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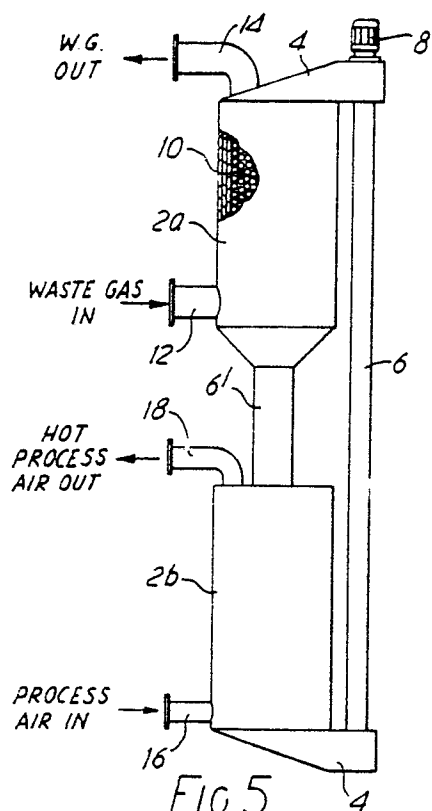
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54 **Heat exchangers.**

57 A heat exchanger has first and second chambers (2a,2b) through which flow respectively donor and acceptor gases. Heat is transferred between the gases by solid bodies (10), which fill both chambers (2a,2b) and are continuously circulated between the chambers (2a,2b) via conduits (6) by drive means - (8,54), located in at least one of the conduits (6). The chambers (2a,2b) may be disposed one above the other in which case the bodies (10) move from the upper (2a) to the lower chamber (2b) by gravity, and are returned by drive means (8). To reduce gas leakage between the chambers (2a,2b), finely divided particles may be mixed with the bodies (10) in the conduits (6).



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HEAT EXCHANGERS

This invention relates to heat exchangers in which heat is transferred between gaseous media.

Such heat exchangers are known in which the heat is transferred from a donor flow to an acceptor flow by conduction through a separating wall between the flows. Since there is a temperature gradient through the wall, related to its conductivity, the heat transfer is limited thereby and the acceptor gas outlet temperatures are considerably lower than the donor gas inlet temperatures.

It is possible to achieve higher heating temperatures in regenerative heat exchangers comprising stoves that contain a heat-absorbing mass. In one known type there are two stoves and the heating gas, e.g. a furnace off-gas, is passed alternately through each stove to heat the material inside. The acceptor gas, e.g. furnace combustion air, also flows alternately through each stove but in opposite phase to the exhaust gas, so that while one stove is receiving heat from the hot gas the other is giving it up to the combustion air. The alternating exposures of the heat-absorbing medium may be controlled by valves that switch the two stoves, or in a continuous arrangement the heat-absorbing medium is transferred between stoves continuously, as in a rotary regenerative heat exchanger, so that the waste gas and combustion air do not have to be diverted.

In practice the design of such regenerative heat exchangers has proved difficult because of the problem of sealing to avoid mixing of the two gas flows. While designs such as the "heat wheel" have been used commercially their success has been limited due to sealing problems and to the occurrence of blockages, particularly when used with gas flows that carry solid contaminants.

According to the present invention, there is provided a heat exchanger comprising respective chambers for the flow of donor and acceptor gases, connection means between said chambers establishing a closed path extending through said chambers, and means for circulating a quantity of solid bodies around said path to transfer heat between the respective gases.

The bodies being used as a heat transfer medium should preferably substantially fill the connection means defining said path between said chambers so as to offer a high resistance to any leakage gas flow therethrough. Preferably, they also substantially fill the chambers themselves so as to optimise the exposure of the gas flows to the heat exchange bodies.

A mass of small bodies may be used, preferably generally spherical in form and, they may be composed of or have an outer coating of a desired chemical reagent so that they can promote a chemical reaction with one or more of the gas flows as well as transfer heat between the chambers.

Drive means for maintaining the circulation of the bodies through the chambers are preferably disposed in the connection means between the chambers, and it is further preferred to have such drive means in the path of the cooled bodies before they are reheated by the donor flow. The drive means may comprise a screw conveyor or a drag link or chain conveyor, e.g. in the form of a bucket chain or a scraper conveyor or an entrainment chain (sometimes known as an "en masse" conveyor).

Conveniently, the bodies are allowed to flow by gravity through the chambers from donor gas flow chamber to acceptor gas flow chamber.

It is also possible within the scope of the invention to provide a closed circulation path which comprises a plurality of branches in parallel where the flow of the bodies is distributed between a plurality of donor gas chambers and/or acceptor gas chambers. For example two or more pairs of donor and acceptor gas chambers may be connected in parallel to a common recirculating conduit.

