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(54) **Steam generator**

Dampferzeuger

Générateur de vapeur

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Description

[0001] The present invention, in its most general aspect, refers to a steam generator comprising at least one heat exchange unit in fluid communication with at least one liquid-gas separation chamber and it is particularly but not exclusively recommended for use in thermoelectric plants, preferably in so-called gas/steam combined cycle thermoelectric plants.

[0002] In the rest of the description reference shall be made, purely as a non-limiting example, to the technical field relative to combined cycle thermoelectric plants, i.e. plants in which two technological cycles are provided, one carried out by air and natural gas (gas cycle) and the other carried out by water and steam (steam cycle), both intended to produce electrical energy with high yield.

Prior Art

[0003] It is known that the gas cycle of a combined cycle thermoelectric plant of the considered type 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 introduced 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 pipes, 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 a heat recovery steam generator precisely because to generate steam the heat of the hot gasses (at about 600°C) discharged by the gas turbine is "exploited".

[0006] The water-steam mixture, formed continuously in the heat exchange unit, is fed to an appropriate gas-liquid separation chamber. In this chamber the water is separated from the steam for example by gravity (in this case we are talking about a natural circulation steam generator), or with a suitable diaphragm or through separator cyclones (in this case we are talking about an assisted or controlled circulation steam generator).

[0007] The separation chamber is generally formed in a so-called steam drum comprising a cylindrical shell that has an internal diameter and thickness appropriately correlated to the generally strict operating conditions for pressure and temperature and it is preferably made from steel.

[0008] For example, the shell of a steam drum with an internal diameter of 2000 mm can have a thickness even greater than 150 mm, when the relative pressure and the operating temperature are 110 bar and 320°C respectively.

[0009] Although advantageous from various points of view, a steam generator structured in the way schematically described above (i.e. comprising at least one heat exchange unit and at least one separation chamber), has recognized drawbacks that occur above all when one has to tackle the ever-increasing need to subject the generator to repeated steps of starting and stop.

[0010] In the case of the heat recovery steam generator, this need is linked to the increasing requirement for greater operating flexibility of the thermoelectric plant, which requires ever decreasing start-up times, both for cold starting and for restarting after a short stop.

[0011] The main drawback of the steam generator of the aforementioned type is linked to the large thickness of the shell of the steam drum, which is the thickest component of the steam generator itself.

[0012] Indeed, during the starting of the steam generator, a temperature difference is created between the inner surface of the steam drum, in contact with the heating fluids (i.e. with the boiling water and the steam that frees itself from it), and the outer surface of the steam drum, exposed to room temperature. In the case of so-called "cold" starting (i.e. after a prolonged stop), the aforementioned temperature difference can greatly exceed 50°C.

[0013] Such a temperature difference is, of course, substantially zeroed when normal operating conditions are reached (where the temperatures are stable and homogeneous), thanks to the transmission of heat by conduction, for example after a transition period of:

- 45 minutes, in the case of a stop of about 8 hours;
- 75 minutes, in the case of a stop of about 48 hours;
- 170 minutes, in the case of a stop of about 72 hours.

[0014] It is therefore clear that, at each starting step, the metal material from which the steam drum is made is subjected to a cycle in which there are differentiated thermal dilations along the thickness of the shell of the steam drum itself. In other words, the metal material is subjected to localized mechanical stresses, which repeat cyclically, i.e. the metal material is subjected to the phenomena of fatigue wear: to prevent the formation of cracks it is necessary, at the design stage, to pre-establish the maximum number of cycles (i.e. of starting steps) that when reached it is necessary to replace the steam drum.

[0015] US-A-5588400 discloses a forced-through-flow boiler wherein the evaporator is divided in at least two

sections to facilitate start-up.

Summary of the invention

[0016] The technical problem forming the basis of the present invention is that of devising and providing a steam generator of the type considered, capable of satisfying the need outlined above, i.e. of allowing a flexibility of operation in plants for producing electrical energy or of allowing a series of starting steps and stops, at the same time drastically reducing the amount of the phenomena of the fatigue wear on the metal material of the steam drum of the generator itself, so as to overcome the aforementioned limitations and/or drawbacks with reference to the prior art in a simple and cost-effective manner.

[0017] This problem is solved, according to the present invention, by a steam generator and use of heating means in a steam generator according to the claims.

[0018] Characteristics and advantages of the invention shall become clearer from the following description of a preferred embodiment thereof, provided for indicating and not limiting purposes with reference to the attached drawings.

