US 20030145596A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2003/0145596 A1

Noelscher (43) Pub. Date: Aug. 7, 2003

(54) METHOD FOR OPERATING A STEAM TURBINE INSTALLATION AND A STEAM TURBINE INSTALLATION THAT FUNCTIONS ACCORDING THERETO

(76) Inventor: Christoph Noelscher, Nuernberg (DE)

Correspondence Address:
HARNESS, DICKEY & PIERCE, P.L.C.
P.O.BOX 8910
RESTON, VA 20195 (US)

(21) Appl. No.: 10/168,686

(22) PCT Filed: Dec. 8, 2000

(86) PCT No.: PCT/DE00/04373

(30) Foreign Application Priority Data

Dec. 21, 1999 (DE) 199 61 808.9

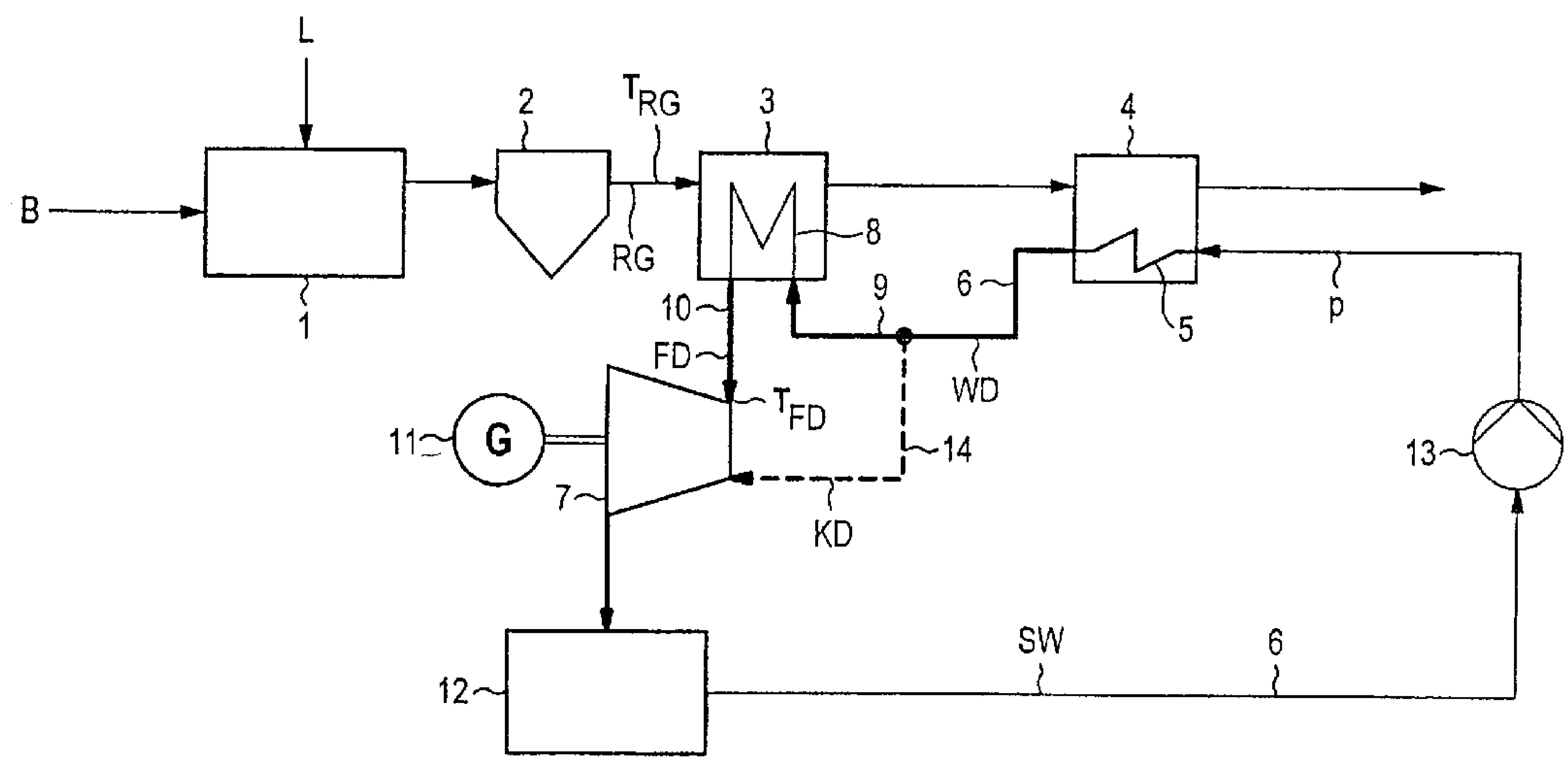
Publication Classification

(51) Int. Cl.[7] F01K 1/00

(52) U.S. Cl. 60/670

(57) ABSTRACT

During the operation of a steam turbine installation (1), flue gas (RG) produced by combusting a fossil fuel (B) is firstly guided in a high-temperature heat exchanger (3) while exchanging heat with water vapor (WD) which flows in the water-steam circuit (6) of a steam turbine (7) and which is fed to the steam turbine (7) as fresh steam (FD) having a fresh steam temperature (T_{FD}) of preferably greater than 800 ° C. The flue gas (RG) that is cooled down in the high-temperature heat exchanger (3) is subsequently guided in a waste heat stem generator (4) while exchanging heat with feed water (SW), which flows in the water-steam circuit, whereupon inducing the production of water vapor (WD).



