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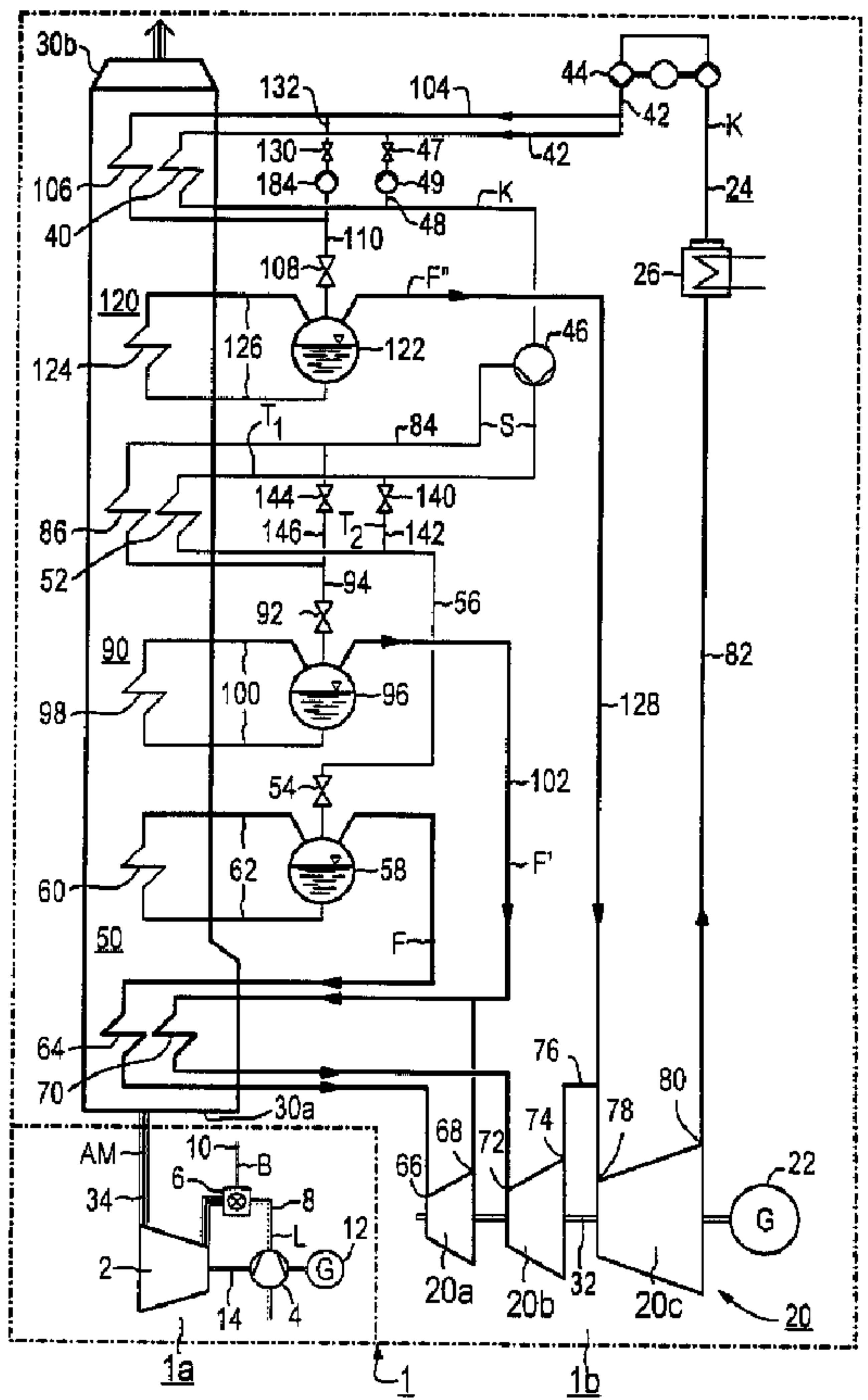
(54) Titre : PROCEDE D'OPERATION D'UNE CENTRALE A CYCLE COMBINE ET CENTRALE A CYCLE COMBINE PERMETTANT DE METTRE EN OEUVRE CE PROCEDE

(54) Title: METHOD OF OPERATING A COMBINED-CYCLE POWER PLANT AND COMBINED-CYCLE POWER PLANT FOR CARRYING OUT THE METHOD



(57) Abrégé/Abstract:

