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(54) **Heat recovery steam generator and method for operating said generator**

(57) A heat recovery steam generator (1) is disclosed, comprising a main casing (2) with a hot gas inlet (3), a plurality of tube bundles (4-8) arranged inside said casing, wherein a first tube bundle or group of tube bundles (4, 5) form a hot portion (11) of said generator, and a second tube bundle or group of tube bundles (6-8) form a cold portion (12) of said generator, the hot portion having a mean temperature, under normal operating conditions, greater than said cold portion, said generator also comprising a multi-louver shutter operable between said hot portion and said cold portion, to provide a thermal insulation means between said hot portion and cold portion.

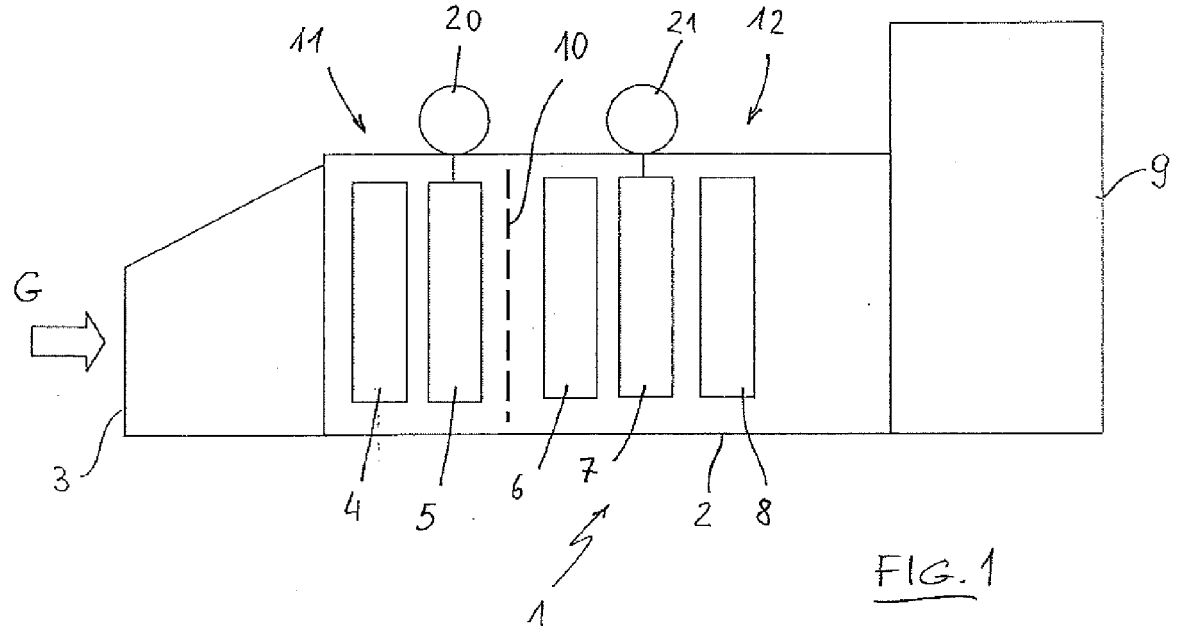

FIG. 1

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Description

Field of the invention

[0001] The present invention relates to a heat recovery steam generator (HRSG) and a method for operating a heat recovery steam generator. The term of generator, without a further specification, will be used with reference to a heat recovery steam generator.

Prior Art

[0002] A heat recovery steam generator produces steam by recovering heat from a hot gas stream. A common application is found in combined-cycle power stations, where the exhaust stream of a gas turbine is directed to a HRSG to generate steam, which feeds a steam turbine.

[0003] A HRSG comprises several heat exchange sections, usually in the form of structurally independent tube bundles. Commonly, a single-pressure HRSG comprises at least an economizer which pre-heats the liquid water feed, an evaporator and a steam superheater, each of said components having a respective tube bundle. A multi-pressure HRSG generates steam at two or more pressure levels and then comprises further tube bundles, including typically economizers and evaporators running at different pressure levels, a high-pressure superheater and possibly a steam re-heater which reheats steam at an intermediate pressure after expansion in a first turbine stage. For example a double-pressure HRSG comprises typically a low-pressure (LP) economizer, a LP evaporator, a high-pressure (HP) economizer, a HP evaporator, and a superheater.

