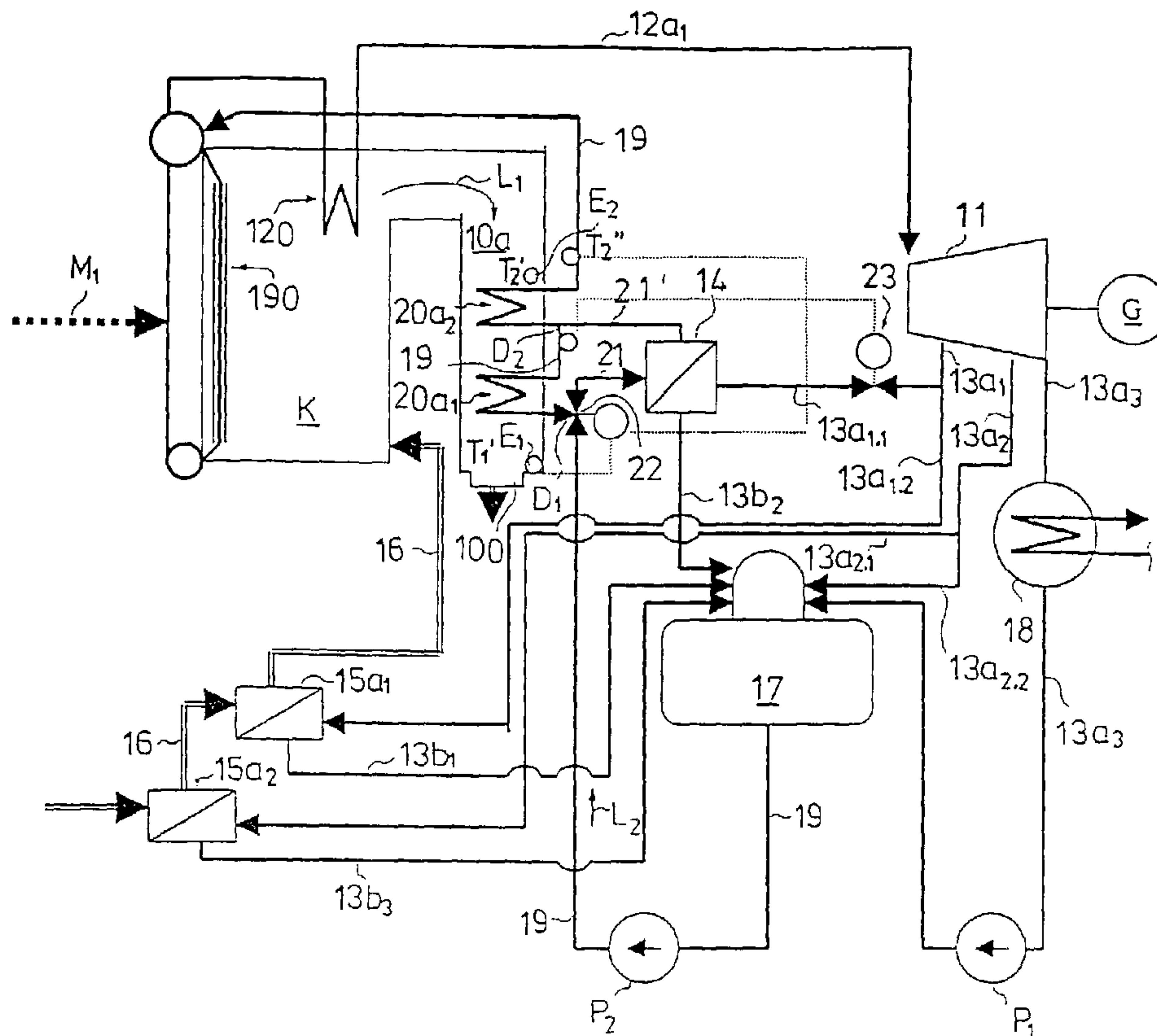




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(54) Titre : ENSEMBLE INTEGRE CHAUDIERE ET TURBINE A VAPEUR ET PROCEDE DE PRECHAUFFAGE D'UNE EAU D'ALIMENTATION POUR UNE TURBINE A VAPEUR, ET FONCTIONNEMENT CORRESPONDANT
 (54) Title: INTEGRATION CONSTRUCTION BETWEEN A BOILER AND A STEAM TURBINE AND METHOD IN PREHEATING OF THE SUPPLY WATER FOR A STEAM TURBINE AND IN ITS CONTROL



(57) Abrégé/Abstract:

The present invention concerns an integration construction between a steam boiler provided with a combustion chamber and a steam turbine. The steam is conducted from the steam boiler (10) along a connector to the steam turbine (11) for rotating an

