Title: METHOD FOR PRODUCING A CONTINUOUS STEAM GENERATOR AND CONTINUOUS STEAM GENERATOR

Abstract:
The aim of the invention is to provide a suitable method for producing a continuous steam generator (1) that can operate at high steam pressures, said method being cost-effective and involving simple technology. This is achieved by a number of pipe segments (18), which are produced from a material of a first material category, are designed to form the steam generator pipes (12) and are combined into a number of modules (17). Each module (17) is equipped with a respective adapter (19) at a number of connection points that are designed to connect an additional module (17), said adapter being produced from a material of a second category.
Abstract

The aim of the invention is to provide a suitable method for producing a continuous steam generator (1) that can operate at high steam pressures, said method being cost-effective and involving simple technology. This is achieved by a number of pipe segments (18), which are produced from a material of a first material category, are designed to form the steam generator pipes (12) and are combined into a number of modules (17). Each module (17) is equipped with a respective adapter (19) at a number of connection points that are designed to connect an additional module (17), said adapter being produced from a material of a second category.
Description

Method for producing a continuous steam generator and a continuous steam generator

The invention relates to a method for producing a continuous steam generator, having an enclosing wall formed from steam generator pipes welded together in a gas-tight fashion, said wall being prefabricated in modules in the workshop, said modules being welded together during final assembly. It also relates to a continuous steam generator that is particularly suitable for production by such a method.

In a continuous steam generator a number of steam generator pipes, which together form the gas-tight enclosing wall of the combustion chamber, are heated to evaporate a fluid medium in the steam generator pipes completely in one passage. The fluid medium - generally water - is fed after evaporation to the superheater pipes connected after the steam generator pipes and superheated there. The steam generator pipes of the continuous steam generator can thereby be arranged vertically or in a spiral fashion and therefore at an angle.

In contrast to a natural circulation steam generator, a continuous steam generator is not subject to pressure limitation so that it can be designed for live steam pressures well above the critical pressure of water \( (P_{\text{crit}} = 221 \text{ bar}) \), where it is impossible to differentiate between the water and steam phases and phase separation is therefore not possible. A high live steam pressure favors a high level of thermal efficiency and therefore lower \( \text{CO}_2 \) emissions from a fossil-fuel power plant.
The enclosing walls of large combustion chambers - for example for continuous steam generators with a design output of more than 100 MWel - cannot be manufactured whole in the workshop for transport reasons. In such instances final assembly is required at the actual site of deployment, during which process the parts or even modules provided to form the enclosing wall of the combustion chamber are welded together directly on site. To facilitate production, a modular structure can be provided, with which the enclosing wall is prefabricated in modules, which have to be welded together during final assembly. Such a structure however significantly restricts the selection of materials that can be used, as when using materials that are subject to comparatively high thermal and mechanical loading, a subsequent heat treatment may be essential when welding.

Subsequent heat treatment of the weld seams involves a significant technical outlay and can therefore generally only be undertaken in the workshop and not on site during final assembly. Therefore when producing enclosing walls for large combustion chambers of continuous steam generators until now only materials that did not require subsequent heat treatment of the weld seams were used.

However to increase the efficiency and therefore reduce the CO₂ emissions of a fossil-fuel power plant, it is desirable to design continuous steam generators for particularly high live steam pressures and temperatures. The production of such continuous steam generators requires materials which withstand loading due to high heat flow densities at high steam temperatures and therefore high material temperatures. However these are the materials that require subsequent heat treatment of the weld seams.
A possible alternative to these materials would be nickel-based materials, which despite their ability to withstand a high thermal load do not require subsequent heat treatment of the weld seams, the use of which would however significantly complicate production and render it more expensive.

The object of the invention is therefore to specify a method of the type mentioned above for producing a continuous steam generator that can operate at high steam pressures, which is cost-effective and involves simple technology. Also a suitable continuous steam generator for production using such a method is to be specified.

With regard to the method, this object is achieved according to the invention in that a number of pipe segments provided to form the steam generator pipes and made from a material of a first material category are combined into a number of modules, each module being provided with an adapter at a number of connection points provided for connection to a further module, said module being made from a material of a second material category.

The invention is thereby based on the consideration that technical outlay and cost can be kept low when producing the continuous steam generator, in that the continuous steam generator is designed for the consequent processing of conventional materials rather than expensive nickel-based materials which are difficult to process. The continuous steam generator to be produced should thereby be designed in a suitable fashion for loading due to high live steam pressures and temperatures. Primary consideration is given to the fact that the essential components of the steam generator pipes
forming the enclosing wall are made from a material that is suitable for this purpose.