In a method for operating a combined-cycle power plant (1), in which the heat contained in the expanded working medium (AM) of an associated gas turbine (2) operable with both gas and oil as fuel is utilized in order to generate steam for an associated steam

(57) Abrégé(suite)/Abstract(continued):
turbine (20) comprising at least one high-pressure stage (50), particularly high plant efficiency being capable of being achieved by means of the said method, irrespective of the fuel used for the gas turbine, at a low outlay in terms of apparatus and operational requirements, according to the invention, after a change of the operation of the gas turbine (2) from gas to oil, feed water (S) to be supplied to the high-pressure stage (50) is divided into a first and a second part stream (T1, T2), only one of the part streams (T1, T2) being preheated. In a combined-cycle power plant (1) particularly suitable for carrying out the method, a bypass line (142) is connected in parallel with the feed-water preheater (52) assigned to the high-pressure stage (50).

Abstract

Method for operating a combined-cycle power plant and combined-cycle power plant for carrying out the method

In a method for operating a combined-cycle power plant (1), in which the heat contained in the expanded working medium (AM) of an associated gas turbine (2) operable with both gas and oil as fuel is utilized in order to generate steam for an associated steam turbine (20) comprising at least one high-pressure stage (50), particularly high plant efficiency being capable of being achieved by means of the said method, irrespective of the fuel used for the gas turbine, at a low outlay in terms of apparatus and operational requirements, according to the invention, after a change of the operation of the gas turbine (2) from gas to oil, feed water (S) to be supplied to the high-pressure stage (50) is divided into a first and a second part stream (T1, T2), only one of the part streams (T1, T2) being preheated. In a combined-cycle power plant (1) particularly suitable for carrying out the method, a bypass line (142) is connected in parallel with the feed-water preheater (52) assigned to the high-pressure stage (50).

Description

Method for operating a combined-cycle power plant and combined-cycle power plant for carrying out the method

The invention relates to a method for operating a combined-cycle power plant, in which the heat contained in the expanded working medium of an associated gas turbine operable with both gas and oil as fuel is utilized in order to generate steam for an associated steam turbine comprising at least one high-pressure stage. It is further directed at a combined-cycle power plant particularly suitable for carrying out the method, having a gas turbine operable with both gas and oil as fuel and having a waste-heat steam generator following the gas turbine on the flue-gas side and intended for generating steam for an associated steam turbine comprising at least one high-pressure stage.

In a combined-cycle power plant, the heat contained in the expanded working medium from the gas turbine is utilized in order to generate steam for the steam turbine. Heat transmission takes place in a waste-heat steam generator which follows the gas turbine and in which the heating surfaces in the form of tubes or tube bundles are arranged. These, in turn, are connected into the water/steam circuit of the steam turbine. The water/steam circuit comprises one or more, for example two or three, pressure stages, each pressure stage conventionally having a preheating heating surface (economizer), an evaporator heating surface and a superheater heating surface. Depending on the pressure conditions prevailing in the water/steam circuit of the steam turbine, a thermodynamic efficiency of about 50% or more is achieved by means of a combined-cycle power plant of this type which is known, for example, from EP 0,148,973 B1.

The gas turbine of a combined-cycle power plant of this type may be designed to operate with different kinds of fuel. However, the requirements placed on the waste-heat steam generator following the gas turbine on the flue-gas side are different, depending on the type of fuel on which the design is based. For example, gas, as fuel for the gas turbine, normally has high purity, so that flue gas flowing out of the gas turbine contains only small amounts of impurities.

In contrast to this, if the fuel for the gas turbine is fuel oil, impurities in the flue gas flowing out of the gas turbine are to be expected. In this case, in particular, sulphur dioxide ($SO_2$) or sulphur trioxide ($SO_3$) may occur, which, after reacting with water in the form of sulphuric acid ($H_2SO_4$), may settle on the heating surfaces in the waste-heat steam generator and attack these. The requirements placed on the waste-heat steam generator when oil is used as fuel for the gas turbine must therefore be different from those when gas is used as fuel for the latter.

In particular, when oil is used as fuel for the gas turbine, it is necessary to ensure that the heating surfaces connected into the water/steam circuit of the steam turbine and the line components inside the waste-heat steam generator are at a sufficiently high temperature, namely a temperature above the dew point of sulphuric acid. For this purpose, when the gas turbine operates with oil, the inlet temperature of the water or condensate flowing into the waste-heat steam generator is raised, as compared with the gas turbine operating with the gas, and is set at about 120° to 130°C.

