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(54) **Titre : RADIATEUR SOMBRE**
(54) **Title: DARK RADIATOR**

(57) **Abrégé/Abstract:**
The invention relates to a dark radiator, comprising a first burner, a fan (2) and a radiant tube (3), wherein the first burner is connected to a fuel gas supply, wherein the fan (2) is designed to supply the first burner with combustion air, wherein the first burner is designed to output a flame into the radiant tube (3). The fuel gas supply is connected to a hydrogen source as a fuel gas source and a secondary burner (4) is connected downstream in the radiant tube (3) spaced apart from the first burner functioning as the primary burner (1) in the flame direction, and the fuel gas supply thereof is connected to a hydrogen source as a fuel gas source, wherein the the exhaust gas flow of the upstream primary burner (1) is supplied to the secondary burner (4) as combustion air.

Abstract

The invention relates to a dark radiator, comprising a first burner, a fan (2) and a radiant tube (3), wherein the first burner is connected to a fuel gas supply, wherein the fan (2) is designed to supply the first burner with combustion air, wherein the first burner is designed to output a flame into the radiant tube (3). The fuel gas supply is connected to a hydrogen source as a fuel gas source and a secondary burner (4) is connected downstream in the radiant tube (3) spaced apart from the first burner functioning as the primary burner (1) in the flame direction, and the fuel gas supply thereof is connected to a hydrogen source as a fuel gas source, wherein the the exhaust gas flow of the upstream primary burner (1) is supplied to the secondary burner (4) as combustion air.

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# Dark radiator

The invention relates to a dark radiator having a first burner, a fan, and a radiant tube, wherein the first burner is connected to a fuel gas supply, wherein the first fan is set up for supplying combustion air to the burner, wherein the burner is set up for outputting a flame into the radiant tube.

In the commercial and industrial sector, dark radiators are frequently used for heating production and warehousing sites. Dark radiators have one or more radiant tubes as radiating elements, to which at least one burner is assigned. By means of combustion of a mixture of fuel gas and air within the burner, a flame is generated, which can be distributed over the entire length of the radiant tube, using a fan. Natural gas or liquefied gas serves as the fuel gas, which is mixed in a predetermined ratio in a mixing chamber and afterward conducted into the combustion chamber by way of a jet and ignited. As a flashback barrier, the fuel gas/air mixture is passed through a grid or a mesh, which simultaneously has the task of holding the flame. The radiant tubes are regularly to be continuous and linear or U-shaped subsequent to the burner, and are supposed to

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emit the heat generated by the flame uniformly over the entire tube progression. The radiant tube is uniformly heated by the flame and generates a heat radiation that is emitted to a region to be heated. To increase the degree of effectiveness, reflectors are frequently used in this regard. The exhaust gases that result from combustion are removed from the radiant tube using the fan, for example they are conducted away to the outside air by way of exhaust gas tubes.

In order to minimize the harmful substances that are formed during combustion of the fuel gas, there is a constant effort to achieve an optimal stoichiometric ratio between fuel gas and air, so as to achieve the most complete combustion possible, during which the emission of harmful substances is minimized. For this purpose, it is proposed, for example in DE 10 2014 019 765 A1, to control the fan and the gas valve by means of a regulating device, so as to ensure complete combustion of the mixture of fuel gas and air. It is furthermore proposed in EP 2 708 814 A1 to equip the burner with a mixer and at least one secondary air channel, wherein the burner is set up so that part of the air supplied by the fan is passed to the mixer and another part of the air is passed to a secondary air channel, so as to supply part of the supplied combustion air to the flame

without fuel. In DE 10 2014 019 766 A1, it is furthermore proposed to detect the current mixture ratio and/or the type of gas by way of a sensor, in particular with reference to the admixture of other types of gas, and to supply gas and/or air to the burner as a function of the result of a comparison of the measured and the required mixture ratio, until the necessary mixture ratio has been produced.

