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(54) **A STEAM POWER PLANT WITH POWER BOOST THROUGH THE USE OF TOP HEATER DRAIN REHEATING**

(57) A power plant having a steam cycle and a water cycle. In order to initiate a load jump steam extracted from the steam cycle is condensed against boiler feed

water and directed back into a cold reheat line (10a) between a steam turbine (6) and a reheater (4).

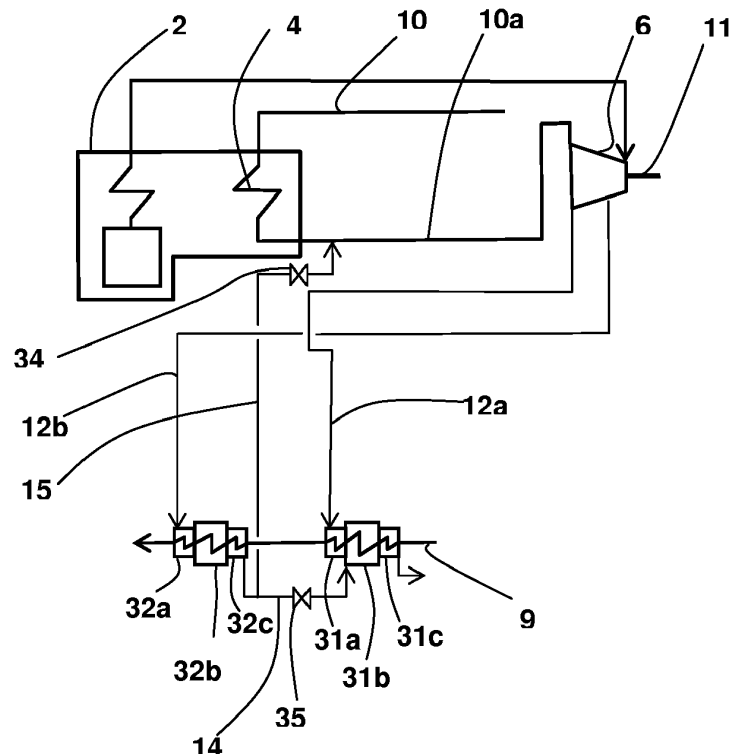


FIG. 2

Description

TECHNICAL FIELD

[0001] The present invention pertains to a power plant comprising a steam production unit, a steam turbine and water steam cycle, and in particular to a power plant of this type that is designed for dynamic response. The invention pertains furthermore to a method of operating such power plant.

BACKGROUND INFORMATION

[0002] Power plants are operated and regulated such that they can provide power corresponding to the demand in electrical energy in the grid. Variations in the magnitude of the demand can occur for example when a large user is added or stopped, a large electricity producer trips, or a transmission line fails due to overload, disruption, or short circuit. Large variations in demand or supply of electricity typically result in a variation of the AC-frequency. In order to compensate for this frequency variation, power plants are designed to provide a dynamic response, which is the ability to respond to changes in the demand of electrical energy upon detection of the frequency variations and maintain a balance between the electrical energy drawn and electrical energy provided.

[0003] Variations in the energy drawn from the grid can be both large in magnitude as well as rapid that are within a time span as short as a few seconds. They can occur when a number of large users alter their demand or other providers connected to the same grid decrease or stop their service. A dynamic response must be able to react to frequency changes by providing a load change of the power plants still connected to the grid within a short time.

[0004] In several countries grid codes are established by requiring that power plants be able to generate a minimum load response within a certain time frame when rapid frequency variations occur. Such grid code is given for example for the national grid in Great Britain. As documented in "The Grid Code", Issue 4, by the National Grid Electricity Transmission plc, it requires that a power plant operating between 65 and 90% of its nominal power be able to increase the power generated by 10% of its nominal power within 10 seconds. However, many power plants cannot fulfil such requirements because their system reaction times are too long and/or their load changes are too small in amplitude.

[0005] Several methods providing frequency response by means of load changes are conventionally known. For example, the live steam injected into the turbines is regulated by means of valves in the high-pressure steam inlet together with a control wheel. This method allows partial steam injection enabling optimization of plant efficiency during part-load operation. It has proven successful up to certain power levels of the power plant. However, above a certain power level control wheels are

no longer reliable, as greater power requires a larger control wheel and the length of the blades of a control wheel is limited due to fatigue stresses, which can occur at super critical pressures.

