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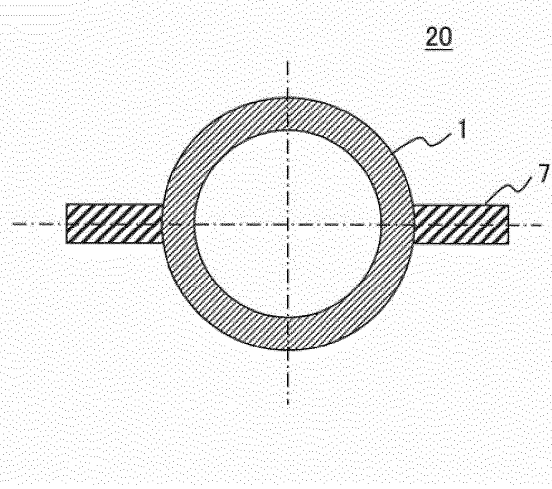
(54) **Heat treatment method for boiler membrane panel and boiler processed by the same heat treatment**

(57) A heat treatment method for boiler membrane panel in which pipes of boiler membrane panels are welded, a plurality of the boiler membrane panels (20) forming a water wall of a boiler furnace, the boiler membrane panel (20) including a plurality of the pipes (1) as heat-transfer pipes forming the water wall of the boiler furnace and a plurality of membrane bars (7) joining the pipes (1), comprising the steps of: positioning an ignition body (3, 3b, 3c, 3d, 3e) on the outer circumferential side of the pipe (1) including a welding portion (2) of the pipe of the boiler membrane panel (20) when an operation of the boiler is stopped; flowing a high-temperature heat medium (5) inside of the pipe (1) of the boiler membrane panel (20); raising the temperature of the pipe (1) to the ignition point of the ignition body (3, 3b, 3c, 3d, 3e) by flow of the high-temperature heat medium (5) and starting combustion of the ignition body (3, 3b, 3c, 3d, 3e) positioned on the outer circumferential side of the pipe (1); and heating the welding portion (2) of the pipe (1) and a heat-affecting area of the welding portion (2) through combustion of the ignition body (3, 3b, 3c, 3d, 3e), and raising the temperature of the pipe (1) by flow of the high-temperature heat medium (5) inside of the pipe (1), whereby a welding residual stress applied to the welding portion (2) of the pipe (1) and the heat-affecting area of the welding portion (2) is reduced.

FIG. 1




EP 2 746 655 A1

## Description

{Background of the Invention}

{Field of the Invention}

**[0001]** The present invention relates to a heat treatment method for boiler membrane panel capable of reducing a residual stress on a welding portion of a membrane panel constituting a water wall of a boiler furnace, and a boiler processed by this heat treatment.

{Description of Related Art}

**[0002]** A boiler membrane panel which forms a water wall of a boiler furnace included in a boiler has a plurality of pipes corresponding to heat transfer pipes through the inside of which boiler water or vapor flows, and membrane bars having a predetermined shape and connecting the pipes at predetermined intervals by welding. A plurality of the membrane panels having a predetermined shape are butt-welded to each other at both ends of the pipes to form a water wall of a boiler furnace.

**[0003]** For joining the plural boiler membrane panels, both ends of the respective membrane bars are partially notched to produce a clearance providing a welding work space at the time of butt-welding of the ends of the pipes. After butt-welding of the ends of the pipes, an auxiliary membrane bar is inserted into the clearance to close the clearance, in which condition the ends of the auxiliary membrane bar and the membrane bar are welded to the pipes to join the plural membrane panels and form the water wall of the boiler furnace.

**[0004]** Methods performing these steps for manufacturing boiler membrane panel are known in the art. For example, JP-A-2007-64608 discloses a technology associated with a boiler membrane panel of the type described above.

**[0005]** The above described joining of the membrane panels forming the water wall of the boiler furnace is typically performed on the site where boiler equipment is installed.

**[0006]** However, in welded parts in which the boiler membrane panels forming the water wall of the boiler furnace are joined, welding residual stress due to welding is generated.

**[0007]** After the welding for joining the boiler membrane panels, generally, postweld heat treatment is performed on the welded parts and the welding residual stress generated in the welded parts is reduced.

**[0008]** Typically, the heat treatment after welding for the welding portion performed after the welding between the boiler membrane panels uses an electric heater or gas burner.

**[0009]** In this case, the heat treatment after welding requires a number of steps, including a series of works for setting the heater or gas burner on the welding portion, raising and retaining the temperature of the welding portion by energization of the heater or combustion of the burner, and removing the heater or gas burner.

{Patent Literature 1}

Japanese Patent Laid-open No. 2007-64608

{Summary of the Invention}

**[0010]** According to the boiler membrane panels, therefore, a welding residual stress is applied to the welding portions of the pipes by butt-welding of the pipes of the respective membrane panels for joining between the plural boiler membrane panels. Moreover, a welding residual stress is also produced by welding between the pipes and the ends of the auxiliary membrane bars and the membrane bars after the butt-welding of the pipes.

**[0011]** These welding residual stresses can be reduced by conducting heat treatment after welding for the welding portions in the same manner as described above.

**[0012]** Steel material induces creep strain when a load is applied thereto at a high temperature. When heat treatment is carried out after welding, the residual stress decreases by the effect of the creep strain. The creep strain occurs at the room temperature, but the magnitude of the strain is lower than that of the elastic strain generating the residual stress. Accordingly, the stress does not greatly decrease by the creep strain generated at the room temperature.

**[0013]** The generation of the creep strain becomes more remarkable as the temperature increases. For example, it is known that iron induces creep strain contributing to reduction of the residual stress when held at about 400°C for several tens of hours.

**[0014]** Each of the pipes constituting the boiler membrane panel, membrane bars, and welding metal forming the welding portions is made of the same material of low alloy steel or carbon steel.

**[0015]** According to the heating treatment after welding which welds the boiler membrane panel made of low alloy steel by using the same metal of low alloy steel, the retention temperature and retention time have an effect on the residual stress remaining after the heat treatment after welding.

**[0016]** Therefore, in the case of the heat treatment after welding performed for the welding portions of the boiler membrane panels, the highest increased temperature of the heat treatment after welding is required to reach the temperature range of creep generation.

**[0017]** For welding low alloy steel constituting the welding portions of the boiler membrane panels, generation of creep strain becomes remarkable when low alloy steel is retained at 400°C similarly to iron. Thus, it is preferable that the temperature of the welding portions formed by low alloy steel is raised to a temperature exceeding 400°C during the heat treatment after welding so as to cause remarkable generation of creep strain at the welding portions where low alloy steel is welded to the boiler membrane panels.

**[0018]** According to the welding portions where carbon steel is welded to the boiler membrane panels made of the same carbon steel, it is known that generation of creep strain becomes remarkable in the temperature range of 600°C or higher. In this case, even when the retention time at 600°C is zero hour, that is, when the temperature of the welding portion is decreased immediately after the temperature reaches 600°C, it is known that the residual stress on the welding portions and heat-affecting areas of the welding portions can be considerably reduced.

**[0019]** For example, when the temperature of the welding portions of the boiler membrane panel reaches 500°C by operation of the boiler, the residual stress on the welding portions and the heat-affecting areas of the welding portion can be decreased by raising the temperature of the welding portions to a temperature higher than the ambient temperature by 100°C.

**[0020]** However, when the residual stress on the welding portions of the boiler membrane panels is reduced by using a conventional electric heater, a burner or the like generally employed, for example, a great number of steps are required for the heat treatment of the welding portions. In this case, it is difficult to effectively prevent generation or development of stress corrosion cracking on the welding portions, therefore continuation of highly reliable operation of the boiler becomes difficult.

**[0021]** An object of the invention is to provide a heat treatment method for boiler membrane panel capable of easily performing heat treatment for a welding portion where pipes constituting boiler membrane panels are butt-welded without using an electric heater, or a burner or the like which requires a number of processing steps so as to remove factors producing a tension residual stress and thereby prevent generation and development of stress corrosion cracking on the welding portion of the boiler membrane panels and allow continuation of highly reliable operation of a boiler, and a boiler processed by this heat treatment.

**[0022]** A heat treatment method for boiler membrane panel of the present invention in which pipes of boiler membrane panels are welded, a plurality of the boiler membrane panels forming a water wall of a boiler furnace, the boiler membrane panel including a plurality of the pipes as heat-transfer pipes forming the water wall of the boiler furnace and a plurality of membrane bars joining the pipes, comprising the steps of: positioning an ignition body on the outer circumferential side of the pipe including a welding portion of the pipe of the boiler membrane panel when an operation of the boiler is stopped; flowing a high-temperature heat medium inside of the pipe of the boiler membrane panel; raising the temperature of the pipe to the ignition point of the ignition body by flow of the high-temperature heat medium and starting combustion of the ignition body positioned on the outer circumferential side of the pipe; and heating the welding portion of the pipe and a heat-affecting area of the welding portion through combustion of the ignition body, and raising the temperature of the pipe by flow of the high-temperature heat medium inside of the pipe, whereby a welding residual stress applied to the welding portion of the pipe and the heat-affecting area of the welding portion is reduced.