The above solutions have proven themselves in practice, and therefore dark radiators today have a relatively low emission of harmful substances with a simultaneously high degree of effectiveness. The present invention is based on the task of making available a dark radiator having a further reduced emission of harmful substances while keeping the degree of effectiveness at least the same. According to the invention, this task is accomplished by means of the characteristics of the characterizing part of claim 1.

With the invention, a dark radiator is made available that has a degree of effectiveness that at least remains the same in comparison with the state of the art, and in which the emission of harmful substances is reduced. Because of the fact that the fuel gas supply is connected to a hydrogen source as the fuel

gas source, and that a secondary burner follows the first burner, which serves as the primary burner, in the radiant tube, at a distance from the first burner, in the flame direction, the fuel gas supply of which secondary burner is connected to a hydrogen source as the fuel gas source, wherein the exhaust gas stream of the upstream primary burner is supplied to the secondary burner as combustion air, theoretically no harmful substances containing carbon, such as carbon monoxide, carbon dioxide or hydrocarbons, are contained in the exhaust gas, since hydrogen does not contain any carbon. By means of the secondary burner that follows the primary burner, subsequent treatment of the exhaust gas of the primary burner is achieved, and thereby an emission of nitrogen oxides is minimized to a great extent. It has been shown that due to the great reactivity of hydrogen, the content of oxygen remaining in the exhaust gas of the primary burner is easily sufficient for combustion of the hydrogen of the secondary burner. Furthermore, the combustion process in the secondary burner is promoted by the temperature of the exhaust gas stream of the primary burner.

In a further development of the invention, the fan is connected to an ejector having a suction connector connected with the hydrogen supply, wherein the combustion air drawn in by the fan

serves as a driving medium, so that a hydrogen/combustion air mixture is supplied to the burner by the fan. As a result, feed of a hydrogen/combustion air mixture in a defined mixture ratio is made possible, and thereby setting of the flame temperature is achieved. By means of setting a high air number, in other words a high air excess, a reduction of the flame temperature can be achieved. Because of the great reactivity of hydrogen, a high air number of 2.5 to 3 is possible. In this way, the flame temperature can be brought to below the boundary temperatures of nitrogen oxide formation and of the materials of the radiant tube.

In an embodiment of the invention, an equalization element in the form of a compensator is arranged between the primary burner and the secondary burner, to equalize thermally related length changes within the radiant tube. This compensator, which is preferably configured as an axial compensator, absorbs the movement of the radiant tube along the axis, and thereby damage to the radiant tube is prevented.

In a further embodiment of the invention, the primary burner and/or the secondary burner comprise(s) a gas jet, wherein the fan is set up for flushing the gas jet with combustion air, and

whereby no fuel gas mixing chamber is provided for pre-mixing fuel gas and combustion air, and the gas jet is supplied exclusively with fuel gas. In this way, a simple and cost-advantageous structure of the burner is achieved. Surprisingly it has been shown that due to the great reactivity of hydrogen, complete combustion of the hydrogen is achieved without pre-mixing with combustion air. In this regard, a great distance of the flame from the gas jet occurs up to the required pre-mixing of the hydrogen with the combustion air that flushes the fan, and thereby no thermal impairment of the gas jet occurs. Furthermore, it has been shown that the risk of a flame flashback also does not exist, and therefore the flame holder required in the state of the art, in the form of a perforated plate or a wire mesh, is not required.

In a further embodiment of the invention, the primary burner comprises a gas jet that supplies a mixing tube arranged in the radiant tube with hydrogen, wherein the mixing tube is flushed with combustion air by the fan, wherein the gas jet forms an ejector with the mixing tube, wherein the driving medium of the ejector is hydrogen introduced by the gas jet and the medium drawn into the mixing tube is combustion air situated in the radiant tube, and wherein an ignition apparatus for igniting the

hydrogen/combustion air mixture follows at a distance from the mixing tube, in the flame direction. As a result, supply of a hydrogen/combustion air mixture in a defined ratio is made possible, so to speak. Because of the fact that mixing of the hydrogen with the combustion air only takes place outside of the fan, in the mixing tube, the demands on the fan material are reduced, since the risk of flame flashback into the fan is not possible here. Preferably a flashback barrier is arranged in the mixing tube, at its end directed in the flame direction. In this way, flame flashback into the mixing tube is prevented.