[0006] In further methods the steam flow through the turbines is increased thereby providing a load increase. As an example, opening a high-pressure throttle valve increases the live steam flow entering the high-pressure turbine. However, there is an inherent delay of such a system due to the steam flow characteristics at the intermediate-pressure stage, i.e. the temperature and pressure adjust only after a full minute following the opening of the high-pressure throttle. Large load changes can therefore not be accommodated by this method within a short time.

[0007] In a yet further method, frequently referred to as condensate stop, a steam extraction from the steam turbines is stopped and the condensate flow extracted by the condensate pump is recirculated back to the condensate well. By this measure, the total amount of steam passing through the steam turbines is immediately increased and the power output of the generator is increased proportionally. The recirculation of the condensate flow and therefore shutdown of the condensate flow through the condensate preheaters prevents a drop in the temperature of the feedwater in the feedwater tank. The temperature at the boiler inlet is therefore maintained. A condensate stop can be maintained as long as the level in the feedwater tank remains above a critical level necessary to prevent a tripping of the boiler and so condensate stop is an effective method to generate a load jump. However, the method is effective only over a short time period that is on the order of a few minutes. This is due to the diminished steam extraction resulting in a drop in the feedwater tank level and an increase in condensate level in the condenser well as a condensate stop can only be maintained until certain critical levels are reached in the feedwater tank and condenser well.

[0008] Presently operating power plants equipped for a condensate stop have several preheaters for the preheating of condensate and feedwater, where the feedwater tank is arranged following five condensate preheaters in series and prior to three feedwater preheaters. Such power plants are able to provide a load jump by means of a condensate stop of up to 7% load increase and are able to maintain the increased power output for 6-8 minutes. Such power plant design is based on thermodynamic and cost considerations, in particular the cost of fabrication and mounting of the feedwater tank. The design is furthermore based on considerations of the grid code requirements at the time of their construction.

[0009] DE 4344118 discloses a method of operating a power plant including condensate stop together with a control of the power reserve in order provide a primary frequency response.

[0010] In a further method, as disclosed for example EP1368555, the amount of high-pressure steam extracted for the preheating of feedwater is reduced or shut-off

and a load increase is affected by the resulting increase of the high-pressure steam flowing through the high-pressure turbine.

SUMMARY

[0011] Provided is an alternate load jump arrangement which provides a sustained increase in load.

[0012] This problem is overcome by independent claims wherein advantageous alternatives are provided in the dependent claims.

[0013] In its most simplest form the inventor comprises a steam plant with a steam cycle and a water cycle wherein steam is extracted from the steam, condensed against boiler feed water of the water cycle and at least a portion of condensed extraction steam returned into a cold reheat line of the steam cycle, defined a steam line upstream of a reheater.

[0014] This arrangement enables an alternate load jumping operation in which the condensate returned to the cold reheat line increases mass flow going through reheats circuit. As a result, steam temperature entering the reheater is lower due to mixing with the condensate. This allows more energy to be extracted from reheat circuit.

[0015] This solution provides an alternative to the use of an overload valve, without the complexities of an overload valve. For retrofit operation, it additionally provides the option to remove an overload valve installation and install additional stages in the steam turbine, thus increasing turbine expansion which is quite complex.

[0016] One general aspect includes a power plant having a water cycle and a steam cycle. The steam water cycle includes a first high pressure preheater and a second high pressure preheater down of the first high pressure preheater. The a steam cycle includes a boiler, with a reheater and a superheater, a high pressure steam turbine downstream of the superheater configured to expand the steam so as to extract energy from the steam, and a cold reheater line connected to the high pressure steam turbine to the reheater. The power plant also includes an extraction steam line connected to the high pressure steam turbine and the second high pressure preheater, for providing a first extraction steam into the second high pressure preheater, and a condensate drain line connected to the second high pressure preheater and the first high pressure preheater, configured and arranged to direct a condensed first extraction steam into the first high pressure preheater. A first valve in the condensate drain line is configured to at least partially restricts flow from the second high pressure preheater to the first high pressure preheater. A line further connects the condensate drain line upstream of the first valve and the cold reheater line.

