United States Patent [19]

Siegla

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[45] **Dec. 24, 1974**

[54] **REGENERATOR SEAL**

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[73] Assignee: **General Motors Corporation,** Detroit, Mich.

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[21] Appl. No.: **343,199**

[52] **U.S. Cl.** **165/9,** 277/88, 277/96

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

[58] **Field of Search** 165/9; 277/88, 96

[56] **References Cited**

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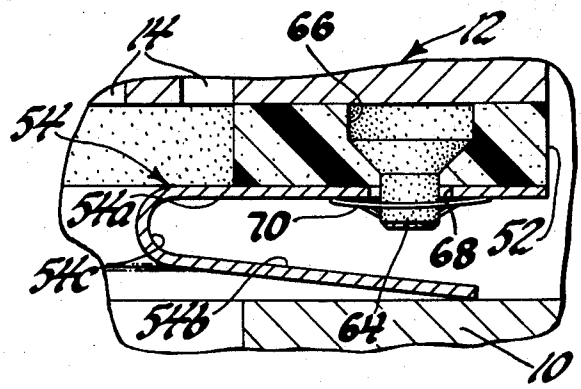
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Primary Examiner—Albert W. Davis, Jr.
Attorney, Agent, or Firm—A. N. Krein

[57] **ABSTRACT**

A regenerator seal structure for the cold side of a rotary regenerator heat exchange apparatus which includes a one-piece wear seal element, made of a graphite filled polyimide plastic, biased into sealing engagement with the matrix of the regenerator by a leaf seal U-shaped in cross section.

