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(71) Applicant: **Ptacek, Milan**
75301 Hranice (CZ)

(72) Inventor: **Ptacek, Milan**
75301 Hranice (CZ)

(74) Representative: **Kania, Frantisek**
Kania Sedlak Smola,
Mendlovo Namesti 1 a
603 00 Brno (CZ)

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(54) **Method and apparatus for waste heat recovery from exhaust gas**

(57) The invention relates to a method for the utilisation of the residual heat of flue gases having a temperature, which exceeds their dew point and containing aggressive constituents, in particular of flue gases discharged from solid fuel fired boilers. The flue gases are blown along the process water causing the thermal energy of the flue gases to be transferred to the process water in order to heat the latter at most up to the boiling temperature of the same under given ambient atmospheric and pressure conditions, the pH value of the process water being adjusted to enable the neutralization of the corrosive action of the condensing flue gas constituents. After the process water is heated up by the flue gases, its heat is transferred to the cooling water. Then, the cooled process water re-enters the flue gas flow in order to extract thermal energy from it. The device for performing the method according to the invention comprises the direct-contact heat exchanger (1) for extracting heat from the flue gases and transferring it to the process water, the direct-contact heat exchanger (1) having a flue-gas inlet, which is connected to the flue-gas outlet of a solid fuel fired boiler and/or to that of an incineration plant producing flue gases that contain aggressive constituents, said flue gases being led through the direct-contact heat exchanger (1). On the opposite end of the direct-contact heat exchanger (1), the water inlet is arranged for contact heat transfer between the flue gases and the process water. The process-water outlet of the direct-contact heat exchanger (1) is connected to the process-water inlet of the second heat exchanger (6) for extracting heat from the process water and transferring it to the cooling water, while the process-water outlet of the second heat exchanger (6) is connected to the process-water inlet of the direct-contact heat exchanger (1).

The process-water circuit comprises the inlet for connecting the apparatus (5) for replenishing alkali into the process water in order to maintain the pH value of the process water at a level enabling the corrosive effect of the acids, which are produced during the condensation of flue gases, to be neutralized.

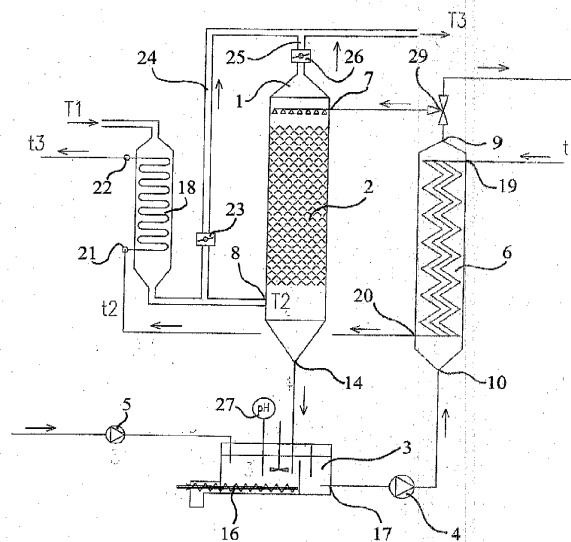


Fig. 1

Description

Technical field

[0001] The present invention relates to a method for the utilisation of a residual heat of flue gases having a temperature, which exceeds their dew point and containing aggressive constituents, in particular of flue gases discharged from solid fuel firing boilers. The present invention also relates to a method for increasing a thermal efficiency of a boiler as well as that of a steam cycle during a generation of an electrical energy of a steam. The present invention also relates to a device for performing the above method.

State of the art

[0002] At the present time, the major portion of the global electrical energy production is covered by solid fuel firing boilers, in particular by coal boilers and also biomass boilers. Such boilers generate a steam which serves as a motive medium for condensing steam turbines, particularly for double-extraction condensing steam turbines used in heating plants. In this connection, there is a continuing effort to increase the efficiency of the thermal to electric, energy conversion. This is mostly accomplished by increasing the parameters of steam, i.e. the pressure and the temperature of the same, which often reach their, so called, critical values. In particular, such approach is adopted for power-plant boiler having outputs in the order of hundreds of Megawatts. For the boilers having outputs under 100 MW, the above way is not yet applicable because economic and technical reasons have to be considered. No other approach than increasing the values of steam parameters have been adopted so far.

[0003] Thus, the contemporary method of steam generation consists in that steam having high parameter values is extracted by a steam turbine and condenses inside the same under low pressure of about 0, 008 MPa and under a temperature, which usually ranges between 30 and 45°C, thus turning to water having approximately the same temperature. The condensed water has to be reheated to reach the temperature of the so called feed-water, usually at least about 105°C. At the present, such reheating of water from about 30- 45°C up to 105°C is accomplished by means of the intermediate, steam extraction. Thus, the so called regeneration of feedwater occurs. As a result, the steam used for reheating the feed-water is lost and cannot contribute to the output power of the turbine any more. Such solid fuel fired boilers used for steam generation work, depending on their size, with the thermal efficiency ranging between 87 and 92, 5%. The temperature of the flue gases discharged from such boilers typically range between 120 and 170°C. The residual heat contained of such flue gases is not utilized for any purpose. The utilization of that residual heat would require the installation of a heat exchanger using a low-

