May 10, 1966 A. L. NYBERG **3,250,316**

REGENERATIVE HEAT EXCHANGERS

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Fig. 2

PRIOR ART

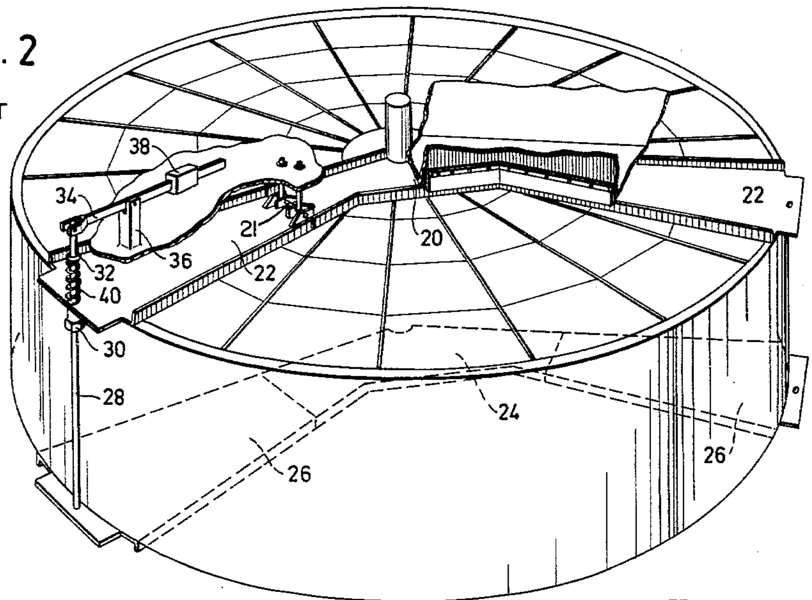


Fig. 1

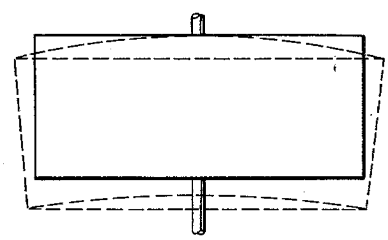
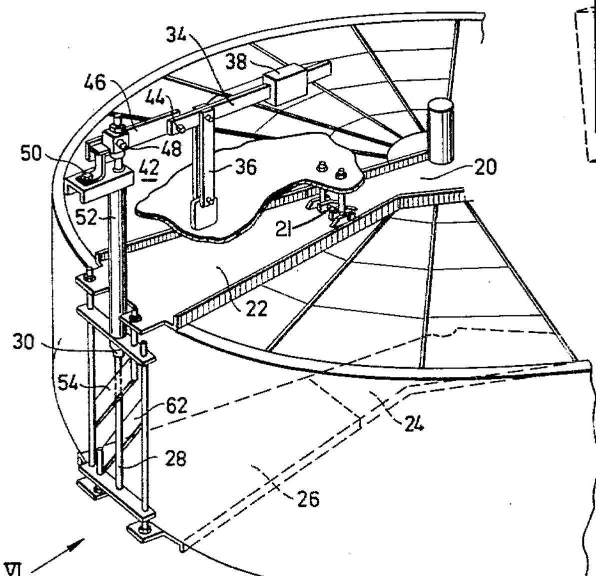


Fig. 3



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REGENERATIVE HEAT EXCHANGERS

