(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 963 252 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**06.01.2016 Bulletin 2016/01**

(51) Int Cl.:
***F01K 9/00*** *(2006.01)*

(21) Application number: **15175173.2**

(22) Date of filing: **03.07.2015**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA ME**
Designated Validation States:
**MA**

(30) Priority: **03.07.2014 FI 20145646**

(71) Applicant: **ÅF-Consult Oy**
**02600 Espoo (FI)**

(72) Inventor: **Raiko, Markku**
**deceased (FI)**

(74) Representative: **Papula Oy**
**P.O. Box 981**
**00101 Helsinki (FI)**

# (54) METHOD AND APPARATUS FOR IMPROVING THE EFFICIENCY OF ELECTRICITY PRODUCTION IN A STEAM POWER PLANT

(57) In a water/steam circuit of a steam power plant, exhaust steam from a steam turbine (3) is condensed and heat that is released during condensation is removed cyclically from the water/steam circuit by means of cooling medium batches in such a way that a cooling medium batch that is used during each cooling cycle is allowed to heat up from an initial temperature to a final temperature and is then replaced with another cooling medium batch at an initial temperature. As a result, the electrical power produced by the steam power plant increases relative to a condensation process in which the temperature of the cooling medium that flows into the condenser is continuously constant. The apparatus comprises one or more cooling medium reservoirs (6a, 6b, 6c), means (10, 10a, 10b, 10c) for feeding exhaust steam into the cooling medium reservoirs (6a, 6b, 6c), means (8, 11, 11a, 11b, 11c) for feeding heated cooling medium from the cooling medium reservoirs (6a, 6b, 6c) into a cooler (9), and means (12, 12a, 12b, 12c) for returning the cooling medium from the cooler (9) back into the cooling medium reservoirs (6a, 6b, 6c).

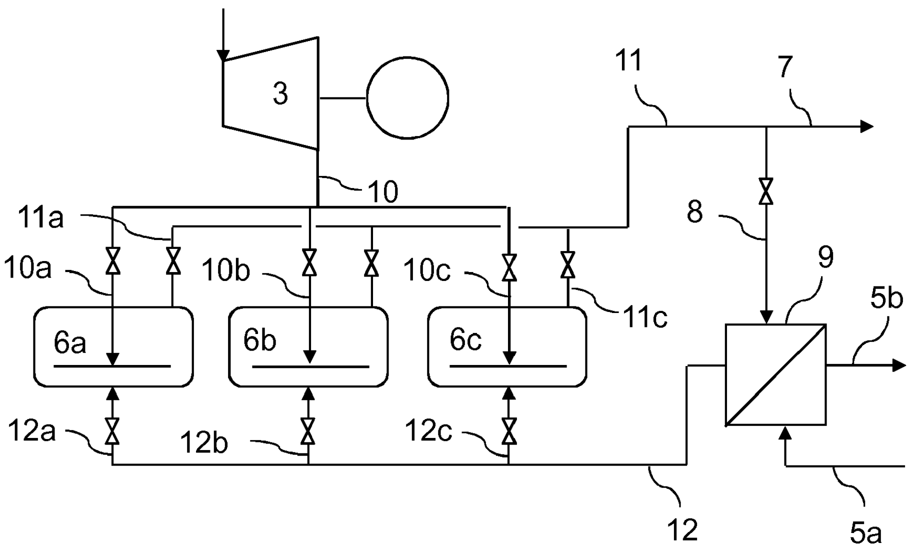


FIG. 3

EP 2 963 252 A1

## Description

### FIELD OF THE INVENTION

**[0001]** The invention relates to a method for improving the efficiency of electricity production in a steam power plant, wherein exhaust steam from a steam turbine is condensed in a water/steam circuit prior to returning the condensate water as feedwater into a steam generator.

**[0002]** The invention also relates to an apparatus for condensing exhaust steam from a steam turbine and for extracting the heat released as the steam is being condensed from a water/steam circuit of a steam power plant.

### BACKGROUND OF THE INVENTION

**[0003]** The operation of a steam power plant is based on a steam power process. A steam power process is a thermodynamic cycle process where the medium is water. The water/steam circuit of the cycle process comprises four stages, namely increase of feedwater pressure with a pump 1, steam generation from water in a steam boiler 2, expansion of the steam obtained in a steam turbine 3, and condensation of expanded steam in a condenser 4 by means of cooling water 5 (Fig. 1). The condensed water is returned as feedwater to the first stage of the cycle process.

**[0004]** The efficiency of a steam power process can be defined by means of theoretical isothermal cycle process efficiency, i.e. Carnot efficiency, which gives the electrical efficiency of a cycle process as a function of heat input and heat output temperatures. The heat input temperature is the temperature of steam before the turbine and the heat output temperature is the condensation temperature of the steam after the turbine.

$$\eta_{Carnot} = 1 - (T_{condensation} / T_{heat\ input})$$

**[0005]** In the prior art it is known to condense exhaust steam from a steam turbine with cooling water which heats up as it continually flows through a condenser as shown in Fig. 2. The aim is to condense the exhaust steam of a steam turbine at the lowest temperature possible, because lowering the condensation temperature reduces the condensation pressure of the steam. Lowering the pressure level of exhaust steam from a steam turbine improves the efficiency of the steam turbine by increasing the inlet to outlet pressure ratio in the steam turbine, i.e. the so-called expansion pressure ratio. In the condenser, cooling is normally carried out using air or water at an ambient temperature.

