

METHOD AND DEVICE FOR PROTECTING HEAT EXCHANGER PIPES AND A
CERAMIC COMPONENT

[01] The invention relates to a method for protecting heat exchanger pipes in boiler systems having at least one heat exchanger pipe, which is surrounded by a ceramic component, into which flue gas is directed from at least two opposite sides. The invention further relates to a device having a heat exchanger pipe, of which the circumferential surface is surrounded by at least one ceramic component, and a ceramic component.

[02] One of the functions of heat exchanger pipes in boiler systems is to evaporate water, and another function is to superheat vaporised water. The temperatures in the heat exchanger pipes of larger boiler systems with a downstream turbine are required to be as high as possible, since the efficiency of the downstream turbine increases as the temperature rises.

[03] One drawback associated in particular with incinerators for burning solid fuels, such as waste and biomass incinerators, is that the heat exchanger pipes become corroded. In the course of many investigations, it has been established that this corrosion is induced by deposits of ash and salts left clinging to the pipes. Gas-phase compounds in the flue gas, such as HCl and SO₂, affect the composition of these deposits but do not result directly in corrosive attacks on these parts.

[04] Corrosion rates of up to one millimetre per 1,000 hours may be observed in waste and biomass incinerator plants.

[05] In order to help protect against corrosion, ceramic insulation elements and metal coatings are used, applied either as build-up welds or by thermal spraying.

[06] German patent no. DE 38 23 439 C2 describes a pre-sintered protective component made from interlocking half-shell elements. These shell elements, which are preferably made from silicon carbide, have not proven particularly successful in practice, because the material required had to be relatively thick and heavy in order to withstand the load to which it is exposed. The protective component was backfilled with mortar. Since the interlocking arrangement did not allow of any thermal expansion, the high operating temperatures caused the shells to crack and even burst open.

[07] Another ceramic protective sleeve made from overlapping silicon carbide half-shells is described in DE 20 2008 006 044 UI.

[08] Ceramic insulation elements on the walls, such as are described in DE 198 16 059 A1 and EP 0 981 015 A1 have proven to be effective on the walls of the furnace. On the other hand, the use of ceramic protective shells for heat exchanger pipes over which flue gas flows from all sides is not practicable, particularly in the superheating area. Besides the static load of the steel construction, the heat exchanger pipes are exposed to mechanical loads in the superheating area during cleaning.

[09] Beating mechanisms that operate mechanically on the pipes in the superheating area to remove the deposits are used widely. Methods using water and steam blowers are also used in attempts to remove the deposits. This causes additional chemical stresses. These stresses severely limit the areas in which ceramic insulation elements can be used to protect against corrosion in the superheating area.

[10] In the radiation ducts, build-up welds have proven to be an effective corrosion protection measure. The material

2.4858 (Inconel 625) has established itself as the welding material of choice.

[11] However, material temperatures above 400 °C, such as are encountered in the superheating area and the vaporisation area under elevated operating pressures, significantly limit the corrosion protection offered by this material. The use of other weld filler materials, such as 2.4606 (Inconel 686), does not provide any significant improvements over other filler materials.

[12] Thermal spraying methods are being used more and more often as a corrosion protection method. Experiments with a wide variety of material compositions as the corrosion protection layer on various boiler parts have revealed that such protective layers can fail unpredictably after a short time. Protective layers of such kind applied by thermal spraying are thus also unable to provide long-term, operationally reliable protection against corrosion.

[13] The method of corrosion protection also affects the effectiveness of the steam generator. Most waste and biogas combustion plants are only operated with steam temperatures of 400 °C at 40 bar, in order to limit the effects of corrosion. If the steam parameters are increased, the rates of corrosion in the boiler pipes also rise substantially, thereby reducing the operational availability of the plant. The known measures for protecting from corrosion did not provide satisfactory improvements in this regard.

[14] The problem addressed by the invention is therefore to significantly reduce the corrosion of heat exchanger pipes in steam boiler systems even at temperatures well above 400 °C.

[15] This problem is solved with a method for protecting heat exchanger pipes in boiler systems having at least one

heat exchanger pipe, which is surrounded by a ceramic component, into which flue gas is directed from at least two opposite sides, wherein gas is fed into the space adjacent to the ceramic component. In this context, for the purposes of the invention the term gas is understood to be a gas-phase fluid, a liquid fluid and any fluid in any aggregate states between the two, as well as various forms of steam.

[16] The invention is based on the realisation that even heat exchanger pipes that pass without support through the combustion chamber, and are preferably suspended from the ceiling thereof, can be protected effectively with ceramic components if a gas is supplied between the heat exchanger pipe and the ceramic element.