potential cooling medium, i.e. a so called flue gas condenser. The main reason why such flue gas condensers are not used consists in that the fuel, particularly coal, contains sulphur and may also contain HCl as well as water. One of the combustion products is sulphur dioxide which would react with water. Such reaction would produce sulphurous acid causing an accelerated degradation of the flue gas condenser. In addition, flue gases often contain a mixture of several acids, thus making the circumstances even more unfavourable. Besides that, dust would also adhere to the heat-exchanging surfaces of the condenser which would result both in the destruction of the latter and in the reduction of the necessary heat transfer. In the case that biomass is fired, sulphur is accompanied by chlorine, which is present in high concentrations in the form of HCl and reacts with water to produce hydrochloric acid having an even stronger caustic potential. If the flue gases were cooled under the temperature corresponding to their dew point, the vapours of the mixture of various oxides and those of HCl would condense simultaneously with water vapours and subsequently produce a mixture of corrosive acids. This would cause the heat exchanger to be subjected to a very strong corrosion supported by relatively high temperatures. No ordinary material used for heat-exchanging surfaces can withstand the action of an acidic mixture, in particular the mixture of sulphurous, sulphuric and hydrochloric acids or, as the case may be, the mixture enriched by carbonic and hydrofluoric acids or the like, the above listing being not exhaustive. The usual service life is shorter than one year. The above ordinary materials are absolutely unsuitable for the construction of heat exchangers. Lead is not acceptable due to its environmental impact, glass and plastic materials are unsuitable due to their poor thermal conductivity. Alloy having increased corrosion resistance (such as those containing Ni, Cr, Mo) may withstand corrosive attacks for a certain period of time but still their service life is limited to a couple of years. Furthermore, such alloys are extremely expensive and difficultly workable.

[0004] The solid fuel fired boilers, which constitute the prior art, produce aggressive flue gases and that is why they discharge residual heat that cannot be economically utilized. Usually, such low-potential heat does not even occur or is only present in negligible amounts in large heating systems comprising industrial-grade boilers, such as long-distance heating systems.

[0005] Nevertheless, no one has yet tried to make use of the fact that the above low-potential heat typically exists in heating systems and power plants equipped with double-extraction condensing turbines, not to mention the additional fact that such heat exists in sufficient amounts. But still the utilization of that heat could significantly contribute to the increase of the thermal efficiency of a steam cycle and, at the same time, to the increase of the overall thermal efficiency of the corresponding boiler. The proposed system (constituting the main aspect of the present invention) can increase the thermal effi-

ciency of a steam cycle in comparison with the commonly used technical solutions (according to the size of the respective unit) by a value ranging between about 5% and about 8.5%. This means that it is possible to save about 5- 8.5% of fuel with the same production of electricity.

[0006] Hence, it is possible to increase the thermal efficiency of the smaller (1- 15 MWe) contemporary combined electricity and heat source by a value ranging between 5 and 8.5%, i.e. up to a efficiency level that is typical for large power plants. In large power plants, the achievable increase of efficiency is slightly lower but the contribution still remains significant. For example, the implementation of the technical solution according to the invention, as described below, in a 1, 000 MWe unit may result in an annual saving totalling more than 200, 000 tons of fuel (more than CZK 100 million/ year) .

Summary of the Invention

[0007] The above mentioned drawbacks of the prior art are largely eliminated by a method for the utilisation of the residual heat of flue gases having a temperature, which exceeds their dew point and containing aggressive constituents, in particular of flue gases discharged from solid fuel fired boilers, wherein the flue gases are blown along the process water causing the thermal energy of the flue gases to be transferred to the process water in order to heat the latter at most up to the boiling temperature of the same under given ambient atmospheric and pressure conditions, the pH value of the process water being adjusted to enable the neutralization of the corrosive action of the condensing flue gas constituents. After the process water is heated up by the flue gases, its heat is transferred to the cooling water. Then, the cooled process water re-enters the flue gas flow in order to extract thermal energy from it.

[0008] In a preferred embodiment of the invention, the cooling water is heated up to a temperature exceeding its inlet temperature, but at most to a temperature corresponding to the boiling point of the process water under give ambient atmospheric and pressure conditions.

[0009] In other preferred embodiments of the invention, such cooling water is the condensate produced by the condensation of steam, typically the condensate produced by the condensation of steam used as the motive medium for a steam turbine or the condensate produced by the condensation of steam downstream of a condensing steam turbine. The cooling water may be the cooled water returning from the heating system and having a temperature in the range of 0°C to 80°C, or preferably to 60°C, or more preferably to 50°C, or most preferably to 40°C.

[0010] After having been heated up by the process water, the condenser is favourably usable for the treatment of the feedwater flowing into the steam boiler, particularly for the water returning from the heating system.

[0011] The outlet temperature of the cooling water heated up by the flue gases through the mediation of the

process water preferably ranges from 40°C, or from 50°C, or from 60°C up to the boiling point of the process water under given ambient atmospheric and pressure conditions, while the inlet temperature of the cooling water heated up by the flue gases through the mediation of the process water ranges from 0°C to 80 °C, or preferably to 60 °C, or more preferably to 50 °C, or most preferably to 40°C.

[0012] In a particularly preferred embodiment, the cooling water heated up by the flue gases through the mediation of the process water is additionally fed into the flue gas flow upstream of the zone, where the flue gases are blown along the process water, in order be heated up to a still higher temperature.

[0013] The pH value of the process water, along which the flue gases are blown. is greater than 5.0, preferably greater than 6.5, more preferably greater than 6.9 and most preferably greater than 7.5.

[0014] Preferably, solid sediments are separated from the process water.

[0015] The above described method can be also used in case that the dew point is exceeded and acids are produced having a lower level of aggressiveness in comparison with the flue gases containing the sulphurous, sulphuric or hydrochloric acids.

[0016] The above mentioned drawbacks of the prior art are also largely eliminated by the device for performing the above method, wherein said device has the features described below. The device according to the invention comprises a direct-contact heat exchanger for extracting heat from the flue gases and transferring it to the process water. The flue-gas inlet of the direct-contact heat exchanger is connected to the flue-gas outlet of a solid fuel fired boiler and/or to that of an incineration plant producing flue gases that contain aggressive constituents, said flue gases being led through the direct-contact heat exchanger. On the opposite end of the direct-contact heat exchanger, the water inlet is arranged for contact heat transfer between the flue gases and the process water. The process-water outlet of the direct-contact heat exchanger is connected to the process-water inlet of the second heat exchanger for extracting heat from the process water and transferring it to the cooling water while the process-water outlet of the second heat exchanger is connected to the process-water inlet of the direct-contact heat exchanger. The process-water circuit comprises the inlet for connecting an apparatus for replenishing alkali into the process water in order to maintain the pH value of the process water at a level enabling the corrosive effect of the acids, which are produced during the condensation of flue gases, to be neutralized.