Brief description of the drawings

[0019]

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

Figure 2a schematically represents an enlarged and cutaway side view of a detail of figure 1.

Figure 2b schematically represents a cutaway side view of an alternative of the detail of figure 2a.

Figure 3 schematically represents a cross section of the detail of figure 2a, taken according to the plane of figure 2a having III-III trace.

Detailed description of a preferred embodiment

[0020] With reference to the figures, a steam generator in accordance with the present invention is shown globally indicated with 10.

[0021] The steam generator 10 comprises a heat exchange unit 11 in fluid communication with a gas-liquid separation chamber 12, formed in a so-called steam drum comprising a cylindrical shell 13 that has predetermined internal diameter and thickness, preferably made from steel.

[0022] Alternatively, many heat exchange units and many steam drums can be provided that operate at different pressures, respectively. In the case of figure 1 (heat recovery steam generator), three steam drums 12, 14 and 16 are provided, which operate at high pressure (for example 110 bar of relative pressure), medium pressure (for example 25 bar of relative pressure) and low pressure (for example 5 bar of relative pressure), respectively.

[0023] The cylindrical shell 13 of the steam drum 12 has a substantially horizontal axis and is closed at the opposite ends by respective bottoms 13a and 13b, being equipped with at least one inlet opening 12a for a water/steam mixture, with at least one outlet opening 12b for water and with at least one outlet opening 12c for steam.

[0024] In accordance with the present invention, the steam generator 10 comprises heating means 18 externally associated with the cylindrical shell 13 of said separation chamber 12 and able to be activated autonomously on it. Alternatively, the heating means 18 are externally associated with at least part of said cylindrical shell 13. In the case in which there are many steam drums (14 and 16), the heating means can also be associated with them.

[0025] More specifically, said heating means 18 comprise a tube 20 wound in a spiral on the shell 13 (figure 2a) and run by a heating fluid (liquid or gas), such as diathermic oil or steam (a part of the steam produced by the generator 10 itself can be used) or even hot gases coming, for example, from the discharge of a gas turbine, arranged upstream of the steam generator 10 in a combined cycle thermoelectric plant. Alternatively, the tube 20, as well as being wound in a spiral on the shell 13, can also be shaped in a serpentine manner, as shown in figure 2b. Moreover, a plurality of tubes of the same type as the tube 20 can be provided. In a further alternative, a plurality of ring-shaped tubes, run by a heating fluid of the aforementioned type, can be provided, that are wound around the shell 13 and that are preferably connected in parallel through a tube that acts as a distributor.

[0026] In an alternative, said heating means 18 comprise a cylindrical jacket provided around the shell 13, in contact with it and run by a heating fluid of the aforementioned type.

[0027] In a further alternative, said heating means 18 comprise electrical resistances wound in a spiral on the shell 13.

[0028] A thermally insulating coating 22 is provided around the tube 20, the jacket or the electrical resistances associated with the shell 13, respectively, which are in contact with it, in order to heat the outer surface of the shell 13 in an efficient manner.

[0029] The heating means 18 can also comprise tubes 24, or electrical resistances, wound in a spiral on the inlet and outlet openings 12a and 12b and on the outlet opening 12c. Alternatively, the tubes 24, or the electrical resistances, are wound in a spiral on at least one of the aforementioned openings.

[0030] More generally, the heating means 18 are provided for those components of the generator 10 that have a large thickness, such as collectors and tubes of superheated steam and valves with a large diameter.

[0031] Even more generally, heating means 18 can be provided that are externally associated with at least part of portions with large thickness of the steam generator 10 and able to be activated autonomously on them. The invention also refers to the use of heating means 18 in the steam generator 10, said heating means 18 being suitable for being externally associated with at least part of said portions of the steam generator 10 itself and being suitable for being able to be activated autonomously on them.

[0032] The operation of the steam generator 10 according to the invention shall now be specified.

[0033] The heat exchange unit 11 is arranged in a heat exchange relationship with a heat source, thanks to which a water/steam mixture is generated, fed continuously to the separation chamber 12 through the inlet opening 12a.

[0034] Each time the steam generator 10 is started, thanks to the heating means 18 of the present invention, the difference between the temperature of the outer wall of the cylindrical shell 13 and the temperature of the inner surface of the cylindrical shell 13 itself, subjected to the heat carried by said water/steam mixture, is substantially zeroed or, in any case, it is drastically reduced.

[0035] Preferably, the heating means 18 act on the entire outer surface of the shell 13 of the steam drum 12 and, where it is provided, on those components of the generator 10 that have a large thickness, such as collectors and tubes of superheated steam and valves with a large diameter.

