

"Regenerator"

The present invention relates to a regenerator comprising a regenerative heat exchanger which is rotatable about an axis of rotation and which is capable of having media streams flowing through separate regions thereof so that one stream of medium supplies heat to the other medium, the exchanger affected having a heat-absorbing or heat-transmitting heat carrier material substantially uniformly or homogeneously disposed in the regions thereof impacted by the streams of media, the rotation of the heat exchanger being such as to cause the regions of the heat exchanger impacted by one stream of medium and flowing therethrough to enter continuously a region in which it is impacted by the other stream of medium which flows therethrough so as to cause the heat exchange between the streams of media to take place through the heat carrier material.

A regenerator of this type is already known in which the heat exchanger is in the form of a circular disc which rotates slowly about an axis of rotation. The exchanger is filled with heat carrier material in a packing density which is substantially uniform. In one half, the circular disc has a first gas stream flowing axially therethrough which stream, for example, supplies heat. The heat carrier material is heated up in the disc whilst, in the other half a second gas stream, separated from the first gas

stream, flows axially therethrough and thus absorbs heat. Consequently, the heat is transported by the rotation of the heat carrier disc, whereby the hot medium delivers its heat content to the heat carrier material which, in turn, heats the cold medium.

Regenerators of this known type of construction have certain disadvantages. For example, they are generally of limited length but of large diameter. They are therefore difficult to integrate in plants or other systems. In the majority of its uses, particularly in industrial systems, but also in air-conditioning systems, very deep flow conduits are necessary, but such conduits have a low overall height. In addition, in industrial systems, conduits generally have rectangular cross-sections which must be altered to a circular or semicircular cross-section in the throughflow region of the disc-shaped heat exchangers. This is not only costly but necessitates the use of conduit transition pieces which have disadvantageous effects on the flow.

In order to utilise fully the heat-exchanging characteristics compound or substance from which the circular disc is made, the two streams of media must pass as close as possible to the diameter of the circular disc which separates the streams of medium from one another. This necessitates the use of conduit guides and also results in an almost

complete screening of the mounting for the circular disc.

5 The structural form of the circular disc is therefore strictly limited, especially if the heat exchanger is intended for use in a high temperature range. A further, serious deficiency in known regenerators is that the temperature distribution is very irregular over the flow cross-sections in the streams of media.

10 Regenerators employing a hollow cylindrical heat exchanger in the form of a rotor are also known. In such arrangements, the interior of the rotor is divided into two passages by means of a fixed wall. Each of the media passes through the
15 interior of the rotor in a substantially radial direction and are supplied to, and removed from, the rotor by inlet and outlet channels respectively. The inlet and outlet channel for each medium are, however, substantially diametrically opposed one
20 another. The radial passages and the inlet and outlet channels for each media are, therefore, only aligned with one another in the vicinity of the medial longitudinal plane corresponding to the fixed wall between the passages for the media.
25 The media flowing through the rotor must, therefore, change direction both at the inlet to, and the outlet from, the rotor and the change of direction becomes more marked as the distance from the

dividing wall that the media enters the rotor increases. Such changes in direction are associated with disadvantageous higher flow resistance. This fact can be demonstrated by determining the effective input flow cross-section of the media at various
5 distances from the dividing wall.

The present invention seeks to provide a regenerator comprising a rotatable, regenerative heat exchanger which has separate streams of media flowing therethrough which can be easily installed in existing conduit systems existing in
10 conventional plants. Moreover, the invention seeks to provide a regenerator in which the exchange of heat between at least two streams of media is improved by ensuring a substantially uniform temperature distribution over the cross-sections of at least the flow conduits which conduct the heated flow medium
15 and also to provide a regenerator which has a wider field of application than known devices.

In accordance with the present invention there is provided a regenerator comprising a hollow cylindrical heat exchanger roller rotatable about an axis of rotation, the
20 roller shell being formed of a heat exchanger material

and within which the media between which heat is transferred
flow through regions which are separated from one
another, the interior of the hollow cylinder being divided
by a dividing wall into the regions for the flow of the
5 media, each medium flowing through the shell into the
hollow interior and thence out through the shell in such
a manner that each such flow through the shell is
substantially radial and is at right angles to the axis
of rotation of the heat exchanger, wherein the heat
10 exchanger roller is located in a housing having radially
directed inlet and outlet channels for the flows of media,
the inlet and outlet channels for each medium being
disposed at substantially 90° to one another.

In such an arrangement, the streams of media
15 thus each flow twice through the roller shell which
accommodates the heat carrier material. If the
packing density of the heat carrier material is
substantially uniform, improved heat exchange between
the streams of media and the heat carrier material
20 should occur.

