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(54) **HEAT TRANSFER PIPE SUPPORT STRUCTURE AND WASTE HEAT RECOVERY BOILER**

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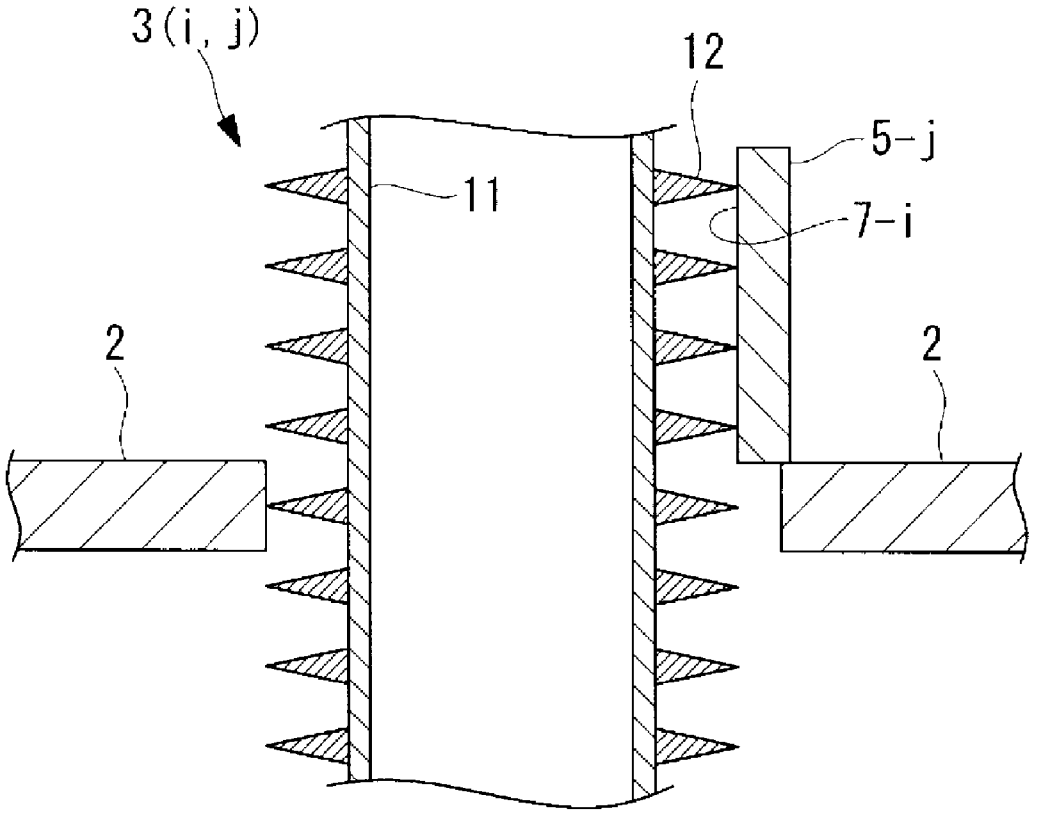
(57) **ABSTRACT**

A heat transfer pipe support structure has a heat transfer pipe support plate with through-holes formed therein, heat transfer pipes inserted through the through-holes, and a vibration-damping support plate joined to the heat transfer pipe support plate. An edge of the vibration-damping support plate is joined to the heat transfer pipe support plate so that the heat transfer pipes are held between the edges of the through-holes and the vibration-damping support plate. As a result, the clearance between the edges of the through-holes and the heat transfer pipes is reduced, enabling vibration of the heat transfer pipes to be reduced. This results in a reduction of sliding movement of the heat transfer pipes with respect to the edges of the through-holes, and thereby, wear of the heat transfer pipes is reduced.



