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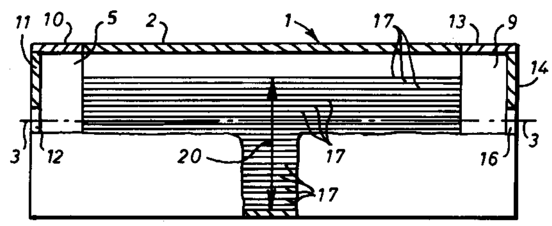
(54) Heat regenerator.

(57) Heat regenerator (1) comprising a cylindrical, open ended housing (2) rotatably arranged about its central longitudinal axis (3), a first manifold (5) communicating with one open end of the housing (2), a second manifold (9) communicating with the opposite open end of the housing (2), and a plurality of rods (17) arranged in the housing (2) parallel to the central longitudinal axis (3) of the housing (2), wherein the degree of filling the housing (2) is less than 1.

FIG.1



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The present invention relates to a heat regenerator. A heat regenerator is a device for exchanging heat from one fluid stream to another fluid stream. To this end the heat regenerator is provided with a mass of material which stores heat from a hot fluid stream and which delivers subsequently the heat to a cold fluid stream. This feature distinguishes a heat regenerator from a continuously operating heat exchanger which is provided with a wall separating the hot and cold fluid streams passing simultaneously through the heat exchanger.

In particular the invention relates to a heat regenerator comprising a cylindrical, open ended housing rotatably arranged about its central longitudinal axis, a first manifold communicating with one open end of the housing, a second manifold communicating with the opposite open end of the housing, and a mass of material arranged in the housing. An example of such a heat exchanger is the Ljungström heat regenerator as described in Ullmans Encyklopädie der technische Chemie, 4th Edition, Band 2, pages 428-430. In the known heat regenerator, the mass of material comprises an annular element provided with a plurality of parallel passages through which the gas streams flow during normal operation to receive and deliver heat.

A problem encountered with the known heat exchanger is that it is not suitable for cooling a hot gas, for example flue gas, which hot gas contains particulate material such as dust or fly ash which can easily stick to the inner surfaces of the passages. Gradually passages get clogged with deposited particulate matter and the efficiency of the heat exchanger decreases.

It is an object of the present invention to overcome this problem.

To this end the heat exchanger according to the present invention comprises a cylindrical, open ended housing rotatably arranged about its central longitudinal axis, a first manifold communicating with one open end of the housing, a second manifold communicating with the opposite open end of the housing, and a plurality of slim cylindrical elements arranged in the housing parallel to the central longitudinal axis of the housing, wherein the degree of filling the housing is less than 1.

The invention further relates to a method of exchanging heat between a hot gas and a cool gas using a heat exchanger including the above heat regenerator, which method comprises rotating the housing about its central longitudinal axis and further comprises the sequential steps of

(a) passing the hot gas through the heat regenerator until the heat regenerator is heated to a predetermined level;

(b) interrupting the flow of hot gas through the heat regenerator;

(c) passing the cold gas through the heat regenerator until the heat regenerator is cooled to a predetermined level; and

(d) interrupting the flow of cold gas through the heat regenerator.

The term "degree of filing" used in the claims and in the specification is defined as the average height of the segment of the housing loaded with the slim cylindrical elements divided by the inner diameter of the housing. Since the degree of filling is less than 1, there is an empty segment, and as a result during normal operation, when the open ended housing is rotated, the slim cylindrical elements can rub against each other to remove deposited material.

The term "slim cylindrical elements" used in the claims and in the specification is used to refer to cylindrical elements, pipes or rods, having a length which is much greater than the outer diameter. The length of a cylindrical element is greater than the diameter of the housing, for example greater than between 1.5 to 2 times the diameter of the housing. The maximum length of a cylindrical element is the length of the housing. The outer diameter of a cylindrical element is suitably between 10^{-1} and 10^{-3} times the inner diameter of the housing.

