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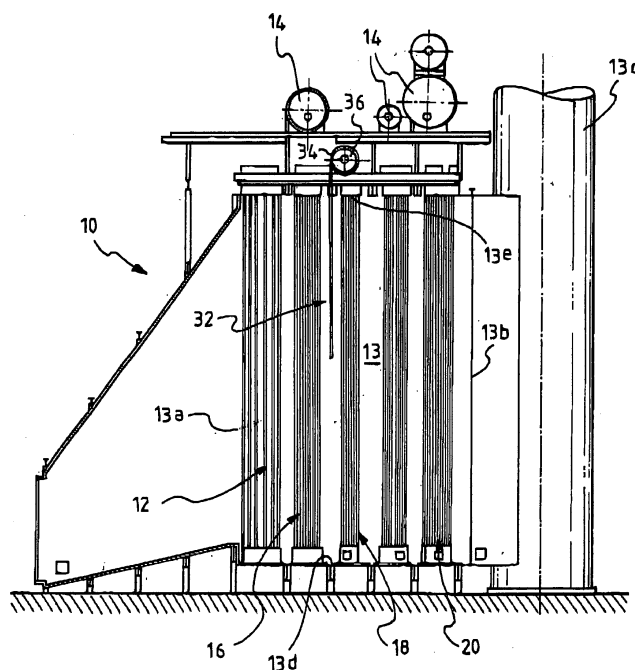
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**(54) Heat recovery steam generator**

(57) A heat recovery steam generator (10, 110, 210) comprises a heat exchange unit (12) in which, in normal operative conditions, is defined a hot portion (16), with high metal temperatures and high temperatures of the water/steam mixture enclosed there, and a relatively cool portion (18, 20), with lower metal temperatures and lower temperatures of the water/steam mixture enclosed there, with respect to those of said hot portion (16); substantially

shutter-shaped means (32, 132, 232) are interposed between said hot portion (16) and said relatively cool portion (18, 20) in order to thermally insulate said hot portion (16) from said relatively cool portion (18, 20), said substantially shutter-shaped means (32, 132, 232) being at least partially removable in order to put said hot portion (16) and said relatively cool portion (18, 20) again in fluid communication with each other.



**Fig. 1**

## Description

### Field of application

**[0001]** The present invention, in its most general aspect, refers to a heat recovery steam generator (which is also indicated with the acronym RSG - Recovery Steam Generator or HRSG - Heat Recovery Steam Generator or HRB - Heat Recovery Boiler) comprising a heat exchange unit in fluid communication with at least one water-steam separation chamber and is particularly but not exclusively intended for use in thermoelectric plants of the so-called gas/steam combined cycle type.

**[0002]** In the rest of the description reference shall be made, only as a not limiting example, to the technological field relative to the gas/steam combined cycle thermoelectric plants, i.e. plants in which two technological cycles are provided, one carried out by air and fuel (gas or Joule cycle) and the other carried out by water and steam (steam or Rankine cycle), both intended to produce electrical energy with high yield (typically greater than 55%) and/or electrical energy and thermal energy that may be intended for users such as, for example, teleheating networks, desalination plants, and steam distribution networks for industrial processes.

### Prior Art

**[0003]** It is known that the gas cycle of a combined cycle thermoelectric plant of the type considered essentially comprises a compressor, a combustion chamber, a gas turbine and an alternator. The compressor takes in air from the atmosphere taking it to a predetermined high pressure; the air thus compressed is injected into the combustion chamber together with a fuel, generally consisting of natural gas; the mixture that forms is ignited and the high pressure and high temperature gases produced are made to expand in the gas turbine that moves the alternator, which generates electrical energy.

**[0004]** The steam cycle of the aforementioned thermoelectric plant, on the other hand, comprises a steam generator, a steam turbine and a further alternator. The heat exchange unit of said steam generator, generally comprising heat exchangers of the type with water tubes, is placed in a heat exchange relationship with the hot gases discharged by the gas turbine of the aforementioned gas cycle, with a consequent great and quick heating of the water and generation of steam. The steam thus produced is sent to the steam turbine that makes the respective alternator operate to generate electrical energy.

**[0005]** A steam generator used in the aforementioned way is called heat recovery steam generator precisely because to generate steam the heat of the hot gases (at about 600°C) discharged by the gas turbine is "exploited".