[0004] Pre-heating of water in the economizer(s) takes place at a relatively low temperature, e.g. around 200 °C or less, while evaporation and superheating take place at higher temperatures, up to 500 °C and more.

[0005] In order to maximize the heat exchange, the tube bundles operating at a higher temperature, such as the HP evaporator and superheater of a multi-pressure HRSG, are located near the hot gas inlet, in such a way that they are exposed first to the hot gas stream. Then, the tube bundles are arranged in order of decreasing working temperature, the first bundle being usually the HP superheater, and the last bundle being usually the LP economizer. Hence, the HRSG comprises a "hot portion" or "hot end" where temperature of the tube bundles is the highest, and a "cold portion" where the temperature is significantly lower. In a multi-pressure generator, the hot portion typically includes the superheater, the HP evaporator and possibly the steam re-heater.

[0006] The difference between the hot end and the relatively cold portion is usually at least 80 - 90 °C, or more. During normal operation, the mean temperature of the tube bundles of said hot portion is well over 200 °C, usually in the range 300 - 400 °C, while the mean temperature of the tube bundles of the cool portion is about 200 °C.

[0007] As an example, a triple-pressure HRSG of a combined-cycle power station, fed by hot exhaust gas at about 600 °C coming from a 250 MW gas turbine, may comprise:

- a hot portion formed by a superheater, a re-superheater and high pressure evaporators, having a mass of about 900 tons at a mean temperature around 360 - 380°C, and
- a cold portion including the preheater and low pressure evaporators, having a mass of about 1800 tons, including the tube bundles and the water/steam mixture contained therein, at a mean temperature around 190 - 200°C.

[0008] As seen in this example, the overall mass of the tube bundles of the cold portion is normally greater (e.g. twice) than that of the hot portion.

[0009] A drawback of known conventional HRSGs is the considerable start-up time which is necessary to bring the hot portion to the operating temperature and pressure. In particular, it has been found that the start-up time is mostly affected by the need to heat and pressurize the high pressure evaporator and high pressure steam drum. Further to this, it has been noted that during a shutdown the hot portion quickly cools down and loses pressure, due to the natural heat exchange occurring inside the casing between the tube bundles. The cold portion, having a large mass and then a huge heat capacity, much greater than the heat capacity of the hot portion, rapidly collects heat from the hot portion, so that the temperature and pressure inside the casing of the HRSG equalize in a few hours. For example, during a typical night shutdown (8 hours), the hot portion would completely lose its pressure, resulting in a time and energy consuming start-up, to restore the high temperature and high pressure of said hot portion.

[0010] There is an increasing effort to eliminate or at least reduce this drawback, in order to allow an efficient use of combined-cycle power stations also for load- following applications, subject to frequent shutdowns.

[0011] EP-A-1710499 faces the above problem and discloses a heat recovery steam generator wherein a rolling or folding shutter is interposed between the hot portion and the relatively cold portion. During a shutdown, said rolling or folding shutter is closed in order to thermally insulate the hot portion from the cold portion.

Summary of the invention

[0012] The aim of the invention is to still improve the above referred prior art. A rolling or folding shutter needs lateral guide elements and is relatively slow when opening/closing. These shortcomings are overcome, according to the invention, by the provision of a shutter operating according to the principle of a multi-louver shutter, located inside the casing of a HRSG, between the aforesaid

hot portion and cold portion.

[0013] A first aspect of the invention is then a heat recovery steam generator comprising a main casing with a hot gas inlet, a plurality of tube bundles arranged inside said casing, wherein a first tube bundle or group of tube bundles form a hot portion of said generator, and a second tube bundle or group of tube bundles form a cold portion of said generator, the tube bundle(s) of the hot portion being closer to said hot gas inlet and thus having a mean temperature, under normal operating conditions, greater than the mean temperature of the tube bundle(s) of the cold portion, said generator also comprising a shutter located inside said casing between said hot portion and said cold portion, said shutter being able to provide a thermal insulation means between said hot portion and cold portion, when the shutter is in a closing state, the generator being characterized in that:

- said shutter has a multi-louver structure, comprising a plurality of louvers with adjustable inclination, said louvers being distributed in a cross-sectional plane of said main casing.