By providing a regenerator comprising a heat carrier roller, the shell of which is twice traversed by the streams of media separated from one another in the hollow interior of the cylinder by the intermediate wall, the regenerator has a relatively simple construction, can be manufactured economically, has a high efficiency and has range of application which is substantially larger than the regenerators of the prior art. Above all, the regenerator of the invention can be adapted to the requirements of its intended use. Thus, for example, the length of the heat exchanger roller can be selected to correspond to the depth of the plant conduits, and this, of course, simplifies installation in plants having rectangular conduits of low height and large depth. Irrespective of its overall length, a temperature distribution which is substantially uniform is achieved in the heated stream of medium. The regenerator can also be used in a temperature environment if in accordance with a preferred embodiment, temperature sensitive components, such as bearing for the roller and rotational drive means, are disposed externally of the roller in region remote from the regions

transversed by the media.

The bearing and drive means, if located externally of the flow channels, are maintained cool and servicing and maintenance thereof is facilitated.

5 The compartments in the hollow interior of the roller, which are separated from one another by the intermediate wall may be of the same size as each other or different so that the regenerator can be adapted for use in dependence upon the media being used and
10 heat exchange characteristics required.

In the arrangement of the present invention, the feed and discharge conduit for one stream of medium is disposed on the one side of the intermediate wall and the feed and discharge conduit for
15 the other stream of medium is disposed on the other side of the wall. If low leakage rate of the media is necessary, even

at a high pressure, sealing may be effected by means of sealing strips whereby, by suitably selecting the material, even the high temperature region can be controlled.

5 For the efficiency of the heat exchange, the nature of the heat carrier material is of importance. In addition to a high specific heat, good thermal conductivity and a high surface area, the use of a pourable or fluid heat carrier material is advantageous, for example, in a granulated form. In such a case, the layer of heat carrier material accommodated in the roller shell has a packing density which is substantially uniform, and the roller shell may be radially defined by an inner cylinder and an outer cylinder, which cylinders are concentric with one another, such that an annular space which accommodates the heat carrier material is defined therebetween, throughflow paths for the gas media streams being provided. The cylinders comprise perforated metal sheets, wire meshes or combinations of perforated metal sheets and wire meshes. Radial webs or ribs may be disposed at substantially equi-
10 angular spacings from one another to correct the two cylinders.

15 These webs or ribs maintain the shape of the cylinders. The distances between the radial webs or ribs is not greater than the spacing between adjacent walls of adjacent conduits in the housing.

In another particularly preferred embodiment of the invention, the granular-like heat carrier material is sintered together to form the hollow-cylindrical shape itself, in which case there is no need for the provision of cylinders to accommodate the heat carrier material.

Alternatively, the heat carrier material may be in the form of laminations which are disposed in the roller shell so as to define radial throughflow gaps therebetween. These laminations may be circular discs which are coaxial with one another and which are anchored in the roller shell, for example, by means of support pins which extend axially through the discs. The laminations may also be axially extending web sheets which are disposed at the same angles of separation. When designing the shell for the heat carrier roller, it is advantageous to provide the laminations with surface variations, which are moulded into the radially extending flow-through gaps, for example, in the form of stamped-out or notched-out portions extending at right angles to the surface extensions of the laminations, so as to obtain as turbulent a flow as possible and thin, short temperature boundary layers.

The invention will be further described, by way of example, with reference to the accompanying drawings, in which:-

Fig. 1 is a schematic end view, partially in section, through a regenerator in accordance with the present invention, the regenerator having a rotating heat carrier roller;

5 Figs. 2 a to 2 d show, schematically alternative arrangement for conducting streams of media through separate regions of a heat exchanger roller forming part of the regenerator shown in Fig. 1;

10 Fig. 3 is a perspective view, partially in section, of a cross-flow regenerator in which streams of medium are deflected through 90° during their passage through the heat exchanger roller;

15 Fig. 4 is a sectional view, similar to that shown in Fig. 1, of an alternative embodiment of a regenerator and showing additional flow conduits for the media streams, which additional conduits are connected to the conduits formed in the housing;

Fig. 5 shows one possible embodiment of the roller shell shown in Fig. 1;

20 Fig. 6 shows a detail of a second possible embodiment of the roller shell;

Fig. 7 shows a detail of a third possible embodiment of the roller shell;

25 Fig. 8 shows a roller shell in which granulated material is located, the granulated material having been sintered together to form the cylindrical shape;

Fig. 9 shows a possible embodiment for the roller shell in which laminations act as the heat carrier material;

5 Fig. 10 shows an embodiment of the roller shell which is an alternative to that shown in Fig. 9, and;

Fig. 11 is a detailed view of a modified form of the laminations shown in Fig. 9.

