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(54) **Modular heat pipe heat exchanger**

(57) A heat pipe heat exchanger (12, 12') for transferring heat from a hot gas to a cold gas comprises a housing with a first chamber (14) for feeding a hot gas therethrough; a second chamber (20) for feeding a cold gas therethrough; and a plurality of heat pipes (26) extending between the first chamber (14) and the second chamber (20) for transferring heat from the hot gas to the cold gas. The heat pipe heat exchanger (12, 12') further comprises one or more heat pipe cartridges (36) removably arranged in the housing. Each heat pipe cartridge (36) comprises a frame (38) with a support panel (40) for supporting a plurality of heat pipes (26); the support panel (40) being arranged such that, when the heat pipe cartridge (36) is arranged in the housing, the support panel (40) cooperates with a separation wall (32) between the first chamber (14) and the second chamber (20) to form a gas-tight partition between the first and second chambers (14, 20). The heat pipes (26) traverse the support panel (40) and are secured thereto in a gas-tight manner.

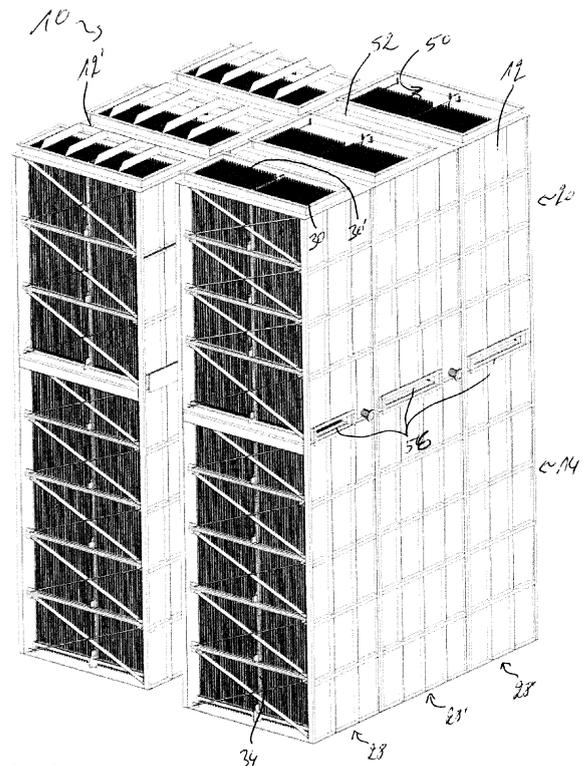


Fig.2

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Description

FIELD OF THE INVENTION

[0001] The present invention generally relates to a heat pipe heat exchanger for transferring heat from a hot gas to a cold gas, in particular in heat recovery installations for preheating combustion air and/or combustion gas.

BACKGROUND OF THE INVENTION

[0002] Heat recovery systems are used in various industries in order to recover heat from one medium and transfer it to another medium. The use of excess heat of one gas to preheat another gas reduces energy consumption and is therefore also more environment friendly.

[0003] One such heat recovery system is e.g. disclosed in US 4,434,004, which relates to a method and an apparatus for the recovery and recycling of heat from hot exhaust gases, specifically from exhaust gases in metallurgical processes and from warm gases. Warm or hot exhaust gases transfer their retained heat to the lower portions of vertically positioned heat pipes. Cold air or gas is then directed past the upper portion of the heat pipes, thereby transferring the heat of the heat pipes to the cold air or gas. The apparatus comprises a lower chamber through which the hot gas is fed and an upper chamber through which the cold gas is fed. Heat pipes are vertically arranged in the two chambers and extend from one chamber into the other. As the hot gas passes through the lower chamber, heat from this hot gas is absorbed by the lower portion of the heat pipes thereby cooling down the hot gas. In the heat pipes, the heat is transferred from its lower portion to its upper portion. The cold gas passing through the upper chamber is heated up by passing through the hotter upper portion of the heat pipes.

