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(54) STEAM GENERATOR COMPRISING SUCCESSIVE COMBUSTION CHAMBERS

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(57) **ABSTRACT**

A steam generator includes at least two successive combustion hearths with at least one burner supplied with fuel and oxidizer, a vaporization zone comprising a vaporization exchanger, a superheating zone comprising a superheating exchanger, a preheating zone comprising a preheating exchanger and a collecting drum, Each hearth includes at least one vaporization exchanger.

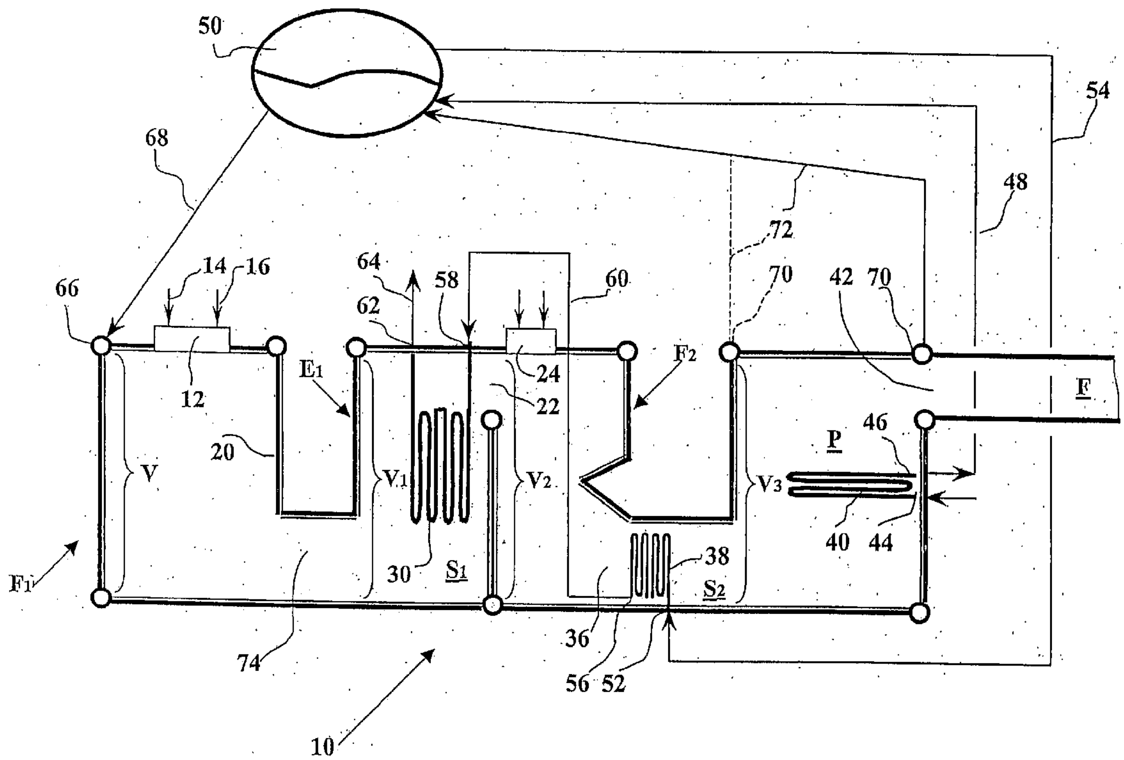
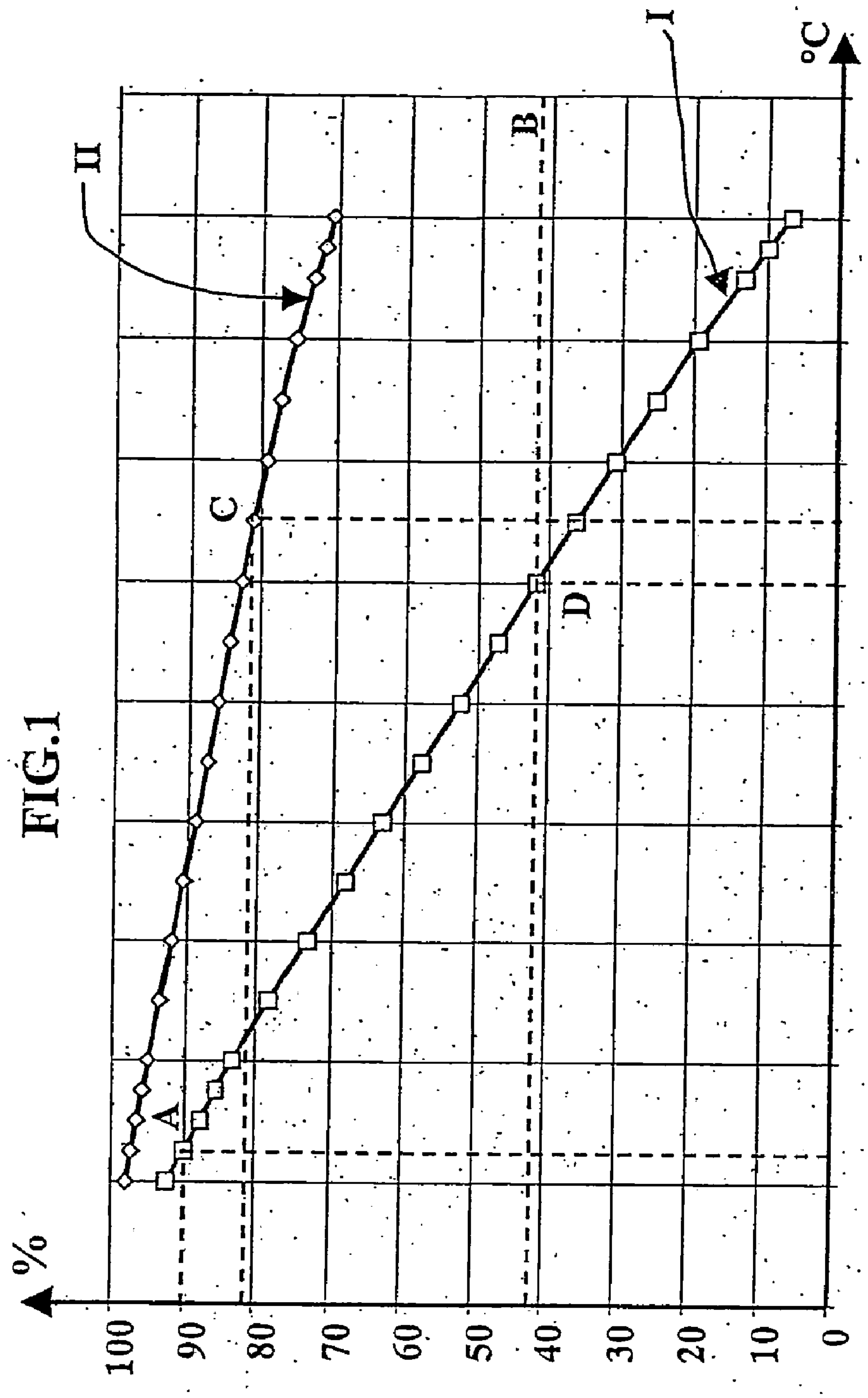