A combined-cycle power plant, in which fuel oil is provided as fuel for the gas turbine only for a brief operating period, for example for 500 to 1,500 h/a, as "back-up" to natural gas, is usually designed and optimized primarily for the gas turbine to operate with natural gas. In order to ensure that, when the gas turbine operates with fuel oil, the condensate flowing into the waste-heat steam generator has a sufficiently high inlet temperature, the necessary heat may be extracted from the waste-heat steam generator itself in various ways.

One possibility is to bypass a conventionally provided condensate preheater completely or partially and to heat the condensate by the supply of low-pressure steam in a feed-water tank connected into the water/steam circuit. However, at low steam pressures, such a method necessitates a large-volume and possibly multi-stage heating steam system in the feed-water tank, and, in the case of long heating-up periods, this may put at risk a deaeration function which normally takes place in the feed-water tank.

In order to ensure effective deaeration of the condensate, the condensate temperature in the feed-water tank must always be maintained in a temperature range of between 130° and 160°C, and the heating-up period of the condensate in the feed-water tank should be kept as short as possible. This may be carried out, for example, by preheating the condensate via an additional preheater heated by means of steam.

In order to provide sufficient heat for this purpose, in the case of two-pressure or three-pressure plants it is often necessary to extract hot water from a high-pressure economizer of the waste-heat steam generator. The disadvantage of this, however, particularly in the case of three-pressure plants, is that the delivery of a normally provided high-pressure feed pump may be influenced, and that the additional condensate preheater has to be designed in a particularly inefficient way for the high pressure and large temperature differences.

Furthermore, in the case of fuel-oil operation, throttle losses of the or each feed pump occur adversely. Moreover, the extraction of hot water from the high-pressure economizer leads to a reduction in the high-pressure steam quantity due to a lowering of a so-called high-pressure approach temperature, thus, in turn, leading to a reduction in plant efficiency.

Another proven method is, when the gas turbine operates with oil, to assist the heating-up of the condensate in the feed-water tank or in the deaerator by means of steam extracted from an intermediate superheater line. However, this method cannot be employed in the case of plants without a feed-water tank or without a deaerator.

The above-mentioned concepts of condensate preheating when oil is used as fuel for the gas turbine are complicated in view of the components which are required and also in view of the operating mode of the combined-cycle power plant. Moreover, plant efficiency is only limited when the gas turbine operates with oil.

The object on which the invention is based is, therefore, to specify a method for operating a combined-cycle power plant of the above-mentioned type, by means of which, irrespective of the fuel used for the gas turbine, particularly high plant efficiency can be achieved at a low outlay in terms of apparatus and operation requirements. Moreover, a combined-cycle power plant particularly suitable for carrying out the method is to be specified.

According to one aspect of the present invention, there is provided method for operating a combined-cycle power plant, in which the heat contained in an expanded working medium of an associated gas turbine operable with both gas and oil as fuel is utilized in order to generate steam for an associated steam turbine comprising at least one high-pressure stage, and in which, after a change of the operation of the gas turbine from gas to oil, feed water to be supplied to the high-pressure stage is divided into a first and a second part stream, only one of the part streams being preheated.

According to another aspect of the present invention, there is provided combined-cycle power plant having a gas turbine operable with both gas and oil as fuel and having a waste-heat steam generator following the gas turbine on the flue-gas side and intended for generating steam for an associated steam turbine comprising at least one low-pressure stage and one high-pressure stage, wherein a bypass line is connected in parallel with a feed-water preheater assigned to the high-pressure stage.

With regard to the method, the object mentioned is achieved, according to the invention, in that, after a change in the operation of the gas turbine from gas to oil, feed water to be supplied to the high-pressure stage of the steam turbine is divided into a first and a second part stream, only one of the part streams being preheated.

The invention proceeds from the notion that the condensate preheating additionally necessary when the gas turbine operates with oil is ensured by particularly simple means and in a particularly simple way by transmitting the heat required for this purpose to the condensate not via the water/steam circuit, but, instead, via the flue gas from the gas turbine. In this case, the components, such as, for example, heat exchangers, mixing preheaters, steam reducing stations and/or corresponding pipelines, which are necessary in the transmission of heat via the water/steam circuit, may be dispensed with. Instead, when a gas turbine operates with oil, the extraction of heat from the flue gas of the gas turbine is reduced at a suitable point, as compared with the operation of the gas turbine with gas, so that a sufficiently large amount of exhaust-gas heat is available for condensate preheating.