[0017] In a preferred embodiment of the device according to the invention, the direct-contact heat exchanger is equipped with a built-in structure for increasing the heat transfer efficiency, in particular for increasing the efficiency of the heat transfer between flue gases and process water, and/or for rinsing the interior surfaces of the exchanger and/or for increasing the efficiency of the neu-

tralization the corrosive effect of the acids produced during the condensation of flue gases. The flue-gas inlet, which is connected to the flue-gas outlet of a solid fuel fired boiler and/or to that of another source of aggressive flue gases, is preferably arranged in the bottom portion of the direct-contact heat exchanger, while the process-water inlet for rinsing the interior surfaces of the direct-contact heat exchanger and for receiving the heat extracted from flue gases is arranged in the top portion of the direct-contact heat exchanger.

[0018] In another preferred embodiment of the device according to the invention, the heated-up condensate is used as feedwater for a steam boiler and/or for another heat source and/or for another heating circuit.

[0019] In another preferred embodiment, the device according to the invention further comprises a sedimentation vessel for settling of the solid particles flushed out from the direct-contact heat exchanger, said vessel being pranced between the direct-contact heat exchanger and the second heat exchanger and preferably provided with a ploughing apparatus for removing sediments from the sedimentation vessel. In another preferred embodiment, the device according to the invention further comprises a process water pump which is arranged between the sedimentation vessel for settling of the solid particles flushed out from the direct-contact heat exchanger and the second heat exchanger for extracting heat from the process water and transferring it to the cooling water.

[0020] The apparatus for replenishing alkali into the process water in order to maintain the pH value of the process water at a level enabling the corrosive effect of the acids, which are produced during the condensation of flue gases, to be neutralized, is preferably adjusted to maintain the pH value of the process water at a level greater than 5.0, particularly greater than 6.5, more preferably greater than 6.9 and most preferably greater than 7.5. The apparatus for replenishing alkali into the process water is preferably incorporated into the process-water circuit between the process-water inlet of the direct-contact heat exchanger and a process-water pump.

[0021] In another preferred embodiment of the invention, the device further comprises a third heat exchanger which is arranged between the flue-gas outlet of the heat source and the flue-gas inlet of the direct-contact heat exchanger. The second heat exchanger is provided with the cooling water outlet, which is connected to the cooling water inlet of the third heat exchanger for extracting heat from the flue gases and transferring it to the cooling water, while the cooling water outlet of the third heat exchanger is connected to the feed tank of a heat source and/or to the heating circuit of a boiler and/or to another heating circuit.

[0022] In order to increase the outlet temperature of flue gases and/or to enable the final temperature of flue gases to be regulated and/or to enable the amount of the heat output being transferred to the heat exchangers to be regulated, another preferred embodiment envisages that the device according to the invention further com-

prises a branch which is arranged upstream of the flue-gas inlet of the direct-contact heat exchanger, said branch being provided with a regulating member and routed to the flue-gas outlet of the direct-contact heat exchanger.

[0023] In another exemplary preferred embodiment, the device according to the invention further comprises an apparatus for replenishing the supply of process water and/or for draining the latter, said apparatus being arranged between the process-water outlet of the second heat-exchanger and the process-water inlet of the direct-contact heat exchanger.

[0024] In still another preferred embodiment of the device according to the invention, the second heat exchanger is provided with a dedicated cooling water inlet connected to a steam condenser located downstream of the condensing section of a steam turbine and/or downstream of a steam turbine itself and/or downstream of a steam heating system, the cooling water being a steam condensate having a temperature ranging between 0 and 80°C, or between 0 and 70°C, or between 0 and 60°C, or between 0 and 50°C, or between 0 and 40 °C.

[0025] In another preferred embodiment of the device according to the invention, the cooling water outlet of the third heat exchanger and/or the cooling water outlet of the second heat exchanger are connected to a thermal circuit, in particular to a thermal circuit incorporating a boiler.

[0026] Finally, in yet another preferred embodiment of the device according to the invention, the cooling water outlet of the third heat exchanger and/or the cooling water outlet of the second heat exchanger are connected to the feedwater inlet of a steam boiler and/or another heat source and/or another heating circuit.

[0027] The above described device can be also used in case that the dew point is exceeded and acids are produced having a lower level of aggressiveness in comparison with the flue gases containing the sulphurous, sulphuric or hydrochloric acids.

Brief description of the drawings

[0028] For more detail, the invention will be further described by means of the accompanying drawings wherein Fig. 1 shows the first exemplary embodiment of the device according to the invention and Fig. 2 shows the second exemplary embodiment of the device according to the invention.

Exemplifying embodiments of the invention

[0029] Hereinafter, an exemplifying embodiment of the method for the utilisation of the residual heat of flue gases will be described, wherein the flue gases have a temperature, which exceeds their dew point, and contain aggressive constituents. Such flue gases are particularly those discharged from solid fuel fired boilers, in particular by coal boilers and also biomass boilers. In this exem-

plifying embodiment, the flue gases discharged from a heat source, e.g. from a solid fuel fired boiler, are blown along the process water causing the thermal energy of the flue gases to be transferred to the process water in order to heat the latter at most up to the boiling temperature of the same under given ambient atmospheric and pressure conditions. Simultaneously, the pH value of the process water is adjusted to enable the neutralization of the corrosive action of the condensing flue gas constituents and is maintained at a level higher than 5, preferably at a level higher than 7.5. After the process water is heated up by the flue gases, its heat is transferred to the cooling water. Then, the cooled process water re- enters the flue gas flow in order to extract thermal energy from it.