[0004] Heat pipe heat exchangers are often used for their very rapid heat transfer. They do however, like other types of heat exchangers, face the problem of fouling and contamination of dirt, dust and particles in the fluids. Such dirt may indeed be deposited on the heat transfer surface of the heat pipe and thereby reduce the heat transfer efficiency between the heat pipe and the fluid to be heated or cooled. Furthermore, as more and more dirt is deposited, the heat pipe heat exchanger becomes clogged and the pressure drop through the heat exchanger is then increased.

[0005] It is thus periodically necessary to perform a maintenance shutdown of the heat recovery system to clean up the contamination and open up the flow passages through the heat exchanger. In view of the large number of heat pipes arranged in such a heat exchanger, the cleaning of the heat pipes is generally a very time consuming process. Furthermore, the difficult access to the various areas in the heat exchanger does not facilitate

the clean up process. Prolonged shutdown periods necessarily result in production losses and high operational costs.

5 OBJECT OF THE INVENTION

[0006] The object of the present invention is to provide a heat pipe heat exchanger, which avoids the above disadvantages.

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SUMMARY OF THE INVENTION

[0007] This object is achieved by a heat pipe heat exchanger as claimed in claim 1.

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[0008] A heat pipe heat exchanger for transferring heat from a hot gas to a cold gas comprises a housing with a first chamber for feeding a hot gas therethrough; a second chamber for feeding a cold gas therethrough; and a plurality of heat pipes extending between the first chamber and the second chamber for transferring heat from the hot gas to the cold gas. According to an important aspect of the invention, one or more heat pipe cartridges removably arranged in the housing. Each heat pipe cartridge comprises a frame with a support panel for supporting a plurality of heat pipes. The support panel is arranged such that, when the heat pipe cartridge is arranged in the housing, the support panel cooperates with a separation wall between the first chamber and the second chamber to form a gas-tight partition between the first and second chambers; Furthermore, the heat pipes traversing the support panel and being secured thereto in a gas-tight manner.

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[0009] According to the present invention, the heat pipes are bundled together in heat pipe cartridges for facilitating the heat exchanger maintenance. The heat exchanger is divided into a number of heat pipe compartments, each of which is designed and configured so as to receive one heat pipe cartridge therein.

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[0010] Such a heat pipe cartridge is installed in the heat exchanger such that its support panel is level with the separation wall. The support panel is connected to the separation wall so as to form a separation between the first and second chambers.

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[0011] During a maintenance shutdown, the heat pipes can be inspected. If one or more of the heat pipe cartridges require maintenance, e.g. because of a broken heat pipe or heavily contaminated heat transfer surfaces, the heat pipe cartridges concerned can be lifted out of the heat exchanger. A replacement heat pipe cartridge may then be installed into the heat exchanger and the heat transfer system can be put back into operation. The damaged heat pipe cartridge can be cleaned or mended outside of the heat exchanger, thus without prolonging the stoppage period of the heat recovery system. Indeed, the most time consuming part of the maintenance can now be performed outside the heat exchanger, while the latter is in operation. By providing a modular heat pipe heat exchanger with exchangeable heat pipe cartridges,

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the stoppage period of the heat recovery system can be greatly reduced.

[0012] The support panel of the heat pipe cartridge is preferably welded to the separation wall to form a gas-tight seal between the first and second chambers. A circumferential weld is performed after installation of the heat pipe cartridge on the heat exchanger. Before removal of the heat pipe cartridge from the heat exchanger, this circumferential weld can be broken.

[0013] According to a preferred embodiment of the invention, partition panels are arranged in the first and second chambers for dividing the chambers into heat pipe compartments, the partition panels being arranged in a plane essentially parallel to the flow of gas through the chambers. One or more partition panels divide the cross-section of gas flow into two or more smaller cross-sections. This division of the chambers, along their width, into smaller compartments enhances the acoustic characteristics of the heat exchanger by reducing the flow-induced vibrations that may lead to a structural collapse of the heat exchanger. In the heat exchangers of the present invention, vibration of the heat pipes is greatly reduced, thereby avoiding such a structural collapse.

[0014] The heat exchanger preferably comprises a first opening in an outer wall of the second chamber and a second opening in the separation wall between the first and second chambers; the first and second openings being arranged and dimensioned so as to feed a heat pipe cartridge therethrough. The first and second openings allow for the heat pipe cartridge to be easily and quickly fed into or removed from the heat exchanger.