**[0006]** In place of the cooling water, it is known per se to use district heating water, in which case all condensation heat can be utilized in district heating. District heating requires water that is hotter than the ambient temperature. Typically, the temperature of district heating water is 50-120 °C. Due to its higher condensation temperature, a steam power process that produces district heat has lower electricity production efficiency that a steam power plant that uses similar technology with the cooling medium at an ambient temperature. Typically, the difference of their efficiencies is of the order of approximately 25%.

**[0007]** Fig. 2 shows the temperature dependence in a typical condensation arrangement for exhaust steam of a steam turbine. In the figure, $T_1$ is the initial temperature of the cooling water, $T_2$ is the final temperature of the cooling water, and $T_3$ is the condensation temperature. The horizontal axis represents dimensionless power $\Phi$. For example, the temperature values in condensing power plants would be $T_1$ = 5°C, $T_2$ = 17°C and $T_3$ = 20°C. In district heating, the respective temperature values would be $T_1$ = 50°C, $T_2$ = 90°C and $T_3$ = 93°C.

**[0008]** In the conventional technical solutions, the condensers for exhaust steam of a steam turbine are stationarily operated process equipment devices in which the cooling medium and the steam to be condensed flow while being separated by a heat transfer surface.

**[0009]** In power plants, it is known per se to use mixing preheaters for preheating the feedwater by heating the feedwater in a feedwater reservoir with bled steam extracted from the steam turbine as it condenses in the water contained in the reservoir. Typically, one of the feedwater preheaters is a mixing preheater, i.e. a so-called feedwater reservoir, other preheaters being heat exchangers provided with a heat exchange surface. In addition to functioning as a preheater, the feedwater reservoir also functions as an outlet for uncondensed gases and as a feedwater storage tank. The functioning of the feedwater reservoir as a preheater is basically stationary.

### OBJECTIVE OF THE INVENTION

**[0010]** The objective of the invention is to reduce the condensation temperature of a steam power process and so to improve the efficiency of the steam power process. A specific objective is to improve the efficiency in the case where the residual heat from a steam power process is utilized in district heat production.

## DESCRIPTION OF THE INVENTION

**[0011]** The method according to the invention is characterized by the features presented in claim 1. Correspondingly, the apparatus according to the invention is characterized by the features presented in claim 9.

**[0012]** The present invention is based on an idea that the cooling power required for condensing exhaust steam from a steam turbine is provided from the condensing steam to the cooling medium flow in a batch-type manner. The cooling medium at an initial temperature is collected into batches or charges of a desired volume which are allowed to heat up from the initial temperature to a final temperature one batch at a time. Then, a cooling medium batch that has heated up to a final temperature is replaced with a new batch at an initial temperature. It is not necessary in the method to change the volume or the rise of temperature of the cooling medium used for cooling relative to the conventional condenser cooling. Advantage is gained because the power obtained from the steam turbine is increased during the stage where the temperature of a cooling medium batch is lower than the final temperature. As a result, the efficiency of the thermal power process is improved.

**[0013]** When the temperature of a cooling medium batch is lower than the final temperature of a cycle, the condensation temperature of exhaust steam decreases. By means of the invention, it is thus possible to decrease the average condensation temperature of exhaust steam during a cooling cycle. In accordance with the Carnot efficiency formula, the electrical power produced by a steam power plant increases when using the condensation method for exhaust steam according to the invention relative to the conventional method because the condensation temperature of the exhaust steam decreases. In the conventional condensation method, the input and output temperature of the cooling medium remain constant, so the condensation temperature for the steam turbine also remains constant.

**[0014]** It is not possible to gain the advantage described above in a feedwater reservoir that operates by means of bled steam, as the pressure of bled steam does not change when the pressure of the feedwater reservoir changes, but depends on the volume flow rate of the steam that flows in the turbine.

## LIST OF FIGURES

**[0015]** The invention will be described below by means of some of its preferred embodiments with reference to the accompanying drawing figures.

Fig. 1 is a functional diagram of a steam power process.
Fig. 2 is a chart illustrating the heating up of cooling water in a condenser of a prior art steam power process.
Fig. 3 is a diagrammatic illustration of a process which comprises three batch-operated condensate water reservoirs.
Fig. 4a is a chart illustrating the heating up of cooling water at an initial stage of a batch-operated cooling cycle.
Fig. 4b is a chart illustrating the heating up of cooling water at an intermediate stage of a batch-operated cooling cycle.
Fig. 4c is a chart illustrating the heating up of cooling water at a final stage of a batch-operated cooling cycle.
Fig. 5 is a chart illustrating electrical power as a function of time using the conventional ($P_1$) and the inventive ($P_2$) condensation system for exhaust steam of a steam turbine.
Fig. 6 is a diagrammatic illustration of a process which comprises two batch-operated condensate water reservoirs.
Fig. 7 is a diagrammatic illustration of a process which comprises one condensate water reservoir with a number of steam discharge points at different heights.
Fig. 8 is a diagrammatic illustration of a process which comprises a conventional condenser for exhaust steam and two batch-operated cooling medium reservoirs for cooling the cooling medium that circulates through the condenser.

