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(54) **Boiler having a fluidized bed heat exchanger**

(57) The invention relates to a fluidized bed heat exchanger (3A), the heat exchanger (3A) including a plurality of tubes (7) forming a tube bundle, each tube (7) following a vertical boustrophedon path, the tubes (7) being supported by at least two vertical supporting de-

vices (41,42) placed on both sides of the tube bundle, characterized in that every vertical supporting device (41,42) comprises at least two vertical supports (411,412; 421,422) for fixing the tubes (7).

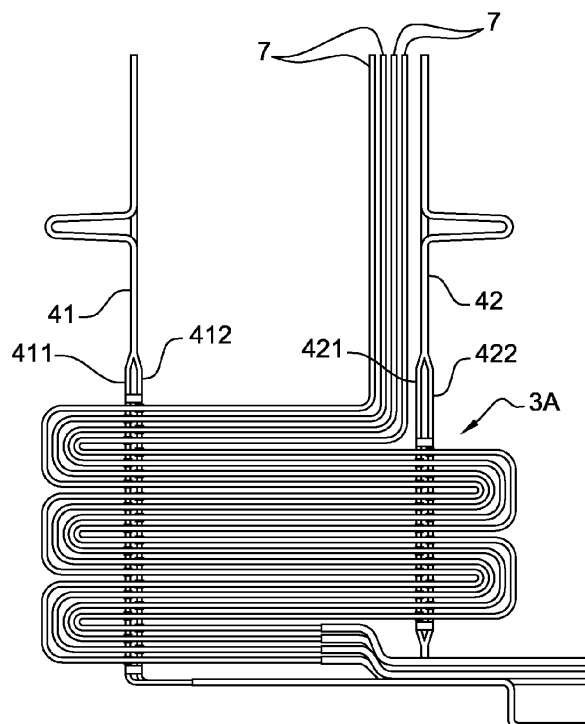


Fig. 2

Description

[0001] The invention is related to a boiler, typically a circulating fluidized bed boiler (CFB), which comprises a fluidized bed heat exchanger. Circulating fluidized bed boilers include a reactor where the solid particles are fluidized and where chemical reactions and/or combustion reactions can take place. The circulating fluidized regime enhances the mixing of particles along with potential exothermic or endothermic chemical reactions.

[0002] The operating principle of a fluidized bed heat exchanger is relatively simple: hot solids are brought into a chamber, in which they are fluidized with air or re-circulated flue gas as a slowly bubbling fluidized bed. Heat exchanger elements, often in the form of tube coils following a boustrophedon path, are located inside this fluidized bed and are fed with a coolant fluid.

[0003] The tube coils have to be maintained by supports. It is known to use a sliding connection with supports allowing differential movements between the tubes and the supports. The drawback of this sliding connection is that gaps and wearing associated therewith may occur.

[0004] It is also known to use shims. However, this solution requires high construction skills to install all the different parts of the fluidized bed heat exchanger without gaps along with the difficulty to assess the good execution of the work afterwards.

[0005] Thus, an object of the present invention is to provide a boiler having a fluidized bed heat exchanger as to solve the above-described problems.

[0006] The object mentioned above is accomplished by a boiler comprising a fluidized bed heat exchanger, the heat exchanger including a plurality of tubes forming a tube bundle, each tube following a vertical boustrophedon path, the tubes being supported by at least two vertical supporting devices, typically at least two separate vertical supporting devices, placed on both sides of the tube bundle.

[0007] In the boiler of the invention, every vertical supporting device comprises at least two vertical supports for fixing the tubes, typically at least two separate vertical supports.

[0008] Thus, the fixation of the tubes on the vertical supports prevents local vibrations and possible abrasions resulting therefrom. Using at least two supports by device makes it possible to split the amount of efforts.

[0009] The boustrophedon path of each tube can comprise horizontal portions, two consecutive horizontal portions being linked together by a vertical portion thus forming a bend between the horizontal portions.

[0010] One supporting device can be located on the left side of the tube bundle and one supporting device can be located on the right side of the tube bundle.

[0011] The vertical supports can be vertical tubes.

[0012] The tubes forming the vertical supports can be cooled or uncooled.

[0013] For at least one supporting device, at least one horizontal portion - preferably each horizontal portion -

of each tube of the heat exchanger is preferably fixed to only one vertical support of the supporting device.

[0014] For each supporting device, at least one horizontal portion - preferably each horizontal portion - of each tube of the heat exchanger is preferably fixed to only one vertical support of the supporting device.

[0015] For at least one supporting device, two consecutive horizontal portions of at least one tube - preferably each tube - of the heat exchanger are preferably not fixed to the same vertical support of the supporting device.

[0016] For each supporting device, two consecutive horizontal portions of at least one tube - preferably each tube - of the heat exchanger are preferably not fixed to the same vertical support of the supporting device.