[0017] Implementations may include one or more of the following features. The power plant where the extraction line is connected to an intermediate stage of the high pressure steam turbine. The power plant where the line

includes a valve for isolating the cold reheat line from the condensate drain line. The power plant where the second high pressure preheater includes a desuperheater section configured and arranged to remove superheat from extraction steam, a condenser section configured and arranged to condense extraction steam and a drain cooler section configured and arranged to cool condensed extraction steam, while the first high pressure preheater includes a desuperheater section configured and arranged to remove superheat from extraction steam and a condenser section configured and arranged to condense extraction steam. The power plant may also include a drain line is connected between the drain cooler section of the second high pressure preheater and the condenser section of the first high pressure preheater.

[0018] One general aspect includes a method for operating a steam plant including the steps of:

a) providing a steam plant with steam cycle and a water cycle;

b) condensing a steam extracted from the steam cycle against boiler feed water; and

c) directing at least a portion of condensed extraction steam into a cold reheat line between a steam turbine and a reheater.

[0019] Implementations may include one or more of the following features. The method where The method where step b) is realised using the extraction steam line and the second high pressure preheater. The method where step c) further includes stopping the condensed extraction steam to the first high pressure preheater using the first valve.

[0020] It is a further object of the invention to overcome or at least ameliorate the disadvantages and shortcomings of the prior art or provide a useful alternative.

[0021] Other aspects and advantages of the present disclosure will become apparent from the following description, taken in connection with the accompanying drawings which by way of example illustrate exemplary embodiments of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] By way of example, an embodiment of the present disclosure is described more fully hereinafter with reference to the accompanying drawings, in which:

Figure 1 is a general arrangement drawing of a prior art steam plant;

Figure 2 is an expanded view of part of a steam/condensate of an embodiment an exemplary embodiment that represents a modification of the steam plant of Fig. 1.

DETAILED DESCRIPTION

[0023] Exemplary embodiments of the present disclosure are now described with references to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth to provide a thorough understanding of the disclosure. However, the present disclosure may be practiced without these specific details, and is not limited to the exemplary embodiment disclosed herein.

[0024] Fig. 1 shows a power plant PP of the prior art to which exemplary embodiments of the invention may be applied. The power plant PP has a boiler 2 comprising, a superheater 3, and a reheater 4, and several steam turbines 6,7,8 which include a high-pressure turbine stage 6, to which superheated steam from a boiler 2 steam is fed via a line, an intermediate-pressure turbine stage 7 and a low-pressure turbine stage 8. Steam expanded in the high-pressure turbine stage 6 is fed via a cold reheat line 10a to a reheater 4 located in the boiler 2 before being lead into the intermediate-pressure turbine stage 7 a reheat line 10. After expansion in the intermediate-pressure turbine stage 7 the steam is further expanded in the low-pressure turbine stage 8. All turbines are mounted on one or more shaft 11 that drive a generator. From the end of the steam turbine 6,7,8 i.e. the low-pressure turbine 8 exhaust steam is then lead to a condenser 13, where resulting condensate collects in a condensate well wherein it is then pumped through a boiler feed water preheat system by a condensate extraction pump 14 pumps.

[0025] The boiler feedwater preheat system comprising a series of low pressure condensate preheaters 21, 22, 24, 25, which are each operated by steam extracted from the low- and intermediate-pressure steam turbine stages 7, 8 and lead to the condensate preheaters 21, 22, 24, 25 via extraction lines.

[0026] During normal operation of the water-steam cycle, the condensate preheated in the low-pressure preheaters 21, 22, 24, 25 is collected in the boiler feedwater tank 30. Additional heat may be provided to the feedwater tank 30 via a steam extraction line from the intermediate-pressure turbine stage 7, which is used for preheating in a third high pressure preheater 33 and subsequently a fourth high pressure preheater 34.

[0027] A feedwater pump FWP directs the feedwater through high-pressure preheaters 34,33,32,31. Following the fourth high pressure heater 34 feedwater is next feed through a first high pressure preheater 31, a second high pressure preheater 32 and then a third high pressure preheater 33 and finally to the boiler 2 thus completing the water steam cycle of the power plant PP.

[0028] In another exemplary embodiment the feedwater pump FWP directs the feedwater through high-pressure preheater 32, 31. Following the first high pressure heater 31 feedwater is next feed through a second high pressure preheater 32 and then finally to the boiler 2 thus

completing the water steam cycle of the power plant PP.