## DETAILED DESCRIPTION OF THE INVENTION

**[0016]** Fig. 3 shows one embodiment of the apparatus according to the invention, comprising three batch-operated condensate water reservoirs 6a, 6b, 6c where exhaust steam from a steam turbine 3 is condensed into condensate water contained in said reservoirs, and a cooler 9 where heat contained in the condensate water is transferred to a cooling medium through a heat transfer surface. The system also comprises pipelines 10, 10a, 10b, 10c for feeding exhaust steam from the steam turbine 3 at a time into each of the condensate water reservoirs 6a, 6b, 6c below the fluid level, pipelines 11a, 11b, 11c, 11 and 8 for conveying water that has heated up during cooling of the condensate water from each of the condensate water reservoirs 6a, 6b, 6c at a time into the cooler 9, as well as pipelines 12, 12a, 12b, 12c for conveying water that has been cooled by the cooling medium from the cooler 9 at a time into each of the condensate water reservoirs 6a, 6b, 6c. Each pipeline is provided with necessary valves allowing the flow to be directed each time to a desired destination. The cooler 9 is connected to a source of a cooling medium (not illustrated) via pipelines 5a, 5b. For example, water or air can be used as the cooling medium. The system also comprises a pipeline 7 via which part of the water that has heated up in the condensate water reservoirs 6a, 6b, 6c can be conveyed as feedwater into a steam generator of a water/steam circuit.

**[0017]** Each of the three condensate water reservoirs 6a, 6b, 6c is used at a time for condensing exhaust steam from the steam turbine 3 in the following way.

**[0018]** At the beginning of a first cycle, the first condensate water reservoir 6a is full of cooled condensate water, the second condensate water reservoir 6b is full of condensate water that has heated up to a final temperature, and the third condensate water reservoir 6c is empty. The pipeline 10a that leads from the steam turbine 3 to the first condensate water reservoir 6a is opened, and the pipeline 10b that leads from the steam turbine 3 to the second condensate water reservoir 6b is closed. At the same time, emptying of the second condensate water reservoir 6b is started by opening the pipeline 11b that leads from the second condensate water reservoir 6b to the cooler 9. The condensate water that has heated up in the second condensate water reservoir 6b is cooled in the cooler 9 by means of a cooling medium flow. The cooled condensate water is conveyed from the cooler 9 into the third condensate water reservoir 6c along pipeline 12c.

**[0019]** During a second cycle, exhaust steam from the steam turbine 3 is conveyed via pipeline 10c into the third condensate water reservoir 6c containing water that has been cooled to an initial temperature $T_1$ and, from the first condensate water reservoir 6a, water that has heated up to a final temperature $T_2$ is conveyed via pipeline 11a into the cooler 9. In the cooler 9, the condensate water is cooled back to an initial temperature $T_1$, after which the cooled condensate water is conveyed into the second condensate water reservoir 6b via pipeline 12b.

**[0020]** During a third cycle, exhaust steam from the steam turbine 3 is conveyed via pipeline 10b into the second reservoir 6b which, at the beginning of the cycle, is full of water that has been cooled to an initial temperature $T_1$. At the same time, the water in the third reservoir 6c is conveyed via pipeline 11c into the cooler 9 and further, when cooled to an initial temperature $T_1$, into the first condensate water reservoir 6a via pipeline 12a.

**[0021]** After this, the first, the second and the third cycles are repeated in the above described order. The cooling medium that flows in pipelines 5a, 5b can be for example sea water or district heating water.

**[0022]** Fig. 4a, 4b and 4c illustrate the condensation temperature as a function of dimensionless power $\Phi$ at different stages of batch-type cooling when condensing exhaust steam from a steam turbine. At the beginning of a cooling cycle (Fig. 4a), the condensation temperature $T_3$ is the same as the initial temperature $T_1$ of the cooling water. Fig. 4b illustrates a point where approximately half of the time used for heating a cooling medium batch has passed. Fig. 4c illustrates a situation reached at the end of a batch-specific stage. At this stage, the final temperature $T_2$ of the cooling medium corresponds to the condensation temperature $T_3$ that is possible to reach by applying the prior art condenser cooling.

**[0023]** Fig. 5 illustrates the additional power gained by the method according to the invention, which is possible to be produced by a steam power process. The straight $P_1$ represents power that can be produced in a steam power process carried out with the conventional cooling method. The saw tooth pattern $P_2$ represents power that can be produced in a steam power plant that operates according to the inventive principle. When using batch cooling, the additional power is cyclically time-dependent. Momentarily, the additional power ($P_2$-$P_1$) is reduced to nil but, most of the time, additional power is obtainable. Thus, advantage is gained as a greater amount of electrical energy produced. In steam power processes for producing district heat, it is possible to significantly increase, on an annual level, the amount of electricity produced through back-pressure production, for example for 5-20 %, due to the improved power to heat ratio.

**[0024]** In the production of district heat, it is known to store district heating water in a reservoir where hot district heating water is situated in the upper part of the reservoir and cold district heating water in the lower part of the reservoir. For these types of water, the density and viscosity differences arising from their temperature difference are sufficient to prevent the water from being mixed in the reservoir. Heat exchange between the layers of water is quite small. The height of the boundary layer between the hot and cold layers of water is typically approximately 30 cm.

**[0025]** Fig. 6 shows another embodiment of the invention using alternately two condensate water reservoirs 6a, 6b. In this apparatus, exhaust steam from the steam turbine 3 is cyclically conveyed into either of the two reservoirs 6a, 6b that contain cooled condensate water. A portion of heated condensate water that corresponds to the condensate quantity of the exhaust steam from the steam turbine 3 is conveyed as feedwater for a steam power process via pipeline 7. Most of the condensate water that has heated up in the reservoir 6a or 6b is returned cyclically via pipeline 8 and the cooler 9 into either of the reservoirs 6a or 6b.