FIG.1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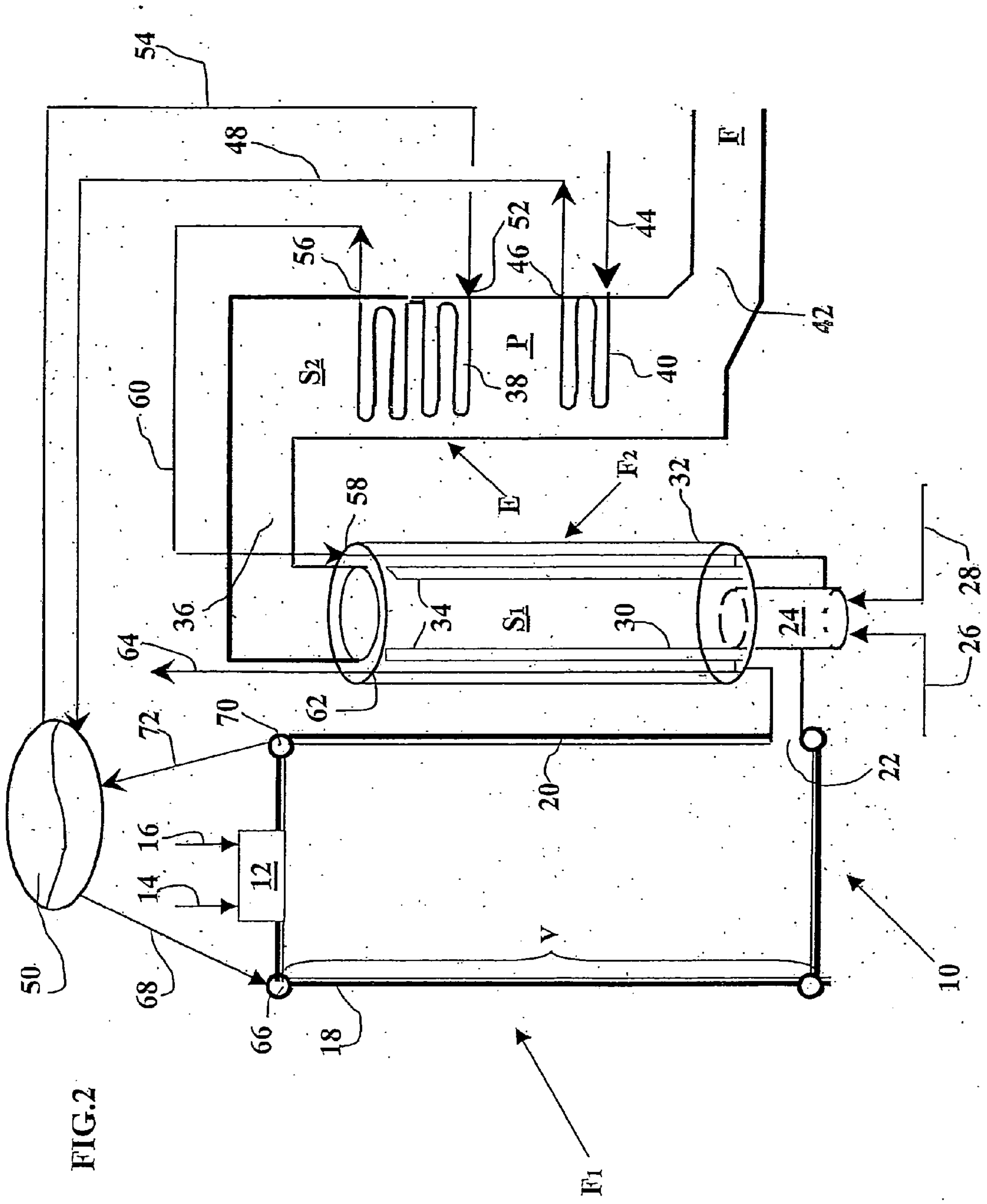
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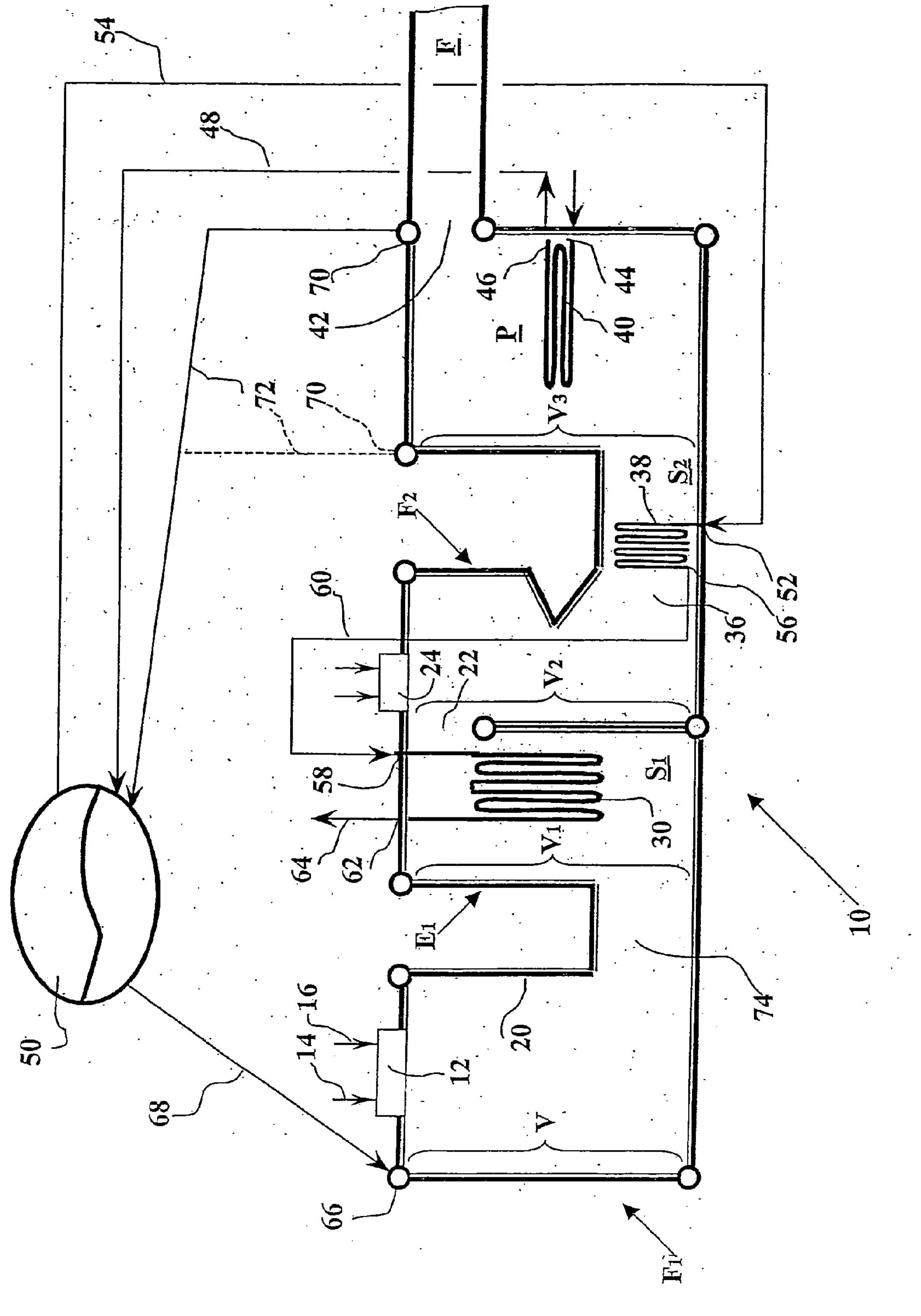
FIG.2

