Nov. 9, 1965 B. M. GALLAGHER 3,216,487

REGENERATORS

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Fig. 1

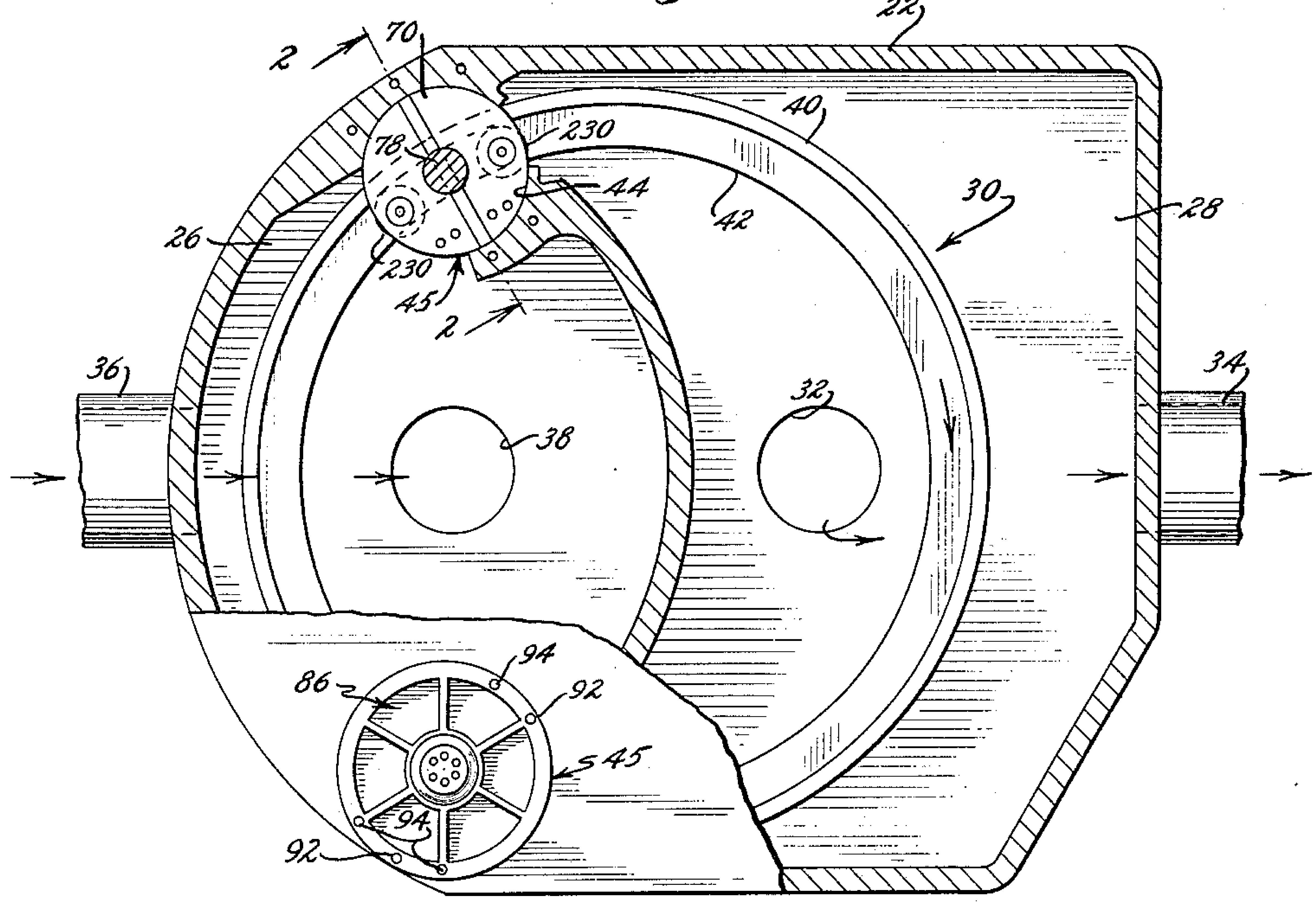
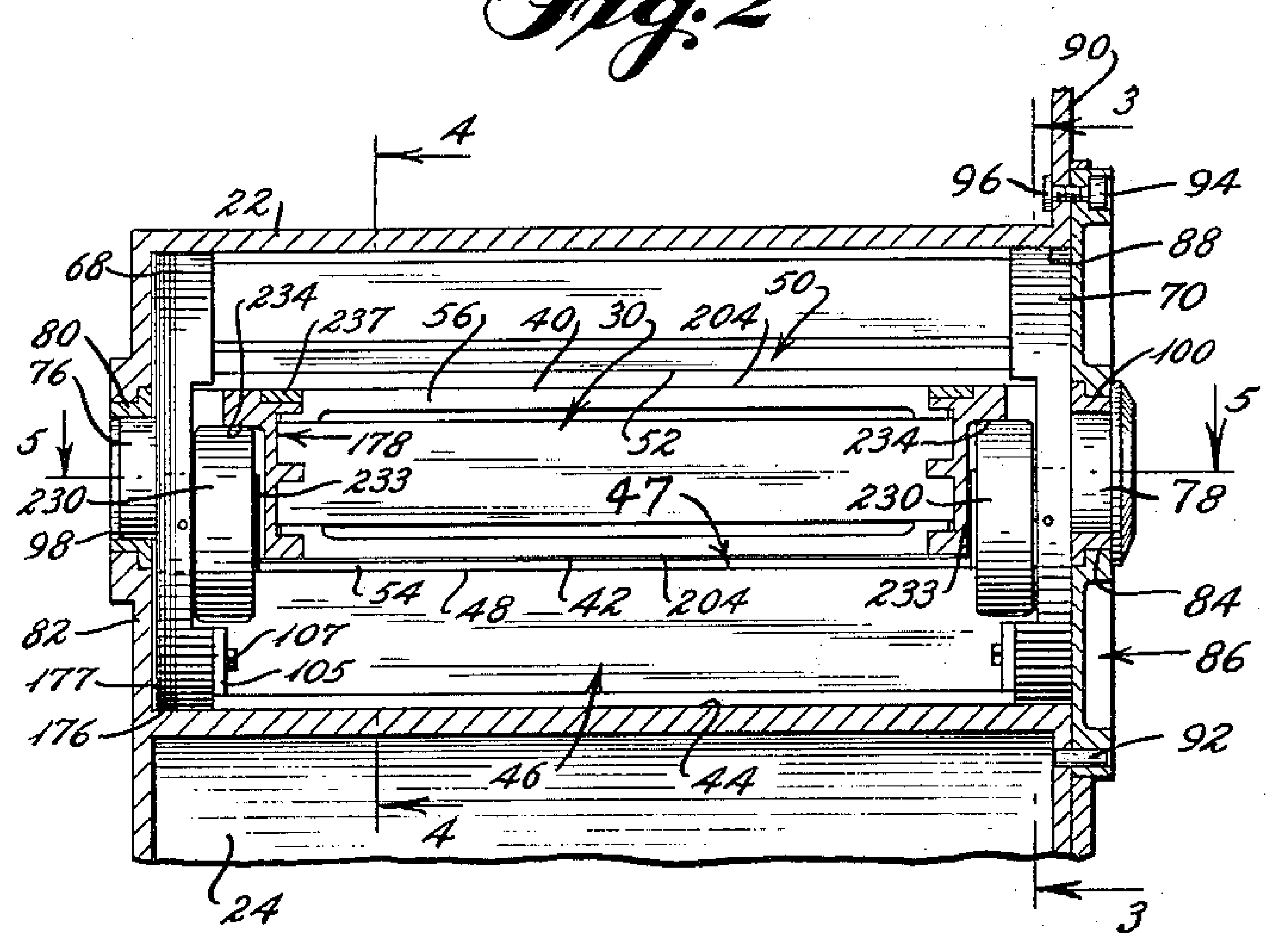