[0017] For each supporting device, each tube of the heat exchanger is preferably fixed to only one vertical support of the supporting device and, for each supporting device, two consecutive horizontal portions of each tube of the heat exchanger are preferably not fixed to the same vertical support of the supporting device.

[0018] The boiler can comprise a furnace in which combustion of solid particles is sustained and the fluidized bed heat exchanger can be placed outside the furnace.

[0019] Other features and advantages of the invention will become apparent from the following description of an embodiment of the invention given by way of a non-limiting example only, and with reference to the accompanying drawings, in which:

- Figure 1 is a diagram of a boiler according to the invention, and
- Figures 2 to 10 are partial view of the boiler showing the fluidized bed heat exchanger support system of the invention.

[0020] Figure 1 illustrates a boiler that includes a furnace 1 in which combustion of solid particles is sustained. The top of the furnace 1 is connected to a separator member 2 via an extraction duct 12 which conveys the flue gases and the recycled particles.

[0021] The separator member 2, e.g. a cyclone, delivers the gas to a flue duct 20 leading off from its top, and it delivers the particles to a recycling duct 23 which leads into an external dense fluidized bed 3 that is placed outside the furnace 1. The recycling duct 23 is generally provided with a siphon and with lagging. The external bed 3 is provided with a first heat exchanger 3A, and which, in this example, is in the form of a nest of tubes that zigzag in vertical planes, following a boustrophedon path, so that the long tube segments are preferably horizontal. The first heat exchanger 3A is fed with a coolant fluid, e.g. water, via an inlet 39. The outlet 30 of the heat exchanger 3A can be connected to a second heat exchanger 3B which can be located in the furnace 1.

[0022] The remainder of the description is dedicated to the support of the heat exchanger 3A. It is to be noted that the invention is not limited to external fluidized bed heat exchangers but can also be used with other fluidized

bed heat exchangers.

[0023] As illustrated in Figure 2, and in Figure 3 in a perspective view, the heat exchanger 3A includes a plurality of tubes 7 (four tubes in this example) zigzagging in a vertical plane. The tubes 7 can be of a square or circular cross-section. The serpentine tubes 7 follow each a boustrophedon path. Boustrophedon is a kind of bi-directional text, mostly seen in ancient manuscripts and other inscriptions. Every other line of writing is flipped or reversed, with reversed letters. Rather than going left-to-right as in modern English, or right-to-left as in Arabic and Hebrew, alternate lines in boustrophedon must be read in opposite directions. The name "boustrophedon" is taken from the Greek language. Its etymology is from bous, "ox" and strephein, "to turn", because the hand of the writer goes back and forth like an ox drawing a plough across a field and turning at the end of each row to return in the opposite direction (i.e., "as the ox ploughs"). In this way, the tubes path goes alternately from right to left and from left to right.

[0024] Two or more distinct supporting devices 41,42 separated by an empty space realize the support of the fluidized bed heat exchangers bundle tubes. One device 41 is located on the left side of the exchanger and the other device 42 is located on the right side of the exchanger. Each device 41,42 comprises at least two vertical supports 411,412;421,422 separated by an empty space and which are two close hanger tubes along with alternately welded interference clamps supports, which position can be adapted according to mechanical calculation results. The hanger tubes 411,412;421,422 may be cooled, as is the case in the High Temperature Superheater (HTS) bundles. Alternatively, the hanger tubes 411,412;421,422 may be uncooled, as is the case in the Intermediate Temperature Superheater (ITS) bundles.

[0025] Figure 4 illustrates the fixation points 6 between the tubes 7 and the vertical tubes 411,412,421,422.

[0026] As illustrated in Figure 5, the fixations 6 of the tubes 7 being represented by circles, for each supporting device 41,42, each horizontal portion of each exchanger tube 7 is preferably fixed to only one vertical tube of the supporting device 41,42. This allows to decrease the bending stresses in the exchanger. Also for a decreasing of the bending stresses, as illustrated in Figure 6, for each supporting device 41,42, two consecutive horizontal portions of a tube 7 (i.e. an horizontal portion of the tube placed before one bend of the boustrophedon path and the horizontal portion placed after the bend) are preferably not fixed to the same vertical tube.

[0027] A first fixation embodiment which is consistent with these preferred conditions is shown on Figure 7. On the left side, the first supporting device 41 comprises two vertical supports 411,412, i.e. one left support 411 and one right support 412. In the same manner, on the right side, the second supporting device 42 comprises two vertical supports 421,422, i.e. one left support 421 and one right support 422. The tube bundle comprises five tubes 71 to 75. The tubes 71,72,73,74,75 follow a boustroph-

edon path including four bends A,B,C,D. Naturally, the number of tubes and the number of bends are given by way of example, and a person skilled in the art can choose a different number of tubes and bends.