In a further development of the invention, a combustion air mixing chamber is arranged to precede the primary burner in the flame direction, which chamber is connected to an air source and to an exhaust gas discharge line connected to the radiant tube. By means of supplying exhaust gases to the combustion air, a reduction in oxygen is achieved, and thereby it is made possible to lower the flame temperature. Furthermore, a reduction in nitrogen oxide emissions is brought about by the recirculation of the exhaust gas.

In an embodiment of the invention, the fan is arranged to precede the primary burner in the flame direction, and the

combustion air mixing chamber is arranged within the fan. In this way, good mixing of combustion air and exhaust gas within the fan is achieved.

In a further embodiment of the invention, the connection between the exhaust gas discharge line and the combustion air mixing chamber comprises a branching-off device by means of which the ratio of the branched-off exhaust gas volume stream, passed along to the combustion air mixing chamber, and the total exhaust gas volume stream is determined. In this way, setting of the oxygen content of the combustion air/exhaust gas mixture is made possible. Preferably the branching-off device comprises an adjustment device by means of which the ratio of the branched-off exhaust gas volume stream and the combustion air volume stream can be set.

Other further developments and embodiments of the invention are indicated in the remaining dependent claims. Exemplary embodiments of the invention are shown in the drawings and will be described in detail below. The figures show:

Figure 1 the schematic representation of a dark radiator;

Figure 2 the schematic representation of a dark radiator in a second embodiment, and

Figure 3 the schematic representation of a dark radiator in a third embodiment.

The dark radiator according to Figure 1, selected as an exemplary embodiment, comprises a primary burner 1 that is connected to a fan 2 and followed by a radiant tube 3. The radiant tube 3 is merely indicated in Figure 1; the radiant tube 3 can certainly extend over several meters in length and be formed from multiple radiant tube elements. In the exemplary embodiment, the radiant tube 3 is formed as a highly heat-resistant stainless steel tube. Alternatively, special steels having a thermally applied aluminum oxide layer can also be used. In the exemplary embodiment, the radiant tube 3 is enclosed by a reflector - not shown - which is formed, in the exemplary embodiment, from surface-structured sheet aluminum and has bulkhead plates on both sides, to reduce convective losses.

The primary burner 1 comprises a gas jet 11 that serves as a gas/air mixture jet and is provided, in the exemplary embodiment, with a flashback barrier, and is connected to a hydrogen supply 12. At a distance from the gas jet 11, an

ignition electrode 13 is arranged in the primary burner 1. The fan 2 is connected to a combustion air supply 21 on the suction side, and set toward the primary burner 1 in such a manner that it flushes the gas jet 11 with combustion air. The hydrogen gas that exits from the gas jet 11 is ignited by the ignition electrode 13 after it is mixed with the combustion air that is supplied by way of the fan 2, and thereby a flame that extends through the radiant tube 3 is generated.

Alternatively the gas jet can also be connected to the fan 2, wherein the fan 2 is connected, on its suction side, to an ejector, the drive connector of which is connected to a combustion air supply and the suction connector of which is connected to a hydrogen supply. The combustion air drawn in by the fan 2 serves as a driving medium here, by means of which intake of the hydrogen is brought about. On the pressure side, the gas jet 11 has a hydrogen/combustion air mixture supplied to it by the fan 2 as a result, in this case; after this mixture exits through the gas jet 11, it is ignited by the ignition electrode 12.

The primary burner 1 is followed, in the flame direction, by a radiant tube 3 configured in U shape, which tube is connected to

a secondary burner 4 by way of an equalization element 31. In the exemplary embodiment, the equalization element is configured as an axial compensator that absorbs the movements of the tube line along the axis. Once again, a second part of the radiant tube 3 follows the secondary burner 4, which part is once again configured in U shape in the exemplary embodiment.

The secondary burner once again comprises a gas jet 4 connected to a hydrogen supply 42, wherein an ignition electrode 43 is positioned at a distance from the gas jet 41.