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electric generator (G) producing electricity. The supply water circulated via the steam boiler (10) is vaporized in vaporizer (190) located in the steam boiler (10) and superheated in a superheater (120). The supply water is conducted into the boiler through an economizer (20) acting as a heat exchanger, in which heat is transferred from the flue gases of the boiler into the supply water. The economizer (20) is provided with at least two sections, comprising at least one first economizer section (20a₁) and at least one second economizer section (20a₂). The supply water preheated with bled steams of the steam turbine is conducted in the steam boiler (10) further from the economizer (20) to the vaporizer and the superheater and therethrough, in the form of steam, to the steam turbine. A connector (19) leading to the economizer sections (20a₁, 20a₂) comprises a branch point (D₁) to a by-pass connector (21) of supply water, whereby the economizer section (20a₁) can be bypassed by at least part of the supply water flow. The invention also concerns a method in preheating of the supply water for the steam turbine and in its control.

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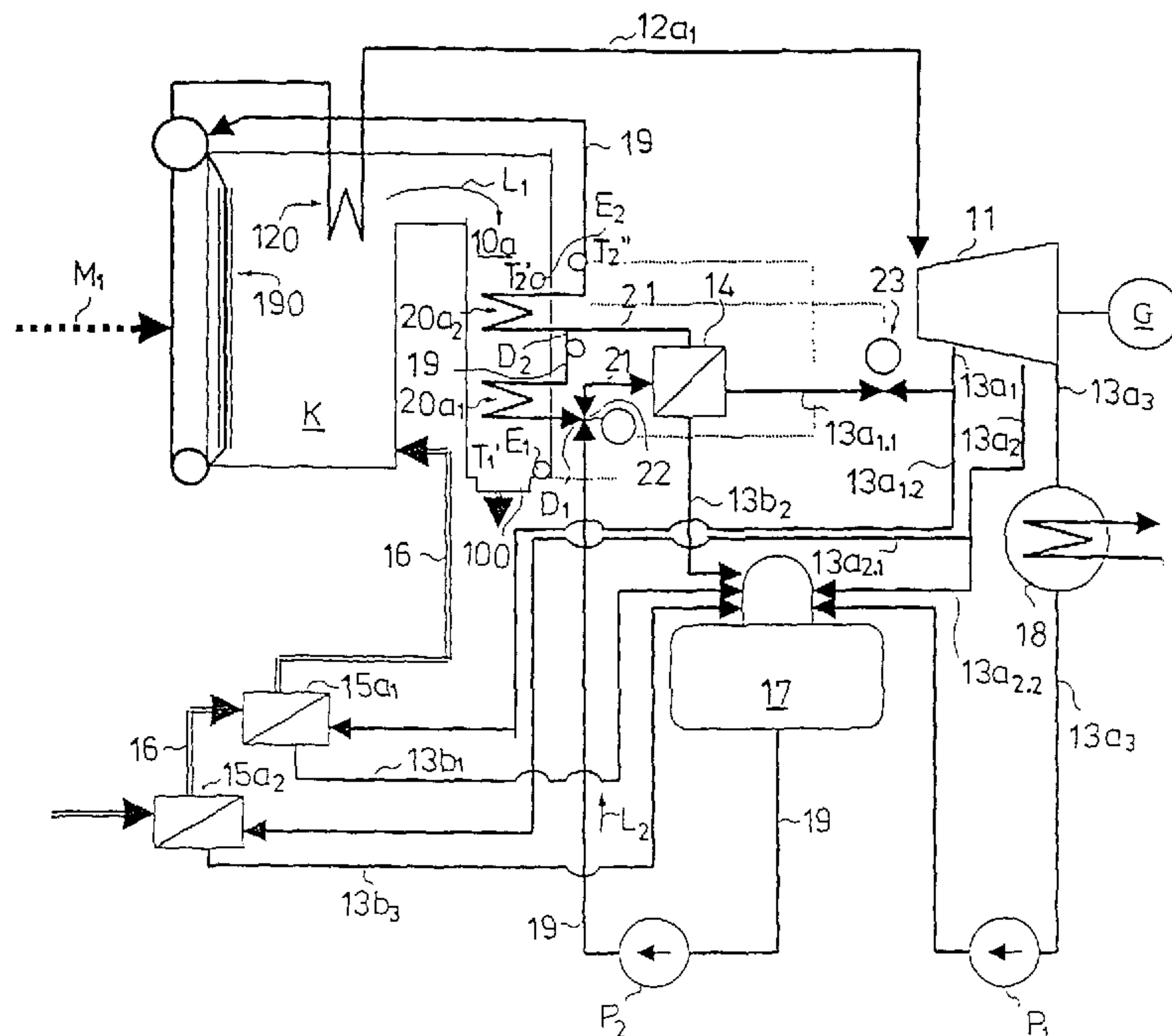
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(54) Title: INTEGRATION CONSTRUCTION BETWEEN A BOILER AND A STEAM TURBINE AND METHOD IN PRE-HEATING OF THE SUPPLY WATER FOR A STEAM TURBINE AND IN ITS CONTROL