[0014] The shutter can be opened and closed by adjusting inclination of said louvers. In a preferred embodiment, each louver is pivotable around a respective axis, the pivoting axes of said louvers being parallel. In preferred embodiments, said pivoting axes are horizontal.

[0015] Each of said louvers may be composed of a single blade, extending substantially over the entire width of the casing, or of a plurality of louver elements, which are aligned side by side. In the latter case, said louver elements are preferably connected to a common frame structure of the louver. The louvers shall be made of a suitable heat-resistant material; in a preferred embodiment the louvers are made of steel, eventually with a heat resistant coating, for example a ceramic coating.

[0016] The louvers are operated simultaneously with a mechanical opening and closing device. Said device is preferably equipped with a suitable fail-safe system to provide the opening of the shutter when the HRSG is started and the hot gas starts to flow inside the casing. A manually operated device may be provided in addition.

[0017] Each louver is adjustable between a first position where the louver is substantially parallel to the flow direction of the hot gas stream, and a second position where the louver is inclined or substantially perpendicular relative to said direction.

[0018] When all the louvers are in said first position, the shutter is in a closing state and provides a means of insulation between the hot portion and the cold portion of the generator. The shutter shields the thermal radiation emitted by the hot tube bundles, and prevents convective heat transfer from the hot portion to the cold portion. When the louvers are in said second position, the shutter is in opening state, allowing the hot gases to flow between the louvers. Although the louvers remain in the path of the hot gas, they cause a negligible disturbance to the gas flow.

[0019] The shutter is strategically located downstream the hot end of the heat recovery steam generator, on the path of the hot gas. Said hot end may comprise one or more tube bundles. Typically, the first group includes tube bundles of one or more of the following: HP evaporator, steam superheater, steam reheater. The second group includes evaporators and economizers at medium or low pressure. In a preferred embodiment, said shutter is located downstream a hot end comprising a high pressure evaporator and a high pressure superheater and, when provided, a steam re-heater.

[0020] Compared to a rolling or folding shutter, the multi-louver shutter of the invention has the advantages of simple construction and installation, no need of external linear guides, faster opening and closing action. The multi-louver shutter is also less sensitive to failure or jamming, since each of the louver elements can be directly operated by a respective rod or shaft, as further explained hereinbelow.

[0021] According to a first general embodiment of the invention, the louvers are made with substantially plane elements, for example rectangular metal plates, in order to achieve simple construction and low cost. According to a second general embodiment, the louvers can be shaped to allow self-opening of the shutter when the shutter is exposed to hot gas flow. More in detail, said second embodiment can be realized with louvers having a suitable wing shape. The force generated by the hot gas flow on wing-shaped louvers tends to cause a rotation of the louvers around their pivoting axes and then causes a fail-safe, self-opening of the shutter, or at least provides assistance to the opening. This self-opening feature is however optional.

[0022] In a further embodiment, the louvers can be arranged so that they close under their own weight, and open under the action of the hot gas. In this latter case, an automatic operation can be achieved.

[0023] A further aspect of the invention is a method for operating a heat recovery steam generator, said generator comprising a plurality of tube bundles inside a main casing, the method being characterized in that, during a shut-down of said generator, a hot end of said generator is thermally isolated from a cold end of said generator, by means of a shutter having a multi-louver structure. Hence, another aspect of the invention is the use of a shutter according to the multi-louver concept, for providing thermal insulation between a hot portion and a cold portion of a heat recovery steam generator during a shut-down of said generator, to reduce heat exchange between said hot portion and said cold portion, and related temperature and pressure loss of said hot portion.

Brief description of the drawings

[0024]

Fig. 1 is a simplified scheme of a heat recovery steam

generator according to one embodiment of the present invention.

Fig. 2 is a sectional view of the hot end of a heat recovery steam generator according to one embodiment of the invention.

Fig. 3 is a cross section according to line III of Fig. 2, showing one embodiment of the invention with horizontal multi-louver shutter.

Fig. 4 is a front view of a louver of the multi-louver shutter of the heat recovery steam generator of Figs. 2 and 3, according to a preferred embodiment.

Fig. 5 is a side view of the louver of Fig. 4.

Fig. 6 is a side view of the louver of Figs. 4 and 5, showing the louver in opening and closing state.

Fig. 7 shows an embodiment of the invention with vertical multi-louver shutter.