Fig. 2



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REGENERATORS

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Fig. 3

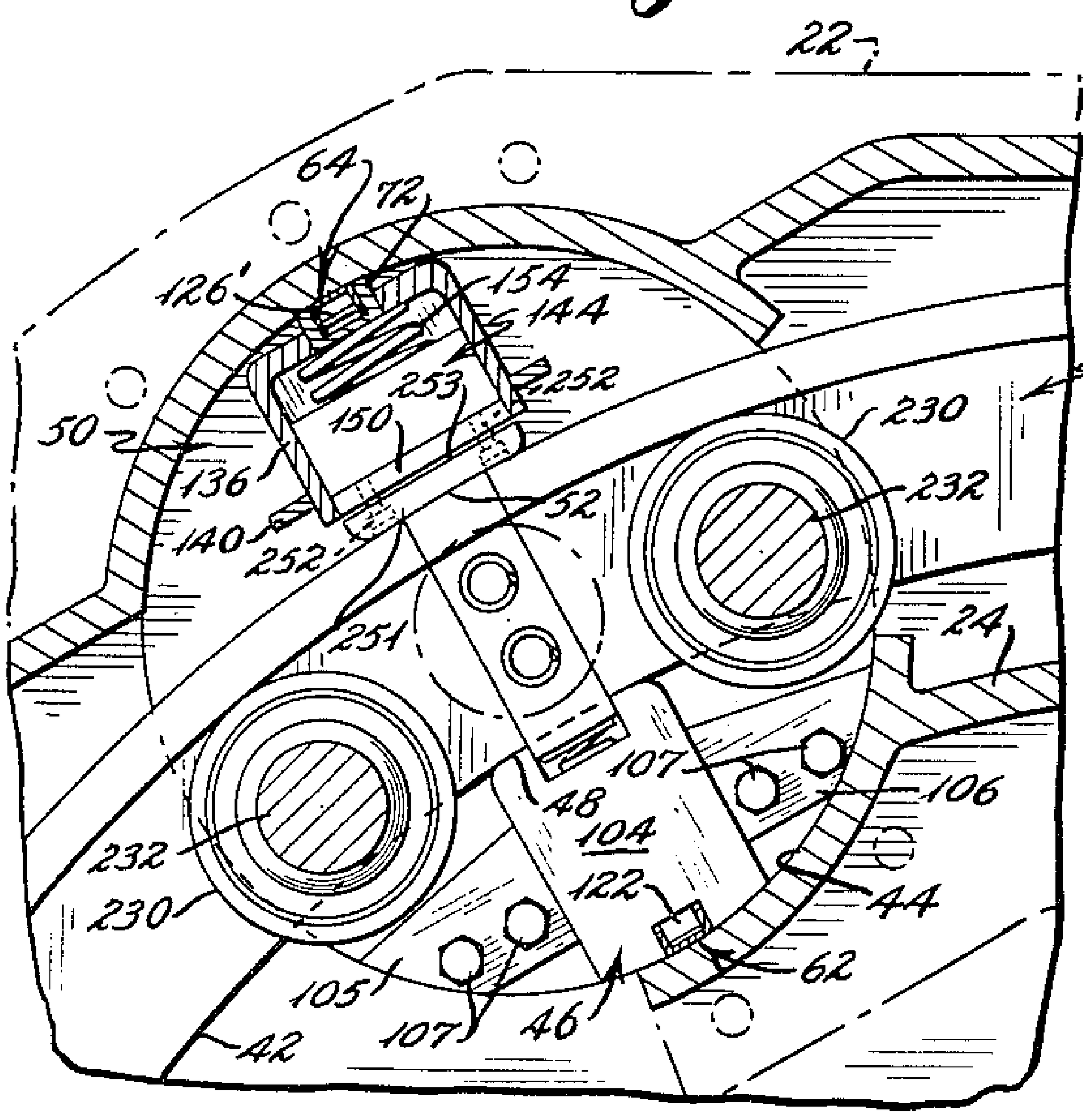

Fig. 4

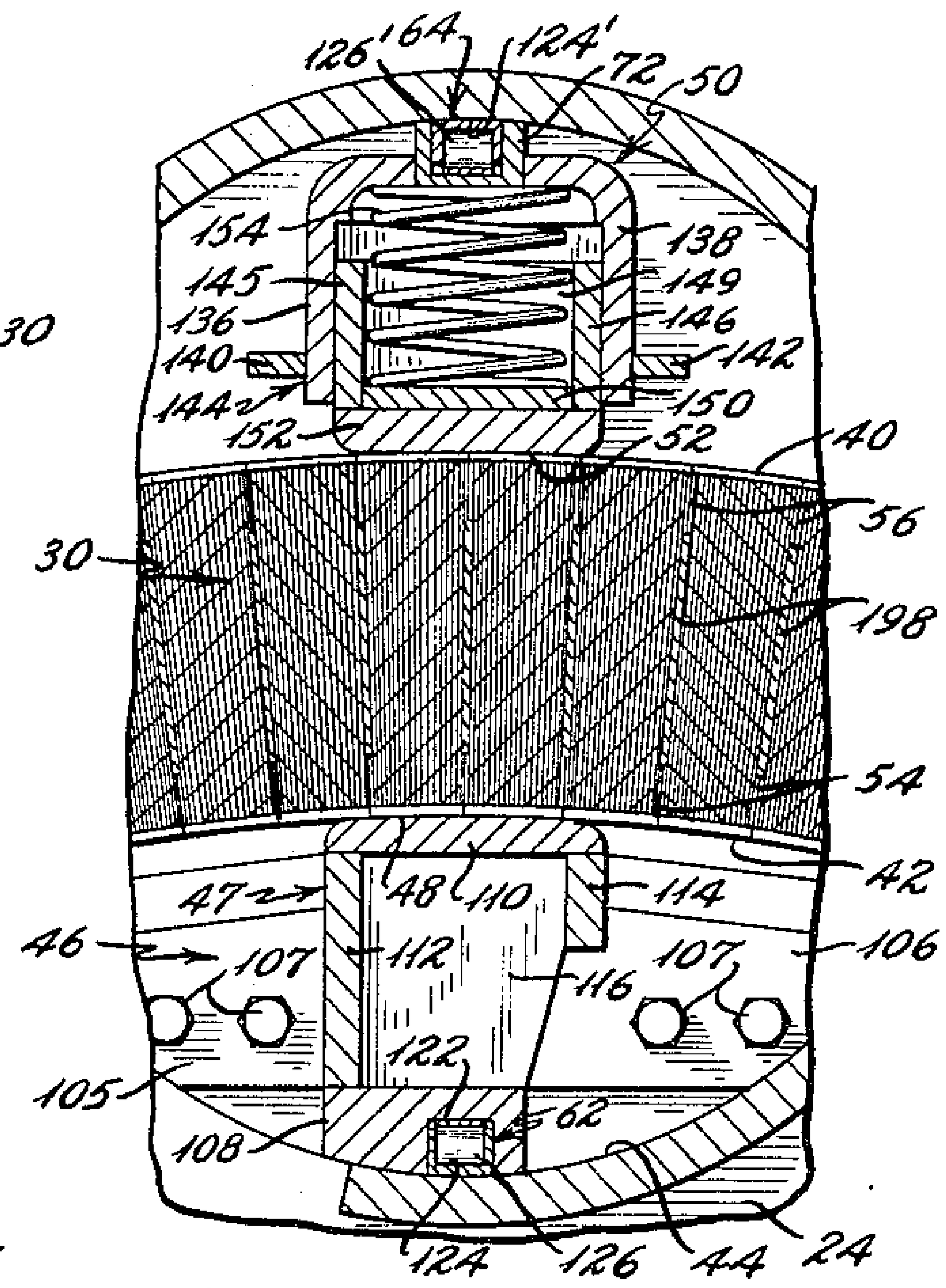

Fig. 5

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REGENERATORS