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Fig. 4

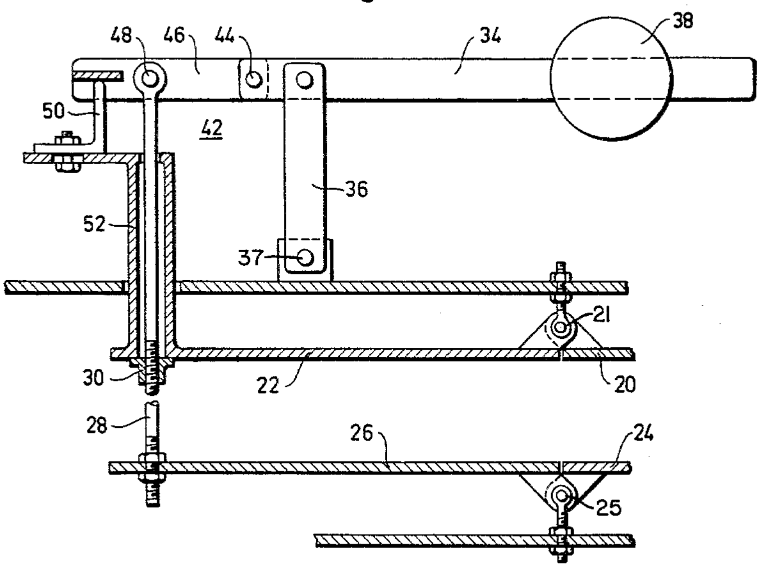
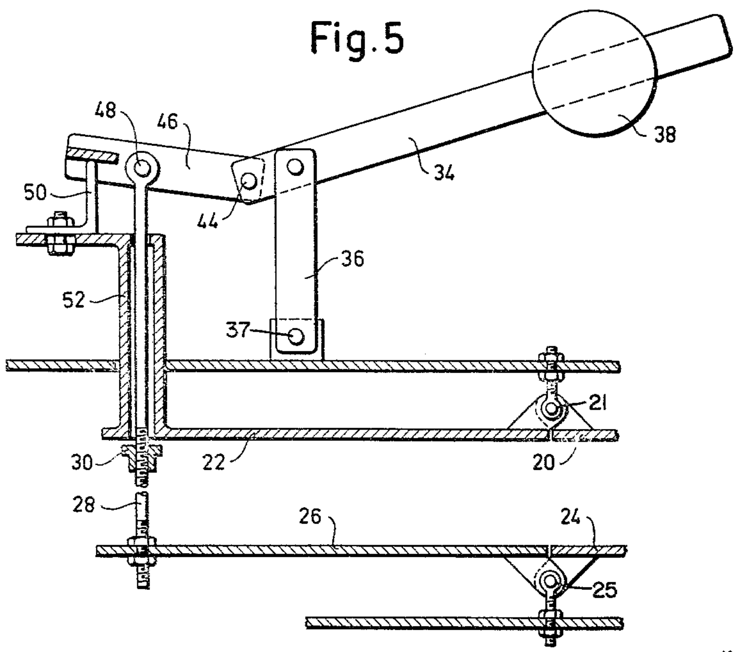


Fig. 5



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REGENERATIVE HEAT EXCHANGERS

