US 20120012280A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2012/0012280 A1**

(43) **Pub. Date: Jan. 19, 2012**

Gromoll

(54) **DEVICE AND METHOD FOR GENERATING STEAM WITH A HIGH LEVEL OF EFFICIENCY**

(76) Inventor: **Bernd Gromoll**, Baiersdorf (DE)

(21) Appl. No.: **13/138,700**

(22) PCT Filed: **Mar. 17, 2010**

(86) PCT No.: **PCT/EP2010/053432**

§ 371 (c)(1),
(2), (4) Date: **Sep. 20, 2011**

(30) **Foreign Application Priority Data**

Mar. 20, 2009 (DE) 10 2009 014 036.0

Publication Classification

(51) **Int. Cl.**
F28D 15/00 (2006.01)

(52) **U.S. Cl.** **165/104.21**

(57) **ABSTRACT**

Steam is produced from a working medium of a steam generator, e.g., a waste heat steam generator, a Kalina steam generator or an ORC steam generator, using a thermal generator mounted upstream from the steam generator. To evaporate the working medium, the steam generator uses a hot heat transmitting medium that is heated in the thermal generator before being supplied to the steam generator, thereby increasing the efficiency of the steam generator. The residual or waste heat of an industrial plant or a geothermal plant using geothermal energy is used, for example, as a heat source for the thermal generator