**[0023]** Further, a heat treatment method for boiler membrane panel of the present invention in which pipes of boiler membrane panels are welded, a plurality of the boiler membrane panels forming a water wall of a boiler furnace, the boiler membrane panel including a plurality of the pipes as heat-transfer pipes forming the water wall of the boiler furnace and a plurality of membrane bars joining the pipes, comprising the steps of: positioning an ignition body on the outer circumferential side of the pipe including a welding portion of the pipe of the boiler membrane panel when an operation of the boiler is stopped; flowing down a high-temperature combustion gas generated by combustion of fuel inside the boiler furnace by startup of the boiler to outer circumferential side of the pipe of the boiler membrane panel; raising the temperature of the ignition body positioned on the outer circumferential side of the pipe to the ignition point of the ignition body by flow of the high-temperature combustion gas and starting combustion of the ignition body; and heating the welding portion of the pipe and a heat-affecting area of the welding portion through combustion of the ignition body, and raising the temperature of the pipe by flow of the high-temperature combustion gas on the circumferential side of the pipe, whereby a welding residual stress applied to the welding portion of the pipe and the heat-affecting area of the welding portion is reduced.

**[0024]** According to the invention, a heat treatment method for boiler membrane panel and a boiler processed by this heat treatment method are provided as technologies improved in the following points. The heat treatment method can remove a factor of a tension residual stress applied to the welding portion by easily performing heat treatment for the welding portion where the pipes constituting the boiler membrane panels are butt-welded without using an electric heater, a burner or the like which requires a number of steps. Accordingly, the heat treatment method prevents generation or development of stress corrosion cracking on the welding portion of the boiler membrane panels, and allows continuation of highly reliable operation of a boiler.

{Brief Description of the Drawings}

**[0025]**

FIG. 1 illustrates a part of a pipe and a membrane bar constituting a membrane panel according to a heat treatment method for a boiler membrane panel in a first embodiment of the invention.

FIG. 2 is a partial cross-sectional view illustrating a welding portion in the circumferential direction where the ends of the pipes constituting the membrane panels are butt-welded, and the pipes including the welding portion according to the heat treatment method for the boiler membrane panel in the first embodiment of the invention.

FIG. 3A is a cross-sectional view of a structure of the pipes in the axial direction, showing an ignition body positioned on the outer circumference of the pipes and having holes through which air is introduced into the ignition body according to the heat treatment method for the boiler membrane panel in the first embodiment of the invention.

FIG. 3B is a cross-sectional view illustrating the structure of the pipes in the direction perpendicular to the axis of the pipe, showing the ignition body positioned on the outer circumference of the pipes and has the holes through which air is introduced into the ignition body according to the heat treatment method for the boiler membrane panel in the first embodiment of the invention.

FIG. 4 illustrates a condition in which a heat medium flows within the pipes according to the heat treatment method for the boiler membrane panel in the first embodiment of the invention.

FIG. 5 shows characteristics of the relationship between the heat treatment temperature after welding and the residual stress of low alloy steel forming the pipes according to the heat treatment method for the boiler membrane panel in the first embodiment of the invention.

FIG. 6 illustrates a condition in which a combustion gas flows on the outer circumference of the pipes according to the heat treatment method for the boiler membrane panel in a second embodiment of the invention.

FIG. 7 is a cross-sectional view illustrating a condition in which the thickness of the ignition body positioned on the outer circumference of the pipes is varied according to the heat treatment method for the boiler membrane panel in the third embodiment of the invention.

FIG. 8 is a cross-sectional view illustrating a condition in which an ignition body positioned on the outer circumference of the pipes includes briquette according to the heat treatment method for the boiler membrane panel in a fourth embodiment of the invention.

FIG. 9 is a cross-sectional view illustrating a condition in which an ignition body positioned on the outer circumference of the pipes includes charcoal and a wire netting covering the charcoal according to the heat treatment method for the boiler membrane panel in a fifth embodiment of the invention.

FIG. 10 is a cross-sectional view illustrating a condition in which an ignition body positioned on the outer circumference of the pipes has a double layer structure including an inner-layer ignition body made of material having a relatively low ignition temperature and an outer-layer ignition body made of material having a relatively high ignition temperature according to the heat treatment method for the boiler membrane panel in a sixth embodiment of the invention.

{Detailed Description of the Invention}

**[0026]** A heat treatment method for a boiler membrane panel embodying the invention is hereinafter described with reference to the drawings.

[Embodiment 1]

**[0027]** A heat treatment method for a boiler membrane panel according to a first embodiment of the present invention is now explained in conjunction with FIGS. 1 through 5.

**[0028]** According to the heat treatment method for a boiler membrane panel in this embodiment which will be discussed below, a boiler membrane panel 20 made of low alloy steel includes a plurality of pipes 1 corresponding to heat transfer pipes through the inside of which boiler water or vapor flows, and membrane bars 7 having a predetermined shape and connecting the pipes 1 at predetermined intervals by welding. The pipes 1 and the membrane bars 7 are made of the same low alloy steel as the material of the boiler membrane panel 20.

**[0029]** A welding portion 2 is provided as a portion where both ends of the pipes 1 of the respective membrane panels 20 having a predetermined shape are butt-welded by using welding metal of low alloy steel. The plural membrane panels 20 thus constructed constitute a water wall of a boiler furnace.

**[0030]** For reducing a welding residual stress applied to each of the welding portions 2 where the pipes 1 of the boiler membrane panels 20 are butt-welded, the following heat treatment method is performed for the welding portion 2 of the boiler membrane panel 20. Initially, a cylindrical ignition body 3 is positioned on the outer surface side of the pipe 1 of the boiler membrane panel 20 at the position including the welding portion 2 corresponding to butt-welding.

**[0031]** After the positioning of the ignition body 3, a high-temperature heat medium 5 is caused to flow within the pipe 1 constituting the boiler membrane panel 20 made of low alloy steel to heat the ignition body 3 positioned on the outer surface side of the pipe 1 to the ignition point of the ignition body 3 by raising the temperature of the pipe 1 using the high-temperature heat medium 5.

**[0032]** The heating by the heat medium 5 ignites the ignition body 3 provided on the outer surface of the pipe 1, and the combustion heat generated by the combustion of the ignition body 3 further heats the pipe 1. This heating is continued to increase the temperatures of the welding portion 2 of the pipe 1 and a heat-affecting area of the welding portion 2 to 600°C at which generation of a creep strain becomes considerably remarkable so as to reduce the welding residual stress applied to the welding portion 2 of the pipe 1 and the heat-affecting area of the welding portion 2.

**[0033]** According to this embodiment, the heat-affecting area of the welding portion 2 where the pipe 1 of the boiler membrane panel 20 is butt-welded refers to an area where the characteristics of the base material change due to a temperature change thereof in accordance with entrance of welding heat from welding metal when the welding portion for welding the base material is produced using the welding metal. The heat-affecting area usually corresponds to an area expanded to the base material side for approximately 10 mm from the boundary between the welding metal of the welding portion and the base material.

**[0034]** The heat treatment method for the boiler membrane panel according to this embodiment is now explained in detail. FIGS. 1 and 2 illustrate the heat treatment method for the boiler membrane panel according to the first embodiment of the present invention.

**[0035]** According to the heat treatment method for the boiler membrane panel in this embodiment, the boiler membrane panel 20 includes a plurality of the pipes 1 corresponding to the heat transfer pipes the interior of which boiler water or vapor flows, and the membrane bars 7 having a predetermined shape and connecting the pipes 1 at predetermined intervals by welding as illustrated in FIG. 1. The welding portion 2 is provided as a portion where both ends of the pipes 1 of the plural membrane panels 20 having a predetermined shape are butt-welded. The plural boiler membrane panels 20 thus constructed are connected to produce a water wall of a boiler furnace.

**[0036]** According to the heat treatment method for the boiler membrane panel in this embodiment, the pipes 1 constituting the boiler membrane panels 20 are connected by the welding portion 2 which joins the end of the pipe 1 included in one of the adjoining membrane panels 20 with the end of the pipe 1 included in the other of the adjoining membrane panels 20 by welding as illustrated in FIG. 2.

**[0037]** Each of the pipe 1 constituting the boiler membrane panel 20, the membrane bar 7, and the welding metal of the welding portion 2 is formed by the same material of low alloy steel or carbon steel.

**[0038]** According to the heat treatment method for the boiler membrane panel in this embodiment performed for the welding portion where the pipes 1 of the boiler membrane panels 20 are butt-welded to each other, the cylindrical ignition body 3 is positioned on the outer circumferential side, i.e., the outer surfaces of the end of the pipe 1 of one of the adjoining membrane panels 20 including the welding portion 2, and the end of the pipe 1 of the other of the adjoining membrane panels 20 including the welding portion 2 after the welding portion 2 is formed by butt-welding the pipes 1 as illustrated in FIG. 2.

**[0039]** FIG. 2 is a cross-sectional view of the pipes 1 including the welding portion 2 in the circumferential direction where the ends of the pipes 1 of the membrane panels 20 are butt-welded according to the heat treatment method for the boiler membrane panel in this embodiment.

**[0040]** According to the heat treatment method for the boiler membrane panel in this embodiment, the welding portion 2 is formed on the outer circumferential side of the end of the pipe 1 of the membrane panel 20 by butt-welding the end of the pipe 1 to constitute the water wall of the boiler furnace.

**[0041]** Then, fine coal in the form of clay formed by kneading a mixture of fine coal and water is applied to the outer circumferential surface of the pipe 1 on the outer circumferential side of the end of the pipe 1 of the boiler membrane panel 20 constituting the water wall of the boiler furnace in such a position as to cover the welding portion 2 formed by butt-welding the end of the pipe 1 during operation stop of the boiler (before start of the boiler or during operation suspension of the boiler).

**[0042]** Subsequently, the fine coal in the form of clay applied to the outer circumferential surfaces of the pipe 1 is dried to form the solid ignition body 3 in a cylindrical solid shape, for example. The ignition body 3 thus produced is attached to the outer circumferential side of the pipe 1 including the butt-welding portion 2 at the end of the pipe 1.