**[0026]** During a first cycle, the first condensate water reservoir 6a is full of cooled condensate water. The pipeline 10a that leads from the steam turbine 3 to the first reservoir 6a is opened and the pipeline 10b that leads from the steam turbine 3 to the second reservoir 6b is closed. At this stage, the condensate water contained in the second reservoir 6b has heated up to a final temperature $T_2$, and its cooling is started by conveying the water into the cooler 9 via pipeline 11b. The heated condensate water is cooled in the cooler 9 with the cooling medium and returned to the bottom of the first condensate water reservoir 6a. Finally, the pipeline 12b that leads from the cooler 9 to the second condensate water reservoir 6b is opened and the pipeline 12a that leads to the first condensate water reservoir 6a is closed. The water from the second condensate water reservoir 6b is circulated, after having been cooled by the cooler 9, to the bottom of the second reservoir 6b. The mixing of water with the hot water situated in the upper part of the reservoir is prevented in the same way as in thermal accumulators designed for storing district heat. At the same time as the water of the first reservoir 6a heats up, the boundary surface between cold and hot water in the second reservoir 6b rises until it reaches the upper limit of the reservoir 6b.

**[0027]** During a second cycle, exhaust steam from the steam turbine 3 is conveyed into the second condensate water reservoir 6b and water from the first condensate water reservoir 6a is conveyed into the cooler 9 via pipeline 11a.

**[0028]** Fig. 7 shows an embodiment of the invention that is based on one condensate water reservoir 6. The operation of the method is based on circulating heated condensate water from the upper part of the reservoir 6 via the cooler 9 into the lower part of the reservoir 6. Exhaust steam from the steam turbine 3 is conveyed into the reservoir 6 through a distribution system 18 comprising a number of different discharge points at different heights of the reservoir. The discharge height of the steam from the distribution system 18 can be adjusted to the rate at which the surface of cold water in the tank 6 rises due to the circulation of cooled water. The cooling medium batch above the discharge point remains isothermal due to internal mixing arising from the density differences, i.e. natural circulation. For the same reason, the hot water in the upper part of the reservoir 6 is not mixed with the total volume of water in the batch. When the temperature at the discharge point of the steam rises to the level of the steam exhaust temperature, the discharge point of the steam is moved to the next lower start level for using a new cooling water batch.

**[0029]** The number of condensate water reservoirs may be, instead of one, two or three reservoirs described hereinabove, any other number by which similar cyclic condensation of exhaust steam from a steam turbine is possible to carry out.

**[0030]** The condensation of exhaust steam from a steam turbine can also be carried out indirectly using the conventional condensation construction, wherein the cooling water circulation connected to a batch-operated condensate water reservoir has a greater heat capacity flow than the stationary heat capacity flow of the cooling water. The reservoir can in this case be for example a district heat accumulator.

**[0031]** Fig. 8 shows an embodiment of the invention wherein exhaust steam from the steam turbine 3 is conveyed into the conventional steam turbine condenser 4. The batch-operated feature in use of the cooling medium can be implemented by alternately cooling, with a continuously operated cooler 9, the water in the reservoirs 6a and 6b, so that the hot water is discharged from the upper part of the reservoir 6a, 6b via pipeline 11 and returned to the lower part of the reservoir 6a, 6b via pipeline 12 by means of a pump 15. During the same cycle, the water of the second reservoir 6a, 6b is circulated via the condenser 4 by means of a pump 16 and pipelines 14, 17. If the pumped volume of the cooling medium is greater in the flow circuit of the condenser 4 than in the flow circuit of the cooler 9, the efficiency advantage of batch-type cooling can be gained at least in part due to instantaneous decrease of the average condensation temperature.

**[0032]** In the batch-type condensation of exhaust steam from a steam turbine, the duration of one cycle can be a few minutes or several hours. Regarding the operation of the steam turbine, the time constant for the cycles may vary rather freely.

**EXAMPLE**

**[0033]** In district heat production, the condensation temperature for the steam of a steam turbine is, when applying the prior art approach, 100°C and the return temperature of the district heat is 50°C. Using the method according to the invention, it is possible to reduce the average final pressure for a steam turbine from approximately 1 bar to approximately 0.5 bars ($t_{saturated}$ = 75°C). An increase of approximately 20% is gained in the production of electrical energy.

**[0034]** By means of the invention, it is thus possible to increase the amount to which electrical energy can be produced. The invention causes cyclical variation in the electrical power. However, this does not cause problems when electricity is produced for a grid where variations in the production are compensated for.

**Claims**

1. A method for improving the efficiency of electricity production in a steam power plant by reducing the condensation temperature, wherein exhaust steam from a steam turbine (3) is condensed in a water/steam circuit of the steam power plant prior to returning the condensate water as feedwater into a steam generator (2), **characterized in that** heat that is released due to condensation of the exhaust steam is cyclically removed from the water/steam circuit by means of cooling medium batches in such a way that a cooling medium batch used during each cooling cycle is allowed to heat up from an initial temperature ($T_1$) to a final temperature ($T_2$), after which it is replaced with another cooling medium batch at an initial temperature ($T_1$), so that the electrical power ($P_2$) produced by the steam power plant increases relative to a condensation process in which the temperature of the cooling medium that flows into the condenser is continuously constant.

2. The method according to claim 1, **characterized in that**, during the period of time that passes for heating a cooling medium batch, the steam flow that enters the steam turbine (3) and the cooling medium flow used for removing the heat released from the exhaust steam remain invariably constant or their mutual relationship remains invariably

constant.

3. The method according to claim 1 or 2, **characterized in that** the exhaust steam from the steam turbine (3) is condensed in one or more reservoirs (6, 6a, 6b, 6c) that are filled with a cooling medium by mixing the exhaust steam with the cooling medium in the reservoir (6, 6a, 6b, 6c).

