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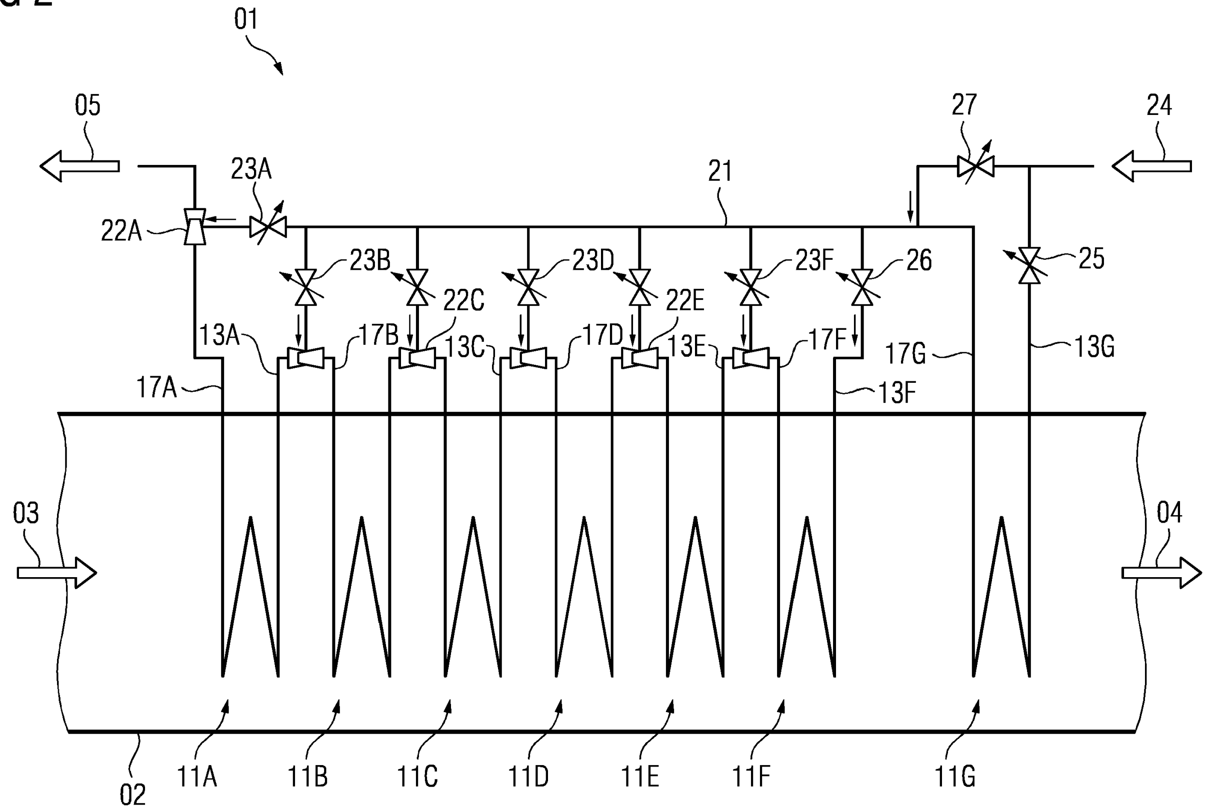
(54) **STEAM GENERATOR WITH ATTEMPERATORS**

(57) The invention is about an advantage steam generator (01) and a steam generation system with an arrangement of heat-exchangers (11) within a hot gas path (02). To protect the facilities and to increase the efficiency at least at the output of several heat-exchangers (11) an attemperator (22) is arranged, wherein each of them (22) is connected via a fluid valve (23) with a distribution piping (21).

FIG 2



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Description

[0001] The invention relates to a steam generator and a steam generation system. In particular, the invention is about the protection of the steam generator and a further steam turbine against rapidly increase of steam temperature and the efficient heat transfer from a hot gas to an evaporation medium.

[0002] A power plant often combines a gas turbine with a steam turbine to create electrical energy with the best efficiency. Usually a steam generator is used to convert the hot gas from the gas turbine into hot steam for the steam turbine.

[0003] Therefore, the common steam generator comprises first a hot gas path from a hot gas input to a waste gas output. Inside the hot gas path several heat exchangers are arranged, starting form an economizer at the waste gas output side over a series of further heat exchangers up to a superheater at the hot gas output side. The temperature of the fluid flowing through the heat exchangers increases from one heat exchanger to the next, whereby the economizer is feed with cold water and a hot steam is leaving the superheater.

[0004] Gas turbines enables a quick response to the request for electrical energy with the result of a rapidly increase of the temperature of the hot gas leaving the gas turbine. Without protection methods the quick temperature change bears the risk of too high thermal stress especially at the steam turbine.

[0005] Therefore, a common solution is to arrange attemperators within the connection piping from the steam generator to the steam turbine. The attemperator is used to inject water into the hot steam after the superheater. Thus, leads to a reduction of the temperature of the hot steam delivered to the steam turbine.

[0006] Although the protection of the steam turbine by the usage of an attemperator is well established, there is no protection of the steam generator itself upstream (along the flow of steam) the attemperator. The highest temperatures and the highest temperature changes arise inside the exit of the superheater close to the hot gas inlet of the hot gas path. This leads further to high thermal stress inside the piping from the superheater at least up to the location of the attemperator. This leads to an oversized dimension of the used installations.

[0007] Therefore, further solutions are known from the state of the art, where an attemperator is arranged between the second last heat exchanger and the superheater as last heat exchanger. Compared to the forgoing solution the superheater itself and consequently also the piping at the exit of the superheater is less stressed.

[0008] But the solution with the attemperator in front of the superheater have the drawback of the bad adjustability of the temperature of the hot steam at the output of the superheater. This could lead to some loss of efficiency at the startup of the powerplant or at a rapid increase of power output.

[0009] A further disadvantage of common systems is the problem, that the control of the attemperator is very sensitive. To prevent overshoot due to the sensitive control of the steam temperature by opening/closing a valve in the cold-water line to the attemperator it is commonly necessary to keep a further distance between the actual temperature / temperature change during the operation, especially at startup of the turbine and the admissible temperature / temperature change.

[0010] As result, the arrangement of an attemperator in from of the superheater is no improvement regarding the necessary distance between the actual temperature / temperature change during the operation and the admissible temperature / temperature change.

[0011] From state of the art it is also known that once-through steam generators can be slow in responding to temperature changes because of long traveling time of the feed water through all the heat exchangers towards the superheater outlet.

[0012] The task for the current invention is therefore to enable a good and fast adjustability of the hot steam temperature and further protect the piping of the superheater at the output side and further the piping to the steam turbine against rapid temperature changes.

[0013] The task is solved by a steam generator according to claim 1. A steam generating system to enable the operation is stated in claim 4. An inventive method to operate a steam generating system is stated in claim 7. Further claims specify advantageous solution.

[0014] A generic kind of a steam generator has a casing with a hot gas path inside passing through the casing from a hot gas input to a waste gas output. The steam generator comprises serval heat exchangers, which are arranged at least partially inside the hot gas path.

[0015] A superheater as one of the heat exchangers is arranged close to the hot gas input. The superheater comprises a superheater output as connection to further facilities, e.g. a steam turbine, to deliver a flow of hot steam. The superheater further comprises a superheater input.

[0016] Further within the hot gas path a first heat exchanger is arranged. This comprises analog a first output and a first input. Here the first output is in connection with the superheater input.