[0028] If one considers tube 71 (i.e. a tube numbered N), this tube 71 is connected before the bend A to the right support 412 of the first supporting device 41 and after the bend A to the left support 411 of the first supporting device 41. After the bend A, the tube 71 is then connected before the bend B to the left support 421 of the second supporting device 42 and after the bend B to the right support 422 of the second supporting device 42. The same connection mode is then repeated: the tube 71 is connected before the bend C to the right support 412 of the first supporting device 41 and after the bend C to the left support 411 of the first supporting device 41. The tube 71 is then connected before the bend D to the left support 421 of the second supporting device 42 and after the bend D to the right support 422 of the second supporting device 42.

[0029] The tubes 73 and 75 (i.e. tubes numbered N+2) are connected in the same way as for the tube 71 (a tube numbered N).

[0030] According to this first embodiment, the tubes 72 and 74 (i.e. tubes numbered N+1) are connected in the opposite way, i.e. a connection of a tube N to the right support 412 of the first supporting device 41 is replaced for a tube N+1 by a connection to the left support 411 of the first supporting device 41 and vice versa. In the same manner, a connection of a tube N to the right support 422 of the second supporting device 42 is replaced for a tube N+1 by a connection to the left support 421 of the second supporting device 41 and vice versa.

[0031] A second embodiment is shown on Figure 8. According to this embodiment, all the tubes 71 to 75 are connected before the bend A to the right support 412 of the first supporting device 41. Thus, all the tubes 71 to 75 are connected after the bend A to the left support 411 of the first supporting device 41. In the same manner, all the tubes 71 to 75 are connected before the bend B and after the bend A to the right support 422 of the second supporting device 42. Thus, all the tubes 71 to 75 are connected after the bend B to the left support 421 of the second supporting device 42.

[0032] Figures 9 and 10 show a third and a fourth embodiment, respectively.

[0033] Thus, one skilled in the art is taught that various configurations can be carried out. These configurations are consistent with the two conditions illustrated in Figures 5 and 6, i.e. 1) for at least one supporting device, and preferably for both supporting devices, each horizontal portion of an exchanger tube is fixed to only one vertical tube of the supporting device, and 2) for each supporting device, and preferably for both supporting devices, two consecutive horizontal portions of an exchanger tube (i.e. an horizontal portion of the tube placed before one bend of the boustrophedon path and the horizontal portion placed after the bend) are fixed to a different ver-

tical tube of the supporting device.

Claims

1. A boiler comprising a fluidized bed heat exchanger (3A), the heat exchanger (3A) including a plurality of tubes (7) forming a tube bundle, each tube (7) following a vertical boustrophedon path, the tubes (7) being supported by at least two vertical supporting devices (41,42) placed on both sides of the tube bundle, **characterized in that** every vertical supporting device (41,42) comprises at least two vertical supports (411,412;421,422) for fixing the tubes (7).

2. A boiler according to claim 1, **characterized in that** the boustrophedon path of each tube (7) comprise horizontal portions, two consecutive horizontal portions being linked together by a vertical portion thus forming a bend between the horizontal portions.

3. A boiler according to claim 1 or 2, **characterized in that** one supporting device (41) is located on the left side of the tube bundle and **in that** one supporting device (42) is located on the right side of the tube bundle.

4. A boiler according to any of claim 1 to 3, **characterized in that** the vertical supports (411,412;421,422) are vertical tubes.

5. A boiler according to claim 4, **characterized in that** the tubes forming the vertical supports (411,412;421,422) are cooled or uncooled.

6. A boiler according to any of claim 2 to 5, **characterized in that**, for at least one supporting device (41,42), each horizontal portion of each tube (7) of the heat exchanger (3A) is fixed to only one vertical support (411,412;421,422) of the supporting device (41,42).

7. A boiler according to claim 6, **characterized in that**, for each supporting device (41,42), each horizontal portion of each tube (7) of the heat exchanger (3A) is fixed to only one vertical support (411,412;421,422) of the supporting device (41,42).

8. A boiler according to any of claim 2 to 7, **characterized in that**, for at least one supporting device (41,42), two consecutive horizontal portions of each tube (7) of the heat exchanger (3A) are not fixed to the same vertical support (411,412;421,422) of the supporting device (41,42).

9. A boiler according claim 8, **characterized in that**, for each supporting device (41,42), two consecutive horizontal portions of each tube (7) of the heat ex-

changer (3A) are not fixed to the same vertical support (411,412;421,422) of the supporting device (41,42).

10. A boiler according to any of claim 1 to 9, **characterized in that**, for each supporting device (41,42), each horizontal portion of tube (7) of the heat exchanger (3A) is fixed to only one vertical support (411,412;421,422) of the supporting device (41,42) and **in that**, for each supporting device (41,42), two consecutive horizontal portions of each tube (7) of the heat exchanger (3A) are not fixed to the same vertical support (411,412;421,422) of the supporting device (41,42).