**[0006]** In modern combined cycles the steam is preferably produced at different pressure levels in order to be able to optimize the energy recovery.

**[0007]** In particular, the most widely used plant configuration for high-power embodiments provides three pressure levels (high, medium and low) plus a re-superheating of the medium pressure steam returning from the steam turbine, i.e. of the so-called cold re-superheated steam.

**[0008]** As known, the recovery steam generator, for each pressure level, takes care of three well-defined heat exchange operations:

- preheating of liquid water coming from a feed pump or from a condensate extraction pump, carried out in a section of the heat exchange unit known as economizer or preheater;
- evaporation of the water for the generation of saturated steam, carried out in a section of the heat exchange unit known as evaporator;
- superheating of the steam, carried out in a section of the heat exchange unit known as superheater.

**[0009]** The tube bundles that take care of the three different operations are structurally independent.

**[0010]** In the presence of several pressure levels, the recovery steam generator has several evaporation steps (two or three), at different pressures and as a consequence at different saturation temperatures.

**[0011]** There is, therefore, a production of steam at high pressure (and therefore at high temperature, capable of developing a lot of energy in the subsequent expansion in steam turbine) where the gases of the gas turbine are hotter, followed by the production of steam at lower pressures where the gases are progressively cooled.

**[0012]** From that mentioned, it is therefore distinguished, inside the heat exchange unit of the steam generator, different sections or portions at progressively decreasing temperature. In particular, in the heat exchange unit, in normal operative conditions, a hot portion may always be defined, with high metal temperatures and high temperatures of the water/steam mixture enclosed there, and a relatively cool portion, with lower metal temperatures and lower temperatures of the water/steam mixture enclosed there, with respect to those of said hot portion.

**[0013]** To be precise, in the present patent application, the phrase "metal temperatures" is intended to indicate the mean temperature of the metal with which the components of the heat exchange unit itself are realized, in particular the mean temperature of the tubes through which the water/steam mixture passes.

**[0014]** The recovery steam generator described above has recognized drawbacks, including that of requiring relatively long time periods to be brought to normal pressure and temperature operative conditions. Such a drawback is particularly serious considering the present need to have available a great flexibility of operation of the thermoelectric plant.

### Summary of the invention

**[0015]** The technical problem underlying the present invention is that of devising and providing a recovery steam generator of the type considered, capable of overcoming, in a simple and economic manner, the limitations and/or the drawbacks mentioned with reference to the known art; in particular reducing the time of restarting of the steam generator following a shutdown, i.e. the possibility to frequently carry out shutdowns and start-ups of the considered plant, with re-starting times as reduced as possible while respecting the admissible thermal gradients for the components of greater thickness.

**[0016]** This problem is solved, according to the present invention, by a heat recovery steam generator, comprising a heat exchange unit in which, in normal operative conditions, is defined a hot portion, with high metal temperatures and high temperatures of the water/steam mixture enclosed there, and a relatively cool portion, with lower metal temperatures and lower temperatures of the water/steam mixture enclosed there, with respect to those of said hot portion, and characterized in that substantially shutter-shaped means are interposed between said hot portion and said relatively cool portion in order to thermally insulate said hot portion from said relatively cool portion, said substantially shutter-shaped means being at least partially removable in order to put said hot portion and said relatively cool portion again in fluid communication with each other.

**[0017]** Further characteristics and the advantages of the steam generator according to the present invention shall result from the following description of a preferred example embodiment thereof, provided for indicating and not limiting purposes with reference to the attached drawings.

### Brief description of the drawings

#### **[0018]**

Figure 1 schematically represents a side elevation view of a recovery steam generator according to the invention.

Figure 2 schematically represents a side elevation view of a second embodiment of a recovery steam generator according to the invention.

Figure 3 schematically represents a side elevation view of a third embodiment of a recovery steam generator according to the invention.

### Detailed description of a preferred embodiment

**[0019]** With reference to figure 1, a heat recovery steam generator is shown in accordance with the present invention and globally indicated with 10.

**[0020]** The recovery steam generator 10 comprises a

heat exchange unit 12, comprising a plurality of tube bundles in which, in normal operating conditions, is defined a hot portion, with high metal temperatures and high temperatures of the water/steam mixture enclosed there, and a relatively cool portion, with lower metal temperatures and lower temperatures of the water/steam mixture enclosed there, with respect to those of said hot portion.