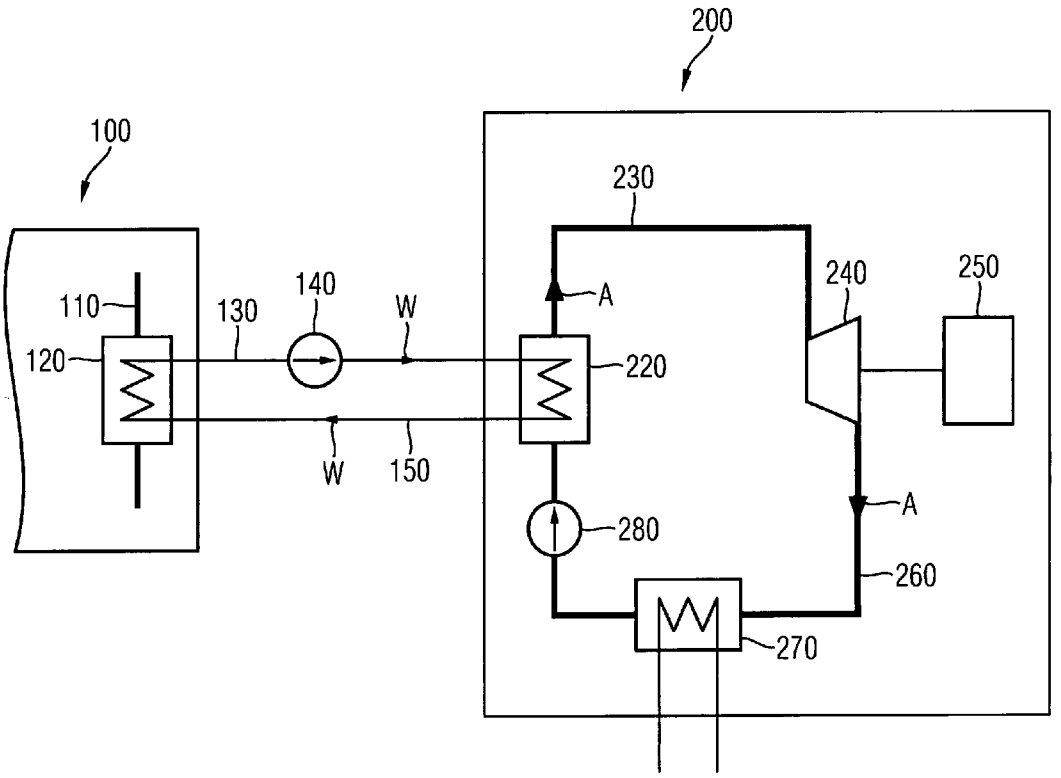


FIG 1