[0017] Next, within the hot gas path a second heat exchanger is arranged. This comprises analog a second output and a second input. Here the second output is in connection with the first input.

[0018] Next, within the hot gas path a third heat exchanger is arranged. This comprises analog a third output and a third input. Here the third output is in connection with the second input.

[0019] Next, within the hot gas path a fourth heat exchanger is arranged. This comprises analog a fourth output and a fourth input. Here the fourth output is in connection with the third input.

[0020] In a further embodiment it is also possible to arrange a fifth heat exchanger in the series next to the fourth heat exchanger or even further heat exchangers in the series, each comprising a fluid input and a fluid output, which are connected in the series of heat exchangers.

[0021] Last within the hot gas path an economizer is arranged. This comprises analog an economizer output and an economizer input. Here the economizer output is in connection with the fluid input of the last heat exchanger. The economizer input is in connection with a source of cold fluid. In the common solution water is used as fluid, but other fluids which could be evaporated could also be used.

[0022] It should be noted that it is not necessary, that the superheater and the heat exchangers and the economizer are arranged immediate and/or in the respective sequence to each other inside the hot gas path. Also, other features or other heat exchanges, which are not connected along the series of heat exchanges according the generic solution, could be arranged within the hot gas path and also between the heat exchangers of the generic solution.

[0023] It should be noted further that it is not necessary, that the superheater and the heat exchangers and the economizer are connected directly to each other. It is also possible, that further devices, e.g. other heat exchangers or vessels, are arranged in between the superheater and/or the heat exchangers and/or the economizer according the generic solution. But the preferred solution provides a direct connection from the superheater to the first heat exchanger and a direct connection from the first heat exchanger to the second heat exchanger and so on until the last heat exchanger in the series is connected to the economizer.

[0024] Each of the superheater and the heat exchanges and the economizer comprise a fluid input, with is connected to a further heat exchanger or another part of the steam generator. During operation fluid, e.g. water and/or steam, with a lower temperature is supplied at the fluid input. The fluid input is connected to one or more distribution pipes to split the fluid flow into different pipes. Each of the superheater and the heat exchanges and the economizer further comprises several heat exchange tubes, each connected to one of the respective distribution pipes. The heat exchange tubes are arranged at least partially, in particular complete, inside the hot gas path. In operation the flow of hot gas along the hot gas path passing the heat exchangers leads to a transfer of heat from the hot gas to the fluid, e.g. water/steam, inside the heat exchange tubes. Each of the heat exchange tubes is connected to a collection pipe, where each of the superheater and the heat exchanges and the economizer comprises one or more collection pipes to collect the hot fluid from the heat exchange tubes. The collection pipes are in connection with a fluid output, which serves as connection to a further heat exchanger or other facilities, e.g. a steam turbine.

[0025] The steam generator further comprises a distribution piping to distribute a certain kind of fluid.

[0026] Within the piping from the first output of the first heat exchanger to the superheater input a first attemperator is arranged. This first attemperator comprises a connection to a distribution piping, wherein in the connection to the distribution piping a first valve is arranged to control the flow from the distribution piping to the first attemperator.

[0027] To improve the stability of the control of the steam generator for the inventive solution further attemperators are provided at the heat exchangers.

[0028] Therefore, within the piping from the second output of the second heat exchanger to the first input of the first heat exchanger a second attemperator is arranged. This second attemperator comprises also a connection to a distribution piping, wherein in the connection to the distribution piping a second valve is arranged to control the flow from the distribution piping to the second attemperator.

[0029] Further, within the piping from the third output to the second input a third attemperator is arranged. This third attemperator comprises also a connection to a distribution piping, wherein in the connection to the distribution piping a third valve is arranged to control the flow from the distribution piping to the third attemperator.

[0030] Next, within the piping from the fourth output to the third input a fourth attemperator is arranged. This fourth attemperator comprises also a connection to a distribution piping, wherein in the connection to the distribution piping a fourth valve is arranged to control the flow from the distribution piping to the fourth attemperator.

[0031] If further heat exchangers are arranged between the fourth heat exchanger and the economizer it is possible to arrange further attemperators at the respective connection from one heat exchanger to the next heat exchanger in the series of heat exchangers. In this embodiment it is further advantage to arrange a respective valve in the connection from the further attemperator to the distribution piping.

[0032] It is necessary for the inventive solution to supply the attemperators with a fluid. Therefore, the distribution piping is in connection with the economizer output. To enable a control of the temperature and the flow rate through the distribution piping a further connection from the distribution piping to the source of cold fluid is available.

[0033] This enables the possibility to supply a warm, not evaporated fluid, e.g. hot water, to the different attemperators to enable a beneficial control of the temperatures while reaching an advantageous efficiency.

[0034] Each of the attemperators comprises one or more fluid nozzles to introduce a cooling fluid, e.g. water, into the steam flowing through the attemperator, e.g. the connection from one heat exchanger to the next heat exchanger or superheater in the series. The fluid nozzle itself is connected with the distribution piping as a cooling fluid supply for the attemperators. The flow of the cooling fluid from the distribution piping to the fluid nozzles could be controlled by the usage of respective fluid valves.

[0035] As result, the steam generation is enhanced by adding extra fluid in the evaporator section, shortening the traveling time, improving the response time, and without increasing ex-ergy loss since the attemperator fluid is added in a boiling environment and thus the fluid temperature remains constant.

[0036] In a preferred embodiment a last valve is arranged between the input of the last heat exchanger before the economizer and the economizer output. This enables the control of the flow of the fluid into the last heat exchangers.

[0037] In a further particular solution, a fluid supply valve is arranged at the economizer input or at the economizer output. This enables the control of the flow of fluid through the economizer.

[0038] If the flow of fluid through the economizer should be prevented or if the flow of fluid through the economizer is not enough to supply the last heat exchanger and the distribution piping a bypass to the economizer could be used. To enable a control of the flow through the bypass, within the connection from the distribution piping to the source of cold fluid in the advantageous solution a fluid bypass valve is arranged.

[0039] To enable an advantageous control of the steam temperature at the output of the superheater in a preferred solution a main attemperator is arranged in the superheater output. This attemperator is also connected to the distribution piping with a main valve arranged within this connection. This enables a precise control of the steam temperature, especially at the start of a steam turbine.

[0040] To protect the piping between heat-exchangers and especially the piping at the superheater output it is advantageous to arrange attemperators within at least two collection pipes of a heat exchanger and/or preferably in the superheater. It is in particular advantageous to arrange an attemperator within each existing collection pipe of a heat exchanger respectively superheater.

[0041] With the arrangement of attemperators in the collection pipes it is possible to enable a beneficial control of the temperature of the hot fluid, e.g. steam, at the output of the heat exchanger respectively superheater with a fast response to a change of the heat input. Further the fluid output line could be protected against a rapid temperature change. As result, especially an increase of the lifetime could be expected and in the best case a limitation of start-ups of the steam generator could be omitted.

[0042] The solution with the attemperators in the collection pipes is the best compromise between the effort to implement the cooling solution and the protection against thermal stress.

[0043] Here it is necessary to connect each of the attemperator with the distribution piping, wherein it is possible to connect all attemperators of one heat exchanger respectively superheater with one fluid valve, which controls the cooling fluid flow to all of the attemperators at the same time.