(57) Abstract: The present invention concerns an integration construction between a steam boiler provided with a combustion chamber and a steam turbine. The steam is conducted from the steam boiler (10) along a connector to the steam turbine (11) for rotating an electric generator (G) producing electricity. The supply water circulated via the steam boiler (10) is vaporized in vaporizer (190) located in the steam boiler (10) and superheated in a superheater (120). The supply water is conducted into the boiler through an economizer (20) acting as a heat exchanger, in which heat is transferred from the flue gases of the boiler into the supply water. The economizer (20) is provided with at least two sections, comprising at least one first economizer section (20a₁) and at least one second economizer section (20a₂). The supply water

preheated with bled steams of the steam turbine is conducted in the steam boiler (10) further from the economizer (20) to the vaporizer and the superheater and therethrough, in the form of steam, to the steam turbine. A connector (19) leading to the economizer sections (20a₁, 20a₂) comprises a branch point (D₁) to a by-pass connector (21) of supply water, whereby the economizer section (20a₁) can be bypassed by at least part of the supply water flow. The invention also concerns a method in preheating of the supply water for the steam turbine and in its control.

Integration construction between a boiler and a steam turbine and method in preheating of the supply water for a steam turbine and in its control

5

The present invention relates to an integration construction between a boiler and a steam turbine and a method in preheating the supply water for a steam turbine and in its control.

10 The last heat face of a steam boiler before the smoke stack is either a flue-gas/air heat exchanger or an economizer. In the present application, a flue-gas/air heat exchanger is understood as a heat exchanger between flue gas and combustion air, in which the heat is transferred from flue gas to combustion air to preheat the combustion air. In the present application, an economizer is understood as a heat
15 exchanger in which thermal energy is transferred from the flue gases to the supply water.

When a flue-gas/air heat exchanger is used, the supply water for the boiler can be preheated by means of bled steam from the steam turbine, whereby the efficiency
20 of the steam turbine process is improved. A flue-gas/air heat exchanger, i.e. a heat exchanger, in which thermal energy is transferred from the flue gases directly into the combustion air, is usually not used in small steam power plants because of its high cost.

25 When a flue-gas/air heat exchanger is not used, the flue gases of the steam boiler are cooled before passing into the smoke stack using an economizer. In such case, the supply water cannot be preheated with the aid of the bled steam of the steam boiler because the preheating would raise the ultimate temperature of the flue gases and thereby lower the efficiency of the boiler.

30

In the economizer of a steam boiler, heat is transferred from the flue gases into the

supply water. For a steam boiler, a steam boiler provided with a combustion chamber is used. A change in the temperature of the supply water in the economizer is lower than a change in the temperature of the flue-gas side. The temperature rise in the supply water is usually 40 to 50 per cent of the respective lowering of temperature on the flue-gas side. Therefore, a difference in the temperature at the hot end of the economizer is considerably higher than at the cold end. This observation results in that, in addition to the heat obtained from the flue gases, heat from other sources can be transferred into the supply water. In a steam turbine process, it is advantageous to utilize bled steam for preheating the supply water.

The economizer of the steam boiler in a steam power plant is divided into two or more parts, the supply water being preheated in the preheaters of the high-pressure side provided between said economizer parts by the bled steam from the steam turbine.

With the aid of a connection, the integration of the steam boiler and the steam turbine process is made more efficient. By means of such arrangement, the flue gases of the steam boiler can be cooled efficiently simultaneously with enhanced efficiency of the steam turbine process.

The investment cost is lower than in an alternative provided with a flue-gas/air heat exchanger:

- improved controllability and boiler efficiency
- smaller boiler building
- lower cost of the boiler.

When a flue-gas/air heat-exchanger solution is unprofitable, an improved process can be implemented with the structure since the use of bled steam can be increased.

The arrangement is preferred especially in an instance in which the combustion air of the steam boiler is heated in one or more steam/air heat exchanger(s) connected in series and utilizing bled steam.

5 In a prior FI patent No. 101 163 of the applicant, the advantageous integration construction between the steam boiler and the steam turbine is known. It has proved to be useful that the temperature of the supply water flown through economizers positioned in the flue-gas duct. An amendment to the integration construction disclosed in the FI patent No. 101 163 is described in the present
10 application.