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Fig. 6

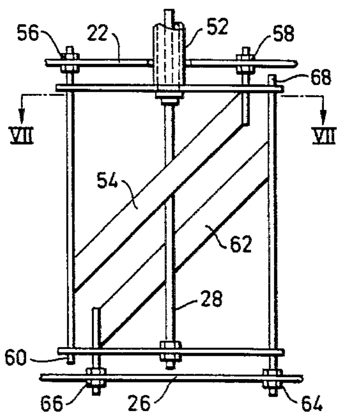

Fig. 7

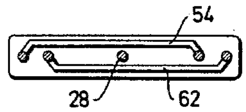

Fig. 8

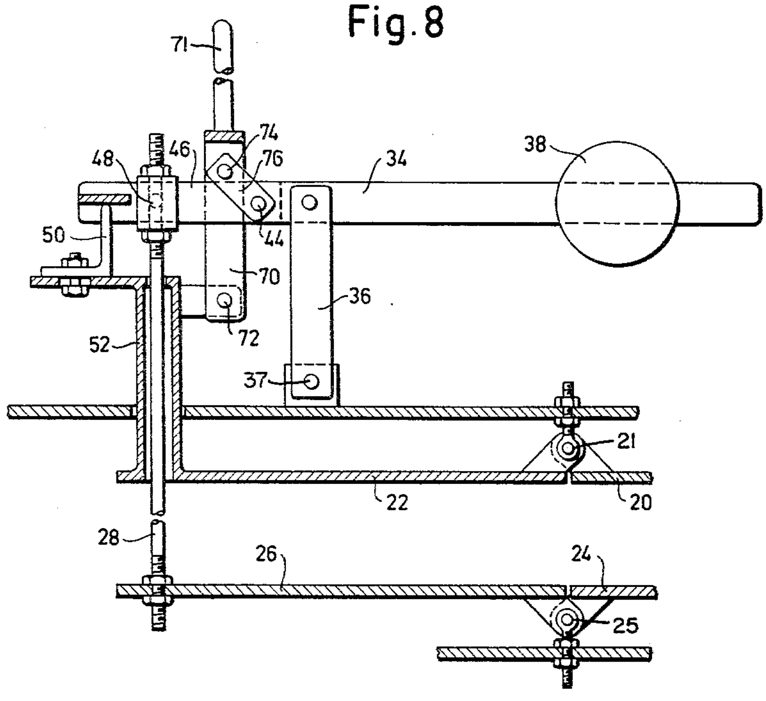

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Fig. 9

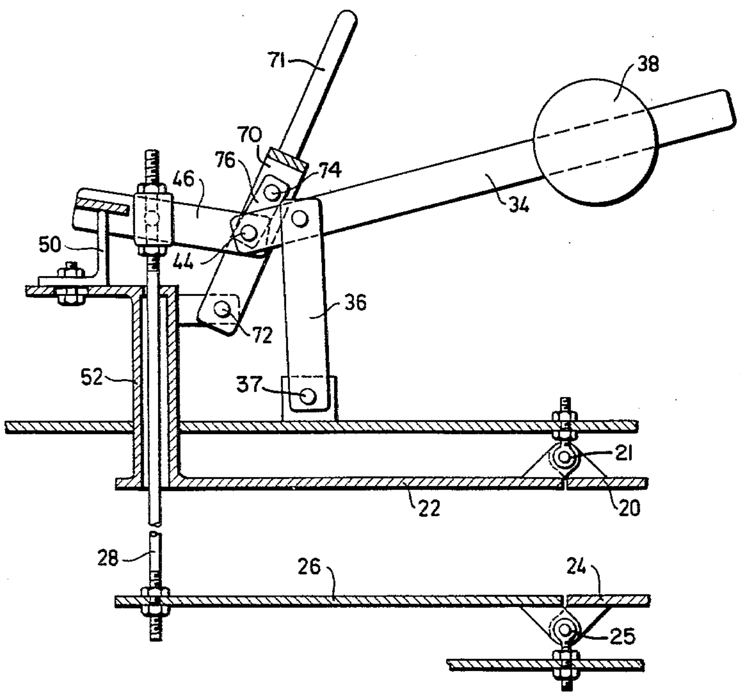
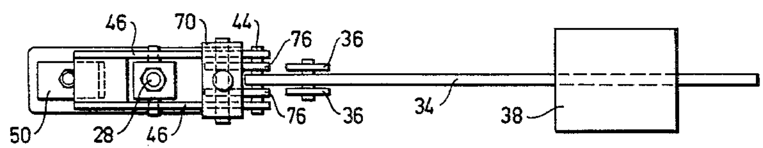


Fig. 10



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REGENERATIVE HEAT EXCHANGERS

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Fig. 11

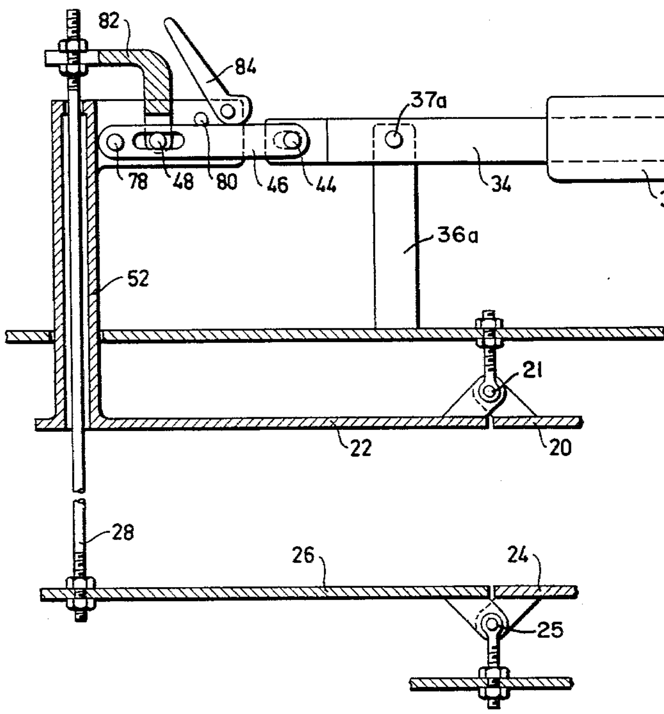
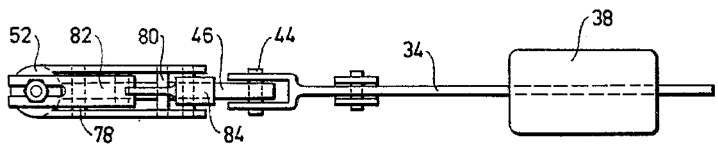


Fig. 12



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REGENERATIVE HEAT EXCHANGERS