11. A boiler according to any of claim 1 to 10, **characterized in that** the boiler comprises a furnace (1) in which combustion of solid particles is sustained and **in that** the fluidized bed heat exchanger (3A) is placed outside the furnace (1).

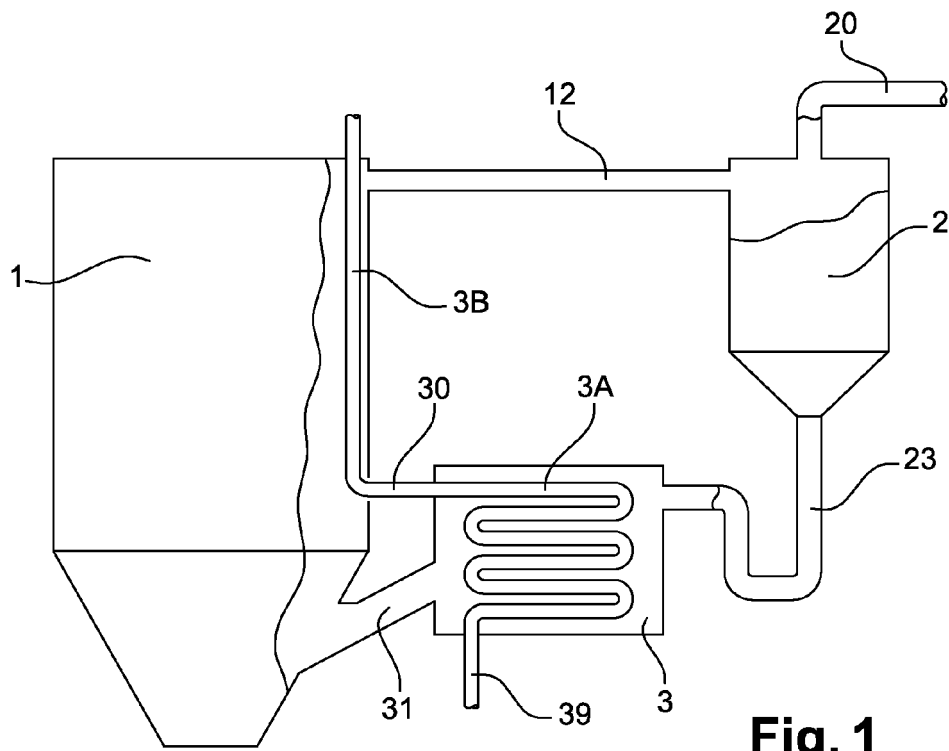


Fig. 1