It is disclosed in the present application that by controlling the by-pass flow of the first economizer of the preheater in a divided economizer and possibly by controlling the amount of bled steam of the preheater of supply water also in a by-
15 pass connector, the integration degree of the steam turbine process can be controlled. The preheating is limited by the boiling temperature of the hottest economizer, and the lower limit is the closing of the bled. The control method exerts an efficient impact on the electricity production while deteriorating slightly the efficiency of the boiler when the use of bled steam exceeds the scheduled
20 value. A change in the degree of integration is of the order 10%. A change in the efficiency of the boiler is 2 to 3% at most.

By controlling the flow portion of the supply water flowing past the economizer it is possible

- 25 (a) to control the ultimate temperature of the flue gas of the boiler as the power of the boiler changes and as the quality of the fuel varies
- (b) to control the ultimate temperature of the supply water so that the ultimate temperature of the supply water after the economizer is as desired (being e.g. 10 to 20 °C below the boiling temperature).

30

Particularly when a soda recovery boiler is in question, the flue gases are highly

soiling and corroding, and therefore, the soda recovery boilers cannot be provided with a flue-gas/air heat exchanger. The flue gases of the boiler are cooled by supplying supply water at about 120°C into the boiler. The preheating of the combustion air is important because of the combustion of black lye and therefore, the combustion air is heated with the aid of plant steam, typically to about 150°C.

The above integration is not optimal considering the steam turbine process and therefore, the electricity power obtained from a back-pressure turbine will be low. As regards the boiler, an optimal situation prevails when the temperature of the flue gases exiting the boiler is as low as possible and no excessive soiling and corrosion of the heat faces is taking place yet. When the supply water into the boiler is in constant temperature, the temperature of the flue gases varies in accordance with the power level, the quality of fuel and the soiling situation of the heat faces. An optimal temperature is reached only occasionally on partial powers.

As described above, the optimal manner of driving the boiler is reached by integrating a soda recovery boiler and the steam turbine process as follows. The combustion air is preheated, instead of the plant steam, with bled steams of the steam turbine to about 200°C, and a connector is connected between the economizers positioned in the flue gas duct of the boiler from the supply water preheater using bled steam. By controlling the temperature of the supply water entering into the boiler with the aid of the amount of the bled steam passing through the by-pass duct into the preheater and/or by controlling simultaneously the temperature of the supply water so that the amount of bled steam entering into the preheater is controlled, the ultimate temperature of the boiler flue gases can be controlled as desired in all running situations.

In accordance with one aspect of the present invention, there is provided an integrated construction of a steam boiler provided with a combustion chamber and a steam turbine, in which steam is conducted from a steam boiler along a connector to a steam turbine for rotating an electric generator generating electricity, supply water circulated through the steam boiler is vaporized in a vaporizer located in the steam boiler and superheated in a superheater, the supply water is conducted into the boiler through an economizer acting as

a heat exchanger, in which heat is transferred from the flue gases of the boiler into the supply water, the economizer is provided with at least two sections, comprising at least one first economizer section and at least one second economizer section, which are in series, the supply water, preheated with bled steams of the steam turbine, is conducted in the steam boiler further to a vaporizer and a superheater and therethrough, in the form of steam, to the steam turbine, wherein a connector leading to the economizer sections comprises a branch point to a by-pass connector of supply water, so that the first economizer section is by-passable, at least concerning part of the supply water flow, and the branch point comprises a distribution valve, where with the supply water flow can be controlled between the first economizer section and the by-pass connector and the integrated construction comprises temperature sensors measuring the temperature of the flue gases or temperature sensors measuring the temperature of the supply water in the economizer for controlling the distribution valve.

In accordance with a further aspect of the present invention, there is a method of preheating of supply water for a steam turbine and its control, in which the supply water is conducted into an economizer of a steam boiler provided with a combustion chamber, in which heat is transferred in a heat exchanger from the flue gases into the supply water, the economizer is arranged to be located, at least partly by its heat faces, in a flue-gas duct of the steam boiler, the economizer provided with at least two sections, namely a first section and a second section, is used for heating the supply water, the sections being in series in relation to each other, the combustion air is heated with the aid of the energy obtained from bled steams, wherein the first section is by-passable with a by-pass flow, the amount of the by-pass flow of the supply water of the economizer being controlled with a valve and the valve is controlled on the basis of the temperature measurement of the flue gases and/or of the supply water made to flow through the economizer.

The invention is described below referring to the advantageous embodiments of the invention illustrated in the drawings of the accompanying figures, whereto, however, the invention is not intended to be exclusively confined.