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Fig.13

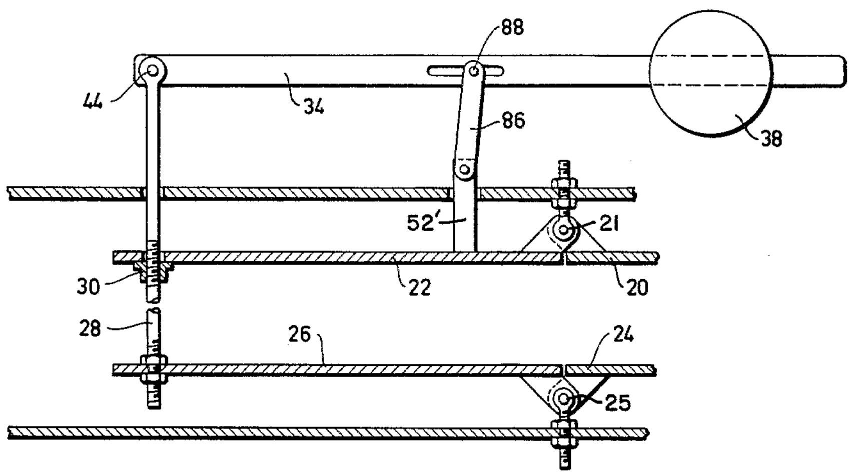
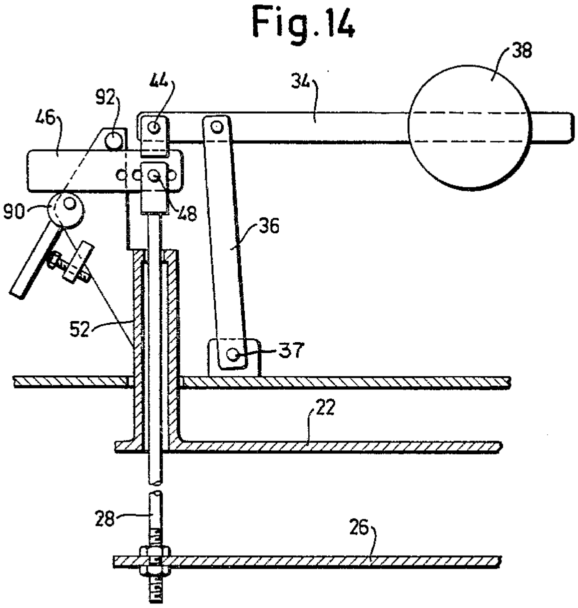


Fig.14



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United States Patent Office 3,250,316
Patented May 10, 1966

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3,250,316
REGENERATIVE HEAT EXCHANGERS

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Filed Apr. 16, 1964, Ser. No. 360,263
16 Claims. (Cl. 165—9)

This invention relates to regenerative heat exchangers, for instance such as used in thermal power plants for heating combustion air by means of hot flue gases. A heat exchanger of this kind comprises two principal components or parts rotatably mounted in relation to each other around a common and usually substantially vertical axis.

One of these components comprises a substantially cylindrical heat transferring part containing a regenerative mass while the other part comprises ducts having axial inlets and outlets for the heat emitting and heat absorbing media, said inlets and outlets being separated by sector shaped plates located in sealing proximity to the end surfaces of the cylindrical part and hinged to axially fixed center plates provided at the ends of the cylindrical part and secured to the duct part. Each sector plate at one end of the cylindrical part is axially aligned with a sector plate at the opposite end of said part and yieldably connected to said last mentioned plate at its outer end by means comprising a stop member limiting the movement of the sector plate ends towards each other and a counter-weight counterbalancing the weight of the sector plates and elements carried by said plates.

Usually the cylindrical parts is subdivided into several compartments by means of radial partitions which carry sealing strips or the like moving in close proximity to the sector plates in order to prevent leakage flows between the inlet and outlet at each end of the cylindrical part. A prerequisite for the proper operation of such a sealing device is that the distance between the sector plates remains substantially constant during operation. However, due to a non-uniform temperature distribution the cylindrical part is subject to thermal distortion and warping but thanks to their hinged connections the sector plates adapt themselves to the varying form of the cylindrical part during the starting period and at load variations. In accordance with the prior art the sector plates are biased towards each other by spring means which hold the sector plates in a normal working position in which the distance between the plates is minimum as determined by the stop member. Further, the counter-balancing system is made such that as to its function it is independent of the swinging positions of the sector plates. Therefore the plates may swing in common in parallel relationship without causing any changes of the force holding them together.