[0029] A suitable boiler 2 may be any boiler fired by fossil fuel, such as gas, coal or oil, or a heat exchanger that utilises a hot fluid, such as a gas or liquid as an energy source, wherein the superheater 3 is an exchanger located in the boiler 2 whose primary duty is to convert feedwater from the feed water preheat system to steam, while a reheater 4, located in the same boiler reheats steam expanded in the high pressure steam turbine stage 6.

[0030] Each of the steam turbine stages of the steam turbine train are in part defined as a stage by being enclosed in a house separate from other stages of the steam turbine train. That is, while a single steam turbine stage may include multiple stationary and moving turbine vane and blade rows as well as multiple inlets and outlets along the expansion path of the steam turbine stage, the steam turbine stage is defined by a housing that encompasses these multiple vane and blade rows.

[0031] The pressure designation of the low pressure preheaters and high pressure preheaters defined the relative pressure of feedwater passing through the preheaters in normal operation.

[0032] In an exemplary embodiment shown in Fig.2 each of the first and second high pressure preheaters 31, 32 is heated with steam extracted from the steam circuit via steam extraction lines 12 taken from the last stage of the high pressure steam turbine 6/ cold reheat line 10a and an intermediate stage of the high pressure steam turbine 6 respectively. The extracted steam is directed through the shell sides of the first high-pressure heater 31 and the second high pressure preheater 32 while boiler feed water is directed through the tube side.

[0033] In an exemplary embodiment shown in Fig. 2 both the first and second high pressure preheaters includes a desuperheater section 31 a, 32a configured to remove at least some of the superheat from extraction steam, a condensing section 31 b, 32b wherein extraction steam is condensed, and a drain cooler section 31 c, 31 c where condensed extraction steam is cooled below its saturated temperature. The configuration and presence of the desuperheater section 31 a, 32a and the drain cooler section 31 c, 32c is dependent on the actual configuration of the steam plant to which the invention is applied, including whether or not extraction steam includes superheat.

[0034] In an exemplary embodiment a drain line 14 connects the drain cooler section 32c of the second high pressure preheater 32 to the condensing section 31 b of the first high pressure preheater 31. In another exemplary embodiment where the second high pressure preheater 32 does not include a drain cooler section 32c, the drain line 14 connects the drain cooler section 32c of the second high pressure preheater 32 to the condensing section 31 b of the first high pressure preheater 31. Both of these embodiments include a valve 35 in the drain line 14, for isolating or at least limiting the flow of condensed extraction steam from the second high pressure preheat-

er 32 to the first high pressure preheater 31, and a further drain line 15 that branches from the drain line 14 upstream of the valve 35 and is further connected to the cold reheat line 10a. The further drain line 15 also includes a valve 34.

[0035] In an exemplary embodiment a load jump case where output need to be increased, The valve 35 of the first drain line is at least partially closed while the valve 34 of the further drain line 15 is opened thus send extraction steam condensate from the second high pressure preheater 32 to cold reheat line. The result is that condensed extraction steam mixes with cold reheat flow reducing the temperature of the cold reheat steam while increasing its mass flow with the added condensate. As result energy can be can be extracted in the reheater 4 thus providing a load jump.

[0036] Although suitable embodiments of the invention may be applied to the power plant PP shown in Fig. 1 embodiments may be applied to other power plants PP having the same basic power plant configurations comprising a boiler 2 having a superheater 3 and reheater 4, a steam turbine train having a high pressure steam turbine stage 6 and subsequent lower pressure steam turbine stage 7,8 and a feedwater preheat system comprising one or more low pressure preheaters 21, 22, 24, 25, a feedwater tank 30 and at least two high pressure preheaters 31, 32. As such the presently disclosed embodiments are therefore considered in all respects to be illustrative and not restricted. The scope of the disclosure is indicated by the appended claims rather than the foregoing description and all changes that come within the meaning and range and equivalences thereof are intended to be embraced therein.