The gas jet 11 of the primary burner 1 is flushed with combustion air by the fan 2. The hydrogen/combustion air mixture that forms in front of the gas jet 11 is ignited by the ignition electrode 13, and thereby a first flame forms at a distance in front of the hydrogen jet 11. The exhaust gas stream of this first flame flows through the equalization element 31 and flushes the gas jet 41 of the secondary burner 4. The exhaust gas/hydrogen mixture that forms in front of the gas jet 41 has a sufficiently high oxygen content so that it can be ignited by the ignition electrode 43, and thereby a second flame is formed, which extends along the second part of the radiant tube 3. The exhaust gas stream 32 of this second flame is

derived from the second part of the radiant tube 3. The equalization element 31, which is positioned in the section of the radiant tube 3 that is exposed to a high temperature, by means of the secondary burner 4, serves for equalization of thermally caused length changes within the radiant tube.

In this exemplary embodiment, combustion air is supplied to the primary burner 1 by way of the fan 2, which air flushes the gas jet 11 of the primary burner 1. In a modified embodiment, the fan 2 that precedes the primary burner 1 can also be connected to an ejector, wherein the combustion air that is drawn in serves as a driving medium, by way of which an exhaust gas stream is drawn in from the second part of the radiant tube 3. In this way, the flame temperature of the first flame of the primary burner 1 can be adjusted. Furthermore, in this way a further reduction in the nitrogen oxide content of the exhaust gas that is conducted away is made possible.

In the exemplary embodiment according to Figure 2, a mixing tube 14 is arranged in the primary burner 1', which tube runs coaxially to the radiant tube 3 and projects into the gas jet 11, wherein a radial suction gap 15 of an ejector formed by the gas jet 11 and the mixing tube 14 is formed between mixing tube

14 and gas jet 11. The mixing tube 14 is held in the primary burner 1' by way of a separating frame 16 that clamps the tube in place and is provided with flushing openings. On its end that lies opposite the gas jet 11, a flashback barrier 141 is arranged in the mixing tube 14. For the remainder, the structure of the dark radiator of this exemplary embodiment corresponds to the exemplary embodiment according to Figure 1 that was described above, wherein in the case of this exemplary embodiment, as well, the embodiments mentioned there for mixing part of the exhaust gas stream of the second part of the radiant tube 3 into the combustion air drawn in by the fan 2 are possible.

The fan 2 is oriented in such a manner that it flushes the gas jet 11 and the mixing tube 14 with combustion air. By means of the hydrogen stream introduced into the mixing tube 14 by way of the gas jet 11, combustion air is drawn in by way of the suction gap 15, which air mixes with the hydrogen. The hydrogen/combustion air mixture exiting from the mixing tube 14 is ignited by means of the ignition electrode 13 arranged at a distance from the mixing tube 14, and thereby a flame is formed, which extends into the radiant tube 3 over its length. A part of the combustion air 5 blown into the primary burner 1 by the

fan flows through the flushing openings of the separating frame 16 and flushes the flame that extends into the radiant tube 3, which flame is thereby cooled. The ejector formed by the gas jet 11 and the mixing tube 14 is configured in such a manner that combustion air having an air number of 2.5 is supplied to the hydrogen in the mixing tube 14, and thereby a temperature of about 900 °C is achieved.

In the exemplary embodiment according to Figure 3, an ejector tube 5 is connected to the second part of the radiant tube 3, following the secondary burner in the flame direction, which ejector tube is connected to the fan 2 by way of a suction tube 22.