**[0043]** Prior to dry for solidification, a plurality of holes 4 are formed in the applied fine coal in the form of clay which constitutes the cylindrical solid ignition body 3 attached to the outer circumferential side of the pipe 1. These holes 4 are so configured as to separate from each other and penetrate the cylindrical solid ignition body 3 in the longitudinal direction as openings as illustrated in FIGS. 3A and 3B.

**[0044]** The solid ignition body 3 attached to the outer circumferential side of the pipe 1 is heated and ignited by raising the temperature of the pipe 1 to a high temperature using the high-temperature heat medium 5 flowing inside the pipe 1. In this case, air is introduced into the plural holes 4 penetrating the cylindrical solid ignition body 3 in the longitudinal direction at the time of ignition and combustion of the ignition body 3 to allow combustion of the ignition body 3 to reach the inside of the holes 4.

**[0045]** FIG. 4 illustrates a condition in which the high-temperature heat medium 5 having a temperature of 500°C for heating the pipe 1 is caused to flow inside the pipe 1 constituting the boiler membrane panel 20 so as to burn the cylindrical solid ignition body 3 positioned on the outer circumferential side of the pipe 1 including the welding portion 2 where the end of the pipe 1 of the boiler membrane panel 20 is butt-welded according to the heat treatment method for the boiler membrane panel in this embodiment.

**[0046]** The examples of the high-temperature heat medium 5 involve highly pressurized boiling water or high-temperature vapor. The temperatures of the pipe 1 and the membrane bar 7 joined with the pipe 1 rise by the flow of this type of the high-temperature heat medium 5 inside the pipe 1.

**[0047]** The temperature increase of the pipe 1 achieved by the flow of the high-temperature heat medium 5 inside the pipe 1 starts from the inner surface of the pipe 1 where the heat medium 5 flows. This temperature increase is conducted to the outer surface of the pipe 1 and the membrane bar 7.

**[0048]** The ignition temperature of the cylindrical solid ignition body 3 formed by drying fine coal in the form of clay and attached to the outer circumferential side of the pipe 1 including the welding portion 2 where the end of the pipe 1 is butt-welded varies in accordance with the ratio of the quantities of fine coal and water, ranging from 200°C to 300°C.

**[0049]** Thus, when the temperatures of the outer surfaces of the pipe 1 and the membrane bar 7 reach at least 300°C, the solid ignition body 3 produced from dried fine coal attached to the outer circumferential side of the pipe 1 including the welding portion 2 ignites and starts burning.

**[0050]** The combustion of the ignition body 3 generates combustion heat. Since the temperature of the heat medium 5 flowing inside the pipe 1 is 500°C, the temperatures of the pipe 1 and the membrane bar 7 are raised to 500°C by heat conduction from the heat medium 5.

**[0051]** In addition to the temperature increase by the heat condition from the heat medium 5, the combustion heat generated by the combustion of the cylindrical solid ignition body 3 produced by drying fine coal in the form of clay and provided on the outer circumferential side of the pipe 1 including the welding portion 2 can be used to further increase the temperatures of the pipe 1 and the membrane bar 7.

**[0052]** For example, 46.2kJ is required as the quantity of heat for increasing the temperature of a portion of the pipe 1 having an outside diameter of 40mm, a thickness of 6mm, and a length of 200mm and constituting the membrane panel 20 by 100°C.

**[0053]** The combustion heat generated from the solid ignition body 3 produced by drying fine coal in the form of clay is 25, 000 kJ/kg. Assuming that 1% of the combustion heat is consumed by the temperature increase of the part of the pipe 1, fine coal with a weight of 185g needs to be provided on the outer circumferential side of the pipe 1 in an area of a 200 mm-long range as the solid ignition body 3.

**[0054]** As discussed above, the cylindrical solid ignition body 3 is positioned on the outer circumferential side of the pipe 1 including the welding portion 2. The pipe 1 is heated by the high-temperature heat medium 5 flowing within the pipe 1 to increase the temperature of the ignition body 3 provided on the outer circumferential side of the pipe 1 and ignite and burn the ignition body 3. As a result, the temperature of the pipe 1 including the welding portion 2 is raised to 600°C, therefore the welding residual stress applied to the welding portion 2 and the heat-affecting area of the welding portion 2 can be considerably reduced.

**[0055]** For accurate control of the highest increased temperatures of the welding portion 2 and the heat-affecting area of the welding portion 2 corresponding to the targets for heat treatment method in this embodiment, it is preferable that the temperature of the heat medium 5 flowing within the pipe 1, the temperature of the pipe 1, the ignition temperature of the solid ignition body 3 produced by drying fine coal in the form of clay, the mass of the solid ignition body 3, and the relationship between the temperature of the pipe 1 and time after ignition are measured beforehand by experiments so as to determine the mass of the ignition body 3 (fine coal) necessary for increasing the highest increased temperatures of the welding portion 2 and the heat-affecting area of the welding portion 2 to 600°C.

**[0056]** FIG. 5 shows the relationship between the residual stress and the heat treatment temperature of 11/2Cr-Mo steel as low alloy steel after welding of welding metal of the same material. The residual stress on the welding portion after welding of 11/2Cr-Mo steel can be decreased to about 12 kg/mm$^2$ or lower as indicated on the vertical axis when the heat treatment temperature indicated on the horizontal axis is raised to 600°C or higher.

**[0057]** Each of the pipe 1, the membrane bar 7, and the welding metal forming the welding portion 2 constituting the boiler membrane panel 20 according to the heat treatment method for the boiler membrane panel in this embodiment is made of the same low alloy steel. However, these components may be made of the same carbon steel instead of low alloy steel.

**[0058]** As described above, according to the heat treatment method for the boiler membrane panel in this embodiment, the temperature of the solid ignition body 3 produced by drying fine coal and provided on the outer circumferential side of the pipe 1 including the welding portion 2 is raised by using the high-temperature heat medium 5 flowing inside the pipe 1 so that the ignition body 3 can be ignited and burned by the heating of the pipe 1 up to 600°C. By this combustion, the highest increased temperatures of the welding portion 2 and the heat-affecting area of the welding portion 2 are increased to 600°C, whereby the welding residual stress applied to the welding portion 2 and the heat-affecting area of the welding portion 2 of the boiler membrane panel 20 can be considerably reduced.

**[0059]** According to the heat treatment method for the boiler membrane panel in this embodiment, the ignition body 3 becomes ash after combustion.

**[0060]** The ash produced by combustion of the ignition body 3 is blown off from the outer circumferential surface of the pipe 1 by the combustion gas flow generated during operation of the boiler. Thus, the ash does not remain on the surface of the welding portion 2 of the pipe 1 constituting the membrane panel 20 of the operating boiler.

**[0061]** By executing the heat treatment processes for the boiler membrane panel in this embodiment described above, the temperatures of the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2 can reach 600°C. Accordingly, the solid ignition body 3 produced by drying fine coal and provided on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 can be heated and ignited for combustion, whereby the residual stress applied to the welding portion 2 and the heat-affecting area of the welding portion 2 by butt-welding of the pipe 1 can be considerably reduced.

**[0062]** Accordingly, the heat treatment method for the boiler membrane panel in this embodiment can remove the factor of the tension residual stress as one of the factors which generate and develop stress corrosion cracking on the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2.

**[0063]** Therefore, generation and development of stress corrosion cracking on the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2 can be prevented, whereby highly-reliable operation of the boiler can be continued.

**[0064]** According to this embodiment, the heat treatment for the welding portion where the pipe constituting the boiler membrane panel is butt-welded can be easily carried out without the use of an electric heater, a burner or the like which requires a number of steps. Accordingly, the heat treatment method for the boiler membrane panel and the boiler processed by the same heat treatment method in this embodiment can remove the factor of the tension residual stress on the welding portion, and prevent generation and development of stress corrosion cracking on the welding portion of the boiler membrane panel, thereby allowing continuation of highly reliable operation of the boiler.

[Embodiment 2]

**[0065]** A heat treatment method for a boiler membrane panel according to a second embodiment of the present invention is now explained with reference to FIG. 6.

**[0066]** The heat treatment method for the boiler membrane panel according to this embodiment has a basic structure similar to that of the heat treatment method for the boiler membrane panel in the first embodiment shown in FIGS. 1 through 5. Therefore, the explanation common to these methods is not repeated, and only the different points are herein touched upon.

**[0067]** As illustrated in FIG. 6, according to the heat treatment method for the boiler membrane panel in the second embodiment of the present invention, the solid ignition body 3 formed by drying fine coal in the form of clay is positioned on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20.

**[0068]** After attachment of the cylindrical solid ignition body 3 produced by drying fine coal in the form of clay to the outer circumferential side of the pipe 1 including the welding portion 2 where the end of the pipe 1 constituting the boiler membrane panel 20 is butt-welded, the boiler is started.

**[0069]** In accordance with the start of the boiler, a high-temperature combustion gas 6 generated by combustion of fuel flows inside the boiler furnace. The flow of the high-temperature combustion gas 6 is introduced toward the outer circumferential side of the pipe 1 including the welding portion 2 where the pipe 1 of the membrane panel 20 is butt-welded. When the high-temperature combustion gas 6 reaches the solid ignition body 3 produced by drying fine coal in the form of clay and positioned on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1, the temperature of the surface of the ignition body 3 increases by the heat of the combustion gas 6.

**[0070]** The solid ignition body 3 formed by drying fine coal ignites and starts combustion when the temperature of the ignition body 3 reaches at least 300°C. The combustion of the ignition body 3 generates combustion heat.