The invention will now be described by way of example in more detail with reference to the accompanying drawings, wherein

Figure 1 shows schematically a partial longitudinal section of the heat regenerator according to the invention; and

Figure 2 shows schematically an application of a heat exchanger comprising two heat regenerators according to the invention.

Reference is made to Figure 1. The heat regenerator 1 comprises a cylindrical, open ended housing 2 rotatably arranged about its central longitudinal axis 3. The support structure, the bearings and the driving means are not shown.

The heat regenerator 1 further comprises a stationary first manifold 5 communicating with one open end of the housing 2, and a stationary second manifold 9 communicating with the opposite open end of the housing 2. The first manifold 5 comprises a ring 10 and a cover 11 provided with an opening 12, and the second manifold 9 comprises a ring 13 and a cover 14 provided with an opening 16.

The heat regenerator 1 also comprises a mass of material which comprises a plurality of slim cylindrical elements in the form of rods 17 arranged in the housing 2 parallel to the central longitudinal axis 3 of the housing 2. The degree of filling the housing 2, which is the the average height 20 of the segment of the housing 2 loaded with the slim cylindrical elements 17 divided by the inner diameter of the housing 2, is less than 1.

During normal operation, the housing 2 is rotated about its central longitudinal axis 3. Hot gas is supplied to the first manifold 5 through opening 12. The hot gas is passed through the passages between the rods 17 in the housing 2 and heats the mass of material in the housing 2, and the gas is removed through the second manifold 9. When the heat regenerator 1 is heated to a predetermined level, the flow of hot gas through the heat regenerator 1 is interrupted. Thereupon cold gas is supplied to the second manifold 9 and it is passed through the heat regenerator 1 until the heat regenerator 1 is cooled to a predetermined level. Then the flow of cold gas through the heat regenerator 1 is interrupted.

As the housing 2 is rotated, the rods 17 will move relative to each other and any deposits on them will be rubbed off. The removed deposits are removed through a separate outlet (not shown) in one of the two manifolds 5 or 9.

To determine whether the heat regenerator is heated to a predetermined level, or cooled to a predetermined level, the temperature in the housing 2 can be measured directly or the temperature of the fluid leaving the heat regenerator can be measured, wherein the latter is an indirect measurement of the temperature in the housing.

In the above example a heat exchanger consisting of one heat regenerator is used to exchange heat between two gaseous fluids, the method of exchanging heat is then an intermittent one.

When the heat exchanger consists of two heat regenerators, a primary heat regenerator and a secondary heat regenerator, the method becomes a continuous one. Then one cycle of the continuous method method starts with passing the hot gas through the primary heat regenerator until the primary heat regenerator is heated to a predetermined level, and passing cold gas through the secondary heat regenerator until the secondary heat regenerator is cooled to a predetermined level. Then the flow of hot gas through the primary heat regenerator and the flow of cold gas through the secondary heat regenerator are interrupted. Subsequently the cold gas is passed through the primary heat regenerator until the primary heat regenerator is cooled to a predetermined level, and the hot gas is passed through the secondary heat regenerator until the secondary heat regenerator is heated to a predetermined level. Thereafter the flow of cold gas through the primary heat regenerator and the flow of hot gas through the secondary heat regenerator are interrupted. And a new cycle can start.

To illustrate an example of the continuous method, reference is made to Figure 2. A gasification reactor 30 is provided with an outlet conduit 32 through which synthesis gas, a mixture of carbon monoxide and hydrogen, can be removed and an inlet conduit 35 through which an oxidant is supplied to the gasification reactor 30. For the sake of clarity, the conduits for supplying fuel and for removing slag (in the case of a coal gasification reactor) are not shown.

The conduit 32 is connected to the first manifold 40 of primary heat regenerator 41, and from the second manifold 42 of the primary heat regenerator 41 extends conduit 43. Conduit 45 debouches into the first manifold 46 of secondary heat exchanger 47, and second manifold 48 communicates with the conduit 35. The primary and secondary heat regenerator 41 and 47 are of the design of the heat regenerator 1 as shown in Figure 1.