8 Claims, 7 Drawing Figures



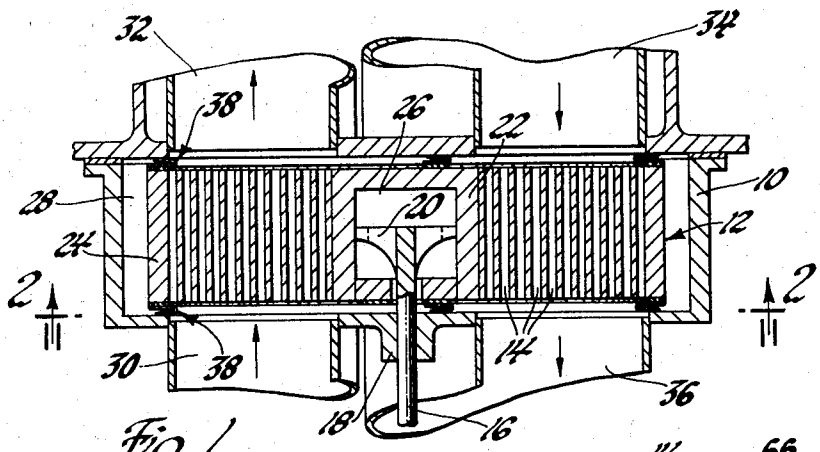


Fig. 1

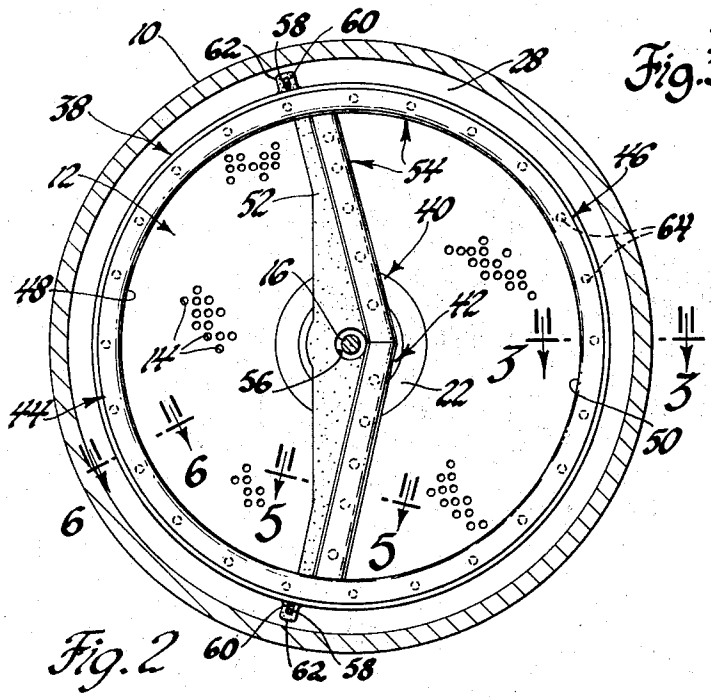


Fig. 2

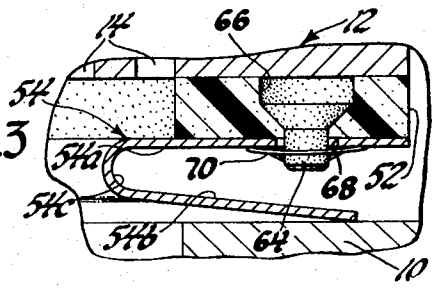


Fig. 3

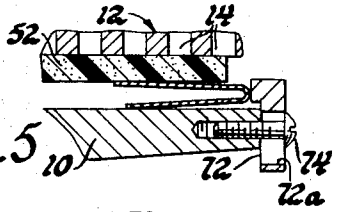


Fig. 5

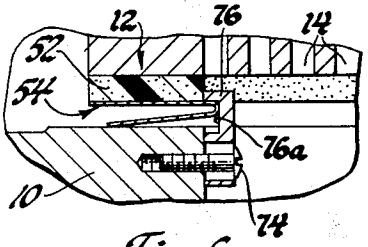


Fig. 6

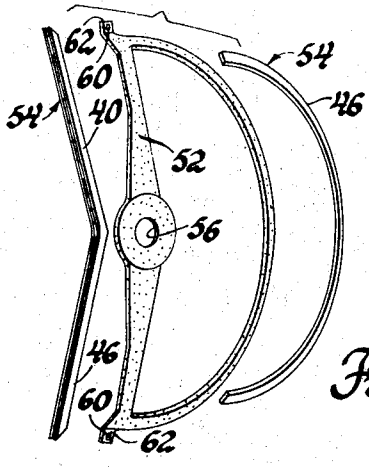


Fig. 4

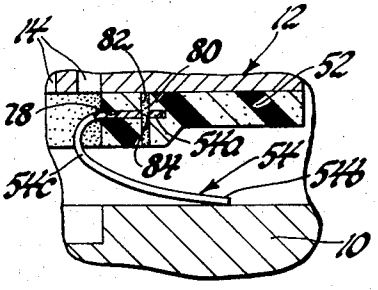


Fig. 7

REGENERATOR SEAL

This invention relates to seals for a rotary regenerator heat exchange apparatus and, in particular, to a seal structure consisting of a wear seal element, made of a graphite filled polyimide plastic material, and a leaf seal.

Rotary regenerators, particularly those of the axial flow type, utilize a porous metal or ceramic disc matrix which is rotated so that each element thereof passes successively through two aeriform fluid flow paths, absorbing heat from a hotter fluid and releasing it to cooler fluid in these flow paths.

One application of such regenerators is in preheating the combustion air in gas turbine engines. In such an application, there is a large pressure difference between the compressed air which is heated and the turbine exhaust gases which give up heat. In order to prevent leakage of the high pressure fluid into the low pressure fluid path and also to prevent each fluid from bypassing the matrix, seals are provided which extend around the perimeter of one or both flow paths on each face of the regenerator, bridging the gap between the regenerator disc and a face of the enclosing member which is proximate to the matrix.

Because of the high temperature at which such a regenerator must operate when employed with gas turbines, the provision of an adequate, durable and economically practicable seal has presented difficult problems. In current regenerator seal structures used with gas turbine engines, the typical seals, used on both the hot side and cold side of the regenerator, are made up of three major components, the wear material or rubbing innerface material which engages the regenerator matrix, the metal structural member or "platform" between the wear material and the sealing member and, the sealing member or leaf seal to effect a flexible pressure seal between the seal "platform" and the engine housing or its related ducting.

In these prior art seal structures, the metal structural member or "platform" between the wear material and the sealing member has been required so as to provide structural support for the wear material which has normally been a graphite or a graphite composition suited to the requirements of the installation. The metal platform, usually made of stainless steel, has had to be rigid enough to prevent the wear material from breaking and of sufficient thickness to permit proper attachment of the graphite wear material, normally fabricated as segments, to this platform. However, because of the mismatch between the linear coefficient of expansion of the graphite wear material and the stainless steel platform, the attachment of the graphite wear material segments to the platform has always been a problem.

It is therefore the primary object of this invention to improve a seal structure for use on the cold side of a rotary regenerator heat exchange apparatus whereby the wear element of the seal structure is a one-piece wear element cooperating with a leaf seal to form the seal structure.