**[0071]** At this time, vapor or high-temperature water flows inside the pipe 1 constituting the boiler membrane panel 20 in the same manner as in the normal start of the boiler.

**[0072]** The boiler membrane panel 20 is heated by the combustion gas 6 flowing within the boiler furnace, whereby the temperature of the solid ignition body 3 provided on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 rise by the combustion gas 6 flowing outside the pipe 1.

**[0073]** For increasing the temperature of the solid ignition body 3 provided on the outer circumferential side of the pipe 1 to 500°C, for example, by the combustion gas 6 flowing outside the pipe 1, the quantity of heat necessary for raising the temperature of the part of the pipe 1 constituting the membrane panel 20 and having an outside diameter of 40mm, a thickness of 6mm, and a length of 200mm by 100°C is 46.2 kJ/kg similarly to the first embodiment. On the other hand, the combustion heat generated from the solid ignition body 3 formed by drying fine coal in the form of clay is 25,000kJ/kg.

**[0074]** Assuming that 1% of the combustion heat is consumed by the temperature increase of the part of the pipe 1, fine coal with a weight of 185g is needed on the outer circumferential side of the pipe 1 in an area of a 200 mm-long range as the solid ignition body 3.

**[0075]** As discussed above, the cylindrical solid ignition body 3 is positioned on the outer circumferential side of the pipe 1 including the welding portion 2, and the ignition body 3 positioned on the outer circumference of the pipe 1 including the welding portion 2 is heated and ignited for combustion by using the high-temperature combustion gas 6 flowing outside the pipe 1. By this method, the temperatures of the welding portion 2 of the pipe 1 and the heat-affecting area of the welding portion 2 can be increased to 600°C. As a consequence, the welding residual stress applied to the welding portion 2 and the heat-affecting area of the welding portion 2 can be considerably reduced.

**[0076]** According to this embodiment, for accurate control of the highest increased temperatures of the welding portion 2 and the heat-affecting area of the welding portion 2 corresponding to the targets for the heat treatment method in this embodiment, it is preferable that the temperature of the combustion gas 6 flowing outside the pipe 1, the temperature of the pipe 1, the ignition temperature of the solid ignition body 3 produced by drying fine coal in the form of clay, the mass of the solid ignition body 3, and the relationship between the temperature of the pipe 1 and time after ignition are measured beforehand by experiments so as to determine the mass of the ignition body 3 (fine coal) necessary for increasing the highest increased temperatures of the welding portion 2 and the heat-affecting area of the welding portion 2 to 600°C similarly to the above embodiment.

**[0077]** According to this embodiment, as can be seen from FIG. 5 which shows the relationship between the residual stress and the heat treatment temperature of 11/2Cr-Mo steel after welding by using welding metal of the same material, the residual stress on the welding portion where 11/2Cr-Mo steel is welded can be reduced to about 12 kg/mm$^2$ or lower as indicated on the vertical axis by increasing the heat treatment temperature indicated on the horizontal axis to 600°C or higher similarly to the first embodiment.

**[0078]** As discussed above, according to the heat treatment method for the boiler membrane panel in this embodiment, the solid ignition body 3 produced by drying fine coal and provided on the outer circumferential side of the pipe 1 including the welding portion 2 is burned by raising the temperature of the pipe 1 to 600°C using the combustion gas 6 flowing outside the pipe 1. The ignition body 3 becomes ash after combustion.

**[0079]** The ash produced from the ignition body 3 after combustion is blown off from the outer circumferential surface of the pipe 1 by the combustion gas flow generated during operation of the boiler. Thus, the ash does not remain on the surface of the welding portion of the pipe 1 constituting the membrane panel 20 of the operating boiler.

**[0080]** According to this embodiment, the combustion of the solid ignition body 3 produced by drying fine coal in the form of clay and provided on the welding portion is heated by using the high-temperature combustion gas flow 6 generated at the startup of the boiler. Thus, this method only requires positioning of the solid ignition body 3 produced by drying fine coal in the form of clay on the outer circumferential side of the pipe 1 including the welding portion 2 before the startup of the boiler, then executes the normal processes for startup of the boiler.

**[0081]** By performing the heat treatment processes for the boiler membrane panel in this embodiment described above, the temperatures of the welding portion 2 of the pipe 1 constituting the membrane panel 20 and the heat-affecting area of the welding portion 2 can reach 600°C, whereby the solid ignition body 3 produced by drying fine coal and provided on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 can be burned. As a result, the residual stress applied to the welding portion 2 and the heat-affecting area of the welding portion 2 by welding of the pipe 1 can be considerably decreased.

**[0082]** Accordingly, the heat treatment method for the boiler membrane panel in this embodiment can remove the factor of the tension residual stress as one of the factors which generate and develop stress corrosion cracking on the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2.

**[0083]** Therefore, generation and development of stress corrosion cracking on the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2 can be prevented, whereby highly-reliable operation of the boiler can be continued.

**[0084]** According to this embodiment, the heat treatment for the welding portion where the pipe constituting the boiler membrane panel is butt-welded can be easily carried out without the use of an electric heater, a burner or the like which requires a number of steps. Accordingly, the heat treatment method for the boiler membrane panel and the boiler processed by the same heat treatment method in this embodiment can remove the factor of the tension residual stress on the welding portion, and prevent generation and development of stress corrosion cracking on the welding portion of the boiler membrane panel, thereby allowing continuation of highly reliable operation of the boiler.

[Embodiment 3]

**[0085]** A heat treatment method for a boiler membrane panel according to a third embodiment of the present invention is now explained with reference to FIG. 7.

**[0086]** The heat treatment method for the boiler membrane panel according to this embodiment has a basic structure similar to that of the heat treatment method for the boiler membrane panel in the first embodiment shown in FIGS. 1 through 5. Therefore, the explanation common to these methods is not repeated, and only the different points are herein touched upon.

**[0087]** As illustrated in FIG. 7, according to the heat treatment method for the boiler membrane panel in this embodiment, a solid ignition body 3b produced by drying fine coal in the form of clay is positioned on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20. The solid ignition body 3b produced by drying fine coal in the form of clay is positioned on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 in this embodiment illustrated in FIG. 7 exhibits the most preferred temperature distribution for executing the heat treatment after welding for the welding portion 2 of the pipe 1 of the boiler membrane panel 20.

**[0088]** More specifically, assuming that the average diameter of the pipe 1 is R, and the thickness of the pipe 1 is t, it is known that the residual stress on the welding portion 2 is distributed in the range from the center of the welding portion 2 to 2.5 $(Rt)^{1/2}$. It is therefore preferable that the temperature of the area of the center on which the ignition body 3b is provided on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1, i.e., a range L extending from the center of the welding portion 2 to 2.5 $(Rt)^{1/2}$ reaches 600°C or higher where the residual stress on the welding portion 2 can considerably decrease.

**[0089]** On the other hand, it is preferable that the temperatures of the welding portion 2 of the pipe 1 and the part of the pipe 1 in the vicinity of the welding portion 2 are distributed with a gradient.

**[0090]** Accordingly, it is preferable that the ignition body 3b provided on the outer circumferential surface of the pipe 1 has a fixed thickness in the area of the center corresponding to the range L extending from the center of the welding portion 2 of the pipe 1 to 2.5 $(Rt)^{1/2}$, and that the thickness of the ignition body 3b gradually decreases with a gradient in the area of the end of the pipe 1 which is positioned out of the range L extending from the center of the welding portion 2 to 2.5 $(Rt)^{1/2}$ and located at a longer distance from the center of the welding portion 2 than the distance of the range L.

**[0091]** According to this method, the gradient of the temperature distribution of the welding portion 2 of the pipe 1 can be decreased in the area from the center of the welding portion 2 to the end of the pipe 1. As a result, generation of the residual stress produced by sharp temperature distribution can be reduced.

**[0092]** The ignition body 3b provided on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 may be ignited and burned either by the heat medium 5 used in the first embodiment or the combustion gas 6 used in the second embodiment, the detailed explanation of which is not given herein.

**[0093]** By performing the heat treatment processes for the boiler membrane panel in this embodiment described above, the temperatures of the welding portion 2 of the pipe 1 constituting the membrane panel 20 and the heat-affecting area of the welding portion 2 can reach 600°C, whereby the solid ignition body 3b produced by drying fine coal and provided on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 can be burned. As a result, the residual stress applied to the welding portion 2 and the heat-affecting area of the welding portion 2 by welding of the pipe 1 can be considerably decreased.

**[0094]** Accordingly, this method can remove the factor of the tension residual stress as one of the factors which generate and develop stress corrosion cracking on the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2.

**[0095]** Therefore, generation and development of stress corrosion cracking on the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2 can be prevented, whereby highly-reliable operation of the boiler can be continued.

**[0096]** According to this embodiment, the heat treatment for the welding portion where the pipe constituting the boiler membrane panel is butt-welded can be easily carried out without the use of an electric heater, a burner or the like which requires a number of steps. Accordingly, the heat treatment method for the boiler membrane panel and the boiler processed by the same heat treatment method in this embodiment can remove the factor of the tension residual stress on the welding portion, and prevent generation and development of stress corrosion cracking on the welding portion of the boiler membrane panel, thereby allowing continuation of highly reliable operation of the boiler.

[Embodiment 4]

**[0097]** A heat treatment method for a boiler membrane panel according to a fourth embodiment of the present invention is now explained with reference to FIG. 8.

**[0098]** The heat treatment method for the boiler membrane panel according to this embodiment has a basic structure similar to that of the heat treatment method for the boiler membrane panel in the first embodiment shown in FIGS. 1 through 5. Therefore, the explanation common to these methods is not repeated, and only the different points are herein touched upon.