In this case, for a suitable modification of the extraction of heat from the flue gas of the gas turbine, the feed-water preheating for the high-pressure stage of the steam turbine is provided. In a combined-cycle power plant designed as a three-pressure plant, a corresponding modification of the feed-water preheating for the medium-pressure stage, the said modification being dependent on the operating mode, may also be provided alternatively or additionally.

In an advantageous development, after the change of the operation of the gas turbine from gas to oil, the operating pressure in a low-pressure stage of the steam turbine is increased. This ensures that the heat, which, when the gas turbine operates with oil, remains in the flue gas due to the comparatively lower preheating of the feed water for the high-pressure stage, is not transmitted to the water/steam circuit of the steam turbine via the low-pressure heating surfaces, but, in actual fact, is carried further in the flue gas and is thus provided reliably for condensate preheating.

In this case, the operating pressure in the low-pressure stage may be set in such a way that steam production in the low-pressure stage comes to a stop. Expediently, however, the operating pressure in the low-pressure stage of the steam turbine is raised, for example to about 10 to 15 bar, in such a way that only some minimum steam production for maintaining the system functions still remains in the low-pressure stage.

For particularly high efficiency, even in a transitional phase after a change in the operating mode of the gas turbine, the branching ratio between the first and the second part stream is advantageously set as a function of the temperature of the condensate to be supplied to the high-pressure stage. In this case, the temperature of the condensate flowing into the waste-heat steam generator may be monitored in a particularly favourable way.

As regards the combined-cycle power plant, the object mentioned is achieved, according to the invention, in that a bypass line is connected in parallel with a feed-water preheater assigned to the high-pressure stage of the steam turbine.

In this case, particularly favourable adaptation of feed-water preheating to the respective operating conditions is made possible preferably by connecting into the bypass line a valve capable of being set as a function of the temperature of the condensate to be supplied to the low-pressure stage.

The advantages achieved by means of the invention are, in particular, that a water inlet temperature into the waste-heat steam generator which is necessary when the gas turbine operates with oil and which is increased, as compared with the operation of the gas turbine with gas, is ensured by particularly simple means. The complicated components, conventionally provided in the additional condensate preheating necessary for this purpose, for transmitting heat from the water/steam circuit to the condensate, for example by the supply of low-pressure steam, may be dispensed with. Instead, sufficient heat transmission to the condensate is ensured due to the fact that the flue gas from the gas turbine still contains sufficient heat in the region of the condensate preheaters. The additional condensate-preheating heat necessary when the gas turbine operates with oil is therefore transmitted to the condensate directly via the flue gas. The outlay in terms of construction and operational requirements which is necessary for this purpose is particularly low.

Furthermore, components of the water/steam circuit, such as, for example, the high-pressure feed-water pumps, may be given comparatively small dimensions, since they do not have to be designed for a bypass mode, when the gas turbine operates with oil, with additional water extraction from the economizer. Moreover, depending on the design of the low-pressure stage of the steam turbine and of the condensate pump, water inlet temperatures into the waste-heat steam generator of up to and above 130°C can be mastered. Virtually the entire fuel-oil spectrum for this purpose (back-up fuel) can therefore be covered, so that standardization is possible.

An exemplary embodiment of the invention is explained in more detail with reference to a drawing in which the figure shows a combined-cycle power plant diagrammatically.

The combined-cycle power plant 1 according to the figure comprises a gas-turbine plant 1a and a steam-turbine plant 1b. The gas-turbine plant 1a comprises a gas turbine 2, with a coupled air compressor 4, and a combustion chamber 6 which precedes the gas turbine 2 and which is connected to a fresh-air line 8 of the air compressor 4. Into the combustion chamber 6 of the gas turbine 2 opens a fuel line 10, via which gas or oil can be selectively supplied to the combustion chamber 6 as a fuel B for the gas turbine 2. The gas turbine 2 and air compressor 4 and a generator 12 are seated on a common shaft 14.

The steam-turbine plant 1b comprises a steam turbine 20, with a coupled generator 22, and, in a water-steam circuit 24, a condenser 26 following the steam turbine 20 and a waste-heat steam generator 30. The steam turbine 20 consists of a first pressure stage or high-pressure part 20a, of a second pressure stage or medium-pressure part 20b and of a third pressure stage or low-pressure part 20c which drive the generator 22 via a common shaft 32.