Detailed description of preferred embodiments

[0025] Fig. 1 is a simplified scheme of a heat recovery steam generator 1 comprising a casing 2 with a hot gas inlet 3 on one side, and a chimney 9 on the other side. A plurality of vertical tube bundles, indicated with numerals 4 to 8 are arranged inside said casing 2. In use, a hot gas flow G, such as gas turbine exhaust flow, is fed to the gas inlet 3. A feed water (not shown) is heated and evaporated in the tube bundles 4 to 8, recovering heat from said gas flow G, to power a steam turbine. The details of the generator 1 are not shown, since they are well known to a skilled person.

[0026] A multi-louver shutter 10 is provided between a hot end 11 and a relatively cold portion 12 of said generator 1. In this example, said hot end 11 comprises the first two tube bundles 4 and 5 closer to the gas inlet 3, while the remaining tube bundles 6 to 8 form the cold portion 12.

[0027] In the exemplificative scheme of Fig. 1, the first tube bundle 4 is a high pressure steam superheater, and the tube bundle 5 is a high pressure evaporator connected to a HP steam drum 20. The tube bundles 6, 7 and 8 of the relatively cold portion 12 include a high-pressure (HP) economizer (tube bundle 6), a low-pressure (LP) evaporator (tube bundle 7) with LP steam drum 21, and a LP economizer (tube bundle 8). It should be noted however that this arrangement is exemplificative and the invention is applicable to any configuration of a heat recovery steam generator, including any combination of the following: horizontal or vertical, single pressure or multi pressure, modular or once-through.

[0028] The multi-louver shutter 10 comprises a plurality of louvers distributed over the cross section of the casing 2. The inclination of the louvers is adjustable between a first end position, where the louvers are substantially parallel to the direction of hot gas flow G, and a second end position where the louvers allow passage of hot gas flow G. The scheme of Fig. 1 relates to a horizontal HRSG with vertical tube bundles, where the louvers of the shutter 10 are rotatable around horizontal axes.

[0029] Turning now to Figs. 2 and 3, the hot end 11 comprising the aforesaid superheater 4 and HP evaporator 5 is shown in a greater detail. A generic louver of the shutter 10 is indicated with numeral 13. Each louver is rotatable around a respective horizontal axis by means of suitable actuators; in the example the louver 13 is rotatable around the horizontal axis X-X by means of a couple of left and right actuating rods 14. Each louver may comprise a plurality of louver elements, to extend over the entire width of the gas duct 2. Fig. 3 shows the louver 13 comprising three louver elements 13a, 13b and 13c.

[0030] Further details of the generic louver 13 can be seen in Fig. 4. The louver elements 13a, 13b and 13c are connected to the rods 14 by means of a frame structure comprising elongate members 15, such as tubes, parallel to said axis X-X, first connection sheets 16 and second connection sheets 17. The tubes 15 are disposed in a triangular arrangement around said axis X-X and are associated to the first sheets 16, which have preferably a substantially triangular shape, as seen in the figures; each of said first sheets 16 is fixed to a sheet 17 which, in turn, is fixed to the appropriate louver element 13a or 13b or 13c. At the left and right ends of the louver 13, the rods 14 are fixed to end sheets 16, thereby actuating the whole frame structure of said louver 13. Fig. 5 illustrates the connection of the louver element 13c to said frame structure.

[0031] The material of said tubes 15, first sheets 16 and second sheets 17 is preferably a suitable metal, such as steel. The louver elements may be optionally coated with a heat-resistant material such as ceramic coating.

[0032] The louver elements 13a - 13c can be made with plane, rectangular metal sheets, as depicted in Fig. 5. The louvers 13 may optionally be designed with a wing-shaped profile, adapted to cause or at least to assist the opening of the shutter 10 upon the passage of the hot gas flow G. More in detail, the louvers may be designed in such a way that the hot gas G, while flowing around a generic louver 13, generates a torque relative to the respective axis X-X, thereby opening the louver. Hence, a fail-safe opening of the shutter 10 is obtained.

[0033] Fig. 6 shows a generic louver 13 in closing state A and opening state B. When in closing state A, the louver is substantially perpendicular to the direction of the hot gas G, while in the opening state B, the louver allows free flow of the hot gas from the hot end 11 to the cold portion 12 of the HRSG.