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

Figs. 1 and 2 are sectional and plan views of a first form of heat exchanger according to the invention, Fig. 1 being a section on the line A-A in Fig. 2,

Fig. 3 is a plan section of one of the chambers in Figs. 1 and 2,

Fig. 4 is a detail illustration in vertical section showing a possible modification,

Figs. 5 and 6 show further forms of heat exchanger according to the invention,

Figs. 7 and 8 are side and front views of another form of heat exchanger according to the invention, and

Figs. 9 and 10 are side views of further forms of heat exchanger according to the invention.

Referring firstly to Figs. 1 and 2, a recuperative heat exchanger is shown comprising two insulated containers or stoves 2a, 2b with inlet and outlet hoods 4 at their upper and lower ends forming chambers in communication with substantially smaller diameter vertical ducts 6a, 6b in each of which a respective conveyor screw 8 is mounted,

driven by an external motor 8'. The ducts 6 thus connect the bottom of each container 2 to the top of the other and a continuous circulation path is provided for a mass of small heat absorbing bodies, in particular balls 10 (see for example Fig. 4), that substantially fill the interior space of the heat exchanger. In the first container 2a, high temperature gases enter through a lower port 12 and exit through an upper port 14 after passing through the heat absorbing bodies 10 in the chamber and the heated bodies are progressively transferred from the bottom of the first container, by the first conveyor screw 8a, to enter the top of the second container 2b. In the second container, combustion air to be heated enters through a lower port 16 and absorbs heat from the bodies 10 before exiting through a top outlet 18 from the container. The second conveyor screw 8b transfers the bodies from the bottom of the second container 2b to the top of the first container 2a where they can be reheated. The heat exchange process is thus carried out continuously.

The two conveyor screws 8 are synchronised so that they transfer heat absorbing bodies 10 at a corresponding rate. It is possible to arrange, nevertheless, that the rate can be varied, whereby with constant gas flows in both chambers the outlet temperatures can be adjusted.

Fig. 3 illustrates the container construction in cross-section. There is an innermost lining 22 of an abrasion-resistant refractory to minimise wear and this is covered an insulating layer 24, for example refractory concrete. The insulating layer lines a supporting metal shell 26 which is covered by back-up insulation 28, e.g. a mineral wool, protected by a final outer cover 30 which may be required to form a weatherproof cladding. The ducts between the containers may be similarly insulated.

It is possible to arrange that the ducts 6 are substantially sealed as far as any gas flow is concerned so that no more than a minimal rate of cross-leakage will occur, e.g. 1-29% of the gas flows through the chambers themselves, corresponding to a pressure drop through the ducts some 50 times that through the containers. In most instances there can be a very large difference between the cross-sectional areas of the containers and the ducts, e.g. in excess of 80:1, which implies a maximum leakage flow of 1:80 in comparison with the gas flows in the containers themselves. The sealing effect in the conduits is also influenced by the contents of each conduit acting as a labyrinth seal to result in a substantially increased pressure drop, and the effect can be enhanced by a number of measures in addition to reducing the duct cross-sections in relation to the container

cross-sections. In particular, the clearances between the conveyor screws and the duct walls are kept to a minimum and the conveyor screw is given a relatively fine pitch.

As a further means of reducing the leakage through the ducts, finely divided particles, such as sand, can be mixed with the heat absorbing bodies 10 at the base of each container where the balls enter the conveyor. Fig. 4 illustrates a modification of the heat exchanger to adapt it for operation in this manner in which, after the particles in the spaces between the bodies have been carried to the top of the conveyor duct, they are separated from the bodies to prevent the particles from entering the following chamber. This is done by providing a sloping face 34 between conveyor duct 6 and the container 2, in which face there is a screen or sieve plate 36. The screen mesh is too small for the bodies 10 but the particles can pass through the screen into a further duct 38 leading to the base or entry region of the conveyor duct 6. The particles are thus circulated continually through the conveyor duct to restrict gas flow through the spaces that exist between the spherical bodies in the duct but they bypass the following heat exchange chamber so that they do not obstruct the gas flow there.

Each of the conveyor ducts 6 may be provided with such a circulating flow of particulate material, but in the case of a regenerative heat exchanger for furnace gases the greater pressure differential will exist between the combustion air outlet and the exhaust gas inlet, so that the duct between those points would have the leakage-restriction means if only one duct were to be so provided. It is also possible to give the particulate material a circulatory path in which it flows alternately through each duct 6a, 6b, restricting any gas flow through both while bypassing the chambers themselves, this does, however, have the disadvantage that as compared with a particle flow circulating only through the duct carrying the bodies heated to their maximum temperature, those bodies will be subject to more cooling before they come into contact with the acceptor gas.