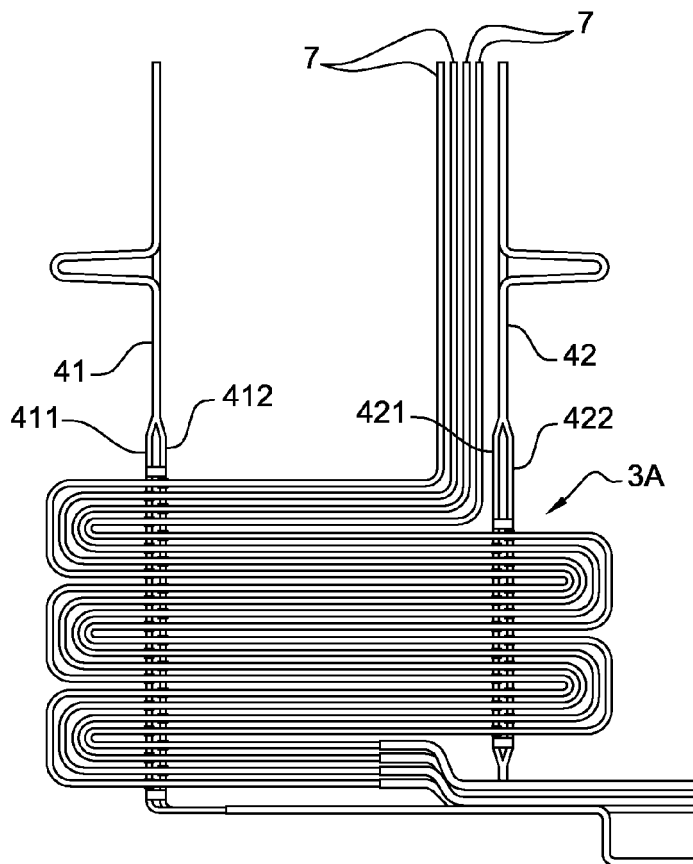


Fig. 2

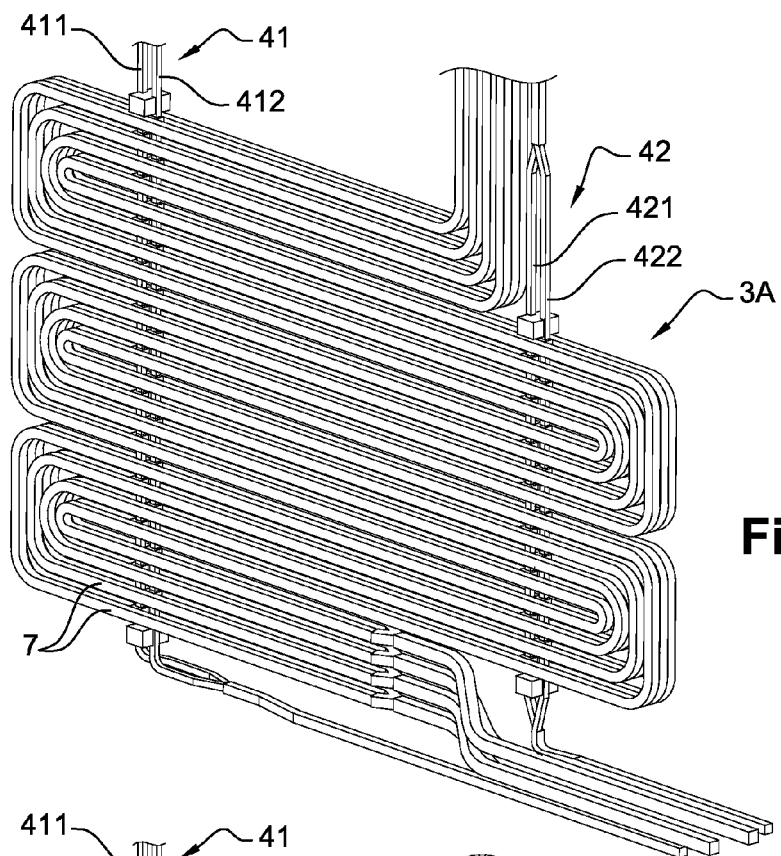


Fig. 3

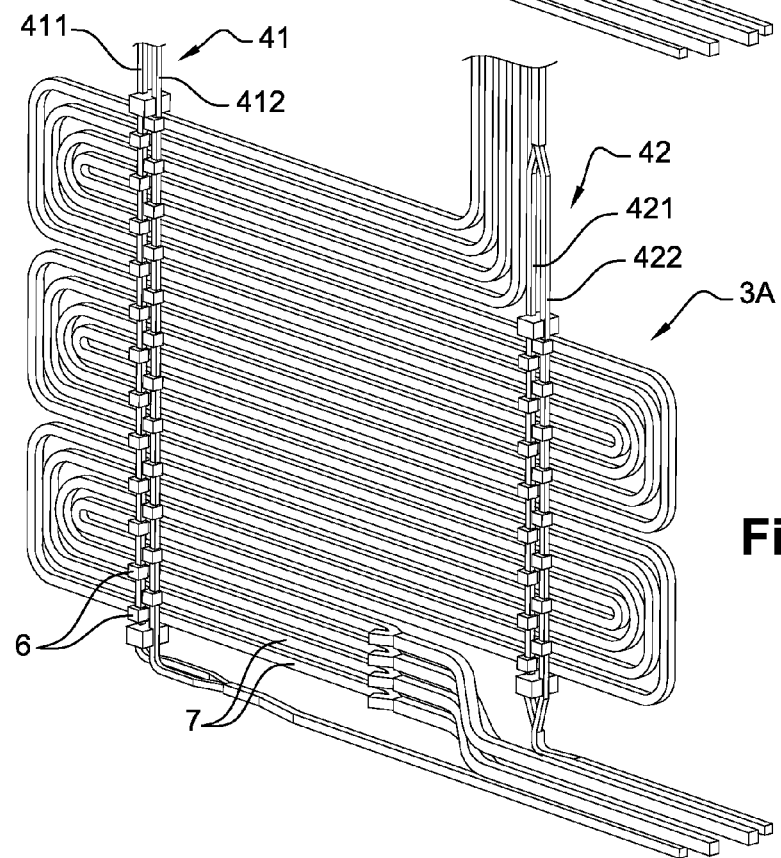


Fig. 4