[0044] Against the previous first realization it is advantageous, if with two or more fluid valves are used. In this case each of the fluid valve is used to control the flow of cooling fluid to at least one attemperator. With the second approach it leads to the possibility to control the temperature of the steam at the output of each of the collection pipes separately.

[0045] As one benefit, with the usage of serval fluid valves simple on-off valves could be used, whereby the number of valves to be opened varies during operation dependent on the temperature of the hot steam.

[0046] The highest temperatures inside the heat exchangers could be expected at the upstream side (with regard to the flow of the hot gas through the steam generator) at the hot gas input. Therefore, it is advantageous, if the arrangement of at least two attemperators within the collection pipes is used at the superheater, especially if it is arranged as the first heat exchanger starting at the hot gas input.

[0047] The inventive steam generator enables an inventive steam generating system, which comprises the inventive steam generator according to the forgoing description. Here it is necessary, that the steam generating system comprises a control system. The control system is in connection with the fluid valve to control the opening position of each of the fluid valves.

[0048] To enable a preferred operation of the steam generation system with the control system especially for the different heat-exchangers respectively superheater it is advantageous, if the different fluid valves of the steam generator could be controlled separately.

[0049] Furthermore, it is advantageous, if different valves of the number of valves could be controlled in groups at the same time dependent from each other.

[0050] To enable an optimized control it is further advantageous, if the control system is able to control the fluid valves stepwise so that the strength of the flow of fluid from the distribution piping to the respective attemperator corresponds to the needs.

[0051] To control the steam generating system two different kind of information about the status of the steam generator could be preferably used.

[0052] In a first embodiment the steam generating system further comprises a temperature determination system, wherein the temperature determination system comprises a temperature sensor. With the temperature sensor, the temperature determination system is able to determine at least the temperature of the hot steam leaving one of the heat-exchangers respectively the superheater or the temperature of the piping at the fluid output.

[0053] The temperature determination system should be able to determine the actual temperature of the fluid at the fluid output of the heat exchanger respectively superheater. As example a temperature sensor inside the fluid output could be applied.

[0054] But instead it could be sufficient to measure the temperature of the fluid output, that means the tubing, itself. Then it should be possible to calculate also the temperature of the hot steam inside the fluid output.

[0055] To enable an improved control of the different fluid valves the preferred embodiment comprises at least one further temperature sensor. This could be additional to a first temperature sensor a second temperature sensor, which is able to measure the temperature of the steam and/or of the piping before or after a second attemperator, e.g. at the second output at the second heat-exchanger.

[0056] A third temperature sensor is preferable able to measure the temperature of the steam and/or of the piping before or after the third attemperator.

[0057] The same applies for the further heat-exchangers respectively superheater with the preferred usage of further temperature sensors to analyze the temperature at the other attemperators.

[0058] With the temperature determination systems with the ability to determine several temperatures at the different attemperators, the control system is then enabled to control the different fluid valves separately depending on the different temperatures at the respective attemperators.

[0059] For a second embodiment of an inventive steam generating system a vapor determination system is necessary. Here the vapor determination system must be possible to determine at least one share of vapor in the fluid inside the piping before and/or after one of the attemperators.

[0060] If the mass flow from the distribution piping to the first attemperator and the mass flow through the attemperator is known, the share of vapor could be calculated on the other side of the attemperator (it the measuring of the share of vapor is arranged upstream it could be determined for the downstream side and vice versa).

[0061] Analogues to the determination of the temperature it is advantageous if the vapor determination system is able to determine the vapor at further attemperators.

[0062] With the vapor determination systems able to determine the share of vapor at different attemperators, the control system is then enabled to control the different fluid valves separately depending on the share of vapor at the respective attemperators .

[0063] In a third embodiment the steam generation system combines the first and second embodiment with a temperature determination system and a vapor determination system. Here the steam generating system enables with the control system the control of the fluid valves dependent on the measured temperatures respective temperature changes and dependent on the analyzed share of vapor at the attemperators.

[0064] The new steam generation system as described before enables a new inventive method to control the steam generation system. Dependent on the determination system used different implementations are possible.

[0065] With the steam generation system comprising a temperature determination system in a first step it is necessary to determine the actual temperature at a fluid output of the heat-exchanger. As already explained, this could be the temperature of the piping itself or the temperature of the fluid inside the piping. In the first case it should be possible to estimate the temperature of the fluid and in the second case it should be possible to estimate the temperature of the piping.

[0066] Additionally, it is possible to determine an actual temperature change.

[0067] Second, the actual temperature has to be compared with a predetermined value.

[0068] In a third step at least one fluid valve is controlled dependent on the outcome of the comparison between the actual temperature / temperature change and the predetermined value. Here it is at least possible to open or close at least one fluid valve.

[0069] Preferably it is possible to open the fluid valve stepwise and/or to open/close several fluid valves.

[0070] The control system can compare the determined actual temperature or temperature change with a predetermined value and dependent on the result, mainly if the actual temperature or an actual temperature change exceeds the predetermined value, the control system is able to control at least one fluid valve of the several fluid valves.

[0071] In a first and obvious solution the predetermined value could be a maximum allowable temperature. If the actual temperature exceeds the maximum temperature an opening of a fluid valve will lead to an introduction of cooling fluid into the steam and therefore a lowering of the temperature of the fluid and the piping.

[0072] It could be, that the introduction of the cooling fluid, e.g. water, into the fluid (steam, hot water) at the output of the heat exchanger respectively superheater is only necessary under certain circumstances, especially if there is a threat of a too high temperature or especially a too fast increase of the temperature.

[0073] In a further embodiment a maximum temperature change could be used as predetermined value. If the increase of the main temperature goes beyond the maximum temperature change an opening of at least one fluid valve is triggered. This will reduce of even stop a further increase of the temperature of the steam and the piping.

[0074] Also, both limits could be used in combination to analyze an inadmissible temperature or the danger of reaching an inadmissible temperature.

[0075] With the input from the temperature determination system the control system should be able to calculate the necessary reaction to protect the steam generating system and subsequent facilities from overheating or a too fast heat increase. Therefore, the control system must be connected with the fluid valves. On exceeding a predetermined value, the control system can open one or more of the fluid valves accordingly.

[0076] As predetermined value to trigger the opening of the at least one fluid vale a maximum temperature could be used. It is also possible to use a maximum allowable temperature change as predetermined value.

[0077] It is further possible to define a predetermined value as a maximum temperature dependent to the actual temperature change. A predefined dependence of the maximal temperature to the temperature change could be defined with for example a higher maximal temperature if the temperature change is small and a lower maximal temperature if the temperature change is large.

[0078] Respectively as a predetermined value a maximum temperature change dependent on the actual temperature could be used. In this case for example a greater maximum temperature change could be allowed at lower temperatures and a smaller maximum temperature change at higher temperatures. As result at a range of uncritical temperatures faster temperature changes could be allowed with a faster increase of the power output and protective smaller temperature changes are applied if the temperature reaches relevant material limits.

[0079] In the preferred case the temperature of the fluid at the fluid output and/or the temperature of the fluid output is relevant to trigger the control system and further to trigger the opening the fluid valve in case of exceeding the predetermined value to protect the facilities.

[0080] It is obvious, that in case of the usage of the maximum temperature change as a predetermined value the actual temperature change is used and not only the actual temperature.

[0081] It is also possible to use not only one fixed predetermined value but instead a characteristic curve as predetermined value. The characteristic curve could be a predefined maximum temperature, which chances the value depending on a temperature change. The characteristic curve is in this case predefined. As result the control system uses the characteristic curve, which leads to predetermined value which is different dependent from the actual temperature change.