[0030] In this method, the thermal energy of the flue gases, which would otherwise escape into the outside environment, is transferred to the process water which flows in a opposite direction with respect to that of the flue gases, neutralizes the flue gases and is further heated up by the same. Thus, the neutralized process water becomes a heat transport medium that prevents the corrosion of the heat-exchanging surfaces, particularly those of the second heat exchanger, from developing. The process water flows along the outer surface of the built-in structure of the heat exchanger which means that a direct heat transfer from flue gas to process water takes place and heat does not permeate through the material of the built-in structure of the heat exchanger. Therefore, the direct-contact heat exchanger can be made of materials which are not typical for heat exchangers, i.e. materials having poor thermal conductivity, in particular plastic materials, such as polypropylene, polyethylene, PVDF etc., the above listing being not exhaustive. Such materials are cheap and exist in an unlimited number of types. Besides that, such plastic materials may be used for the fabrication of a louver-type or tubular built-in structure that enlarges the overall contact surface areas of the heat exchanger, thus increasing the efficiency of the flue-gases to process water thermal energy conversion. Since the process water flows through the built-in structure of the heat exchanger over a prolonged time, it has increased time for absorbing the heat and neutralizes the flue gases more efficiently. If treated processed water with a higher pH value was used, it would be possible to use ordinary metallic materials for the built-in structure of the heat exchanger, particularly for a louver-type one. In this case, the process water would flow along such metal surfaces and continuously neutralize the acids produced during the condensation of flue gases, thus protecting those surfaces from corrosion. In such case, the flue gases cause the built-in metal structure of the heat exchanger to be heated up from below, thus allowing the thermal energy to be directly transferred to the process water flowing along the built-in metal structure of the heat exchanger. In this way, the process water can absorb additional heat to that gained through the blowing action of the flue gases.

[0031] Fig. 1 shows a schematical view of an exempli-

fying embodiment of a device for the utilisation of the residual heat of flue gases according to the invention. The device comprises a direct-contact heat exchanger **1** for extracting heat from the flue gases and transferring it to the process water and a second heat exchanger **6** for extracting heat from the process water and transferring it into the cooling water. The direct-contact heat exchanger **1** comprises a flue-gas inlet **8** a process water inlet **7** and a process water outlet **14**. The process water inlet **7** of the direct-contact heat exchanger **1** is connected to the process water outlet **9** of the second heat exchanger **6** while the process water outlet **14** of the direct-contact heat exchanger **1** is connected to the first process water inlet **10** of the second heat exchanger **6**. The device further comprises the apparatus **5** for replenishing alkali into the process water in order to maintain the pH value of the process water at a level enabling to neutralize the corrosive effect of the acids, which are produced during the condensation of flue gases. The apparatus **5** is connected to the process-water circuit through the sedimentation vessel **3**. The direct-contact heat exchanger **1** is equipped with the built-in structure **2** for increasing the heat transfer efficiency. The built-in structure **2** may be e.g. a honeycomb one, through which the flue gases flow from below and along which the process water having a suitably adjusted pH value flows from above. The built-in structure **2** is also useful for increasing the efficiency of the heat transfer between flue gases and process water or, as the case may be, for increasing the efficiency of the neutralization the corrosive effect of the acids produced during the condensation of flue gases. Nevertheless, the built-in structure does not necessarily be a honeycomb one. Instead, a tubular built-in structure or a another structure acting similarly to a honeycomb one may be used.

[0032] The cooling water is typically the condensate produced in a steam condenser located downstream of the condensing section of a steam turbine and/or downstream of a steam turbine itself and/or downstream of a steam heating system, and having a temperature ranging between 0 and 80°C, or preferably between 0 and 50°C, or more preferably between 0 and 40°C. The heated-up condensate may be then used as feedwater for a steam boiler and/or for another heat source and/or for another heating circuit.

[0033] The device further comprises the sedimentation vessel **3** for settling of the solid particles flushed out from the direct-contact heat exchanger **1**, said vessel being arranged between the direct-contact heat exchanger **1** and the second heat exchanger **6** and connected to the same. The device further comprises the apparatus **5** for replenishing alkali into the process water in order to maintain the pH value of the process water at a level enabling the corrosive effect of the acids, which are produced during the condensation of flue gases, to be neutralized. The apparatus **5** is connected to the process-water circuit through the sedimentation vessel **3**. The sedimentation vessel **3** is further provided with the pH meter **27** and with

the ploughing apparatus **16** for removing sediments from the sedimentation vessel **3**.

[0034] The apparatus **5** for replenishing alkali into the process water is connected to the sedimentation vessel **3**. The device further comprises the first process water pump **4** which is arranged between the first process-water outlet **17** of the sedimentation vessel **3** and the first process water inlet **10** of the second heat exchanger **6**. However, the apparatus **5** for replenishing alkali into the process water may be incorporated into the process water circuit between the process water outlet **14** of the direct-contact heat exchanger **1** and the first process water pump **4**, the outlet of the latter being in turn connected to the first process water inlet **10** of the second heat exchanger **6**. The apparatus **5** for replenishing alkali into the process water maintains the pH value of the process water at a level enabling the corrosive effect of the acids produced during the condensation of flue gases to be neutralized. A sufficient level may correspond to a pH value greater than 5.0, under different circumstances a pH value greater than 6.5 or 6.6 may be required. However, a pH value greater than 7.5 is considered most favourable for the operation of the device.

[0035] In this exemplary embodiment, the device according to the invention further comprises the third heat exchanger **18** which is arranged between the flue-gas outlet of the heat source and the flue-gas inlet **8** of the direct-contact heat exchanger **1**. The second heat exchanger **6** is provided with the cooling water inlet **19** and the cooling water outlet **20**, which is connected to the cooling water inlet **21** of the third heat exchanger **18** for extracting heat from the flue gases and transferring it to the cooling water. The cooling water outlet **22** of the third heat exchanger **18** is connected to the feed tank of a heat source and/or to the heating circuit of a boiler and/or to another heating circuit. The third heat exchanger **18** does not suffer from corrosion because the temperature of its heated-up inlet water exceeds the dew point of the flue gases. Thus, the flue gases do not condense on the surface of the third heat exchanger **18** along which they are blown and no acids are produced.