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Fig. 6

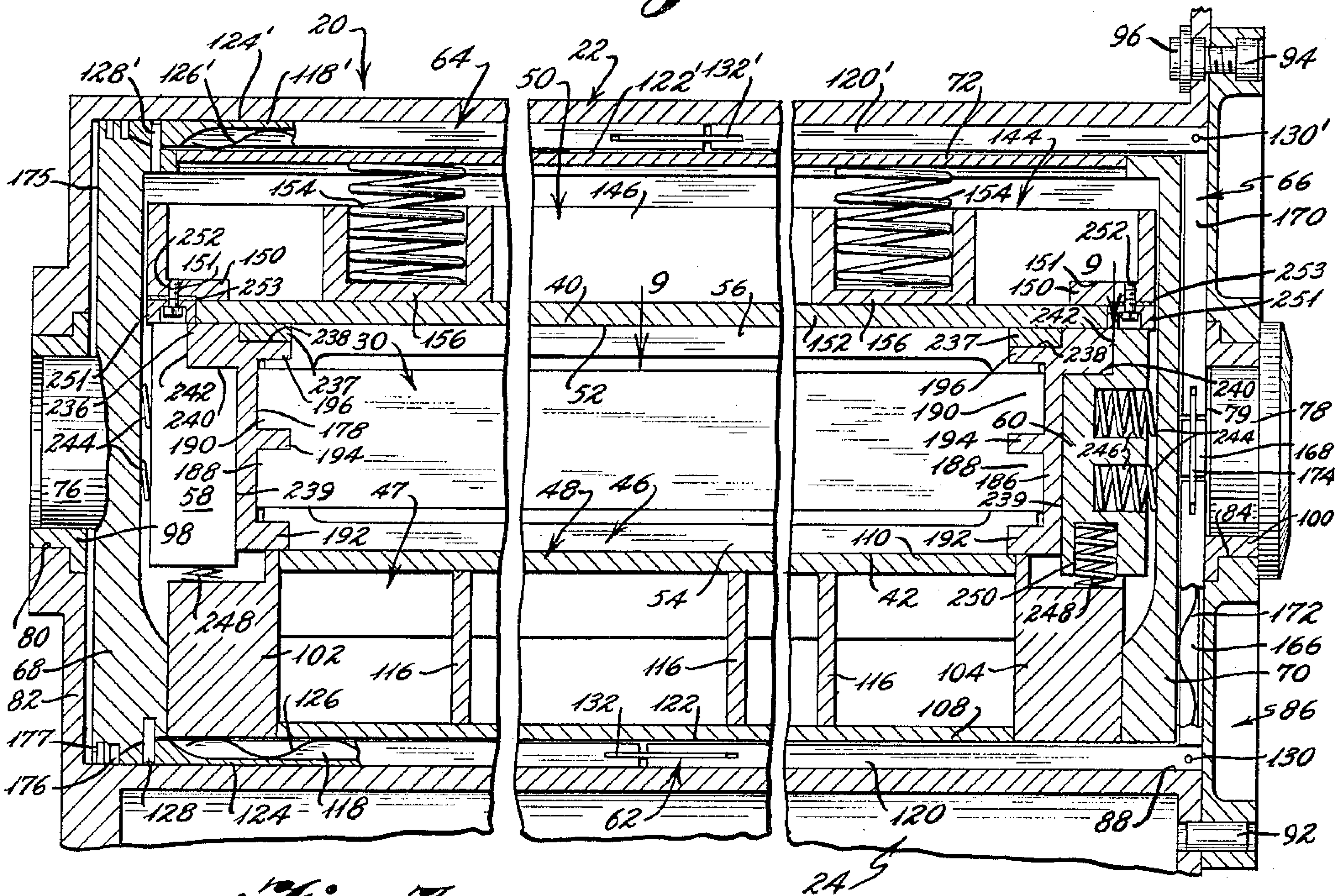


Fig. 7

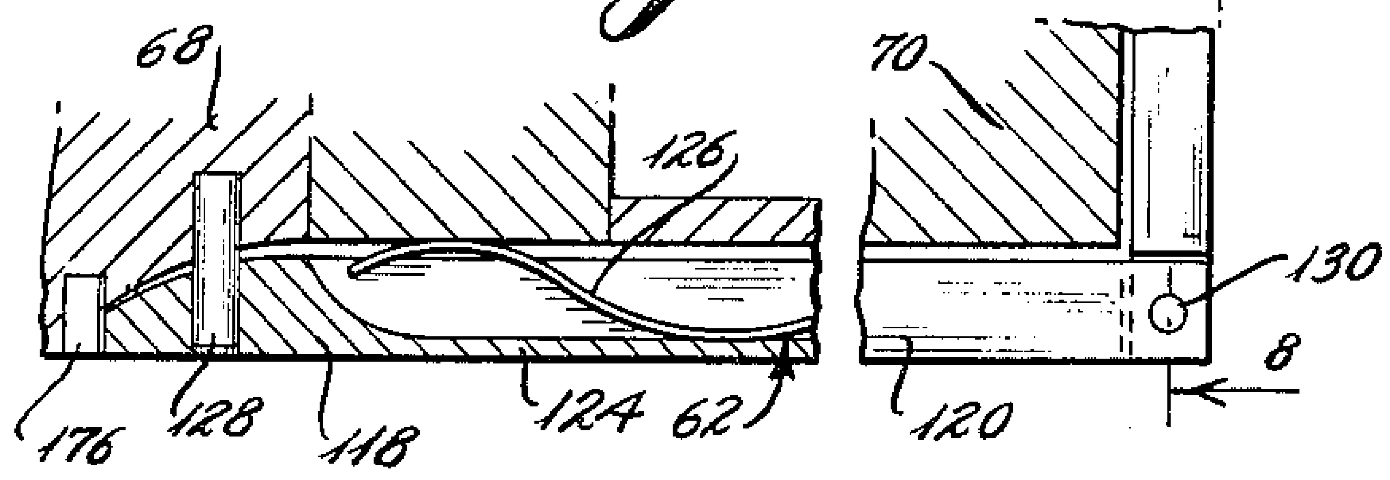


Fig. 8

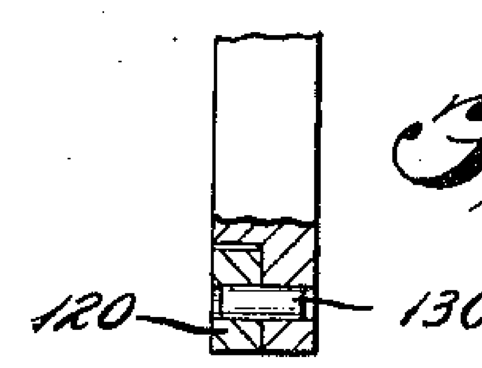
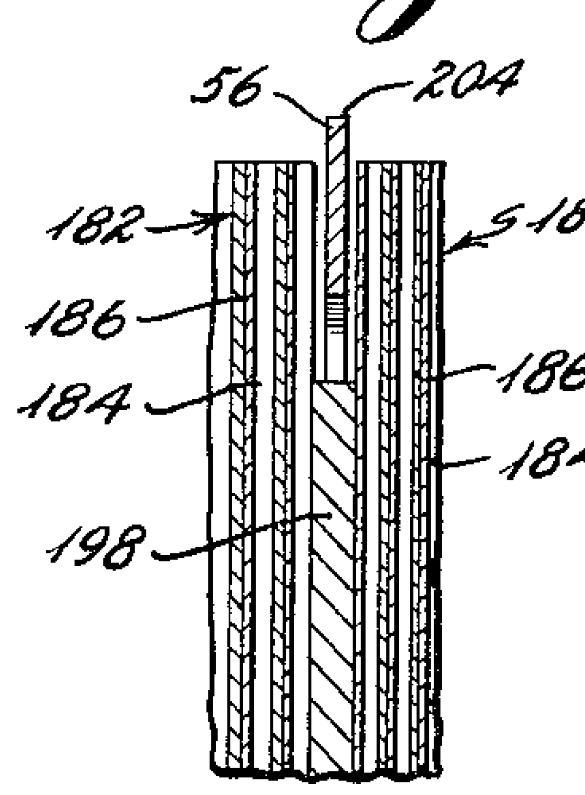