[0082] Reverse it is also possible to define a characteristic curve with a predefined maximum temperature change, which chances the value depending on a temperature. This leads to a predefined value as a comparative for the control system with a maximum temperature change dependent from the actual temperature.

[0083] To enable a further advantageous control of the steam generating system, there is not only a comparison of the temperature / temperature change and the predetermined value but further a consideration of the distance of the actual temperature respectively of the actual temperature change and the allowable process conditions. Therefore, advantageously the difference between the actual temperature respectively the actual temperature change and the predetermined value is calculated.

[0084] In a further advantageous step, it is possible to perform a trend analysis for the actual temperature. Therefore, the actual temperature needs to be recorded for a period. With this data of past temperatures and the current temperature a predictive temperature could be calculated. This leads to the possibility to compare not only the actual temperature with the predetermined value but also the predictive temperature and further the predictive temperature with the predetermined value. Also, a difference could be determined. With this information a further anticipatory driving of the fluid vales is possible.

[0085] The advantageous method uses a steam generation system, which is enabled to determine the temperature / temperature change at all fluid outputs at all heat-exchangers respectively the superheater. This leads to the possibility to compare all actual temperatures / temperature changes with respective predetermined values and to control the fluid valves dependent to the comparison both each fluid valve dependent to the respective comparison and also dependent to the comparison for other than the respective attemperator.

[0086] In a further step the fluid valves are opened dependent on the distance between the current situation and the allowable situation. So, if the difference is available, then it is further advantageous, to open a number of fluid valves of the several fluid valves dependent on the calculated difference. Here the "to be opened fluid valves" could be chosen according further rules.

[0087] The protecting the steam generator could be improved and/or the efficiency could be increased, if there are not only an on-off state of the fluid vale. In an advantageous solution the at least one fluid valve could be opened stepwise for example dependent on the difference between the actual temperature or temperature change and the predetermined value. Analog, the fluid valves to be triggered could also be chosen according further rules.

[0088] Obviously, it is possible to implement a control system with both options, that a number of the several fluid valves are opened individually in a stepwise manner.

[0089] The preferred solution with the further temperature sensors a further advantageous method to operate the steam generator system is enabled. Here it is necessary in a first step to determine at least one or more further temperatures. This could be a main temperature of a main temperature sensor at the fluid output of the superheater or a first temperature of the first temperature sensor at the first fluid output of the first heat exchanger or a second temperature of the second temperature sensor at the second fluid output of the second heat-exchanger, and so on. Further a main temperature change respectively a first temperature change respectively a second temperature change (and so on) could be determined.

[0090] With this example having several actual temperatures in a next step the main and the first respectively second respectively temperature / temperature change (and so on) has to be compared with a main respectively first respectively second respectively third respectively fourth predetermined value (and so on).

[0091] The calculation of the difference enables in the next step to control the respective fluid valve and preferably also the other fluid valve dependent on the determined difference in a stepwise manner.

[0092] It is obvious, that in an easy solution all fluid valves are controlled simultaneously. But in preferred solution the control system is able to control the different fluid valves separately. Here it is advantageous, if the main fluid valve and the first fluid valve and the second fluid valve (and so on, as available) could be controlled separate dependent on exceeding a respective predetermined value.

[0093] To enable an anticipatory control of the steam generating system in an advantageous method the temperature respectively the temperature changes is recorded over a period. Here, it is advantageous to record some or all temperatures at all attemperators over a period.

[0094] With this gathered data a trend analysis could be performed, and an expected future temperature respectively expected future temperature change could be calculated.

[0095] In a next step not only the actual temperature respectively temperature change. Henceforth it is possible to compare the currently determined actual temperature respectively temperature change with the previously predicted value.

[0096] It is obvious, that the same comparison could be done with the further determined temperatures / temperature changes.

[0097] In a further advantageous control method, the difference between the last actual temperature respectively temperature change respectively and the corresponding previously determined predicted value could be calculated.

[0098] Second, it is possible to compare the predicted value with the corresponding predetermined value.

[0099] In a further advantageous control method, the difference between the predicted value and the corresponding predetermined value could be calculated.

[0100] As result the number of fluid valve are opened and/or the fluid valves are opened stepwise dependent from the comparison or preferably the calculated difference. This enables the anticipatory control of the steam temperature.

[0101] The new steam generation system as described before enables also a second inventive method to control the steam generation system. Therefore, again a steam generating system according to any of the preceding description is necessary. This must comprise a vapor determination system. This second method includes the steps:
With the steam generation system comprising a vapor determination system in a first step it is necessary to determine the actual share of vapor of the fluid flowing through the piping before or after an attemperator.

[0102] Independent if the share of vapor is measured before or after the attemperator, with the knowledge about the mass flow from the distribution piping to this attemperator it should be possible to calculate with sufficient accuracy the share of vapor on the other side of the attemperator.

[0103] Analog the usage of the determined temperatures the actual share of vapor has to be compared with a predetermined value.

[0104] In a next step dependent on the comparison the control system is enabled to control at least one fluid valve.

[0105] The predetermined value could be a maximum or minimum allowed share of vapor. Alternative the predetermined value could be the target share of vapor. If a maximum allowed share of vapor is set an (further) opening of the fluid valve could be triggered, if the actual share of vapor is exceeding the maximum allowed share of vapor. On the other hand, an (further) closing of the fluid valve could be triggered, if the share of vapor is below the predefined minimum share of vapor.

[0106] It is advantageous to determine the difference between the actual share of vapor and the predetermined value.

[0107] Especially if the difference is known, it is advantageous, if at least one fluid valve is opened dependent on the determined difference between the actual share of vapor and the respective predetermined value, e.g. the target share vapor.

[0108] Preferably an additional a share of vapor at a further attemperator could be determined. It is particular advantageous, if the share of vapor at all attemperators could be determined.

[0109] Regarding the control of the fluid valves, the same advantageous solutions apply as for the method with the temperature determination system. Therefore, it is advantageous, if the fluid valves could be opened stepwise and/or in groups.

[0110] It is further advantage to set a predetermined value for the share of vapor for the different heat exchangers to reach the sufficient protection of the steam generator and the subsequent facilities and further to reach the best available efficiency of the steam generator.

[0111] Here it is advantageous, if except at the superheater the predetermined value represents a share of vapor of at least 60% at the output of the respective heat exchanger (determined at the location before the following attemperator).

It is particularly advantageous, if the share of vapor is at least 75%.

[0112] On the other hand, it is advantageous, if the share of vapor at the output of the heat-exchangers except the superheater does not reach 100%. Therefore, the predetermined value is advantageous a share of vapor of not more than 90%. It is particularly advantageous, if the predetermined value is a share of vapor of not more than 85%.

[0113] Analog to the method to control the steam generation system comprising a temperature determination system is the advantageous features are also beneficial to apply them to the method to control the steam generation system comprising a vapor determination system.

[0114] Therefore, it is advantageous to determine the share of vapor at several of the attemperators. It is in particular advantageous to determine the share of vapor at all attemperators.

[0115] Next, it is advantageous to control several or all fluid valves, in particular stepwise dependent on the share of vapor at several or all attemperators.