The spring means are stressed so as to withstand the forces caused by the gas pressure in the cylindrical part which forces tend to separate the sector plates. However, under the influence of the high temperature the strength of the springs decreases relatively rapidly due to fatigue and ageing and it is therefore necessary to initially oversize the springs in order to increase their service life. Thus, initially the sector plates are held together by a force which is unnecessarily great.

Under certain conditions, such as at overload, the cylindrical part may be deformed to such an extent that the sealing strips come in mechanical contact with the sector plates and tend to separate them. In a new plant this will result in a relatively high contact pressure involving risks of jamming. Due to the characteristic properties of a spring the contact pressure increases at increasing deflection of the plates.

The present invention has for its object to eliminate this drawback. This is accomplished having each of two interconnected sector plates carry a primary element pivotally connected to a linkage system of levers actuated by the counter-weight, the points of attachment of the elements to the system being located and the system being designed so that the balancing force exerted by the counter-weight produces a force which tends to move the sector plates towards each other and which is substantially independent of the distance between the plates.

In such a device the force tending to hold the plates together remains constant independent of temperature, operating time, magnitude of plate deflection and other conditions. It is therefore possible initially to adjust the device so that said force is just sufficiently great to withstand the gas pressure acting on the plates. If the cylindrical part is abnormally deformed and comes in contact with the plates these plates will yield to such a low contact pressure that the device cannot be damaged even though the abnormal condition should prevail during a relatively long time.

Although it is obvious that the invention is applicable to heat exchangers having a stationary component carrying the regenerative mass and a rotating component comprising fluid ducts, as well as to heat exchangers having a rotating component carrying the regenerative mass, hereinafter referred to as a rotor, and a stationary component comprising fluid ducts, the following specification describes by way of example the last-mentioned kind of heat exchangers for the sake of simplicity.

The invention may be best understood upon consideration of the following detailed description of illustrative embodiments thereof, when read in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagrammatic view of a rotor where the dashed lines indicate the deformation of the rotor.

FIG. 2 is a simplified perspective view of a rotor and hinged sector shaped plates cooperating therewith, which plates are counter-balanced and kept at desired distance from each other in accordance with known practice.

FIG. 3 is a simplified fragmentary perspective view of a rotor and hinged sector shaped plates counter-balanced and kept at desired distance from each other in accordance with the principles of the invention.

FIGS. 4 and 5 are partial vertical sections through the embodiment shown in FIGURE 3.

FIG. 6 shows on a larger scale a detail of FIGURE 3 viewed in direction of arrow VI in said figure.

FIG. 7 is a section on the line VII—VII in FIGURE 6.

FIGS. 8 and 9 show partial vertical sections of another embodiment of the invention.

FIG. 10 is a top view of the embodiment shown in FIGURE 8.

FIG. 11 shows a partial vertical section of a further embodiment of the invention.

FIG. 12 is a top view of the embodiment shown in FIGURE 11.

FIGS. 13 and 14 show partial vertical sections of two further embodiments of the invention.

As different parts of the rotor are exposed to different temperatures the rotor will be deformed as indicated with dashed lines in FIGURE 1. To permit the sector shaped plates to remain in sealing proximity to the rotor independent of its deformation they must be axially movable.

The center plates **20, 24** are fixed to the stationary casing, and the sector shaped plates **22, 26** are hinged respectively, to the center plates **20, 24**, by hinges **21, 25**. A rod **28** fixed to the lower sector plate **26** and provided with two stops **30** and **32** is pivotally connected to a lever **34** supported by the casing through a link **36** and provided with a counterweight **38**. The upper sector plate **22** rests against the stop **30** and is pressed against said stop by means of a spring **40** inserted between the upper side of the sector plate **22** and the stop **32**. In order to move the sector plates apart it is necessary to apply between the plates a force corresponding to the sum of the weight of the upper sector plate **22** and the pre-tension of the spring **40**. This pre-tension must be of such a magnitude that the plates cannot be separated by the gas pressure in the rotor.

The operation of this known embodiment is as follows:

The weights of the sector plates **22** and **26** are counter-balanced by the counter-weight **38** which means that only a very little force is required to swing the plates in common. Thus, a normal deformation of the rotor is possible without any risk of harmful contact pressures between the rotor and the sector plates.

If the axial deformation, however, is bigger than the clearances between the sector plates and the rotor, a force tends to separate the sector plates **22** and **26**.

Owing to the high temperature the strength of the spring decreases in course of time due to fatigue and ageing and the spring must therefore be oversized as indicated in the introductory part of this specification. The force required to swing the sector plates apart may thus be considerable resulting in risk of jamming. In addition, this force increases with increasing deflection of the plates.