To keep production costs low still, the continuous steam generator should thereby be prefabricated to a particularly large extent in the workshop, so that in particular any subsequent heat treatment required for weld seams can take place in relatively simple conditions and with recourse to the plurality of resources available there. The prefabricated modules can therefore be formed from pipe segments of a material suitable for high live steam pressures and temperatures.

To allow final assembly of the modules, which have been prefabricated in a suitable fashion, in respect of these criteria, thereby consequently avoiding the need for subsequent treatment, the modules should be provided with corresponding adapters, which allow welding during final assembly without subsequent heat treatment of the weld seams. To this end, in contrast to the pipe segments, the adapters are made from a material with correspondingly different characteristics.

Advantageous embodiments of the invention are set out in the subclaims.

The materials for the pipe segments on the one hand and the adapters or adapter units formed therefrom on the other hand are preferably selected specifically in respect of the criterion whether subsequent heat treatment of the weld seams is required. A particularly suitable criterion for assessing whether a material requires subsequent heat treatment of the weld seams is the so-called Vickers hardness (DIN 50 133).
The parts of the combustion chamber walls of the continuous steam generator subject to a high level of loading due to high heat flow densities are therefore expediently made from a material of a first material category, the Vickers hardness of which is higher than the Vickers hardness of the parts of the combustion chamber walls subject to a lower level of loading. The latter are expediently made from a material of the second material category, the Vickers hardness HV10 of the materials of the second material category thereby preferably being less than around 350 to 400.

Adjacent steam generator pipes connected parallel to the flow of a fluid medium are advantageously connected together via fins, in particular to ensure a high specific heat input into the steam generator pipes. These fins are advantageously made from a material of the second material category. As has been proven, as the fins are components of the continuous steam generator through which there is no flow, they are not subject to excessive loading due to the lack of internal pressure, with the result that the material specifications relating to them are by comparison not so stringent. These less stringent material specifications are also met by materials of the second material category. Such fins also allow the individual modules to be connected without any problem in a horizontal direction during final assembly when the pipes of the continuous steam generator are vertical. To this end half-width fins are preferably welded onto the modules at the points provided for connection to other modules in the workshop and are used for connection purposes during final assembly.
The individual modules are expediently connected in a vertical direction via adapter units comprising a number of adapters and if necessary additional bend couplings. An adapter made from a material of the second material category for example is thereby welded in the workshop to a pipe segment made from a material of the first material category and the weld seam is subsequently heat-treated. During final assembly two pipe segments produced in this fashion are for example connected directly or by means of a bend coupling, which is also made from the material of the second material category. The weld seams applied during final assembly do not have to undergo subsequent heat treatment, because the material used does not require this.

With regard to the continuous steam generator the said object is achieved in that at least some of the steam generator pipes respectively are formed from a number of pipe segments connected one behind the other on the fluid medium side and that pipe segments of a steam generator pipe connected one after the other in the direction of flow are each connected via an adapter unit made from a material of a second material category.

The adapter unit thereby advantageously comprises a number of adapters and in some instances a bend coupling and is arranged such that a weld seam applied to connect an adapter to a further component is outside a wall surface provided by the pipe segments.

Adjacent steam generator pipes are expediently connected together in a gas-tight fashion via fins, the fins also being made from a material of the second material category.
The advantages achieved with the invention are in particular that by using different materials in the enclosing wall of the combustion chamber, i.e. for the pipe segments on the one hand and for the adapters and the adapter units formed therefrom on the other hand, with characteristics, which are tailored to the respective thermal loading of the steam generator pipes, the production method for continuous steam generators for high steam pressures can be kept particularly simple. The use and combination of different types of material allows this in particular in that the steam generator pipes are prefabricated in the workshop from a material of the first material category, welded to form modules, subjected to subsequent heat treatment and provided with adapters made from a material of the second material category, which does not require subsequent heat treatment, at the points provided for connection to other modules during assembly. Suitable arrangement of these adapters outside the area exposed to high heat flow densities prevents the material being subjected to excessive loading. The weld seams resulting from welding the individual modules together during assembly do not require subsequent heat treatment, as only materials of the second material category have to be welded during final assembly.