[0036] In order to increase the outlet temperature of flue gases and/or to enable the final temperature of flue gases to be regulated and/or to enable the amount of the heat output being transferred to the heat exchangers **1**, **6**, and - to a certain extent - to the heat exchanger **18** to be controlled, the device according to the invention further comprises the branch **24** which is arranged upstream of the flue-gas inlet **8** of the direct-contact heat exchanger **1**, said branch being provided with the regulating member **23** and routed to the flue-gas outlet **25** of the direct-contact heat exchanger **1** which may optionally comprise the regulating flap **26**.

[0037] The device according to the invention further comprises the apparatus **29** for replenishing the supply of process water and/or for draining the latter, said apparatus being arranged between the process-water outlet **9** of the second heat-exchanger **6** and the process-

water inlet **7** of the direct-contact heat exchanger **1**.

[0038] When the latter apparatus is in operation, the flue gases have the initial temperature T1 upon entering the third heat exchanger **18** and the temperature T2 upon leaving the third heat exchanger **18**. The temperature T2 is then the initial one of the flue gases upon entering the direct-contact heat exchanger **1**. Upon leaving the direct-contact heat exchanger **1** the flue gases having the temperature T3 are discharged into the ambient atmosphere. This means that if the flue gases pass through the heat exchangers **18** and **1**, their temperature will decrease from T1 over T2 up to T3. Since the temperature T2 still exceeds the dew point of the flue gases, the third heat exchanger **18** can be made of a material without any special requirements regarding corrosion resistance. During the passage through the direct-contact heat exchanger **1**, the temperature of the flue gases is dropping below the dew point of the flue gases but the acids produced in the built-in structure **2** of the direct-contact heat exchanger **1** are immediately neutralized by the process water that has a suitably adjusted pH value and continuously flows along the surfaces of the built-in structure **2**. Thus, the flue gases being discharged into the ambient atmosphere are cooled below their dew point and cannot cause the corrosion of the heat-exchanging surfaces to develop.

[0039] The process water is fed to the process-water inlet **7** in the upper portion of the direct-contact heat exchanger **1**, flows down along the surfaces of the built-in structure **2** of the direct-contact heat exchanger **1**, where it encounters the flue gases being blown in the opposite direction and is heated up by the same, then it flows down through the process-water outlet **14** of the direct-contact heat exchanger **1** into the sedimentation vessel **3** where solid particles which have been flushed out from the direct-contact heat exchanger **1** settle. Subsequently, these sediments are removed by the ploughing apparatus **16** from the sedimentation vessel **3** and thus eliminated from further circulation. The process water is pumped by the first process water pump **4** from the first process-water outlet **17** of the sedimentation vessel **3** into the first process-water-inlet **10** of the second heat exchanger **6**.

[0040] In the second heat exchanger **6**, the thermal energy of the process water is transferred to the cooling water, the latter entering the second heat exchanger **6** through its first cooling water inlet **19** and having the initial temperature t1 typically ranging between about 35 and 40 °C. Upon leaving the outlet **20**, the cooling water has the temperature t2 typically ranging between 90 and 95°C. The cooling water is led into the cooling water inlet **21** of the third heat exchanger **18** for extracting heat from the flue gases and transferring it to the cooling water. Then, the cooling water having the temperature t3, typically between 105 - 135°C, leaves the cooling water outlet **22** of the third heat exchanger **18** and flows to the feed tank of a heat source and/or to the heating circuit of a boiler and/or to another heating circuit.

[0041] In order to enable the temperature of the cooling water to be regulated, the branch **24**, which is arranged upstream of the flue-gas inlet **8** of the direct-contact heat exchanger **1**, is provided with the regulating member **23** and routed to the flue-gas outlet **25** of the direct-contact heat exchanger **1**, thus allowing a certain amount of flue gas to be directly discharged into the ambient atmosphere after passing through the third heat exchanger **18**. The flue-gas outlet **25** of the direct-contact heat exchanger **1** is routed into the ambient atmosphere through the regulating flap **26**. In the case of need, the temperature of the cooling water can be decreased through partly opening the regulating member **23** and throttling the regulating flap **26**. Thus, a certain amount of the flue gases can be discharged from the third heat exchanger **18** directly into the ambient atmosphere without having to pass through the direct-contact heat exchanger **1** and without losing any part of the thermal energy which would be otherwise transferred to the process water.

[0042] Fig. 2 shows another exemplifying embodiment of the device according to the invention. The flue-gas circuit is identical to that of the device shown in Fig. 1. The section of the process-water circuit, in which the process water flows from the sedimentation vessel **3** through the second heat exchanger **6** into the process-water inlet **7** of the direct-contact heat exchanger **1**, is complemented by the parallel section leading from the second process-water outlet **11** of the sedimentation vessels **3** through the second process water pump **28** into the process-water inlet **12** of the fourth heat exchanger **13** and then from the fourth heat exchanger **13** into the second process-water inlet **15** of the second heat exchanger **6**. After passing through the fourth heat exchanger **13** and the second heat exchanger **6** the process water is cooled and its temperature drops to tp_3 (typically 61°C) and tp_2 (typically 40°C), respectively. When passing through the direct-contact heat exchanger **1**, the process water is reheated and its temperature is increased to tp_1 , typically ranging between 90 and 95°C . In this exemplary embodiment, there are also two cooling water circuit, the first one being identical with that described with reference to Fig. 1 and the second one containing e.g. circulating water of a heating system. In this embodiment, the circulating water of a heating system, which passes through the fourth heat exchanger **13**, may have, for example, the typical inlet temperature $t_4 = 60^\circ\text{C}$ and the typical outlet temperature $t_5 = 90^\circ\text{C}$.