[0015] The heat pipes are advantageously secured to the support panel by means of a screw and counter-nut mechanism with metal gaskets provided on both sides of the support panel thereby providing a gas-tight connection that may nevertheless be loosened for the replacement of the heat pipes for maintenance and replacement purposes.

[0016] These and other preferred embodiments are recited in the appended dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1: is a perspective view of a heat recovery system with two heat pipe heat exchangers according to the present invention;

FIG. 2: is a perspective view of a heat recovery system of Fig.1 without its transition hoods;

FIG. 3: is a perspective view of a heat pipe cartridge for the heat recovery system of Fig.1; and

FIG. 4: is a perspective view of the frame of the heat

pipe cartridge of Fig.3.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

[0018] Fig.1 shows a preferred embodiment of a heat pipe recovery system 10 with two heat pipe heat exchangers 12, 12' according to the present invention. One heat exchanger 12, 12' may be used for preheating combustion gas, while the other one 12, 12' may be used for preheating combustion air.

[0019] Each heat exchanger 12, 12' comprises a first chamber 14 with a first port 16 and a second port 18 and a second chamber 20 with a third port 22 and a fourth port 24. The second chamber 20 is, in the embodiment shown in the figures, vertically arranged above the first chamber 14. A plurality of heat pipes 26 - generally a few thousand - is vertically arranged in the first and second chambers 14, 20. These heat pipes 26 generally extend over the whole height of the second chamber 20, pass through a separation wall (not visible in Fig.1) from the second chamber 20 to the first chamber 14 and extend over the whole height of the first chamber 14. The air or gas flow through the heat exchanger may be from the first and third ports 16, 22 to the second and fourth ports 18, 24 respectively. Preferably, however, the heat exchanger is operated in a counter-flow mode, wherein air or gas flow through the heat exchanger from the first and fourth ports 16, 24 to the second and third ports 18, 22 respectively.

[0020] According to the present invention, the heat pipes 26 are bundled together in heat pipe cartridges for facilitating the heat exchanger maintenance. The heat exchanger 12 shown in Fig.1 is divided, in the gas flow direction, into three heat pipe modules 28, 28', 28", each of which are again divided, perpendicular to the gas flow direction, into two heat pipe compartments 30, 30'. Each heat pipe compartment 30, 30' is designed and configured so as to receive one heat pipe cartridge therein.

[0021] The heat pipe modules 28, 28', 28" and heat pipe compartments 30, 30' are more apparent on Fig.2, which represents the heat recovery system 10 of Fig.1 wherein the transition hoods for connection with ducts of have been removed. Fig.2 also shows the separation wall 32 between the first and second chambers 14, 20.

[0022] It can also be seen that partition panels 34 are arranged between the heat pipe compartments 30, 30'. These partition panels 34 are in a direction parallel to the flow of gas through the heat exchanger 12, 12' and divide the cross-section of gas flow into two smaller cross-sections. This division of the chambers 14, 20, along their width, into smaller compartments enhances the acoustic characteristics of the heat exchanger by reducing the flow-induced vibration. In the heat exchangers 12, 12' of the present invention, vibration of the heat pipes is greatly reduced, thereby reducing noise pollution by the heat exchangers. The partition panels 34 are preferably removably arranged so that they may be removed during

a maintenance shutdown for facilitating access to the heat pipes 26. More than one partition panel 34 may be provided so as to divide the cross-section of gas flow into more than two smaller cross-sections.

[0023] As stated above, the heat pipes 26 are, according to the present invention, bundled together in heat pipe cartridges 36, one of which is shown in more detail on Fig.3. The heat pipe cartridge 36 is now more closely described by referring to Figs 3 and 4, the latter representing the heat pipe cartridge 36 of Fig.3 with all of the heat pipes removed.