FIG.3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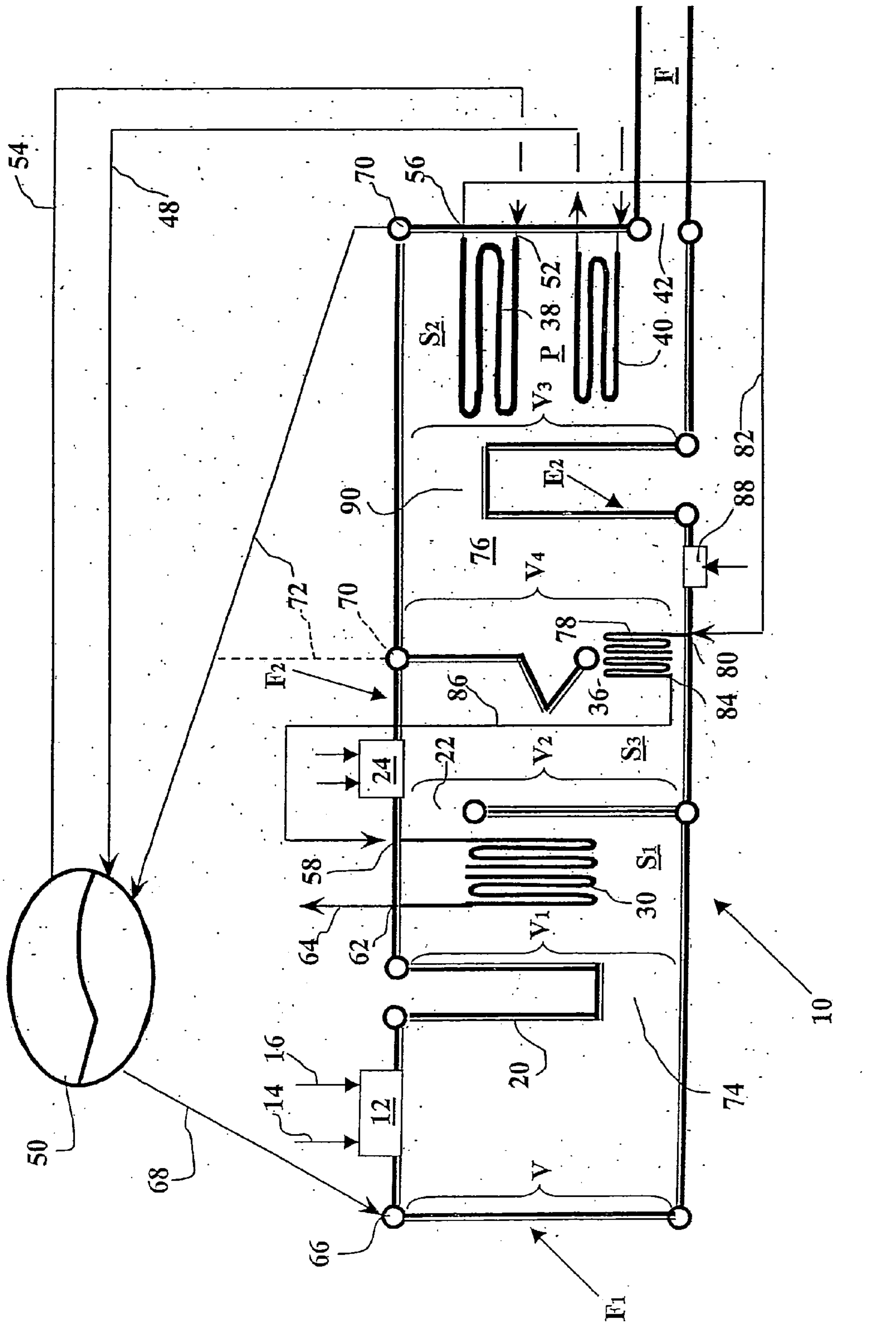
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86
F2
24
22
V2
S3
58
S1
30
64
62
V1
50
20
74
10
16
14
12
68
66
V
F1

FIG.4

STEAM GENERATOR COMPRISING SUCCESSIVE COMBUSTION CHAMBERS

FIELD OF THE INVENTION

[0001] The present invention relates to a thermal generator intended for steam production.

[0002] More particularly, it relates to a steam generator, more commonly referred to as boiler, working from the combustion of a fuel, in particular fuel containing sulfur and nitrogen, in the presence of an oxidizer, more particularly an oxidizer with a high oxygen content, generally above 80%.

[0003] Such a generator can be used notably for driving rotating machines such as steam turbines of thermal power plants, for which it is necessary to produce steam at high temperature, referred to as superheated steam, with a temperature of the order of 560° C. Another possible application of this generator is the production of steam in refineries to meet the requirements of petroleum conversion processes. It is also possible to use such a generator to produce steam for crude oil extraction.

BACKGROUND OF THE INVENTION

[0004] A steam generator working from the combustion of a fuel in the presence of air is already known, notably from document FR-2,528,540. This generator comprises a combustion hearth (or combustion chamber) provided with at least one burner and includes successively, one after the other, a vaporization zone comprising at least one vaporization exchanger referred to as vaporization screen or evaporator, a superheating zone comprising a superheating exchanger or superheater, a preheating zone comprising a preheating exchanger or economizer and a fumes discharge zone and/or a fumes recirculation zone. A means for storing the water in the gas phase and in the liquid phase, referred to as drum, which supplies the evaporator with heated water and the superheater with steam, is also provided.