In Fig. 5 a modified arrangement is shown in which the two containers 2a, 2b are mounted one above the other with the heating gas passing through the upper container 2a so that the bodies 10 heated there flow by gravity through a second insulated duct 6' to the lower container 2b. A conveyor screw shrouded in the duct 6 transfers the cooled bodies back to the top entry region of the upper container. As compared with the first example, a higher maximum temperature can be maintained because a mechanical drive is not required to move the heat absorbing bodies between the

upper to the lower container, when the bodies are at their hottest. In addition, because the chambers are linked by a gravity feed, the flow of the bodies between the chambers is self-synchronizing.

As a further modification, Fig. 6 shows a heat exchanger similar to that in Fig. 5 but in which the two insulated containers 2a, 2b have different volumes, to provide a larger chamber for the acceptor gas flow than for the donor gas flow. As compared with the previous example, this allows a larger volume of gas to be heated, albeit to a lower maximum temperature, with a lower pressure drop because of the increased cross-section.

If either or both of the gas flows carry any significant quantity of fine particles, for example if the donor gas is the exhaust gas from a coal combustion process and contains ash, it may be desirable to provide a means of removing this material so as to prevent it accumulating within the heat exchanger, as is done in the example of Figs. 7 and 8, which is similar in many respects to the examples of Figs. 5 and 6. In this further embodiment, somewhat analogously to the example of Fig. 3, a lateral offset between the two chambers 2a, 2b is provided to leave an inclined bottom wall 40 in the passage between the containers. By providing that wall with a screen of suitable mesh size, small-size particles of contaminating material deposited from the upper chamber can fall through the screen into an integral bin 42 from which they are carried away by a screw feeder 44 or similar device to be collected in a sealed vessel 46. When the vessel is full a valve 48 in the entry line 50 to it is closed and the vessel can be emptied; the interior of the heat exchanger therefore remains sealed throughout.

If the hot gas is produced by the combustion of coal or some other fuel that contains sulphur, it is possible to adapt a heat exchanger according to the invention to reduce the sulphur emission level by coating the heat absorbing bodies with a suitable material such as limestone or dolomite which will react with and fix sulphur in the gas. Because the material would be fully calcined ($\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$) and because the very large surface area of the bodies is constantly abraded to expose fresh material, this reaction can be maintained at a high efficiency. Of course, regular replacement of the bodies would be required to replenish the supply of reactant, at a rate of about the same order of magnitude as the sulphur content in the hot gas. Depending upon the parameters, it may not be necessary for all the bodies to carry reactive material and if a mixture is used it may be preferred, e.g. for replenishment of the reactant, to make the different bodies of different sizes so that they can be separated by screening.

As a means of reducing sulphur emissions, it is possible additionally or alternatively to introduce CaCO_3 as a powder or in fine pellet form, such material possibly being injected with the incoming hot gas. As with material abraded from the bodies, these small particles can be removed with the ash in the manner illustrated in Figs. 7 and 8. In all instances the sulphur-fixing reaction may be accelerated by the presence of a suitable catalyst either in the material of the bodies themselves, or as a coating on the bodies, or as a separate additive.

The forms of apparatus shown in Figs. 5 to 8 may be difficult to accommodate in some applications because of the large overall height of the heat exchanger. If required, however, a modified configuration such as that shown in Fig. 9 can be employed to reduce the overall height. The two insulated containers 2a, 2b are mounted with their longitudinal axes oppositely inclined at a relatively small angle only marginally greater than the angle of repose of the bodies 10. At the end regions of the containers that are at a larger vertical spacing a conveyer screw in the insulated duct 6 transfers the cooled bodies from the lower container to the upper container. The bodies heated in the upper container are transferred by gravity through a short insulated duct 6" at their opposite, closer ends. This latter duct, which may have its axis canted out of the vertical plane, has a length that is calculated to give an acceptable compromise as regards the limitation of cross-leakage of gases between the containers and the restriction of the overall height of the apparatus.

In Fig. 10 a further embodiment of the invention is illustrated in which three pairs of the insulated containers 2a, 2b are connected in parallel to an insulated duct 6c, as in previous examples each pair of containers providing an upper chamber for the donor gas flow and a lower chamber for the acceptor gas flow. A drag link conveyor 54 within the duct 6c raises the heat-absorbing bodies 10 from the acceptor gas chamber exits to return them to the donor gas chamber entries. The conveyor 54 may take the form of a bucket chain conveyor, but preferably it is of the kind that moves the bodies in a continuous stream. An example of such a conveyor is the Redler "en masse" elevator manufactured by Redler Limited of Stroud, Glos., England. Using an "en masse" conveyor, distribution of the heat exchange bodies between the pairs of chambers can be controlled at the exits from the acceptor gas chambers; baffles 56a, 56b at the exits of the first two chambers in the direction of travel of the conveyor limit the depth of deposition from these chambers onto the conveyor. The baffles are

so adjusted that a similar rate of deposition is maintained from each of the three exits and therefore a similar throughput rate is maintained in each pair of containers.