[0024] The heat pipe cartridge 36 comprises a plurality of heat pipes 26 - a few hundred thereof - mounted in a frame 38. Such a frame 38 comprises a support panel 40 with an upper surface 42 facing, when installed, the second chamber 20 and a lower surface 44 facing, when installed, the first chamber 14. The support panel 40 comprises a number of apertures for passing the individual heat pipes 26 therethrough. Connection means, which are more closely described below, are provided for securing each heat pipe 26 to the support panel 40. The frame 38 further comprises a number of auxiliary panels 46 with apertures for passing the individual heat pipes 26 therethrough. The auxiliary panels 46 are arranged parallel to and at a predetermined distance from the support panel 40 and each other. The apertures of the auxiliary panels 46 have a diameter large enough to pass the heat pipes 26 with their associated fins therethrough without creating a secure connection between the auxiliary panels 46 and the heat pipes 26. Indeed, the purpose of the auxiliary panels 46 is mainly to keep neighbouring heat pipes 26 at a predetermined distance from each other. The auxiliary panels 46 serve as distance guide and keep the heat pipes in line during operation.

[0025] The support panel 40 and the auxiliary panels 46 are, as shown in fig.4, connected together by means of four connection rods 48. The support panel 40, the auxiliary panels 46 and four connection rods 48 are securely connected together, e.g. by welding, to form the frame 38 of the heat pipe cartridge 36.

[0026] The heat pipes 26 are securely connected to the support panel 40 and, in order to avoid the transfer of gas from one chamber 14, 20 into the other, the connection of the heat pipes should be gas tight. A number of connection means are known, such as e.g. welding of the heat pipe directly to the support panel; pressing and tightening with seal rings; or screwing into the support panel. Preferably, however, a screw and counter-nut mechanism is used wherein tightness is achieved on both sides of the support panel by the screw head on the one side and the counter-nut on the other. Metal gaskets are preferably provided on both sides of the support panel 40 between the screw head and the upper surface 42 of the support panel 40 and between the counter-nut and the lower surface 44 of the support panel 40.

[0027] The screw and counter-nut mechanism has the advantage that individual heat pipes 26 can be removed from the support panel 40 and replaced. Damaged heat

pipes can thus be replaced easily. Furthermore, a gas-tight seal is formed between the upper and lower surfaces 42, 44 of the support panel 40 so that gas from the first chamber 14 does not mix with gas from the second chamber 20. This is of particular importance if one of the gasses is a combustion gas.

[0028] In order to install and remove the heat pipe cartridges 36, the heat exchanger is provided with a first opening 50 in an outer wall 52 of the second chamber 20. A second opening 54 is arranged in the separation wall 32 between the first and second chambers 14, 20.

[0029] During installation, a heat pipe cartridge 36 is vertically lowered into the heat exchanger 12, 12' through the first opening 50 and the second opening 54. The support panel 40 is lowered to the level of the separation wall 32 to close the second opening 54. Preferably, the support panel 40 rests with its edge on the separation wall 32 before it is welded thereto on the whole of its circumference, thereby creating a gas-tight connection between the support panel 40 and the separation wall 32. Once installed in the heat exchanger 12, 12', the lower portion of the heat pipes 26 is arranged in the first chamber 14 and acts as evaporator when hot gas is fed through the first chamber 14, while the upper portion of the heat pipes 26 is arranged in the second chamber 20 and acts as condenser when cold gas is fed through the second chamber 20.

[0030] During a routine maintenance shutdown, the heat pipes 26 can be inspected via manholes and inspection windows 56 arranged in the sidewalls of the heat exchanger 12, 12'. If one or more of the heat pipe cartridges 36 require maintenance, e.g. because of a broken heat pipe or heavily contaminated heat transfer surfaces, the heat pipe cartridges 36 concerned can be removed by breaking the weld between the support panel 40 and the separation wall 32 and by lifting the damaged heat pipe cartridge 36 out of the heat exchanger 12, 12'. A replacement heat pipe cartridge 36 is then installed into the heat exchanger and the heat transfer system can be put back into operation. The damaged heat pipe cartridge 36 can be cleaned or mended outside of the heat exchanger, thus without prolonging the stoppage period of the heat recovery system. Indeed, the most time consuming part of the maintenance can now be performed outside the heat exchanger, while the latter is in operation. By providing a modular heat pipe heat exchanger with exchangeable heat pipe cartridges, the stoppage period of the heat recovery system can be greatly reduced.