**[0099]** As illustrated in FIG. 8, according to the heat treatment method for the boiler membrane panel in this embodiment, a cylindrical ignition body 3c formed by briquette 8 and divided into two parts is provided on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and is attached to the pipe 1.

**[0100]** The ignition body 3c disposed on the outer circumferential side of the pipe 1 including the welding portion 2 in this embodiment is constituted by the cylindrical briquette 8 divided into two parts. The ignition body 3c has a cylindrical shape divided into two parts so configured as to correspond to the shape of the outer surface of the pipe 1 including the welding portion 2 and the shape of a part of the membrane bar 7. The ignition body 3c are closely attached to the outer circumference of the pipe 1 including the butt-welding portion 2 of the pipe 1 in such a manner as to cover the surface of the welding portion 2, a part of the membrane bar 7, and the end of the pipe 1 by the ignition body 3c formed by the cylindrical briquette 8 divided into the two parts.

**[0101]** By performing the heat treatment processes for the boiler membrane panel in this embodiment, the temperatures of the welding portion 2 of the pipe 1 constituting the membrane panel 20 and the heat-affecting area of the welding portion 2 can reach 600°C, whereby the residual stress applied to the welding portion 2 and the heat-affecting area of the welding portion 2 by welding of the pipe 1 can be reduced by burning the ignition body 3c formed by the briquette 8 and provided on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1.

**[0102]** Accordingly, the heat treatment method for the boiler membrane panel in this embodiment can remove the factor of the tension residual stress as one of the factors which generate and develop stress corrosion cracking on the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2. Therefore, generation and development of stress corrosion cracking on the welding portion 2 can be prevented, whereby continuation of highly-reliable operation of the boiler is allowed.

**[0103]** According to the heat treatment processes for the boiler membrane panel in this embodiment, the ignition body 3c formed by the cylindrical briquette 8 and having a structure divided into two parts so configured as to correspond to the outer surface shape of the pipe 1 including the welding portion 2 may be prepared for each of the process target portions beforehand so that the same number of the ignition bodies 3c as that of the process target portions can be attached to the outer surfaces of the pipes 1 including the welding portions 2 after the butt-welding of the pipes 1. In this case, the time required for positioning the ignition bodies 3c to the outer surfaces of the pipes 1 including the welding portions 2 becomes considerably shorter than that time of the structure which separately attaches the ignition bodies 3c to the outer surfaces of the pipes 1 including the welding portions 2.

**[0104]** The cylindrical ignition body 3c formed by the briquette 8 used in this embodiment has the plural holes 4 separated from each other and penetrating the cylindrical solid ignition body 3c in the longitudinal direction as openings similarly to the ignition body 3 shown in FIGS. 3A and 3B in the first embodiment.

**[0105]** The ignition body 3c formed by briquette 8 attached to the outer circumferential side of the pipe 1 is ignited by raising the temperature of the pipe 1 to a high temperature using the heat medium 5 flowing inside the pipe 1 or the combustion gas 6 flowing outside the pipe 1. In this case, air is introduced into the plural holes 4 penetrating the cylindrical ignition body 3c formed by the briquette 8 in the longitudinal direction at the time of combustion of the ignition body 3c so that the inside of the ignition body 3c can be burned.

**[0106]** The ignition body 3c formed by the briquette 8 and provided on the outer circumferential side of the pipe 1 including the welding portion 2 may be ignited either by the high-temperature heat medium 5 used in the first embodiment and flowing inside the pipe 1, or the high-temperature combustion gas 6 in the second embodiment generated by the startup of the boiler and flowing outside the pipe 1.

**[0107]** By performing the heat treatment processes for the boiler membrane panel in this embodiment described above, the temperatures of the welding portion 2 of the pipe 1 constituting the membrane panel 20 and the heat-affecting area of the welding portion 2 can reach 600°C, whereby the ignition body 3c formed by the briquette 8 and provided on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 can be burned. As a result, the residual stress applied to the welding portion 2 and the heat-affecting area of the welding portion 2 by welding of the pipe 1 can be considerably decreased.

**[0108]** Accordingly, the heat treatment method for the boiler membrane panel in this embodiment can remove the factor of the tension residual stress as one of the factors which generate and develop stress corrosion cracking on the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2.

**[0109]** Therefore, generation and development of stress corrosion cracking on the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2 can be prevented, whereby highly-reliable operation of the boiler can be continued.

**[0110]** According to this embodiment, the heat treatment for the welding portion where the pipe constituting the boiler membrane panel is butt-welded can be easily carried out without the use of an electric heater, a burner or the like which requires a number of steps. Accordingly, the heat treatment method for the boiler membrane panel and the boiler processed by the same heat treatment method in this embodiment can remove the factor of the tension residual stress on the welding portion, and prevent generation and development of stress corrosion cracking on the welding portion of the boiler membrane panel, thereby allowing continuation of highly reliable operation of the boiler.

[Embodiment 5]

**[0111]** A heat treatment method for a boiler membrane panel according to a fifth embodiment of the present invention is now explained with reference to FIG. 9.

**[0112]** The heat treatment method for the boiler membrane panel according to this embodiment shown in FIG. 9 has a basic structure similar to that of the heat treatment method for the boiler membrane panel in the first embodiment shown in FIGS. 1 through 5. Therefore, the explanation common to these methods is not repeated, and only the different points are herein touched upon.

**[0113]** According to the heat treatment method for the boiler membrane panel in this embodiment, charcoal 9 is contained in an ignition body 3d provided on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20. The charcoal 9 is accommodated in a net-shaped (wire netting) cover 10 made of incombustible material to constitute the ignition body 3d which is to be positioned on the membrane bar 7 on the outer circumferential side of the pipe 1 including the welding

**[0114]** portion 2 of the pipe 1.

**[0115]** The end of the wire netting cover 10 which contains the charcoal 9 constituting the ignition body 3d can be easily joined to the membrane bar 7 by spot welding 11. Moreover, the time required for positioning the ignition body 3d on the outer circumferential side of the pipe 1 including the welding portion 2 can be reduced by using the charcoal 9 as the ignition body 3d.

**[0116]** More specifically, the wire netting cover 10 can be easily attached to the membrane bar 7 on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1, while containing the ignition body 3d.

**[0117]** The charcoal 9 which forms the ignition body 3d contained in the net-shaped cover 10 and constituting the ignition body 3d may be ignited either by the high-temperature heat medium 5 in the first embodiment flowing inside the pipe 1, or the high-temperature combustion gas 6 in the second embodiment produced by startup of the boiler and flowing outside the pipe 1.

**[0118]** The welding portion 2 of the pipe 1 and the heat-affecting portion of the welding portion 2 can be heated by igniting and burning the charcoal 9 forming the ignition body 3d contained in the net-shaped cover 10 with the net-shaped cover 10 left in the same condition.

**[0119]** By performing the heat treatment processes for the boiler membrane panel in this embodiment described above, the temperatures of the welding portion 2 of the pipe 1 constituting the membrane panel 20 and the heat-affecting area of the welding portion 2 can reach 600°C, whereby the ignition body 3d formed by the charcoal 9 contained in the net-shaped cover 10 and provided on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 can be burned. As a result, the residual stress applied to the welding portion 2 and the heat-affecting area of the welding portion 2 by welding of the pipe 1 can be considerably reduced.

**[0120]** Accordingly, the heat treatment method for the boiler membrane panel in this embodiment can remove the factor of the tension residual stress as one of the factors which generate and develop stress corrosion cracking on the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2.

**[0121]** Therefore, generation and development of stress corrosion cracking on the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2 can be prevented, whereby highly-reliable operation of the boiler can be continued.

**[0122]** According to this embodiment, the heat treatment for the welding portion where the pipe constituting the boiler membrane panel is butt-welded can be easily carried out without the use of an electric heater, a burner or the like which requires a number of steps. Accordingly, the heat treatment method for the boiler membrane panel and the boiler processed by the same heat treatment method in this embodiment can remove the factor of the tension residual stress on the welding portion, and prevent generation and development of stress corrosion cracking on the welding portion of the boiler membrane panel, thereby allowing continuation of highly reliable operation of the boiler.

[Embodiment 6]

**[0123]** A heat treatment method for a boiler membrane panel according to a sixth embodiment of the present invention is now explained with reference to FIG. 10.

**[0124]** The heat treatment method for the boiler membrane panel according to this embodiment shown in FIG. 10 has a basic structure similar to that of the heat treatment method for the boiler membrane panel in the first embodiment shown in FIGS. 1 through 5. Therefore, the explanation common to these methods is not repeated, and only the different points are herein touched upon.

**[0125]** As illustrated in FIG. 10, according to the heat treatment method for the boiler membrane panel in this embodiment, an ignition body 3e is positioned on and attached to the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20.

**[0126]** The ignition body 3e provided on the outer circumferential side of the pipe 1 including the welding portion 2 to be used in this embodiment has a double layer structure constituted by a cylindrical inner layer 12 made of material having a relatively low ignition temperature, and a cylindrical outer layer 13 made of material having a relatively higher ignition temperature than the ignition temperature of the cylindrical inner layer 12. The materials of the outer layer 13 and the inner layer 12 are selected such that the combustion heat of the material of the outer layer 13 having the relatively high ignition temperature becomes greater than the combustion heat of the material of the inner layer 12 having the relatively low ignition temperature.

