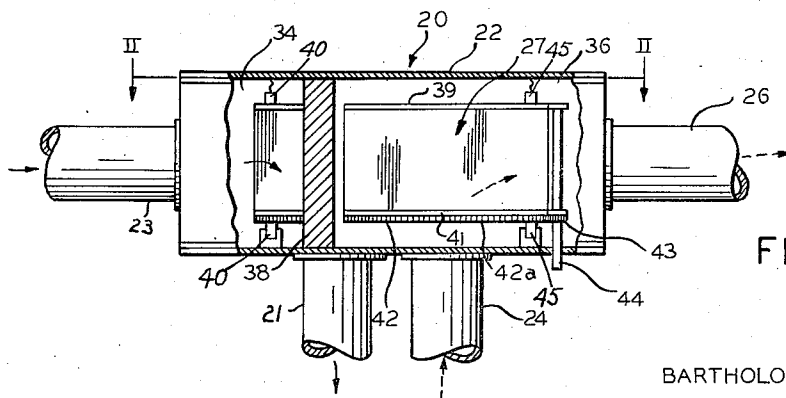


FIG. 3

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2 Sheets-Sheet 2

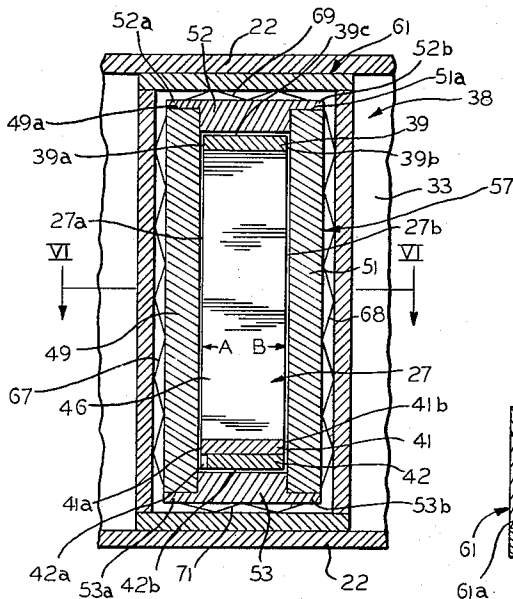


FIG. 4

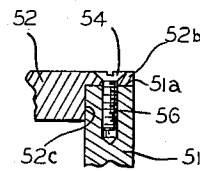


FIG. 5

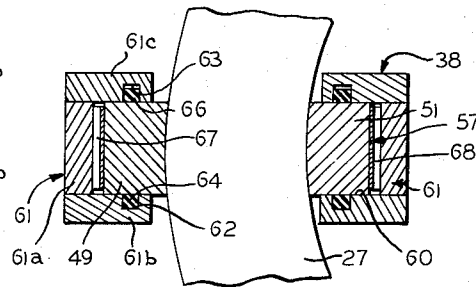


FIG. 6

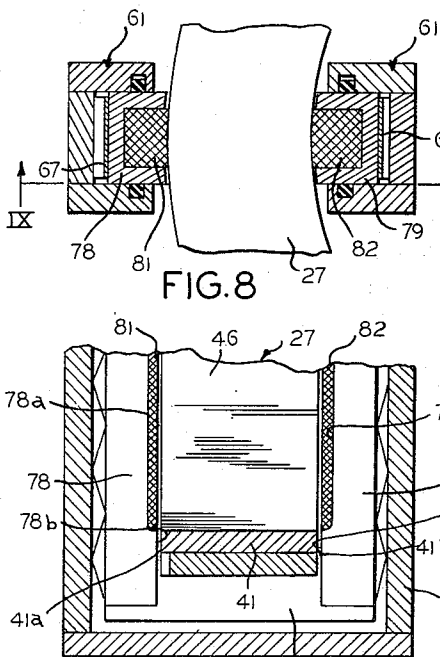


FIG. 8

FIG. 9

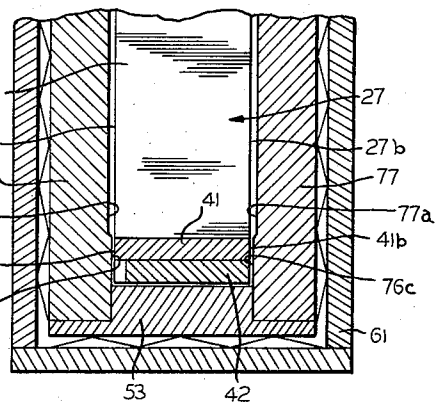


FIG. 7

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SEAL MEANS FOR A ROTARY HEAT EXCHANGER

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5 Claims. (Cl. 257-269)

The present invention relates to improvements in rotary regenerators for use with gas turbines and more particularly to a regenerator having a matrix drum rotating through a partition between high pressure and low pressure chambers with an improved seal to prevent the escape of gas past the outer surfaces of the drum as it passes through the partition.

The invention especially contemplates use with a gas turbine provided with a combustor for supplying heated gases to the turbine and a compressor delivering compressed air to the combustor. A rotary regenerator is provided to transfer heat from the exhaust gases from the turbine to the air delivered from the compressor to the combustor. The regenerator includes a rotary matrix drum. The matrix drum is annular in shape and has a plurality of radial passages for the flow of gas and air. The walls of the passages become heated when exhaust gas flows through the passages and the walls then heat the air when it flows through the passages. The drum rotates through gas and air chambers so that the passages alternately receive a flow of gas or air. The drum is mounted for rotation in a housing provided with a high pressure, low temperature air chamber and a high temperature, low pressure gas chamber. Air flows from the compressor through the high pressure chamber of the regenerator, is heated by the regenerator drum, and flows into the combustor. The exhaust from the gas turbine flows through the low pressure chamber of the regenerator to heat the drum. Thus, as the matrix rotates, heat energy is transferred from the turbine exhaust to the compressed air.