[0031] It should be noted that the present description relates to a heat exchanger associated to a hot stove installation. Such a heat exchanger generally has the two chambers 14, 20 arranged vertically one above the other. It is however also in the scope of the invention to place the two chambers 14, 20 almost horizontally one next to the other. The heat pipes should however present a slight inclination (e.g. at least 5°) with respect to the horizontal. Such arrangements may be used for other applications

such as e.g. power plants.

LIST OF REFERENCE SIGNS

[0032]

10 heat recovery system
 12 heat pipe heat exchanger
 14 first chamber
 16 first port
 18 second port
 20 second chamber
 22 third port
 24 fourth port
 26 heat pipe
 28 heat pipe module
 30 heat pipe compartment
 32 separation wall
 34 partition panel
 36 heat pipe cartridge
 38 frame
 40 support panel
 42 upper surface
 44 lower surface
 46 auxiliary panel
 48 connection rod
 50 first opening
 52 outer wall
 54 second opening
 56 inspection window

Claims

1. Heat pipe heat exchanger for transferring heat from

a hot gas to a cold gas, said heat pipe heat exchanger (12, 12') comprising a housing with
 a first chamber (14) for feeding a hot gas there-through;
 a second chamber (20) for feeding a cold gas there-through; and
 a plurality of heat pipes (26) extending between the first chamber (14) and the second chamber (20) for transferring heat from said hot gas to said cold gas
characterized by
 one or more heat pipe cartridges (36) removably arranged in said housing; wherein each heat pipe cartridge (36) comprises a frame (38) with a support panel (40) for supporting a plurality of heat pipes (26); said support panel (40) being arranged such that, when said heat pipe cartridge (36) is arranged in said housing, said support panel (40) cooperates with a separation wall (32) between said first chamber (14) and said second chamber (20) to form a gas-tight partition between said first and second chambers (14, 20); said heat pipes (26) traversing said support panel (40) and being secured thereto in a gas-tight manner.

2. The heat pipe heat exchanger according to claim 1, wherein said support panel (40) of said heat pipe cartridge 36 is welded to said separation wall (32) to form a gas-tight seal between said first and second chambers (14, 20).

3. The heat pipe heat exchanger according to any of claims 1 to 2, wherein said frame (38) further comprises one or more auxiliary panels (46), each auxiliary panel (46) comprising a plurality of apertures for receiving heat pipes (26) therethrough, said apertures being arranged so as to provide guides for said heat pipes (26) and keep said heat pipes (26) essentially parallel to each other.

4. The heat pipe heat exchanger according to claim 3, wherein said heat pipes (26) are provided with fins and said apertures of said auxiliary panels (46) have a diameter large enough to pass said fins there-through.

5. The heat pipe heat exchanger according to any of claims 3 to 4, wherein said frame comprises one or more connection rods (48) for connecting said support panel (40) and said auxiliary panels (46) thereto.

6. The heat pipe heat exchanger according to any of claims 1 to 5, wherein partition panels (34) are arranged in said first and second chambers (14, 20) for dividing said chambers (14, 20) into heat pipe compartments (30, 30') said partition panels (34) being arranged in a plane essentially parallel to the flow of gas through said chambers (14, 20).