[0036] The dispensing of heat by the heating means 18 begins as soon as the generator 10 is started or rather in a period of time that precedes the actual starting of the generator 10, i.e. before the operating fluids (i.e. the water/steam mixture and the steam that frees itself from it) circulate in the steam drum 12 itself.

[0037] Preferably, the dispensing of heat is controlled in such a way that the temperatures assumed along the thickness of the steam drum 12 are substantially uniform, during the entire start-up.

[0038] For such a purpose, preferably, suitable control means are also provided that detect the temperature on the outer wall of the shell 13 of the steam drum 12 and of the components to be heated and that regulate the thermal energy to be dispensed, so that the amount of heat brought by the heating means 18 is suitable during the entire starting of the generator 10.

[0039] The dispensing of heat is interrupted after said starting of the generator 10, once the normal operating conditions have been reached.

[0040] From the previous description it can clearly be seen that the steam generator according to the invention solves the technical problem and gives numerous advantages the first of which lies in the fact that the generator can be started an unusually high number of times.

[0041] In other words, the starting times of the generator can be very quick, without risk to the production life of the thickest components, in particular of the steam drum operating at a high pressure.

[0042] It should be noted that in the case of use of the steam generator according to the invention in a thermoelectric plant, i.e. in the case of use as a heat recovery steam generator, the heat exchange unit of the generator is placed in heat exchange relationship with the hot gases discharged by the gas turbine of the gas cycle of the thermoelectric plant itself.

[0043] In the case of use of the steam generator according to the invention as a steam generator of the so-called fuel type, used for example in the production of technological steam, the heat exchange unit of the generator is placed in heat exchange relationship with the hot fumes originating from the burning of the fuel in a combustion chamber provided in the generator itself.

[0044] Of course, a man skilled in the art can make numerous modifications and variants to the 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. Steam generator (10), comprising at least one heat exchange unit (11) in fluid communication with at least one liquid-gas separation chamber (12, 14, 16), said liquid-gas separation chamber equipped with portions (12a, 12b, 12c, 13) with a predetermined thickness, **characterized in that** it comprises heating means (18) externally associated with at least part of said portions (12a, 12b, 12c, 13) of said steam generator (10) and able to be activated autonomously on them.

2. Steam generator (10) according to claim 1, wherein said at least one liquid-gas separation chamber (12, 14, 16) comprises a cylindrical shell (13) of predetermined internal diameter and thickness, and said heating means (18) are externally associated with at least part of said cylindrical shell (13) of said at least one liquid-gas separation chambers (12, 14, 16) and able to be activated autonomously on it.

3. Steam generator (10) according to claim 2, **characterized in that** said heating means (18) comprise at least one tube (20) wound in a spiral on said shell (13) and run by a heating fluid.

4. Steam generator (10) according to claim 2, **characterized in that** said heating means (18) comprise a plurality of ring-shaped tubes, run by a heating fluid, which are wound around said shell (13) and that are connected in parallel through a tube that acts as a distributor.

5. Steam generator (10) according to claim 2, **charac-**

terized in that said heating means (18) comprise a cylindrical jacket provided around said shell (13), in contact with it and run by a heating fluid.

6. Steam generator (10) according to claim 3 or 4 or 5, **characterized in that** said heating fluid is hot gases coming from the discharge of a gas turbine, or is diathermic oil or is steam.

7. Steam generator (10) according to claim 3, **characterized in that** said at least one tube (20) is shaped in a serpentine manner.

8. Steam generator (10) according to claim 2, **characterized in that** said heating means (18) comprise electrical resistances wound in a spiral on said shell (13).

9. Steam generator (10) according to claim 2, **characterized in that** a thermally insulating coating (22) is provided around said heating means (18).

10. Steam generator (10) according to claim 2, **characterized in that** control means are provided that detect temperatures on the outer wall of said shell (13).

11. Steam generator (10) according to claim 2, wherein said cylindrical shell (13) is equipped with at least one inlet opening (12a) for a water/steam mixture, with at least one outlet opening (12b) for water and with at least one outlet opening (12c) for steam, **characterized in that** said heating means (18) are externally associated with at least part of said cylindrical shell (13) of at least one of said separation chambers (12, 14, 16) and externally associated with at least one of said openings (12a, 12b, 12c), said heating means (18) being able to be activated autonomously on said at least part of said cylindrical shell (13) and on said at least one of said openings (12a, 12b, 12c).