4. The method according to any one of the preceding claims, **characterized in that** the exhaust steam from the steam turbine (3) is conveyed into a reservoir (6) that is filled with a cooling medium and that comprises means (18) for selecting the feeding height for the exhaust steam.

5. The method according to any one of the preceding claims, **characterized in that** the exhaust steam from the steam turbine (3) is condensed by transferring heat from the exhaust steam into a cooled condensate water batch cooled by means of a cooling medium.

6. The method according to claim 5, **characterized in that** the exhaust steam from the steam turbine (3) is condensed in a condenser (4) that is cooled by means of cyclically varying cooling medium batches.

7. The method according to claim 5, **characterized in that** the heat capacity flow of the cooling medium flow that circulates in the cooling of the condenser (4) is greater than the heat capacity flow of the cooling flow that is transferred from the cooling medium batches out of the power plant via the cooler (9).

8. The method according to any of the preceding claims, **characterized in that** the heat that is released in the condensation and cooling of the exhaust steam from a steam turbine is used as district heat or industrial process heat.

9. An apparatus for condensing exhaust steam from a steam turbine (3) and for transferring heat that is released during condensation of the steam out from a water/steam circuit of a steam power plant, **characterized in that** the apparatus comprises:

   - one or more cooling medium reservoirs (6, 6a, 6b, 6c),
   - means (10, 10a, 10b, 10c, 17) for feeding exhaust steam or cooling medium that carries the heat released from the exhaust steam into each of said cooling medium reservoirs (6, 6a, 6b, 6c),
   - means (8, 11, 11a, 11b, 11c) for feeding heated cooling medium from each cooling medium reservoir (6, 6a, 6b, 6c) into a cooler (9),
   - means (12, 12a, 12b, 12c) for conveying cooled cooling medium from the cooler (9) back into the cooling medium reservoirs (6, 6a, 6b, 6c),

   the apparatus being arranged to operate cyclically in such a way that each cooling medium batch that is being used during each cooling cycle is allowed to heat up from an initial temperature ($T_1$) to a final temperature ($T_2$), after which it is replaced with another cooling medium batch at an initial temperature ($T_1$), so that the electrical power ($P_2$) produced by the steam power plant increases relative to a condensation process in which the temperature of the cooling medium that flows into the condenser is continuously constant.

10. The apparatus according to claim 9, **characterized in that** between the steam turbine (3) and the reservoir (6) or reservoirs (6a, 6b, 6c) there are pipelines (10, 10a, 10b, 10c) for condensing exhaust steam by mixing the exhaust steam with a cooling medium.

11. The apparatus according to claim 9 or 10, **characterized in that** it comprises two or more cooling medium reservoirs (6a, 6b, 6c) used alternately in such a way that when one of the reservoirs (6a, 6b, 6c) is connected in flow contact with an outlet for exhaust steam of the steam turbine (3), at least one other reservoir (6a, 6b, 6c) is connected in flow contact with an inlet and/or outlet of the cooler (9).

12. The apparatus according to claim 9 or 10, **characterized in that** it comprises a cooling medium reservoir (6) provided with a distribution system (18) for adjusting the discharge point (18) of steam to correspond to the rate at which the cooling medium flow moves.