5 Figure 1 presents as a schematic diagram an integration construction between a boiler and a steam turbine.

Figure 2 presents a decrease of the flue-gas temperature in a flue-gas duct and an increase of temperature in the supply water of an economizer in a control of the
10 invention.

Figure 1 presents an integration construction of the invention between a boiler and a steam turbine, comprising a steam boiler, such as soda recovery boiler, to which fuel is brought as shown by arrow M_1 . The boiler is indicated by reference
15 numeral 10. The evaporator is indicated by reference numeral 190 and the superheater thereafter in a connector 12a₁ by reference numeral 120. The flue gases are discharged during a second draught 10a from the boiler 10 into a smoke stack 100 and therethrough into the outside air as shown by arrow L_1 . The second
20 draught 10a is the part of the boiler which comprises the heat faces prior to the smoke stack 100. The superheated steam is conducted to the steam turbine 11 along the connector 12a₁ and the steam turbine 11 is arranged to rotate a generator G producing electricity. From the steam turbine 11, connectors 13a₁ and 13a₂ are provided for bled steams and a connector 13a₃ into a condensator 18 for exit steam or back-pressure steam entering into the industrial process. The connector 13a₁ is
25 branched into branch connectors 13a_{1.1} and 13a_{1.2}, of which the connector 13a_{1.1} conducts the supply water running in the connector 19 to a preheater 14 and the connector 13a_{1.2} conducts the combustion air to a preheater 15a₁ which is provided with a return connector 13b₂ to a supply water tank 17. From the preheater 14 of the supply water, a return connector 13₂ is provided into the supply water tank 17.
30 The combustion air is conducted along a connector or an air duct 16 via combustion air preheaters 15a₁ and 15a₂ in series into the combustion chamber K

of the boiler.

In the integration construction, the temperature of the supply water is continuously raised in a first economizer section 20a₁ and from the first economizer section
5 20a₁ to a second economizer section 20a₂. In the preheater 14, the supply water is heater with the aid of thermal energy obtained from bled steams.

From the steam turbine 11, a connector 13a₂ for bled steam is furthermore provided, being branched into branch connectors 13a_{2.1}, 13a_{2.2}. The connector
10 13a_{2.1} leads to a second combustion air preheater 15a₂. From the air preheater 15a₂, a discharge connector 13b₃ is provided into the supply water tank 17. The connector 13a_{2.2} leads to the supply water tank 17. A discharge steam connector 13a₃ of the steam turbine 11 is lead to a condensator 18. On the trailing side of the condensator 18 the connector 13a₃ is provided with a pump P₁ to pump water into
15 the supply water tank 17 from the condensator 18.

A pump P₂ is connected to a connector 19 leading from the supply water tank 15 to a first economizer section 20a₁ of the economizer 20 in the flue-gas duct 10a, said first economizer section 20a₁ being further connected to a second economizer
20 section 20a₂, which economizer sections 20a₁ and 20a₂ are in this manner in series in relation to each other and between which economizer sections 20a₁ and 20a₂, a connector 21' is connected, being conducted to a branch point D₂ from the supply water preheater 14, to provide the energy from the bled steam. The economizer 20 is made at least of two sections. The flow direction of the supply water in the
25 connector 19 is denoted by arrow L₂. The supply water in the connector 19 is made to flow to the first economizer section 20a₁ and therefrom to the second economizer section 20a₂ or via a by-pass connector 21 to the supply water preheater 14 and therefrom into the connector 19 between the first economizer section 20a₁ and the second economizer section 20a₂. The first economizer section
30 20a₁ and the second economizer section 20a₂ are connected in series in relation to each other.

Prior to the economizer section 20a₁, the connector 19 includes a branch point D₁ for a by-pass connector or a by-pass duct 21, wherewith the economizer section 20a₁ positioned first relative to the supply water flow is by-passed. Thus, said
5 economizer section 20a₁ is bypassable and the supply water is conductable directly to the second economizer section 20a₂ and preferably, through the supply water preheater 14. The branch point D₁ comprises advantageously a distribution valve 22 for the supply water flow, which can be a three-way valve, that is, the flow is controlled therewith between the economizer section 20a₁ and the by-pass duct,
10 i.e. the by-pass connector 21. Using the valve 22, the by-pass flow of the economizer section 20a₁ can therefore be controlled as desired to conform to the running conditions of the boiler. The connector 19 is in this manner connected to the distribution valve 22 having an outlet to the by-pass connector 21, which is connected to the preheater 14, and a second outlet, which is connected to the first
15 economizer section 20a₁. The connector 21' from the preheater 14 is connected via a branch point D₂ to the connector 19 between the economizer sections 20a₁ and 20a₂.