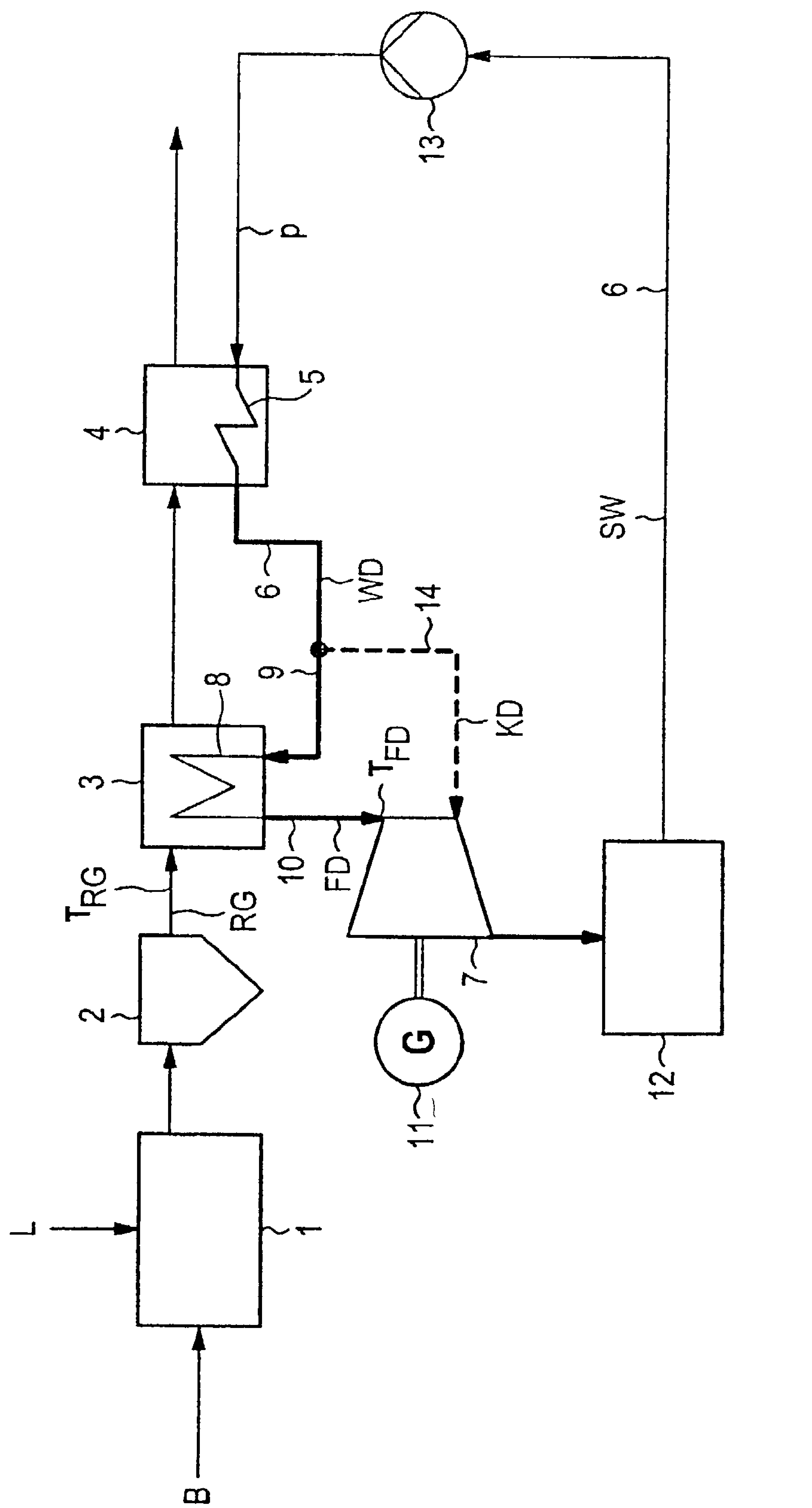


Fig. 1

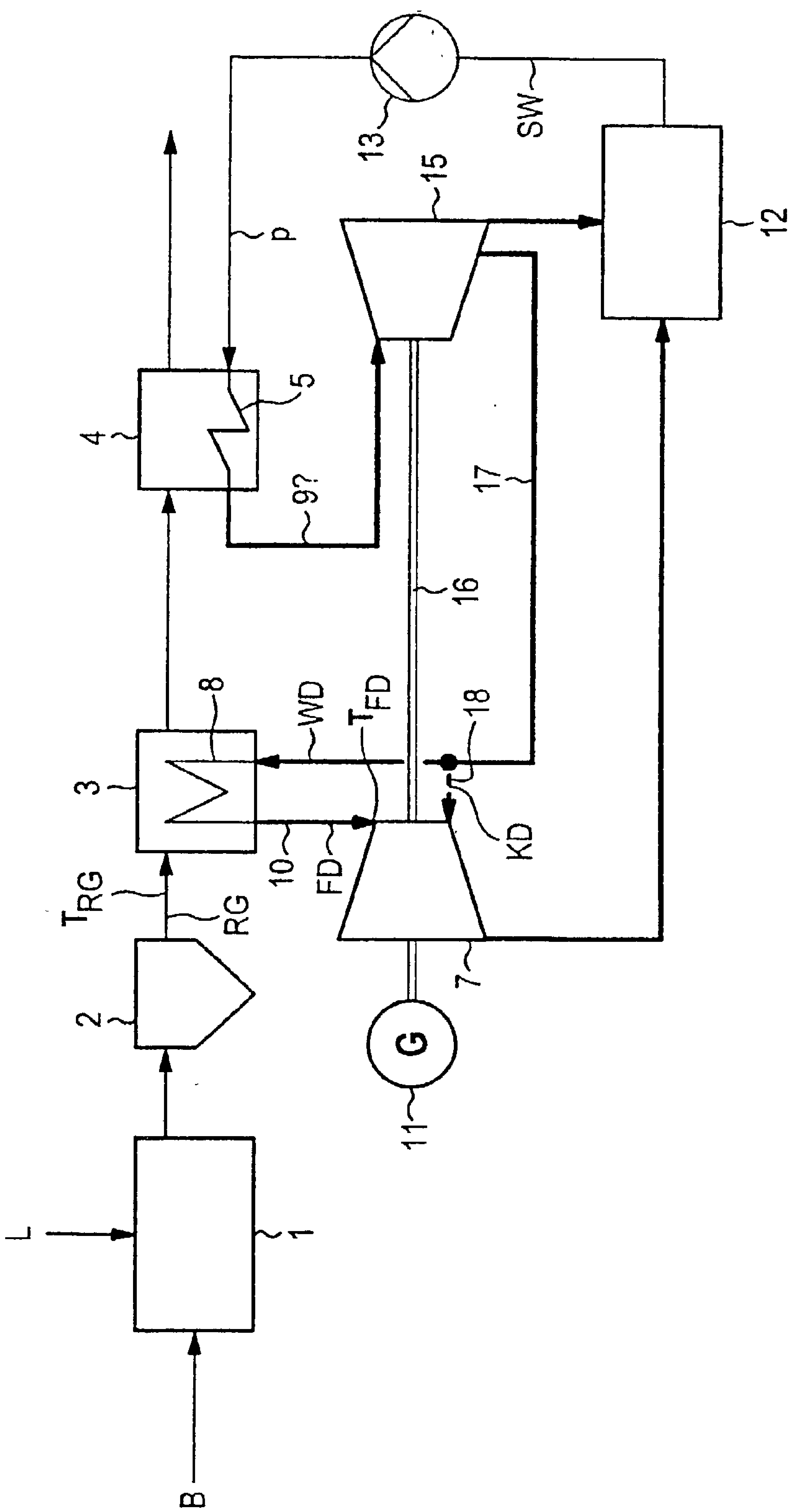


Fig. 2

METHOD FOR OPERATING A STEAM TURBINE INSTALLATION AND A STEAM TURBINE INSTALLATION THAT FUNCTIONS ACCORDING THERETO

[0001] The invention relates to a method of operating a steam turbine installation, in which method combustion gas generated by combustion of a fossil fuel is guided so as to exchange heat with a medium flowing in the water/steam cycle of a steam turbine. It also relates to a steam turbine installation operating according to this method.

[0002] In power stations employed for electricity generation, in which a fossil fuel, in particular coal, is employed as the primary energy carrier, various so-called combined processes can be applied which have in common the combined employment of a gas turbine installation and a steam turbine installation. In the case of so-called pressurized coal gasification (Integrated Gasification Combined Cycle—IGCC) for example, coal is gasified with the supply of oxygen generated in an air separation plant and the gaseous fuel generated is burnt in a combustion chamber after gas cleaning has taken place. The hot combustion gas generated during the combustion is expanded in a gas turbine at an inlet temperature of between 1000° C. and 1400° C. The combustion gas, expanded—with work output—and cooled to approximately 540° C., is guided in a waste-heat steam generator so as to exchange heat with a medium flowing in the water/steam cycle of a steam turbine in the form of a water/water/steam mixture. The live steam generated in the process is expanded—with work output—at an inlet temperature of approximately 540° C. in the steam turbine.