It is another object of this invention to improve a regenerator seal structure whereby the wear element of the seal structure is made of such a material so as to enable it to also serve as the structural member to which the leaf seal may be attached.

A further object of this invention is to improve a regenerator seal structure whereby a graphite filled polyimide plastic material is used in fabricating the wear element to permit direct use of this wear element with a leaf seal.

These and other objects of the invention are attained by means of a seal structure comprising a one-piece wear seal element of a graphite filled polyimide plastic and a leaf seal.

For a better understanding of the invention, as well as other objects and further features thereof, reference is had to the following detailed description of the invention to be read in connection with the accompanying drawings, wherein:

FIG. **1** is a schematic view of a rotary regenerator taken in a plane containing the axis of rotation of the matrix thereof for the purpose of illustrating the location and general arrangement of the hot and cold side seals as used in such a regenerator;

FIG. **2** is a sectional view taken along line **2—2** of FIG. **1** showing the cold side seal structure of the rotary regenerator in accordance with one embodiment of the invention;

FIG. **3** is an enlarged sectional view taken along line **3—3** of FIG. **2** illustrating the embodiment of the seal structure of FIG. **2**, in which the leaf seal and wear element are secured together;

FIG. **4** is an exploded perspective view of a seal structure for use on the cold side of the rotary regenerator, the seal structure shown being in accordance with a second embodiment of the invention;

FIG. **5** is an enlarged sectional view taken along a line corresponding to line **5—5** of FIG. **4** illustrating the rim seal of the seal structure of FIG. **2** and its mounting arrangement in a rotary regenerator;

FIG. **6** is an enlarged sectional view taken along a line corresponding to line **6—6** of FIG. **2** illustrating only the cross arm seal of the seal structure of FIG. **4** and its mounting arrangement in accordance with the invention; and,

FIG. **7** is an enlarged sectional view similar to FIG. **3** illustrating another embodiment of a wear seal element and leaf spring mounting arrangement.

Referring now to FIG. **1**, there is shown a rotary regenerator heat exchange apparatus which includes a housing **10**, generally drum-shaped, to enclose an annular foraminous disc or matrix **12** which is of such construction so as to define a multiplicity of pores or passages **14**, greatly enlarged in FIG. **1**, extending from face to face of the matrix generally parallel to the axis of rotation defined by a matrix locating and driving shaft **16**. Shaft **16** is suitably journalled in the boss **18** of the housing **10** and terminates in a spider **20** which is coupled to the matrix by means, not illustrated, which may be of the type described in U.S. Pat. No. 3,476,173 issued Nov. 4, 1969, to Joseph W. Bracken, Jr. and William S. Hubble, so that the matrix may be rotated slowly.

The matrix preferably includes a nonporous inner rim **22** and an outer nonporous rim **24**, but such rims are not essential. A generally cylindrical space **26** is defined within the interior of the matrix and a space **28** extends around the periphery of the matrix within the housing **10**.

An inlet **30** for cool high pressure air enters one face of the housing and, opposite to it, and outlet **32** is provided for the discharge of compressed air which is heated after having passed through the matrix. Hot low pressure exhaust gases enter through an inlet **34** and leave the regenerator through an outlet **36**, the two

streams being thus in counterflow relation in the embodiment of the regenerator illustrated. As shown, the hot gas passage is of larger area than the cool air passage because of the difference in density between these fluids. Since the exhaust gases entering through the inlet **34** engage first the upper face of the matrix, as seen in FIG. **1**, this is the hot side, while the lower face of the matrix is then referred to as the cold side.

A sealing means or seal assembly **38** is provided between each face of the matrix and the housing to confine the cold and hot fluids to the desired flow paths through the matrix from inlet to outlet and to minimize leakage between the paths. With reference to FIG. **1**, the upper seal assembly **38** would thus be the hot side seal while the lower seal assembly **38** would be the cold side seal.

As shown more clearly in FIG. **2**, such a seal assembly comprises two arms **40** and **42** extending radially of the matrix face preferably joined at the center of the matrix and joined at the outer rim of the matrix by an arcuate rim or bypass seal **44** extending around the high pressure path and an arcuate rim or bypass seal **46** extending around the low pressure path. The seal assembly thus defines an opening **48** for the cool high pressure air and an opening **50** for the cooled low pressure exhaust gases, these openings as shown in the cold side seal of FIG. **2** conforming generally to the outline of the ducts **30** and **36**, respectively.