7. The heat pipe heat exchanger according to any of claims 1 to 6, wherein said heat exchanger (12, 12') comprises a first opening (50) in an outer wall (52) of said second chamber (20) and a second opening (54) in said separation wall between said first and second chambers (14, 20); said first and second openings being arranged and dimensioned so as to feed a heat pipe cartridge therethrough. 5
8. The heat pipe heat exchanger according to any of claims 1 to 7, wherein said support panel (40) is welded to said separation wall (32) when said heat pipe cartridges (36) is installed in said heat exchanger (12, 12'). 10
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9. The heat pipe heat exchanger according to any of claims 1 to 8, wherein manholes and inspection windows (56) are arranged in the sidewalls of said heat exchanger (12, 12'). 20
10. The heat pipe heat exchanger according to any of claims 1 to 9, wherein the heat pipes (26) are secured to said support panel (40) by means of a screw and counter-nut mechanism. 25
11. The heat pipe heat exchanger according to claim 10, wherein a metal gasket is provided between a screw head of the screw and an upper surface (42) of said support panel (40); and/or between a counter-nut and a lower surface (44) of said support panel (40). 30
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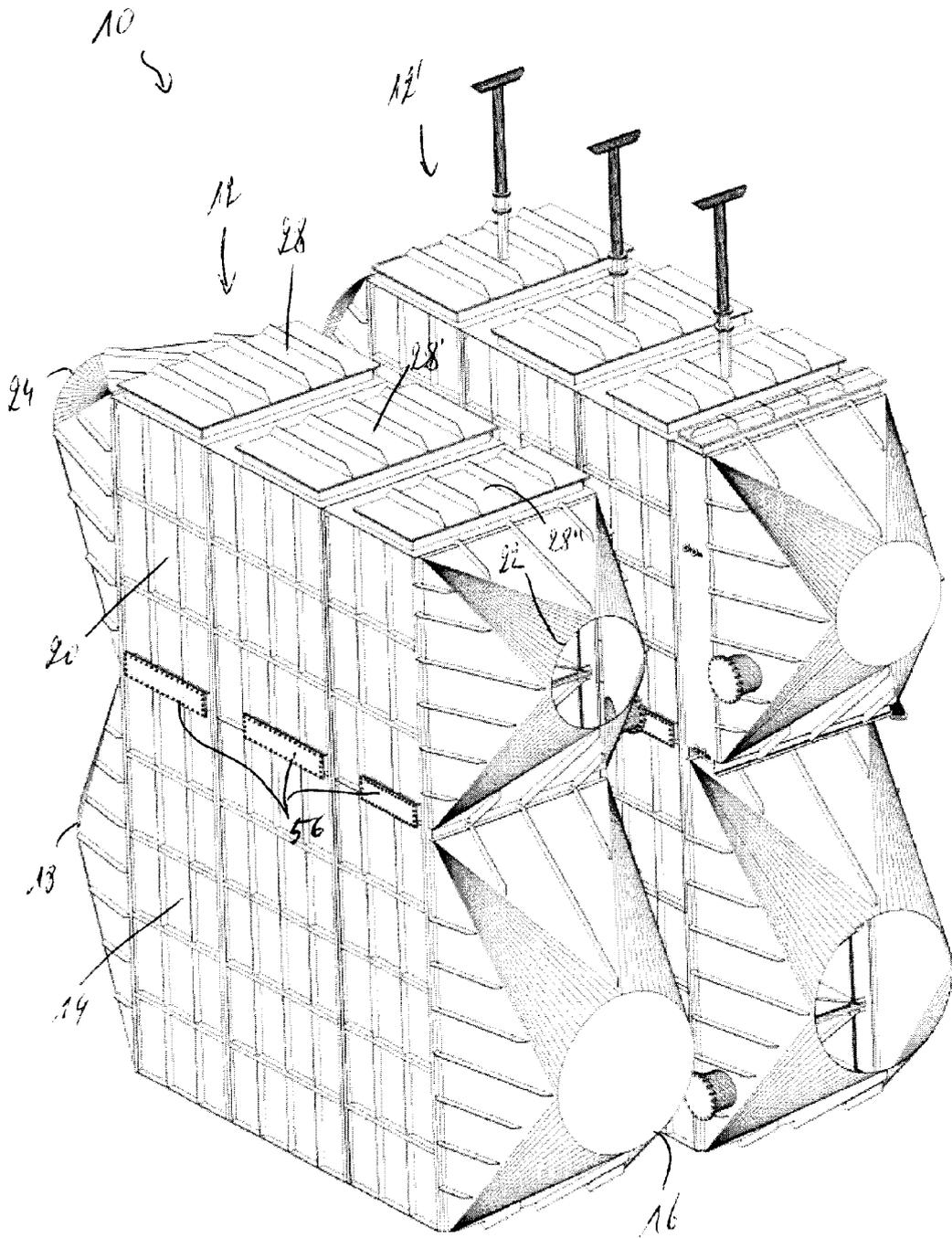