12. Steam generator according to claim 11, wherein the heating means (18) comprise tubes (24) or electrical resistances wound in a spiral on at least one of said inlet and outlet openings.

13. Use of heating means (18) in a steam generator (10), comprising at least one heat exchange unit (11) in fluid communication with at least one liquid-gas separation chamber (12, 14, 16) and equipped with portions (12a, 12b, 12c, 13) with large thickness, said heating means (18) being suitable for being externally associated with at least part of said portions (12a, 12b, 12c, 13) of said steam generator (10) and being suitable for being able to be activated autonomously on them.

Patentansprüche

1. Dampfgenerator (10), der zumindest eine Wärmetauschereinheit (11) umfasst, die in Fluidverbindung mit mindestens einer Flüssigkeits/Gas-Trennkammer (12, 14, 16) steht, wobei die Flüssigkeits/Gas-Trennkammer mit Abschnitten (12a, 12b, 12c, 13) mit einer vorbestimmten Dicke ausgestattet ist, **dadurch gekennzeichnet, dass** er Erwärmungseinrichtungen (18) aufweist, die außen mit zumindest einem Teil der Abschnitte (12a, 12b, 12c, 13) des Dampfgenerators (10) verbunden sind und mit eigener Regelung an diesen aktiviert werden können.

2. Dampfgenerator (10) nach Anspruch 1, wobei die mindestens eine Flüssigkeits/Gas-Trennkammer (12, 14, 16) eine zylindrische Hülle (13) mit vorbestimmtem Innendurchmesser und vorbestimmter Dicke aufweist, und die Erwärmungseinrichtungen (18) außen mit zumindest einem Teil der zylindrischen Hülle (13) der mindestens einen Flüssigkeits/Gas-Trennkammer (12, 14, 16) verbunden sind und mit eigener Regelung an ihr aktiviert werden können.

3. Dampfgenerator (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** die Erwärmungseinrichtungen (18) zumindest ein Rohr (20) umfassen, das in einer Spirale um die Hülle (13) gelegt ist und von einem Erwärmungsfluid durchströmt wird.

4. Dampfgenerator (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** die Erwärmungseinrichtungen (18) mehrere ringförmige Rohre aufweisen, die von einem Erwärmungsfluid durchströmt werden und um die Hülle (13) gelegt sind, wobei die Rohre durch ein Rohr, welches als Verteiler wirkt, parallel miteinander verbunden sind.

5. Dampfgenerator (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** die Erwärmungseinrichtungen (18) einen zylindrischen Mantel umfassen, der um die Hülle (13) herum vorgesehen ist, in Berührung mit dieser steht und von einem Erwärmungsfluid durchströmt wird.

6. Dampfgenerator (10) nach Anspruch 3 oder 4 oder 5, **dadurch gekennzeichnet, dass** das Erwärmungsfluid aus heißen Gasen besteht, die vom Auslass einer Gasturbine kommen, oder ein diathermisches Öl oder Dampf ist.

7. Dampfgenerator (10) nach Anspruch 3, **dadurch gekennzeichnet, dass** das mindestens eine Rohr (20) schlangenlinienförmig gestaltet ist.

8. Dampfgenerator (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** die Erwärmungseinrichtun-

gen (18) elektrische Widerstände aufweisen, die in einer Spirale um die Hülle (13) gelegt sind.

9. Dampfgenerator (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** um die Erwärmungseinrichtungen (18) herum eine wärmeisolierende Beschichtung (22) vorgesehen ist.

10. Dampfgenerator (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** Steuereinrichtungen vorgesehen sind, die Temperaturen an der Außenwand der Hülle (13) erfassen.

11. Dampfgenerator (10) nach Anspruch 2, wobei die zylindrische Hülle (13) mit mindestens einer Einlassöffnung (12a) für ein Wasser/Dampf-Gemisch, mit mindestens einer Auslassöffnung (12b) für Wasser und mindestens einer Auslassöffnung (12c) für Dampf ausgestattet ist, **dadurch gekennzeichnet, dass** die Erwärmungseinrichtungen (18) außen mit mindestens einem Teil der zylindrischen Hülle (13) von mindestens einer der Trennkammern (12, 14, 16) verbunden sind und außen mit mindestens einer der Öffnungen (12a, 12b, 12c) verbunden sind, wobei die Erwärmungseinrichtungen (18) an dem zumindest einen Teil der zylindrischen Hülle (13) und an der mindestens einen der Öffnungen (12a, 12b, 12c) mit eigener Regelung aktiviert werden können.