A feature of the invention is the provision of an improved seal for sealing the planar surfaces of the rotating regenerator matrix drum as it passes through a partition between the chambers in the housing. The seal embodies inner and outer seal shoes which face the inner and outer curved surfaces of the matrix drum and top and bottom seal shoes which face the top and bottom surface of the matrix drum. The shoes are rigidly attached to each other at their ends to form a rigid collar which extends in a radial plane around the matrix drum and which is held in a seal box provided with secondary seals to prevent gas leakage around the shoes. The seal box is supported on the partition and the collar is yieldingly supported within the seal box to follow drum movement.

An object of the present invention is to provide an improved rotary regenerator construction having improved performance characteristics and efficiency due to the reduction of leakage past the regenerator drum at the seals.

Another object of the invention is to provide an improved seal construction for a rotary regenerator drum which is capable of providing a continuous reliable seal which can withstand pressure differentials and not become tilted or cocked and is capable of obtaining a long wearing life.

Another object of the invention is to provide an improved full floating clearance seal for a rotary regenerator drum which is capable of effective operation without suffering disadvantages due to the severe effects of temperature change on the regenerator parts.

A further object of the invention is to provide an improved regenerator seal of simplified construction to re-

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duce the cost of manufacturing, assembly and maintenance.

Other objects and advantages will become more apparent with the teaching of the principles of the invention in connection with the disclosure and showing of the preferred embodiment thereof in the specification, claims and drawings, in which:

FIGURE 1 is an elevational view shown partially in schematic form and illustrated with parts broken away, of a gas turbine unit with a regenerator embodying the principles of the present invention;

FIGURE 2 is a horizontal sectional view taken substantially along line II—II of FIGURE 3 and illustrating the construction of a rotary regenerator with seals embodying the principles of the present invention;

FIGURE 3 is an elevational view of a rotary regenerator with parts broken away to illustrate details within the housing;