The valve 22 can be an on/or valve in structure, so that the entire supply water
20 quantity of the connector 19 is made to flow either through the by-pass connector 21 or through the economizer section 20a₁, or the valve 22 can be a so-called proportional valve in structure, whereby, when the by-pass flow through the by-pass connector 21 is increased, the flow through the economizer section 20a₁ is reduced by an equal amount, however, to the extent that some of the flow passes
25 through the economizer section 20a₁ and other part thereof passes through the by-pass connector 21.

By controlling the amount of bled steam to the preheater 14 with a valve 23, the temperature of the supply water can be regulated intensively to be as desired in
30 different parts of the economizer 20 including several portions in different running conditions of the boiler 10. In the preheater 14, the thermal energy passes from the

bled steam directly to the supply water or either indirectly through a medium, for instance via water. The preheater 14 is thus a heat exchanger in which heat energy is transferred into the supply water.

5 In Figure 2, the ascending angle of the cold economizer changes as a main impact of the control. The by-pass is illustrated by a horizontal graph. The temperature of the supply water can be controlled as desired in different spots of the economizer sections 20a₁, 20a₂. On the inlet side of the economizer section 20a₁ and on the outlet side of the flue-gas duct 10a, the flue-gas temperature is marked by T₁' and
10 the temperature of the supply water by T₁". On the outlet side of the second economizer section 20a₂ and on the inlet side of the flue-gas duct the markings of Figure 2 are as follows: the flue-gas temperature is T₂' and the supply water temperature is T₂". The flue-gas duct 10a may comprise temperature sensors: a temperature sensor E₂, measuring the temperature on the inlet side of the flue-gas
15 duct (viewing in the flow direction L₁ of the flue gas), and a temperature sensor E₁, measuring the temperature of the flue gas on the outlet side of the flue-gas duct 10a. In addition, the apparatus may comprise temperature sensors in the connector of the supply water 19. Temperature can be measured from the supply water after the first economizer section 20a₁ before the second economizer section
20 20a₂ and from the supply water after the second economizer section 20a₂ when viewed in the flow direction L₂ of the supply water. The flow direction of the supply water in the connector 19 is marked by arrow L₂.

In the method, in preheating the supply water of the steam turbine and in its
25 control, the procedure is as follows. The supply water is conducted into an economizer 20 of the steam boiler 10 provided with a combustion chamber K, in which heat is transferred in a heat exchanger from the flue gases into the supply water. The economizer 20 by its heat faces is arranged to be positioned, at least in part, in a flue-gas duct 10a of the steam boiler 10. At least a two-portion
30 economizer 20a₁, 20a₂ is used for heating the supply water, said portions being in series. The supply water preheated with the aid of bled steams is conducted to a

second economizer section 20a₂ and further to a vaporizer 190 and a superheater 120 and further, in the form of steam, to the steam turbine 11 to rotate the electric generator G and to produce electricity. In the method, also the combustion air is heated with the aid of the energy acquired from bled steams. In the method, the
5 by-pass quantity of the supply water of the economizer 20 is controlled with a valve 22. In addition to the by-pass, the amount of bled steam flow flown into the preheater 14 of the supply water is controlled with a valve 23. In the method, the valve(s) 22 and/or 23 is/are controlled on the basis of temperature measurement of supply water flown through temperature measurement of flue gases and/or the
10 economizer 20.

The embodiments of the invention, in which an exclusive property or privilege is claimed, are defined as follows:

1. An integrated construction of a steam boiler provided with a combustion chamber and a steam turbine, in which steam is conducted from a steam boiler along a connector to a steam turbine for rotating an electric generator generating electricity, supply water circulated through the steam boiler is vaporized in a vaporizer located in the steam boiler and superheated in a superheater, the supply water is conducted into the boiler through an economizer acting as a heat exchanger, in which heat is transferred from the flue gases of the boiler into the supply water, the economizer is provided with at least two sections, comprising at least one first economizer section and at least one second economizer section, which are in series, the supply water, preheated with bled steams of the steam turbine, is conducted in the steam boiler further to a vaporizer and a superheater and therethrough, in the form of steam, to the steam turbine, wherein a connector leading to the economizer sections comprises a branch point to a by-pass connector of supply water, so that the first economizer section is by-passable, at least concerning part of the supply water flow, and the branch point comprises a distribution valve, where with the supply water flow can be controlled between the first economizer section and the by-pass connector and the integrated construction comprises temperature sensors measuring the temperature of the flue gases or temperature sensors measuring the temperature of the supply water in the economizer for controlling the distribution valve.
2. An integrated construction according to claim 1, wherein the by-pass connector is connected to a preheater of supply water and, from the preheater, a further connector leads through a branch point to the connector between the economizer sections and the bled steam is conducted to the preheater of supply water from the steam turbine.
3. An integrated construction according to claim 2, wherein the connector leading to the supply water preheater comprises a valve for controlling the amount of bled steam flow to the preheater.