[0003] Further combined processes are pressurized fluidized bed combustion (PFBC) and pressurized pulverized coal combustion (PPCC), in which coal is likewise burnt as the primary energy carrier and the cleaned combustion product is supplied as hot combustion gas directly to the gas turbine. In these combined processes also, the combustion gas expanded—with work output—and cooled to approximately 500° C. to 550° C. in the gas turbine is guided in a waste-heat steam generator or heat exchanger so as to exchange heat with the medium flowing in the water/steam cycle of the steam turbine. The steam generated in the process is superheated either in the waste-heat steam generator itself or in the combustion installation and again supplied as live steam to the steam turbine.

[0004] Just as in a purely fossil-fired steam turbine installation, the steam expanded—with work output—in the steam turbine is again condensed in its combined processes, in a condenser connected downstream of the steam turbine and is supplied anew as feed water to the water/steam cycle.

[0005] In addition to these combined processes, the so-called externally fired combined cycle (EFCC) is described in the article "EFCC—Ein zukütnftiges Konzept für Kohle-Kombi-Kraftwerk (EFCC-Afuture concept for combined coal power station)?", in VGB Kraftwerkstechnik 77 (1997), Volume 7, Pages 537 to 543. In this combined process, a high-temperature heat exchanger is employed in which hot combustion gas generated by the combustion of coal is guided so as to exchange heat with compressed air. The air heated in this process to a temperature of approximately 1400° C. is supplied to the gas turbine as the