**[0127]** The inner layer 12 made of the material having the relatively low ignition temperature is positioned and dried on the outer circumferential surface of the welding portion 2. Then, the outer layer 13 made of the material having the relatively high ignition temperature is positioned and dried on the outer circumferential surface of the inner layer 12. By this method, the ignition body 3e having the double layer structure of the inner layer 12 and the outer layer 13 is formed on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1.

**[0128]** The inner layer 12 made of the material having the relatively low ignition temperature is constituted by charcoal. The ignition temperature of charcoal lies in the range from 200°C to 300°C. The outer layer 13 made of the material having the relatively high ignition temperature is constituted by coke. The ignition temperature of coke is 400°C, and generates high combustion heat when ignited.

**[0129]** After the ignition body 3e having the inner layer 12 and the outer layer 13 is positioned on the outer circumferential side of the pipe 1 including the welding portion 2 constituting the boiler membrane panel 20, the heat medium 5 having a temperature of 500°C is caused to flow within the pipe 1 to heat the pipe 1.

**[0130]** When the temperature of the pipe 1 reaches 300°C, the charcoal contained in the inner layer 12 constituting the ignition body 3e is ignited. The ignition of the charcoal of the inner layer 12 further ignites the coke of the outer layer 13 provided on the outer circumferential side of the inner layer 12 and constituting the ignition body 3e.

**[0131]** The combustion of the coke of the outer layer 13 generates combustion heat which increases the temperature of the welding portion 2 of the pipe 1, thereby raising the highest increased temperatures of the welding portion 2 of the pipe 1 and the heat-affecting area of the welding portion 2 to 600°C or higher.

**[0132]** By performing the heat treatment processes for the boiler membrane panel in this embodiment described above, the temperatures of the welding portion 2 of the pipe 1 constituting the membrane panel 20 and the heat-affecting area of the welding portion 2 can reach 600°C. As a result, the inner layer 12 and the outer layer 13 which constitute the ignition body 3e provided on the outer circumferential side of the pipe 1 including the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 can be burned, whereby the residual stress applied to the welding portion 2 and the heat-affecting area of the welding portion 2 by welding of the pipe 1 can be considerably decreased.

**[0133]** Accordingly, the heat treatment method for the boiler membrane panel in this embodiment can remove the factor of the tension residual stress as one of the factors which generate and develop stress corrosion cracking on the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2.

**[0134]** Therefore, generation and development of stress corrosion cracking on the welding portion 2 of the pipe 1 constituting the boiler membrane panel 20 and the heat-affecting area of the welding portion 2 can be prevented, whereby highly-reliable operation of the boiler can be continued.

**[0135]** According to this embodiment, the heat treatment for the welding portion where the pipe constituting the boiler membrane panel is butt-welded can be easily carried out without the use of an electric heater, a burner or the like which requires a number of steps. Accordingly, the heat treatment method for the boiler membrane panel and the boiler processed by the same heat treatment method in this embodiment can remove the factor of the tension residual stress on the welding portion, and prevent generation and development of stress corrosion cracking on the welding portion of the boiler membrane panel, thereby allowing continuation of highly reliable operation of the boiler.

## Claims

1. A heat treatment method for boiler membrane panel in which pipes of boiler membrane panels are welded, a plurality of the boiler membrane panels (20) forming a water wall of a boiler furnace, the boiler membrane panel (20) including a plurality of the pipes (1) as heat-transfer pipes forming the water wall of the boiler furnace and a plurality of membrane bars (7) joining the pipes (1), comprising the steps of:

   positioning an ignition body (3, 3b, 3c, 3d, 3e) on the outer circumferential side of the pipe (1) including a welding portion (2) of the pipe of the boiler membrane panel (20) when an operation of the boiler is stopped;
   flowing a high-temperature heat medium (5) inside of the pipe (1) of the boiler membrane panel (20);
   raising the temperature of the pipe (1) to the ignition point of the ignition body (3, 3b, 3c, 3d, 3e) by flow of the high-temperature heat medium (5) and starting combustion of the ignition body (3, 3b, 3c, 3d, 3e) positioned on the outer circumferential side of the pipe (1); and
   heating the welding portion (2) of the pipe (1) and a heat-affecting area of the welding portion (2) through combustion of the ignition body (3, 3b, 3c, 3d, 3e), and raising the temperature of the pipe (1) by flow of the high-temperature heat medium (5) inside of the pipe(1), whereby a welding residual stress applied to the welding portion (2) of the pipe (1) and the heat-affecting area of the welding portion (2) is reduced.

2. A heat treatment method for boiler membrane panel in which pipes of boiler membrane panels are welded, a plurality of the boiler membrane panels (20) forming a water wall of a boiler furnace, the boiler membrane panel (20) including a plurality of the pipes (1) as heat-transfer pipes forming the water wall of the boiler furnace and a plurality of membrane bars (7) joining the pipes (1), comprising the steps of:

   positioning an ignition body (3, 3b, 3c, 3d, 3e) on the outer circumferential side of the pipe (1) including a welding portion (2) of the pipe (1) of the boiler membrane panel (20) when an operation of the boiler is stopped;
   flowing down a high-temperature combustion gas (6) generated by combustion of fuel inside the boiler furnace by startup of the boiler to outer circumferential side of the pipe (1) of the boiler

membrane panel (20);
raising the temperature of the ignition body (3, 3b, 3c, 3d, 3e) positioned on the outer circumferential side of the pipe (1) to the ignition point of the ignition body (3, 3b, 3c, 3d, 3e) by flow of the high-temperature combustion gas (6) and starting combustion of the ignition body (3, 3b, 3c, 3d, 3e); and
heating the welding portion (2) of the pipe (1) and a heat-affecting area of the welding portion (2) through combustion of the ignition body (3, 3b, 3c, 3d, 3e), and raising the temperature of the pipe (1) by flow of the high-temperature combustion gas (6) on the circumferential side of the pipe (1), whereby a welding residual stress applied to the welding portion (2) of the pipe (1) and the heat-affecting area of the welding portion is reduced.

**3.** The heat treatment method for boiler membrane panel according to claim 1 or 2, wherein:

the ignition body (3, 3b, 3c, 3d) positioned on the outer circumferential side of the pipe (1) including the welding portion (2) of the pipe (1) is produced by attaching fine coal in the form of clay obtained by kneading a mixture of fine coal and water to the outer surface of the pipe (1) including the welding portion (2) of the pipe (1), and then
drying the fine coal in the form of clay to form the solid ignition body (3) positioned on the outer circumferential side of the pipe (1) including the welding portion (2) of the pipe (1).

**4.** The heat treatment method for boiler membrane panel according to claim 1 or 2, wherein the ignition body (3c) positioned on the outer circumferential side of the pipe (1) including the welding portion (2) of the pipe (1) is briquette (8) having a divided shape so configured as to correspond to the shape of the outer surface of the pipe (1) including the welding portion (2) of the pipe (1) of the boiler membrane panel (20), and disposed on the outer circumferential side of the pipe (1).

**5.** The heat treatment method for boiler membrane panel according to claim 1 or 2, wherein the ignition body (3d) positioned on the outer circumferential side of the pipe (1) including the welding portion (2) of the pipe (1) is charcoal (9) covered by a net-shaped cover (10) made of incombustible material, and positioned on the outer circumferential side of the pipe (1) by fixation of the end of the cover to the membrane bar (7).

**6.** The heat treatment method for boiler membrane panel according to claim 5, wherein the net-shaped cover (10) made of incombustible material is formed by steel.

**7.** The heat treatment method for boiler membrane panel according to claim 1 or 2, wherein the ignition body (3b) positioned on the outer circumferential side of the pipe (1) including the welding portion (2) of the pipe (1) has a cylindrical central area (L) having a constant thickness, and an end area continuously formed from both ends of the cylindrical central area and having a gradient of the thickness which gradually decreases.

**8.** The heat treatment method for boiler membrane panel according to any one of claims 1 through 7, wherein:

each of the pipe (1), the membrane bar (7), and the welding metal which forms the welding portion (2) forming the boiler membrane panel (20) is made of low alloy steel;
igniting the ignition body (3, 3b) positioned on the outer circumferential side of the pipe (1) including the welding portion (2) of the pipe (1) by flowing the high-temperature heat medium (5) inside the pipe (1) or flowing down the high-temperature combustion gas (6) on the outer circumferential side of the pipe (1); and
raising the temperatures of the welding portion (2) of the pipe (1) and the heat-affecting area of the welding portion (2) to reach 600°C or higher at the highest increased temperatures.

**9.** The heat treatment method for boiler membrane panel according to any one of claims 1 through 7, wherein:

each of the pipe (1), the membrane bar (7), and the welding metal which forms the welding portion (2) forming the boiler membrane panel (20) is made of carbon steel;
igniting the ignition body (3, 3b) positioned on the outer circumferential side of the pipe (1) including the welding portion (2) of the pipe (1) by flowing the high-temperature heat medium (5) inside the pipe (1) or flowing down the high-temperature combustion gas (6) on the outer circumferential side of the pipe (1); and
raising the temperatures of the welding portion (2) of the pipe (1) and the heat-affecting area of the welding portion (2) to reach 600°C or higher at the highest increased temperatures.

**10.** The heat treatment method for boiler membrane panel according to any one of claim 1, 2, or 4, wherein:

a plurality of holes (4) penetrate the ignition body

(3, 3c) provided on the outer circumferential side of the pipe (1) including the welding portion (2) of the pipe (1) to form openings (4) in the ignition body (3, 3c); and
air is introduced through the openings of the holes (4) into the ignition body (3, 3c).