**[0021]** The heat exchange unit 12 is in fluid communication with one (or more) water-steam separation chambers 14, in jargon also called cylindrical bodies (in figure 1 three cylindrical bodies are shown, operating at different pressures).

**[0022]** The heat exchange unit 12 is supported in a smoke flue 13, for example substantially parallelepiped, with a face or section 13a in fluid communication with the exhaust gases of a gas turbine and with an opposite face or section 13b in fluid communication with a chimney stack 13c. The cylindrical bodies 14 are placed above said smoke flue 13.

**[0023]** The heat exchange unit 12 of figure 1 comprises a high pressure section 16, which realizes said hot portion, and sections at medium pressure 18 and at low pressure 20, which realize said relatively cool portion. Exemplifying pressure values are 130 bar for the high pressure section, 30 bar for the medium pressure section, and 5 bar for that at low pressure.

**[0024]** The hot portion, at high temperature, comprises a high pressure evaporator and several bundles of superheating/resuperheating tubes, and possibly a high pressure economizer.

**[0025]** The relatively cool portion, at relatively low temperature, comprises the medium and low pressure levels, the preheater and possibly a part of the high pressure economizer.

**[0026]** In accordance with the present invention, substantially shutter-shaped means 32 are interposed between said hot portion and said relatively cool portion in order to thermally insulate said hot portion from said relatively cool portion. Said substantially shutter-shaped means 32 are at least partially removable in order to put said hot portion and said relatively cool portion again in fluid communication with each other.

**[0027]** In accordance with a preferred embodiment, such means 32 comprise a rolling shutter 34, having width substantially equal to the width of the smoke flue 13.

**[0028]** Preferably, the corresponding winding roller 36 of the rolling shutter 34 is arranged at the upper face, or side, or top 13e of the smoke flue 13.

**[0029]** The shutter 34 may descend, in substantially vertical manner, until at the lower face, or side, or base 13d of the substantially parallelepiped smoke flue 13, thus insulating the two said portions of said heat exchange unit 12 from each other.

**[0030]** Figure 2 shows a second embodiment of a steam generator 110 according to the invention, in which the components analogous to those of the steam generator 10 are indicated with the same reference number.

**[0031]** In this case, substantially shutter-shaped

means 132 are interposed between said hot portion and said relatively cool portion in order to thermally insulate said hot portion from said relatively cool portion. Said substantially shutter-shaped means 132 are at least partially removable in order to put said hot portion and said relatively cool portion again in fluid communication with each other.

**[0032]** Such means 132 comprise a rolling shutter 134, having width substantially equal to the width of the smoke flue 13.

**[0033]** Preferably, the corresponding winding roller 136 of the rolling shutter 134 is arranged at the lower face, or side, or base 13d of the substantially parallelepiped smoke flue 13.

**[0034]** The shutter 134 may rise, by means of an actuator 138 provided with cables 140, in substantially vertical manner, until at the upper face 13e of the substantially parallelepiped smoke flue 13, thus insulating said two portions of said heat exchange unit 12.

**[0035]** Figure 3 shows a third embodiment of a steam generator 210 according to the invention, in which the components analogous to those of the steam generator 110 are indicated with the same reference number.

**[0036]** In this case, substantially shutter-shaped means 232 are interposed between said hot portion and said relatively cool portion in order to thermally insulate said hot portion from said relatively cool portion. Said substantially shutter-shaped means 232 are at least partially removable in order to put said hot portion and said relatively cool portion again in fluid communication with each other.

**[0037]** Such means 232 comprise a folding shutter 234, having width substantially equal to the width of the smoke flue 13.

**[0038]** A lower end 236 of the folding shutter 234 is constrained to the lower face 13d of the substantially parallelepiped smoke flue 13.

**[0039]** The shutter 234 may rise, by means of an actuator 238 provided with cables 240, in substantially vertical manner, until at the upper face 13e of the substantially parallelepiped smoke flue 13, thus insulating said two portions of said heat exchange unit 12.

**[0040]** The operation of the recovery steam generators 10, 110 and 210 is detailed below.

**[0041]** The shutters 34, 134 and 234, which may be automatically or manually operated, insulate said two portions of the heat exchange unit 12 preferably immediately after having begun the generator shutdown procedure, and after stopping the gas flow coming from the turbine.