It will be understood that the various modifications of the apparatus referred to above have been illustrated and described separately for the sake of simplicity and that combinations of these modifications can be provided in apparatus according to the invention.

It will be noted that in each of the examples that have been given, no high temperature valving is required in the heat exchanger, so simplifying the construction and permitting the use of higher maximum temperatures. Because the bodies are constantly in rubbing contact their surfaces are continually cleaned and it is possible to use the apparatus with dirty gases that might cause contamination or a build-up of deposits in known forms of heat exchanger. Because it can be arranged that fine particles, including fly ash, can be removed automatically from the circulation path of the bodies, the heat exchangers can be employed in coal fired applications without risk of blockage.

The apparatus can be operated so that temperature fluctuations in the acceptor gas flow can be reduced or removed, making the heat exchanger particularly suitable for many applications, e.g. for the heating of combustion air, where maintaining the air output at a constant temperature facilitates control of the furnace in which it is to be used.

Claims

1. A heat exchanger comprising respective chambers (2a,2b) for flows of donor and acceptor gases, and means (8) for displacing a heat absorbing mass between said chambers to transfer heat between the respective gases, characterised in that the heat absorbing mass comprises a quantity of solid bodies (10), and connection means (4,6) are provided between the chambers establishing closed path extending through the chambers for circulation of solid bodies therethrough.

2. A heat exchanger according to claim 1 wherein there is a pair of said chambers (2a,2b) disposed one higher than the other to permit a flow under gravity from the upper chamber (2a) to the lower chamber (2b).

3. A heat exchanger according to claim 2 wherein said upper chamber (2a) is arranged to receive the donor gas flow whereby the heated bodies (10) are transferred with the aid of gravity to the lower chamber (2b).

4. A heat exchanger according to claim 2 or claim 3 wherein the chambers (2a,2b) are oppositely inclined at oblique angles greater than the angle of repose of the bodies (10), the respective chambers having one pair of end regions more closely spaced vertically and between which the bodies are arranged to be transferred by gravity, and an opposite pair of end regions more widely spaced vertically between which drive means (8) displace the bodies to return them from the lower to the upper chamber.

5. A heat exchanger according to any one of claims 1 to 3 wherein drive means (8) for displacing the bodies (10) are provided in at least one part of the connection means (4,6) between the chambers.