working medium. The combustion gas which has been cooled by heat exchange with the compressed air is again supplied to a waste-heat steam generator. Subsequent to the heat exchange taking place there with the medium guided in the water/steam cycle of a steam turbine, the cooled combustion gas is cleaned in an installation which removes oxides of nitrogen and/or sulfur (DENOX, REA plant) before it is exhausted to the surroundings through a chimney.

[0006] The hot combustion gas generated in the case of the EFCC process in a so-called slag tap firing process is first cleaned by ash separation and subsequently supplied to the high-temperature heat exchanger. The parts of the latter exposed to the high combustion gas temperature, for example tube bundles through which the compressed air flows and around which the hot combustion gas flows, consist of a ceramic or a metallic material involving a special high-temperature resistant alloy.

[0007] This new concept promises an increase in the installation efficiency, at between 51% and 53%, relative to the combined processes with integrated gasification combined cycle(IGCC), pressurized fluidized bed combustion (PFBC) or pressurized pulverized coal combustion (PPCC). A disadvantage in this combined process with externally fired combustion cycle (EFCC) is, however, the fact that the air used as working medium for the gas turbine must be mechanically compressed. Although the compression energy necessary for this is reused, in part, by expansion in the gas turbine, the overall process is subject to loss, particularly as the mechanical energy necessary is only used in an unfavorable manner for the generation of electricity.