**11.** The heat treatment method for boiler membrane panel according to claim 1 or 2, wherein:

the ignition body (3, 3b, 3c, 3d, 3e) provided on the outer circumferential side of the pipe (1) including the welding portion (2) of the pipe (1) has a double layer structure which has an-inner layer ignition body (12) made of material having a relatively low ignition temperature and positioned on the outer circumferential side of the pipe (1) including the welding portion (2), and an outer-layer ignition body (13) made of material having a relatively high ignition temperature and positioned on the outer circumferential side of the inner-layer ignition body (12); and
the material of the outer-layer ignition body (13) and the material of the inner-layer ignition body (12) are determined such that the combustion heat of the material forming the outer-layer ignition body (13) and having a relatively high ignition temperature becomes greater than the combustion heat of the material forming the inner-layer ignition body (12) and having a relatively low ignition temperature.

**12.** A boiler which includes a boiler membrane panel processed by the heat treatment method for the boiler membrane panel according to any one of claims 1 through 11.

FIG. 1

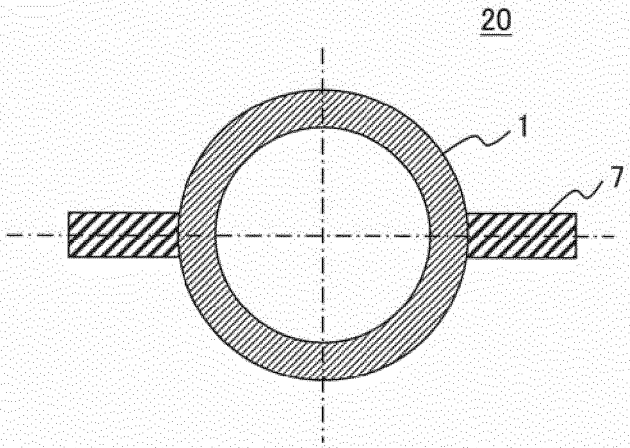



FIG. 2

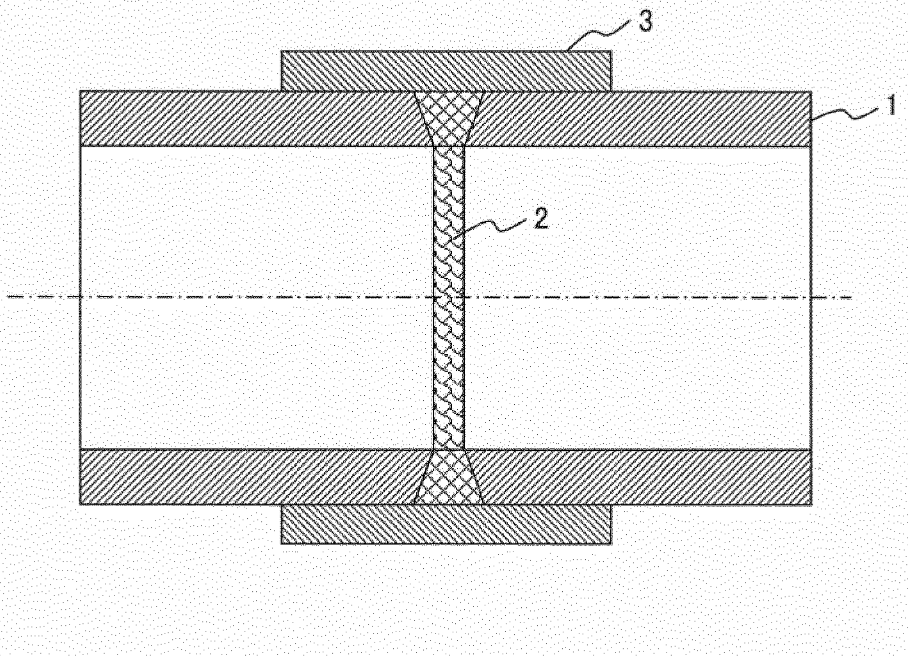


FIG. 3A

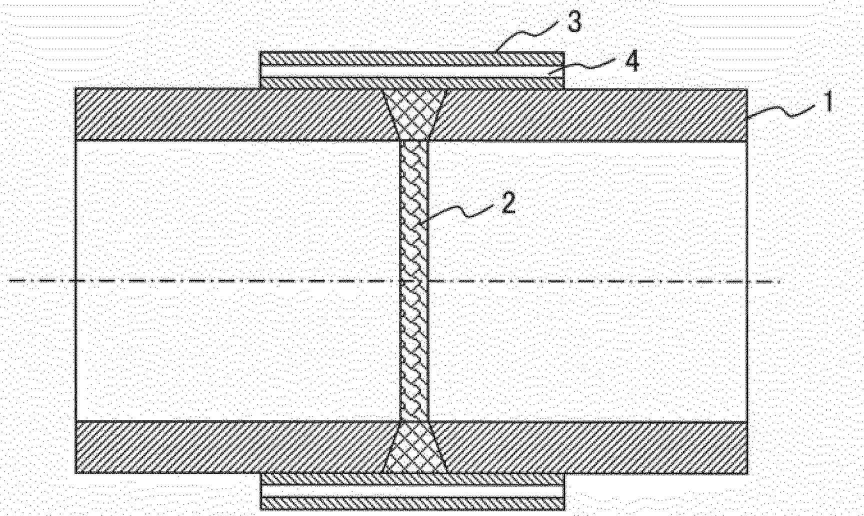



FIG. 3B

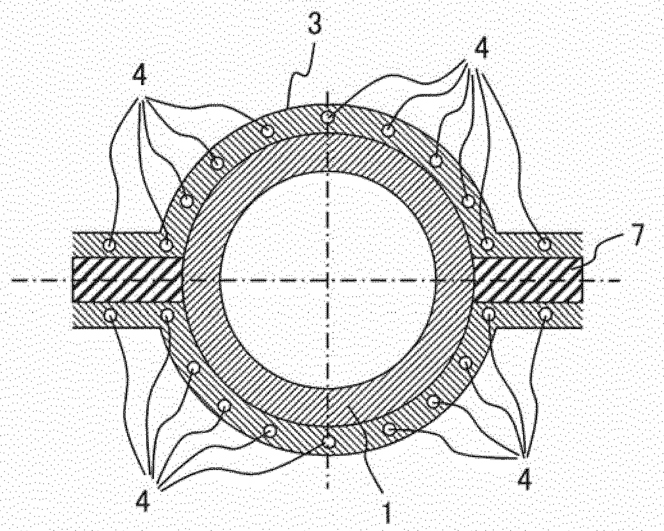


FIG. 4

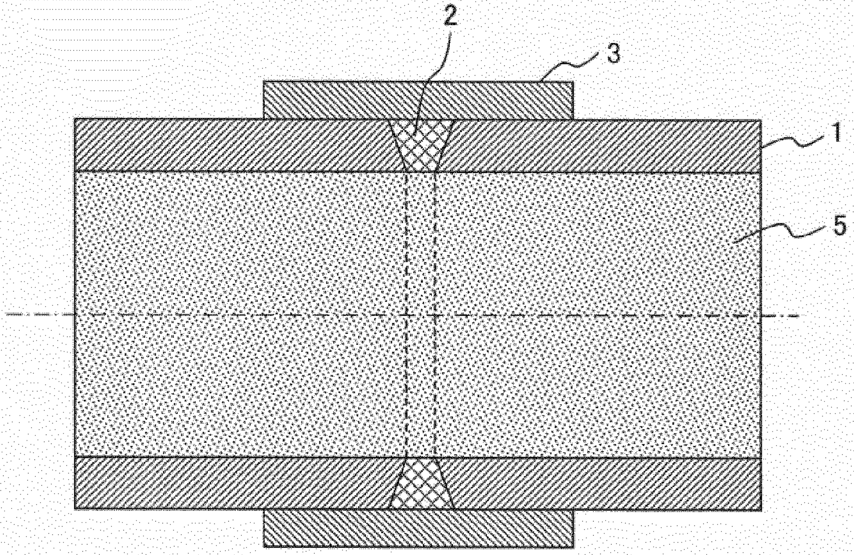

2
3
1
5

FIG. 5

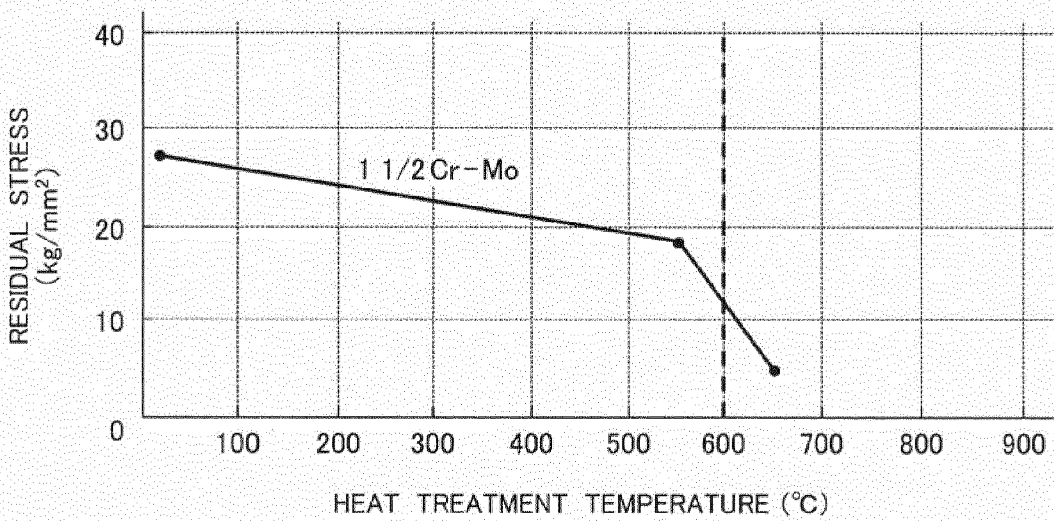

RESIDUAL STRESS (kg/mm²)
40
30
20
10
0
100
200
300
400
500
600
700
800
900
1 1/2 Cr−Mo
HEAT TREATMENT TEMPERATURE (°C)