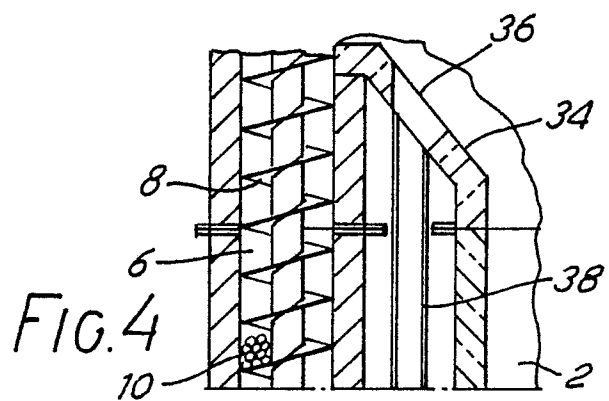
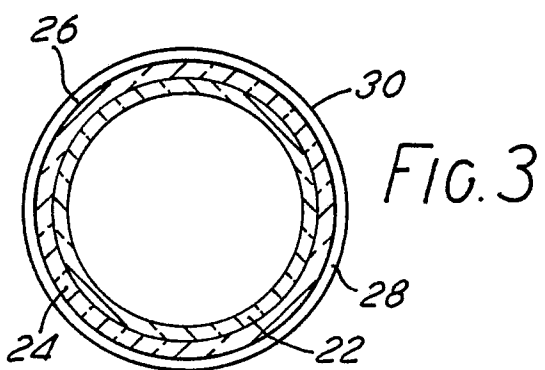
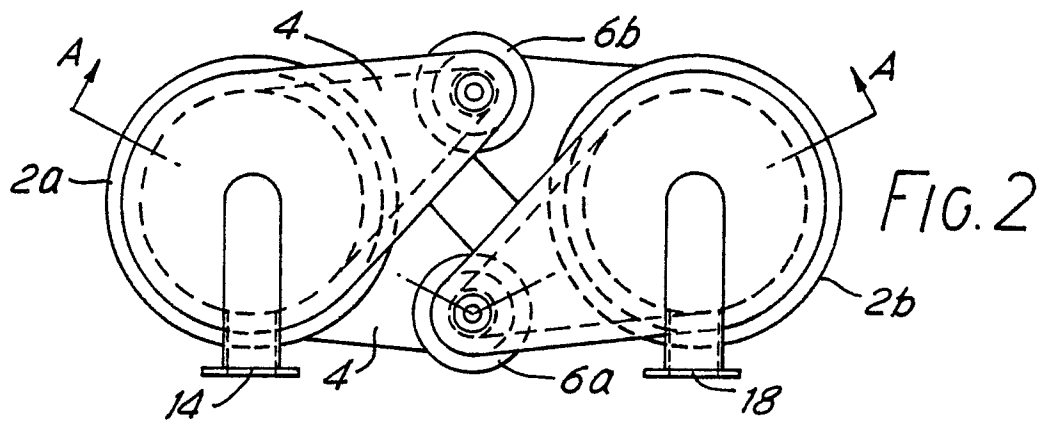
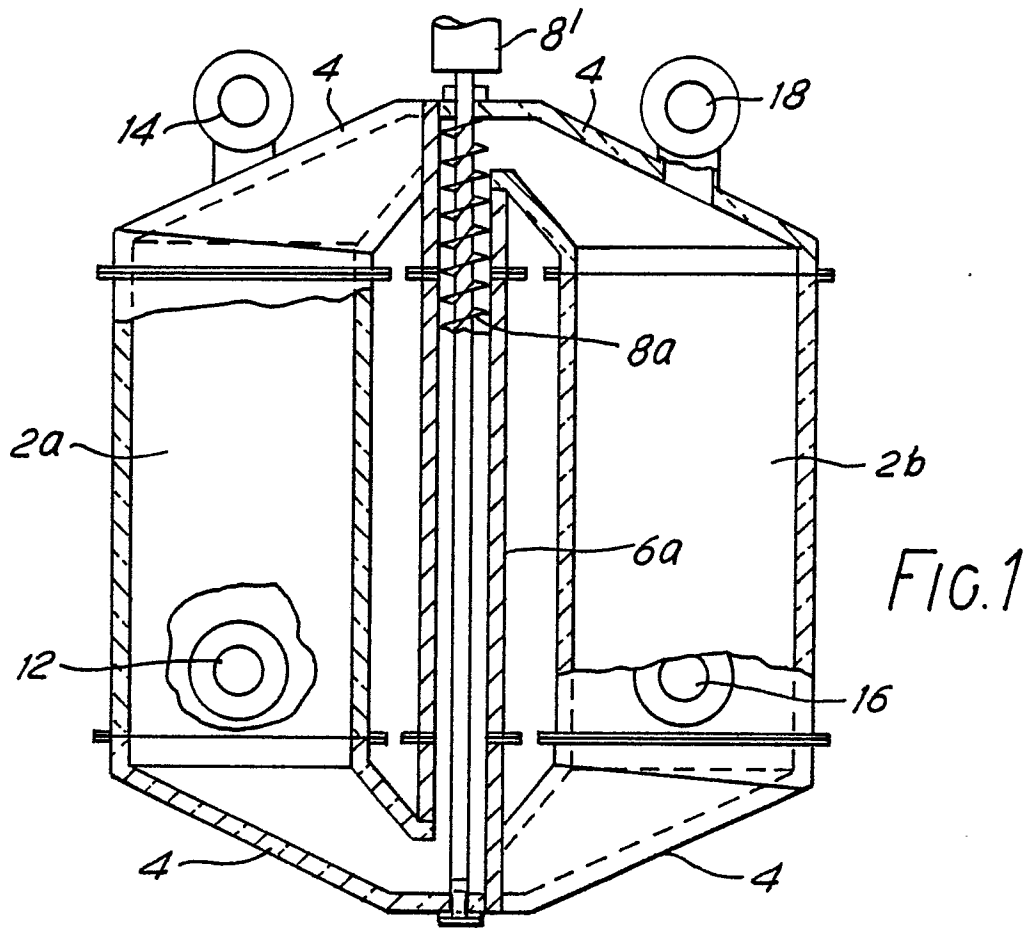
6. A heat exchanger according to claim 5 wherein said drive means comprises a conveyor screw (8) extending axially along a duct (6) defining said part of the path.