In FIG. 3 the sector plates **22** and **26** are connected by means of a lever system, generally denoted at **42**, suspended on a pivot **44** on the lever **34**. The operation of the lever system may easiest be seen in FIGS. 4 and 5. A rod **28**, fixed to the lower sector plate **26** and provided with an adjustable stop **30** against which the plate **22** rests, is pivotally connected to a suspension lever **46** at a point **48** between the lever ends. One end of the lever **46** is pivotally connected to the lever **34** at **44** and the other end of the lever **46** is supported by an element **50** fixed to the upper sector plate **22** by means of a tubular member **52** which surrounds the rod **28**. The lever **34** is carried by the casing by means of a link **36**, one end of which being pivotally connected to the lever **34** while the other end is on the casing so as to permit a linear expansion of the sector plates without bending of the rod **28** and the tubular member **52**.

Also in this case the weight of the swingable system inclusive of the hinged sector plates is counter-balanced by the counter-weight **38**, the balancing force being applied at the pivot **44**. This force tends to swing the suspension lever **46** counter-clockwise about the pivot **48** which may be regarded as stationary for the sake of simplicity. This means that the element **50** is pressed downwardly by a force which is proportional to the weight of the suspended system and the magnitude of which is dependent on the lever ratio of the lever **46**. This last-mentioned force corresponds to the pre-tension of spring **40** in the known device described above and may be adjusted by adjustment of the contact point between the element **50** and the lever **46**.

As distinguished from the spring force the force derived from the balancing force remains constant under all conditions and need not therefore be greater than what is necessary to prevent the sector plates from being separated by the gas pressure. Thus, in case of an excessive axial deformation of the rotor the sector plates will yield to very small contact pressures between the plates and the rotor. FIG. 5 illustrates the positions of the different members at such an excessive rotor deformation.

To prevent the non-uniform load caused by the gas forces from twisting the plates **22** and **26**, there is provided a guide system keeping the plates parallel to each other. According to FIGS. 6 and 7 a plate **54** is fixed to the sector plate **22** by means of bolts **56** and **58** and by means of a pin **60** guided in a guideway fixed to the plate **26**. A plate **62** is correspondingly fixed to the plate **26** by means of bolts **64** and **66** and by means of a pin **68** guided in a guide way fixed to the sector plate **22**.

FIGS. 8–10 show another embodiment of the invention. Here a link **70** is connected to the tubular member **52** by means of a pivot **72** and a pivot **74** on the link **70** rests against the suspension lever **46**. A link **76** connects the pivot **74** with the pivot **44** to which the counter-balancing force is applied.

From FIG. 8 it is clear that the lever **46** cannot be swung counter-clockwise and therefore the sector plates cannot be moved towards each other from the position shown. The minimum distance between the sector plates may be adjusted by adjustment of the pivot **48** along the bar **28**.

The operation of this device is substantially the same as that of the embodiment according to FIGS. 3 to 5. When the rotor is excessively deformed the sector plates **22, 26** are moved apart and the different members will then occupy the positions shown in FIG. 9.

The link **70** is provided with a handle **71** by means of which the link may be swung manually from the position shown in FIG. 8 to the position shown in FIG. 9, the links **70** and **76** then acting as a toggle-joint device so that the lever **46** is swung clockwise. Thus, if desired, the sector plates may be separated manually.

In the embodiment shown in FIGS. 11 and 12 the pivot **44** connecting the levers **34** and **46** is guided in an oblong hole in the lever **34**. The pivot **48** forming the attachment point of the lower sector plate **26** is guided in an oblong hole in the lever **46** and supported by an arm **82** which is adjustable in vertical as well as in horizontal direction relative to the bar **28**. The tubular member **52** carried by the upper sector plate **22** is connected to the left end of the lever **46** by means of a pivot **78** and also carries a stop member **80** which prevents the lever **46** from being swung counter-clockwise from the position shown in FIG. 11. The tubular member **52** further carries an eccentric **84** by means of which the lever may be swung clockwise for manual separation of the sector plates. The device functions substantially in the same manner as those previously described.