[0008] The invention is based on the object of providing a method of operating a steam turbine installation in which, in a simple manner, as high as possible an installation efficiency is achieved by a live steam inlet temperature, for the steam turbine, which is as high as possible. A particularly suitable steam turbine installation for carrying out the method is, in addition, to be provided.

[0009] With respect to the method, the object is achieved according to the invention by the features of claim 1. For this purpose, the hot combustion gas generated by combustion of a fossil fuel is first guided as the primary medium in a high-temperature heat exchanger so as to exchange heat with steam, flowing in the water/steam cycle of the steam turbine, as the secondary medium. The steam heated in the process to a temperature of preferably more than 800° C. is supplied as live steam to the steam turbine. The combustion gas cooled in the high-temperature heat exchanger is subsequently guided in a waste-heat steam generator so as to exchange heat with feed water flowing in the water/steam cycle in order to generate the steam.

[0010] In the combustion of problematic fuels, such as in refuse combustion, it is in fact known from DE 693 16 634 T2 to use, for steam generation, hot exhaust gas which has been generated with the application of a high-temperature heat exchanger. In this arrangement, however, the high-temperature heat exchanger and a waste-heat boiler are connected in parallel on the waste-gas side and air, for example, as an additional energy carrier, flows through a superheater connected downstream on the steam side of the waste-heat boiler and the high-temperature heat exchanger in a closed cycle.

[0011] The invention, then, is based on the consideration that the mechanical compression energy for the electricity generation necessary in the EFCC process can be more favorably used if, instead of air, a liquid is compressed and subsequently thermally evaporated. The heating of steam, which is extracted from a conventional water/steam cycle of a steam turbine, is then particularly favorable. This steam can then be heated in the high-temperature heat exchanger to a temperature of between 1200° C. and 1400° C. and subsequently expanded in a cooled high-temperature steam turbine. The latter then drives a generator or also a feed-water pump.

[**0012**] In this way, the energy extracted from the high-temperature heat exchanger can be exergetically better used, as compared with the EFCC process. Even in the case where the efficiency is the same, a smaller installation volume can, in the case of the heating of steam for a steam turbine, be achieved for the same useful mechanical energy as compared with the EFCC process. On the one hand, this is based on the fact that, for the same transmission of high-temperature heat, the fuel utilization is higher as compared with the EFCC process because, in the latter, the gas turbine waste heat is usually supplied to the combustion process. On the other hand, the high-temperature heat exchanger can have a smaller configuration as compared with the EFCC process because the fuel utilization must, for the same effectiveness, be the same for the same useful mechanical energy. For the same electrical power, the more efficient utilization of the high-temperature heat by the steam turbine additionally permits a reduction in the conventional steam constituent as compared with the EFCC process. Furthermore, the air compressor necessary with the latter is dispensed with.

[**0013**] In order to deal with the high live steam temperatures of more than or equal to 800° C., it is expedient to cool the steam turbine. Steam extracted from the water/steam cycle is advantageously used for this purpose.

[**0014**] In an advantageous embodiment, the steam produced in the waste-heat steam generator is first expanded—with work output—in a separate (conventional) steam turbine before this expanded steam is heated in the high-temperature heat exchanger to the live steam temperature of the steam turbine connected downstream of the high-temperature heat exchanger on the steam side. The two steam turbines, together with a generator, can then be seated on a common shaft (single-shaft embodiment) and can operate on a common condenser, which is connected upstream of the heating surfaces of the waste-heat steam generator within the water/steam cycle. The steam turbine connected downstream of the high-temperature heat exchanger on the steam side then forms, so to speak, the high-temperature part of the steam turbine connected upstream of the high-temperature heat exchanger on the steam side.

[**0015**] With respect to the steam turbine installation, the object is achieved, according to the invention, by the features of claim 5. Advantageous configurations are the subject matter of the sub-claims which refer back to claim 5.

[**0016**] A high-temperature heat exchanger connected upstream of the waste-heat steam generator on the combustion gas side and downstream on the steam side—with heat-exchanger heating surfaces in, for example, ceramic material—is connected upstream, on the steam side, of a preferably steam-cooled high-temperature steam turbine. In order to cool the steam turbine, a cooling steam line, by means of which steam extracted from the water/steam cycle can be supplied as cooling steam to the steam turbine, is guided to the latter. In this arrangement, the cooling steam line is expediently connected to a steam line connecting the high-temperature heat exchanger to the waste-heat steam generator. The cooling steam line is, in the case of the embodiment with a separate steam turbine which [lacuna] expediently connected to a steam line connecting the latter to the high-temperature heat exchanger, by means of which steam line the steam to be heated or to be superheated is also guided.