Fig.1

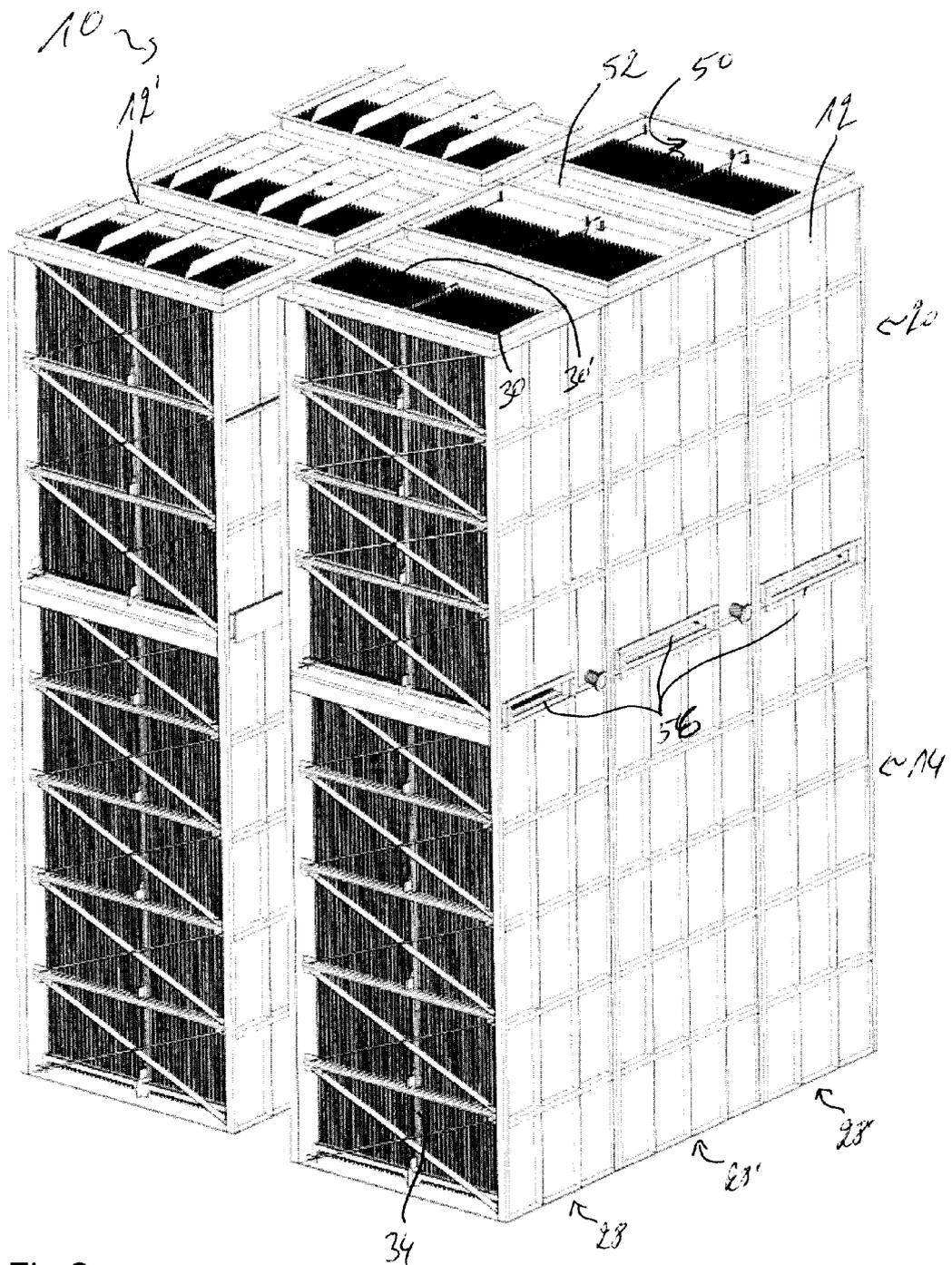


Fig.2

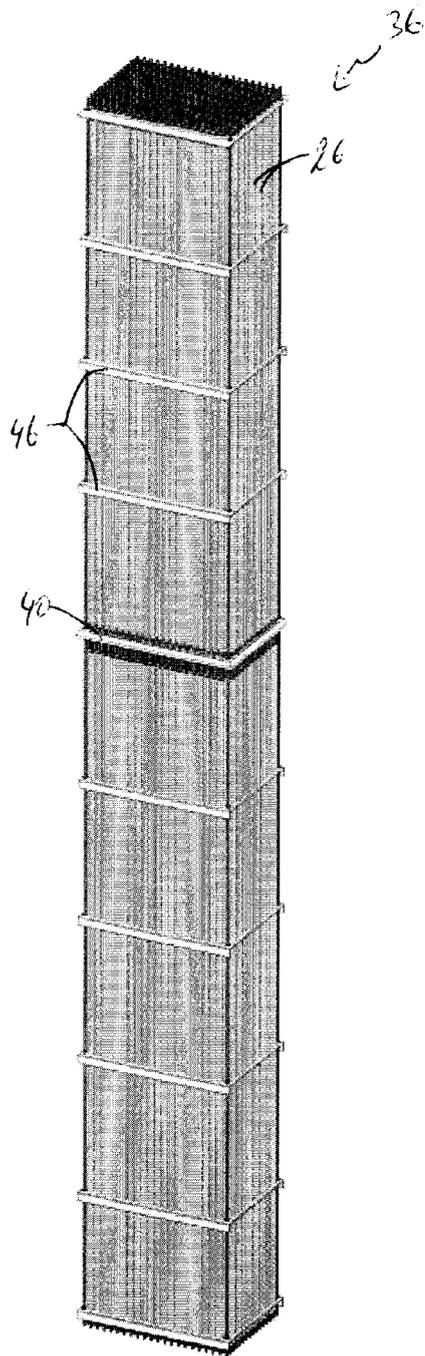


Fig.3

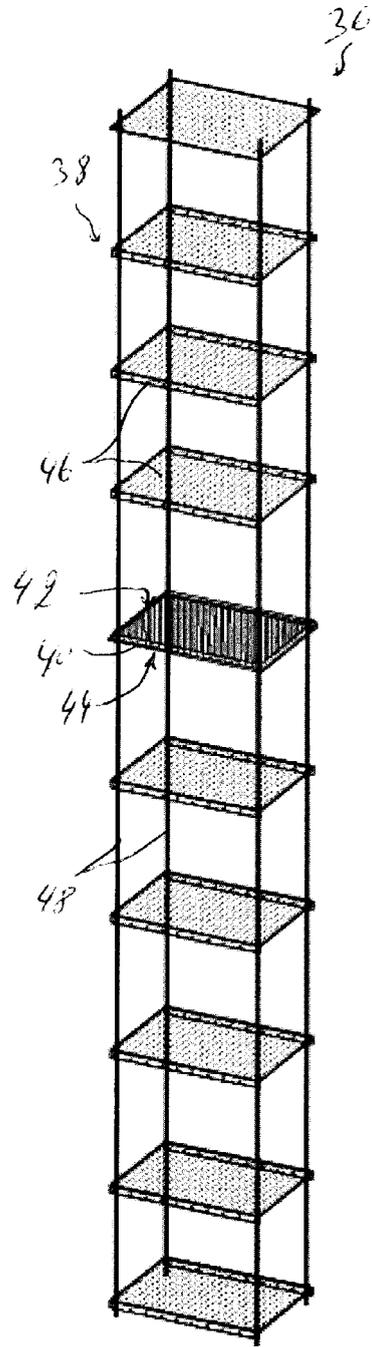


Fig.4



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EUROPEAN SEARCH REPORT

Application Number
EP 10 16 0783

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 1 725 906 A (GAY FRAZER W) 27 August 1929 (1929-08-27) * page 1, line 35 - line 41; figures 1-5 * * page 1, line 104 - page 3, line 14 * -----	1,4,7	INV. F28D15/02
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X	DE 43 45 107 A1 (LANG JUERGEN DIPL ING [DE]) 29 June 1995 (1995-06-29) * column 2, line 35 - line 51; figures 2,3 * -----	1	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			F28D
Place of search		Date of completion of the search	Examiner
Munich		21 October 2010	Martínez Rico, Celia
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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	

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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