In the regenerator shown in section in
10 Fig. 1, there is provided a heat exchanger in the form of a hollow-cylindrical roller 10 having a large overall length relative to its diameter. The heat exchanger roller 10 is rotatably mounted in a housing 20 and is provided with drive means (not shown)
15 for rotating it at low rotational speeds. The heat exchanger roller 10 is rotatably mounted in the housing 20 by means of bearings (not shown) disposed externally thereof. The exterior portion of the roller 10 comprises a roller shell 11. Heat carrier material
20 is accommodated in the roller shell 11 in a manner which will be described hereinafter. Flow paths, which run particularly in radial directions, extend through the roller shell carrying the heat carrier material. The hollow central portion of the heat exchanger
25 roller 10 is sub-divided into two separate, substantially semi-cylindrical compartments 13, 14, by means of a substantially vertical, diametric intermediate wall 12.

The wall 12 extends over substantially the entire length of the roller and is sealed relative to both the inner cylindrical surface of the shell 11 and in the region of the front ends of the roller.

5 The housing 20 has four pairs of walls 21, 22, 23, 24, each pair of walls being staggered by 90° relative to the pairs of adjacent thereto. The pairs of walls 21, 22, 23, 24, define conduits 25, 26, 10 27, 28 respectively which may be feed or discharge conduits depending upon the disposition of internal intermediate wall 12 in the hollow cylinder. Generally speaking, however, there will be one feed and one discharge conduit on each side of the wall 12. Additional conduits for supplying and discharging 15 gas streams are connectable to the conduits 25, 26, 27, 28, which conduits extend substantially over the entire length of the heat exchanger roller 10, as will be described in greater detail hereinafter with reference to Fig. 4. At least in the plane spanned by the 20 intermediate wall 12, the gaps between the roller shell 11 and the housing 20 are sealed by means of sealing strips (not shown). Similar seals (also not shown) are located in the region of the front ends of the roller.

25 In the regenerator of the present invention, streams of media, between which heat exchange is to take place pass through the heat carrier material accommodated in the roller shell. Each medium flows

through the roller shell twice, both times in substantially radial directions. The schematic views in Figs. 2a to 2d show various methods of achieving this objective.

5 Apart from the omission of the regenerator housing 20, Fig. 2b shows an arrangement which is identical to Fig. 1. It will be assumed that the roller 10 rotates in a clockwise direction as denoted by the arrow 16 about its axis of rotation 15.

10 One stream of medium 30 is supplied through the supply conduit 25 in the housing 20, passes through the roller shell 11 in a substantially radial direction and enters the semicylindrical internal compartment 13 of the hollow interior of the roller 10. The

15 medium flowing out through the roller shell into the discharge conduit 26 formed in the housing. A second stream of medium 31 is supplied through the supply conduit 27 of the housing, flows through the roller shell 11, and enters the other semicylindrical

20 compartment 14 of the hollow interior of the roller 10. It is then discharged through the discharge conduit 28 after its direction of flow has been altered and after it has passed again through the roller shell. The two streams of medium 30, 31 are separated from

25 one another in the interior of the roller 10 by the intermediate wall 12. If it is assumed that the stream of medium 30 is the hotter medium, then during the double passage thereof through the roller shell,

the heat carrier medium collected in the roller shell is heated. In view of the rotation of the heat exchanger roller in the direction of the arrow 16, the regions of the roller which are traversed by the heat-supplying stream 30 rotate beyond the vertically extending plane of separation between the two streams of medium, that is to say, past the wall 12 and thus enter the regions in which they are traversed by the stream of medium 31. The stream 31 is thus heated up and consequently removes heat from the previously heated heat carrier material. In such a case, the media streams are conducted in a direction generally opposite to the direction of rotation of the heat exchanger roller 10, so that, when the heat-supplying stream of medium 30 is discharged from the interior compartment 13, of the roller, the heat carrier material is pre-heated. When the heat carrier material reaches the region of the feed conduit 25 for the medium 30, it is heated to its final temperature. However, the stream of medium 31, which removes heat from the heat exchanger roller 10, then flows through the now heated heat carrier medium in the region of the discharge conduit 28 from the other compartment 14. Thus, after heat has, to a considerable extent, been removed from the heat carrier material during the above-mentioned traversing, the material enters the region of the feed conduit 27 to the compartment 14. In view of the correspondingly low

inlet temperature of this stream of medium 31, the heat still contained in the heat carrier material when it reaches this region of the roller shell is removed. Because of the double traversing of the roller shell in the opposite direction to the direction of rotation of the roller, an almost contra-flow type transmission of heat is ensured in the region of the two streams of medium.