An exemplary embodiment of the invention is described in more detail below with reference to a drawing, in which:

FIG 1 shows a schematic illustration of a continuous steam generator with vertically arranged evaporator pipes,
FIG 2 shows two pipe segments connected together by means of an adapter unit,
FIG 3 shows two pipe segments connected together by means of an alternative embodiment of an adapter unit,
FIG 4 shows two pipe segments connected together by means of a further alternative embodiment of an adapter unit and

FIG 5 shows a cross-section through evaporator pipes connected together via fins.

Identical parts are marked with the same reference characters in all the figures.

Figure 1 shows a schematic illustration of a continuous steam generator 1, the vertical gas duct of which is surrounded by an enclosing wall 4 and forms a combustion chamber, with a bell-shaped base 6 at the lower end. The base 6 encloses an outlet opening 8 (not shown here) for ash.

In the area A of the gas duct a number of burners 10, of which only one is shown, are attached in the enclosing wall of the combustion chamber formed from vertically arranged steam generator pipes 12. The vertically arranged steam generator pipes 12 are welded together via fins 14 to the gas-tight enclosing wall 4.

During operation of the continuous steam generator 1 a body of flame 16 results in the combustion chamber during combustion of a fossil fuel. This body of flame 16 exposes the area marked A of the continuous steam generator 1 to a very high heat flow density during its operation. The body of flame 16 has a temperature profile, which decreases in a vertical direction starting from the area of the burner. Below the area A is an area B that is remote from the flame and above the area A is a further area C also remote from the flame, both of
which are exposed to a comparatively low level of heat due to the resulting temperature profile.

The continuous steam generator 1 is designed to be suitable for operation at high live steam pressures and temperatures and therefore for a particularly high level of efficiency even with quite limited production outlay. To this end the steam generator pipes 12, in particular in the area of high heat flow densities and high material temperatures, are made from a material, which withstands loading due to high heat flow densities. To keep production outlay and cost low at the same time, the enclosing wall 4 of the combustion chamber is prefabricated in modules 17 in the workshop. During prefabrication of the modules 17 in the workshop specific use is made of the fact that a large number of resources are available there without further outlay, so that it is possible in particular to process materials that can be subjected to a high level of thermal loading despite the associated outlay in particular during the subsequent heat treatment of weld seams.

To produce the modules 17 therefore finished pipe segments 18 made from a material of a first material category, that can in particular be subjected to a high level of thermal loading, are welded together. The pipe segments 18 are thereby selected such that after final assembly a plurality of pipe segments 18 connected one behind the other on the fluid medium side respectively form a steam generator pipe 12.

To be able to avoid subsequent heat treatment during final assembly of the modules 17, said modules 17 are then provided - still in the workshop - at the connection points provided for connection to a further module 17 with an adapter 19 made from a material of a second material category. The material of
the second material category is thereby selected such that it is suitable for welding without subsequent heat treatment. During attachment to the respectively assigned pipe segment 18 - also still in the workshop - said weld seam is subjected to a subsequent heat treatment, in order to satisfy the requirements of the material forming the respective pipe segment 18. The materials of the second material category thereby have a lower Vickers hardness than the materials of the first material category.

During final assembly on site the individual modules 17 are finally welded together at horizontal joints 20 and vertical joints 21 respectively via the adapters 19, with only components made from a material of the second material category being connected together so that no subsequent heat treatment is required.

At the vertical joints 21 a connection is achieved via fins 14 and at the horizontal joints 20 via adapter units 22 formed from a plurality of adapters 19 welded together.

Figure 2 shows an exemplary embodiment of the transition area at a horizontal joint 20, which is particularly suitable for use in the area A in proximity to the flame. Two steam generator pipes 12, provided for use in the area A, in which the heat flow density is particularly high, are connected there via an adapter unit 22 in the direction of flow. The adapter unit 22 thereby comprises two adapters 19 and a bend coupling 23, each made from a material of the second material category. Two connectors 24 made from a material of the first material category are provided to connect the adapters 22 to the steam generator pipes 12.
A weld seam 25 between a pipe segment 18 and a connector 24 is executed in the workshop, because it requires subsequent heat treatment due to the characteristics of the material of the pipe segments 18; the same applies to a weld seam 26 between a connector 24 and an adapter 19. A weld seam 27 between an adapter 19 and a bend coupling 23 on the other hand can be executed during final assembly, as it does not require subsequent heat treatment due to the material characteristics of the adapters 19 and the bend coupling 23.