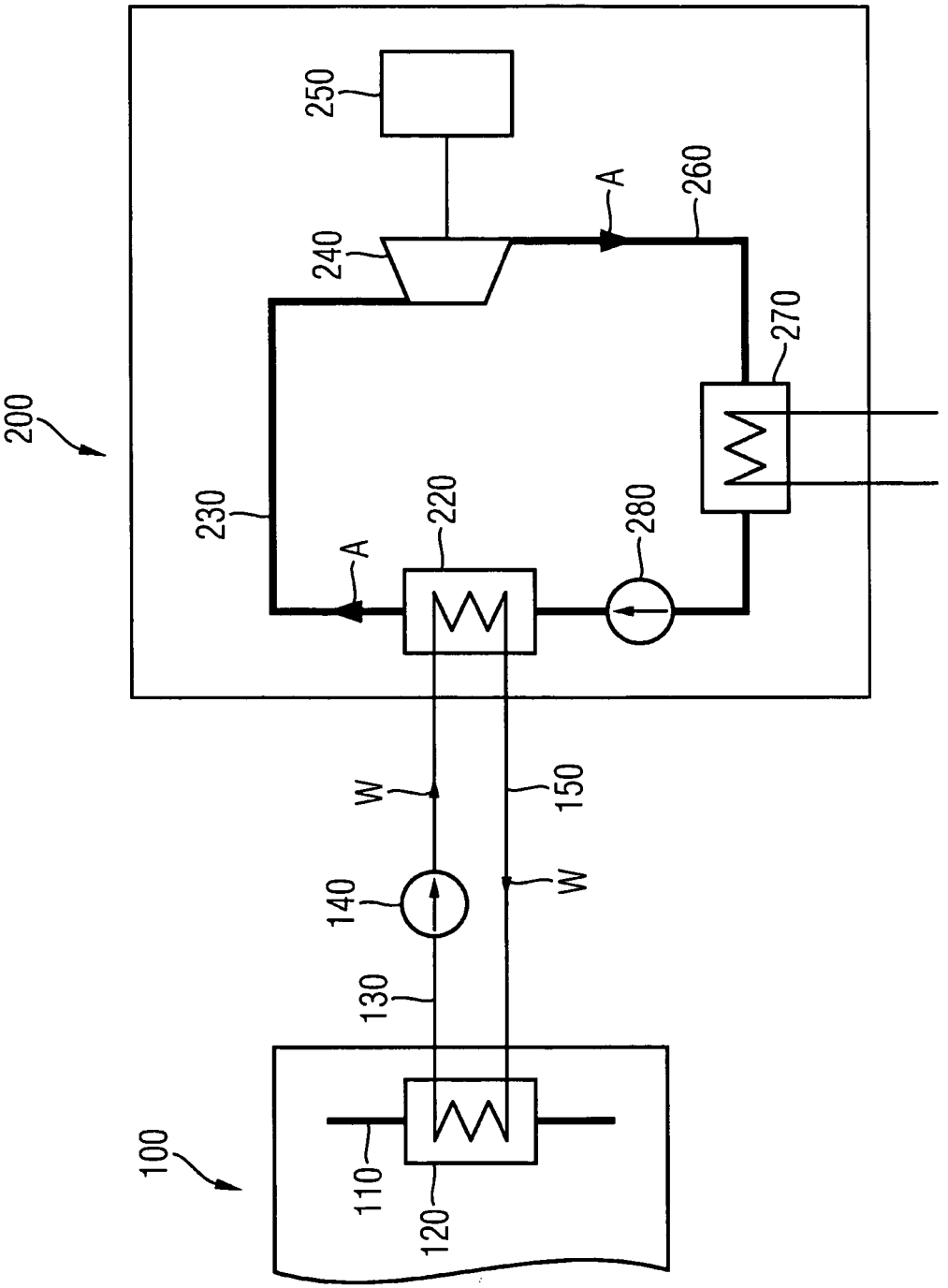


FIG 2

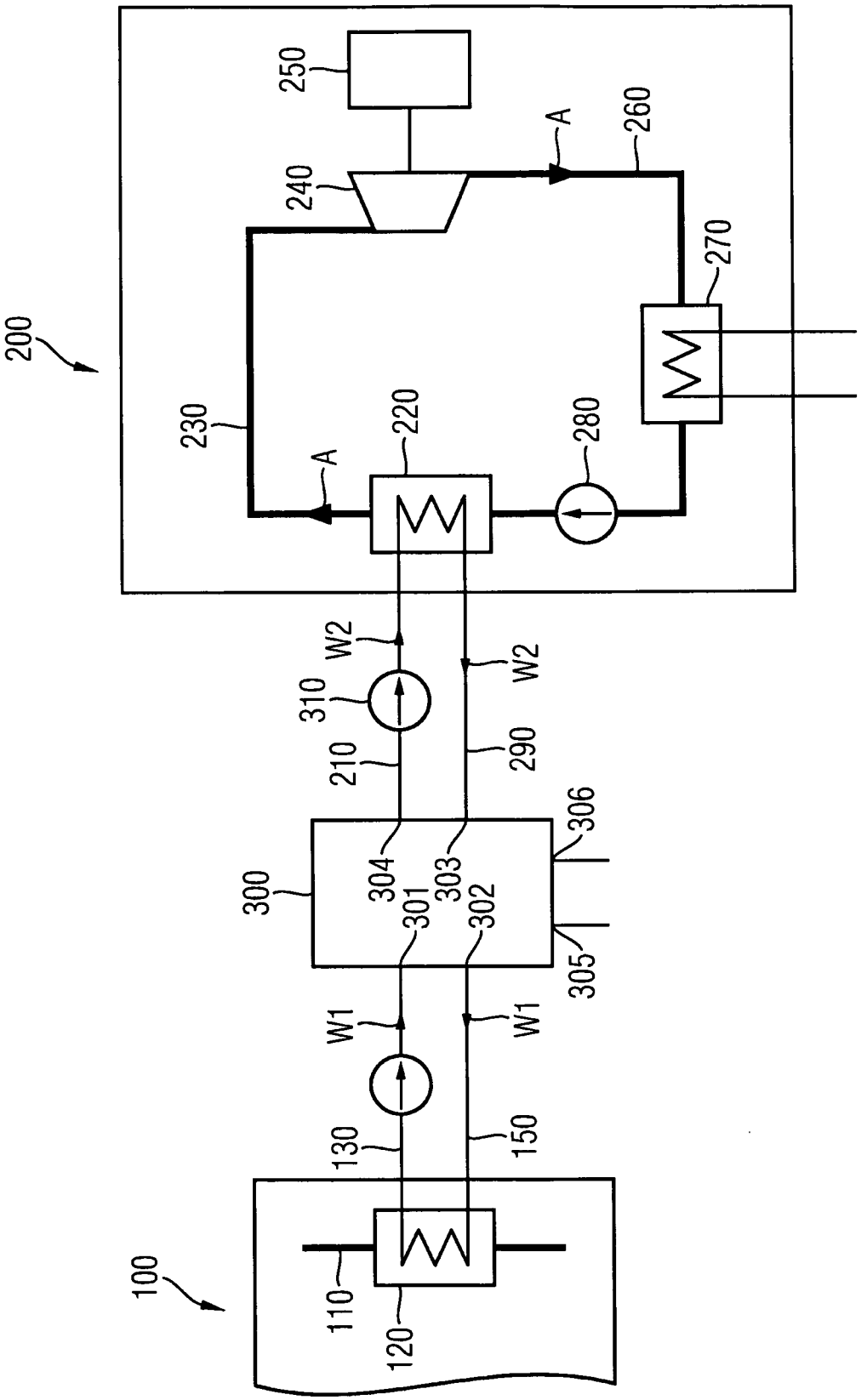