**[0042]** In this manner, the internal convection of the generator is limited, between the hottest tube bundles and the coolest, i.e. the transfer of heat from the hot portion to the relatively cool portion by convection and irradiation is limited.

**[0043]** As an example, in a three-pressure level steam generator with re-superheating, placed downstream a 250 MW gas turbine, at the moment of a shutdown carried

out beginning from the nominal load there is approximately the following situation:

- hot portion (superheater, re-superheater and high pressure evaporator): about 900 t of metal and 30 t of water/steam mixture at the mean temperature of about 360-380°C.
- relatively cool portion: about 1600 t of metal and 180 t of water/steam mixture at the mean temperature of about 190-200°C.

**[0044]** It is therefore evident that, for example, in the 8 hours of a night shutdown (in the case of two shifts every day) or in the 48 hours of a possible shutdown during the weekend, the transfer of a considerable amount of heat is limited, from the hot portion (which consequently cools and diminishes its own pressure) to the relatively cool portion: since the high pressure evaporator, and more precisely the cylindrical body of the related water-steam separation chamber, is the element limiting the start-up gradient, it follows that such reduction of cooling leads to a shortening of the start-up transient period.

**[0045]** The shutters must be in completely open position during the normal operation of the generators, so to not generate pressure drops and consequently energy dissipations.

**[0046]** The location of the shutter is preferably comprised between the high pressure evaporator inlet and medium pressure evaporator outlet for the generators illustrated in the figures (three-pressure level generators) or the low pressure evaporator inlet for two-pressure level generators (not illustrated).

**[0047]** In the case of a possible four-pressure level embodiment, the shutter may be situated in a position between the downstream of the high pressure evaporator and the downstream of the third pressure level evaporator.

**[0048]** In all of the aforementioned cases, the installation with more than one shutter may be provided.

**[0049]** In the case of an embodiment with a single pressure level, the shutter may be situated downstream of the evaporator.

**[0050]** The shutter may be realized with metallic materials (stainless steel) or textile materials. Preferably the shutter is covered with thermally insulating materials. The form indicated in the figures is purely indicative and not limiting.

**[0051]** In one alternative, the substantially shutter-shaped means may comprise devices of bulkhead type.

**[0052]** The levers and/or motorizations for the actuators may be of different types and are arranged inside or outside of the smoke flue. In specifically contingent cases, there may also be provided a manual type actuation.

**[0053]** From the preceding description it results in evident manner that the recovery steam generator according to the invention achieves numerous advantages, the

first of which lies in the fact that the restart-up times are unusually brief, permitting significant improvements on the full load operation times of the thermoelectric plant.

[0054] Indeed, at the time of each restarting of the steam generator according to the invention following a shutdown of limited duration (for example, less than 72 hours duration), it is possible to proceed to the start-up from higher pressures and consequently higher temperatures in the high pressure circuit, thus consistently reducing the start-up time, thermomechanical stresses induced in the most critical steam generator components being equal, i.e. in the components of greater thickness such as the high pressure cylindrical bodies.

[0055] Another advantage of the steam generator according to the invention is that, during the shutdown, the flow of cool air inside the generator is limited, which, in the absence of the shutter, would occur due to the draft of the chimney stack, leading to an additional cooling of the generator during the shutdown.

[0056] Of course, a man skilled in the art can make numerous modifications and variants to the recovery steam generator described above in order to satisfy specific and contingent requirements, all of which are in any case covered by the scope of protection of the present invention as defined by the following claims.