During normal operation, the housings of the heat regenerators 41 and 47 are rotated. Oxidant is supplied through conduit 45 at a temperature of about 100 °C to the secondary heat exchanger 47 and it is heated to about 800 °C, hot oxidant is supplied through conduit 35 into the gasification reactor 30.

In the gasification reactor 30 fuel, for example a hydrocarbon oil, coal or natural gas, is partly oxidized to synthesis gas which is removed at a temperature of about 1 500 °C through conduit 32. In this conduit 32 the hot synthesis gas can be mixed with quench gas to lower the temperature to about 900 °C. The hot gas is passed through the primary heat regenerator 41 and cooled synthesis gas is removed through conduit 43. Once the primary heat regenerator 41 is heated to a predetermined level and the secondary heat regenerator 47 is cooled to a predetermined level, the flows are rerouted so that conduit 45 and conduit 35 are connected to the primary heat exchanger 41 and that conduit 32 and conduit 43 are connected to the secondary heat exchanger 47. The necessary connection conduits and valves are not shown.

Suitably the degree of filling is between 0.70 and 0.95. To obtain a larger mass for storing heat the degree of filling the housing is between 0.90 and 0.95.

The central longitudinal axis 3 of the housing 2 of the heat regenerator 1 as shown in Figure 1 is horizontal. Suitably the central longitudinal axis is substantially horizontal, that is the angle between a horizontal plane and the central longitudinal axis of the housing is less than 20°. To facilitate removing material from the housing, the angle between a horizontal plane and the central longitudinal axis of the housing is suitably between 1° and 20°.

The slim cylindrical elements can also be pipes, an advantage is that the pressure drop over the heat regenerator is decreased. However, the mass of the material is decreased as well so that pipes have to be applied with a larger degree of filling than in case rods of the same diameter are used or the frequency of switching between passing hot gas trough the heat regenerator and passing cold gas through it has to be increased.

The cylindrical elements can be made of any heat-resistant material and suitably they are made from refractory material, such as ceramic material.

Claims

1. Heat regenerator comprising a cylindrical, open ended housing rotatably arranged about its central longitudinal axis, a first manifold communicating with one open end of the housing, a second manifold communicating with the opposite open end of the housing, and a plurality of slim cylindrical elements arranged in the housing parallel to the central longitudinal axis of the housing, wherein the degree of filling the housing is less than 1.

2. Heat regenerator as claimed in claim 1, wherein the degree of filling the housing is between 0.70 and 0.95.

3. Heat regenerator as claimed in claim 2, wherein the degree of filling the housing is between 0.90 and 0.95.

3. Heat regenerator as claimed in anyone of the claims 1-3, wherein the angle between a horizontal plane and the central longitudinal axis of the housing is between 1° and 20°.

5. Method of exchanging heat between a hot gas and a cool gas using a heat exchanger including a heat regenerator as claimed in anyone of the claims 1-4, which method comprises rotating the housing about its central longitudinal axis and further comprises the sequential steps of

(a) passing the hot gas through the heat regenerator until the heat regenerator is heated to a predetermined level;

(b) interrupting the flow of hot gas through the heat regenerator;

(c) passing the cold gas through the heat regenerator until the heat regenerator is cooled to a predetermined level; and

(d) interrupting the flow of cold gas through the heat regenerator.

6. Method as claimed in claim 5, wherein the heat exchanger further includes a secondary heat regenerator of the kind as claimed in anyone of the claims 1-4, which method further comprises rotating the housing of the secondary heat regenerator, wherein step (a) further comprises passing cold gas through the secondary heat regenerator until the secondary heat regenerator is cooled to a predetermined level, wherein step (b) further comprises interrupting the flow of cold gas through the secondary heat regenerator, wherein step (c) further comprises passing the hot gas through the secondary heat regenerator until the secondary heat regenerator is heated to a predetermined level, and wherein step (d) further comprises interrupting the flow of hot gas through the secondary heat regenerator.

7. Method according to claim 6, wherein the hot gas is synthesis gas from a gasification plant in which a fuel is partly oxidized to manufacture the synthesis gas, and wherein the cold gas is an oxidant for the partly oxidation of the fuel in the gasification plant.