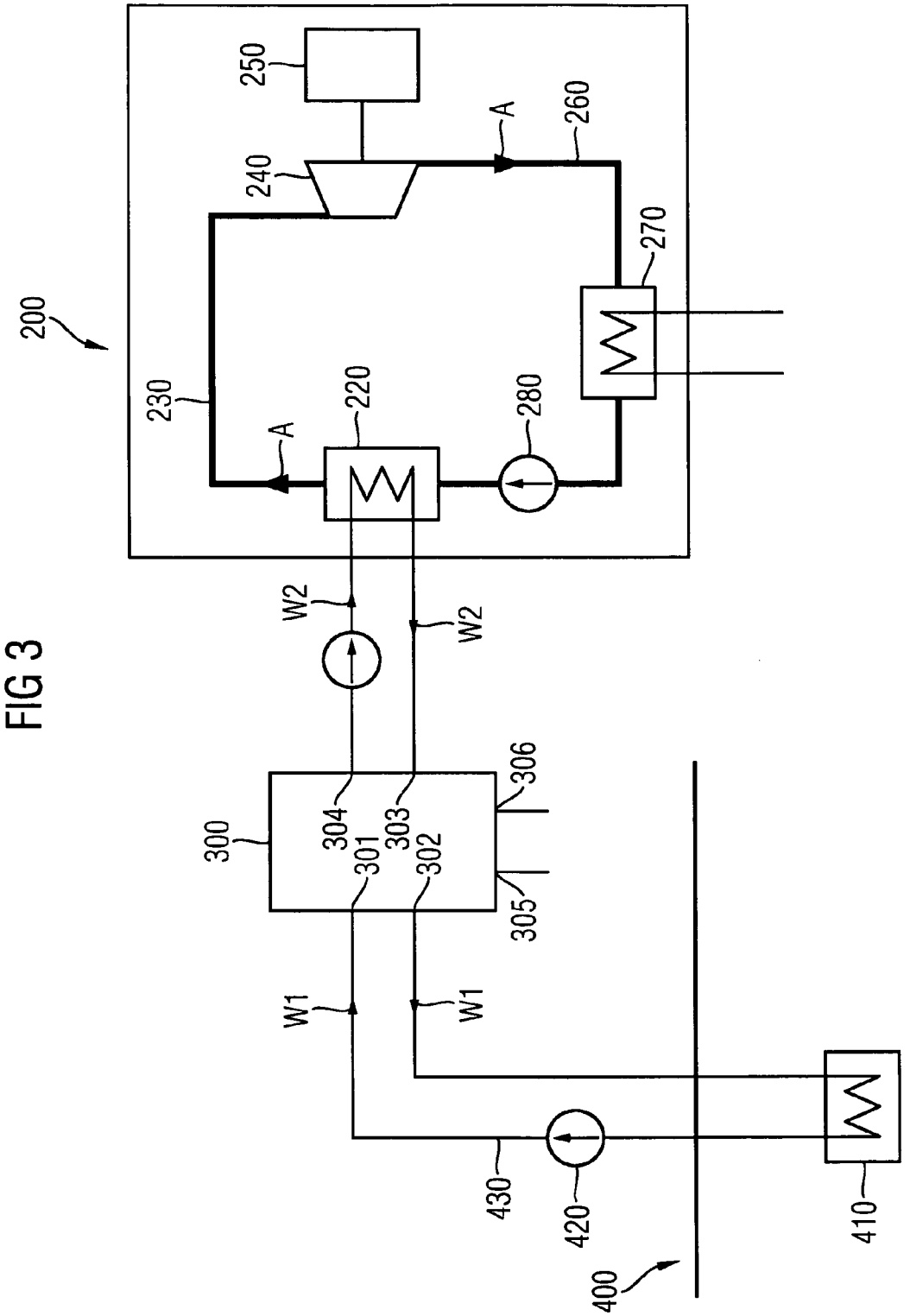