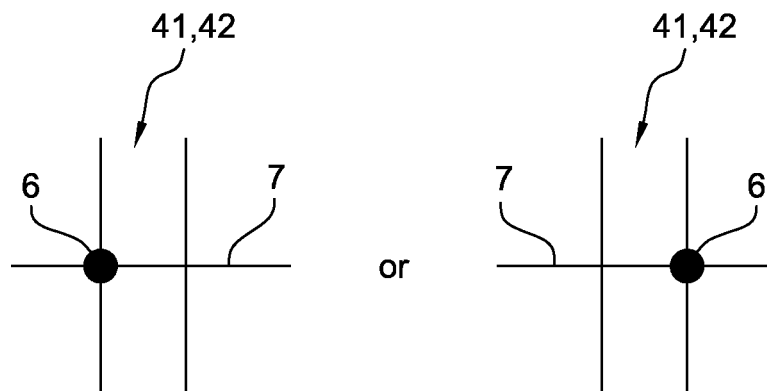


Fig. 5

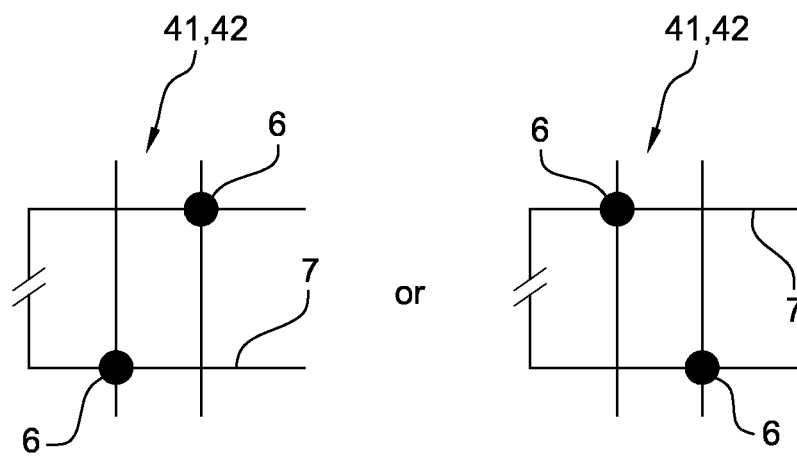
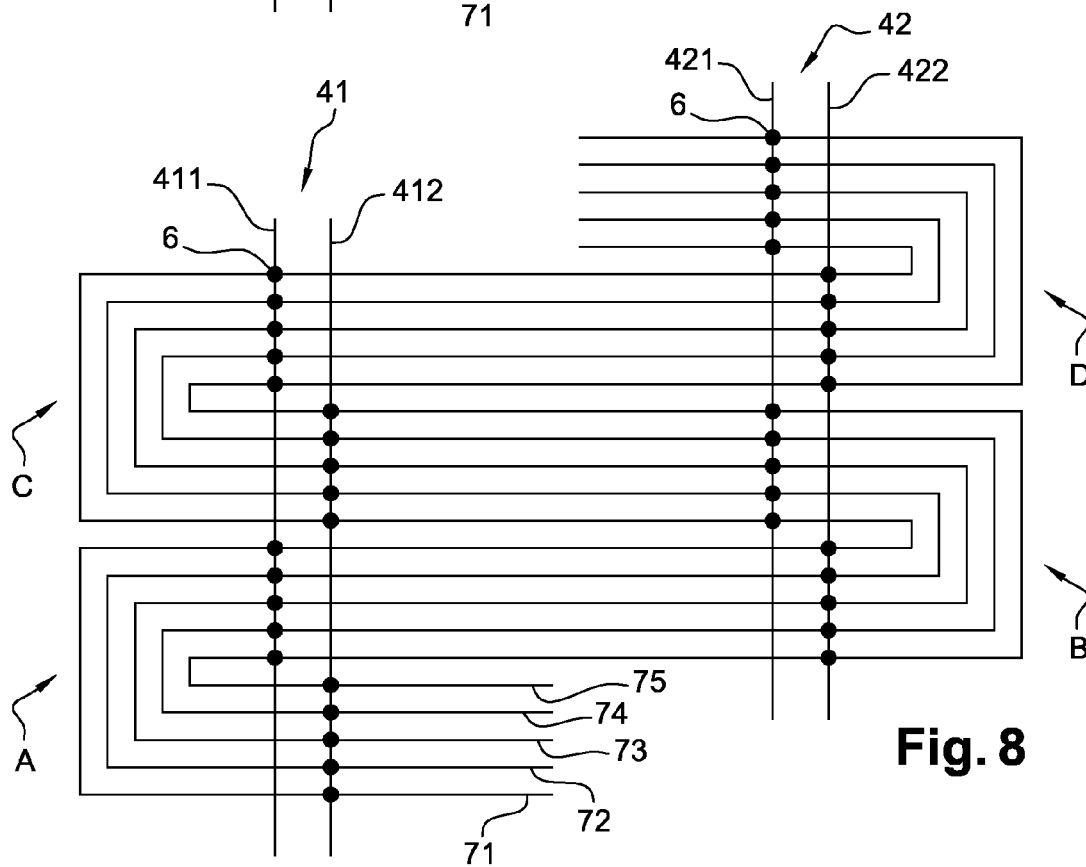
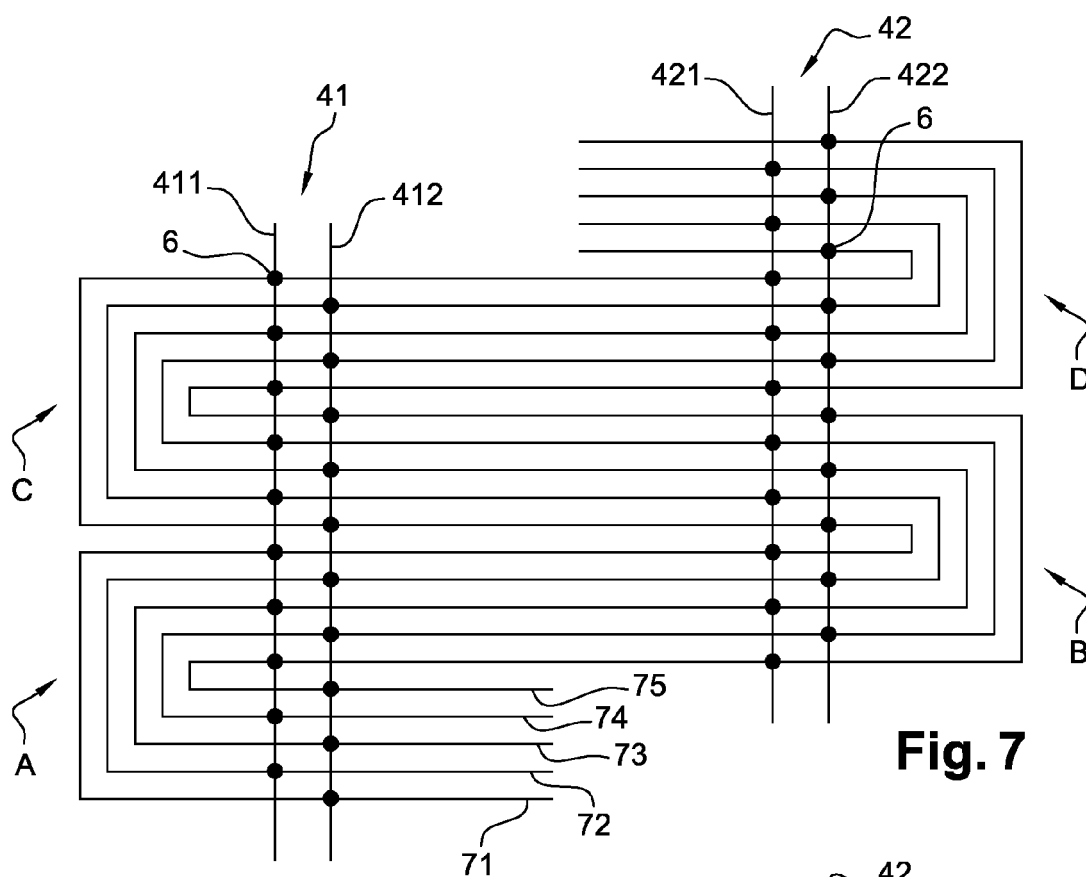