FIGURE 4 is a vertical sectional view taken substantially along line IV—IV of FIGURE 2, and illustrating in enlarged detail features of the seal assembly;

FIGURE 5 is an enlarged detailed fragmentary sectional view showing a connection between seal shoes;

FIGURE 6 is a horizontal sectional view taken substantially along line VI—VI of FIGURE 4;

FIGURE 7 is an enlarged detailed vertical sectional view illustrating a modified form of the invention;

FIGURE 8 is a horizontal sectional view, similar to FIGURE 6, but illustrating a modified form of the invention; and

FIGURE 9 is a vertical sectional view taken substantially along line IX—IX of FIGURE 8.

As shown on the drawings:

FIGURE 1 illustrates a turbine assembly including a turbine housing 11 with a turbine rotor 12 therein. The turbine is a gas turbine and a flow of heated operating gases is delivered to the turbine at 13 and the gases after driving the rotor 12 are exhausted at 14. The turbine rotor drives a shaft 16. Operating gases are delivered to the turbine from a combustion chamber 17 which is supplied with fuel at 18 and which receives compressed air through a line 19. The compressed air is heated by a regenerator 20 having a housing 22 and delivering the heated compressed air from the outlet 21. Air is received by the regenerator through an inlet 23. Heat energy to be transferred to the air is received from the exhaust gases of the turbine which enter the regenerator through a gas inlet 24 and are exhausted through a gas outlet 26 and flow through passages in a matrix drum 27 within the regenerator housing 22. Compressed air is delivered to the regenerator from a compressor having a housing 28 within which is a compressor rotor 29 mounted on a shaft 16. Ambient air is taken in through the compressor inlet 31 and delivered from the compressor through a line 32.

The regenerator details are shown in FIGURES 2 through 6, with alternate forms being shown in FIGURES 7, 8 and 9.

As illustrated primarily in FIGURES 2 and 3, the regenerator housing 22 has a partition 33 extending there-through to divide the housing interior into a high pressure low temperature first chamber 34 and a lower pressure high temperature second chamber 36. The air which will be heated flows through the intake 23 and enters the first chamber 34, flowing through passages in the matrix drum 27 and leaves through the outlet 21. The air is heated by the heat of the drum material surrounding the passages and this material is heated while the passages are in the second chamber 36 and receive a flow of high temperature turbine exhaust gases which enter the chamber at 24 and flow radially outwardly through the drum

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to leave through the outlet 26. The flow of air is indicated by the solid line arrows in FIGURES 2 and 3 and the flow of hot gases is indicated by the dotted line arrows.

To prevent the escape of high pressure air along the surface of the matrix drum, from the high pressure first chamber 34 to the lower pressure second chamber 36, first the second seals 37 and 38 surround the drum and are mounted in the partition 33. These seals prevent the flow of gases along the surface of the drum as it is rotated within the housing 22.

The drum 27 in a preferred form, as illustrated primarily in FIGURES 1, 2, 3 and 4, is annular in shape and includes an annular top flange member 39 and an annular bottom flange member 41. The top flange member has circular inner and outer surfaces 39a and 39b, respectively, and an annular upper surface 39c. The lower flange has outer and inner circular surfaces 41a and 41b, respectively. Secured below the bottom flange is a driving ring gear 42 with teeth 42a and an annular lower surface 42b. A pinion 43 meshes with the teeth 42a of the ring gear and is driven by supporting shaft 44 to drive the matrix drum assembly 27 in rotation during operation.

Between the top and bottom flange members 39 and 41 are a plurality of radially extending passages 46 for the flow of air and gas. These passages are formed of a good heat transfer material, the material which defines the passages is heated during exposure to the gases in the second chamber 36 and gives up heat to the air during exposure to the air in the first chamber 34.