[**0017**] Embodiment examples of the invention are explained in more detail below using a drawing. In this:

[**0018**] **FIG. 1** shows, diagrammatically, a steam turbine installation with a high-temperature heat exchanger for the generation of live steam for a cooled high-temperature steam turbine and

[**0019**] **FIG. 2** shows, in a representation corresponding to **FIG. 1, a** steam turbine installation with two steam turbines in single-shaft embodiment.

[**0020**] Mutually corresponding parts in the two figures are provided with the same designations.

[**0021**] The steam turbine installation shown in **FIG. 1** comprises a combustion installation **1** in the form, for example, of an atmospheric pulverized coal firing with liquidized ash removal in a separator **2** (slag tap firing), together with a high-temperature heat exchanger **3** and a waste-heat steam generator **4** connected downstream of it on the combustion gas side. The heating surfaces **5** of the waste-heat steam generator **4** are connected into the water/steam cycle **6** of a steam turbine **7**. The high-temperature heat exchanger **3** is connected, on the steam side, downstream of the waste-heat steam generator **4** and upstream of the steam turbine **7**. For this purpose, heating surfaces **8** of the high-temperature heat exchanger **3**, consisting for example of ceramic material or of a special high-temperature resistant metal alloy, for example an oxide dispersion strengthened (ODS) alloy, are connected downstream, by means of a steam line **9**, to the heating surfaces **5** of the waste-heat steam generator **4** and upstream, by means of a high-temperature steam line **10**, to the steam turbine **7**.

[**0022**] During operation of the steam turbine installation, fuel B, in particular coal, is burnt in the combustion installation **1** with the supply of air L. The hot combustion product generated by this is supplied, after a cleaning process in the ash separator **2**, to the high-temperature heat exchanger **3** on the primary side as combustion gas RG with a combustion gas temperature T_{RG} of, for example, 800° C. to 1400° C. In the high-temperature heat exchanger **3**, an exchange of heat takes place between the hot combustion gas RG and steam WD guided over the secondary-side heating surfaces **8** of the high-temperature heat exchanger **3**. The steam heated by this process is supplied to the steam turbine **7** as live steam FD with a live steam or inlet temperature T_{FD} greater than or equal to 800° C. The steam turbine **7**, in which the live steam FD expands—with work output drives a generator **11** for the generation of electricity.

[**0023**] The live steam FD expanded—with work output—in the steam turbine **7** is condensed in a condenser **12** connected downstream of the steam turbine **7**. The resulting condensate or feed water SW is supplied, by means of a feed-water pump **13**, to the heating surfaces **5** of the waste-heat steam generator **4**, in the form for example of a preheater and an evaporator connected downstream of it. The steam WD generated in the waste-heat steam generator **4** is guided via the steam line **9** to the steam side of the high-temperature heat exchanger **3**.

[**0024**] The steam turbine **7** is cooled by means of cooling steam KD and is therefore preferably embodied as a high-temperature steam turbine. In the embodiment example, the cooling steam KD is extracted from the water/steam cycle **6** from the steam line **9**. For this purpose, a cooling steam line **14** is connected to the steam line **9** connecting the high-temperature heat exchanger **3** to the waste-heat steam generator **4**.

[**0025**] In the exemplary embodiment shown in **FIG. 2**, the steam turbine installation comprises, in addition to the high-temperature steam turbine **7**, a further steam turbine **15**, which drive the generator **11** via a common shaft **16** (single shaft). The generation of the hot combustion gas RG takes place in a manner analogous to the exemplary embodiment of **FIG. 1**. In this arrangement, the hot combustion gas RG is again guided in the high-temperature heat exchanger **3** so that it exchanges heat with steam WD, which is extracted from the further steam turbine **15** in this case. For this purpose, the steam turbine **15** is connected on the steam side between the waste-heat steam generator **4** and the high-temperature heat exchanger **3**. The further steam turbine **15** is again connected on the exhaust steam side to the condenser **12**, into which the high-temperature steam turbine **7** also opens on the exhaust steam side.