For supplying working medium AM or flue gas expanded in the gas turbine 2 into the waste-heat steam generator 30, an exhaust-gas line 34 is connected to an inlet 30a of the waste-heat steam generator 30. The expanded working medium AM from the gas turbine 2 leaves the waste-heat steam generator 30, via the outlet 30b of the latter, in the direction of a chimney not illustrated in any more detail.

The waste-heat steam generator 30 comprises a first condensate preheater 40 which can be fed with condensate K from the condenser 26 on the inlet side via a condensate line 42, into which a condensate pump unit 44 is connected. The condensate preheater 40 is connected on the outlet side to a high-pressure pump

46. Moreover, the condensate line 42 is connected to the condensate line 45 via a circulating line 48 which can be shut off by means of a valve 47 and into which a circulating pump 49 is connected. The circulating line 48, condensate line 42, condensate preheater 40 and condensate line 45 thus form a circulating loop for the condensate K, so that there is no need for a feed-water tank. Moreover, in order, if required, to bypass the high-pressure preheater 40, the condensate line 42 can be connected directly to the high-pressure pump 46 via a bypass line which is not illustrated.

The high-pressure pump 46 brings the preheated condensate K, flowing out of the condensate preheater 40, to a pressure level suitable for a high-pressure stage 50 of the water/steam circuit 24, the said high-pressure stage being assigned to the steam turbine 20. The condensate, which is under high pressure, can be supplied to the high-pressure stage 50 as feed water S via a feed-water preheater 52 which is connected on the outlet side to a high-pressure drum 58 via a feed-water line 56 capable of being shut off by means of a valve 54. The high-pressure drum 58 is connected to a high-pressure evaporator 60, arranged in the waste-heat steam generator 30, so as to form a water-steam cycle 62. For the discharge of fresh steam F, the high-pressure drum 58 is connected to a high-pressure superheater 64 which is arranged in the waste-heat steam generator 30 and which is connected on the outlet side to the steam inlet 66 of the high-pressure part 20a of the steam turbine 20.

The steam outlet 68 of the high-pressure part 20a of the steam turbine 20 is connected to the steam inlet 72 of the medium-pressure part 20b of the steam turbine 20 via an intermediate superheater 70. The steam outlet 74 of the said medium-pressure part is connected via an overflow line 76 to the steam inlet 78 of the low-pressure part 20c of the steam turbine 20. The steam outlet 80 of the low-pressure part 20c of the steam turbine 20 is connected to the condenser 26 via a steam line 82, so that a closed water/steam circuit 24 is obtained.

Moreover, a branch line 84 branches off from the high-pressure pump 46 at a point at which the condensate K has reached a medium pressure. The said branch line is connected via a second feed-water preheater 86 to a medium-pressure stage 90 of the water/steam circuit, the said medium-pressure stage being assigned to the steam turbine 20. The second feed-water preheater 86 is connected on the outlet side to a medium-pressure drum 96 of the medium-pressure stage 90 via a feed-water line 94 capable of being shut off by means of a valve 92. The medium-pressure drum 96 is connected to a medium-pressure evaporator 98, arranged in the waste-heat steam generator 30, so as to form a water-steam cycle. For the discharge of medium-pressure fresh steam F′, the medium-pressure drum 96 is connected via a steam line 102 to the intermediate superheater and therefore to the steam inlet 72 of the medium-pressure part 20b of the steam turbine 20.

Downstream of the condensate pump unit 44, as seen in the direction of flow of the condensate K, moreover, a further condensate line 104 branches off from the condensate line 42 and opens into a second condensate preheater 106 arranged in the waste-heat steam generator 30. The second condensate preheater 106 is connected on the outlet side, via a condensate line 110 capable of being shut off by means of a valve 108, to a low-pressure stage 120 of the water/steam circuit 24, the said low-pressure stage being assigned to the steam turbine 20.

The low-pressure stage 120 comprises a low-pressure drum 122 which is connected to a low-pressure evaporator 124, arranged in the waste-heat steam generator 30, so as to form a water/steam cycle 126. For the discharge of low-pressure fresh steam F″, the low-pressure drum 122 is connected to the overflow line 76 via a steam line 128. Moreover, the condensate line 110 is connected to the condensate line 104 via a circulating line 132 which is capable of being shut off by means of a valve 130 and into which a circulating pump 134 is connected. By means of the circulating pump 134, condensate K can be circulated in a circulating loop formed by the circulating line 132, condensate line 104, condensate preheater 106 and condensate line 110, so that there is no need for a feed-water tank. Moreover, in order, if required, to bypass the condensate preheater 106, the condensate line 104 can be connected directly to the condensate line 110 via a bypass line which is not illustrated.