[0116] Analog, different predetermined values could be used to trigger an action. The predetermined value could be a defined share of vapor. It is also possible to use the change of the share of vapor to control the fluid valves. Next, a difference between the actual share of vapor and a predefined share of vapor could be used to determine the necessary to act on at least one fluid valve. Also, a trend analysis could be used.

[0117] To enable an anticipatory control of the steam generating system in an advantageous method analog the vapor share is recorded over a period. Here, it is advantageous to record the share of vapor at all attemperators over a period.

[0118] Analog to the previous description with the temperature the same applies advantageously for the share of vapor. Therefore, with the gathered data a trend analysis could be performed, and an expected future share vapor could be calculated.

[0119] It is also advantageous to include all determined shares of vapor at all attemperators.

[0120] If the share of vapor is known within the piping before or after at least one attemperator and with the knowing of the mass flow through at least one heat exchanger or the evaporator it should be possible to estimate the mass flow through the steam generator. But it is in particular advantageous, if the share of vapor is known at all attemperators and if the mass flow is known to the evaporator and also through the distribution piping to each of the attemperators. Then a precise determination of the mass flow and the share of vapor at each heat exchanger respective the superheater could be determined to enable the control system to determine the best setting for the fluid valve could be found to archive a high efficiency with lowering the risk of thermal damage.

[0121] The following figures shows two different examples for an implementation of the inventive solution at a steam generator:

Fig. 1 shows schematically a power plant with a steam generator;

Fig. 2 shows schematically a steam generator with a first version of a superheater with cooling nozzles;

Fig. 3 shows schematically a steam generator with a second version of a superheater with cooling nozzles.

[0122] The figure 1 shows schematically a power plant 07 with a gas turbine 09 and a steam turbine 08 and further as main part of the invention the steam generator 01. The steam generator 01 comprises hot gas path 02 pass through the steam generator 01 from in hot gas input side to a waste gas output side.

[0123] In operation the gas turbine 09 delivers - while enabling the generation of electrical energy with a generator - a flow of hot gas to the hot gas input side of the steam generator 01. After passing through the hot gas path 02 the previous hot gas will leave the steam generator 01 with a reduced temperature as waste gas at the waste gas output side.

[0124] The steam generator 01 comprises further several heat exchangers 11, which 11 are arranged at least partly within a hot gas path 02. Within the heat exchangers 11 an evaporation fluid, e.g. water/steam, flows from the respective fluid input 13 to the respective fluid output 17 in a direction generally opposite to the hot gas and gets heated while the hot gas gets cooled.

[0125] As common usual the first heat exchanger along the hot gas path starting from the upstream hot gas input side is a so-called superheater 11A - see also fig 2. The fluid output line 12 is in connection with the steam turbine 02 to enable the further generation of electrical energy.

[0126] At the start-up of the power plant 07 or with a sudden increase of the necessary power to be delivered by the power plan 07 the gas turbine 09 increases its output of hot gas very quickly. This leads to the high increase of the heat input into the steam inside the superheater 11. This leads to high thermal stress at the steam turbine 08 and also at the piping inside the steam generator 01, e.g. the fluid output 17, and also for the piping from the steam generator 01 to the steam turbine 08.

[0127] Next, at common steam generators the fluid flows from one heat exchanger to the next heat exchanger with an increase of the temperature. But the share of vapor has not been considered for the design of a steam generator.

[0128] An example for the inventive steam generator 01 is shown schematically in figure 2 with a number of heat exchangers 11 and attemperators 22.

[0129] First, the steam generator 01 comprises as main part a casing with a hot gas path 02. The hot gas path 02 extends from an input opening, where hot gas 03 is brought into the hot gas path 02. While crossing the steam generator 01 the gas cools down and leaves as waste gas 04 at an output side the hot gas path 02.

[0130] The steam generator comprises further several heat exchangers 11A-G. Those are arranged in this example adjacent to each other, whereby they could be also arranged with other elements in-between or in another order.

[0131] Here, the heat exchanger close to the hot gas input is a so-called superheater 11A. It 11A comprises a superheater fluid input 13A, wherein a superheater fluid output 17A of the superheater 11A delivers a stream of hot steam 05 and is connected with the steam turbine 08.

[0132] Next to the superheater 11A a first heat exchanger 11B is arranged. This 11B comprises analog a first fluid input 13B and a first fluid output 17B, whereby the first output 17B is connected with the superheater input 13A.

[0133] In the same way next to the first heat exchanger 11B a second heat exchanger 11C is arranged. This 11B comprises analog a second fluid input 13C and a second fluid output 17C, whereby the second output 17C is connected with the first input 13B.

[0134] Further next to the second heat exchanger 11C a third heat exchanger 11D is arranged. This 11D comprises analog a third input 13D and a third output 17D, whereby the third output 17D2 is connected with the second input 13C.

[0135] One more next to the third heat exchanger 11D a fourth heat exchanger 11E is arranged. This 11E comprises analog a fourth input 13E and a fourth output 17E, whereby the fourth output 17E is connected with the third input 13D.

[0136] And again, next to the fourth heat exchanger 11E a fifth heat exchanger 11F is arranged. This 11F comprises analog a fifth input 13F and a fifth output 17F, whereby the fifth output 17F is connected with the fourth input 13E.

[0137] As last in the row within the hot gas path 02 an economizer 11G is arranged. This 11G comprises analog an economizer fluid input 13G and an economizer fluid output 17G. Here the economizer output 17G is connected with the fifth input 13F.

[0138] Each of the superheater 11A and heat-exchangers 11B-11F enables and the economizer 11G enable the transfer of the heat from the hot gas 03 onto the fluid steam crossing the respective superheater 11A and heat-exchangers 11A-11F and economizer 11G. On the respective fluid input 13 a fluid steam with a less high temperature and with a lower share of vapor is supplied. After the heat transfer the fluid stream leaves the respective fluid output 17 with a higher temperature and with a higher share of vapor.

[0139] The economizer input 13G is connected with a source of cold fluid 24. This is regular cold water. To control the flow of cold fluid through the economizer 11G a fluid supply valve 25 is arranged within the connection from the source of cold fluid 24 to the economizer input 13G.

[0140] During operation the cold fluid from the source of cold fluid 24 should be heated in the economizer 11G by the usage of the remaining heat within the gas flowing through the hot gas path 02 up to a preferred temperature close the evaporation temperature but not exceeding this point. As result a hot, not evaporated fluid leaves the economizer 11G at the economizer output 17G.

[0141] To supply the following last heat-exchanger, namely the fifth heat exchanger 11F, with sufficient fluid flow in all situations at the fluid input 13F of the last heat exchanger a bypass line connects the source of cold fluid 24 with connection from the economizer output 17G to the last fluid input 13F. It is obvious, that further a fluid bypass valve 27 is necessary to control the flow of cold fluid through the bypass.

[0142] To enable a control of the flow of hot fluid from the economizer 11G and/or the flow of cold fluid from the bypass into the last heat-exchanger, namely the fifth heat exchanger 11F a main fluid valve 26 is arranged at the last fluid input 13F.

[0143] Now in the series of heat exchangers, namely the fifth, the fourth, the third, the second, the first heat exchanger 11F, 11E, 11D, 11C, 11B and further the superheater 11A in each connection from one heat exchanger 11 to the next heat exchanger 11B-F respectively superheater 11A from the fluid output 17 to next fluid input 13 an attemperator 22F, 22D, 22C, 22B is arranged. To enable the function of the attemperators 22 each of them 22 is connected with a distribution piping 21 to supply the respective attemperator 22 with a flow of not evaporated fluid.