[17] Heat exchanger pipes that are suspended freely in the smoke flue are only accessible at one end. If a gas is fed into an area between the heat exchanger pipe and the ceramic element, there is a risk that this gas will immediately escape into the combustion chamber through the first gaps between the ceramic elements, and not provide effective protection for all of the heat exchanger pipes. Consequently, the supply of gas was only used for heat exchanger pipes on membrane walls of boiler systems, because there it is easy to deliver the gas to any area of the heat exchanger pipes, and particularly to the areas that are exposed to extreme thermal stresses.

[18] The areas of heat exchanger pipes arranged inside a boiler that are exposed to extreme thermal stresses are at a great distance from the membrane walls and are therefore difficult to reach with the supplied gas. Moreover, the introduction of too much gas into the combustion chamber of the flue ducts has a negative effect on the efficiency of the system.

[19] However, it has been discovered that, with appropriate pressure and design of the ceramic elements, a gas can be delivered to the areas of the heat exchanger pipe that are exposed to the heaviest thermal loading, and then protects the heat exchanger pipe inside a gap between the heat exchanger pipe and the ceramic element in that a slight overpressure is created by the gas and prevents the flue gases from escaping through the ceramic component to the heat exchanger pipes.

[20] The chamber may comprise various parts. It preferably consists only of the heat exchanger pipe and the ceramic component.

[21] It is particularly advantageous if the gas is delivered at the hottest point between the heat exchanger pipe and the ceramic element. The result of this is that the gas is under the greatest pressure at the point where the heat exchanger pipe is under particular thermal stress. Depending on the construction of the boiler system, it may also be advantageous to deliver the gas to the point where the flue gas pressure is highest, that is to say where the counterpressure on the ceramic element is highest.

[22] The ceramic component may be configured such that the supplied gas is routed through the ceramic component. However, since the ceramic component is usually constructed from a plurality of ceramic elements, there is a risk that the delivered gas might escape prematurely between the ceramic elements, with the result that all areas of the heat exchanger pipe might not be exposed to the gas. Even a layer of mortar that is preferably applied between the ceramic elements and connects said ceramic elements is often unable to prevent the gas from escaping.

[23] Therefore, it is suggested to introduce the gas through a pipe included in the ceramic component. This pipe

may be made from ceramic, and for example may also be constructed from multiple pipe elements. However, this pipe is preferably a metal pipe. Since this pipe is enclosed by the ceramic component and the inside thereof is cooled by the gas that is passed through it, the gas may be delivered in a metal pipe to the site of a heat exchanger pipe that is under the greatest thermal load. From there, the gas may be distributed, and the gas continues to function as protection for the heat exchanger pipes even if the ceramic component forms a gas-tight casing. This pipe is preferably arranged between the heat exchanger pipes. It is preferably disposed in the middle between an inflow and an outflow heat exchanger pipe.

[24] The gas that is fed into the area between the heat exchanger pipe and the ceramic element at the point of the highest counterpressure may flow along the heat exchanger pipe in gaps between the heat exchanger pipe and the ceramic component, in order to prevent the flue gas from getting into the heat exchanger pipe along the entire length of the heat exchanger pipes.

[25] Particularly in the case of very long heat exchanger pipes, it may be advantageous to introduce the gas at multiple points. Therefore, it is suggested that the gas be supplied through a plurality of apertures in a gas pipe arranged at defined distances along the length of the heat exchanger pipe. The gas serving as the barrier air may then be delivered through a plurality of infeed means arranged all the way up the radiation superheater. This delivery may be effected through apertures or holes between a central air supply channel and the superheating pipes inside the ceramic component, which may be constructed as a shaped brick package. If there is a fault in ceramic components, this results in an assured supply with barrier air even above the damage site.

[26] The task underlying the invention is also solved with a device having a heat exchanger pipe, of which the circumferential surface is surrounded by at least one ceramic component, and which comprises a gas supply to a space adjacent to the heat exchanger pipe and the ceramic component. The device relates to heat exchanger pipes that are not only protected on one side by a ceramic component, but wherein the circumferential surface thereof is also surrounded by at least one ceramic component. In this way, the entire circumferential surface of the heat exchanger pipe is surrounded and protected by the ceramic component, while the gas infeed ensures that no flue gas is able to escape into the heat exchanger pipe through gaps in the ceramic component.