[0005] This type of generator generally uses two circuits, a first circuit referred to as water circuit, which comprises the exchangers of the vaporization, superheating, preheating zones and the drum, and a second circuit, referred to as fumes circuit, which uses the fumes resulting from the combustion of a fuel with an oxidizer and which is intended for transferring the thermal energy released through combustion to the various exchangers as they flow from the burner to the fumes discharge zones.

[0006] In practice, the fumes resulting from combustion are high-temperature fumes which flow through the exchangers to transfer their heat by convection and/or by radiation to the various exchangers so as to heat the water, then to vaporize it and finally to superheat the steam resulting from vaporization. In addition, these fumes can then be sent to a complex processing plant such as a dust collector, followed by a fumes processing unit, prior to being discharged to the atmosphere through a stack.

[0007] In the water circuit, the water available on the site is pumped to be injected into the economizer where it is preheated. The preheated water is then sent to either the drum (in the case of natural circulation generators) from which the preheated water feeds the evaporator, or directly to this evaporator (for forced circulation generators) by means of which a large part of the preheated water is vaporized. The two-phase liquid water-steam mixture is then sent to the drum where the liquid phase and the vapour phase are separated. The steam from the drum feeds the superheater which allows to produce steam at very high temperature.

[0008] Thus, as it is well known, vaporization of the water occurs for a large part in the evaporator of the combustion hearth, because it is the zone where the highest thermal level of the fumes is reached and where the energy requirements for converting the water to a two-phase fluid in the evaporator are the greatest. A thermal transfer of the energy of the fumes to the superheater then occurs in the superheating zone, a transfer which also requires a high temperature level to obtain superheated steam. Finally, when leaving the superheating zone, the fumes exchange their thermal energies with the economizer which uses the fumes at their lowest temperature levels to preheat the water. All these thermal exchange operations allow to maximize the generator efficiency by using at maximum the heat of the fumes.

[0009] It can also be interesting to operate this type of generator using an oxidizer with a high oxygen content, preferably above 80%, and to profit from such a combustion, notably through the reduction of the nitrogen ballast contained in this oxidizer.

[0010] In fact, when removing at least part of the nitrogen from the oxidizer, the fumes flow rate and the energy discharged by the combustion fumes through the stack are reduced, and the thermal efficiency of such a steam generator can thus be increased. Thus, for the same transferred heat amount, the fuel consumption is decreased. By way of example, the thermal losses at the stack of a generator running with air and discharging fumes at 250° C. are of the order of 10% of the thermal power provided by the fuel whereas, for identical operating conditions, the thermal losses are reduced to 3% when using pure oxygen as the oxidizer, which generates an energy efficiency increase of the order of 7%. Similarly, the fumes flow rate is reduced by a factor four at least. Furthermore, when using combustion with oxygen, emissions are greatly reduced. More particularly, nitrogen oxides emissions (NOx) resulting from both the thermal dissociation of the molecular nitrogen and from the reaction of the nitrogen contained in the fuel are decreased by a factor one to five for the same burner technology.

[0011] Besides, processing of the fumes in order to remove the sulfur oxides can also be simplified considering the increase in the sulfur oxides concentration in the combustion fumes. Significant savings can therefore be obtained as regards the cost of the sulfur oxides processing equipments.

[0012] However, the architecture of the steam generators wherein combustion takes place between air and a fuel cannot apply to the generators for which combustion takes place in the presence of an oxidizer with a high proportion of oxygen, or oxycombustion.

[0013] In fact, **FIG. 1** which is a graph showing, in abscissa, the temperature of the fumes (in ° C.) and, in ordinate, the combustion efficiency (in %), shows the efficiency difference between a combustion with air (curve I) and oxycombustion (curve II).

[0014] The definition of the main characteristics of a generator working with oxycombustion first required calculation of the thermal exchange distribution in the various steam production stages.

[0015] This will be clear with the example of a 100-MW air generator delivering 124 ton/hour of superheated steam at a temperature of 480° C. and a pressure of 80 bars. In this case, for a fumes temperature at the economizer outlet of 250° C., the distribution of the powers obtained from the enthalpy tables is as follows:

Vaporization of the water in the evaporator	43.8%
Steam superheating in the superheater	18.8%
Preheating of the water by the economizer	27.6%
Thermal losses at discharge	9.8%.

[0016] **FIG. 1** gives a 90.2% thermal efficiency for a fumes temperature of 250° C. (point A) at the economizer outlet.

[0017] By keeping this fumes temperature of 250° C. at the economizer outlet, **FIG. 1** shows that the temperature of the fumes at the outlet of an evaporator consuming 43.8% of the power delivered by an oxycombustion generator using an oxidizer whose composition is of the order of 95% oxygen, of the order of 3% nitrogen and of the order of 2% argon, is greatly above 2000° C. (line B).

[0018] Such a temperature is harmful as regards emissions such as nitrogen oxides (NOx). More particularly, it has been shown that there is an exponential dependence between the NOx formation rate and the temperature of the fumes with a very fast increase in the conversion of the molecular nitrogen of the oxidizer to NO from a fumes temperature of the order of 1500° C. Furthermore, the fumes enter the superheater at a temperature above 2000° C. and the tubes generally making up the superheater are thus subjected to very high fumes temperatures. This solution poses a thermal resistance problem for the superheater tubes within which dry steam already circulates.

[0019] In relation to the formation of nitrogen oxides, the experience acquired by the applicant through considerable research work shows that it is preferable not to exceed a fumes temperature of about 1300° C. at the combustion hearth outlet.

[0020] **FIG. 1** shows that the thermal efficiency associated with this temperature is of the order of 80.9% (point C) for a combustion chamber working under oxycombustion, which is markedly higher than the efficiency required by the evaporator, which is 43.8% for a temperature of about 1200° C. (point D).

[0021] It has also been observed that, in the case of conventional boilers working with air, the energy balance showed that about 30% of the thermal energy was absorbed for heating the water, about 40% for its vaporization, about 20% for superheating and about 10% for the thermal losses. In the case of boilers working with oxycombustion, a fumes temperature of the order of 1300° C. at the combustion chamber outlet requires transfer of about 80% of the energy to this combustion chamber, which leaves an insufficient residual thermal energy for the steam superheating and water preheating stage.

[0022] The present invention aims to overcome the aforementioned drawbacks by means of a generator wherein the fumes temperature level allowing to obtain steam superheated to a required temperature is obtained in a simple way using techniques and materials commonly used in boilers.

SUMMARY OF THE INVENTION

[0023] The present invention thus relates to a steam generator comprising at least two successive combustion hearths with at least one burner supplied with fuel and oxidizer, a vaporization zone comprising a vaporization exchanger, a superheating zone comprising an superheating exchanger, a preheating zone comprising a preheating exchanger and a collecting drum, characterized in that each hearth comprises at least one vaporization exchanger.

[0024] Preferably, each hearth can comprise at least one superheating exchanger.

[0025] Each hearth can also comprise at least one preheating exchanger.

[0026] One of the hearths can comprise at least one vaporization exchanger and the other hearth can comprise at least one superheating exchanger.