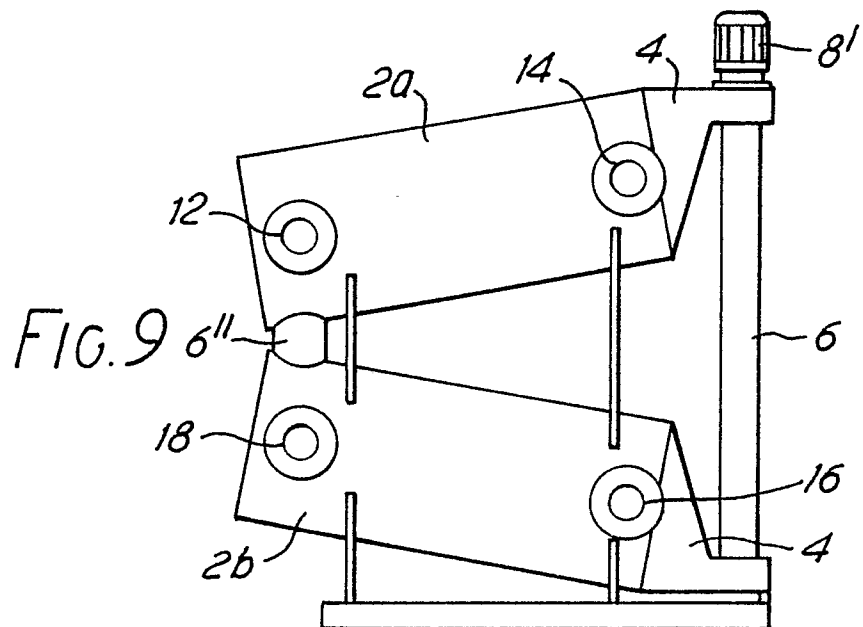
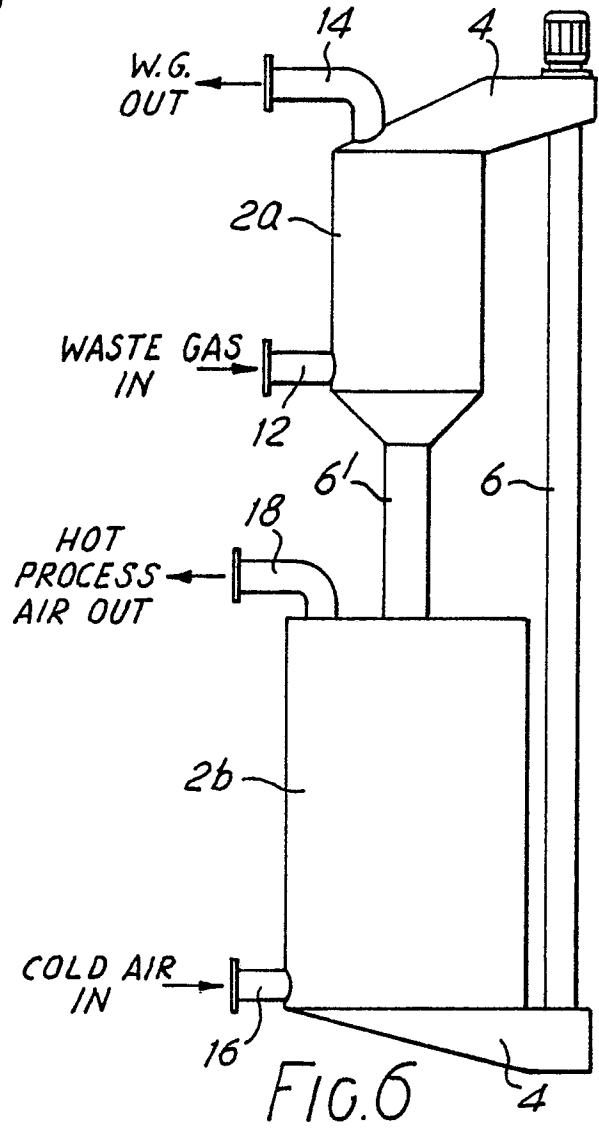
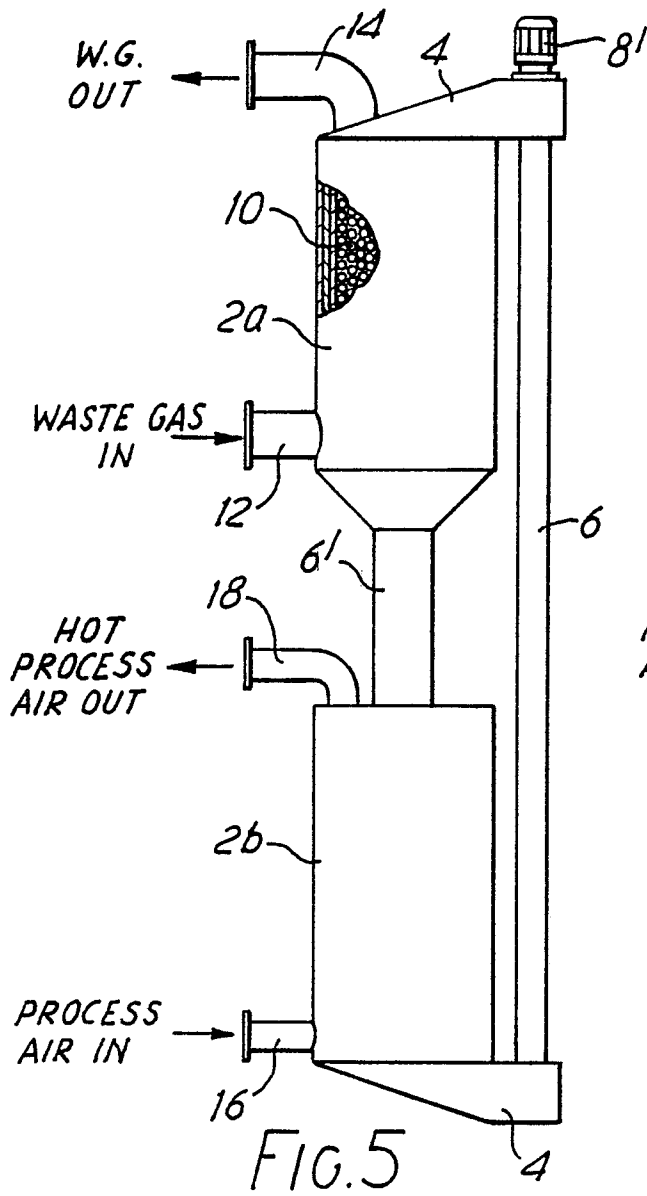
7. A heat exchanger according to claim 5 wherein said drive means comprises a recirculating conveyor chain (54).