[27] Since the circumferential surface of the heat exchanger pipe is surrounded by the ceramic component, it is suggested that the gas infeed takes place first in the direction of the heat exchanger pipes in the ceramic component, before the gas flows back in the lengthwise direction of the heat exchanger pipes and builds up a gas pressure at gaps in the ceramic component, therefore preventing the flue gas from getting in.

[28] The gas infeed should therefore comprise a fan. Said fan enables the gas pressure to be adjusted such that not too much gas flows through the ceramic component and into the combustion chamber, and on the other hand that sufficient counterpressure is built up over the length of the heat exchanger pipes to prevent flue gases from infiltrating the heat exchanger pipes.

[29] In order to realise this purpose simply, it is suggested that the gas supply comprises a gas pipe that passes inside the ceramic component. The routing inside the ceramic component holds the gas pipe and enables the gas

pipe to be supported by the ceramic of the ceramic component.

[30] In many applications, heat exchanger pipes suspended in the combustion chamber are bent into a U-shape to direct water or steam into the combustion chamber and remove it therefrom. With such a configuration, it is suggested that the gas infeed terminates in the area of bend. This makes it possible particularly to cool the bend area, which is particularly heavily loaded, with freshly supplied gas, and/or preferably to build a counterpressure at this loaded site, which prevents flue gases from penetrating as far as the heat exchanger pipe.

[31] In order to ensure a sufficient supply of barrier air even in the event of a fault in the ceramic component, it is suggested that the gas pipe comprises a plurality of apertures positioned at a distance from each other along the length of the heat exchanger pipe. These apertures are preferably provided all the way up the radiation superheater or along the length of the heat exchanger pipe.

[32] The supplied gas is typically air. However, a gas that promotes combustion or affects the combustion, such as oxygen, may be used. Thus for example flue gas or particularly recirculated flue gas after an exhaust gas scrubbing apparatus may also be introduced as the gas.

[33] For both the method and device according to the invention, a ceramic component containing preferably more than 85% silicon carbide and consisting of at least two cuboid ceramic elements having a cross section of arcuate corrugations that are secured to each other by mating corrugation troughs, so that two heat exchanger pipe sections may be arranged in two opposing corrugation troughs and a gas feed pipe section may be arranged in two

opposing corrugation troughs between said pair of corrugation troughs.

[34] With such a ceramic component, heat exchanger pipe sections may be protected, a gas may be introduced and a gas pressure may be created between ceramic elements to prevent flue gases from flowing into the heat exchanger pipe sections in particularly simple manner. In this context, the ceramic component is preferably constructed in such manner that contact between the heat exchanger pipe and the ceramic element is avoided.

[35] The method and an advantageous embodiment as well as ceramic element are represented in the drawing and will be described in the following. In the drawing:

Figure 1 shows the first duct of a boiler system having superheater coils hanging from the ceiling,

Figure 2 shows a cross section through the duct of figure 1 along line A-A,

Figure 3 is an enlarged diagrammatic illustration of heat exchanger pipes with ceramic elements,

Figure 4 shows a cross section through a ceramic element for a bent pipe, and

Figure 5 shows a cross section through a ceramic element for straight pipes.

[36] Boiler system 1 shown in figure 1 consists of a grating 2, a combustion chamber 3 and a superheater coil 5 suspended from ceiling 4. Superheater coil 5 is surrounded by a ceramic component 6, which consists of a plurality of ceramic elements 7, which are connected to each other by mortar. Ceramic component 6 is connected to a fan 9 via a

line 8, and heat exchanger pipes 10 of superheater coil 5 are connected to a boiler system 11.

[37] With this configuration, it is possible to feed air between heat exchanger pipes 10 and ceramic component 6 via channels 12 from fan 9 and gas pipes 13. Since ceramic component 6 consists of a plurality of ceramic elements 7, which lie flush with each other but are unconnected, and the mortar between them often does not form a reliable seal, in the event of a leak it is possible to air to flow through ceramic component 6 and into flue gas duct 14, thereby preventing flue gas from escaping flue gas 14 to reach heat exchanger pipes 10.

[38] Figure 2 shows ceiling 4 of flue gas duct 14 with boiler system 11. Ceiling 4 is preferably constructed in such manner that by opening ceiling 4 not only heat exchanger pipes 10 but also gas pipes 13 may be passed in a straight line through gas flue duct 14. In this context, it is advantageous if a ceramic element 7 of ceramic component 6 protrudes through ceiling 4, to ensure that heat exchanger pipes 10 inside flue gas duct 14 are completely covered even in the event of lengthwise variations in the area of heat exchanger pipes 10 and ceramic elements 7.