The diagrammatically shown embodiment of Fig. 2a differs from the embodiment of Fig. 2b merely in that the internal intermediate wall 112 extending diametrically at an angle of substantially 45° relative to the horizontal. In such a case, the streams of media 130, 131 are each supplied to the roller in a generally horizontal direction and are removed therefrom in a generally vertical direction.

Fig. 2c shows that it is possible to use two streams of medium 230, 231 which, externally of the heat exchanger roller 210, flow substantially in alignment with one another, albeit in opposite directions but which can still be caused to pass through the roller shell twice each time in a substantially radial direction.

The construction in Fig. 2d shows a different arrangement for sub-dividing the inner hollow cylinder of the heat exchanger roller 310. This is effected by using an internal intermediate wall 312. In this embodiment, the compartments 313,

314, extend over different circumferential angles of the roller shell. In this embodiment, both streams of medium 330, 331 still each flow twice through the roller shell substantially radially.

5 It will be apparent, from Fig. 2d, that a sub-division of the hollow interior of the heat carrier roller into more than two separate interiors is also possible. If necessary, therefore, more than two streams of medium may be used, each of which passes through
10 the roller shell twice.

Fig. 3 shows a perspective view, partially in section, overall of a regenerator and it can clearly be seen that the length thereof is large in proportion to the diameter of the heat exchanger roller 10'.

15 Moreover, the conduits in the housing 20' which serve to supply and discharge the streams of media, have a depth, which corresponds substantially to the length of the heat exchanger roller and have comparatively small extension portions extending at right angles

20 thereto. The division of hollow interior of the heat exchanger roller into two substantially semi-cylindrical compartments by means of a vertically extending intermediate wall can also be clearly seen.

One stream of medium is supplied substantially
25 horizontally, as shown by the arrow 35, through the inlet conduit defined by the pair of walls 21'. This stream flows through the shell 11' of the heat exchanger roller 10' twice and is then discharged substantially

vertically through the discharge conduit defined by the pair of walls 22', in the direction of arrow 36. The other stream of medium is supplied substantially horizontally, as indicated by the arrow 37, through the conduit 27' and, after flowing twice through the roller shell, is discharged substantially vertically upwards through the discharge conduit 28' in the direction of arrow 38. In this embodiment, both streams of media traverse the roller shell twice, both times in a substantially radial direction.

Fig. 4 shows a regenerator as shown in Fig. 1 but also shows additional conduits 40,41,42,43 which connect with the conduits defining pairs of walls 21,22,23 and 24. In this arrangement the additional conduits 40,41 serve respectively, to supply and discharge one stream of medium, and are substantially in alignment with one another whilst the additional conduits 42,43, which serve, respectively, to supply and discharge the other stream of medium are substantially at right angles to one another.

The arrangement shown in Fig. 4 could equally be used with the arrangements in Figs. 2a,2c, and 2d, and, accordingly, the regenerator according to the present invention is versatile.

The efficiency of the heat exchange between a heat carrier material and a stream of medium flowing therethrough is dependent upon the properties of the heat carrier material (especially its heat retention and its thermal conductivity) and upon the type of flow around the heat carrier material.

The best heat transmission figures are achieved by causing the flow to be extremely turbulent or by having flow boundary layers having lengths which are as short as possible.

5 Pourable or fluid materials in spherical or granular form have proved to be especially suitable for use as the heat carrier material and they are accommodated in the roller shell of the heat exchanger roller in a layer thickness which depends upon the
10 specific requirements of the pertinent application of use. One such arrangement is shown in Fig. 5. In this arrangement, the roller shell comprises an inner and an outer cylinder 50, 51, respectively, each provided with flow paths therethrough. The cylinders are
15 concentric with one another, so as to define an annular space therebetween, the cylinders being interconnected by means of radial webs 52 which are substantially equiangularly spaced apart. Into the roller shell thus formed, granulated material 53,
20 which acts as the heat carrier material, is inserted in a packing density which is substantially uniform. The spaces between the radial ribs 52 are, in this embodiment, smaller than the width of housing ribs between adjacent conduits in the roller housing so that,
25 when the heat exchanger roller is rotating, at least one radial web is always located in the region of each and every housing web. The two cylinders which together define the roller shell may comprise perforated,

preferably metal, sheets 54 which are surrounded by a fine-mesh wire grid 56 which covers the flow-through apertures 55, see Fig 6. Alternatively, the cylinders, between which the heat carrier material is accommodated, may each comprise a coarse lattice mat 57, which provides the substantially cylindrical shape and which comprises intersecting longitudinal and transverse wires, a fine-mesh wire grid 58 then surrounding the lattice mat. Such an arrangement is shown in Fig. 7. Another possibility is to use granulated material 60 which has been sintered together to form a cylindrical shape, as is shown in Fig. 8.