The seal arms **40** and **42** together may be termed a cross arm seal lying between the high pressure and low pressure fluid paths and, the seal portions **44** and **46** may be termed a rim seal or bypass seal, these being engaged with the matrix adjacent to its periphery. The rim seal **44** and the cross arm seal surround the high pressure passage and the cross arm seal and rim seal portion **46** surround the low pressure gas passage. It is common practice to permit the high pressure air to flow into the space **28** radially outward of the matrix **12**, in which case the rim seal **44** may be omitted at the inlet **30** to the matrix. Such a seal structure is shown in the embodiment of the seal structure shown in FIG. **4** to be described in detail hereinafter. The structure thus far generally described may be considered background to the present invention which lies in aspects of the seal structure not shown in detail in FIG. **1**, which figure serves more to illustrate the environment of the improved seal structure while FIG. **2** serves to illustrate the general configuration of such a seal structure and one embodiment of a seal structure in accordance with the invention.

With reference to the figures, a seal constructed in accordance with the invention, includes a one-piece wear seal element **52** of a suitable wear material having sufficient strength so that a platform is not required to effect support of the seal wear element and a leaf seal **54.** In a preferred embodiment of the invention, wear seal element **52** is fabricated from a suitable graphite filled high temperature resistant plastic material, such as a graphite filled polyimide resin commercially available from the E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware, this material being commercially identified as du Pont standard polyimide composition SP-22. This polyimide composition SP-22 is a polyimide resin containing normally forty percent (40 percent) by weight of graphite, the polyimide resin used in this material being generally of the type disclosed in U.S. Pat. No. 3,179,631 entitled "Aromatic Polyimide Particles from Polycyclic Diamines," issued Apr. 20, 1965, to Andrew L. Endrey and U.S. Pat. No. 3,179,633 entitled "Aromatic Polyimides from Meta-Phenylene Diamine and Para-Phenylene Diamine," issued Apr. 20, 1965 to Andrew L. Endrey.

Any suitable graphite filled high temperature plastic material may be used for fabricating the wear seal element to obtain the desired strength and heat resistance required for a particular regenerator. The percentage by weight of graphite in the wear material composition can be varied as desired, it being apparent that the lower percentage limit of graphite in the composition will be set by the rate of friction that can be tolerated in a particular installation in which the wear seal element is to be used while the upper percentage limit of graphite in the composition would be limited by the physical strength characteristics desired for the wear material as used in a particular installation.

The wear seal element **52** of the embodiment illustrated in FIG. **3**, is substantially rectangular in cross section and the desired configuration to conform, for example, to the configuration of the cross arms **40, 42** and to the arcuate rim seals **44** and **46**, with reference to FIG. **2**, if the rim seal **44** is desired around the cool high pressure air inlet **30.** In addition, a suitable aperture **56** is provided in the cross arm portion of the wear seal element **52** to rotatably receive the shaft **16.**

By using a graphite filled polyimide resin material, it is now possible, in effect, to make a one-piece combination wear face and platform molded to finished size and configuration including pressure grooving, not shown, as desired. This is in contrast to the known prior art wear seals which are made up of a metal platform to which is attached the graphite wear face segments or to which is plasma sprayed a wear face material.

The wear seal element **52** is located positively against rotation and translatory movement transverse to the axis of rotation of the matrix, but is free to move parallel to the axis of rotation of the matrix. This mounting is provided by a number of pins or dowels **58** projecting from the fixed structure of the housing **10** into slots **60** in the lugs **62** extending radially outward from the outer rim portion of the wear seal element **52.** The slots **60** are elongated, in a radial direction, to provide for relative radial expansion between the housing **10** and the wear seal element **52.**

Also, in accordance with the invention, the leaf seal **54** which may comprise segment portions conforming to the general shape of the cross arms **40** and **42** and rim portions **46** and **44**, if the latter is desired, suitably secured together if desired as by welding, is made, for example, of stainless steel. Each segment portion of the leaf seal is roll-formed, before assembly, to the desired cross section, a substantially U-shaped cross section being shown to provide a resilient leaf spring strip having a pair of legs **54***a* and **54***b* joined together by an arcuate portion **54***c* integral therewith. The cross sectional contour of this leaf seal spring is very important in that if it is too weak, the high pressure air acting on the open end of the leaf seal, the right-hand end of the leaf seal as seen in FIG. **3**, will cause the leaf to fail and "blow through" and if it is too stiff, it will not have enough flexibility to seal against the undulations on the leaf spring contacting surface of the engine housing **10.** Thus, the leaf seal **54** is made relatively long so as to have a low spring rate to effect the initial seal at the free end tip of the leg **54***b* of the leaf seal spring where

it engages the housing, as seen, for example, in FIG. 3. Then, as air pressure is increased, the leaf seal spring bows such that the unsupported length or "beam length," that is, the unsupported portion of the leaf seal spring, is decreased until the leaf seal spring becomes strong enough to prevent further distortion.