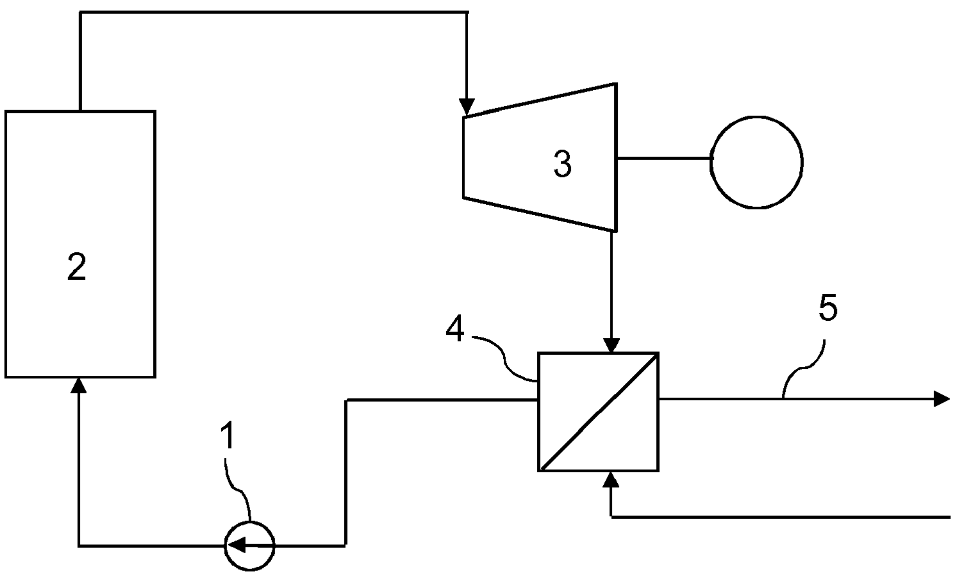


FIG. 1

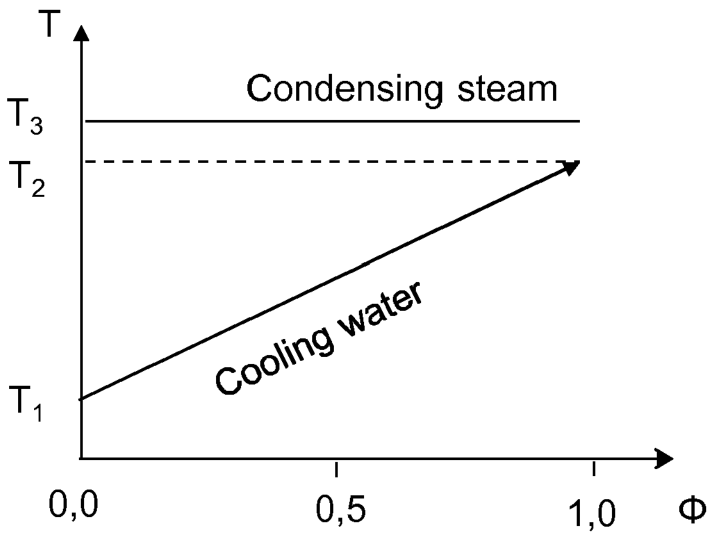


FIG. 2

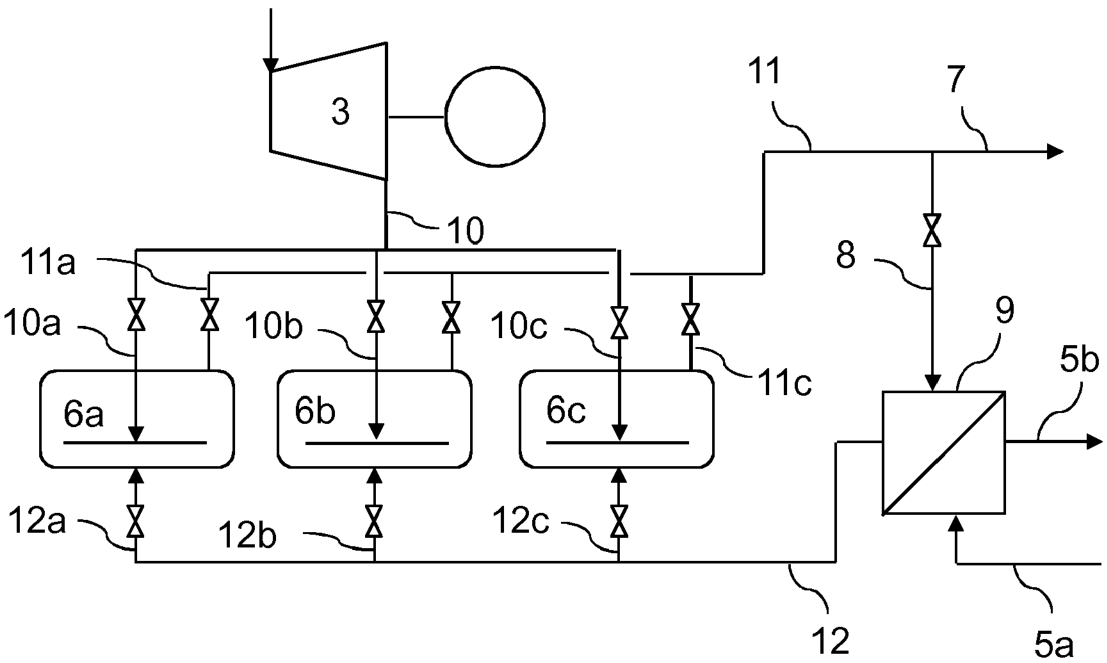
3
11
7
10
11a
8
10a
10b
10c
9
11c
5b
6a
6b
6c
12a
12b
12c
12
5a

FIG. 3

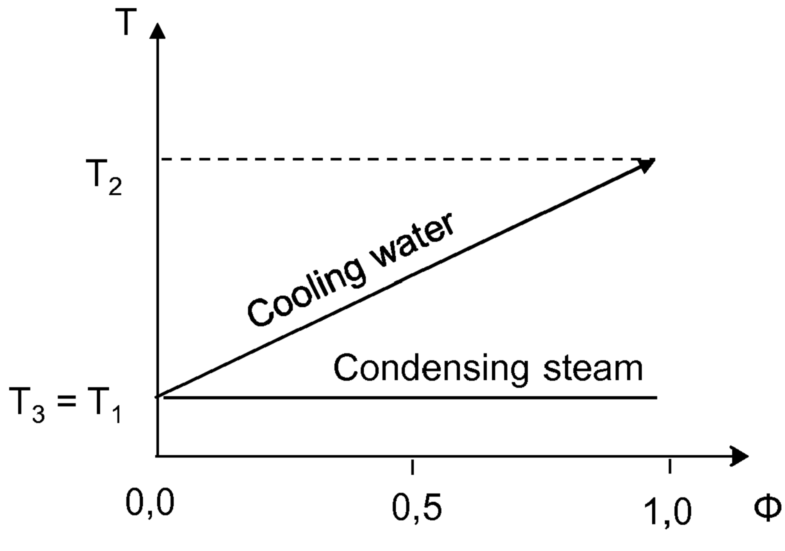
T
$T_2$
Cooling water
Condensing steam
$T_3 = T_1$
0,0
0,5
1,0
Φ