[0034] Referring now to Fig. 7, an embodiment with a vertical multi-louver shutter is depicted. As shown in the figure, several louver elements 13 are pivotably support-

ed around vertical axes, such as the axis Y indicated in the figure. The shutter is supported by a frame of vertical beams 30 crossed by horizontal beams 31, supporting the actuating rods.

Claims

1. A heat recovery steam generator (1) comprising a main casing (2) with a hot gas inlet (3), a plurality of tube bundles (4-8) arranged inside said casing, wherein a first tube bundle or group of tube bundles (4, 5) form a hot portion (11) of said generator, and a second tube bundle or group of tube bundles (6-8) form a cold portion (12) of said generator, the tube bundle(s) of the hot portion being closer to said hot gas inlet and thus having a mean temperature, under normal operating conditions, greater than the mean temperature of the tube bundle(s) of the cold portion, said generator also comprising a shutter located inside said casing between said hot portion and said cold portion, said shutter being able to provide a thermal insulation means between said hot portion and cold portion, when the shutter is in a closing state, the generator being **characterized in that**:

   - said shutter (10) has a multi-louver structure, comprising a plurality of louvers (13) with adjustable inclination, said louvers being distributed over a cross-sectional plane of said main casing.

2. A heat recovery steam generator according to claim 1, each louver (13) of said multi-louver shutter (10) being pivotable around a respective axis (X-X), the pivoting axes of said louvers being parallel.

3. A heat recovery steam generator according to claim 1 or 2, each of said louvers (13) being composed of a single element, extending substantially over the entire width of said casing (2).

4. A heat recovery steam generator according to claim 1 or 2, each of said louvers (13) being composed of a plurality of louver elements (13a, 13b, 13c), which are aligned side by side.

5. A heat recovery steam generator according to any of the previous claims, said louvers being made of steel with a heat resistant coating.

6. A heat recovery steam generator according to claim 5, said coating being a ceramic coating.

7. A heat recovery steam generator according to any of the previous claims, said hot portion (11) comprising a HP evaporator (4) and a steam superheater (5) and eventually a steam re-heater.

8. A heat recovery steam generator according to any of the previous claims, said louvers (13) being made with substantially plane elements, for example rectangular plates.

9. A heat recovery steam generator according to any of the previous claims, said louvers (13) having a wing shape, such that the lift force generated by the hot gas flow (G) on wing-shaped louvers causes a self-opening or at least assists the opening of the shutter (10).

10. A method for operating a heat recovery steam generator (1), said generator comprising a plurality of tube bundles inside a main casing (2), the method being **characterized in that**, during a shut-down of said generator, a hot end (11) of said generator is thermally isolated from a cold end (12) of said generator, by means of a shutter (10) having a multi-louver (13) structure.

11. Use of a shutter (10) according to the multi-louver concept, for providing thermal insulation between a hot portion (11) and a cold portion (12) of a heat recovery steam generator (1) during a shut-down of said generator, to reduce heat exchange between said hot portion and said cold portion, and related temperature and pressure loss of said hot portion.