Now in accordance with the embodiment of the seal structure shown in FIGS. 2 and 3, the wear seal element 52 and the leaf seal 54 are secured together to retain the leaf seal 54 in position relative to the wear seal element to provide the cold-side seal structure for the regenerator. As shown, the wear seal element 52 is secured to one leg of the leaf seal 54 as by means of fasteners which may be formed integral with the wear seal element or, as shown, may be separate rivets 64 made of the same material as the wear seal element. Each of these rivets 64 extends down through a suitable stepped aperture 66 in the seal wear element 52 with the head of the rivet retained in the stepped aperture 66 and with the shank of the rivet extending through a suitable elongated aperture 68 in the leaf seal and being axially retained as by means of a conventional push-on spring type nut 70 secured to the shank of the rivet in engagement with the opposite side of the leaf seal from the side on which the wear seal element is mounted. Preferably, the push-on spring type nuts 70 are made of a suitable stainless steel material or the like. In addition, because of the difference between the thermal expansion of the wear seal element and that of the leaf seal, suitable clearance is provided in each aperture 66 and in each aperture 68 in the leaf seal to permit movement of wear seal element relative to the leaf seal, the spring nut maintaining a tight joint between these elements.

Also in accordance with the invention, the fasteners in the form of rivets 64, if formed as separate elements, are also made of the same material as the wear seal element 52.

In the embodiment of the seal structure shown in FIGS. 4, 5 and 6, the leaf seal 54 is not secured to the wear seal element 52. As best seen in FIG. 4, the one-piece wear seal element 52 in this embodiment is of a configuration including the cross arm portions 40 and 42 and a circular rim portion 46, the rim portion 44 not being used in this embodiment. As previously described, the wear seal element 52 is located positively against rotation and translatory movement transverse to the axis of rotation, but is free to move parallel to the axis of rotation of the matrix by the dowel pins 58 fixed to the housing 10 which extend into the slots 60 in the lugs 62 of the wear seal element.

Since in this embodiment, the leaf seal 54 is not secured to the wear seal element 52, suitable means are provided to maintain the leaf seal 54 in position within the housing 10 so as to permit the leaf seal to cooperate with the wear seal element 52 to provide an effective cold-side seal structure between the matrix 12 and housing 10, the leaf seal 54 being positioned between the housing 10 and the wear seal element 52 to bias the wear seal element into sealing engagement with the matrix 12. In the arrangement shown in FIG. 5, the cross arm portions of the leaf seal 54 are secured against rotation or translatory movement transverse to the axis of rotation of the matrix in one direction, as seen in FIG. 5, by means of a plurality of L-shaped retainers 72 with the short leg of each L-shaped retainer positioned to abut against the arcuate portion 54c of the cross arm portions of the leaf seal 54. The long leg of each retainer 72 is provided with an elongated slot 72a whereby each retainer can be adjustably secured to the housing 10 as by a threaded fastener 74 extending through the slot and threaded into the housing 10. In a similar manner, the rim portion of the leaf seal 54, as shown in FIG. 6, is retained by means of a plurality of retainers 76 secured by threaded fasteners 74 to a portion of the housing 10 in position to encircle the inner curved rim portion of the leaf seal 54, each of these retainers having substantially U-shaped notch 76a in one face thereof into which the arcuate portion 54c of this portion of the leaf seal is engaged, as seen in this figure.

During operation of the regenerator high pressure air flowing through inlet 30 will act on the cross arm portion of the leaf seal 54 to constantly force it against the L-shaped retainers 72, while the high pressure air flowing into the space 28 extending around the matrix 12 within the housing 10 will force the rim portion of the leaf seal 54 radially inward against the retainers 76.