FIG. 4a

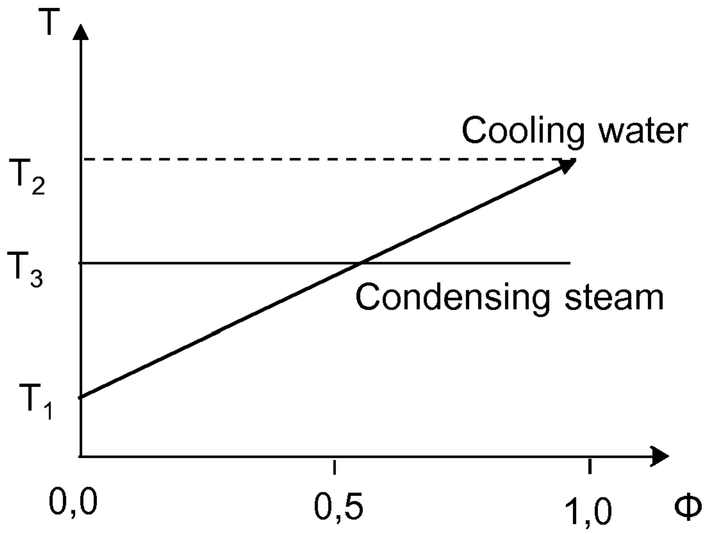
T
Cooling water
$T_2$
$T_3$
Condensing steam
$T_1$
0,0
0,5
1,0
Φ

FIG. 4b

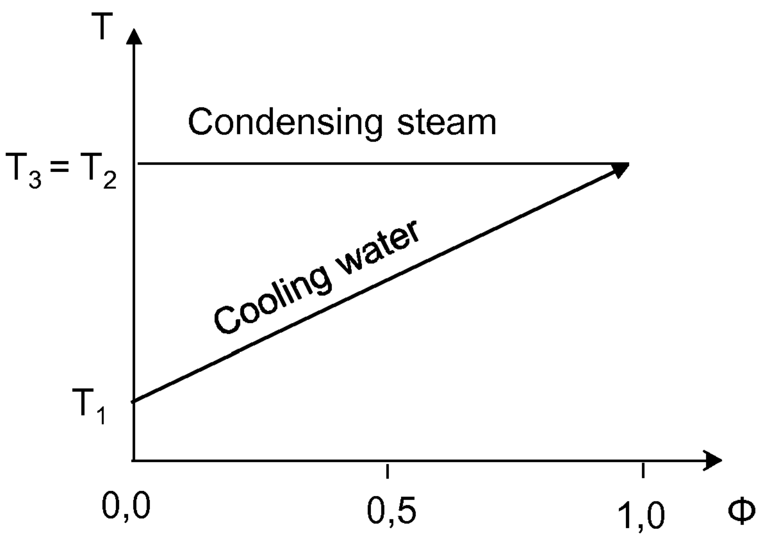
T
Condensing steam
$T_3 = T_2$
Cooling water
$T_1$
0,0
0,5
1,0
Φ

FIG. 4c

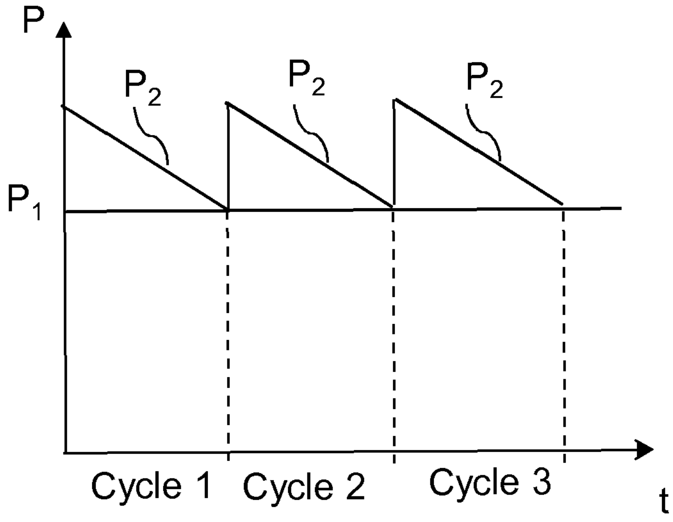
P
P2
P2
P2
P1
Cycle 1
Cycle 2
Cycle 3
t

FIG. 5

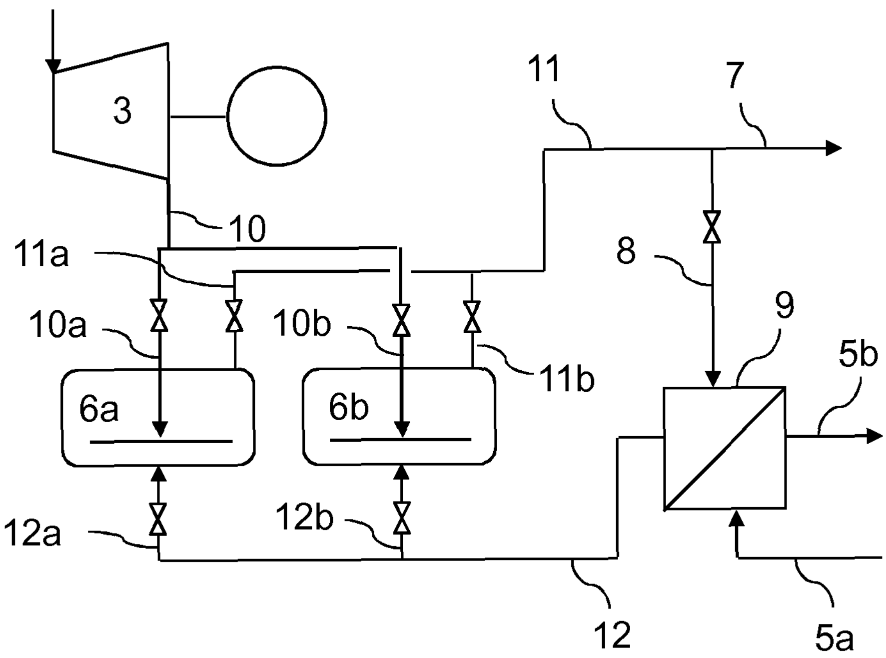
3
11
7
10
11a
8
10a
10b
9
11b
5b
6a
6b
12a
12b
12
5a