REFERENCE NUMBERS

[0037]

2	boiler	
3	superheater	
4	reheater	
6	steam turbine high pressure stage	
7	steam turbine medium pressure stage	
8	steam turbine low pressure stage	
9	boiler feedwater line	
10	reheat line	
10a	cold reheat line	
11	shaft	
12	extraction line	
14,15	drain line	
21,22,24,25	low pressure preheaters	
30	feedwater tank	
31,32,33,34	high pressure preheaters	
31a,32a	desuperheater of a high pressure preheater	
31b,32b	condenser of a high pressure preheater	
31c,32c	drainer cooler of a high pressure preheater	

34,35 valve

Claims

1. A power plant (PP) having a water cycle and a steam cycle, wherein the steam water cycle comprises:

a first high pressure preheater (31); and
a second high pressure preheater (32) down of the first high pressure preheater (31),

a steam cycle comprising:

a boiler (2), with a reheater (4) and a superheater;
a high pressure steam turbine (6), downstream of the superheater, configured to expand the steam so as to extract energy from the steam; and
a cold reheater line connected to the high pressure steam turbine (6) to the reheater (4),

wherein the power plant (PP) further comprises;

an extraction steam line (12a) connected to the high pressure steam turbine (6) and the second high pressure preheater (32), for providing a first extraction steam into the second high pressure preheater (32); and
a condensate drain line (14) connected to the second high pressure preheater (32) and the first high pressure preheater (31) configured and arranged to direct a condensed first extraction steam into the first high pressure preheater (31); and

characterised by:

a first valve (35) in the condensate drain line (14) for at least partially restricting flow from the second high pressure preheater (32) to the first high pressure preheater (31); and
a line (15) connected to the condensate drain line (14) upstream of the first valve (35) and the cold reheater line (10a).

2. The power plant of claim 1 wherein the extraction line is connect ed to an intermediate stage of the high pressure steam turbine (6).

3. The power plant of claim 1 or 2 wherein the line (15) includes a valve (36) for isolating the cold reheat line (10a) from the condensate drain line (14).

4. The power plant of any one of claims 1 to 3, wherein:
the second high pressure preheater (32) in-

cludes:

a desuperheater section (32a) configured and arranged to remove superheat from extraction steam; 5
 a condenser section (32b) configured and arranged to condense extraction steam; and
 a drain cooler section (32b) configured and arranged to cool condensed extraction steam, 10

the first high pressure preheater (31) includes:

a desuperheater section (31 a) configured and arranged to remove superheat from extraction steam; and 15
 a condenser section (31 b) configured and arranged to condense extraction steam, 20

the drain line is connected between the drain cooler section (32b) of the second high pressure preheater (32) and the condenser section (31 b) of the first high pressure preheater (31). 25

5. A method for operating a steam plant comprising the steps of:

a) providing a steam plant with a steam cycle and a water cycle; 30
 b) condensing a steam extracted from the steam cycle against boiler feed water; and
 c) directing at least a portion of condensed extraction steam into a cold reheat line between a steam turbine (6) and a reheater (4). 35

6. The method of claim 5 wherein step a) comprises providing the steam plant of any one of claims 1 to 4.

7. The method of claim 6 wherein step b) is realised using the extraction steam line (12a). 40

8. The method of claim 6 or 7 wherein step b) is realised using the second high pressure preheater (32). 45

9. The method of any one of claims 6 to 8 wherein step c) further includes stopping the condensed extraction steam to the first high pressure preheater (31) using the first valve (15). 50