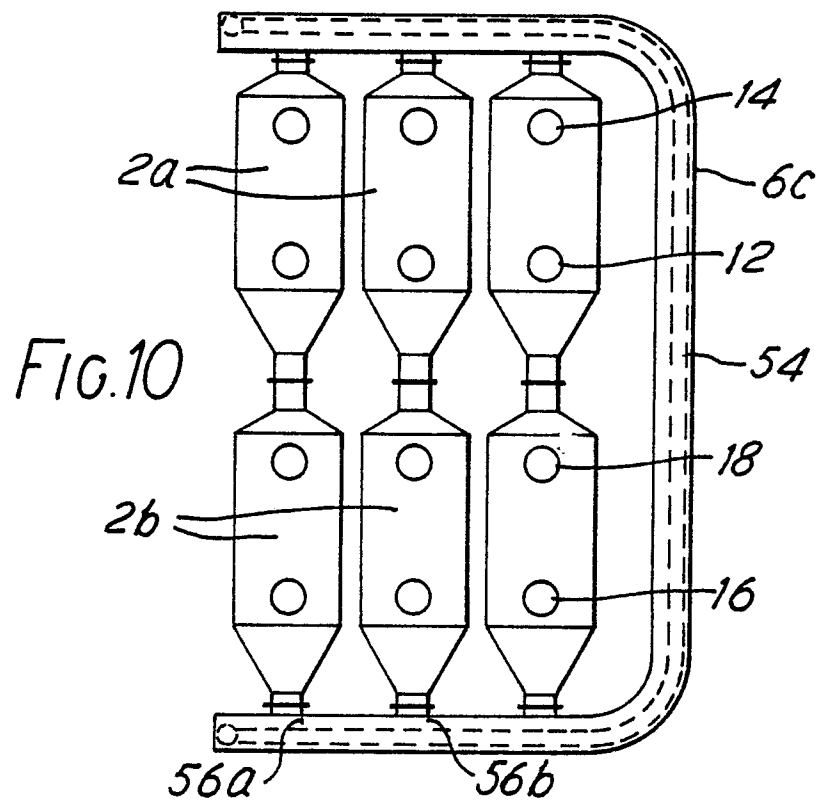
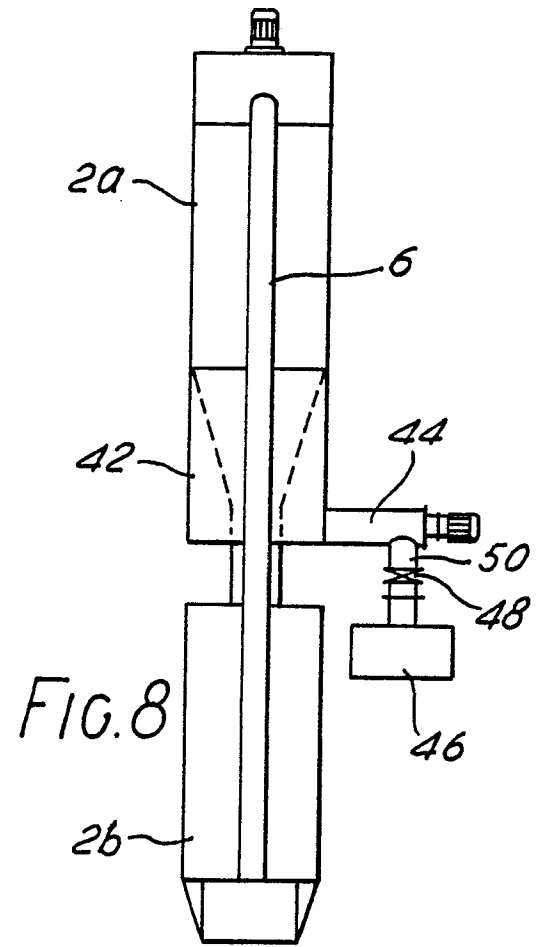
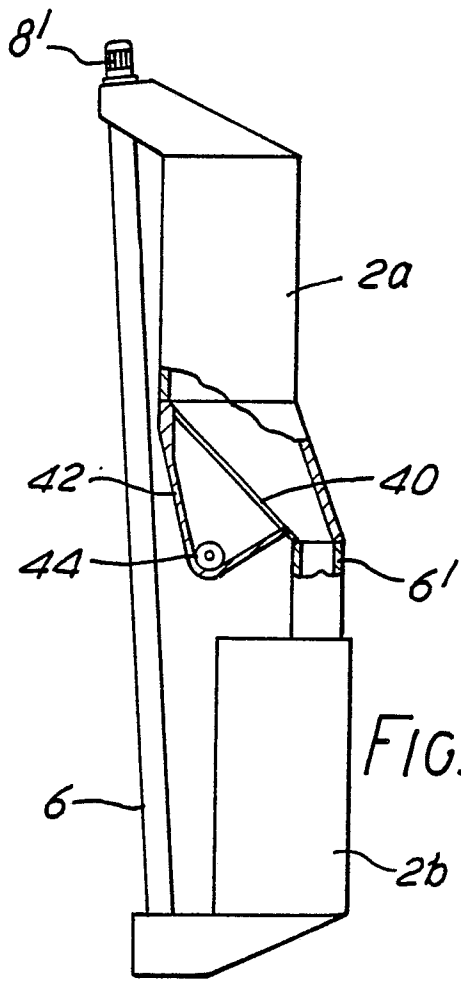
8. A heat exchanger according to any one of the preceding claims comprising means for mixing with the bodies (10), in at least one part of the circulation path between the chambers, a particulate material of small particle size relative to the bodies to act as blocking means for reducing gas leakage through the spaces between the bodies in said part of the path.