FIG.1

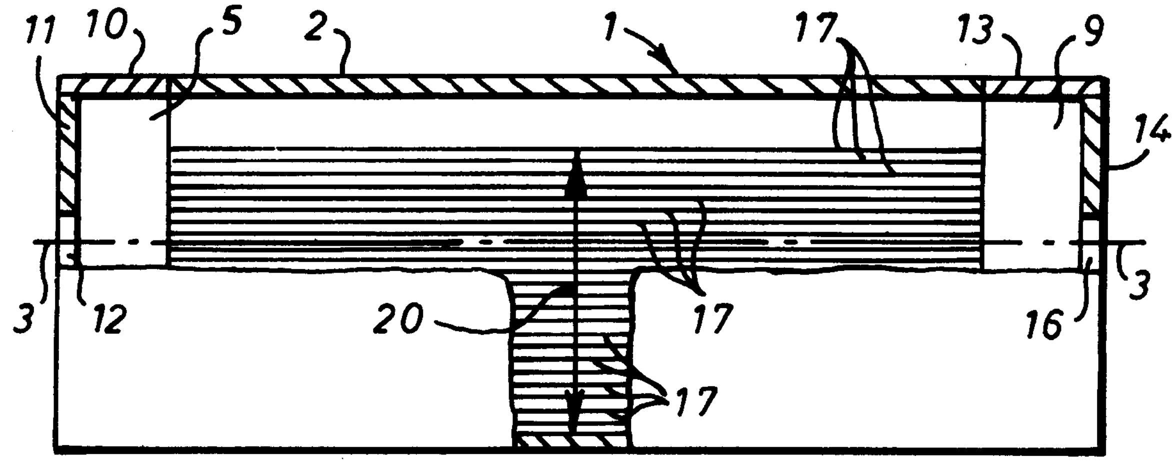
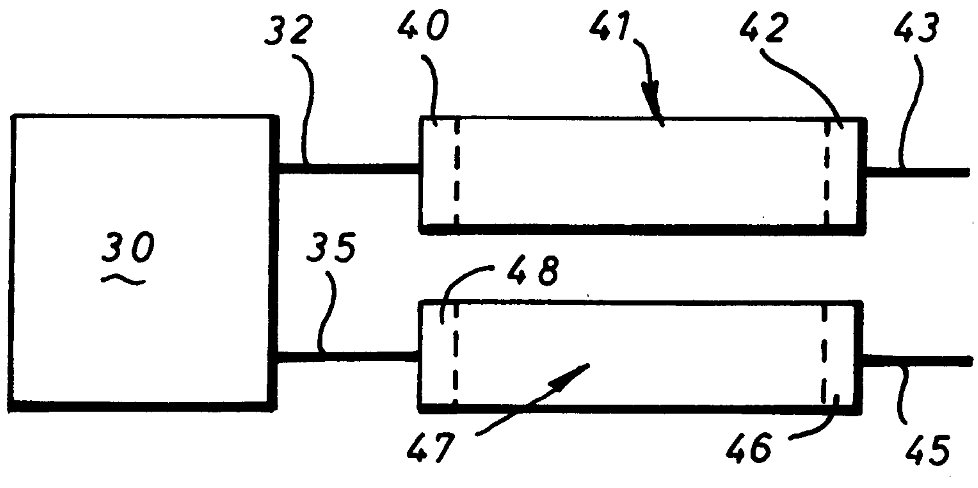


FIG.2



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EUROPEAN SEARCH REPORT

Application Number

EP 93 20 0274

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	DE-C-621 722 (BOJNER) * the whole document * ---	1,2,3,5,6	F28D19/04
Y	GB-A-895 463 (GREEN & SON LTD.) * the whole document * ---	1,2,3,5,6	
A	US-A-4 615 379 (KÜNZEL) * the whole document * -----	1,7	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			F28D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	28 JUNE 1993	SMETS E.D.C.

CATEGORY OF CITED DOCUMENTS

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