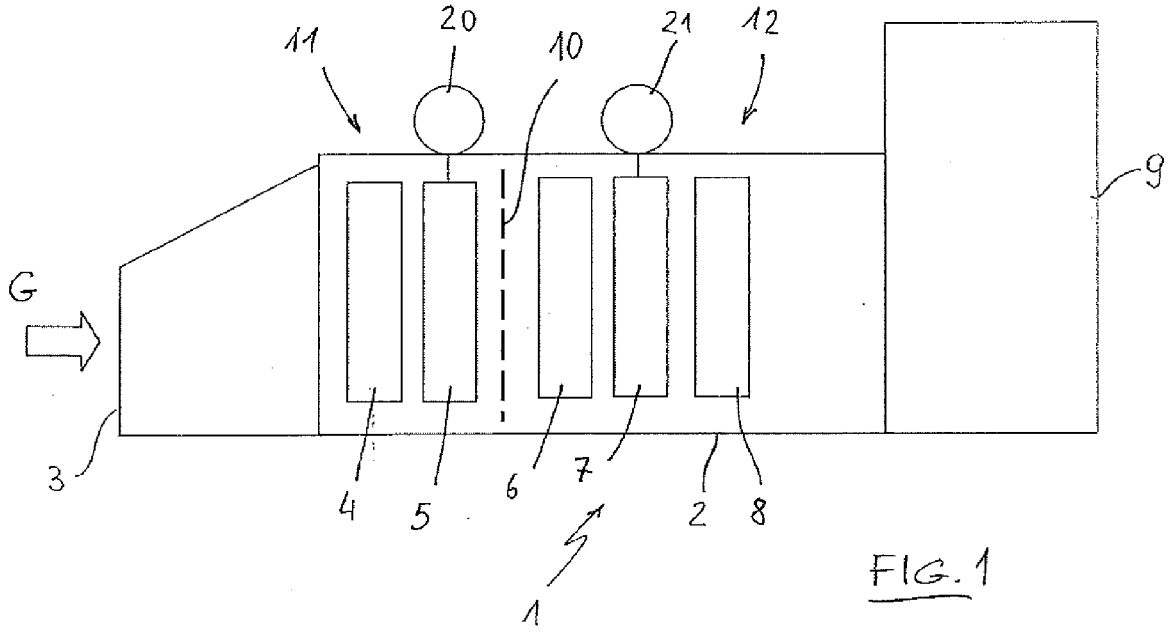

FIG. 1

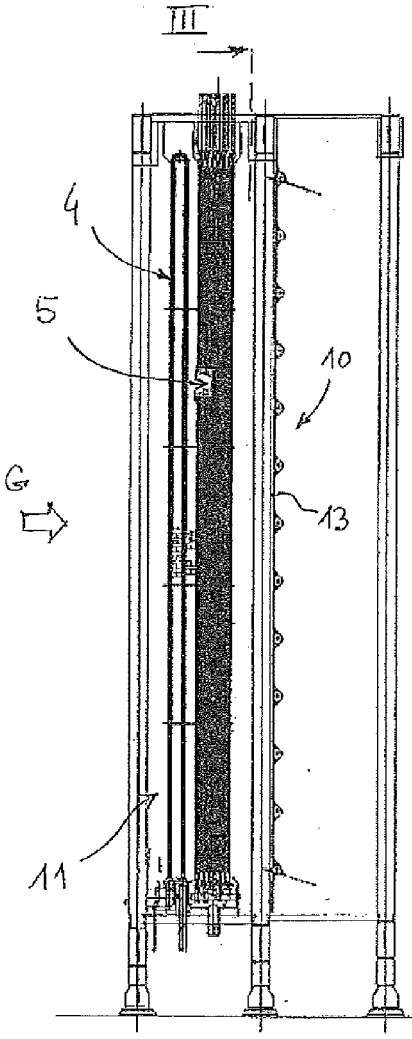

FIG. 2

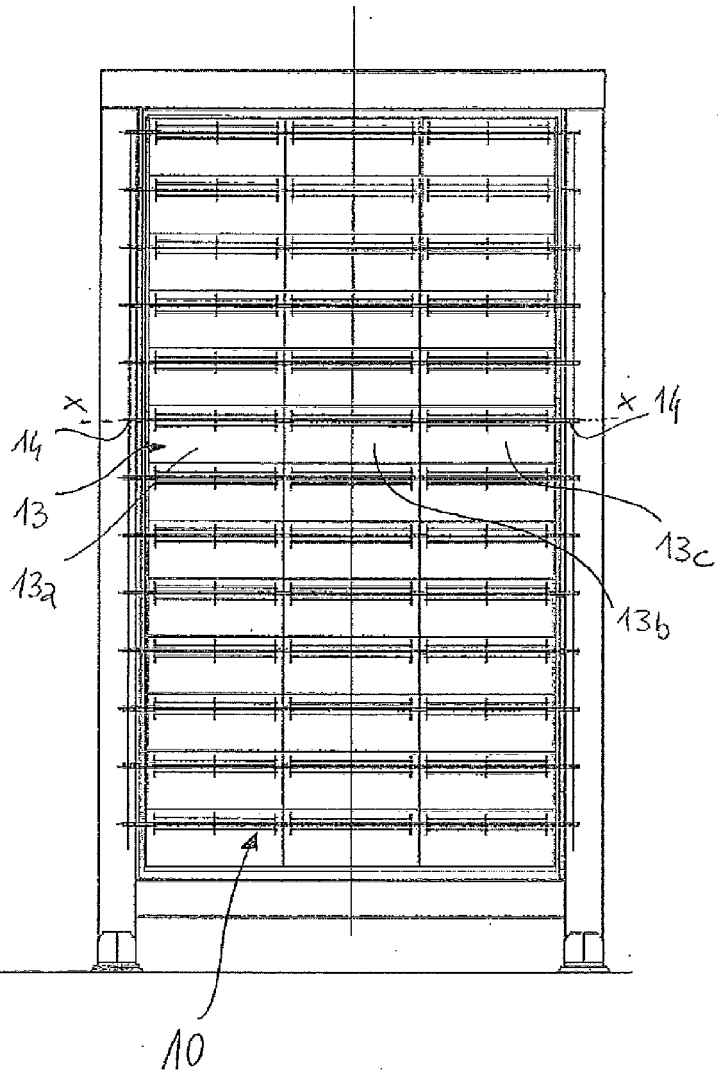

FIG. 3

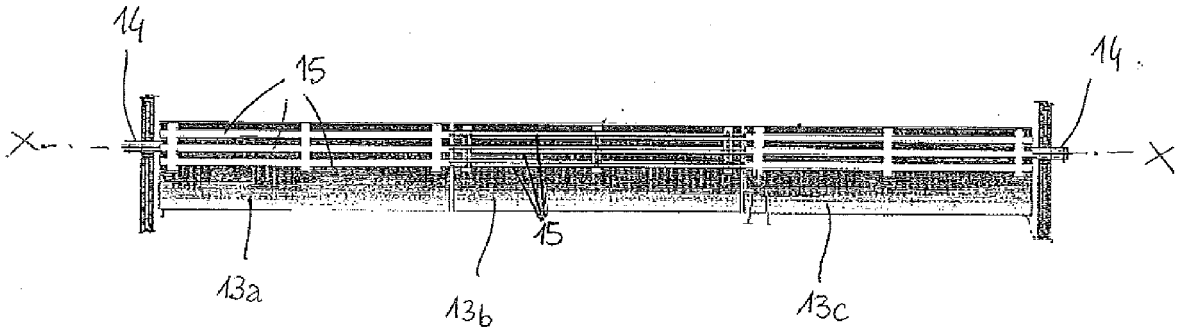

FIG. 4

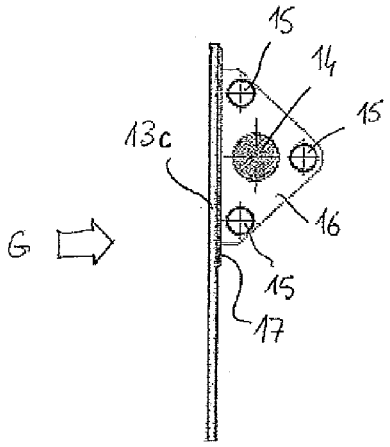

FIG. 5

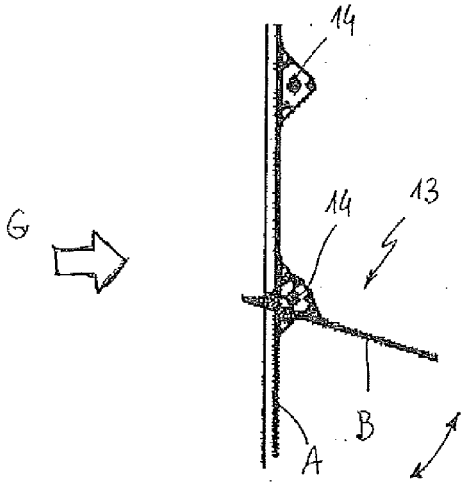

FIG. 6

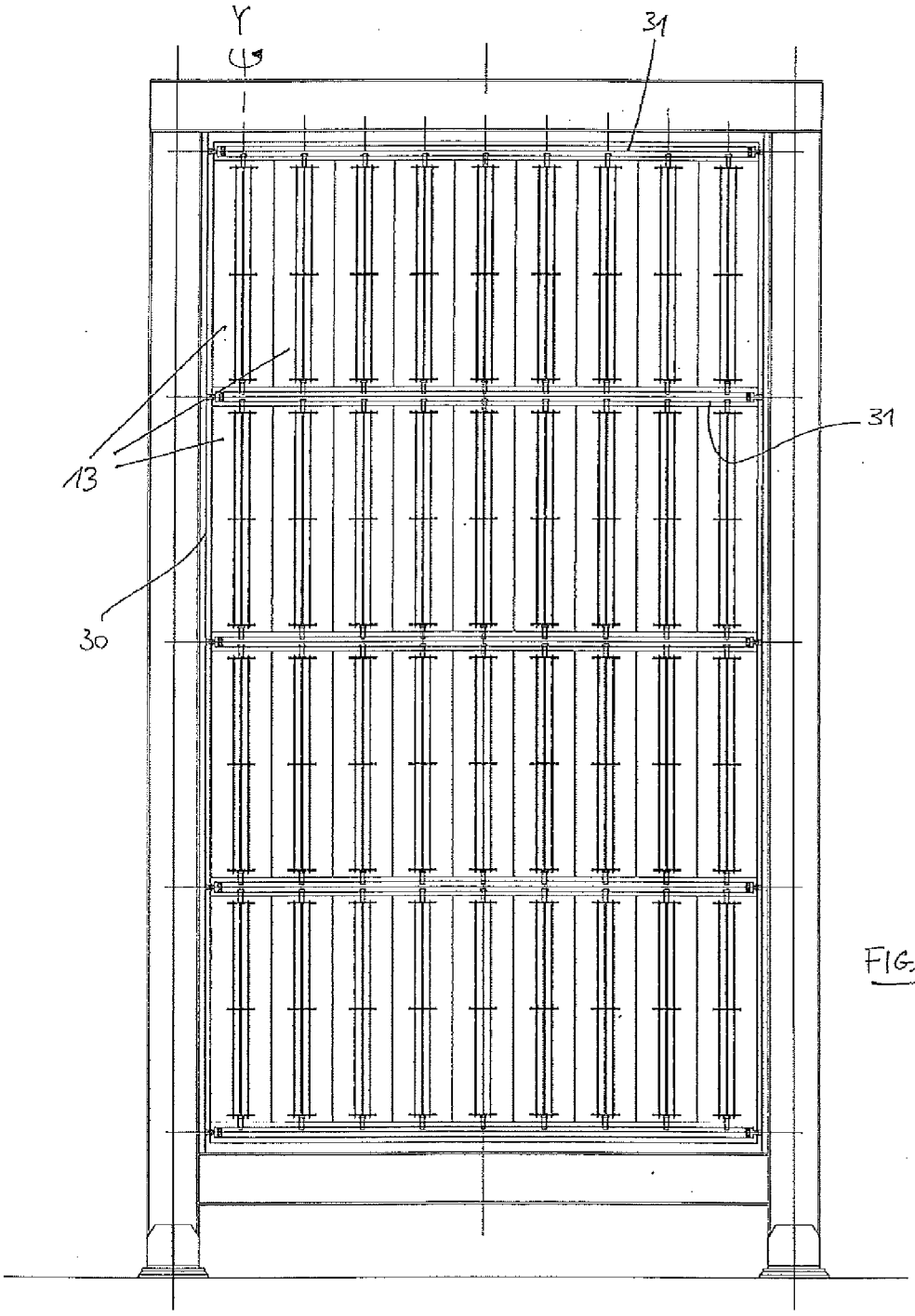

FIG.7

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EUROPEAN SEARCH REPORT

Application Number
EP 10 18 0524

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	EP 1 710 499 A1 (SON S R L [IT]) 11 October 2006 (2006-10-11) * abstract; figure 1 * -----	1-3,5-8, 10,11	INV. F22B37/00
Y	DE 43 19 732 A1 (SIEMENS AG [DE]) 22 December 1994 (1994-12-22) * column 2, line 8 - line 23 * * column 2, line 41 - line 59 * * figure * -----	1-3,5-8, 10,11	

TECHNICAL FIELDS SEARCHED (IPC)

F22B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	2 September 2011	Coquau, Stéphane

CATEGORY OF CITED DOCUMENTS

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02-09-2011

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1710499 A1	11-10-2006	AT 448445 T	15-11-2009
		ES 2336455 T3	13-04-2010
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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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