[0043] The required cooling water having the temperature $t_1 = 35^\circ\text{C}$ can be supplied in the form of the condensate produced in a steam condenser located downstream of a condensing steam turbine having the same temperature. Such condensate can be heated up during the passage through the second heat exchanger **6** to the temperature $t_2 = 90^\circ\text{C}$ and, subsequently, during the passage through the third heat exchanger **18** to the temperature of 135°C . Then, the heated-up condensate is led into a boiler feed tank from where it can be supplied into a boiler in which steam is generated to serve as the mo-

tive medium for a condensing steam turbine.

[0044] Alternatively, the condensate may be the cooled one returning from the heating circuit of a drying plant, e.g. a malt drying kiln, wherein such returning condensed water may be aftercooled by a stream of drying air entering the malt drying kiln on order that the temperature of the same drops to about 40°C . Subsequently, the condensate is heated in the second heat exchanger **6** up to 90°C and then, during the passage through the third heat exchanger **18** up to 105°C . Afterwards, the condensate flows into a boiler feed tank from where it is be supplied into a boiler in which it turns to steam. Such steam is fed into a steam- to- air heat exchanger of the drying plant where it turns to condensed water. Then, the latter is aftercooled by the air taken into the drying plant. Thus, the temperature of the condensed water drops to about 40°C and the complete cycle will be repeated.

[0045] In still another exemplifying embodiment, the cooling water may be cold water returning from the heating circuit and having the temperature $t_1 = 45^\circ\text{C}$. This water is heated up to the temperature $t_2 = 85^\circ\text{C}$ in the second heat exchanger **6** and to the temperature 110°C in the third heat exchanger **18** from where it may be led into the working circuit of a heating system, such as a swimming pool. Alternatively, this water may be led a hot-water boiler where its temperature is further increased, e.g. to 150°C . Such boiler may supply a municipal heating system with hot water.

Industrial applicability

[0046] The invention may be particularly useful in block-type thermal power stations where electrical energy is generated by means of steam condensing turbines, preferably by means of double-extraction condensing steam turbines, and where low-potential cooling media are used, such as condensates produced in condensing steam turbo-sets which are supplied by solid fuel fired boilers or gas fired boilers. The advantages of the invention are especially considerable in those turbo-sets where the heat-exchanging surfaces of the condensers are more or less subject to corrosion attacks. Furthermore, the invention is useful whenever a low-potential medium can be found that requires to be heated up to the boiling temperature of the process liquid of a direct-contact heat exchanger under given ambient atmospheric and pressure conditions.

List of reference signs

[0047]

- 1 - direct-contact heat exchanger
- 2 - built-in structure of the direct-contact heat exchanger
- 3 - sedimentation vessel
- 4 - first process water pump
- 5 - apparatus for replenishing alkali in process water

- 6 - second heat exchanger
- 7 - process-water inlet of the direct-contact heat exchanger
- 8 - flue-gas inlet of the direct-contact heat exchanger
- 9 - process-water outlet of the second heat exchanger
- 10 - process-water inlet of the second heat exchanger
- 11 - second process-water outlet of the sedimentation vessel
- 12 - process-water inlet of the fourth heat exchanger
- 13 - fourth heat exchanger
- 14 - process-water outlet of the direct-contact heat exchanger
- 15 - second process-water inlet of the second heat exchanger
- 16 - ploughing apparatus
- 17 - first process-water outlet of the sedimentation vessel
- 18 - third heat exchanger
- 19 - first cooling water inlet of the second heat exchanger
- 20 - cooling water outlet of the second heat exchanger
- 21 - cooling water inlet of the third heat exchanger
- 22 - cooling water outlet of the third heat exchanger
- 23 - regulating member
- 24 - branch
- 25 - flue-gas outlet of the direct-contact heat exchanger
- 26 - regulating flap
- 27 - pH meter
- 28 - second process water pump
- 29 - apparatus for replenishing the supply of process water and/or for draining process water

Claims

1. A method for a utilisation of a residual heat of flue gases having a temperature, which exceeds their dew point and contains aggressive constituents, in particular flue gases discharged from solid fuel firing boilers, **characterized in that** the flue gases are blown along a process water causing a thermal energy of the flue gases to be transferred to the process water in order to heat the latter at most up to a boiling temperature of the same under given ambient atmospheric and pressure conditions, a pH value of the process water being adjusted to enable a neutralization of a corrosive action of a condensing flue gas constituents, whereupon the process water is heated up by the flue gases, its heat is transferred to a cooling water and subsequently the cooled process water re-enters the flue gas flow in order to extract thermal energy therefrom.
2. The method for the utilisation of the flue gases of according to claim 1, **characterized in that** the cooling water is heated up to a temperature exceeding

its inlet temperature, but at most to a temperature corresponding to the boiling point of the process water under given ambient atmospheric and pressure conditions.

3. The method for the utilisation of the flue gases according to claim 1, **characterized in that** the cooling water is a condensate produced by a condensation of a steam, in particular by the condensation of the steam used as a motive medium for a steam turbine.
4. The method for the utilisation of the flue gases according to claim 1, **characterized in that** the cooling water is the condensate produced by the condensation of the steam downstream of the condensing steam turbine.
5. The method for the utilisation of the flue gases according to claim 1, **characterized in that** the cooling water is the cooled water returning from the heating system and having a temperature in the range of 0°C to 80°C, or preferably to 60°C, or more preferably to 50°C.
6. The method for the utilisation of the flue gases according to claim 3 or 4, **characterized in that** the condensate heated up by the process water is used as a feedwater for a steam boiler.
7. The method for the utilisation of the flue gases according to claim 2, **characterized in that** the cooling water is heated up by the process water to the temperature over 40 °C, or over 50 °C, or over 60°C.
8. The method for the utilisation of flue gases according to claim 1, **characterized in that** the inlet temperature of the cooling water before being heated up by the process water ranges from 0°C to 80°C, or at least to 60°C, or at least to 50°C, or at least to 40°C.
9. The method for the utilisation of the flue gases according to claim 1, **characterized in that** the cooling water heated up by the flue gases through a mediation of the process water is additionally fed into the flue gas flow upstream of a zone, where the flue gases are blown along the process water, in order to be heated up to a still higher temperature.
10. The method for the utilisation of the flue gases according to claim 1, **characterized in that** a pH value of the process water, along which the flue gases are blown, is greater than 5.0, or greater than 6.5, or greater than 6.9.
11. The method for the utilisation of the flue gases according to claim 10, **characterized in that** the pH value of the process water, along which the flue gases are blown, is greater than 7.5.