The ejector tube 5 comprises a main tube piece 51, by way of which the radiant tube 3 is connected to the suction tube 22. An exhaust gas off-take tube 52 branches off from the main tube piece 51, and, at a distance from it, a combustion air supply tube 53 branches off. A recirculation shutter 54 is arranged in the main tube piece 51, between the exhaust gas supply tube 52 and the combustion air supply tube 53. The combustion air stream 531 drawn in by way of the suction tube 22, by means of the fan 2, serves as a drive medium of the ejector tube 5, by

way of which a part of the exhaust gas stream 521 is drawn in by means of the recirculation shutter 54. The exhaust gas/combustion air mixture produced in this way is introduced into the primary burner 1 by means of the fan 2 and flushes the gas jet 11 there. By means of the recirculation shutter 54, the proportion of the exhaust gas stream in the combustion air stream can be adjusted, and thereby, once again, the oxygen content of the exhaust gas/combustion air mixture that flushes the hydrogen jet 11 is determined. The main exhaust gas stream is carried away by way of the exhaust gas off-take tube 52.

The primary burner 1, the parts of the radiant tube 3, the secondary burner 4, the ejector tube 5, and the fan 2 connected to the suction tube 22 are connected to one another, in each instance, by way of flange connections.

Claims

1. Dark radiator having a first burner, a fan (2), and a radiant tube (3), wherein the first burner is connected to a fuel gas supply, wherein the fan (2) is set up for supplying combustion air to the first burner, wherein the first burner is set up for outputting a flame into the radiant tube (3), characterized in that the fuel gas supply is connected to a hydrogen source as the fuel gas source, and that a secondary burner (4) follows the first burner that serves as the primary burner (1), in the radiant tube (3), at a distance from the first in the flame direction, the fuel gas feed of which secondary burner is connected to a hydrogen source as the fuel gas source, wherein the exhaust gas stream of the upstream primary burner (1) is supplied to the secondary burner (4) as combustion air.

2. Dark radiator according to claim 1, characterized in that the fan (2) is connected to an ejector having a suction connector connected to the hydrogen supply, wherein the combustion air drawn in by the fan (2) serves as a driving medium, so that a hydrogen/combustion air mixture is supplied to the burner (1) by the fan (2).

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3. Dark radiator according to claim 1 or 2, characterized in that an equalization element (31) is arranged between the primary burner (1) and the secondary burner (4), to equalize thermally related length changes within the radiant tube (3).

4. Dark radiator according to one of the preceding claims, characterized in that the primary burner (1) comprises a gas jet, wherein the fan (2) is set up for flushing the gas jet (11) with combustion air, and whereby no fuel gas mixing chamber is provided for pre-mixing fuel gas and combustion air, and the gas jet is supplied exclusively with fuel gas.

5. Dark radiator according to one of claims 1 to 3, characterized in that the primary burner (1) comprises a gas jet (11) and a mixing tube (14), which is supplied with hydrogen by the gas jet (11), wherein the mixing tube (14) is flushed with combustion air by the fan (2), wherein the gas jet (11) forms an ejector with the mixing tube (14), wherein the driving medium of the ejector is hydrogen introduced by the gas jet (11) and the medium drawn into

the mixing tube (14) is combustion air situated in the radiant tube (3), and wherein an ignition apparatus (13) for igniting the hydrogen/combustion air mixture follows at a distance from the mixing tube (14), in the flame direction.

6. Dark radiator according to one of the preceding claims, characterized in that a combustion air mixing chamber is arranged to precede the primary burner (1) in the flame direction, which chamber is connected to a combustion air source and to the exhaust gas discharge line.

7. Dark radiator according to claim 6, characterized in that the fan (2) is arranged to precede the burner (1) in the flame direction, and the combustion air mixing chamber is arranged within the fan (2).

8. Dark radiator according to claim 6 or 7, characterized in that the connection between the exhaust gas discharge line and the combustion air mixing chamber comprises a branching-off device (5) by means of which the ratio of the branched-off exhaust gas volume stream and the combustion air volume stream is determined.

9. Dark radiator according to claim 8, characterized in that the branching-off device (5) comprises an adjustment device by means of which the ratio of the exhaust gas volume stream and the combustion air volume stream can be set.