The drum is supported within the housing by suitable upper and lower drum support bearings shown schematically at 40 in chamber 34 and 45 in chamber 36. It will be recognized that incoming air exerts a large force on the drum and supports 47 and 48, which may be in the form of support rollers, help locate the position of the drum in the horizontal direction. The seals 37 and 38 allow the drum to pass through the partition with a minimum of drag on the drum and with a minimum of leakage from the air chamber 34 to the gas chamber 36. It will be recognized that with temperature change some distortion and some dimension change in the drum will be encountered and this must be accommodated by the seals without permitting undue leakage. The pressure gradient which exists across the seals aggravates the sealing problem and tends to cock the elements of the seals and the present invention contemplates the provision of a full floating clearance seal which eliminates the problem of controlling the seal forces and cocking due to pressure gradient.

In the preferred form, as illustrated primarily in FIGURES 4, 5 and 6, the seal 38 is illustrated in detail. Inasmuch as the seals 37 and 38 may be identical in construction, the full details of seal 37 need not be illustrated and described.

The seal 38 includes an outer seal shoe 49 and an inner seal shoe 51 with these seals having surfaces sealingly coacting with outer and inner arcuate surfaces 27a and 27b respectively of the drum. The seal 38 also includes a top seal shoe 52 and a bottom seal shoe 53 with these seal shoes facing the upper surface 39c of the top flange member 39 and facing the lower surface 42b of the ring gear 42. The four shoes together form a shoe assembly which may be referred to as a seal collar 57 that surrounds the drum in a radial plane with a very small sealing clearance, preferably on the order of 0.002 inch or 0.003 inch. The four shoes are rigidly joined at their ends to form the collar 57.

In a preferred form, the ends may be joined in the manner illustrated in FIGURE 5, where the shoe 52 has a laterally extending tongue 52b projecting outwardly beyond an end shoulder 52c of the shoe. The shoe 51 rests against the shoulder 52c and its upper end 51a rests against the lower surface of the tongue and the ends are

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rigidly joined by connecting screw 54 which extends down through an opening in the tongue 52b and into a threaded opening 56 in the shoe 51. A similar joint is formed at the other end of the shoe 52, with a tongue 52a extending over the end 49a of the shoe 49. At the lower end of the shoe assembly or collar 57, the shoe 53 has laterally extending tongues 53a and 53b which are secured to the lower ends of the shoes 49 and 51, respectively. As will be appreciated by those skilled in the art, although the foregoing illustrates the preferred embodiment, other forms of attachment may be utilized.

In one form, the shoes 49, 51 and 52 may be replaced by a single U-shaped member. The lower shoe 53 is attached to this U-shaped member and with this construction only two pieces are required. Any other three of the shoes may be replaced by a U-shaped member with the fourth shoe being removably attached thereto.

The seal assembly or collar 57 is floatingly supported in a seal box 61, which is carried on the partition 33 within the housing. The seal box is U-shaped in cross-section and has a base portion 61a with side portions 61b and 61c, FIGURE 6. The base and side portions form an annular channel 60 within which the shoe assembly 57 is floatingly mounted. The side sections 61b and 61c have grooves 62 and 63 within which are located secondary seals 64 and 66 to prevent the blowby of air through the seal box. At the base of the channel 60 within the box are wave springs 67 and 68, at the sides of the seal assembly, and 69 and 71 at the top and bottom of the seal assembly. These wave springs together with the pressure within the groove or channel 60 provide a yielding or floating support for the shoe assembly 57.

As is illustrated in FIGURE 4, another pressure which is encountered by the seal is caused by air entrapped within the matrix drum and this pressure acts in the directions A and B. The forces on the seal shoe from this pressure are entirely contained within the shoe assembly 57 do not have to be compensated for by any external balancing force or pressure.

The seal will operate with a finite clearance at all times and as the temperature of the drum increases and the drum diameter also increases, the seal can follow drum movement within the seal box 61.