A bypass line 142 capable of being shut off by means of a valve 140 is connected in parallel with the feed-water preheater 52 assigned to the high-pressure stage 50. In this case, the valve 140 can be set as a function of the temperature of the condensate K to be supplied to the high-pressure stage 50 or to the medium-pressure stage 90. For this purpose, the valve 140 is connected, in a way not illustrated in any more detail, to a controller unit, to which an input signal characteristic of the temperature of the condensate K to be supplied to the low-pressure stage 50 or to the medium-pressure stage 90 can be delivered.

A bypass line 146 capable of being shut off by means of a valve 144 is likewise connected in parallel with the feed-water preheater 86 assigned to the medium-pressure stage 90. In a similar way to the valve 140, the valve 144 can be set as a function of the temperature of the condensate K to be supplied to the high-pressure stage 50 or to the medium-pressure stage 90.

The gas turbine 2a of the combined-cycle power plant 1 can be operated with both gas and fuel oil as fuel B. When the gas turbine 2 operates with the gas, the working medium AM supplied to the waste-heat steam generator 30 has comparatively high purity, so that, in this operating stage, the efficiency of the water/steam circuit 24 can be optimized.

In this operating state, the valves 140, 144 are closed, so that the entire feed water S conveyed by the high-pressure pump 46 is led through the feed-water preheaters 52 or 86 and is preheated there.

When the gas turbine 2a operates with oil, the working medium AM supplied to the waste-heat steam generator 30 may contain impurities, in particular with sulphur dioxide $SO_2$ and with sulphuric acid $H_2SO_4$. In order reliably to avoid damage to structural parts within the waste-heat steam generator 30 in this operating state, all the heating surfaces arranged in the waste-heat steam generator 30, that is to say, in particular, also the condensate preheater 40 and the condensate preheater 106, are operated at a temperature of more than the dew point of sulphuric acid. For this purpose, it is necessary to have an increased water inlet temperature for the condensate K flowing into the waste-heat steam generator 30 and, consequently, comparatively higher condensate preheating, as compared with the operation of the gas turbine 2 with gas.

This comparatively higher condensate preheating is not achieved by transmitting heat from the water/steam circuit 24 to the condensate K, but, instead, by transmitting heat from the working medium AM directly to the condensate K. For this purpose, after a change of the operation of the gas turbine 2 from gas to oil, the feed water S to be supplied to the high-pressure stage 50 and that to be supplied to the medium-pressure stage 90 are in each case divided into a first part stream T1 and a second part stream T2, in each case only one of the part streams T1, T2 being preheated.

In order to achieve this, the valves 140 and 144 are in each case partially opened, so that the feed-water stream to be supplied to the high-pressure stage 50 is distributed to the feed-water preheater 52 and to the bypass line 142. The feed-water stream to be supplied to the medium-pressure stage 90 is likewise distributed to the feed-water preheater 86 and the bypass line 146. As a result, less heat is extracted from the working medium AM in the region of the feed-water preheaters 52, 86, as compared with the operation of the gas turbine 2 with gas.

In order to ensure reliable transmission of this heat remaining in the working medium AM to the condensate K, moreover, the operating pressure in the low-pressure stage 120 is raised to about 10 to 15 bar. This prevents the heat which has additionally remained in the working medium AM from being absorbed via the low-pressure evaporators 124. Reliable additional heating-up of the condensate K via the condensate preheaters 40, 106 is thereby ensured.

The combined-cycle power plant 1 can be operated at inlet temperatures of the condensate K into the waste-heat steam generator 30 of up to and above 130°C. A broad spectrum of fuel oils (back-up fuel) can therefore be used for the gas turbine 2, so that standardization of the combined-cycle power plant 1, irrespective of fuel oil, is also possible.

CLAIMS:

1. Method for operating a combined-cycle power plant, in which the heat contained in an expanded working medium of an associated gas turbine operable with both gas and oil as fuel is utilized in order to generate steam for an associated steam turbine comprising at least one high-pressure stage, and in which, after a change of the operation of the gas turbine from gas to oil, feed water to be supplied to the high-pressure stage is divided into a first and a second part stream, only one of the part streams being preheated.