Fig. 12



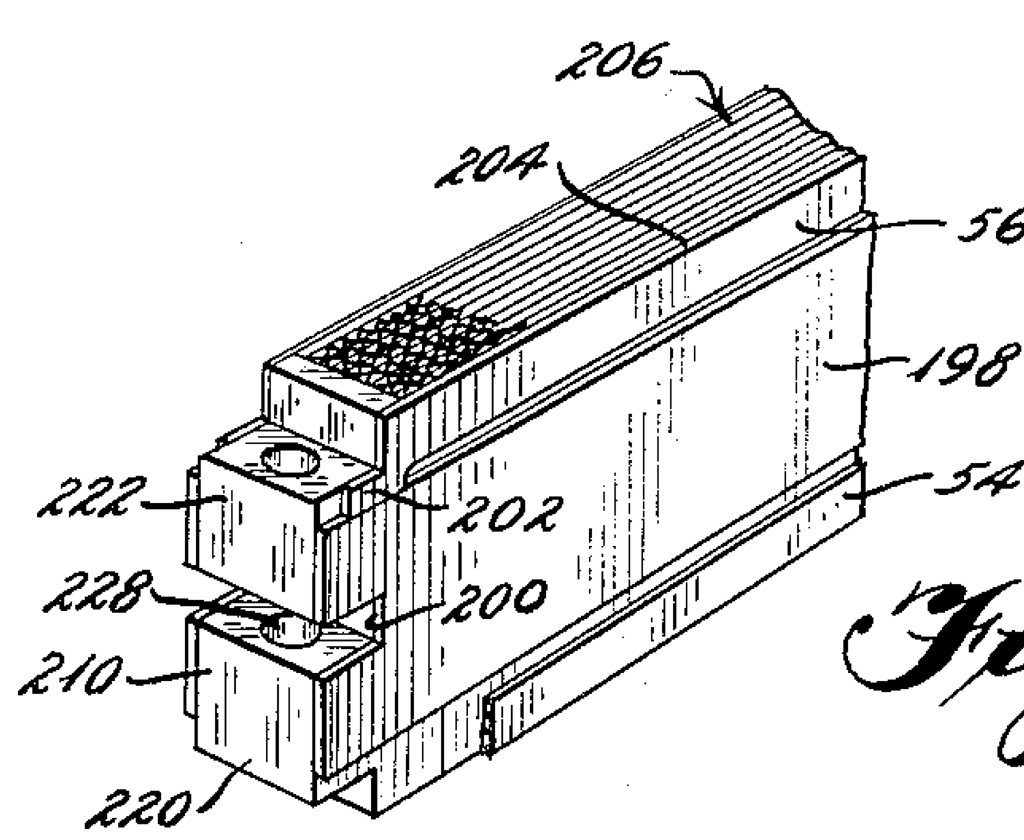


Fig. 13

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REGENERATORS

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Fig. 9

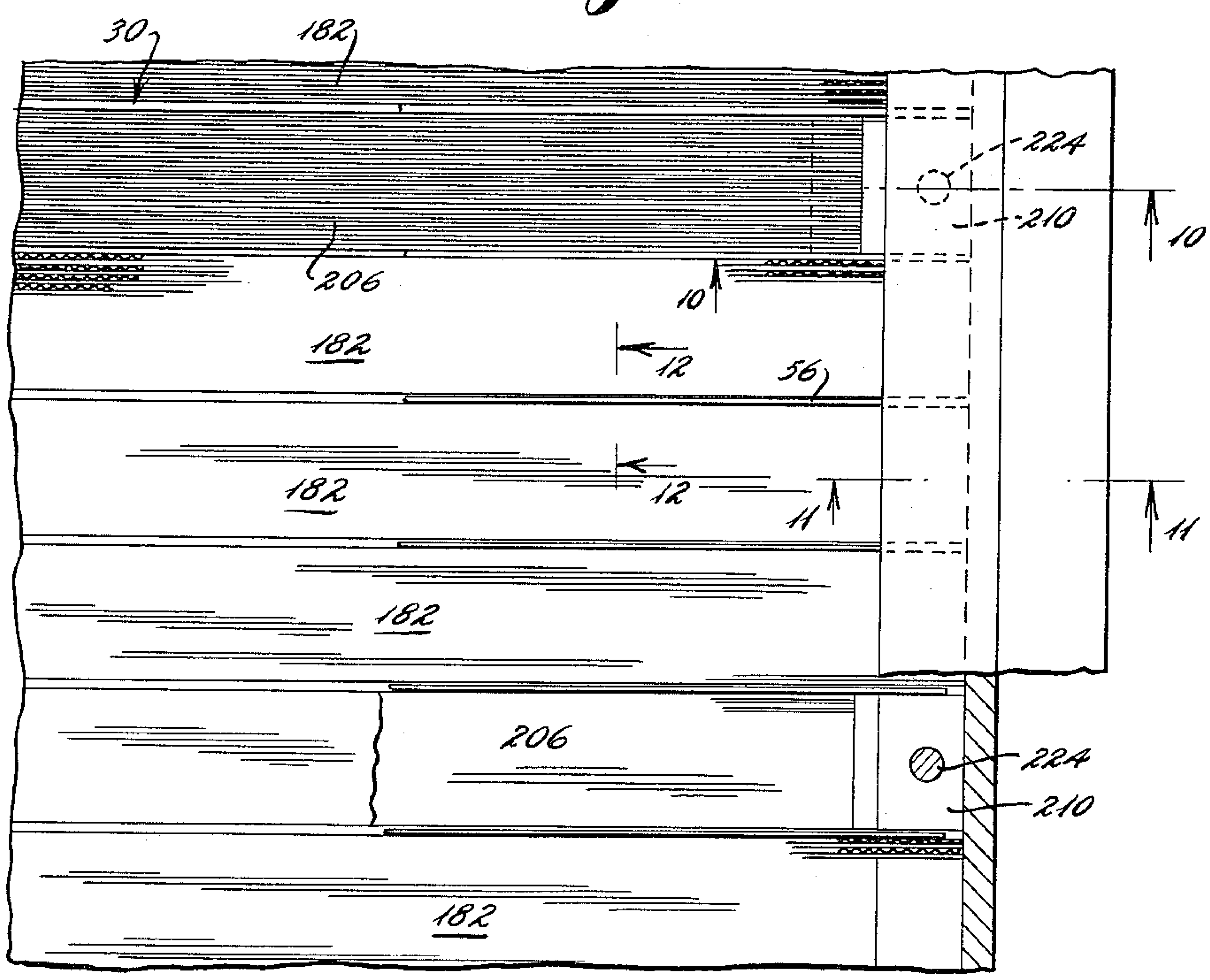


Fig. 10

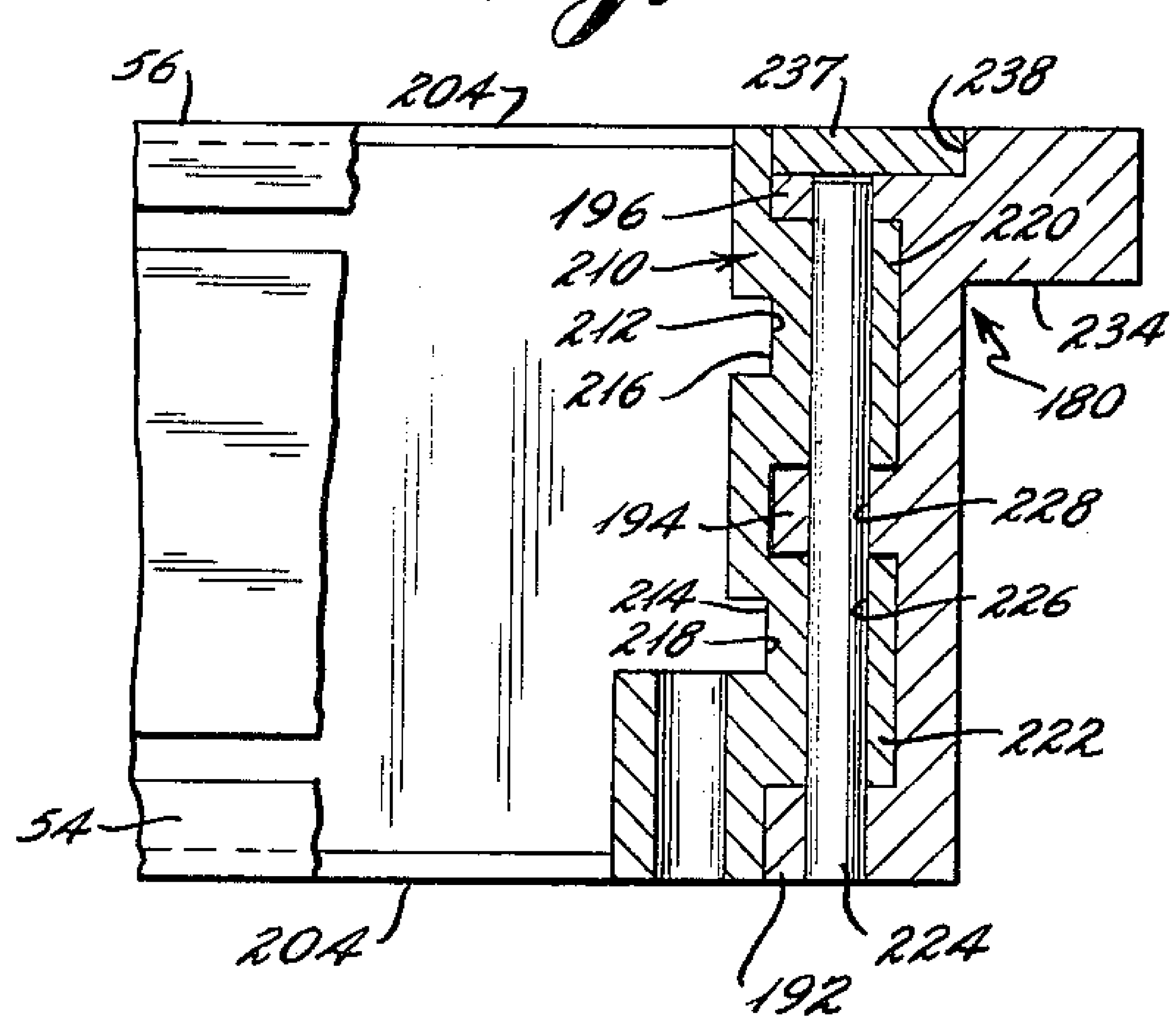
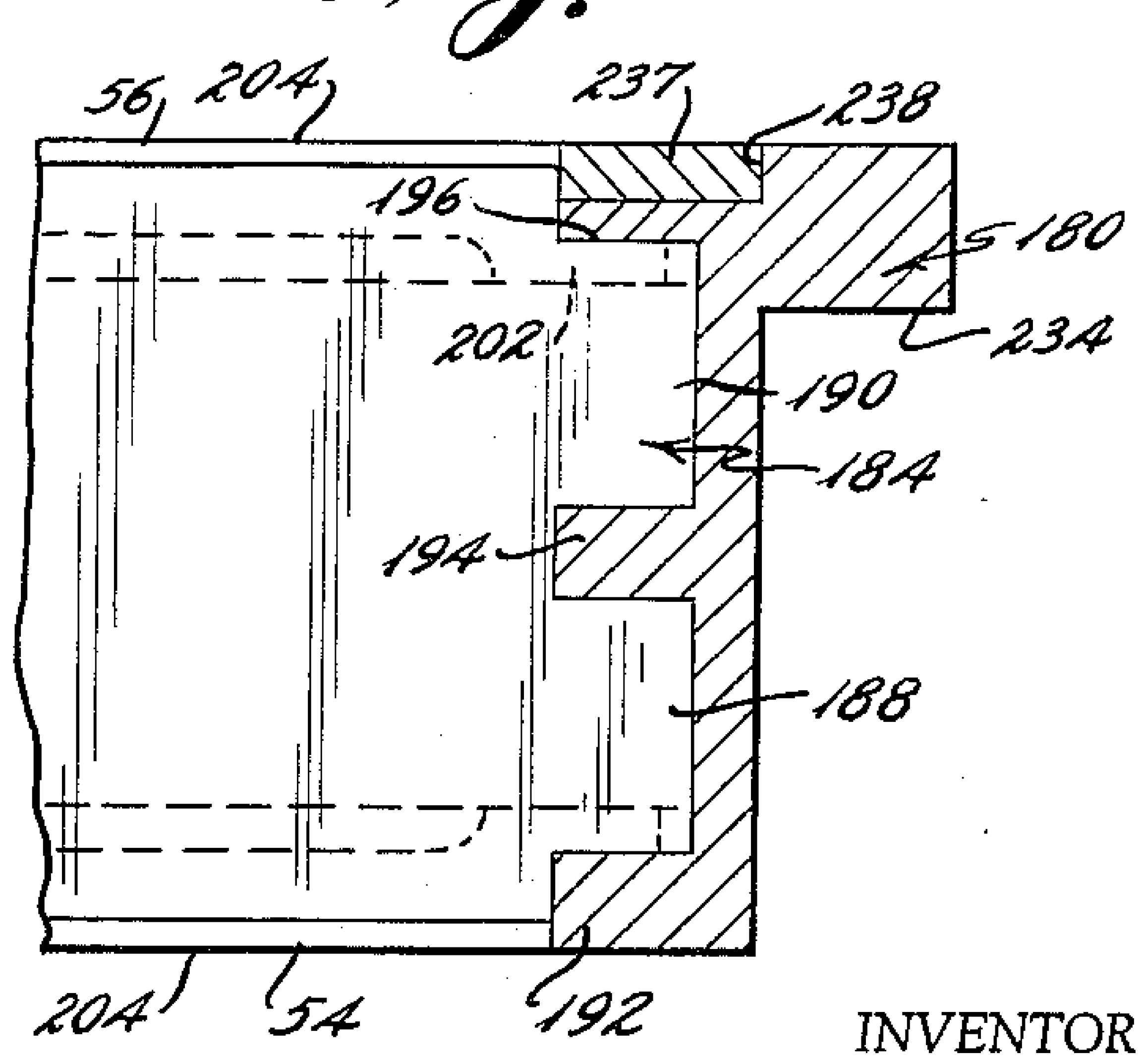