In the embodiment shown in FIG. 13 the rod **28** fixed to the lower sector plate **26** and provided with an adjustable stop **30** against which the upper sector plate **22** rests, is connected directly to the radially directed counter-weight lever **34** by the pivot **44**. A link **86** carried by the upper sector plate **22** supports the lever **34** by means of a pivot **88** located radially inside the pivot **44**. In order to counter-balance the system the counter-weight **38** must in this case be located radially inside the vertical plane defined by the hinges between the sector plates **22, 26** and the center plates **20, 24** as the forces acting on the system on both sides of said plane must be in equilibrium. The link **86** presses the sector plate **22** against the stop **30** with a force the magnitude of which is dependent on the distance between the pivots **44** and **88**. The lever **34** is provided with an oblong hole for the pivot **88** so that a variation of the distance between the pivots **44** and **88** and thus a variation of the force keeping the plates **22** and **26** together is possible.

The lever **34** may in this case also be regarded as a suspension lever which is extended inwardly beyond the hinges of the sector plates.

In the embodiments hitherto described the force holding the sector plates together has always been greater than the force necessary to counter-balance the upper sector plate **22**. FIG. 14 shows a device which renders it possible also to use a smaller force.

According to FIG. 14 one end of the suspension lever **46** is inserted between an eccentric **90** and a stop member **92** carried by the tubular member **52** and located such that a counter-clockwise swinging of the lever **46** from the position shown is impossible. The lever **46** is provided with a plurality of holes for the pivot **48**. In the example illustrated the pivot **48** is inserted in a hole located vertically below the pivot **44**.

The upwardly directed balancing force acting upon the pivot **44** represents the sum of the weights of the sector plates **22** and **26**. Assuming now that the lower sector plate 26 is in contact with the lower end surface of the rotor. If the upper plate 22 is subjected to a lifting force of sufficient magnitude to swing the plate upwardly the stop member 92 is brought out of contact with the upper edge of the lever 46 which is thus relieved from the weight of the upper sector plate 22. At the same time the tension in the rod 28 is increased by a force corresponding to said weight. Therefore, the sector plates are held together by a force corresponding to the weight of the upper sector plate.

If the pivot 48 is moved to the hole located nearest the right end of the lever 46 the weight of the lower sector plate 26 will tend to lift the upper sector plate 22. The force necessary to separate the sector plates is therefore in this case lower than what corresponds to the weight of the upper sector plate.

On the other hand, if the pivot 48 is moved to a hole nearer the opposite end of the lever 46 the force holding the sector plates together will be greater than the force corresponding to the weight of the upper sector plate.

From the foregoing description of the several embodiments illustrated, it will be evident that the principles of the invention may be carried into effect by means of a wide variety of specific structural embodiments, all of which, however, have certain generic features in common. Thus, the entire suspension system as a whole, which may conveniently be referred to as a linkage system and which, while articulated, is rigid rather than resilient since it embodies no yieldable spring forces, turns about a single fulcrum point in all embodiments. In all embodiments with the exception of that of FIG. 13, the fulcrum point, which is a fixed point relative to the duct component of the apparatus, is constituted by a direct pivotal connection between a movable element of the linkage system and a rigid part of the duct component. Thus in the embodiments of FIGS. 3 to 5, FIGS. 8, 9 and FIG. 14, the fulcrum for the entire system is provided by the pivot 37 securing the link 36 to the duct component. In the embodiment of FIG. 11 the supporting bar 36*a*, which is rigidly secured to and in effect forms a part of the duct component, provides at the pivot 37*a* the fulcrum for the movably mounted linkage system. In the embodiment of FIG. 13, the movable linkage system, instead of being connected directly to the duct component as in all of the other embodiments, is connected to that component through the upper sector plate 22, by way of the bar 52′, so that the hinge 21 for the upper sector plate becomes the fulcrum for the system. It is further to be noted that in all cases the system comprises two elements that may conveniently be referred to as terminal elements which are connected respectively to the upper and lower sector plates. In all of the several embodiments, the terminal element connected to the lower sector plate is constituted by the rod 28 and in all the embodiments excepting that of FIG. 13, the terminal element connected to the upper sector plate is constituted by the tubular part 52. In the embodiment of FIG. 13, this terminal element is constituted by the rigid bar 52′ which connects the link 86 with the upper sector plate 22. These terminal elements are in all embodiments connected by means of what may be termed an intermediate linkage consisting of at least two articulated members one of which is constituted by a lever 34, one arm of which carries the counter-weight, and the second of which member of the intermediate linkage is constituted by a member, such as the lever 46 of the embodiments of FIGS. 3, 8, 11, and 14 or the link 86 of FIG. 13.