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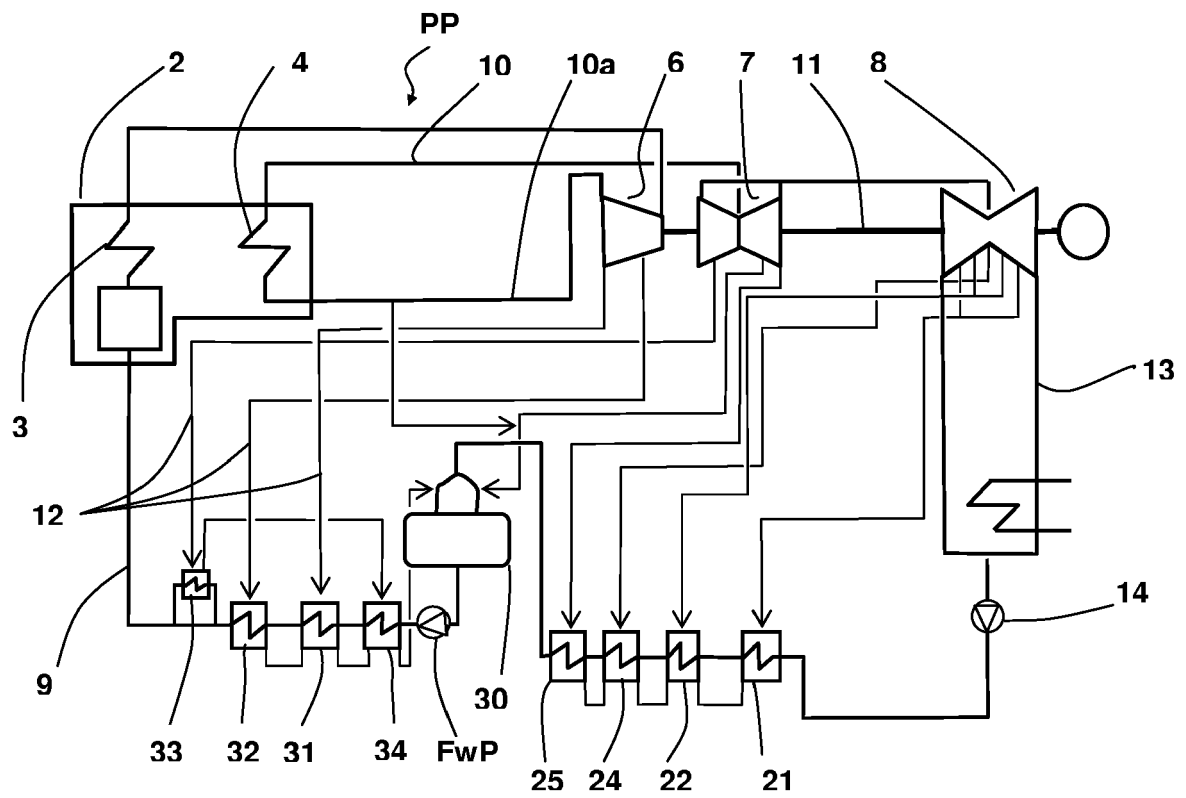


FIG. 1 (Prior Art)

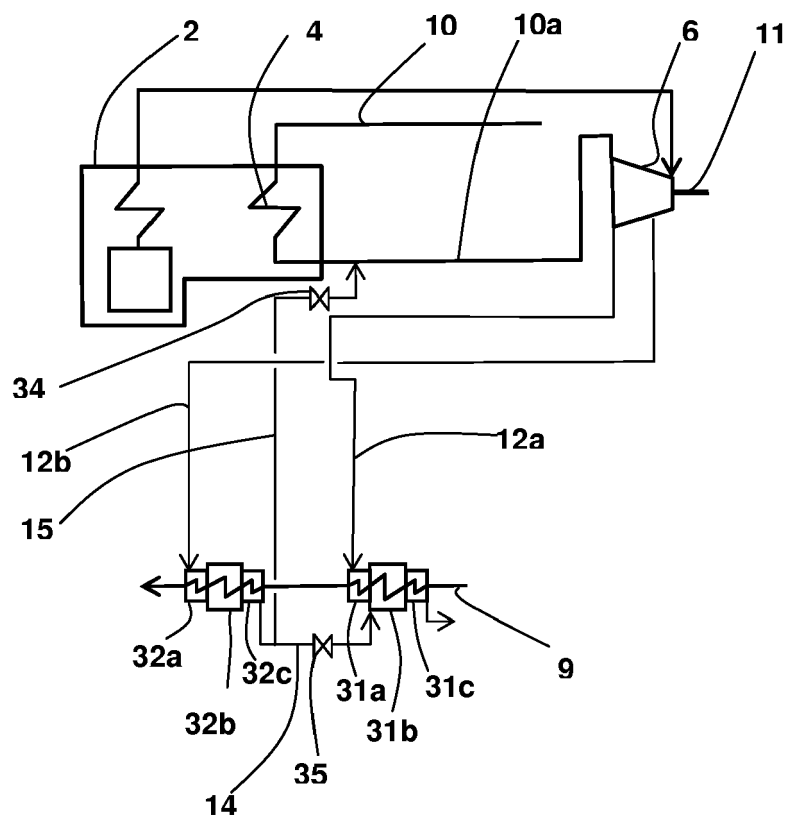


FIG. 2



EUROPEAN SEARCH REPORT

Application Number
EP 16 16 8817

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Place of search Munich		Date of completion of the search 13 October 2016	Examiner Zerf, Georges
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03/02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 16 16 8817

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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