200
250
240
A
260
270
230
220
280
A
W2
310
W2
210
290
306
300
304
303
301
302
305
W1
W1
130
150
100
110
120

FIG 3


200
250
240
A
260
270
230
220
280
A
W2
W2
300
304
303
306
301
302
305
W1
W1
430
420
410
400

DEVICE AND METHOD FOR GENERATING STEAM WITH A HIGH LEVEL OF EFFICIENCY

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is the U.S. national stage of International Application No. PCT/EP2010/053432, filed Mar. 17, 2010 and claims the benefit thereof. The International Application claims the benefits of German Application No. 102009014036.0 filed on Mar. 20, 2009, both applications are incorporated by reference herein in their entirety.

BACKGROUND

[0002] Described below is the generation of steam in a steam generator using a thermal generator which is connected upstream to the steam generator.

[0003] In many industrial processes, such as in steelworks, cement works, in paper production, etc., a source of heat at a medium temperature level—in the form of waste heat—is made available at the end of the process and can be used to operate a steam generator and therefore to ultimately generate electricity. The thermal energy which is stored in the waste heat, and which would otherwise be lost, can thus be advantageously utilized so that the effective efficiency of the entire industrial process can be increased.

[0004] In the steam generator, an operating medium is evaporated in a known manner and then fed to a turbine, for example, which is coupled to an electric generator. For evaporating the operating medium, a heated heat transfer medium is fed to the steam generator, wherein the heat which is stored in the heat transfer medium is transferred to the operating medium, which results in evaporation of the operating medium. In the case of waste heat utilization of an industrial process, this heat transfer medium is heated by using the waste heat. During this, only a medium temperature level of the heat transfer medium in an order of magnitude of about 60° C. to 200° C. can typically be achieved. The efficiency during the steam generation, based on the waste heat of an industrial process, is therefore comparatively poor.

[0005] Alternatively, a geothermal plant can also serve as a heat source, in which the heat transfer medium is pumped in a known manner into a deep well so as to heat up the heat transfer medium using the earth's heat. Also in this case, the heat transfer medium which is extracted from the deep well is only at a medium temperature level. The thermal energy which is stored in the heat transfer medium can be used for steam generation, as described above, but the efficiency of the steam generation is comparatively poor in this case also.

SUMMARY

[0006] Improvement of the efficiency in steam generation by utilizing heat of a heat transfer medium at a medium temperature level is desired.

[0007] The basic idea to improve efficiency is in the use of a thermal generator, also referred to in the literature as a "heat transformer", for increasing the temperature of a heat transfer medium which brings about the evaporation of an operating medium. A thermal generator generally serves for generating heat at a high temperature level by feeding heat at a medium temperature level and discharging heat at a low temperature level.

[0008] A primary heat transfer medium at a medium temperature level is fed to a thermal generator. For example, this primary heat transfer medium may have been brought to a medium temperature by utilizing a heat source like the mentioned waste heat line of an industrial plant or like the geothermal plant. A secondary heat transfer medium inter alia can then be extracted from the thermal generator or heat transformer, the temperature of which is higher than that of the primary heat transfer medium. The operating principle of the thermal generator is known from DE 35 21 195 A1 or from DE 198 16 022 B4, for example, therefore is not explained further at this point.

[0009] With the thermal generator, it is therefore possible to utilize the heat which is stored in the primary heat transfer medium in order to heat the secondary heat transfer medium. With the now comparatively hot second heat transfer medium, an operating medium can then be heated or evaporated with a comparatively high level of efficiency in a steam generator.

[0010] In a method for steam generation, for evaporating an operating medium of a steam generator, which is designed especially as a waste heat steam generator, Kalina steam generator or ORC steam generator ("Organic Rankine Cycle"), thermal energy is transferred from a heat transfer medium to the operating medium in a heat exchanger of the steam generator. Owing to the fact that the temperature of the heat transfer medium is increased in a thermal generator before the heat transfer medium is fed to the heat exchanger, a high level of efficiency of steam generation can be ensured.

[0011] Thermal energy is fed to the thermal generator by an additional heat transfer medium, wherein the temperature of the additional heat transfer medium is increased in a residual or waste heat-producing industrial plant by utilizing the residual or waste heat before the additional heat transfer medium reaches the thermal generator. As a result of this, the possibility of utilizing the residual or waste heat—which is otherwise lost—of the industrial plant for generating steam is achieved.

[0012] Also, in an alternative embodiment, thermal energy is fed to the thermal generator by an additional heat transfer medium. The temperature of the additional heat transfer medium is increased in a geothermal plant by utilizing the earth's heat before the additional heat transfer medium is fed to the thermal generator so that the earth's heat can be effectively utilized to generate steam.

[0013] The temperature of the additional heat transfer medium which is fed to the thermal generator is lower in the two embodiments than the temperature of the heat transfer medium which is fed to the heat exchanger of the steam generator.

[0014] In a device for evaporating an operating medium in a heat exchanger of a steam generator, which is designed especially as a waste heat steam generator, Kalina steam generator or as an ORC steam generator, thermal energy can be transferred from a heat transfer medium to the operating medium in the heat exchanger for evaporating the operating medium. The device furthermore has a thermal generator for increasing the temperature of the heat transfer medium.