[0144] In this solution the distribution piping 21 is then further connected with the economizer output 17G and through the bypass to the source of cold fluid 24 to guarantee a fluid "free of vapor" in the distribution piping 21. The arrangement of a main valve 26 at the input of the last heat exchanger 11F also affects the flow of fluid from the economizer 11A into the distribution piping 21. Further the flow of fluid from the source of cold 24 fluid through the bypass to the distribution piping 21 is controlled by a fluid bypass valve 27 within the bypass.

[0145] To enable a protection of following facilities from a too fast increase of the temperature of the hot steam 05 leaving the steam generator 01, a main attemperator 22A is arranged at the superheater output 17A. This attemperator 22A is also connected with the distribution piping 21, whereby a fluid valve 23A is arranged to control the flow of fluid from the distribution piping 21 into the main attemperator 22A.

[0146] To enables the possibility to control the temperature of the fluid/steam flowing from one heat exchanger 11 to the next heat exchanger 11B-F respectively superheater 11A and furthermore to control the share of vapor at the input of each of the respective heat-exchangers 11B-F / superheater 11A it is necessary to arrange fluid valves 23A, 23B, 23C, 23D, 23E, 23F within each connection from the respective attemperator 22B-F to the distribution piping 21.

[0147] An exemplary solution for an advantage implementation of the invention in further detail at a heat exchanger/superheater 11 is shown in Fig. 3. Here only the relevant part of the steam generator 01 is pictured with the section of the hot gas path 02 and the arrangement of one heat exchanger 11.

[0148] The heat exchanger 11B-11F or superheater 11A comprises a piping with the fluid input 13, which 13 is in connection with forgoing heat exchanger (not shown in this figure). From the fluid input 13 two (exemplary) distribution pipes 14.1 and 14.2 branches off. Several heat exchangers tubes 15 are each connected to one of the distribution pipes 14. On the other end of the heat exchange tubes 18 collection pipes 16.1 and 16.2 are arranged, which 16 then are in connection with the fluid output 17.

[0149] In operation a fluid steam 12 with a lower temperature is supplied to the fluid supply line 13. The steam flows through the distribution pipes 14 into the heat exchange tubes 15, where the heat is transferred from the hot gas inside the hot gas path 02 onto the fluid steam inside the heat exchange tubes 15. Then the hot fluid steam is collected in the collection pipes 16 and transferred to the fluid output 17 and leaves the heat exchanger/superheater 11 as fluid steam 18 with a higher temperature.

[0150] To enable a temperature control of the temperature and the share of vapor of the hot steam 18 attemperators 22.1, 22.2 are arranged. Therefore, in this advantage solution an attemperator 22.1 22.1 and 22.2 is arranged within each of the collection pipes 16.1 and 16.2. The attemperators 22 are supplied with a cooling fluid, e.g. water, from the distribution piping 21. To enable a control of the cooling fluid within each supply line to the attemperators 22.1, 22.2 fluid valves 23.1 and 23.2 are arranged.

[0151] It should be noted, that in an extensive implementation of the forgoing solution it is possible to arrange an attemperator within the end of each heat transfer tube 15.

[0152] Regarding the description of the drawings it should be noted, that 11 represents any of the superheater 11A or heat-exchangers 11B-11F or economizer 11G (same with the fluid input 13, fluid output 17). Further 22 represents any attemperator 22A-22B or 22.1 or 22.2 (same with the fluid valves 23)

List of reference numbers

[0153]

01	steam generator
02	hot gas path
03	hot gas
04	waste gas
05	hot steam output
07	power plant
08	steam turbine
09	gas turbine
11A	superheater
11B-F	first-fifth heat exchanger
11G	economizer
12	fluid with lower temperature
13,13A-G	input
14.1,14.2	distribution pipe
15	heat exchange tubes
16.1,16.2	collection pipe
17,17A-G	output
18	fluid with higher temperature
21	distribution piping
22,22.1,22.2,22A-F	attemperator
23,23.1,23.2,23A-F	fluid valve
24	cold water supply
25	water supply valve
26	main valve
27	water bypass valve

Claims

1. Steam generator (01) with a hot gas path (02) comprising:

   - a superheater (11A), which (11A) has a superheater output (12) to deliver a flow of hot steam (18) and
   - at least four heat exchangers (11B-11F) and
   - an economizer (11G) and
   - a distribution piping (21),

   wherein the superheater (11A) and the heat exchangers (11B-11F) and the economizer (11G) are connected in series and each comprises a fluid input (13) and at least one fluid distribution pipe (14) and several heat exchange tubes (15) arranged inside the hot gas path (02) and at least one collection pipe (16) and a fluid output (17), wherein the economizer input (12G) is connected with the source of cold fluid (24),
   characterized in that
   at the superheater output (17A) and in each connection in the series of superheater (11A) and heat exchangers (11B-11F) at least on attemperator (22) is arranged,
   wherein the distribution piping (21) is connected with the source of cold fluid (24) and with the economizer output (17G) and via respective valves (23) with each of the attemperators (22).

2. Steam generator (01) according to claim 1,
   wherein
   a main valve (26) is arranged at the fluid input (13F) of a last heat exchanger (11F) in the series of heat exchangers (11B-11F) excluding the economizer (11G); and/or a fluid supply valve (25) is arranged at the economizer input (12G); and/or
   a fluid bypass valve (27) is arranged between the source of cold fluid (24) and the distribution piping (21).

3. Steam generator (01) according to claim 1 or 2,
   wherein at least at one of the series of superheater (11A) and heat exchangers (11B-11F) comprises at least two collection pipes (16.1,16.2) each with an attemperator (22.1,22.2), in particular each of them (22.1,22.2) is connected via a respective valve (23.1,23.2) with the distribution piping (09).

4. Steam generating system with a steam generator (01) according to one of the claims 1 to 3 further comprising a control system, wherein the control system is able to control the fluid valves (23, 25-27) and
   a temperature determination system, which is able to determine the temperature of at least one of the fluid outputs (17) and/or the fluids inside, and/or
   a vapor determination system, which is able to determine a share of vapor before and/or after at least one of the attemperators (22).

5. Steam generating system according to claim 4,
   wherein the temperature determination system is able to determine the temperature of each of the fluid outputs (17) and/or the fluids inside; and/or
   wherein the vapor determination system is able to determine the share of vapor at each of the attemperators (22).

6. Steam generating system according to claim 4 or 5,
   wherein
   the control system is able to control the fluid valves (23,25-27) separately and in groups and stepwise; in particular dependent to the temperature of the fluid outputs (17) and/or dependent to the share of vapor at the attemperators (22).

7. Method to control a steam generating system according to one of the preceding claims, with the steps:

   a) determine at least on temperature and/or temperature change at an fluid output (17); and
   b) compare the temperature / temperature change with a predetermined value;
   c) control at least one of the several fluid valves (23, 25-27) dependent on the comparison.

8. Method to control a steam generating system according to one of the preceding claims, with the steps:

   a) determine at least on share of vapor at an attemperator (22); and

b) compare the share of vapor with a predetermined value;
c) control at least one of the several fluid valves (23, 25-27) dependent on the comparison.

9. Method according to claim 7 or 8, wherein

a1) the temperature and/or the temperature change at all fluid outputs (17) is determined; and/or
a1) the share of vapor at all attemperators (22) is determined.