Fig. 11



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United States Patent Office

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3,216,487

REGENERATORS

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Filed Sept. 4, 1962, Ser. No. 221,032

17 Claims. (Cl. 165—9)

This invention relates to rotary gas regenerators and, more specifically, to improved means for preventing leakage between the high pressure air and low pressure gas sides of rotary regenerators.

Regenerators of the type to which the present invention relates include a housing divided by in internal partition into a high pressure air chamber and a low pressure gas chamber (generally termed the air side and the gas side) and a hollow, cylindrical drum or matrix fashioned of heat transfer elements supported in the housing and rotated by a drive connected to an external power source, normally the turbine output shaft. Heated gases, usually turbine exhaust gases at a relatively low pressure, are introduced into the gas side of the regenerator where they give up their heat to the rotating matrix. The heated portion of the matrix then passes from the gas side to the air side where it gives up the heat acquired from the gases to air introduced into the air side, generally by a turbine-driven compressor at a pressure substantially higher than that in the gas side. From the regenerator, the heated air is delivered to the turbine combustion chamber.

Use of such regenerators has long been advocated because of the significant increase in turbine efficiency effected by imparting to the combustion air otherwise wasted heat energy recovered from the turbine exhaust gases. However, the lack of effective sealing means for preventing the leakage of the relatively high pressure air into the low pressure gas side of the regenerator has generally precluded the use of such devices.

The sealing means most commonly employed heretofore for controlling such leakage has been a system of sealing shoes arranged on the inner and outer sides of and in rubbing contact with the rotating matrix. In the prior art regenerators, it has been the general practice to maximize the area of contact between the matrix and the sealing surfaces of the shoes to provide as effective a seal as possible. This approach has decided disadvantages.

First, rotary regenerators operate at such elevated temperatures that the rotating matrix undergoes substantial axial thermal growth during regenerator operation. Because the inner surface of the matrix is (in the conventional construction) contacted first by the hot gases entering the regenerator, the temperature at his surface may be as much as 800° F. higher than the temperature at its outer surface. Because of this temperature differential, the axial thermal growth of the matrix at its inner surface exceeds the growth at its outer surface, causing the inner matrix surface to assume an inwardly bowed configuration. This results in the formation of gaps between the matrix and the sealing shoes. Consequently, air can readily leak from the high pressure side past the matrix into the low pressure gas side of the regenerator. The deflection problem is particularly acute in the prior art regenerators since the heat transfer elements of the matrix are also the elements maintained in rubbing contact with the sealing shoes. These elements are necessarily made of a material having low heat conductivity and such materials have high coefficients of thermal expansion and the amount of bowing or deflection is therefore large.

A further disadvantage of the prior art large contact area rubbing type seals is that in this type of seal, the pressure drop across the sealing area results in the imposition of a unit rubbing load on the matrix of approximately one half the pressure differentiial between the air and gas sides of the regenerator. Since the pressure in the air side may be as high as 40 p.s.i.g. and the pressure in the gas side as low as 0.9 p.s.i.g., high magnitude rubbing loads result. The imposition of high loads on the matrix causes its surfaces to smear and thereby block the flow passages between the heat transfer elements of the matrix. The result is an unacceptable high pressure drop across and early mechanical failure of the matrix.

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In the present invention, the disadvantages of the prior art large contact area rubbing seals are eliminated by employing a labyrinth seal provided by the coaction of substantially conventional sealing shoes and a matrix of unique construction.

The novel matrix provided by the present invention is formed from heat transfer members of material having low heat conductivity. Arranged in pairs at equal intervals between and supported independently of the heat transfer members with one element adjacent each of the matrix surfaces are seal elements of material having a low coefficient of thermal expansion. The seal elements are free from contact with the heat transfer elements and have a width radially of the matrix but a fraction of the latter. Additionally, the seal elements have narrow sealing edges extending radially beyond the inner and outer edges of the heat transfer elements into contact with the sealing surfaces of the inner and outer sealing shoes.

As a result of this unique matrix construction, the heat transfer elements never contact the sealing shoes even though their inner surfaces bow inwardly as they are heated and smearing of the matrix surfaces with the attendant blockage of the flow passages between the heat transfer elements is eliminated, minimizing the pressure drop across the matrix and significantly prolonging its useful life.

Since the seal elements are formed from material having a low coefficient of expansion, since they are relatively narrow so that the differential temperature between their edges is relatively small, and since they are not connected to and therefore move independently of the heat transfer elements, bowing of these elements with the resultant formation of leak-permitting gaps is, for all practical purposes, eliminated. Further, the interval between elements is preferably selected so that there will always be three elements in contact with the sealing surface of each shoe. The result is a highly effective labyrinth seal between the matrix and the sealing surface. Additionally, the air and gas flowing through the matrix exert pressure on the edges of the seal elements opposite their sealing edges, forcing the elements in contact with the sealing surfaces.

It will be apparent from the foregoing discussion that it is an object of the present invention to provide improved rotary regenerators for gas turbines.

Another object of the present invention resides in the provision of rotary regenerators having improved sealing means for eliminating leakage from the high pressure air side to the low pressure gas side of the regenerator.

A further object of the present invention resides in the provision of rotary regenerator matrices which are less subject to mechanical failure than those of the prior art.

It is another object of the present invention to provide rotary regenerators having labyrinth type sealing means between their high pressure air sides and low pressure gas sides.

Another specific object of the present invention is the provision of rotary regenerators having rotating matrices, sealing shoes on the inner and outer sides of the matrices, and sealing spacers incorporated in the matrices and cooperating with sealing surfaces on said sealing shoes to prevent leakage from the high pressure air sides to the low pressure gas sides of the regenerators while maintaining the heat transfer elements of the matrices free of contact with the sealing surfaces.

In conjunction with the preceding object, it is another object of the present invention to provide improved matrices for rotary regenerators in which the heat transfer elements and sealing spacers are independent members.

Another object of the present invention is the provision, in rotary regenerators, of sealing means between the high pressure air side and the low pressure gas side which will remain effective despite the distortion resulting from the temperature differentials encountered during regenerator operation.

Yet another object of the present invention resides in the provision of rotary regenerator matrices amenable to the employment of heat transfer members of materials having lower thermal conductivity than has heretofore been possible.