The fins 14 are not subject to internal pressure from a fluid medium and can therefore be made from a material of the second material category, even if they are in the area A. A weld seam 28 between fins 14 can therefore be executed without any problem during final assembly.

Figure 3 shows an alternative embodiment of the adapter unit 22, which is also used in the area A, comprising two adapters 19 made from a material of the second material category. The pipe segments 18 are thereby bent at the points provided for welding during final assembly such that they curve out from the surface formed by the pipe segments 18 combined to form a module 17. A separate connector 24 is therefore not required with this exemplary embodiment. A weld seam 26 between a pipe segment 18 and an adapter 19 is executed in the workshop, as it requires subsequent heat treatment, while a weld seam 27 between two adapters 19 can be executed during final assembly.

The fins 14 can also be welded together here without any problem at a weld seam 28 during final assembly, as the lack of internal pressure from a fluid medium means that they can be made from a material of the second material category, which does not require subsequent heat treatment.
Figure 4 shows two pipe segments 18, which are connected together via an adapter unit 22, which can be attached in the areas B and C. The adapter unit 22 thereby comprises two adapters 19 made from a material of the second material category. The weld seams 26 between the pipe segments 18 and the adapters 19 are executed in the workshop, while the weld seam 27 can be executed during final assembly, as it is between two materials of the second material category, which do not require subsequent heat treatment. In this exemplary embodiment the adapter unit 22 is not configured for the adapters 19 to be welded together in a plane outside the wall surface provided by the pipe segments 18, as the heat input in the areas B and C that are remote from the flame is low and the arrangement of components made from a material of the second material category in the actual plane of the wall can therefore be permitted.

Figure 5 shows a cross-section through pipe segments 18 combined into a module 17, which are connected together via fins 14 and form the steam generator pipes 12. The steam generator pipes 12 are made from a material of the first material category, while in contrast the fins 14 are made from a material of the second material category. Weld seams 29 between a steam generator pipe 12 and a fin 14 are executed in the workshop, as they require subsequent heat treatment due to the material characteristics of the steam generator pipes 12. In contrast weld seams 30, via which two modules 17 are connected together at vertical joints 21, can be executed during final assembly, as they do not require subsequent heat treatment. During final assembly two modules 17 are welded together at the vertical joints 21 via half-width fins 31.
claims

1. Method for producing a continuous steam generator (1), having an enclosing wall (4) formed from steam generator pipes (12) welded together in a gas-tight fashion, a number of pipe segments (18) made from a material of a first material category and provided to form the steam generator pipes (12) being combined into a number of modules (17), each module (17) being provided respectively with an adapter (19) made from a material of a second material category at a number of connection points provided for connection to a further module (17).

2. Method according to claim 1, wherein the materials of the first material category have a higher Vickers hardness than the materials of the second material category.

3. Method according to claim 1 or 2, wherein the pipe segments (18) are combined into modules (17) such that each module (17) respectively forms a surface, out of which the respective adapters (19) curve such that the adapters (19) provided to connect two adjacent modules (17) can be welded together in a plane that is offset in respect of the respective surface.

4. Method according to one of claims 1 to 3, wherein adjacent steam generator pipes (12) are welded together in a gas-tight fashion via fins (14), with the fins (14) being made from a material of the second material category.

5. Continuous steam generator (1) with an enclosing wall (4) formed from steam generator pipes (12) welded together in a gas-tight fashion and connected in parallel to allow the
passage of a fluid medium, wherein at least some of the steam generator pipes (12) are each formed from a number of pipe segments (18) connected one behind the other on the fluid medium side and made from a material of a first material category and with pipe segments (18) of a steam generator pipe (12) arranged one after the other in the direction of flow being connected together via an adapter unit (22) made from a material of a second material category.

6. Continuous steam generator (1) according to claim 5, with the materials of the first material category having a higher Vickers hardness than the materials of the second material category.

7. Continuous steam generator (1) according to claim 5 or 6, wherein a number of adapter units (22), each comprising a number of adapters (19) made from a material of the second material category, are arranged such that a weld seam applied to connect two adapters (19) of the same adapter unit (22) together is outside a wall surface provided by the pipe segments (18).

8. Continuous steam generator (1) according to one of claims 5 to 7, the combustion chamber wall of which comprises vertical piping.

9. Continuous steam generator (1) according to one of claims 5 to 8, with adjacent steam generator pipes (12) being welded together in a gas-tight fashion via fins (14), the fins (14) being made from a material of a second material category.