FIG. 6

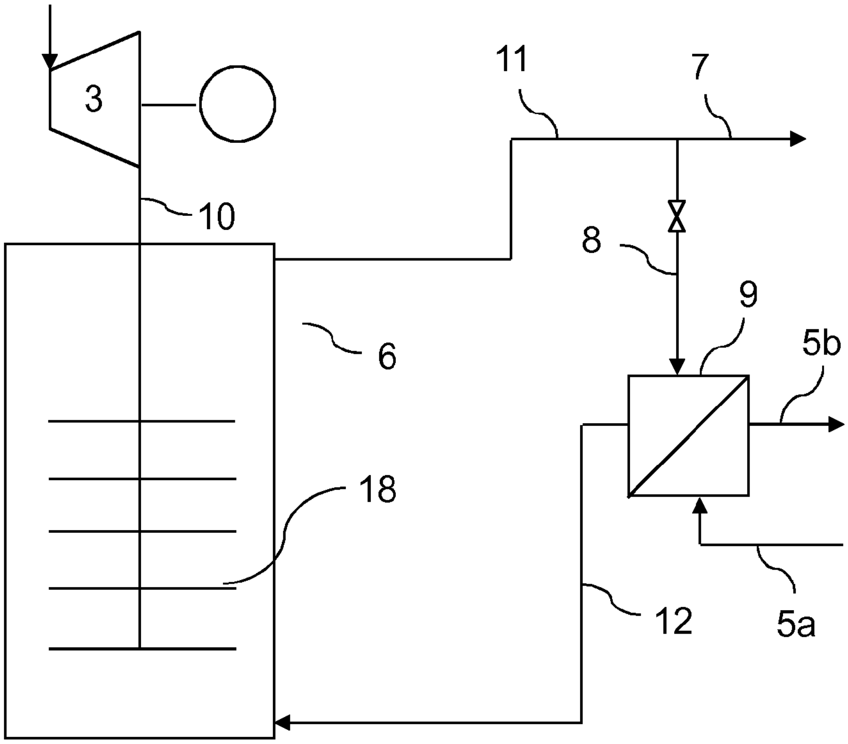


FIG. 7

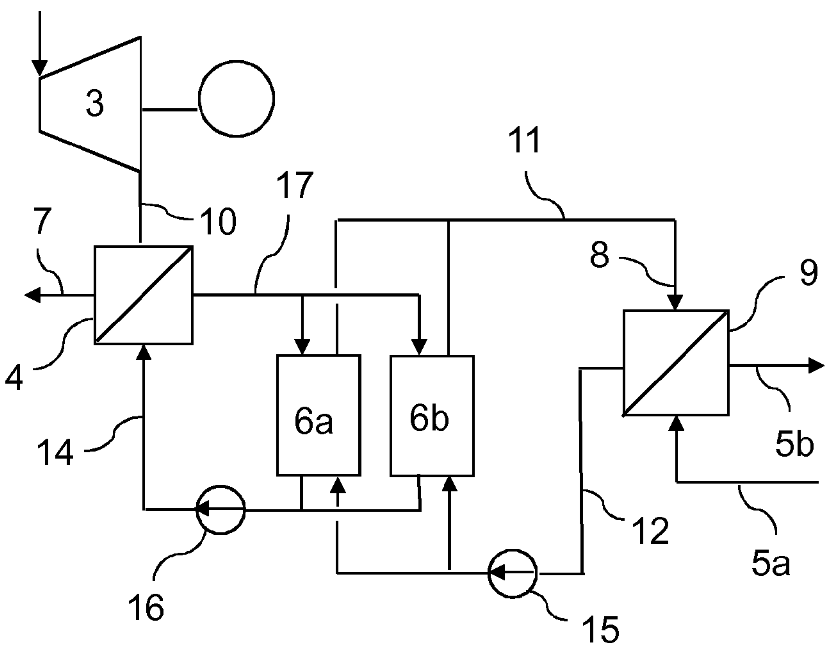


FIG. 8

Europäisches Patentamt
European Patent Office
Office européen des brevets

# EUROPEAN SEARCH REPORT

Application Number
EP 15 17 5173

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| A | US 2013/188939 A1 (JOURDAIN VINCENT [FR] ET AL) 25 July 2013 (2013-07-25)<br>* abstract; figures 2, 3 *<br>* paragraphs [0072] - [0096] *<br>----- | 1-12 | INV.<br>F01K9/00 |
| A | JP 2014 047675 A (MITSUBISHI HEAVY IND LTD) 17 March 2014 (2014-03-17)<br>* abstract; figures 1-5 *<br>* paragraphs [0034] - [0047] *<br>----- | 1-12 | |

TECHNICAL FIELDS SEARCHED (IPC)

F01K

The present search report has been drawn up for all claims

1

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 29 October 2015 | Varelas, Dimitrios |

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 03.82 (P04C01)

## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 15 17 5173

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

29-10-2015

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US 2013188939 A1 | 25-07-2013 | CN 103216818 A | 24-07-2013 |
| | | EP 2682568 A1 | 08-01-2014 |
| | | RU 2013102495 A | 27-07-2014 |
| | | US 2013188939 A1 | 25-07-2013 |
| JP 2014047675 A | 17-03-2014 | JP 2014047675 A | 17-03-2014 |
| | | PH 12014502770 A1 | 02-02-2015 |
| | | US 2015168022 A1 | 18-06-2015 |
| | | WO 2014034354 A1 | 06-03-2014 |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82