10. Method according to claim 8 or 9, wherein the first and/or second and/or third and/or in particular fourth predetermined share of vapor is at least 60%, in particular at least 75%, and/or at most 90%, in particular at most 85%.

FIG 1

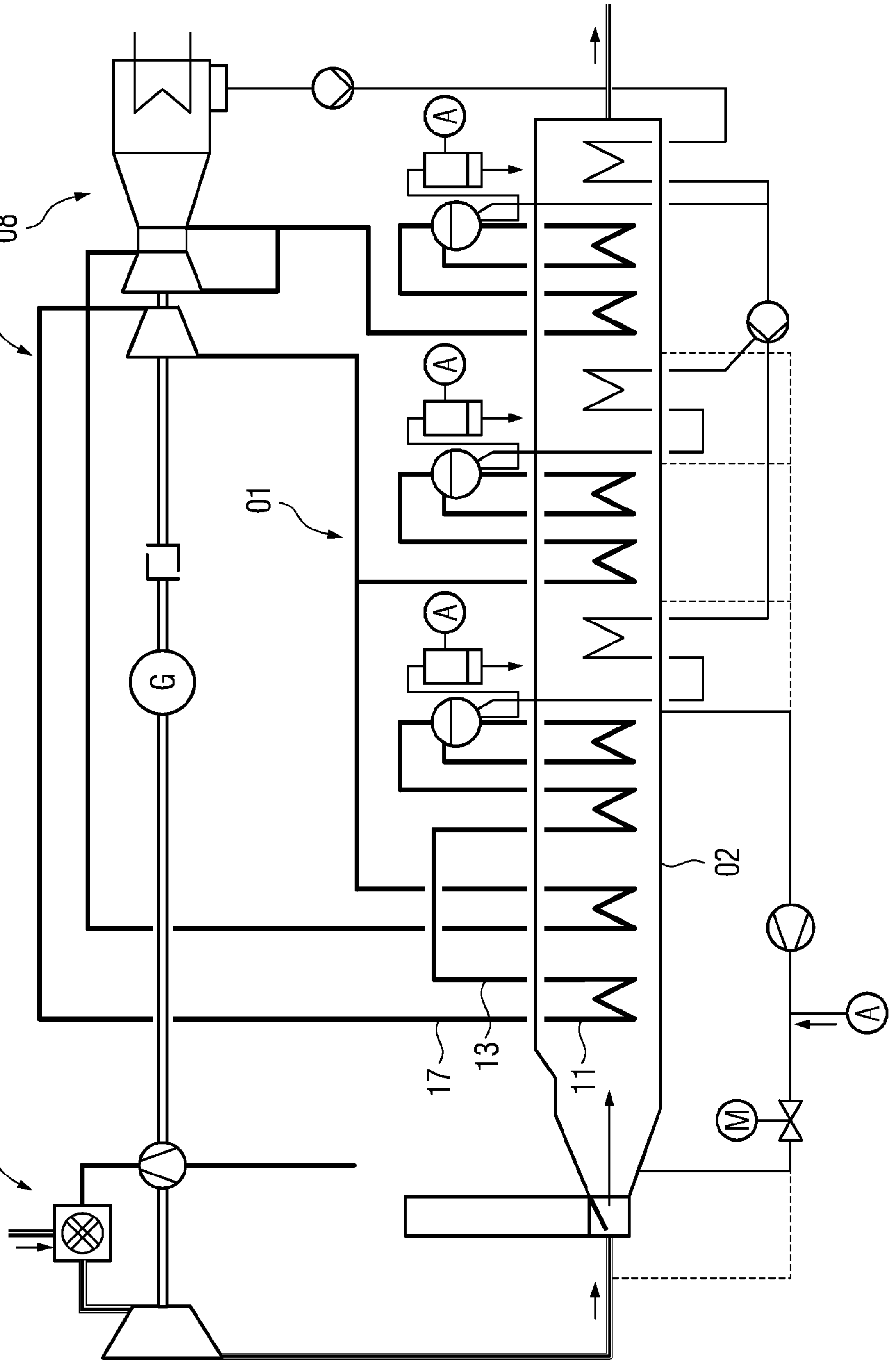
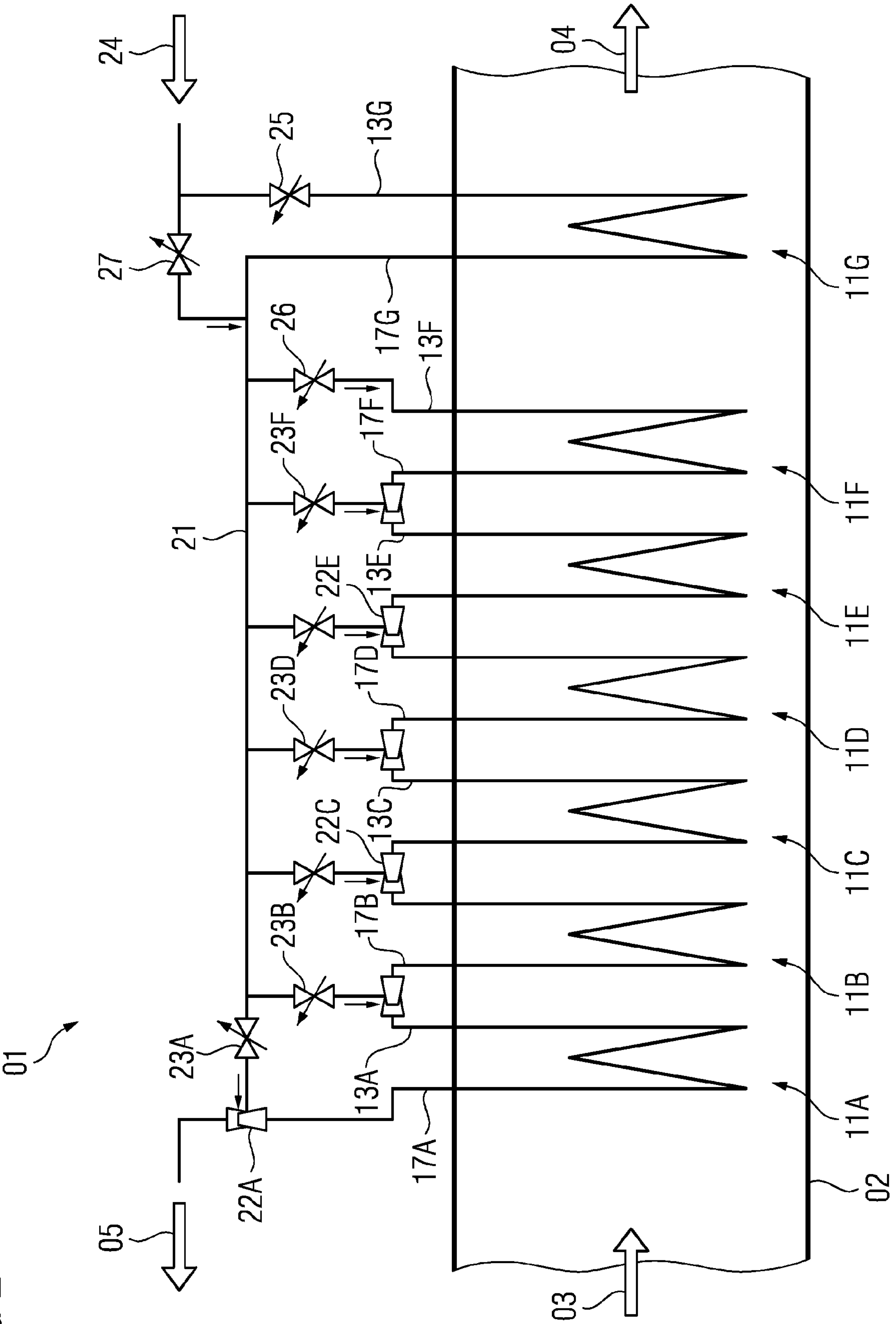