4. A method of preheating of supply water for a steam turbine and its control, in which the supply water is conducted into an economizer of a steam boiler provided with a combustion chamber, in which heat is transferred in a heat exchanger from the flue gases into the supply water, the economizer is arranged to be located, at least partly by its heat faces, in a flue-gas duct of the steam boiler, the economizer provided with at least two sections, namely a first section and a second section, is used for heating the supply water, said sections being in series in relation to each other, the combustion air is heated with the aid of the energy obtained from bled steams, wherein said first section is by-passable with a by-pass flow, the amount of said by-pass flow of the supply water of the economizer being controlled with a valve and the valve is controlled on the basis of the temperature measurement of the flue gases and/or of the supply water made to flow through the economizer.

5. A method according to claim 4, wherein in addition to the by-pass flow, the amount of bled steam flow made to flow into the supply water preheater in a by-pass flow connector is controlled with a further valve and, from the preheater, a connector is provided via a branch point to be in the line between the economizer sections.

6. A method according to claim 5, wherein, in the method, the further valve is controlled on the basis of the temperature measurement of the flue gases and/or of the supply water made to flow through the economizer.

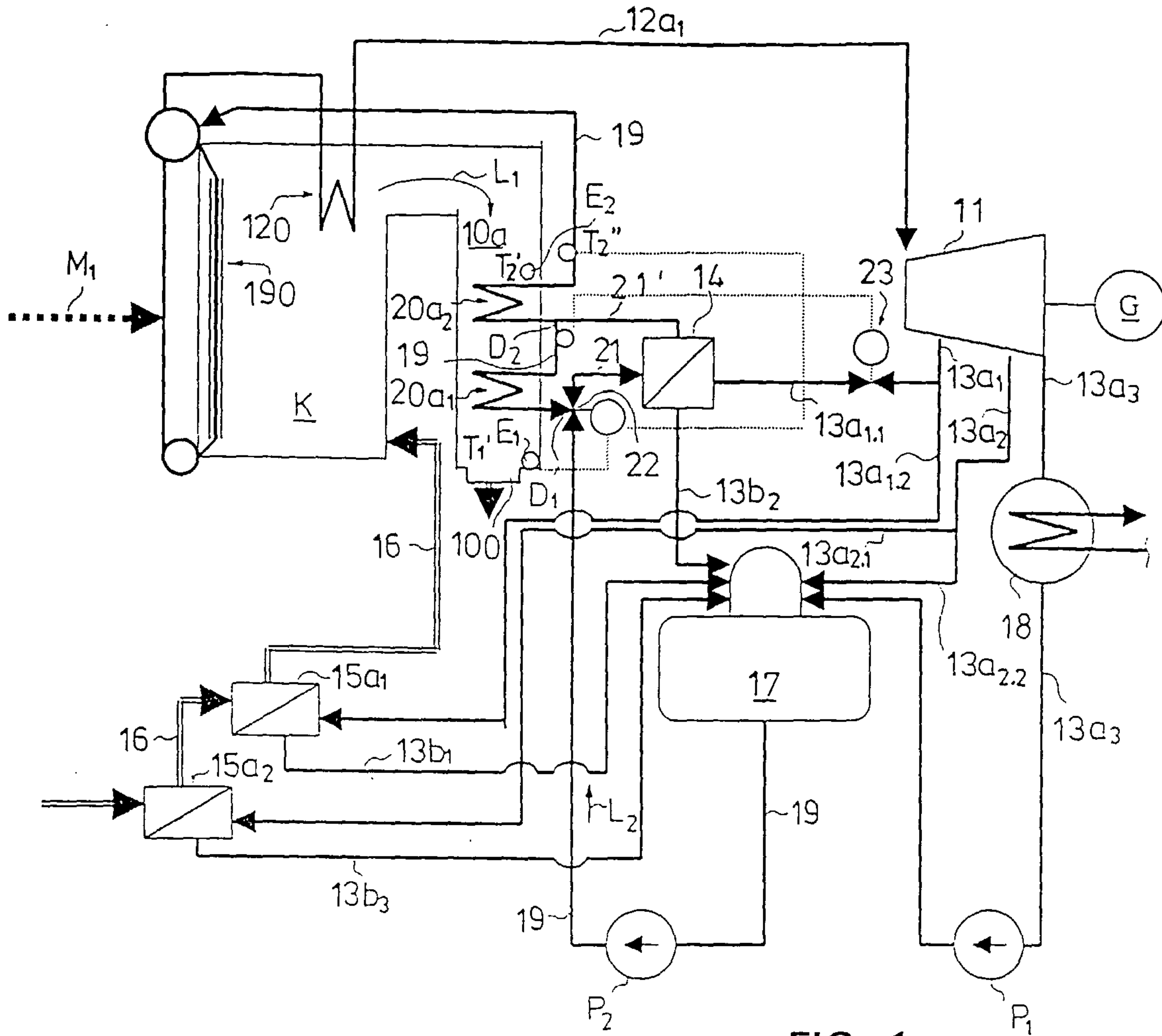


FIG. 1

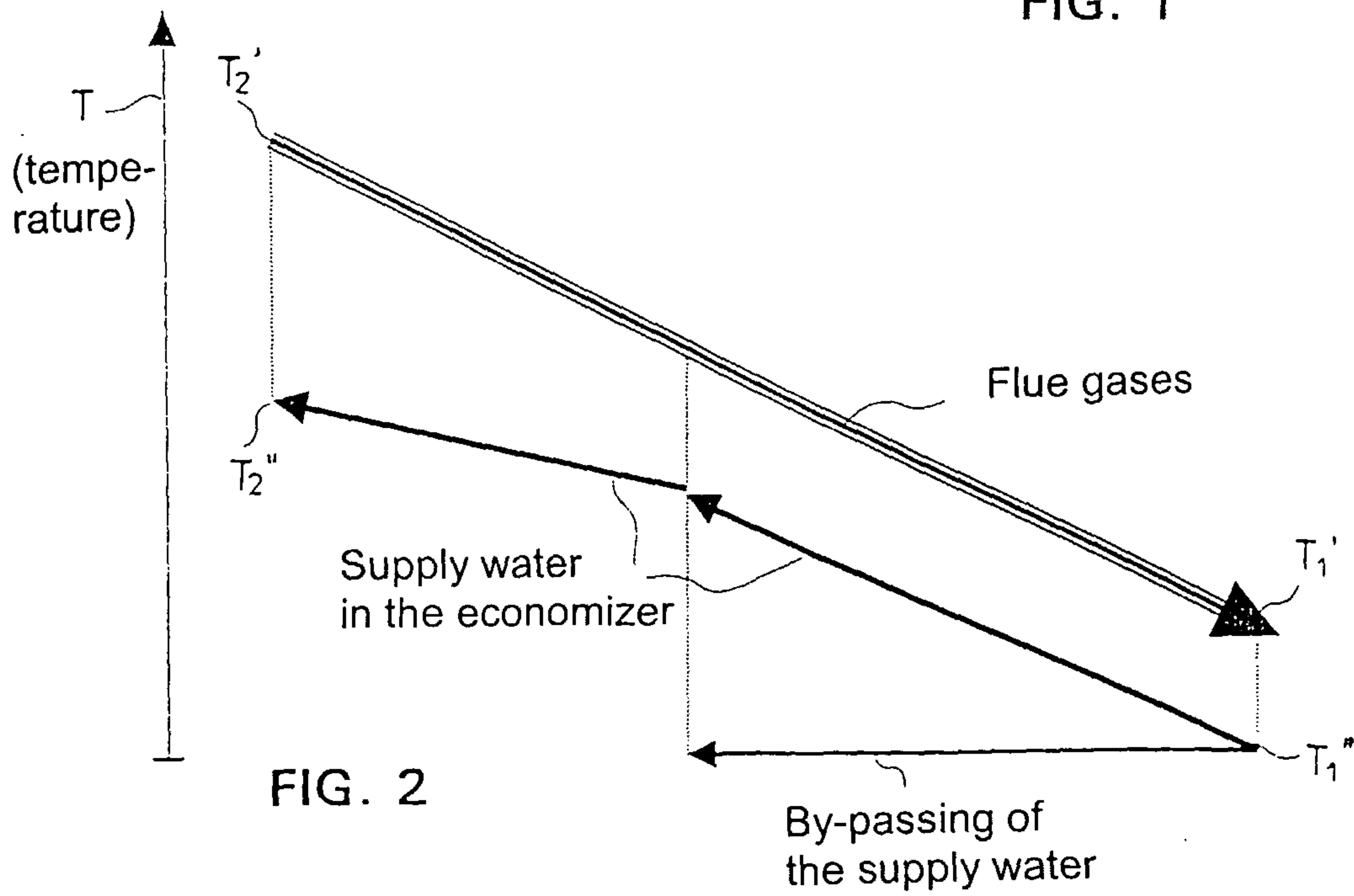


FIG. 2