A further possibility is to construct the roller shell from laminations. In such an arrangement, as can be seen in Fig. 9, laminations 61 extend in the longitudinal direction of the roller, the laminations being in the form of elongated sheet metal strips which are spaced apart from one another so as to form radial throughflow gaps. Alternatively, as shown in Fig. 10 the laminations may be in the form of circular discs 62 which may, for example, be accommodated on support pins 63 extending in the longitudinal direction of the roller. When using laminations as the heat carrier material, it has proved advantageous to provide, in the region of the radially extending throughflow gaps, surface variations 64 such as those shown in Fig. 11.

These may be in the form of stamped-out or notched-

out portions of the laminations and extending
at right angles to the plane of the laminations.



CLAIMS

1. A regenerator comprising a hollow cylindrical heat exchanger roller rotatable about an axis of rotation, the roller shell being formed of a heat exchanger material and within
5 which the media between which heat is transferred flow through regions which are separated from one another, the interior of the hollow cylinder being divided by a dividing wall into the regions for the flow of the media, each medium flowing through the shell into the hollow interior and thence out through the
10 shell in such a manner that each such flow through the shell is substantially radial and is at right angles to the axis of rotation of the heat exchanger, wherein the heat exchanger roller is located in a housing having radially directed inlet and outlet channels for the flows of media, the inlet and outlet
15 channels for each medium being disposed at substantially 90° to one another.
2. A regenerator as claimed in claim 1, wherein the housing is symmetrical about the axis of rotation of the heat exchanger roller.
- 20 3. A regenerator as claimed in claim 1 or 2, wherein the heat exchanger roller has a long axial length compared with its diameter and the inlet and outlet channels along the entire length of the roller.
4. A regenerator as claimed in any one of claims 1 to 3
25 wherein the regions of the interior of the roller separated by the dividing wall extend over the same circumferential angle of the



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heat exchanger roller.

5. A regenerator as claimed in any preceding claim wherein the bearing and/or rotational drive are provided for the heat exchanger roller, the bearing and/or drive being
5 externally of the regions impinged by the flows of media.

6. A regenerator as claimed in any preceding claim wherein the heat transfer material has a high specific heat, good thermal conductivity and a large surface area.

7. A regenerator as claimed in claim 6 wherein the
10 heat transfer material is in the form of a granulate.

8. A regenerator as claimed in claim 7, wherein a layer of heat transfer material is provided in the roller shell, the packing density of the material being substantially uniform over the entire area, the roller shell being radially defined by an
15 inner and an outer cylinder, the cylinders being concentric with one another and enclosing an annular space therebetween for the heat transfer material and provided with conduits for the flow therethrough of the media.

9. A regenerator as claimed in claim 8, wherein the
20 cylinders enclosing the heat transfer material are made of perforated metal sheet, wire mesh or a combination of a perforated metal sheet and wire mesh.

10. A regenerator as claimed in claim 8 or 9, wherein the radially extending webs disposed at substantially equiangular
25 intervals connect the two cylinders.

11. A regenerator as claimed in claim 10, wherein the circumferential separation between adjacent radial conduits



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is not greater than the spacing between adjacent walls of adjacent conduits formed in the housing.

- 5 12. A regenerator as claimed in claim 9, wherein the granular heat transfer material is sintered to form the hollow cylindrical shape.
13. A regenerator as claimed in any one of claims 6, 8, 9 or 10, wherein the heat transfer material comprises laminations which are disposed in the roller shell so as to define radial throughflow passages.
- 10 14. A regenerator as claimed in claim 13, wherein the laminations are circular discs which are coaxial with one another.
15. A regenerator as claimed in claim 13, wherein the laminations are axially extending webs or sheets which are disposed at substantially identical angles of separation.
- 15 16. A regenerator as claimed in one of claims 13 to 15, wherein the laminations are provided with surface variations extending into the radially extending throughflow gaps in order to produce turbulent flow through the gaps, the variations being in the form of stamped-out or notched-out portions extending
- 20 at right angles to the surface direction of the laminations.
17. A regenerator as claimed in claim 1 constructed and arranged to operate substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.