FIG. 6

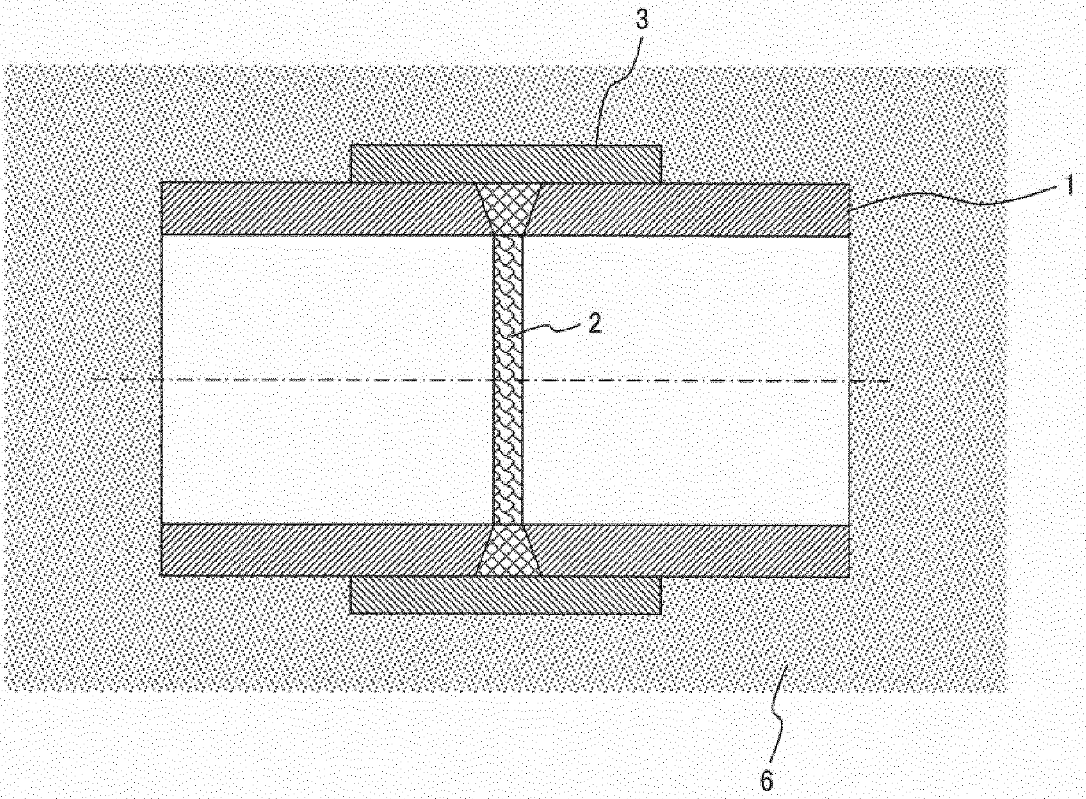


FIG. 7

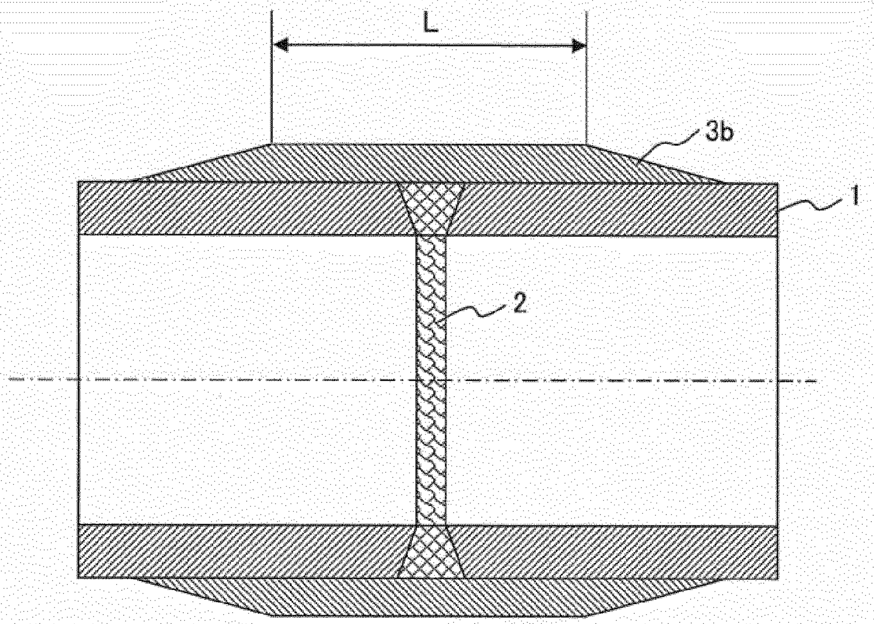



FIG. 8

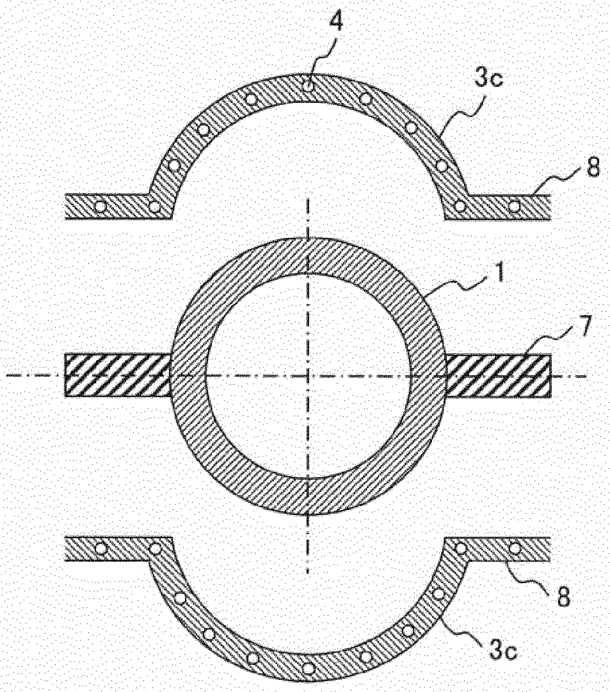


FIG. 9

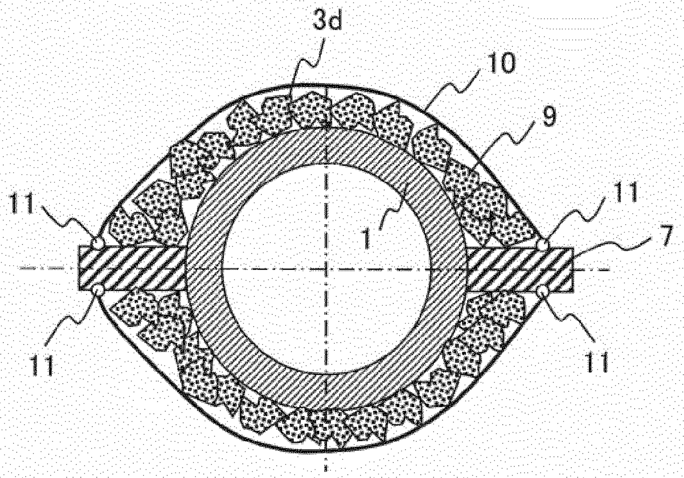
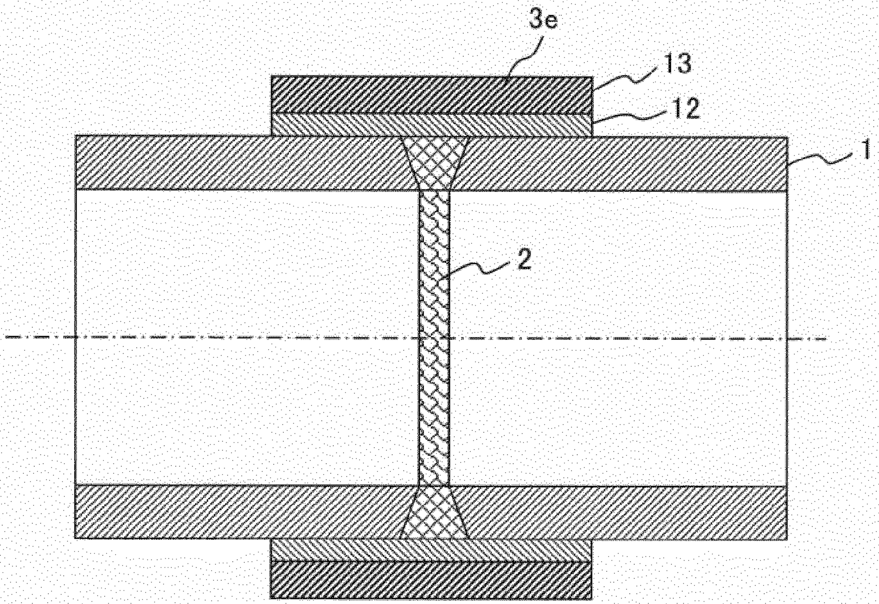



FIG. 10



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# EUROPEAN SEARCH REPORT

Application Number
EP 13 17 9228

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
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The present search report has been drawn up for all claims

1

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 20 May 2014 | Zerf, Georges |

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