[0015] Thermal energy can be fed to the thermal generator by an additional heat transfer medium. The temperature of the additional heat transfer medium can be increased in a residual heat or waste heat-producing industrial plant, by utilizing the residual heat or waste heat, before the additional heat transfer medium is fed to the thermal generator. As a result of this, the

effect is achieved of the otherwise lost residual heat or waste heat of the industrial plant being able to be utilized for generating steam.

[0016] Also, in an alternative embodiment, thermal energy can be fed to the thermal generator by an additional heat transfer medium. The temperature of the additional heat transfer medium can be increased in a geothermal plant, by utilizing the earth's heat, before the additional heat transfer medium is fed to the thermal generator, so that the earth's heat can be effectively utilized for steam generation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] These and other aspects and advantages will become more apparent and more readily appreciated from the following description of the exemplary embodiments with reference to the drawings of which:

[0018] FIG. **1** is a block diagram illustrating waste heat utilization for steam generation according to the related art,

[0019] FIG. **2** is a block diagram illustrating a first exemplary application of a thermal generator for waste heat utilization of an industrial plant,

[0020] FIG. **3** is a block diagram illustrating a second exemplary application of a thermal generator for utilizing the heat which is produced in a geothermal plant.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0021] In the figures, sections, components, component groups or method steps, which are identical or correspond to each other, are identified by the same designations. The flow directions in the lines are identified by arrows.

[0022] FIG. **1** shows an already known possibility for utilizing the waste heat of an industrial plant **100**, for example a steelworks, for evaporating an operating medium A of a steam generator **200**. Installed in a merely indicated waste heat line **110** of the steelworks **100** is a heat exchanger **120** which is exposed to throughflow by a heat transfer medium W. The temperature of the heat transfer medium W is increased in the heat exchanger **120** from a temperature T**1**(W) to a temperature T**2**(W).

[0023] The heated heat transfer medium W, delivered by a pump **140**, finds its way, via a line **130**, to a heat exchanger **220** of the steam generator **200**. The heat exchanger **220** is also exposed to throughflow by the operating medium A which is to be evaporated. In the heat exchanger **220**, a transfer of heat from the heat transfer medium W to the operating medium A takes place, wherein the operating medium A is heated and evaporated while the temperature of the heat transfer medium W correspondingly drops. The cooled heat transfer medium W then finds its way, via a line **150**, back to the heat exchanger **120** in the waste heat line **110** of the steelworks **100** in order to be reheated there.

[0024] The operating medium A which is evaporated in the heat exchanger **220** of the steam generator is fed, via a line **230**, to a turbine **240** and drives this. The turbine **240** is finally connected to a generator **250** for electricity generation so that electricity can ultimately be generated in a known manner per se by utilizing the waste heat of the steelworks **100**. The operating medium A which is expanded in the turbine **240** is typically directed, downstream to the turbine **240**, via a line **260**, to a cooler **270** in order to then be delivered again by a pump **280** to the heat exchanger **220**.

[0025] FIG. **2** shows a first application of the approach. In this case also, it is on the assumption that provision is made in a waste heat line **110** of an industrial plant **100** for a heat exchanger **120** in which the waste heat of the industrial plant **100** is utilized in order to heat a primary heat transfer medium W**1** from one temperature T**1**(W**1**) to a higher temperature T**2**(W**1**). The heated primary heat transfer medium W**1**, by the pump **140**, finds its way, via a line **130**, to an inlet **301** of a thermal generator **300**.

[0026] As mentioned in the introduction, it is possible for the thermal generator **300** to utilize the heat which is stored in the waste heat flow of the industrial plant **100** and is at a relatively low temperature T**1** of about 60° C. to 80° C., in order to increase the temperature of a secondary heat transfer medium W**2** which is used in a process connected downstream to the thermal generator **300**, for example steam generation, in order to increase in its turn the temperature of an operating medium A of the downstream process, especially to evaporate the operating medium A.

[0027] The primary heat transfer medium W**1** passes through the thermal generator **300**, wherein it cools down in the processes which take place there and can finally be extracted at an outlet **302**. From the outlet **302**, the primary heat transfer medium W**1** finds its way, via the line **150**, back to the heat exchanger **120** in the waste heat line **110** of the industrial plant **100** in order to be reheated there.