Fig. 6



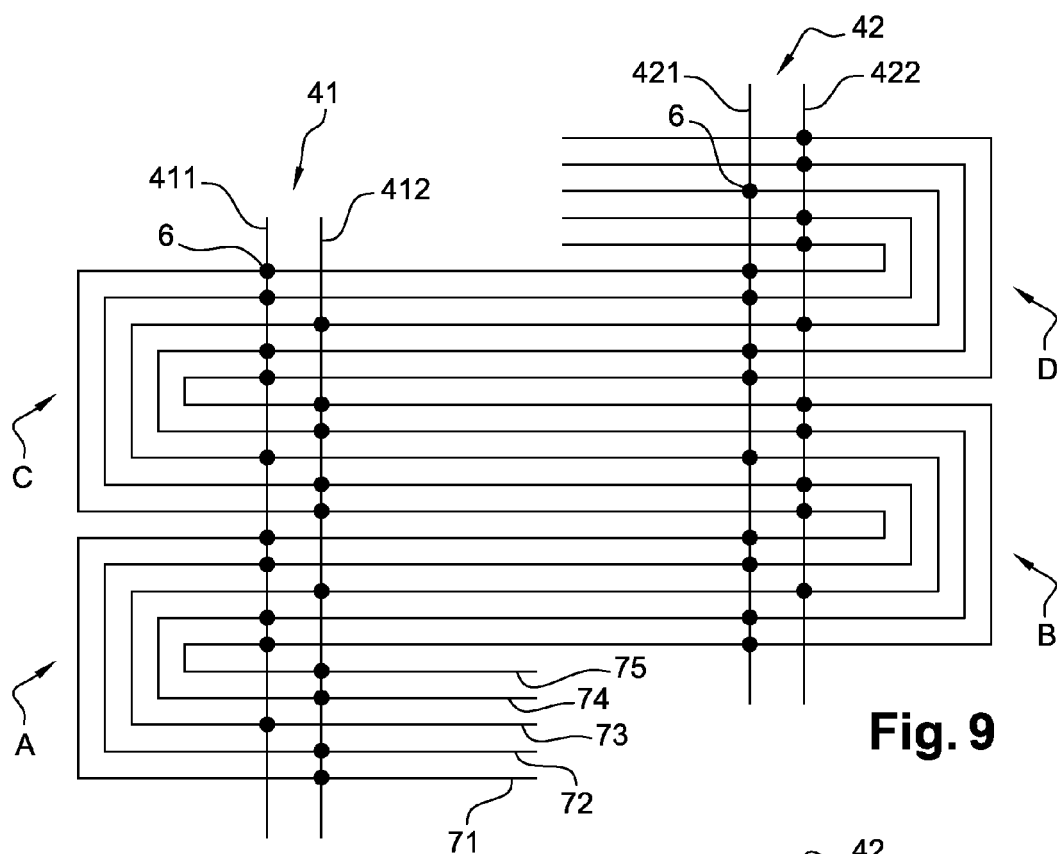


Fig. 9

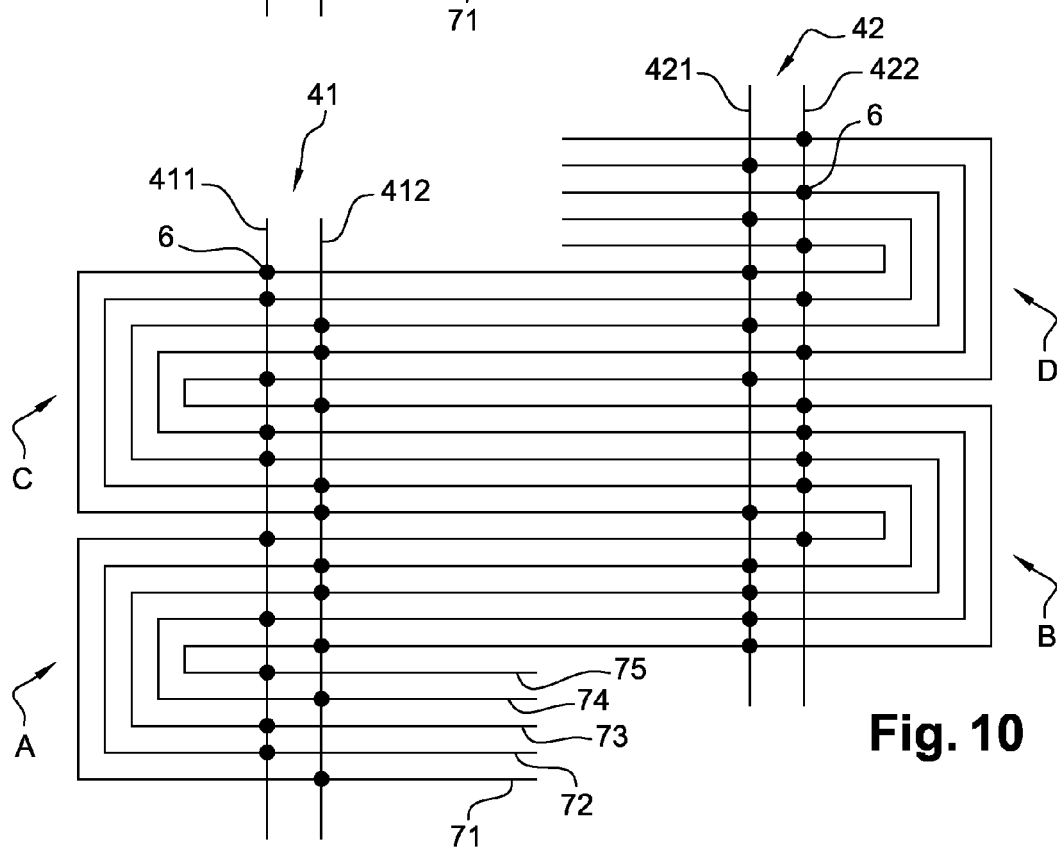


Fig. 10



EUROPEAN SEARCH REPORT

Application Number
EP 12 19 4042

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 3 267 913 A (JAKOB BRUHL) 23 August 1966 (1966-08-23)	1-5	INV. F22B37/20
A	* Vertically finned internally cooled vertical support; column 2, lines 39-59; figures 1,2 *	11	F28F9/013
X	CH 314 447 A (SULZER AG [CH]) 15 June 1956 (1956-06-15)	1-10	
A	* column 1, lines 1-22; figures 1-4 * * column 4, lines 52-61 *	11	
X	DE 40 32 973 A1 (STEINMUELLER GMBH L & C [DE]) 23 April 1992 (1992-04-23)	1-3,6-10	
A	* Uncooled tube supports; column 3, line 4 - column 4, line 2; figures 1-5 *	11	
A	US 4 827 723 A (ENGSTROEM FOLKE [US] ET AL) 9 May 1989 (1989-05-09) * figure 1 *	11	
			TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 17 April 2013	Examiner Degen, Marcello
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	

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 12 19 4042

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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