In another embodiment, as seen in FIG. 7, the wear seal element 52 and the leaf seal 54 are secured together by inserting one leg 54a of the leaf seal into a suitable groove 78 machined or molded into the side of the wear seal element between opposite faces thereof. Since the wear seal element of graphite filled polyimide wear seal element 52 would expand thermally more than the metal leaf seal, the leg 54a of the leaf seal must be free to slide in the groove 78 so that thermal expansion of the wear seal element does not distort the leaf seal. For straight seal sections, such as in the portion corresponding to the cross arms 40 and 42, it is necessary to mechanically pin the leaf seal to the wear seal element so that this portion of the leaf seal is not blown away from the wear seal element. This is accomplished by the use of retaining pins 80, made of a graphite filled polyimide resin, the same as the material used in the wear seal element which are inserted through suitable apertures 82 machined or molded in the wear seal element 52 and suitable apertures 84 formed in the leg 54a of the seal leaf 54.

Whether using the rivet 64 fasteners as seen in FIG. 3 or the pins 80 type fastener as seen in FIG. 7 to secure the wear seal element 52 to the leaf seal 54, it will be apparent that by using the same material in fabricating these fasteners as used in fabricating the wear seal element itself, should the wear seal element wear down to the rivet for example, the rivet head or pin rubbing against the matrix will not damage the matrix.

What is claimed is:

1. In a rotary regenerator heat exchange apparatus having a housing and a matrix carried in said housing for rotation about an axis through two aeriform fluid flow paths including a high pressure fluid flow path and a counterflowing low pressure fluid flow path, the matrix because of these flow paths having a hot side and a cold side and a sealing means disposed between the housing and the matrix on the cold side of the matrix, said sealing means comprising a one-piece wear seal element of graphite filled high temperature plastic material, means associated with the housing and with said wear seal element to retain said wear seal element against rotation and translatory movement transverse to the axis of rotation of the matrix while permitting movement of said wear seal element parallel to the axis of rotation of the matrix, and a leaf seal positioned between the housing and said matrix to bias said wear seal

element into sealing engagement with the matrix, each portion of said leaf seal being substantially U-shaped in cross section and having a first leg portion engaging the housing, a second leg portion engaging said seal wear element and an integral arcuate portion therebetween, and retainer means to retain said leaf seal in position within the housing so that the open ends of said U-shaped cross section portions of said leaf seal are acted on by the fluid flowing in the high pressure fluid path.

2. In a rotary regenerator heat exchange apparatus according to claim **1** wherein said retainer means are a plurality of retainers secured to the housing in position to be engaged by said arcuate portions of said leaf seal.

3. In a rotary regenerator heat exchange apparatus according to claim **1** wherein said seal wear element has stepped apertures therethrough and said second leg portion of said leaf seal is provided with corresponding apertures and wherein said retainer means include rivets, of graphite filled high temperature material, positioned in the stepped apertures in said wear seal element to extend through said apertures in said leaf seal and push-on nut means secured to the portions of said rivets extending through said apertures.

4. In a rotary regenerator heat exchange apparatus according to claim **3** wherein the graphite filled high temperature plastic material of said wear seal element and said rivet is a polyimide resin containing normally forty percent by weight of graphite.

5. In a rotary regenerator heat exchange apparatus according to claim **1** wherein said wear seal element has slots in a side thereof to slidably receive said second leg portion of said leaf seal, said wear seal element and said second leg having aligned apertures therethrough and, wherein said retainer means are retaining pins of graphite filled high temperature plastic material positioned in said apertures to secure said leaf seal to said wear seal element.

6. In a rotary regenerator heat exchange apparatus having a housing and a matrix rotatably carried about an axis in said housing, a sealing means disposed between the housing and one side of the matrix, said sealing means comprising a one-piece wear seal element of graphite filled high temperature plastic material, and a leaf seal of U-shaped cross section having a first leg portion and a second leg portion having apertures therein with an arcuate portion therebetween, said first leg portion being adapted to engage the housing, fastener means of graphite filled high temperature plastic material extending through said wear seal element into said apertures in said second leg portion securing said wear seal element to said leaf seal in position whereby said wear seal element is resiliently urged into engagement with said matrix and means secured to said housing and engaging said sealing means to retain said sealing means in position in said housing against rotary and translatory movement transverse to the axis of rotation of the matrix while permitting movement of said wear seal element axially in the housing.

7. In a rotary regenerator heat exchange apparatus according to claim **6** wherein the graphite filled high temperature plastic material of said wear seal element and said fastener means is a polyimide resin containing normally forty percent by weight of graphite.

8. In a rotary regenerator heat exchange apparatus according to claim **6** wherein said fastener means are rivets each having a head portion positioned in said wear seal elements and a shank portion extending through one of said apertures in said leaf seal and, a nut means secured to said shank portion of said rivet.

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