[**0026**] In the exemplary embodiment of **FIG. 2**, therefore, the actual high-temperature part of the separate steam turbine **15** is embodied in the form of a high-temperature steam turbine **7**, whereas this high-temperature part is integrated into the steam turbine **7** in the exemplary embodiment of **FIG. 1**. In the steam turbine installation of **FIG. 2**, the steam turbine **7**, operating as the high-temperature part, is again cooled by means of cooling steam KD. The latter is extracted from a steam line **17** connecting the further or separate steam turbine **15** to the heating surfaces **8** of the high-temperature heat exchanger **3** and is guided by means of a cooling steam line **18**, which is connected to the steam line **17**, to the high-temperature steam turbine **7**.

[**0027**] The operating pressure of the steam turbine installation **1** is, in practice, approximately limited to between **15** bar and **30** bar at an operating temperature of 1400° C., by the strength of the high-temperature heat exchanger. The operating pressure p in the water/steam cycle **6**, at 30 bar, is therefore relatively low in comparison with a conventional water/steam cycle at approximately 250 bar. The operating pressure can be increased to 150 bar in the case of an operating temperature of 1000° C.

1. A method of operating a steam turbine installation, in which method combustion gas (RG) generated by combustion of a fossil fuel (B) is guided so as to exchange heat with a medium (SW, WD) flowing in the water/steam cycle **(6)** of a steam turbine **(7)**, in which the hot combustion gas (RG) is first supplied to the primary side of a high-temperature heat exchanger **(3)** and is there guided so as to exchange heat with steam (WD), which is supplied to the secondary side of the high-temperature heat exchanger **(3)** and flows in the water/steam cycle **(6)**, the steam heated by this means being supplied to the steam turbine **(7)** as live steam (FD), and in which the combustion gas (RG) cooled in the high-temperature heat exchanger **(3)** is subsequently guided in a waste-heat steam generator **(4)** so as to exchange heat with feed water (SW) flowing in the water/steam cycle **(6)**, the steam (WD) being generated by this means.

2. The method as claimed in claim 1, in which the steam (WD) is heated in the high-temperature heat exchanger **(3)** to a live steam temperature (T_{FD}) greater than or equal to 800° C.

3. The method as claimed in claim 1 or **2**, in which the steam turbine **(7)** is cooled by the steam (WD) extracted from the water/steam cycle **(6)**.

4. The method according to one of claims 1 to 3, in which the steam (WD) generated in the waste-heat steam generator **(4)** is supplied to a separate steam turbine **(15)** and the steam (WD) expanded there—with work output—is supplied to the high-temperature heat exchanger **(3)**.

5. A steam turbine installation having a combustion installation **(1)** for a fossil fuel (B) for the generation of combustion gas (RG), which is guided in a high-temperature heat exchanger **(3)** and in a waste-heat steam generator **(4)** connected downstream on the combustion gas side of the high-temperature heat exchanger **(3)** so as to exchange heat with a medium (SW, WD) flowing in the water/steam cycle **(6)** of a steam turbine **(7)**, and in which the steam side of the high-temperature heat exchanger **(3)** is connected between the waste-heat steam generator **(4)** and the steam turbine **(7)**.

6. The steam turbine installation as claimed in claim 5, characterized in that the steam turbine **(7)** is connected to a cooling steam line **(13)** by means of which the steam (WD) extracted from the water/steam cycle **(6)** can be supplied to the steam turbine **(7)** as cooling steam (KD).

7. The steam turbine installation as claimed in claim 6, characterized in that the cooling steam line **(13)** is connected to a steam line **(9)** connecting the high-temperature heat exchanger **(3)** to the waste-heat steam generator **(4)**.

8. The steam turbine installation as claimed in one of claims 5 to 7, characterized by a separate steam turbine **(15)** connected on the steam side between the waste-heat steam generator **(4)** and the high-temperature heat exchanger **(3)**.

9. The steam turbine installation as claimed in claim 8, characterized by a steam line **(17)** connecting the separate steam turbine **(15)** with heating surfaces **(8)** of the high-temperature heat exchanger **(3)**, to which steam line **(17)** is connected a cooling steam line **(18)** for supplying cooling steam (KD) to the steam turbine **(7)** connected downstream of the high-temperature heat exchanger **(3)** on the steam side.

10. The steam turbine installation as claimed in one of claims 5 to 9, characterized in that an ash separator **(2)** is connected downstream of the combustion installation **(1)**.

* * * * *