## Claims

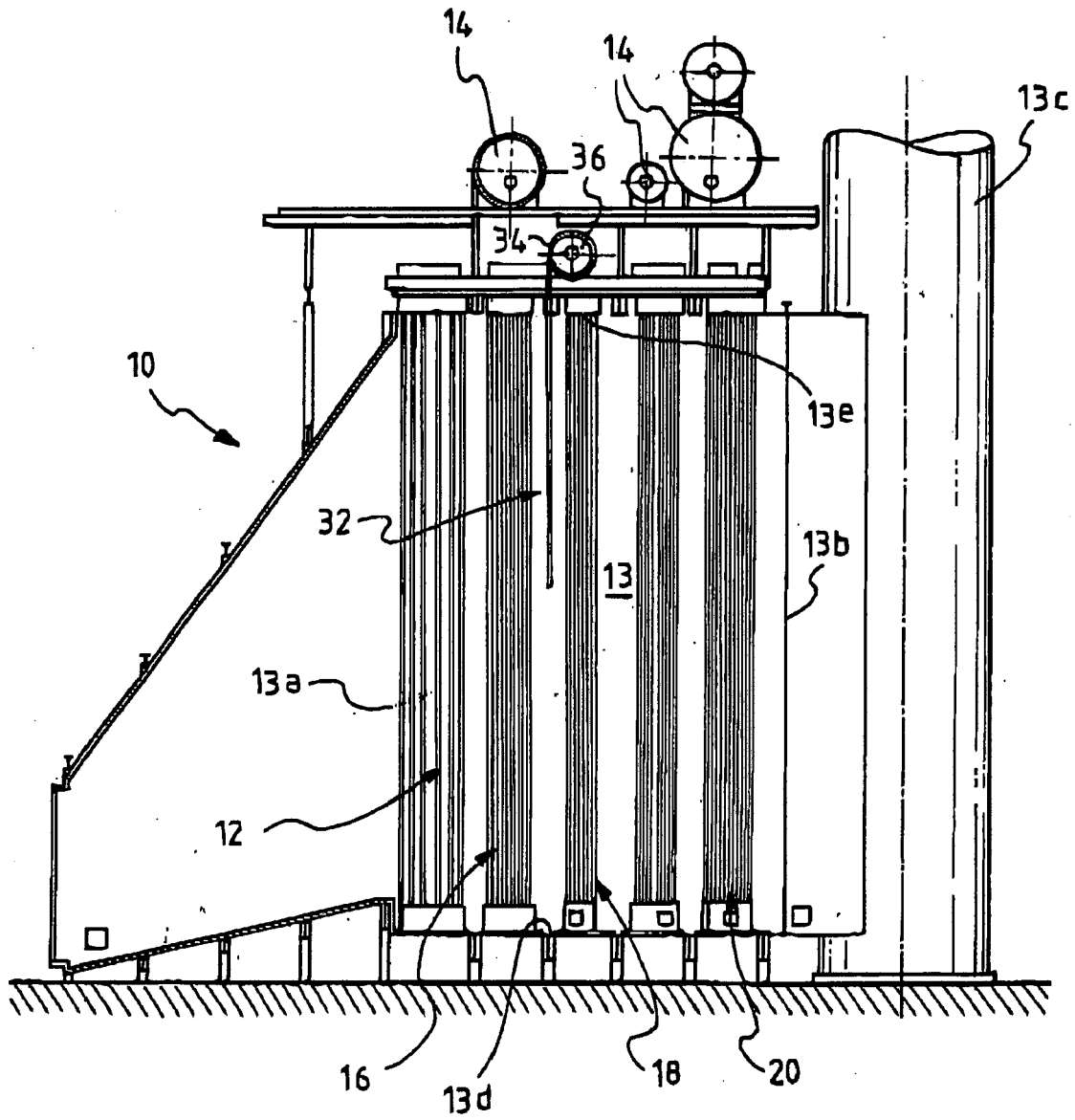
1. Heat recovery steam generator (10, 110, 210), comprising a heat exchange unit (12) in which, in normal operative conditions, is defined a hot portion (16), with high metal temperatures and high temperatures of the water/steam mixture enclosed there, and a relatively cool portion (18, 20), with lower metal temperatures and lower temperatures of the water/steam mixture enclosed there, with respect to those of said hot portion (16), **characterized in that** substantially shutter-shaped means (32, 132, 232) are interposed between said hot portion (16) and said relatively cool portion (18, 20) in order to thermally insulate said hot portion (16) from said relatively cool portion (18, 20), said substantially shutter-shaped means (32, 132, 232) being at least partially removable in order to put said hot portion (16) and said relatively cool portion (18, 20) again in fluid communication with each other.

2. Heat recovery steam generator (10, 110) according to claim 1, **characterized in that** said substantially shutter-shaped means (32, 132) comprise a rolling shutter (34, 134).