[0028] The secondary heat transfer medium W**2** is fed to the thermal generator **300** via an inlet **303**. In the thermal generator, the secondary heat transfer medium W**2** is finally heated from one temperature T**1**(W**2**) to a temperature T**2**(W**2**) by utilizing the heat of the primary heat transfer medium W**1**. The thus heated secondary heat transfer medium W**2** is now extracted at the outlet **304** of the thermal generator **300** and by a pump **310** is fed, via a line **210**, to the heat exchanger **220** of the steam generator **200**. In the heat exchanger **220**, as described in conjunction with FIG. **1**, the evaporation of the operating medium A of the steam generator **200** is carried out so that with the turbine **240** and the generator **250** electricity can be generated as a result. In the process, the secondary heat transfer medium W**2** cools down and is then fed again, via a line **290**, to the inlet **303** of the thermal generator **300** where it is reheated.

[0029] On account of using the thermal generator **300**, the efficiency of the steam or electricity generation is higher than in the case of the plant which is described in conjunction with FIG. **1** and known from the related art. The thermal generator is effectively connected between the waste heat line of the industrial plant and the steam generator and has the effect of the heat transfer medium which is fed to the steam generator having a higher temperature.

[0030] For the sake of completeness, one more inlet **305** and one more outlet **306** are shown in FIG. **2**, via which an additional medium can be fed to, and discharged from, the thermal generator **300**. As mentioned in the introduction, a thermal generator generally serves for generating heat at a high temperature level by feeding heat at a medium temperature level and discharging heat at a low temperature level. The medium which is fed via the inlet **305** and can be extracted at the outlet **306** serves for discharging heat at the low temperature level. Via the primary heat transfer medium W**1**, heat is supplied at a medium temperature level and the secondary heat transfer medium W**2** discharges heat at a high temperature level and transports this to the heat exchanger **220** of the steam generator **200**.

[0031] FIG. **3** shows a second application of the approach. The primary heat transfer medium W**1**, which was previously brought to an increased temperature T**2**(W**1**) by the waste heat of an industrial plant, in this case is heated up in a geothermal plant **400**. In a known manner, the geothermics utilize the heat which is stored in the earth's crust. A heat exchanger **410** is positioned at a specific depth and is exposed to throughflow by a primary heat transfer medium W**1** so that the increased temperature which prevails there can be utilized in order to increase the temperature T(W**1**) of the primary heat transfer medium W**1** to a value of T**2**(W**1**). The thus heated primary heat transfer medium W**1** is delivered by a pump **420**, via a line **430**, to an inlet **301** of a thermal generator **300**. As described above, the thermal generator **300** is used to heat a secondary heat transfer medium W**2** from one temperature T**1**(W**2**) to a higher temperature T**2**(W**2**), based on the heat which is stored in the primary heat transfer medium W**1**. The heated heat transfer medium W**2** is then used in a steam generator **200** for steam and electricity generation, similarly to the method described in conjunction with FIG. **2**.

[0032] In the figures, the method has been described specifically in applications in an industrial plant and in a geothermal plant. The industrial plant can basically be a plant in which residual or waste heat accumulates, i.e. for example a steelworks, a cement works, a paper producer or the like. Also, it is conceivable to utilize the waste heat of a power plant for the purpose described above: The waste heat which is produced in power plants and accumulates, for example, in the flue gases after combusting the fuel and/or downstream of the turbine, contains large energy reserves, especially in the form of residual heat. The residual heat can be utilized according to the method to heat the primary heat transfer medium, described above, which is fed to the thermal generator. This is used to bring the secondary heat transfer medium to a higher temperature. With the secondary heat transfer medium, the combustion air, for example, which is required in the power plant for combustion, can then be preheated in order to bring about a more effective combustion. Also, the secondary heat transfer medium can be used to generate electricity in a steam generator, as described above, for items of equipment of the power plant, for example pumps.

[0033] Generalized, all these plants, i.e. residual or waste heat-producing industrial plants, including power plants, geothermal plants, etc., which are suitable for the application of the method, as described above, can be grouped together under the term "heat source". In this case, therefore, it generally concerns plants which can provide thermal energy with which the primary heat transfer medium is to be heated from the low temperature T**1** (W**1**) to the higher temperature T**2**(W**1**).