[0027] One of the hearths can comprise at least one vaporization exchanger whereas the other hearth can comprise at least one superheating exchanger and at least one preheating exchanger.

[0028] Alternatively, one of the hearths can comprise at least one vaporization exchanger and at least one superheating exchanger, and the other hearth can comprise at least one superheating exchanger and at least one preheating exchanger.

[0029] The steam generator can comprise a depollution chamber for the fumes from the combustion hearths.

[0030] The fumes depollution chamber can be arranged upstream from the preheating zone.

[0031] The fumes depollution chamber can include absorbent injection means.

[0032] The fumes depollution chamber can comprise reducing agent injection means.

[0033] The fumes depollution chamber can comprise at least one vaporization zone.

[0034] The absorbent injected into the fumes depollution chamber can be of calcic or magnesian type.

[0035] The reducing agent injected into the fumes depollution chamber can be of urea or ammonia type.

[0036] The oxidizer is a high oxygen content oxidizer whereas the fuel is a solid, liquid or gaseous fuel, such as heavy fuel oil, a petroleum residue, a gas, oil coke or coal.

[0037] The walls of at least one hearth can consist of a shell or of membrane walls.

BRIEF DESCRIPTION OF THE FIGURES

[0038] Other features and advantages of the invention will be clear from reading the description hereafter, given by way of non limitative example, with reference to the accompanying figures wherein:

[0039] **FIG. 2** shows a generator according to an embodiment of the invention,

[0040] **FIG. 3** shows a first variant of the invention, and

[0041] **FIG. 4** shows another variant of the invention.

DETAILED DESCRIPTION

[0042] In connection with **FIG. 2**, steam generator **10**, more commonly referred to as boiler, comprises two successive combustion hearths F**1** and F**2** wherein a fuel burns in the presence of an oxidizer. The fuel is a solid, liquid or gaseous fuel containing notably sulfur and nitrogen, such as heavy fuel oil, a petroleum residue, a gas, oil coke or coal, whereas the oxidizer is preferably a gas with a very high oxygen content, preferably above 80%, or pure oxygen.

[0043] At least one burner **12** supplied with fuel through a line **14** and with oxidizer through a line **16** is arranged, preferably vertically, in the upper part of primary combustion hearth F**1** as shown in the figure. The layout and the amount of burners will be determined by the man skilled in the art so as to obtain a combustion with low emissions while preventing contact of the burner flame with walls **18** of this hearth. This combustion can also be performed by any other means such as grates, fluidized beds. Depending on the fuel injected, an auxiliary fluid will be judiciously used to optimize combustion, such as steam or a gas or a gas mixture, such as CO_2 or O_2 notably, in order to provide recycling of the fumes that could be used for vaporization of the fuel.

[0044] This primary combustion hearth F**1** comprises a vaporization zone V including at least one vaporization exchanger or vaporizing screen **20**, referred to as evaporator in the description hereafter, which consists, in the example described, of the walls of primary hearth F**1** which are preferably of "membrane wall" type. As it is well known, these membrane walls consist of tubes connected to one another by welded fins so as to form a heat exchanger. The evaporator thus obtained is a high-temperature evaporator which provides at least partial evaporation of the fluid circulating within the tubes.

[0045] Outlet **22** of this vaporization zone V and consequently of primary hearth F**1**, which is arranged in the lower part of this hearth, opens into secondary combustion hearth F**2**, preferably vertical, containing, in the lower part thereof and in connection with outlet **22**, a burner **24** supplied with fuel through a line **26** and with oxidizer through a line **28**, as defined above. Also, the layout and the number of burners will be determined by the man skilled in the art so as to obtain a combustion with low emissions while preventing contact of the burner flame with the walls of secondary hearth F**2**.

[0046] This secondary combustion hearth comprises a high-temperature superheating zone S**1** including at least one superheating exchanger or superheater **30**, referred to as high-temperature superheater, for raising the temperature of the fluid, generally in the vapour phase, flowing therethrough. The walls of this hearth therefore consist of a preferably metallic shell **32** protected from the thermal radiation by an insulating material such as concrete, bricks or a fibrous material. Tube bundles **34** through which steam circulates are installed along this insulating material. This superheater is a high-temperature exchanger providing superheating of the fluid in the vapour phase that flows therethrough.

[0047] Outlet **36** of the high-temperature superheating zone communicates, in the upper part, with a housing E including an additional superheating zone S**2** referred to as low-temperature superheating zone, and preferably a preheating zone P. Low-temperature superheating zone S**2** comprises at least one convective type exchanger **38**, referred to as low-temperature superheater. Preheating zone P also comprises at least one convective type exchanger **40**, referred to as economizer. These convective exchangers **38** and **40** consist, as it is known in the art, of tube bundles connected to collectors. Thus, the steam generator comprises two successive combustion hearths, primary combustion hearth F**1** and, in series with this primary combustion hearth, secondary combustion hearth F**2**. Primary hearth F**1** comprises burner **12** and evaporator **20**, whereas hearth F**2** comprises burner **24**, high-temperature superheater **30** and is followed by housing E consisting of low-temperature superheater **38** and economizer **40**.

[0048] In the lower part of this housing E, outlet **42** of the preheating zone opens into a fumes discharge zone F which communicates with any known fumes processing means or with a stack (not shown).

[0049] Economizer **40** comprises a water inlet **44** and a preheated water outlet **46** ending through a line **48** into a fluid collecting means **50** such as a drum commonly used in this type of generator. Low-temperature superheater **38** comprises an inlet **52** for the steam coming from drum **50** through a line **54** and an outlet **56** for sending the steam to high-temperature superheater **30**. High-temperature superheater **30** comprises an inlet **58** for the steam coming from low-temperature superheater **38** carried by a line **60** and an outlet **62** for a preferably superheated steam that is sent, through a line **64**, to any means using such a superheated steam, such as a thermal power plant turbine. Advantageously, the economizer and the low-temperature superheater can be provided with thermal transfer increasing devices such as fins if the fumes flowing therethrough are not too much dust-laden. Evaporator **20** comprises an inlet **66** supplied with preheated water through a line **68** connecting drum **50** to this inlet and an outlet **70** for sending a water emulsion in two-phase form (liquid water-steam) to drum **50** by means of a line **72**.

[0050] Thus, during operation of this generator, the water is fed into economizer **40** through inlet **44**, it circulates in this economizer while being preheated, then it is collected in drum **50** by means of line **48** connecting this drum to economizer outlet **46**. This hot water is then sent from drum **50** to inlet **66** of evaporator **20** through line **68** in order to be at least partly converted to a two-phase water emulsion at outlet 70. The emulsion leaving the evaporator is sent through line **72** to drum **50** where it is subjected to a separation of the gas phase and of the liquid phase. The steam contained in this drum is then sent through line **54** to inlet **52** of low-temperature superheater **38** where an increase in temperature of this steam takes place so as to obtain at outlet **56** dry steam at a first temperature level. What is understood to be dry steam is steam at a higher temperature than the saturation temperature of the water at the pressure considered. Inlet **58** of high-temperature superheater **30** receives the steam from low-temperature superheater **38** by means of line **60** and this steam flows out through outlet **62** in form of superheated steam, i.e. at a higher temperature than that of the steam from low-temperature superheater **38**.