It is accordingly to be understood that while the several embodiments herein described and illustrated by way of example vary materially in their specific structural arrangements and modes of operation, all are embraced within the scope of the present invention which is to be construed as embracing all structures falling within the scope of the appended claims.

What I claim is:

1. A regenerative heater exchanger comprising two parts relatively rotatable with respect to each other about a common axis, one of said parts being substantially cylindrical and containing a regenerative mass and the other of said parts comprising ducts having axial inlets and outlets for heat emitting and heat absorbing media, sector shaped plates separating said inlets and outlets, said plates being located in sealing proximity to the end surfaces of said cylindrical part, axially fixed center plates secured to said duct part at the ends of said cylindrical part, said sector plate at one end of said cylindrical part being axially aligned with a sector plate at the opposite end thereof, means interconnecting the outer ends of said axially aligned sector plates, said means comprising a lever system including a suspension lever, a first element carried by the upper of said sector plates and a second element carried by the lower one of said sector plates, said two elements being attached to two horizontally spaced points on said suspension lever, a substantially horizontal double-armed lever mounted to swing on a support carried by said duct part, a counterweight secured to one arm of said double-armed lever, the other arm of said double-armed lever being pivotally connected to said suspension lever so as to exert a force on said suspension lever tending to move said sector plates towards each other while said counterweight counterbalances the weight of the sector plates and associated movable parts.

2. A regenerative heat exchanger as defined in claim 1, wherein the distance between the attachment points of said elements is adjustable.

3. A regenerative heat exchanger as defined in claim 1, wherein the location of the pivotal connection between said other arm and said suspension lever is adjustable relative to the attachment points of said two elements.

4. A regenerative heat exchanger as defined in claim 1 and comprising means for manual separation of said sector plates.

5. A regenerative heat exchanger as defined in claim 4, wherein one of said sector plates carries a manually operable mechanism for swinging said suspension lever in a direction to lift said counterweight.

6. A regenerative heat exchanger as defined in claim 5, wherein said manually operable mechanism comprises an eccentric.

7. A regenerative heat exchanger as defined in claim 5, wherein said manually operable mechanism comprises a toggle joint device operable by a lever swingably mounted on one of said plates.

8. A regenerative heat exchanger as defined in claim 1 comprising a stop member limiting the movement of the sector plates toward each other.

9. A regenerative heat exchanger comprising two components relatively rotatable with respect to each other about a common central axis, a first of said components constituting a heat transfer part of cylindrical form and containing regenerative heat transferring mass providing passages for flow of fluid media therethrough from end to end of the part and the second of said components constituting a duct part providing ducts having inlets and outlets for flow of heat emitting and heat absorbing fluid media to and from the opposite ends of said first component, axially fixed center plates secured to said second component at the opposite ends of said first component, movable sector plates hinged to said center plates and extending outwardly therefrom in sealing proximity to the opposite ends of said first component and with the sector plates at said opposite ends being axially aligned to separate said inlets and said outlets, a linkage system connecting said sector plates and a counterweight acting thereon comprising relatively movable terminal elements separately connected to aligned sector plates at the opposite ends of said first component and intermediate linkage comprising members pivotally interconnecting said

terminal elements, said counterweight being carried by one of said members and acting to exert a first force tending to counterbalance the weight of the sector plates and a second force acting through said intermediate linkage tending to move the interconnected sector plates towards one another.

10. A heat exchanger as defined in claim **9** in which said linkage system is movably supported to move as a whole about a fulcrum on said second component.

11. A heat exchanger as defined in claim **10** in which said counterweight is carried by said intermediate linkage laterally to one side of said fulcrum and said terminal elements are connected to said intermediate linkage on the laterally opposite side of said fulcrum.

12. A heat exchanger as defined in claim **10** in which said terminal elements are connected to said intermediate linkage at laterally different distances from said fulcrum.

13. A heat exchanger as defined in claim **10** in which said intermediate linkage is pivotally connected directly to a part of said second component to provide said fulcrum.

14. A heat exchanger as defined in claim **13** in which said intermediate linkage comprises two pivotally connected members the first of which carries said counterweight and the second of which is pivotally connected to one of said terminal elements.

15. A heat exchanger as defined in claim **14** in which said second member is mounted to pivot about a fulcrum carried by the sector plate to which said second member is connected by said one of said terminal elements, the connection between said one of said terminal elements and said second member being located between the last mentioned fulcrum and the connection to said first member.

16. A heat exchanger as defined in claim **10** in which one of the members of said intermediate linkage is pivotally connected through one of said sector plates to the part of said second component providing said fulcrum.

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