3. Heat recovery steam generator (210) according to claim 1, **characterized in that** said substantially shutter-shaped means (232) comprise a folding shutter (234). 4. Heat recovery steam generator (10, 110, 210) according to claim 2 or 3, **characterized**

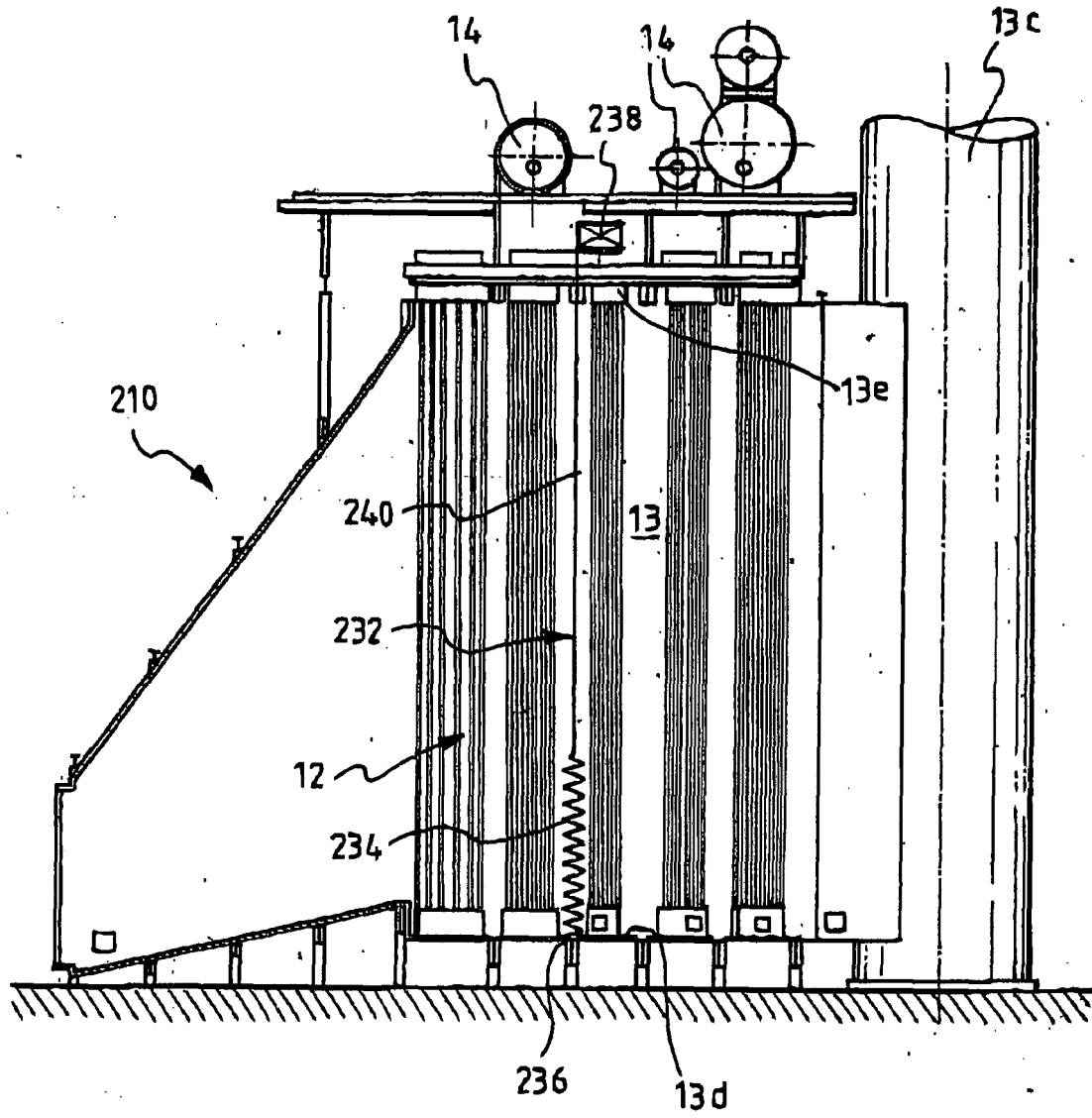
**in that** said shutter (32, 132, 232) is realized with metallic or textile materials.

5. Heat recovery steam generator (10, 110, 210) according to claim 4, **characterized in that** said shutter (32, 132, 232) is covered with thermally insulating material.



*Fig. 1*





*Fig. 3*



| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                          |                                                      |                                         |
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EPO FORM 1503 03/82 (P04/C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
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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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