12. Dampfgenerator nach Anspruch 11, wobei die Erwärmungseinrichtungen (18) Rohre (24) oder elektrische Widerstände umfassen, die in einer Spirale um mindestens eine der Einlass- und Auslassöffnungen gelegt sind.

13. Verwendung von Erwärmungseinrichtungen (18) in einem Dampfgenerator (10), mit mindestens einer Wärmetauschereinheit (11), die in Fluidverbindung mit mindestens einer Flüssigkeits/Gas-Trennkammer (12, 14, 16) steht und mit Abschnitten (12a, 12b, 12c, 13) mit großer Dicke ausgestattet ist, wobei die Erwärmungseinrichtungen (18) dazu geeignet sind, außen mit zumindest einem Teil der Abschnitte (12a, 12b, 12c, 13) des Dampfgenerators (10) verbunden zu werden und dazu geeignet sind, mit eigener Regelung an diesen aktiviert werden zu können.

Revendications

1. Générateur de vapeur (10), comportant au moins une unité d'échange de chaleur (11) en communication fluide avec au moins une chambre de séparation liquide-gaz (12, 14, 16), ladite chambre de séparation de liquide-gaz étant munie de parties (12a, 12b, 12c, 13) ayant une épaisseur prédéterminée, **caractérisé en ce qu'**il comporte des moyens de chauffage (18) associés en externe au moins partiellement auxdites parties (12a, 12b, 12c, 13) dudit générateur de vapeur (10) et pouvant être activés de manière autonome sur celles-ci.

2. Générateur de vapeur (10) selon la revendication 1, dans lequel ladite au moins une chambre de séparation de liquide-gaz (12, 14, 16) comporte une coque cylindrique (13) d'un diamètre et d'une épaisseur internes prédéterminés, et lesdits moyens de chauffage (18) sont associés en externe à au moins une partie de ladite coque cylindrique (13) de ladite au moins une chambre de séparation de liquide-gaz (12, 14, 16) et pouvant être activés de manière autonome sur celle-ci.

3. Générateur de vapeur (10) selon la revendication 2, **caractérisé en ce que** lesdits moyens de chauffage (18) comportent au moins un tube (20) enroulé en spirale sur ladite coque (13) et parcouru par un fluide chauffant.

4. Générateur de vapeur (10) selon la revendication 2, **caractérisé en ce que** lesdits moyens de chauffage (18) comportent une pluralité de tubes en forme d'anneau, parcourus par un fluide chauffant, lesquels sont enroulés autour de ladite coque (13) et **en ce qu'**ils sont montés en parallèle via un tube qui fonctionne en tant que distributeur.

5. Générateur de vapeur (10) selon la revendication 2, **caractérisé en ce que** lesdits moyens de chauffage (18) comportent une chemise cylindrique agencée autour de ladite coque (13), en contact avec celle-ci et parcourue par un fluide chauffant.

6. Générateur de vapeur (10) selon la revendication 3 ou 4 ou 5, **caractérisé en ce que** ledit fluide chauffant est constitué de gaz chauds provenant du refoulement d'une turbine à gaz, ou d'huile diathermane ou de vapeur.

7. Générateur de vapeur (10) selon la revendication 3, **caractérisé en ce que** ledit au moins un tube (20) présente une forme de serpentin.

8. Générateur de vapeur (10) selon la revendication 2, **caractérisé en ce que** lesdits moyens de chauffage (18) comportent des résistances électriques enroulées en spirale sur ladite coque (13).

9. Générateur de vapeur (10) selon la revendication 2, **caractérisé en ce qu'**un revêtement isolant thermiquement (22) est agencé autour desdits moyens de chauffage (18).

10. Générateur de vapeur (10) selon la revendication 2, **caractérisé en ce que** des moyens de commande sont agencés, lesquels détectent des températures

sur la paroi extérieure de ladite coque (13).

11. Générateur de vapeur (10) selon la revendication 2, dans lequel ladite coque cylindrique (13) est munie d'au moins une ouverture d'entrée (12a) pour un mélange eau/vapeur, ayant au moins une ouverture de sortie (12b) pour l'eau et ayant au moins une ouverture de sortie (12c) pour la vapeur, **caractérisé en ce que** lesdits moyens de chauffage (18) sont associés en externe à au moins une partie de ladite coque cylindrique (13) d'au moins l'une desdites chambres de séparation (12, 14, 16) et associés en externe à au moins l'une desdites ouvertures (12a, 12b, 12c), lesdits moyens de chauffage (18) pouvant être activés de manière autonome sur ladite au moins une partie de ladite coque cylindrique (13) et sur ladite au moins une desdites ouvertures (12a, 12b, 12c).