[0051] In order to obtain these different temperature rises and/or phase change of the fluid circulating in the various exchangers, it is necessary to judiciously use the thermal energy produced by the combustion. A proportion of the total amount of gaseous, liquid or solid fuel, typically ranging between 20% and 80% of this total amount, and a proportion of the total amount of the high oxygen content oxidizer, typically ranging between 20% and 80%, are therefore injected through lines **14** and **16** into burner **12** of primary combustion hearth F**1**. This power distribution over at least two hearths allows to provide operation under reduced running conditions and to obtain a higher generator flexibility. The fumes generated by the combustion flow through vaporization zone V and exchange part of their thermal energy with the preheated water circulating in the tubes of evaporator **20** so as to obtain, at outlet **70** of this evaporator, a fluid in two-phase liquid water-steam form.

[0052] At outlet **22** of primary hearth F**1**, the fumes are sent to secondary combustion hearth F**2** where combustion of the remaining fraction of the total amount of fuel and of oxidizer occurs by means of burner **24** supplied with fuel and oxidizer through lines **26** and **28**. The temperature of the fumes is then increased and these fumes flow through high-temperature superheating zone SI which comprises high-temperature superheater **30**. The temperature of the steam circulating in the tubes of this superheater is then increased and this superheated steam is then discharged through line **64** to be used by known means such as a turbine or any process. The fumes leaving high-temperature superheating zone S**1** through outlet **36** are sent to low-temperature superheating zone S**2** comprising low-temperature superheater **38** wherein the steam undergoing a temperature rise circulates. Alternatively, as described more in detail in connection with **FIG. 3**, the fumes are sent to a fumes processing zone with absorbent injection prior to passage into low-temperature superheater **38**. These fumes then flow through preheating zone P wherein the water circulating in economizer **40** undergoes a temperature rise by thermal exchange with the fumes while cooling these fumes to a suitable temperature, generally of the order of 250° C.

[0053] These fumes are then discharged through outlet **42** to zone F and sent to any suitable processing means or to a stack as it is known in the art.

[0054] By way of example, burner **12** generates fumes whose temperature at outlet **22** of hearth F**1** is of the order of 1300° C. These fumes then enter secondary combustion hearth F**2**. By means of burner **24**, they undergo a temperature rise and reach a temperature of the order of 1000° C., after exchange in hearth F**2**, at outlet **36** of zone S**1**. These fumes thus heated enter secondary superheating zone S**2** by exchanging their thermal energies with low-temperature superheater **38** which they leave at a temperature of about 600° C., then they flush through economizer **40** present in preheating zone P and are discharged through outlet **42** to zone F at a temperature of approximately 250° C.

[0055] In parallel, the water is introduced in economizer **40** at a temperature of about 150° C. and it flows out at about 290° C. This preheated water is then partly vaporized in evaporator **20**, after passage through drum **50**, and it flows out at a temperature of about 305° C. prior to being sent to drum **50**. The steam leaving this drum at the same temperature is injected into low-temperature superheater **38** by means of which its temperature increases up to about 375° C. at outlet **56**, from which it is sent to high-temperature superheater **30** which it leaves at approximately 480° C.

[0056] Without departing from the scope of the invention, a multiplicity of combustion hearths can be installed one after the other and arranged in series in relation to one another. Furthermore, it is possible for at least one vaporization and/or superheating and/or preheating zone comprising at least one exchanger, such as an evaporator and/or a superheater and/or an economizer, connected in series to the exchangers arranged after the other combustion hearths, to be arranged in each combustion hearth.

[0057] In the example of **FIG. 3** showing a variant of **FIG. 2**, and which therefore comprises the same reference numbers, a "membrane wall" type secondary combustion hearth F**2** is used and the high-temperature superheating zone is arranged in primary combustion hearth F**1**.

[0058] Advantageously, in this variant, the entire generator comprises "membrane wall" type walls so as to profit from the thermal energy contained in the fumes circulating from primary hearth F**1** to outlet **42**.

[0059] This generator comprises a primary combustion hearth F**1** and a secondary combustion hearth F**2** comprising a low-temperature superheating zone S**2**. This zone opens onto a preheating zone P ended by a fumes discharge zone F. Primary hearth F**1** of "membrane wall" type, as described above, comprises a burner **12**, a vaporization zone V with an evaporator **20** and a fumes outlet **74** which opens onto a high-temperature superheating zone S**1** contained in a housing E**1**. This substantially vertical and elongate housing is also of "membrane wall" type and it contains a high-temperature superheater **30** of conductive type, with a steam inlet **58** and a superheated steam outlet **62**. Outlet **22** of this superheating zone opens into secondary combustion hearth F**2** which comprises a burner **24**, as described in connection with **FIG. 2**, and which also consists of membrane walls. Fumes outlet **36** opens, as described above, onto a low-temperature superheating zone S**2** with a low-temperature superheater **38** comprising a steam inlet **52** and a steam outlet **56**, said zone communicating with a preheating zone P including an economizer **40** provided with a water inlet **44** and a preheated water outlet **46**, this preheating zone communicating with a fumes discharge zone F through an outlet **42**.

[0060] Preferably, low-temperature superheating zone S**2** and preheating zone P comprise "membrane wall" type walls. In this configuration, intake of the preheated water in the evaporator and outflow of the two-phase fluid (liquid water-steam) can occur at different levels. Notably, there can be several preheated water inlets in the membrane walls and several two-phase fluid outlets opening into the drum.

[0061] By way of example, as shown in **FIG. 3**, evaporator **20** comprises a preheated water inlet **66** at primary hearth F**1** and a two-phase fluid (liquid water-steam) outlet **70** located at outlet **42** of the preheating zone, and connected by a line **72** to drum **50**. Combustion hearths F**1** and F**2**, high-temperature superheating zone S**1**, low-temperature superheating zone S**2** and preheating zone P therefore each comprise part of evaporator **20** distributed in the evaporation zones bearing reference numbers V, V**1**, V**2** and V**3** in the figure. If only hearths F**1** and F**2** have membrane walls, two-phase fluid outlet **70** will be located at the outlet of secondary hearth F**2**, this outlet being connected by line **72** to drum **50** as shown in dotted line in the figure, and only evaporation zones V, V**1** and V**2** will remain.