In conjunction with the above object, it is another object of the present invention to provide rotary regenerator matrices having sealing members formed of materials having lower coefficients of expansion than has heretofore been possible.

Other objects and further novel features of the present invention will be apparent from the appended claims and as the ensuing detailed description and discussion proceeds in conjunction with the accompanying drawing, in which:

FIGURE 1 is a vertical section through a rotary regenerator constructed in accordance with the principles of the present invention;

FIGURE 2 is a fragmental section through the regenerator of FIGURE 1, taken substantially along line **2—2** of that figure, and illustrates the mechanism provided for supporting the regenerator matrix for rotational movement within the regenerator housing;

FIGURE 3 is a sectional view of the regenerator of FIGURE 1, taken substantially along line **3—3** of FIGURE 2, and illustrates details of the matrix-supporting rollers shown in FIGURE 2;

FIGURE 4 is a sectional view of the regenerator of FIGURE 1, taken substantially along line **4—4** of FIGURE 2, and illustrates the arrangement employed in the present invention for preventing leakage from the high pressure air side to the low pressure gas side of the regenerator;

FIGURE 5 is a fragmental sectional view of the regenerator, taken substantially along line **5—5** of FIGURE 2, illustrating the relation of the matrix to the matrix-supporting rollers;

FIGURE 6 is a sectional view of the regenerator, taken substantially along line **6—6** of FIGURE 5, and illustrates the sealing shoes employed in the present invention;

FIGURE 7 is a view, to an enlarged scale, of a portion of FIGURE 6, showing one of the spring-biased sealing strips employed to effect a seal between the inner sealing shoe and the regenerator housing;

FIGURE 8 is a sectional view through the sealing strip of FIGURE 7 and is taken substantially along line **8—8** of FIGURE 7;

FIGURE 9 is a fragmentary plan view of the novel matrix provided by the present invention;

FIGURE 10 is a sectional view of the matrix of FIGURE 9, taken substantially along line **10—10** of that figure, and illustrates a modular type heat transfer segment employed in the matrix;

FIGURE 11 is a sectional view of the matrix of FIGURE 9, taken substantially along line **11—11** of that figure, and illustrates a loose pack type heat transfer segment employed in the matrix;

FIGURE 12 is a sectional view of the matrix of FIGURE 9, taken substantially along line **12—12** of FIGURE 10, and illustrates the manner in which the seal elements are arranged between the heat transfer segments in the matrix; and

FIGURE 13 is a perspective view of the modular type heat transfer segment of FIGURE 9.

Referring now to FIGURE 1 of the drawing, the novel rotary regenerator **20** provided by the present invention has an airtight housing **22** divided by a horizontally extending, generally vertical, curved inner partition **24** into a high pressure air chamber **26** (the air side) and a low pressure gas chamber **28** (the gas side). Rotatably mounted in housing **22** is a hollow cylindrical drum or matrix **30** which is formed of a number of multi-element heat transfer segments and which may be rotated by any desired source of power, normally the turbine with which the regenerator is employed. In operation, heated gases, normally the exhaust gases from the turbine, are introduced through an inlet **32** into the gas side **28** of the regenerator where they flow through and heat the rotating matrix **30** and pass out an outlet **34**. At the same time, air is introduced, generally by the turbine compressor, through an inlet **36** into the air side **26** of the regenerator where it flows through and absorbs heat from the matrix **30** and passes through an outlet **38** to the turbine combustion chamber. The rotating matrix **30**, therefore, alternately extracts heat from the turbine exhaust gases and gives up this heat to the turbine combustion air which, being thus preheated, raises the operating efficiency of the turbine.

The turbine exhaust gases flow into the gas side **28** of the regenerator at a relatively low pressure, commonly on the order of 0.9 p.s.i.g. The combustion air, on the other hand, is delivered to the air side **26** of the regenerator at a much higher pressure, generally on the order of 40 p.s.i.g. Because of this substantial pressure differential, the combustion air will tend to leak to the gas side **28** of the regenerator between: (1) the outer surface **40** of the rotating matrix and regenerator housing **22**, (2) the inner surface **42** of the matrix and the edges **44** (only one of which is shown) of internal partition **24**, (3) the ends of the matrix and the end walls of the regenerator housing, and (4) the peripheral edges of the sealing shoes and the regenerator housing and internal partition. It is with a novel sealing arrangement for preventing such leakage that the present invention is primarily concerned. As shown in FIGURE 1, sealing arrangements indicated generally by numeral **45** are employed at both the upper and lower sides of internal partition **24**. Since the sealing arrangements at both locations are identical, only that at the upper side of partition **24** will be described.

Referring next to FIGURE 2, the sealing arrangement provided by the present invention includes an inner sealing shoe carrier assembly **46** providing an inner shoe **47** having a sealing surface **48** adjacent the inner surface **42** of matrix **30**, an outer sealing shoe **50** carried by carrier assembly **46** and providing a sealing surface **52** adjacent the outer surface **40** of matrix **30**, and a matrix construction including seal elements **54** and **56** which cooperate with the sealing surfaces **48** and **52** of the sealing shoes to provide a highly effective labyrinth seal between matrix **30** and the sealing surfaces. Leakage around the ends of matrix **30** is prevented by end seal shoes **58** and **60** (see FIGURE 6). To prevent leakage past the periphery of carrier **46**, a sealing strip assembly **62** (FIGURE 4) is disposed along the inner edge of assembly **46**, a sealing strip assembly **64** is disposed between the outer edge of assembly **46** and regenerator housing **22**, and an end sealing strip assembly **66** (FIGURE 6) is arranged between one end of assembly **46** and the adjacent end wall of the regenerator housing.

Referring further to FIGURES 4 and 6, shoe carrier **46** is a hollow, generally rectangular assembly formed from end members **68** and **70**, a top member **72** extending between end members **68** and **70**, and shoe assembly **47** extending between end members **68** and **70** in spaced relation to top member **72**. Shoe assembly **47** provides the sealing surface **48**. Shoe carrier **46** is pivotably mounted in regenerator housing **22** by outwardly directed bosses or trunnions **76** and **78**, formed on end members **68** and **70** respectively. Boss **76** extends through a circular aperture **80** in the end wall **82** of regenerator housing **22** while boss **78**, which is diametrically slotted at **79** and then plugged at **83** to form a passage for seal strip **66**, extends through a circular aperture **84** in an end cap assembly **86** fastened over an enlarged diameter aperture **88** in the vertical wall **90** of the regenerator housing. Cap assembly **86** is detachably fixed to regenerator housing side wall **90** by pins **92** and by socket head cap screws **94** and nut-like fasteners **96** and may be removed to gain access to the internal components of the regenerator.

Cylindrical bushings **98** and **100**, fixed in aperture **80** in regenerator housing end wall **82** and in aperture **84** in cap assembly **86** in surrounding relationship to trunnions **76** and **78** respectively, promote free rotational movement of shoe carrier **46** in its mounting. The pivotable mounting of shoe carrier **46** permits it to pivot to maintain shoe sealing surfaces **48** and **52** normal to the sealing edges of the seal elements **54** and **56** in matrix **30** during operation of the regenerator.

Shoe assembly **47** of carrier **46** includes end blocks **102** and **104** which are disposed between bars **105** and **106** (FIGURES 3 and 4) fastened to end members **68** and **70** by screws **107**. Extending between and fastened to end blocks **102** and **104** are lower and upper horizontal members **108** and **110** and a pair of spaced apart vertical side wall members **112** and **114**, all of these members being joined together as by brazing or welding. The hollow boxlike assembly thus formed is strengthened by transversely extending stiffener plates **116** fixed between members **112** and **114**. The top surface of the upper horizontal member **110** is the sealing surface **48** of the inner sealing shoe **47**.

As was pointed out previously, a sealing strip assembly **62** is arranged between carrier **46** and the edge **44** of regenerator housing interior partition **24** to prevent air from leaking between the carrier and the partition to the low pressure gas side **28** of the regenerator. Sealing strip assembly **62** includes a pair of generally channel-sectioned elongatd strips **118** and **120** (FIGURE 6) disposed in a slot **122** formed in and opening onto the lower surface of the bottom member **108** in shoe assembly **47**. As is best shown in FIGURES 4 and 7, the webs **124** of strips **118** and **120** contact the upper edge **44** of partition **24**, providing a seal between the partition and carrier **46**. Firm contact between the sealing strips and the partition is maintained by leaf springs **126** which extend between the ends of slot **122** in member **108** and the webs **124** of the sealing strips.

As is best shown in FIGURE 7, strip **118** is fixed to end member **68** of carrier **46** by a pin **128**. Sealing strip **120** (see FIGURE 8) is fixed to the lower end of end sealing strip assembly **66** by a pin **130**. Referring now to FIGURE 6, the adjacent inner ends of strips **118** and **120** are joined by a resilient strip connector **132** which accommodates thermal expansion and distortion of the strips **118** and **120** as the internal regenerator components are heated to elevated temperatures under operating conditions.