[0034] The steam generator **200** which is shown in the figures may be a waste heat steam generator (WHSG or HRSG, "heat recovery steam generator"), a Kalina steam generator, or an ORC steam generator, for example. Common to all these special steam generators is that the operating medium which is to be evaporated has a low boiling point in comparison to water. The so-called "Kalina process" describes a method for steam generation at a low temperature level, wherein the operating medium which is to be evaporated is not water but an ammonia-water mixture which already evaporates at low temperatures. Also known is the so-called "ORC process", in which an organic liquid with low evaporation temperature is used as the operating medium which is to be evaporated.

[0035] On account of the increased temperature T**2**(W**2**) of the secondary heat transfer medium, however, it is also not impossible in principle to use a steam generator which operates with water as operating medium A.

[0036] The ORC process and the Kalina process are certainly both suitable for steam generation by utilizing heat of a heat transfer medium at a low or medium temperature level. The efficiency during the steam generation, however, is very much dependent upon the temperature of the heat source or of the heat transfer medium. For example, the Carnot efficiency is increased threefold if the temperature of the heat transfer medium is increased from 60° C. to 120° C. Raising the temperature to 200° C. results in the efficiency increasing by about five times the value. The use according to the method of a thermal generator, which is connected upstream to the steam generator and brings the heat transfer medium to a higher temperature, therefore has a positive effect upon the efficiency.

[0037] The system also includes permanent or removable storage, such as magnetic and optical discs, RAM, ROM, etc. on which the process and data structures of the present invention can be stored and distributed. The processes can also be distributed via, for example, downloading over a network such as the Internet. The system can output the results to a display device, printer, readily accessible memory or another computer on a network.

[0038] A description has been provided with particular reference to preferred embodiments thereof and examples, but it will be understood that variations and modifications can be effected within the spirit and scope of the claims which may include the phrase "at least one of A, B and C" as an alternative expression that means one or more of A, B and C may be used, contrary to the holding in *Superguide v. DIRECTV,* 358 F3d 870, 69 USPQ2d 1865 (Fed. Cir. 2004).

1-7. (canceled)

8. A method, comprising:

increasing a first temperature of a heat transfer medium in a thermal generator before the heat transfer medium is fed to a heat exchanger in a steam generator;

transferring, after said increasing, thermal energy from the heat transfer medium to an operating medium in the heat exchanger of the steam generator; and

evaporating, in the steam generator, the operating medium of steam.

9. The method as claimed in claim **8**, further comprising:

increasing a second temperature of an additional heat transfer medium in a residual or waste heat-producing industrial plant by utilizing residual or waste heat; and

feeding the additional heat transfer medium to the thermal generator after said increasing of the temperature of the additional heat transfer medium.

10. The method as claimed in claim **8**, further comprising:

increasing the temperature of an additional heat transfer medium in a geothermal plant by utilizing geothermal heat; and

feeding the additional heat transfer medium to the thermal generator after said increasing of the temperature of the additional heat transfer medium.

11. The method as claimed in claim **10**, wherein the second temperature of the additional heat transfer medium which is

fed to the thermal generator is lower than the first temperature of the heat transfer medium which is fed to the heat exchanger of the steam generator.

12. The method as claimed in claim **9**, wherein the second temperature of the additional heat transfer medium which is fed to the thermal generator is lower than the first temperature of the heat transfer medium which is fed to the heat exchanger of the steam generator.

13. The method as claimed in claim **8**, wherein the steam generator is one of a waste heat steam generator, a Kalina steam generator, and an organic Rankine cycle steam generator.

14. A device supplying a heat transfer medium to a heat exchanger of a steam generator that evaporates an operating medium in the steam generator, comprising:

a thermal generator increasing a temperature of the heat transfer medium by utilizing thermal energy of an additional heat transfer medium.

15. The device as claimed in claim **14**, wherein the temperature of the additional heat transfer medium is increased in a residual or waste heat-producing industrial plant by utilizing the residual or waste heat before the additional heat transfer medium is fed to said thermal generator.

16. The device as claimed in claim **14**, wherein the temperature of the additional heat transfer medium is increased in a geothermal plant by utilizing geothermal heat before the additional heat transfer medium is fed to said thermal generator.

17. The device as claimed in claim **14**, wherein the steam generator is one of a waste heat steam generator, a Kalina steam generator, and an organic Rankine cycle steam generator.

* * * * *