9. A heat exchanger according to claim 8 wherein means (34,36) are provided to separate said particulate material from the bodies (10) before the bodies enter the following chamber.

10. A heat exchanger according to any one of the preceding claims wherein the bodies (10) comprise a material for performing or promoting a chemical reaction with at least one constituent of the gas flows through the chambers.









EP 87 30 1302

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. 4)
X	DE-A-3 407 341 (P. KÄHMANN) * Abstract, claim 1, figure *	1-3,5	F 28 D 19/02 B 01 J 8/38
Y	---	4,8-10	
Y	CH-A- 413 883 (SIEMENS-SCHUCKERTWERKE) * Page 4, lines 48-83; figure 8 *	4	
Y	---	8-10	
Y	US-A-3 067 131 (E.V. BERGSTROM) * Column 1, lines 12-21, 33-40, 49-58; column 6, lines 4-27; col- umn 7, lines 44-75; column 8, lines 1-10; figures 1-4 *		
X	---	1-3,5	TECHNICAL FIELDS SEARCHED (Int. Cl. 4)
X	US-A-2 745 656 (L.P. MEADE) * Column 1, lines 19-24, column 3, lines 38-41; figure *		F 28 D B 01 J
X	---	1-3,5	
X	FR-A-1 177 523 (THE AIR PREHEATER CORPORATION) * Claims 1-6; figures 1,2 *		
X	---	1-3,5	
X	DE-A-1 501 567 (LINDE AG) * Claims 1-3,8,12,13; figure *		
X	---	1,5	
X	EP-A-0 016 713 (TUNZINI-NESSI ENTREPRISES D'EQUIPEMENTS) * Abstract; figures 1,6 *		
	---	-/-	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 26-05-1987	Examiner HOERNELL, L.H.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	



DOCUMENTS CONSIDERED TO BE RELEVANT			Page 2
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	US-A-3 104 955 (W.C. MARCHAND) * Figure 1 *	1,5,6	

X	GB-A-1 113 176 (M. BAUDER) * Page 2, lines 22-27; figure 1 *	1,5,7	

A	US-A-1 904 153 (C.E. LUCKE) * Page 1, lines 44-63 *	4,7,8	

			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 26-05-1987	Examiner HOERNELL, L.H.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	