Returning now to FIGURES 4 and 6, the upper member **72** of carrier **46** comprises an upwardly opening channel which extends between and is fixed to end members **68** and **70** as by brazing or welding. Leakage of air to the gas side **28** of the regenerator between outer sealing shoe **50** and regenerator housing **22** is prevented by the sealing strip assembly **64** which is substantially identical to the sealing strip assembly **62** described above and which is mounted in the channel section upper member **72**. Its component parts have been identified by reference characters identical to those employed in describing sealing strip assembly **62**, but primed.

The outer sealing shoe **50**, which is supported by carrier **46**, includes a pair of L-sectioned bars **136** and **138** which cooperate to form a downwardly opening channel and are welded or brazed to top member of carrier **46** and, at their ends, to the carrier end members **68** and **70**. This assembly is strengthened by bars **140** and **142** welded to the L-shaped members **136** and **138** and to end members **68** and **70**.

Slidably mounted for movement radially of the matrix between L-sectioned members **136** and **138** is an outer shoe assembly **144** which includes an open sided rectangular frame formed from side members **145** and **146** and end members **147** and **148** and strengthened by intermediate transverse spacers **149**. Supporting blocks **150** fixed in notches **151** (FIGURE 6) at the ends of side members **145** and **146** support a longitudinally coextensive sealing member **152**. The lower side of sealing member **152** is the sealing surface **52** which, as explained above, cooperates with the seal elements **56** in matrix **30** to prevent leakage of air to the low pressure gas side **28** of the regenerator between the outer surface **40** of the matrix and regenerator housing **22**. Sealing member **152** is biased toward seal elements **56** by coil springs **154** which extend between the horizontal legs of L-sectioned members **136** and **138** and transversely extending retaining channels **156** fixed to the upper side of sealing member **152**.

End sealing strip assembly **66** is formed of three channel-sectioned members **166**, **168**, and **170** disposed between inner sealing shoe end member **70** and end cap assembly **86** in notch **79** in the end member (see FIGURE 5). Leaf springs **172** bias the sealing strips into engagement with the end cap assembly. Strips **166**, **168**, and **170** are joined by a connector **174**. These components of end sealing strip assembly **66** are substantially identical to the corresponding components in sealing strip assemblies **62** and **64** and are, therefore, not deemed to require further elaboration. End sealing strip assembly **66**, as noted previously, prevents air from leaking between the end of matrix **30** and regenerator housing cap assembly **86** to the low pressure gas side **28** of the regenerator.

At the opposite end of the regenerator, a gap **175** is left between end member **68** of shoe carrier **46** and regenerator housing side wall **82** to accommodate axial thermal growth of the sealing arrangement as the internal components of the regenerator heat up during regenerator operation. Annular sealing rings **176** and **177**, disposed in annular grooves of end member **68**, prevent the leakage of air through gap **175** to the gas side **28** of the regenerator.

Referring next to FIGURES 4 and 10–13, the hollow cylindrical rotating matrix **30** is constructed from two types of heat transfer member segments, "loose packs" and modular segments, supported by circular end rings **178** and **180**. The preferred embodiment of regenerator **20** has a matrix fabricated from **32** modular segments and **96** loose packs, there being three loose packs between each module.

Referring now specifically to FIGURES 11 and 12, each loose pack **182** consists of a stack or array of thin metallic leaves. In the preferred embodiment, a combination of flat leaves **184** and transversely convoluted leaves **186** is employed with the flat leaves **184** interspersed between the convoluted leaves **186**. Both the flat leaves **184** and the convoluted leaves **186** are fabricated from thin metal foil having low heat conductivity so that the heat transferred to the rotating matrix by the turbine exhaust gases in gas side **28** of the regenerator will not be dissipated before it can be transferred to the combustion air in the regenerator's air side **26**. Typically, the metal foil from which the flat and convoluted leaves **184** and **186** are fabricated will have a thickness ranging from 0.001 to 0.005 inches and the convolutions in leaves **186** will have a depth on the order of 0.017 inch.

Longitudinally extending, vertically spaced projections **188** and **190** (FIGURE 11) are formed on the ends of both the flat and convoluted leaves **184** and **186**. When the loose packs **182** are assembled into end rings **178** and **180**, projections **188** extend between annularly extending, inner and intermediate flanges **192** and **194** formed on the end rings and projections **190** extend between intermediate flanges **194** and inwardly directed annularly extending flanges **196** formed adjacent the outer edges of the end rings. Assembled into matrix **30** between the juxtaposed flat leaves **184** of adjacent loose packs **182** are side plates **198** (FIGURES 6, 12 and 13). Side plates **198** are provided with spaced, axially directed tabs defining notches **200** supportingly interfitted around the inwardly directed annular projections **194** on end rings **178** and **180**. Side plates **198** are formed of metal preferably with a thickness of about 0.050 inch.

Assembled into matrix **30** adjacent the inner and outer edges of each side plate **198** are identical seal elements **54** and **56**. Because of this identity, only the seal elements **56** will be described in detail.

Seal element **56** (FIGURES 6 and 12) is a thin, narrow, elongated strip of metal having a low coefficient of thermal expansion. Typically, element **56** is about 0.038 inch thick and has a central body width, in the radial direction, of 0.366 inch. Depending, outwardly directed feet **202**, formed on the central body ends of element **56**, extend into the spaces provided between the inner edge of the associated side plate **198** and the inwardly extending end ring flanges **192**. Feet **202** space the opposing edges of the central body of element **56** from side plate **198** so that side plate **198** will not contact and distort the seal element even though the side plate is bowed or deflected radially by thermal expansion under normal operation condition.

Since the seal elements **54** and **56** are fashioned from metal having a low coefficient of thermal expansion and a relatively small width in the radial direction, radial bowing or curving of the seal elements under normal operating conditions will be inconsequential. As a consequence, gaps will not be formed between the sealing edges **204** of the seal elements and the sealing surfaces of the sealing shoes as in the prior art sealing arrangements. Side plate **198**, being substantially thicker than seal elements **54** and **56**, prevent the heat transfer segments, as they swell under thermal expansion, from pressing against and distorting the seal elements.

As best shown in FIGURE 11, the sealing edges **204** of seal elements **54** and **56** extend beyond the inner and outer edges, respectively, of the heat transfer leaves **182** and **184**. Thus, the heat transfer leaves are maintained out of contact with the sealing surfaces **48** and **52** of the inner and outer sealing shoes. This eliminates the smearing and consequent blockage of the fluid flow channels between the heat transfer elements, an objectional condition common in the prior art arrangements in which the heat transfer elements are designed to sealingly contact the sealing surfaces **48** and **52**.

If the preferred number of loose packs and modular segments is employed, the sealing edges of three seal elements **54** and **56** will always be in contact with the sealing surfaces **48** and **52** of the inner and outer sealing shoes **46** and **50**, respectively. This provides a highly effective labyrinth seal, preventing air from leaking between matrix **30** and the sealing surfaces **48** and **52** to the low pressure gas side **28** of the regenerator. The labyrinth seal is made even more effective by the high pressure air in air side **26** of the regenerator which acts against the inner edges of seal elements **54** and **56**, forcing them radially outwardly and inwardly, respectively, thereby assuring firm contact between their sealing edges and sealing surfaces **48** and **52**.

Referring now to FIGURES 10 and 13, modular heat transfer segments **206**, like loose packs **182**, are formed from a stack of alternating flat and convoluted leaves **184** and **186** fabricated from metal having low heat conductance. The convoluted leaves are tapered slightly in a radial inward direction so that a wedge-shaped segment which can be readily assembled into the hollow cylindrical configuration of matrix **30** will be obtained. (Tapering of the convoluted leaves is not necessary in the loose packs because the ends of the leaves are not rigidly fixed to the end rings and the leaves will tilt slightly and their convolutions will spread to provide the desired configuration during the assembly process). In the modular segments these leaves are fixed, as by brazing, to slightly tapered, wedge-like end blocks **210** (only one of which is shown). As shown in FIGURE 10, leaf-supporting lugs **212** and **214** formed on the ends of both the flat and convoluted leaves **184** and **186** extend into correspondingly configured recesses **216** and **218** in the end blocks **210**. Fixed to one side of each segment is a side plate **198** and seal elements **54** and **56**, all of which are identical to the correspondingly numbered components described above in conjunction with loose packs **182**.

The completed modular segments **206** are assembled between the end rings **178** and **180** of matrix **30** with outwardly directed lugs or projections **220** on the end blocks extending between the inwardly directed flanges **194** and **196** on the end rings and similar projections **222** on the end blocks extending between end ring flanges **192** and **194**. The modular segments **206** are retained in place by pins **224** which extend through aligned apertures **226** and **228** in the end block **210** and the flanges of end rings **178** and **180**, respectively.