In the seal construction shown in FIGURES 4-6, the seal shoes are constructed of one material. In the modified form of FIGURE 7, the seal shoes are formed of a single material and the shoe faces are cut back a minute amount to eliminate contact of the seal shoe face on the matrix or passage area 46. The bottom shoe 53 is attached to outer and inner shoes 76 and 77 respectively and the upper end of these shoes (not shown) is attached to the top shoe 52. The outer shoe is cut back at 76a and the inner shoe is cut back at 77a to form a minute clearance space between the inwardly facing surfaces of the shoes and the matrix drum 27. The surfaces 76b and 76c of the shoes will ride against the outer and inner surfaces 41a and 41b of the drum flange 41 so as to position the shoe assembly.

In the form of the invention illustrated in FIGURES 8 and 9, the inner and outer side shoes are formed of two different materials using a harder material to contact the flanges and a softer material to contact the matrix. This again will minimize wear on the matrix.

Outer and inner side shoes are shown at 78 and 79 secured at their lower ends to the bottom shoe 53 and secured at their upper ends (not shown) to the top shoe 52. The shoes are carried in the seal box 61 yieldingly supported by the springs and the gas pressure within the channels of the box. The side shoe 78 is channel-shaped, as illustrated in FIGURE 8 and within the channel is a softer sealing material 81. The shoe 79 is also channel-shaped and within the channel is a softer sealing material 82. The portions of the side shoes 78 and 79 opposite the matrix area 46 of the drum 27 are cut back slightly as illustrated at 78a and 79a. The exposed softer

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seal material 81 and 82 will reduce the wear on the matrix and insure longer operating life while the harder surface of the shoes, such as at 78b and 79b will ride against the outer surfaces 41a and 41b of the flange 41 to position the shoe assembly. The upper ends of the shoes (not shown) similarly ride against the sides of the top flange 39.

As a summary of operation, with reference to FIGURE 1, air is compressed within the compressor housing 28 and delivered to the regenerator 20 to flow radially through the matrix drum 27, as illustrated in FIGURE 2. The air receives heat from the passages in the matrix of the drum 27 and these passages are heated while the drum passes through the chamber 36 which receives a flow of gas from the turbine housing 11. The gas is discharged from the regenerator through the outlet 26. The heated air flows up through the combustor 17 where it mixes with fuel and burns and flows to drive the turbine. The forces and distorting factors acting on the regenerator drum 27 due to pressure differential and temperature changes are accommodated by the seals 37 and 38 which prevent the escape of high pressure air from the chamber 34 to the relatively low pressure gas chamber 36. The seal assembly includes four rigidly interconnected seal shoes which form a seal collar 57 having sealing faces parallel to the flat surfaces of the matrix drum and the collar is yieldingly and resiliently supported in a floating manner to accommodate rotation of the matrix drum and to accommodate deflections and changes in position. While the seal is yieldingly supported, it is rigid to unbalanced forces and will not suffer cocking and spreading of the seal surfaces due to gas pressure differentials.

Thus it will be seen that I have provided an improved combined turbine and regenerator assembly with an improved seal which meet the objectives hereinbefore set forth. The mechanism is capable of continued and reliable operation and will not create undue wear on the regenerator and will retain an effective and efficient sealing ability over a long operating life.

I have, in the drawings and specification, presented a detailed disclosure of the preferred embodiments of my invention, and it is to be understood that I do not intend to limit the invention to the specific forms disclosed, but intend to cover all modifications, changes and alternative constructions and methods falling within the scope of the principles taught by my invention.

I claim as my invention:

1. A regenerator for transferring heat energy comprising an annularly shaped regenerator matrix drum having gas flow passages therethrough and having annular outer surfaces, a regenerator housing enclosing said drum and provided with a partition dividing the housing into first and second flow chambers with said housing having an inlet and an outlet for each of said chambers and said partition having a pair of spaced openings through which said matrix drum extends, a sealing collar in one of said openings circumscribing the regenerator drum and having sealing surfaces in sealing relationship with the annular surfaces of the drum in substantially a radial plane with said sealing surfaces fixed in position with respect to each other and supported on said collar, a yieldable seal in said one opening between the partition and collar, yielding supports for said collar including yieldable biasing means positioned radially outwardly of the collar between the partition and collar and positioned radially inwardly of the collar between the partition and collar for yieldingly supporting the collar with respect to the drum in both radial directions, and means for rotating said drum.