12. The method for the utilisation of the flue gases according to claim 1, **characterized in that** solid sediments are separated from the process water.
13. A device for performing the method according to claims 1 to 12, **characterized in that** it comprises a direct-contact heat exchanger (1) for extracting the heat from the flue gases and transferring it to the process water, a direct-contact heat exchanger (1) having a flue-gas inlet (8), which is connected to a flue-gas outlet of the solid fuel fired boiler and/or to that of an incineration plant producing the flue gases that contain aggressive constituents, said flue gases being led through the direct-contact heat exchanger (1), and a process-water inlet (7), which is arranged on an opposite end, for a contact heat transfer between the flue gases and the process water inside the direct-contact heat exchanger (1), a process-water outlet (14) of the direct-contact heat exchanger (1) being connected to a first process-water inlet (10) of a second heat exchanger (6) for extracting heat from the process water and transferring it to the cooling water, a process-water outlet (9) of the second heat exchanger (6) being connected to the process-water inlet (7) of the direct-contact heat exchanger (1), a process-water circuit further comprising an inlet for connecting an apparatus (5) for replenishing alkali into the process water in order to maintain the pH value of the process water at a level enabling a corrosive effect of acids, which are produced during the condensation of the flue gases, to be neutralized.
14. The device according to claim 13, **characterized in that** the direct-contact heat exchanger (1) is equipped with a built-in structure (2) for increasing a heat transfer efficiency, in particular for increasing the efficiency of the heat transfer between the flue gases and the process water, and/or for rinsing interior surfaces of the direct-contact heat exchanger (1) and/or for an increasing an efficiency of a neutralization of a corrosive effect of the acids produced during the condensation of the flue gases.
15. The device according to claim 13, **characterized in that** the flue-gas inlet (8) of the direct-contact heat exchanger (1) is arranged in a bottom portion of the direct-contact heat exchanger (1) while the process-water inlet (7) for rinsing the interior surfaces of the direct-contact heat exchanger (1) and for receiving the heat extracted from the flue gases is arranged in a top portion of the direct-contact heat exchanger (1).
16. The device according to claim 13, **characterized in that** it further comprises a sedimentation vessel (3) for settling of the solid particles flushed out from the direct-contact
- heat exchanger (1), said vessel being arranged between the direct-contact heat exchanger (1) and the second heat exchanger (6) and connected to the same.
17. The device according to claim 16, **characterized in that** the sedimentation vessel (3) for settling of the solid particles flushed out from the direct-contact heat exchanger (1) is provided with a ploughing apparatus (16) for removing the sediments from the sedimentation vessel (3).
18. The device according to claim 13, **characterized in that** the apparatus (5) for replenishing alkali into the process water in order to maintain the pH value of the process water at a level enabling the corrosive effect of the acids, which are produced during the condensation of the flue gases, to be neutralized, is adjusted to maintain the pH value of the process water at a level greater than 5.0, particularly greater than 6.5, preferably greater than 6.9 and most preferably greater than 7.5.
19. The device according to claim 16, **characterized in that** it further comprises a first process water pump (4) which is arranged between the sedimentation vessel (3) for settling of the solid particles flushed out from the direct-contact heat exchanger (1) and the second heat exchanger (6) for extracting heat from the process water and transferring it to the cooling water.
20. The device according to claim 13, **characterized in that** the apparatus (5) for replenishing alkali into the process water in order to maintain the pH value of the process water at a level enabling the corrosive effect of the acids, which are produced during the condensation of the flue gases, to be neutralized, is connected to the process-water circuit through the sedimentation vessel (3).
21. The device according to claim 13, **characterised in that** the second heat exchanger (6) is provided with a cooling water outlet (30), which is connected to a cooling water inlet (21) of a third heat exchanger (18) for extracting heat from the flue gases and transferring it to the cooling water, the third heat exchanger (18) being arranged between the flue-gas outlet of a heat source and the flue-gas inlet (8) of the direct-contact heat exchanger (1), while a cooling water outlet (22) of the third heat exchanger (18) is connected to a feed tank of a heat source and/or to a heating circuit of a boiler and/or to another heating circuit.
22. The device according to claim 13, **characterized in that** it further

comprises a branch (24), which is arranged upstream of the flue-gas inlet (8) of the direct-contact heat exchanger (1), said branch being provided with a regulating member (23) and routed to a flue-gas outlet (25) of the direct-contact heat exchanger (1), in order to increase the outlet temperature of the flue gases and/or to enable the final temperature of the flue gases to be regulated and/or to enable the amount of the heat output being transferred to the heat exchangers (1, 6, 18) to be regulated.