2. Method according to Claim 1, wherein, after the change of the operation of the gas turbine from gas to oil, the operating pressure in a low-pressure stage of the steam turbine is increased.

3. Method according to Claim 1 or 2, wherein the branching ratio between the first part stream and the second part stream is set as a function of the temperature of the condensate to be supplied to the high-pressure stage.

4. Combined-cycle power plant having a gas turbine operable with both gas and oil as fuel and having a waste-heat steam generator following the gas turbine on the flue-gas side and intended for generating steam for an associated steam turbine comprising at least one low-pressure stage and one high-pressure stage, wherein a bypass line is connected in parallel with a feed-water preheater assigned to the high-pressure stage.

5. Combined-cycle power plant according to Claim 4, in the bypass line of which is connected a valve capable of

being set as a function of the temperature of the condensate to be supplied to the high-pressure stage.

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PATENT AGENTS

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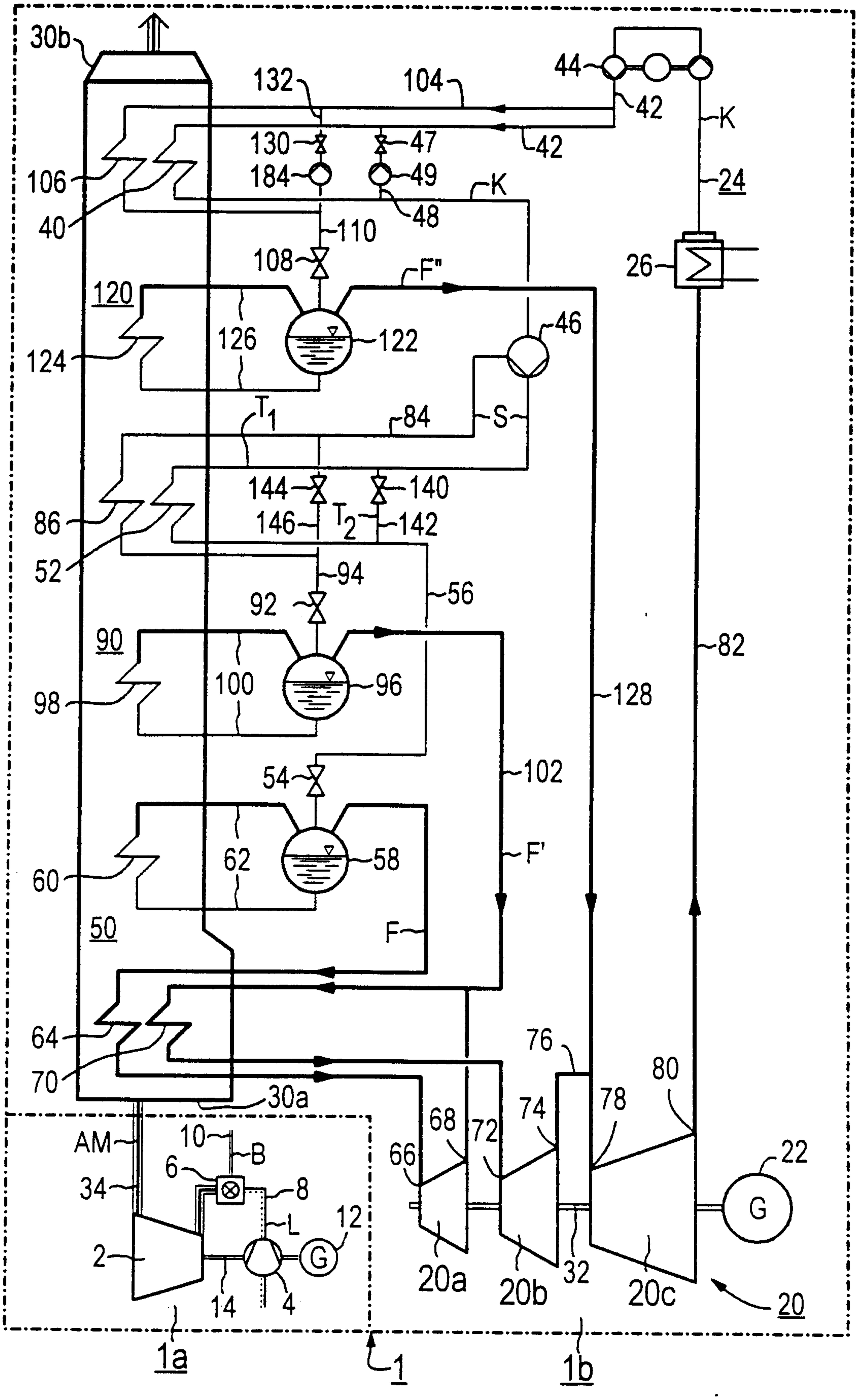