[**0062**] In the variant where all of the walls are of "membrane wall" type, primary hearth comprises burner **12**, evaporation zone V with evaporator **20**, high-temperature superheating zone S**1** with high-temperature superheater **30** and vaporization zone V**1** comprising the tubes of the membrane wall of housing E**1**, whereas secondary hearth F**2** comprises burner **24**, low-temperature superheating zone S**2** with low-temperature superheater **38**, preheating zone P with economizer **40** and vaporization zones V**2** and V**3** comprising the tubes of the membrane walls.

[**0063**] Thus, as described above in connection with **FIG. 2**, burner **12** of primary hearth F**1** is fed by a proportion of the total amount of gaseous, liquid or solid fuel, and a proportion of the total amount of high oxygen amount oxidizer. The fumes of hearth F**1** flow through vaporization zone V and exchange their thermal energies with the preheated water circulating in the tubes of evaporator **20** so as to obtain at the outlet of this exchanger a fluid in a first two-phase liquid-water-steam form. At outlet **74** of evaporation zone V, the fumes flow through high-temperature superheating zone S**1** where they transmit their heat energies, on the one hand, to high-temperature superheater **30** so as to obtain, at the outlet of this superheater, steam at a first temperature level and, on the other hand, to the fluid circulating in the tubes of vaporization zone V**1**.

[**0064**] The fumes leaving superheating zone S**1** are sent through outlet **22** to secondary combustion hearth F**2** where combustion of the remaining fraction of the total amount of fuel and of oxidizer is performed by means of burner **24**. The temperature of these fumes is then increased and they are discharged through outlet **36** to secondary superheating zone S**2** while exchanging their thermal energies with low-temperature superheater **38**. As they flow through the secondary hearth and the high-temperature superheating zone, the fumes also transmit part of their energies to the tubes of vaporization zone V**2**. The fumes leaving low-temperature superheating zone S**2** flow through preheating zone P in which the water circulating in economizer **40** undergoes a temperature increase through the thermal exchanges with the fumes while cooling the fumes to a suitable temperature. Similarly, the fumes transmit their thermal energies to the tubes of the membrane walls forming evaporation zone V**3**. These fumes are then discharged through outlet **42** into zone F and they are sent to any suitable processing means or to a stack as it is known in the art.

[**0065**] During operation, the water flowing into economizer **40** through inlet **44** is sent, after being heated by passing through this economizer, to drum **50** through line **48**. The hot water is then sent through line **68** from this drum to inlet **66** of evaporator **20**. The two-phase liquid water-steam fluid flowing from outlet **70**, which has absorbed the calories of the fumes throughout their flow through the generator, from burner **12** to outlet **42**, is sent through line **72** to drum **50**. In this drum, the two-phase fluid is subjected to a separation between the vapour phase and the liquid phase, and the steam is sent through line **54** to inlet **52** of low-temperature superheater **38** where the temperature of this steam is raised to a first level. At outlet **56** of this superheater, the steam is sent through a line **60** to inlet **58** of high-temperature superheater **30** where the temperature of the steam is raised again to a higher level than the level of low-temperature superheater **38** prior to being discharged through outlet **62** to any device as described above.

[**0066**] Of course, during all these operations, burners **12** and **24** are fed as described in connection with **FIG. 2**.

[**0067**] Still by way of example, the temperatures of the fumes are about 1300° C. at the outlet of evaporation zone V, about 500° C. at the outlet of high-temperature superheating zone S**1**, about 1300° C. at the inlet of low-temperature superheating zone S**2**, about 350° C. at the outlet of this zone and about 200° C. at outlet **42** to fumes discharge zone F. The temperatures of the fluids in the various exchangers are of the order of 150° C. at inlet **44** of economizer **40**, of the order of 165° C. at outlet **46** of this economizer, of the order of 304° C. at outlet **70** of the evaporator and at inlet **52** of low-temperature superheater **38**, of the order of 360° C. at outlet **56** of this superheater and at inlet **58** of high-temperature superheater **30**, and of the order of 480° C. at outlet **62** of this high-temperature superheater.

[**0068**] **FIG. 4** shows a variant of the embodiment of the invention according to **FIG. 3**, which therefore comprises the same reference numbers.

[**0069**] This variant essentially differs from **FIG. 3** in the presence of a housing E**2** containing a fumes depollution chamber **76** and a medium-temperature superheating zone S**3**.

[**0070**] In fact, the applicant has observed that combustion in generators generally produces fumes containing atmospheric pollutants such as sulfur oxides (SOx) and nitrogen oxides (NOx) which have a negative impact on the environment.

[**0071**] Many processes for treating these pollutants are known, but most of them operate at low temperatures, generally on the fumes leaving the preheating zone. However, for simplification of the nitrogen oxides processing or to prevent the condensation of sulfuric acid from the sulfur oxides, these pollutants are preferably treated at high temperatures of the order of 1000° C.

[**0072**] Thus, in the case of the variant of **FIG. 4**, fumes depollution chamber **76**, like a desulfurization chamber, is arranged after outlet **36** of the fumes generated by burner **24** so as to profit from the temperature of the fumes which is at a high level considering the action of this secondary hearth.

[**0073**] As already described in connection with **FIG. 3**, primary hearth F**1** of "membrane wall" type comprises a burner **12**, a vaporization zone V with an evaporator **20**, a high-temperature superheating zone S**1** with a high-temperature superheater **30** and a fumes outlet **22**. Outlet **22** of this superheating zone opens into secondary combustion hearth F**2**. Outlet **36** of the fumes generated by burner **24** of hearth F**2** opens onto a medium-temperature superheating zone S**3** with a medium-temperature superheater **78** comprising an inlet **80** connected by a line **82** to outlet **56** of low-temperature superheater **38** and a steam outlet **84** connected by a line **86** to inlet **58** of high-temperature superheater **30**.

[**0074**] The outlet of this zone communicates with depollution chamber **76** which, in the example shown, is a desulfurization chamber.

[**0075**] This chamber is equipped with at least one absorbent injector **88** allowing fast and homogeneous dispersion of a jet of absorbents in the fumes flowing through this chamber. The injected absorbent can be of calcic or magnesian type, or of any other type allowing reaction with the sulfur oxides contained in the fumes to limit their formation. The grain size and the amounts of injected absorbent will be determined by the man skilled in the art so as to obtain desulfurization rates in accordance with current regulations.

[**0076**] Advantageously, one will profit from this depollution chamber to also provide denitrification of the fumes flowing therethrough by injecting a reducing agent such as urea or ammonia. This reducing agent will be homogeneously dispersed in the depollution chamber by a means similar to absorbent injector **88**.

[**0077**] The number and the layout of the absorbent injectors and/or of reducing agent will be determined by the man skilled in the art so as to provide good distribution of the absorbent and/or of the reducing agent in the depollution chamber.

[**0078**] The walls of this depollution chamber advantageously consist of "membrane wall" type walls and they also take part in the evaporation of the water circulating in the evaporator by forming an evaporation zone V**4**.