- 23.** The device according to claim 22, **characterized in that** it further comprises a regulating flap (26), which is arranged in the flue-gas outlet (25) of the direct-contact heat exchanger (1), in order to increase the outlet temperature of the flue gases and/or to enable the final temperature of the flue gases to be regulated and/or to enable the amount of the heat output being transferred to the heat exchangers (26, 6, 18) to be regulated.
- 24.** The device according to claim 13, **characterized in that** it further comprises an apparatus (29) for replenishing the supply of process water and/or for draining the latter, said apparatus being arranged between the process-water outlet (9) of the second heat-exchanger (6) and the process-water inlet (7) of the direct-contact heat exchanger (1).
- 25.** The device according to claim 13, **characterized in that** the second heat exchanger (6) is provided with a cooling water inlet (19) connected to a steam condenser located downstream of the condensing section of the steam turbine and/or downstream of the steam turbine itself and/or downstream of the steam heating system, the cooling water being the steam condensate having a temperature ranging between 0 and 80°C, or between 0 and 70°C, or between 0 and 60°C, or between 0 and 50°C, or between 0 and 40 °C.
- 26.** The device according to claim 21, **characterized in that** the cooling water outlet (22) of the third heat exchanger (18) and/or the cooling water outlet (20) of the second heat exchanger (6) are connected to the feedwater inlet of the steam boiler and/or another heat source and/or another heating circuit.
- 27.** The device according to claim 21, **characterized in that** the cooling water outlet (22) of the third heat exchanger (18) and/or the cooling water outlet (20) of the second heat exchanger (6) are connected to a thermal circuit, in particular to a thermal circuit incorporating a boiler.

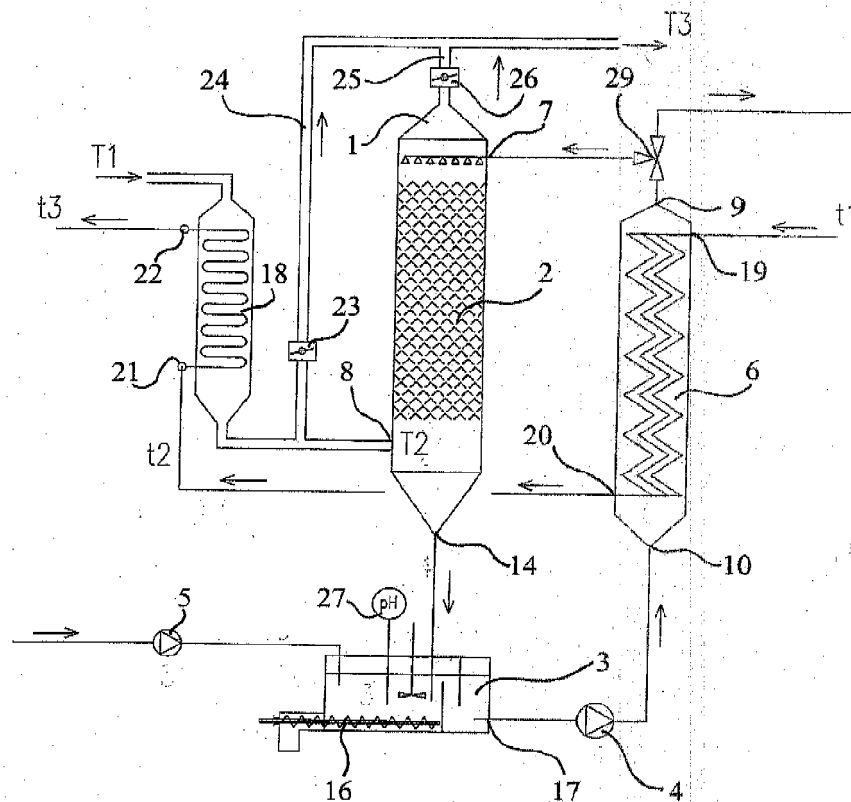


Fig. 1

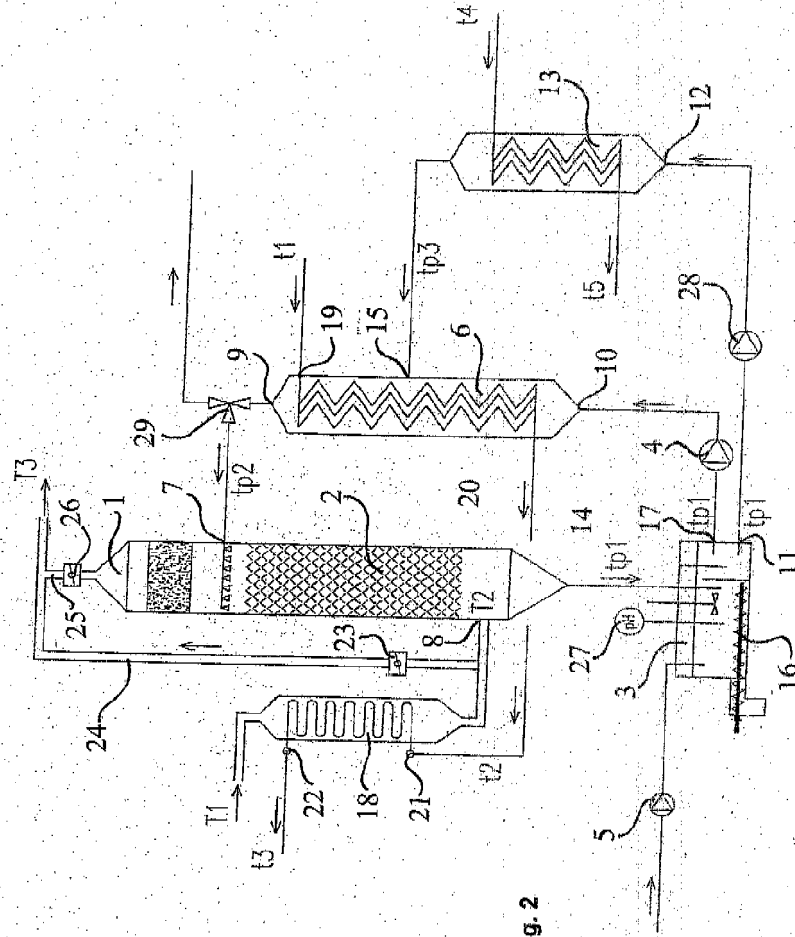


Fig. 2



EUROPEAN SEARCH REPORT

Application Number
EP 13 46 6004

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EUROPEAN SEARCH REPORT

Application Number
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