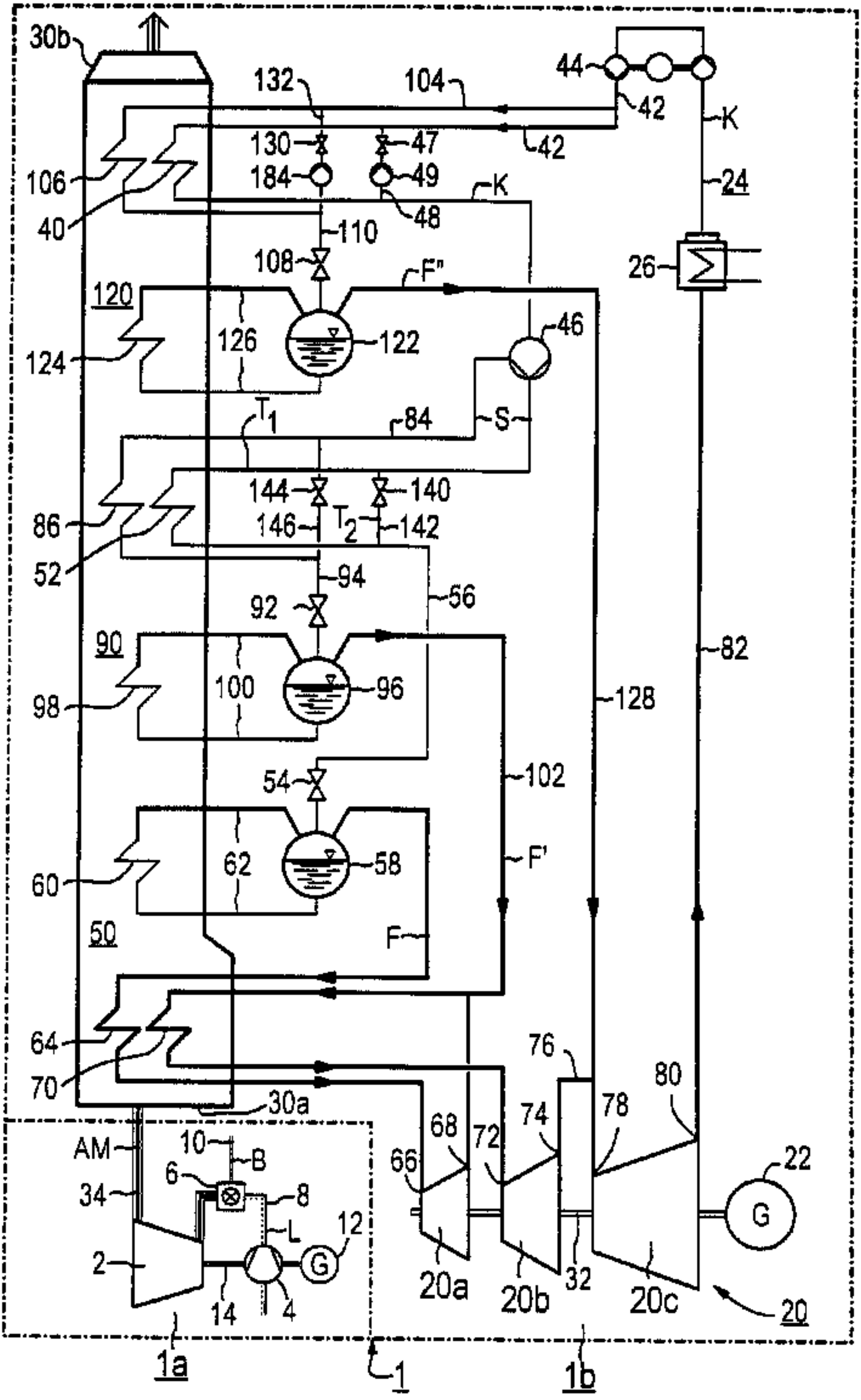

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