[39] The lower end of a part of superheater coil 5 illustrated in figure 3 shows two arched plates 20, 21 and one cuboid plate 22. Each plate consists of two ceramic elements 23, 24, 25, 26 and 27, 28. Arched plates 20, 21 consist of two elements 23, 24 and 25, 26, which are attached to each other via a threaded connection 29, 30 and 31, 32, so that each ceramic element forms two opposite sides of ceramic component 6, to which flue gas may be directed.

[40] Cuboid plate 22, formed from two cuboid ceramic elements 27, 28, is represented in an open position,

showing corrugations 34 on the inside of ceramic elements 27, 28, which mate with each other to form a circular space 48, 49 for the inflow and outflow of U-shaped heat exchanger pipe 10, and a space 50 therebetween for gas pipe 13. The U-shaped arch of heat exchanger pipe 10 and the routing of gas pipe 13 are indicated with a dashed line. This shows that gas pipe 13 of gas feed 12 ends with an opening 36 in the area of arch 35.

[41] Figure 4 shows a cross section through arched plate 20 with threaded connections 29 and 30. The insides of elements 23 and 24 each have two corrugation troughs 36, 37 and 38, 39 to accommodate heat exchanger pipe 10, and two corrugation troughs 40, 41 therebetween to accommodate gas pipe 13.

[42] In a corresponding construction, figure 5 shows cuboid plate 22 constructed from two ceramic elements 27, 28, which are attached to one another in positive locking manner, and the insides of which are furnished with corrugation troughs 42 to 45 for a flue gas pipe 10, and corrugation troughs 46, 47 for a gas pipe.

[43] Gas pipe 13 may include holes 51, 52, 53 spread over the length thereof in order to ensure that, if a ceramic component develops a fault, the heat exchanger pipe areas above the faulty area will continue to be supplied with gas.

CLAIMS

1. A method for protecting heat exchanger pipes (10) in boiler systems (1) having at least one heat exchanger pipe (10), which is surrounded by a ceramic component (6), to which flue gas flows on at least two opposite sides, wherein gas is supplied to a space (48, 49, 50) adjoining the heat exchanger pipe (10) and the component, wherein the gas is supplied by a gas pipe (13) guided in the ceramic component (6).
2. The method according to claim 1, characterized in that the gas is supplied using a fan (9).
3. The method according to claim 2, characterized in that the ceramic component (6) is built from a plurality of ceramic elements and the supplied gas is guided in the ceramic component.
4. The method according to one of the preceding claims, characterized in that the gas pressure of the supplied gas is set by means of a fan (9) such that not too much gas makes it through the ceramic component (6) into the combustion chamber (3) and on the other hand sufficient counter-pressure is built up over the entire length of the heat exchanger pipes (10) to prevent the penetration of flue gases to the heat exchanger pipes (10).
5. The method according to one of the preceding claims, characterized in that the supplied gas is brought up to the most strongly thermally loaded regions of the heat exchanger pipes.
6. The method according to one of the preceding claims, characterized in that the gas is supplied by the gas pipe which ends in the region of a bend of a heat exchanger pipe,

which is bent in a u-shaped manner and suspended in a combustion chamber of the boiler plant.

7. The method according to one of the preceding claims, characterized in that the gas is supplied at a plurality of locations.
8. The method according to one of the preceding claims, characterized in that the gas is supplied by means of a plurality of holes (51, 52, 53) arranged in the gas pipe (13) spaced along the heat exchanger pipe (10).
9. A device having a heat exchanger pipe, the circumferential surface of which is surrounded by at least one ceramic component (6), and a gas feed (12) to a space (48, 49, 50) adjoining the heat exchanger pipe (10) and the component (6), wherein the gas feed (12) has a gas pipe (13) guided in the ceramic component (6).
10. The device according to claim 9, characterized in that the gas feed (12) has a fan (9).
11. The device according to claim 9 or 10, characterized in that the ceramic component is built from a plurality of ceramic elements.
12. The device according to one of claims 9 to 11, characterized in that the heat exchanger pipe is bent in a u-shaped manner and the gas supply ends in the region of the bend.
13. The device according to one of claims 9 to 12, characterized in that the gas pipe (13) has a plurality of holes (51, 52, 53) spaced along the heat exchanger pipe (10).

14. The device according to one of claims 9 to 13, characterized in that the ceramic component (6) has at least two cuboid ceramic elements (7), which have arcuate corrugations in section and are fastened to one another with mutually flush corrugations troughs, so that two heat exchanger pipe sections can be arranged in two opposite corrugation troughs (38, 39) and a gas guide pipe section can be arranged between these corrugation troughs in two opposite corrugation troughs (40, 41).