FIG 2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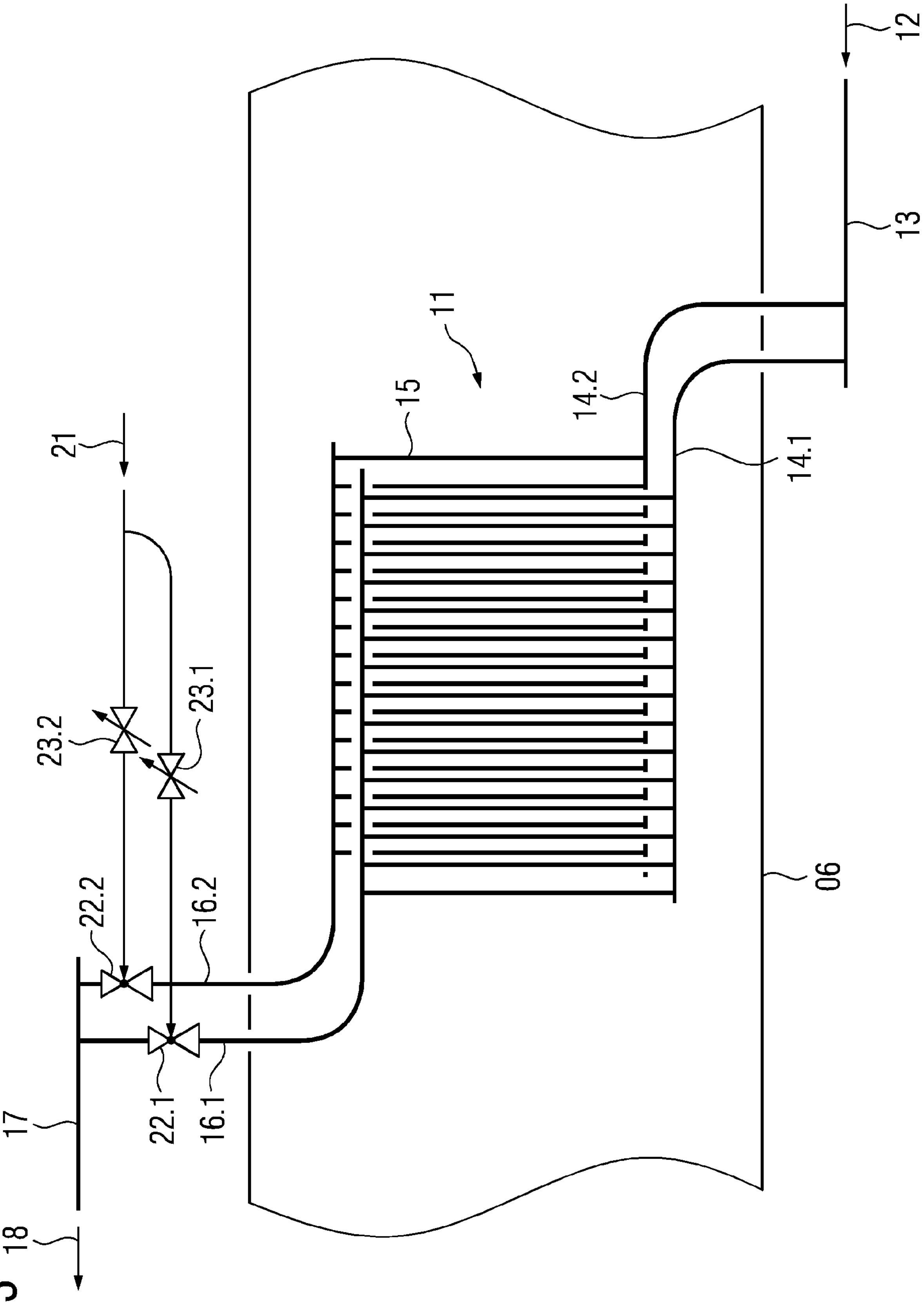

FIG 3

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EUROPEAN SEARCH REPORT

Application Number
EP 20 19 6335

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	JP H08 28808 A (BABCOCK HITACHI KK) 2 February 1996 (1996-02-02) * paragraphs [0020] - [0037]; figures 1,2,6,11,13 *	1-10	INV. F01K23/10 F22B1/18 F22B35/06 F22G5/12
A	US 2005/274113 A1 (SEKIAI TAKAAKI [JP] ET AL) 15 December 2005 (2005-12-15) * paragraphs [0039] - [0068]; figures 1-4 *	1-10	
A	US 2018/371956 A1 (SELMAN UYGAR O [US] ET AL) 27 December 2018 (2018-12-27) * paragraphs [0028] - [0031]; figure 3 *	1-10	
A	DE 197 34 862 A1 (GERICKE BERND [DE]) 18 February 1999 (1999-02-18) * column 2, line 25 - column 3, line 16; figure 1 *	1-10	
A	US 2016/040549 A1 (BRÜCKNER JAN [DE] ET AL) 11 February 2016 (2016-02-11) * paragraphs [0013] - [0015]; figure 1 *	1-10	TECHNICAL FIELDS SEARCHED (IPC)
A	WO 2008/152205 A1 (AAF CONSULT OY [FI]; JANKA PENTTI [FI] ET AL.) 18 December 2008 (2008-12-18) * page 3, line 30 - page 7, line 18; figures 1A,1B *	1-10	F01K F22B F22G

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	4 February 2021	Röberg, Andreas

CATEGORY OF CITED DOCUMENTS

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& : member of the same patent family, corresponding document

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 20 19 6335

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The members are as contained in the European Patent Office EDP file on
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04-02-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP H0828808 A	02-02-1996	NONE	
US 2005274113 A1	15-12-2005	CA 2509558 A1	11-12-2005
		JP 4131859 B2	13-08-2008
		JP 2005351576 A	22-12-2005
		US 2005274113 A1	15-12-2005
US 2018371956 A1	27-12-2018	CN 108474268 A	31-08-2018
		EP 3374604 A1	19-09-2018
		JP 6615358 B2	04-12-2019
		JP 2018538479 A	27-12-2018
		KR 20180095907 A	28-08-2018
		US 2018371956 A1	27-12-2018
		WO 2017111932 A1	29-06-2017
DE 19734862 A1	18-02-1999	NONE	
US 2016040549 A1	11-02-2016	CA 2909159 A1	16-10-2014
		CN 105102771 A	25-11-2015
		EP 2789813 A1	15-10-2014
		EP 2964910 A1	13-01-2016
		ES 2647971 T3	27-12-2017
		JP 6105153 B2	29-03-2017
		JP 2016520748 A	14-07-2016
		KR 20150138388 A	09-12-2015
		PL 2964910 T3	31-01-2018
		US 2016040549 A1	11-02-2016
		WO 2014166739 A1	16-10-2014
WO 2008152205 A1	18-12-2008	NONE	

EPO FORM P0459

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