Fig. 1

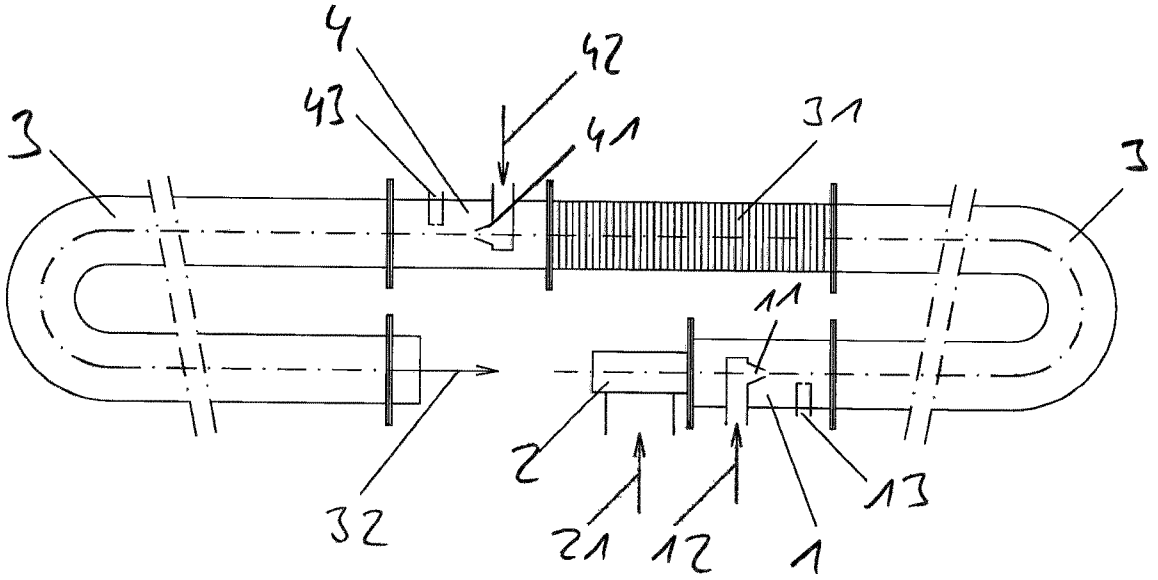

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Fig. 2

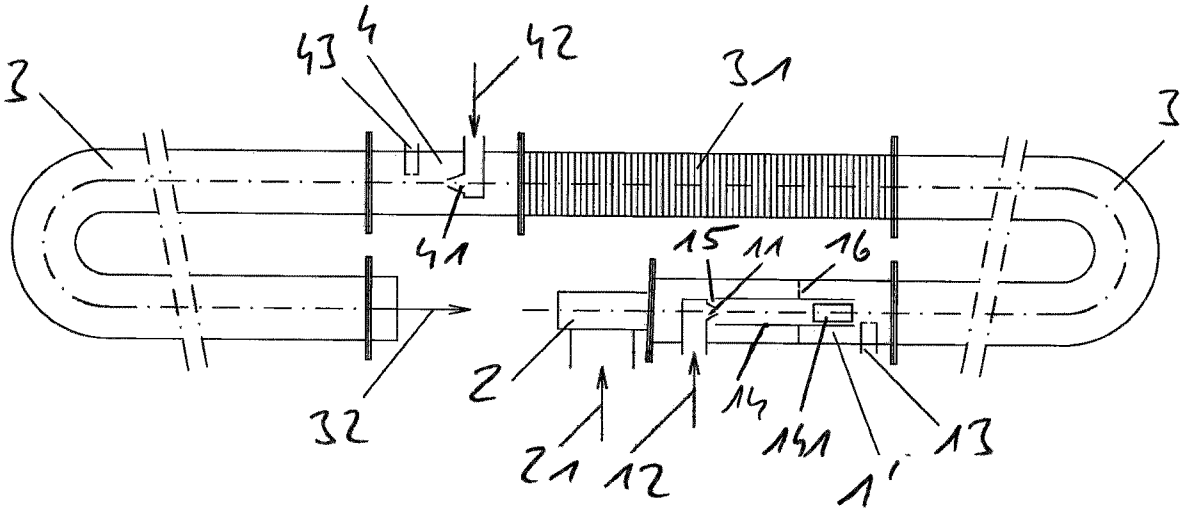

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Fig. 3