12. Générateur de vapeur selon la revendication 11, dans lequel les moyens de chauffage (18) comportent des tubes (24) ou des résistances électriques enroulées en spirale sur au moins l'une desdites ouvertures d'entrée et de sortie.

13. Utilisation de moyens de chaleur (18) dans un générateur de vapeur (10), comportant au moins une unité d'échange de chaleur (11) en communication fluide avec au moins une chambre de séparation de liquide-gaz (12, 14, 16), et munie de parties (12a, 12b, 12c, 13) ayant une grande épaisseur, lesdits moyens de chauffage (18) étant adaptés pour être associés en externe au moins partiellement auxdites parties (12a, 12b, 12c, 13) dudit générateur de vapeur (10) et étant adaptés pour pouvoir être activés de manière autonome sur celles-ci.

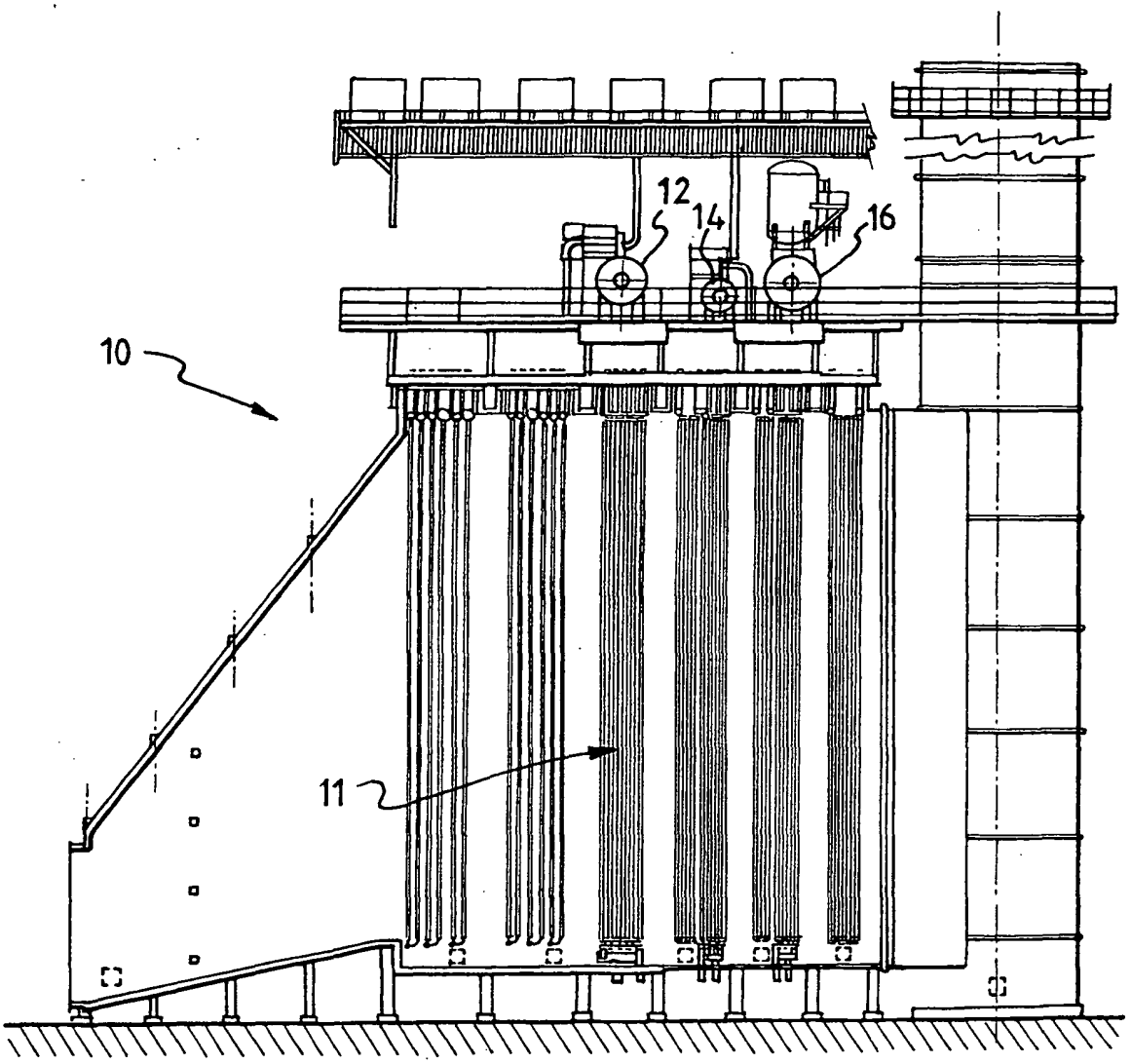

FIG. 1

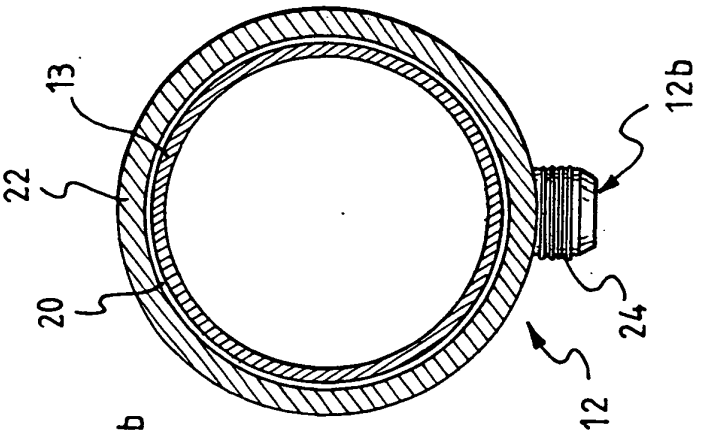

FIG. 3

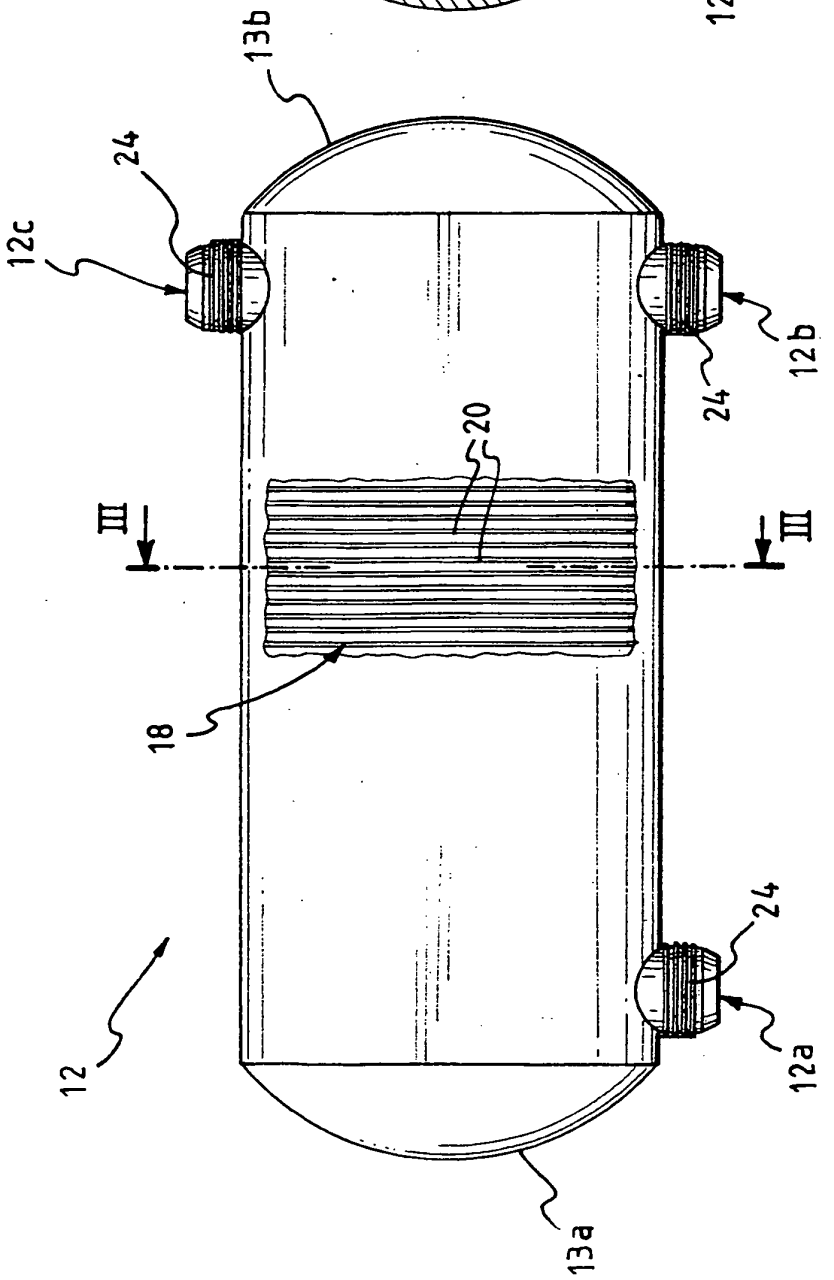

FIG. 2a

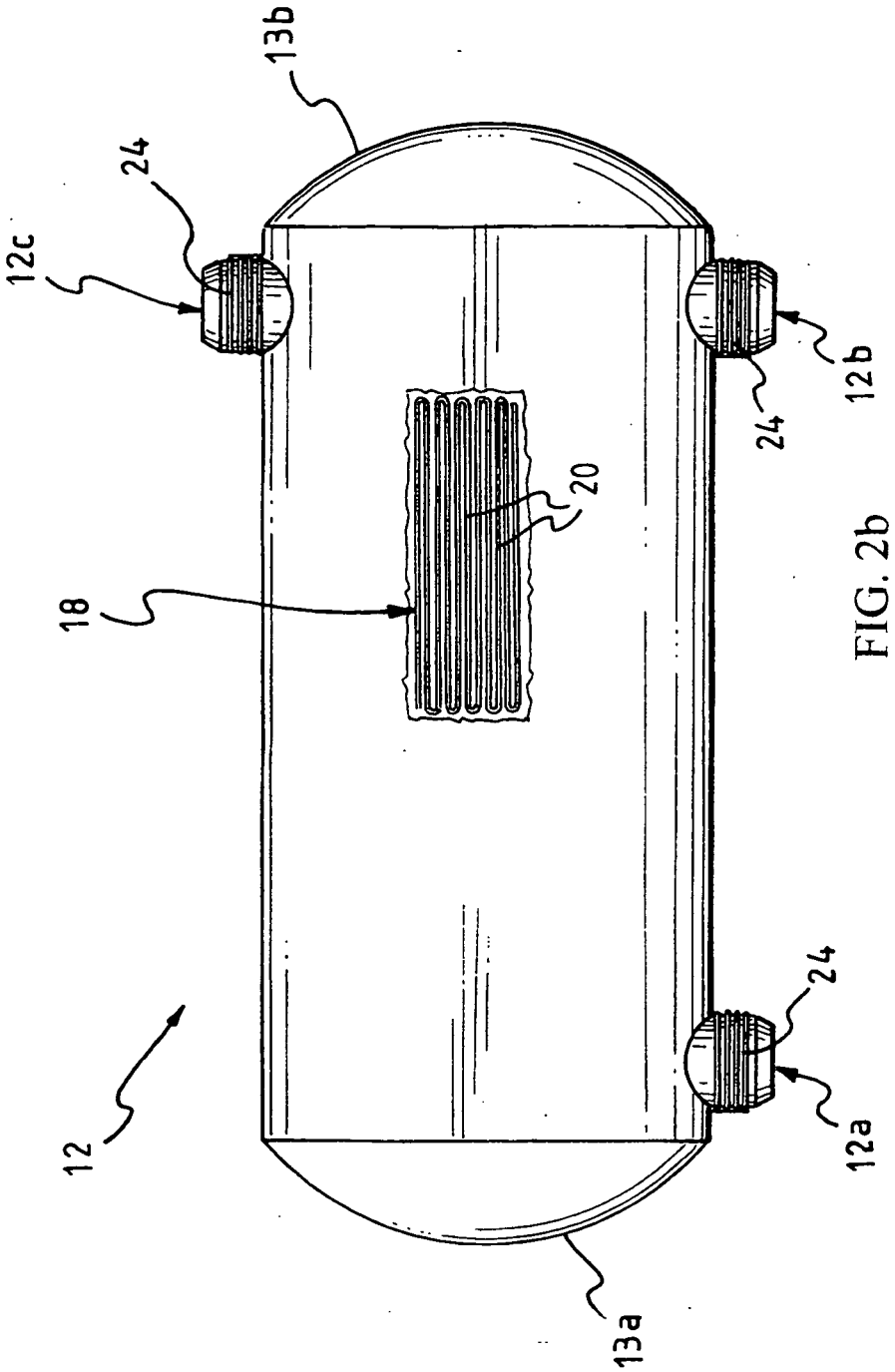

FIG. 2b

REFERENCES CITED IN THE DESCRIPTION

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