[**0079**] Outlet **90** of the depollution chamber communicates, as already described in connection with **FIG. 3**, with a low-temperature superheating zone S**2** and a preheating zone P which opens through outlet **42** onto fumes processing zone F.

[**0080**] During operation, the fumes generated by primary hearth F**1** successively flow through primary vaporization zone V, then high-temperature superheating zone S**1**. At the outlet of this superheating zone, the temperature of the fumes is then raised by means of burner **24**. These fumes then flow through medium-temperature superheating zone S**3** and reach depollution chamber **76** where they are desulfurized and/or denitrified through injection of absorbents and/or of reducing agents. The fumes thus treated reach outlet **90** from which they enter low-temperature superheating zone S**2** and preheating zone P prior to reaching fumes discharge zone F.

[**0081**] In parallel, the water admitted in economizer **40** is heated by passage through this economizer, then it is sent to drum **50**. The hot water present in the drum is sent to evaporator **20**, then the two-phase liquid water-steam fluid from this evaporator is sent to drum **50** through line **72**. The steam present in the drum is sent to low-temperature superheater **38** from where it is sent through line **82** to medium-temperature superheater **78**. The steam coming from this medium-temperature superheater is then sent through line **86** to high-temperature superheater which it leaves through outlet **62** and line **64**.

[**0082**] The fumes flowing through depollution chamber **76** are at a temperature preferably ranging between 600° C. and 1100° C. so as to obtain a required desulfurization rate in accordance with the residence time of the fumes in the depollution chamber. It can be observed that this temperature range also allows denitrification of the fumes if this chamber is equipped with reducing agent injectors as described above.

[**0083**] Furthermore, as already described in connection with **FIG. 3**, the fumes transmit their thermal energies to the tubes of the various vaporization zones V, V**1**, V**2**, V**3** and V**4**.

[**0084**] In an example illustrating this variant, we consider a 100-MW generator working under oxycombustion and delivering 124 tons/hour of steam superheated to a temperature of the order of 480° C. The fuel used consists, in percent by mass, of about 84% carbon, about 9% hydrogen, about 6% sulfur and about 1% nitrogen. The composition by volume of the oxidizer is of the order of 95% oxygen, of the order of 3% nitrogen and of the order of 2% argon. The fuel and oxidizer flow rates are respectively about 1.29 kg/s and 4.24 kg/s for primary combustion hearth F**1**, whereas they are about 1.39 kg/s and 4.56 kg/s for secondary combustion hearth F**2**.

[**0085**] From such conditions, the temperature of the water at the inlet of economizer **40** being 150° C., the temperature of the heated water at the outlet of the economizer is about 180° C., whereas the temperature of the fumes upstream from preheating zone P is about 450° C. and about 250° C. downstream from this zone. The temperature of the two-phase liquid water-steam fluid after passage through evaporator **20** is about 305° C. at outlet **70** of the evaporator. The temperature of the steam at the inlet of low-temperature superheater **38** is of the order of 305° C. and of the order of 330° C. at its outlet, whereas the temperature of the fumes is of the order of 750° C. upstream from low-temperature superheating zone S**2** and of the order of 450° C. downstream from this zone. The temperature of the steam at inlet **80** of medium-temperature superheater **78** is of the order of 330° C. and of the order of 420° C. at its outlet **84**, whereas the temperature of the fumes is of the order of 1300° C. upstream from medium-temperature superheating zone S**3** and of the order of 1000° C. downstream from this zone and at the inlet of depollution chamber **76**. The temperature of the steam at the inlet of high-temperature superheater **30** is of the order of 420° C. and of the order of 480° C. at its outlet **62**, whereas the temperature of the fumes is of the order of 1300° C. upstream from high-temperature superheating zone S**1** and of the order of 500° C. downstream from this superheating zone.

[**0086**] The present invention is not limited to the embodiment examples described above and it includes all variants.

[**0087**] Advantageously, one may consider operating primary combustion hearth F**1** below stoichiometric conditions with an excess amount of fuel in relation to the oxidizer, so as to limit nitrogen oxides emissions.

[**0088**] Under such conditions, in order to obtain a good combustion efficiency, secondary combustion hearth F**2** can work above stoichiometric conditions with an excess amount of oxidizer in relation to the fuel.

[**0089**] Furthermore, considering the thermal energy available in the combustion hearths, it may be advantageous to do without the economizer and to perform preheating of the water by the evaporator which will receive the water at the temperature of the site. This water will be preheated during circulation at the start of the evaporator, then evaporated in the rest of the evaporator.

1) A steam generator comprising at least two successive combustion hearths with at least one burner supplied with fuel and oxidizer, a vaporization zone comprising a vaporization exchanger, a superheating zone comprising an superheating exchanger, a preheating zone comprising a preheating exchanger and a collecting drum, characterized in that each hearth comprises at least one vaporization exchanger.

2) A steam generator as claimed in claim 1, characterized in that each hearth comprises at least one superheating exchanger.

3) A steam generator as claimed in claim 1, characterized in that each hearth comprises at least one preheating exchanger.

4) A steam generator as claimed in claim 1, characterized in that one of the hearths comprises at least one vaporization exchanger and in that the other hearth comprises at least one superheating exchanger.

5) A steam generator as claimed in claim 1, characterized in that one of the hearths comprises at least one vaporization exchanger and in that the other hearth also comprises at least one superheating exchanger and at least one preheating exchanger.

6) A steam generator as claimed in claim 1, characterized in that one of the hearths comprises at least one vaporization exchanger and at least one superheating exchanger and in that the other hearth also comprises at least one superheating exchanger and at least one preheating exchanger.

7) A steam generator as claimed in claim 1, characterized in that it comprises a fumes depollution chamber intended for the fumes coming from combustion hearths.

8) A steam generator as claimed in claim 7, characterized in that the fumes depollution chamber is arranged upstream from the preheating zone.

9) A steam generator as claimed in claim 7, characterized in that the fumes depollution chamber comprises absorbent injection means.

10) A steam generator as claimed in claim 7, characterized in that the fumes depollution chamber comprises reducing agent injection means.

11) A steam generator as claimed in claim 7, characterized in that the fumes depollution chamber comprises at least one vaporization zone.

12) A steam generator as claimed in claim 9, characterized in that the absorbent is of calcic or magnesian type.

13) A steam generator as claimed in claim 10, characterized in that the reducing agent is of urea or ammonia type.

14) A steam generator as claimed in claim 1, characterized in that the oxidizer is a high oxygen content oxidizer.

15) A steam generator as claimed in claim 1, characterized in that the fuel is a solid, liquid or gaseous fuel, such as heavy fuel oil, a petroleum residue, a gas, oil coke or coal.

16) A steam generator as claimed in claim 1, characterized in that the walls of at least one hearth consist of a shell.

17) A steam generator as claimed in claim 1, characterized in that the walls of at least one hearth consist of membrane walls.

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