2. A regenerator for transferring heat energy comprising an annularly shaped regenerator matrix drum having gas flow passages therethrough and having annular outer surfaces, a regenerator housing enclosing said drum and provided with a partition dividing the housing

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into first and second flow chambers with said housing having an inlet and an outlet for each of said chambers and said partition having a pair of spaced openings through which said matrix drum extends, a sealing collar in one of said openings circumscribing the regenerator drum and having sealing surfaces in sealing relationship with the annular surfaces of the drum in substantially a radial plane with said sealing surfaces fixed in position with respect to each other and supported on said collar, a seal box secured on the partition in said one opening extending around the collar in a radial plane and being U-shaped in cross section with the collar floatingly mounted therein, secondary yieldable seals within said box between the collar and box, yielding supports for said collar including yieldable biasing means positioned around the collar between the box and said collar for yieldingly supporting the collar in both axial directions and both radial directions, and means for rotating said drum.

3. A regenerator for transferring heat energy comprising an annularly shaped regenerator matrix drum having gas flow passages therethrough and having annular outer surfaces, a regenerator housing enclosing said drum and provided with a partition dividing the housing into first and second flow chambers with said housing having an inlet and an outlet for each of said chambers and said partition having a pair of spaced openings through which said matrix drum extends, a sealing collar in one of said openings circumscribing the regenerator drum and having sealing surfaces in sealing relationship with the annular surfaces of the drum in substantially a radial plane with said sealing surfaces fixed in position with respect to each other and supported on said collar, a yieldable seal in said one opening between the partition and collar, including yieldable biasing means positioned radially outwardly of the collar between the partition and collar and positioned radially inwardly of the collar between the partition and collar and positioned axially above and below the collar between the collar and partition for yieldingly supporting the collar with respect to the drum in both radial directions and both axial directions, and means for rotating said drum.

4. A regenerator for transferring heat energy comprising an annularly shaped regenerator matrix drum having gas flow passages therethrough and having annular outer surfaces, a regenerator housing enclosing said drum and provided with a partition dividing the housing into first and second flow chambers with said housing having an inlet and an outlet for each of said chambers and said partition having a pair of spaced openings through which said matrix drum extends, a sealing collar in one of said openings circumscribing the regenerator drum and having sealing surfaces in sealing relationship with the annular surfaces of the drum in substantially a radial plane with said sealing surfaces fixed in position with respect to each other and supported on said collar, said collar formed of a hard material and said sealing surfaces including a softer material on the collar positioned radially inwardly and radially outwardly of the drum in sealing relationship therewith, a yieldable seal in said one opening between the partition and collar, yielding supports for said collar including yieldable biasing means positioned radially outwardly of the collar between the partition and collar and positioned radially inwardly of the collar between the partition and collar for yieldingly supporting the collar with respect to the drum in both radial directions, and means for rotating said drum.

5. A regenerator for transferring heat energy comprising an annularly shaped regenerator matrix drum having gas flow passages therethrough and having annular outer surfaces, a regenerator housing enclosing said drum and provided with a partition dividing the housing into first and second flow chambers with said housing having an inlet and an outlet for each of said chambers

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and said partition having a pair of spaced openings through which said matrix drum extends, a sealing collar in one of said openings circumscribing the regenerator drum and having sealing surfaces in sealing relationship with the annular surfaces of the drum in substantially a radial plane with said sealing surfaces fixed in position with respect to each other and supported on said collar, a yieldable seal in said one opening between the partition and collar, a wave spring extending around the collar between the partition and collar for yieldingly

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supporting the collar with respect to the drum in both radial directions and in both axial directions, and means for rotating said drum.

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