Referring now to FIGURES 2, 3, and 5, the assembled matrix **30** is rotatably supported in regenerator housing **22** by a pair of rollers **230** which are, in turn, supported by the seal shoe carrier side members **68** and **70**. As is best shown in FIGURE 5, the rollers **230** are located on opposite sides of end seals **58** and **60** (and outer sealing shoe **50**), are rotatably mounted upon stub shafts **232** which extend inwardly from seal shoe carrier members **68** and **70**, and are retained in place by end caps **233** (see FIGURES 2 and 5) fixed to the stub shafts by Allen head screws (not shown). Outwardly directed, annular shoulders **234**, formed on matrix end rings **178** and **180**, rest and ride on the rollers **230** which thereby support the rotating matrix. As was pointed out above, matrix **30** is continuously rotated from an external source of power, generally the turbine output shaft. Gear teeth **236** (see FIGURE 5), formed on matrix end ring **178** engageable by a driving gear (not shown) rotate the matrix. Wear bands **237** (FIGURES 2, 6, 10 and 11), fixed in notches **238** in the outer edges of matrix end rings **178** and **180**, engage the sealing surface **52** of outer sealing shoe **50** and prevent the end rings from being eroded by rubbing contact with sealing member **152** as matrix **30** is rotated.

As was mentioned above, leakage of air around the ends of matrix **30** to the low pressure gas side **28** of the regenerator is prevented by end sealing members **58** and **60**. Turning now to FIGURES 5 and 6, end sealing member **60** (and end sealing member **58** is identical) is a rectangularly sectioned block of metal having a seal face **239** which engages the outer edge of matrix end ring **180** below shoulder **234** of the end ring, a face **240** which engages the underside of annular shoulder **234**, and a face **242** which engages the outer face of the end ring superjacent shoulder **234**. The engaging surfaces of end sealing member **60** and matrix end ring **180** are preferably case hardened or otherwise made wear resistant to accommodate the continuous rubbing contact between them.

End sealing member **60** is biased against matrix end ring **178** by a pair of coil springs **244** (FIGURE 6) which extend from seal shoe carrier member **70** into pockets or recesses **246** formed in end sealing member **60**. A third spring **248**, which extends from inner sealing shoe member **104** upwardly into a pocket **250** opening through the lower edge of end sealing member **60**, biases the end sealing member 60 into engagement with matrix end ring annular shoulder 234.

Transversely extending strips 251, fixed by cap screws 252 to end block 150 in outer sealing shoe 50 are separated from the end block by shims 253 disposed at two spaced points at each end. By varying the thickness of shims 253, sealing member 150 can be adjusted radially of the matrix 30 and canted to maintain sealing face 52 spaced uniformly .002 to .005 inches from the matrix peripheral face 40 defined by the seal elements 56 and end rings 178 and 180.

The construction of matrix 30 is not limited to the combination of modular and loose pack heat transfer segments described above. Alternatively, matrices fabricated entirely of modular or loose pack segments or of varying ratios of modular to loose pack segments may be employed. The difficulty with employing only modular segments is that it may be difficult to fabricate sets of segments which will exactly fit into the matrix pattern due to the close tolerances required. While loose pack segments avoid this problem, they are more difficult to handle than the modular segments. Thus, from a practical standpoint, a combination of modular and loose pack segments is preferred.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by Letters Patent is:

1. A matrix for a rotary regenerator, comprising: a plurality of elongated heat transfer elements; means confining said elements into a hollow cylindrical configuration having concentric inner and outer surfaces defined by the opposed mating edges of the heat transfer elements; and sealing means including sealing elements arranged in generally parallel relationship to said heat transfer elements, said sealing elements being free of connection to and movable independently of the heat transfer elements and having edges protruding beyond said inner and outer surfaces, and means for preventing said heat transfer elements from expanding against and binding said sealing elements, said last-named means comprising side plates adjacent said sealing elements, said side plates being substantially thicker than said sealing elements.

2. The matrix as defined in claim 1, wherein said heat transfer elements are loosely assembled into plural-membered matrix segments and some of said elements are formed to provide passages between their opposite edges.

3. The matrix as defined in claim 1, wherein a portion of said elements are loosely assembled into plural-membered matrix segments and the remainder of said elements are assembled into modular matrix segments interspersed at intervals among said first-named segments.

4. The matrix as defined in claim 1, wherein said heat transfer elements are formed of material having low heat conductance.

5. The matrix as defined in claim 1, wherein the material from which said sealing elements are formed has a low coefficient of thermal expansion.

6. The matrix as defined in claim 3, wherein said modular segments have a tapered cross section to facilitate assembly of said segments into said cylindrical configuration.

7. The matrix as defined in claim 1, wherein a pair of sealing elements are associated with each of said side plates, said sealing elements being disposed adjacent the opposite edges of said plates.

8. The matrix as defined in claim 1, wherein the coefficient of expansion of the material from which the sealing elements are formed is substantially lower than that of the material from which the heat transfer elements are formed.

9. The matrix as defined in claim 1, wherein the dimension of said sealing elements in a direction normal to said inner and outer surfaces is a relatively small fraction of the distance between said surfaces.

10. A modular segment for use in constructing a rotary regenerator matrix having a hollow cylindrical configuration, comprising: a plurality of elongated heat transfer elements disposed in side-by-side relationship, at least some of said elements being configured to provide passages extending between opposite edges of said segment, said heat transfer elements being free of connection and movable relative to each other; end members attached to said elements to retain them in side-by-side assembled relationship, said segment having the configuration of a wedge; a side spacer plate extending between and fixed to said end members on one side of said segment adjacent the outermost of said heat transfer elements; and inner and outer sealing elements fixed to and extending between said end members adjacent the opposite sides of said spacer plate, said inner and outer sealing elements having sealing edge portions extending radially beyond the inner and outer edges of said heat transfer elements.

11. A rotary gas regenerator, comprising: a housing, a hollow cylindrical matrix comprising a large number of heat transfer elements assembled in side-by-side relationship rotatably mounted in said housing; internal partition means dividing said housing into first and second chambers, said partition means having openings therein for passage of said matrix between said chambers; means providing an inlet to and an outlet from each of said chambers; sealing shoes providing sealing surfaces on the walls of said openings adjacent the inner and outer surfaces of said matrix, said sealing shoes being mounted in said housing for movement about a line parallel to the rotation axis of said matrix, whereby said sealing shoes may pivot to maintain said sealing surfaces normal to the sealing edge of said seal means; and seal means in said matrix extending radially therefrom and cooperating with said sealing surfaces to prevent the passage of fluid from one to the other of said chambers, said seal means including members free of connection to and movable independently of said heat transfer elements in sealing contact with said sealing surfaces over substantially the entire length of said matrix.

12. In a rotary gas regenerator; a housing; a hollow cylindrical matrix comprising a large number of heat transfer elements assembled in side-by-side relationship extending substantially the length of and rotatably mounted in said housing; partition means extending the length of said housing through the hollow interior of said matrix and dividing said housing into high and low pressure chambers; spaced first and second sealing means for preventing the passage of fluid from one to the other of said chambers, said first sealing means comprising means providing an inlet to and an outlet from each of said chambers; a first sealing shoe extending the length of and supported by said housing between said housing and a side edge of said partition, said sealing shoe having an aperture through which said matrix extends and means providing a sealing surface adjacent one side of said matrix; a second sealing shoe carried by said first shoe and providing a sealing surface adjacent the opposite side of said matrix; and sealing elements in said matrix cooperating with said sealing surfaces to form labyrinth seals between said partition and said matrix and between said matrix and said housing, said sealing elements being free of connection to and movable independently of the heat transfer elements.

13. The rotary gas regenerator as defined in claim 12, including resilient biasing means between said first and second sealing shoes to bias the sealing surface of said

second shoe into engagement with said sealing elements.

14. The rotary gas regenerator as defined in claim **12**, including sealing strips carried by said first sealing shoe between said shoe and said partition and housing, respectively, and resilient means between said shoe and said strips biasing said strips into engagement with said housing and said partition.

15. The rotary gas regenerator as defined in claim **12**, wherein said first sealing shoe has end walls adjacent the ends of said matrix and including end sealing shoes and resilient means between said end walls and said sealing shoes biasing said sealing shoes into engagement with the ends of said matrix.

16. The rotary gas regenerator as defined in claim **12**, wherein said first sealing shoe and said regenerator housing have juxtaposed end walls and including a sealing strip between one of said sealing shoe end walls and the juxtaposed housing end wall and resilient means between said sealing shoe end wall and said strip biasing said strip into engagement with said housing end wall, there being a space between the other sealing shoe end wall and the juxtaposed housing end wall to accommodate thermal expansion of said sealing shoes.

17. The rotary gas regenerator as defined in claim **12**, including rollers carried by said first sealing shoe at the ends of said matrix and wherein said matrix includes end rings with flanges extending over and riding on said rollers.

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