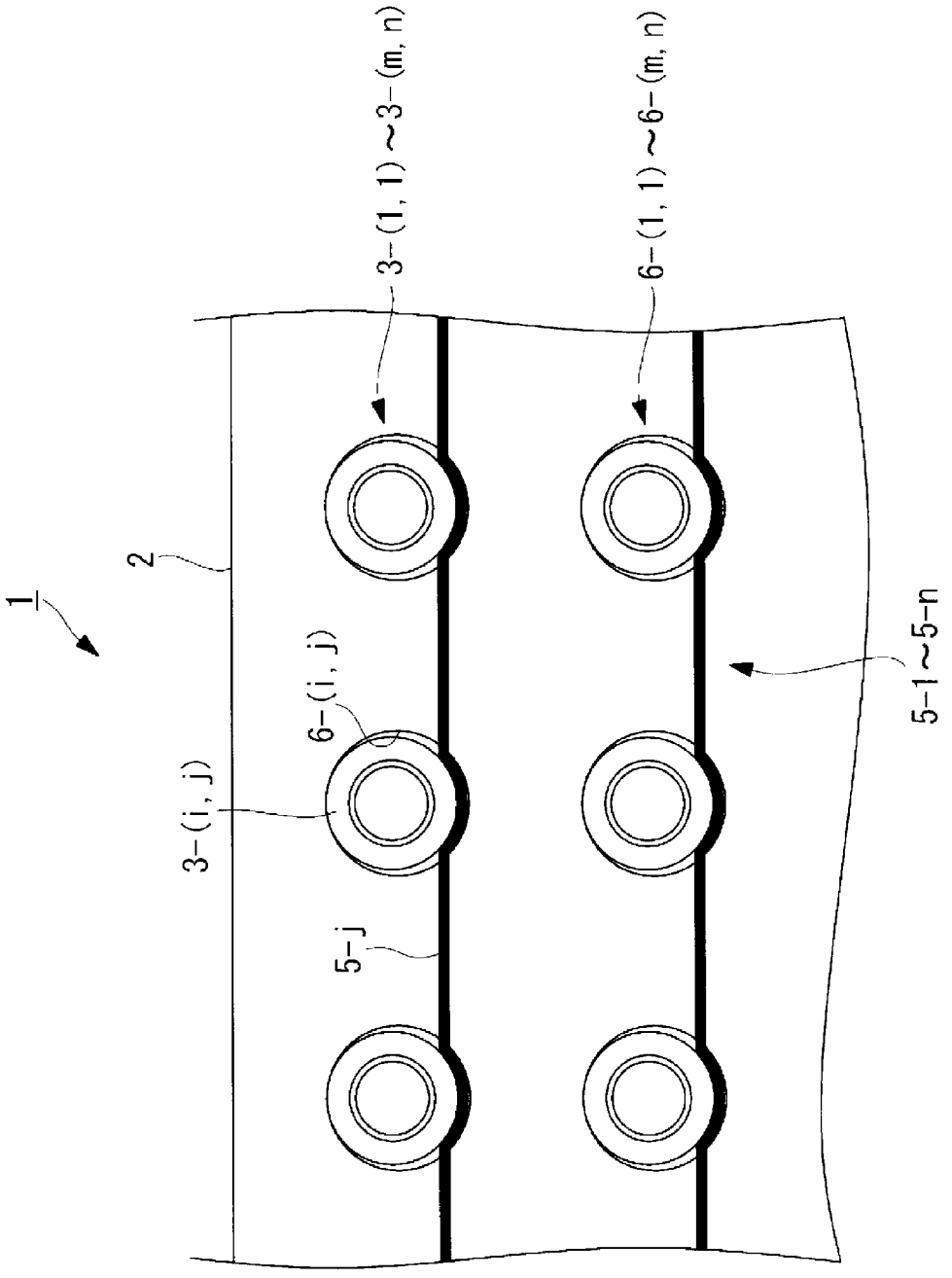


FIG. 1

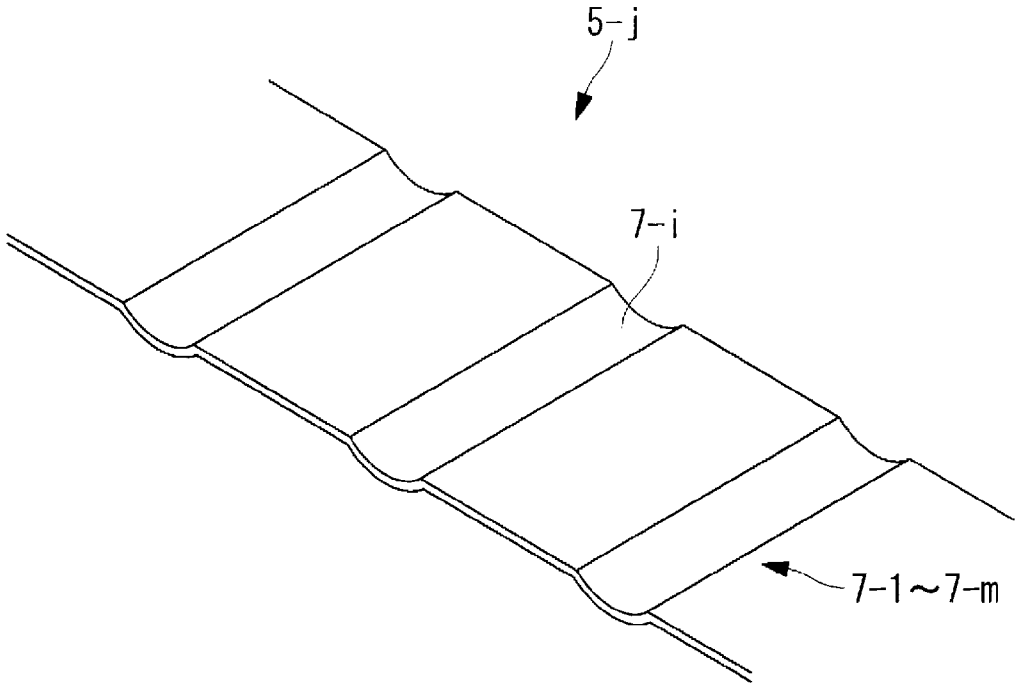


FIG. 2

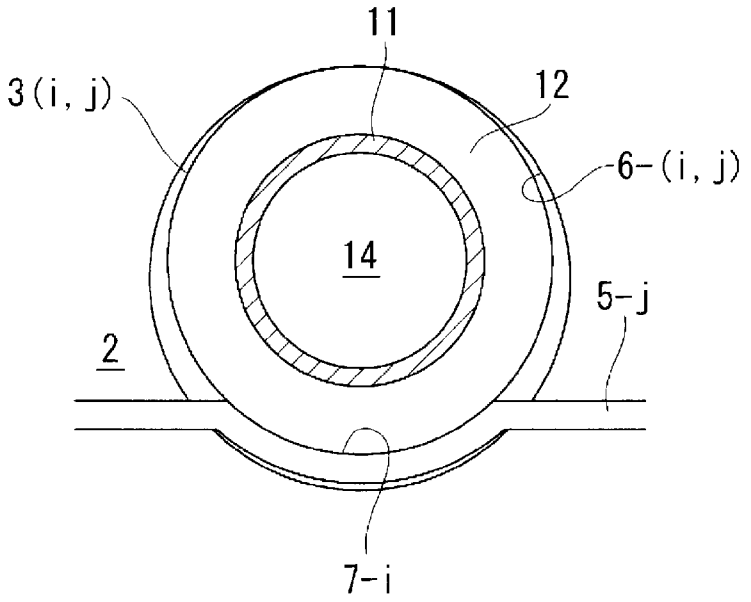


FIG. 3

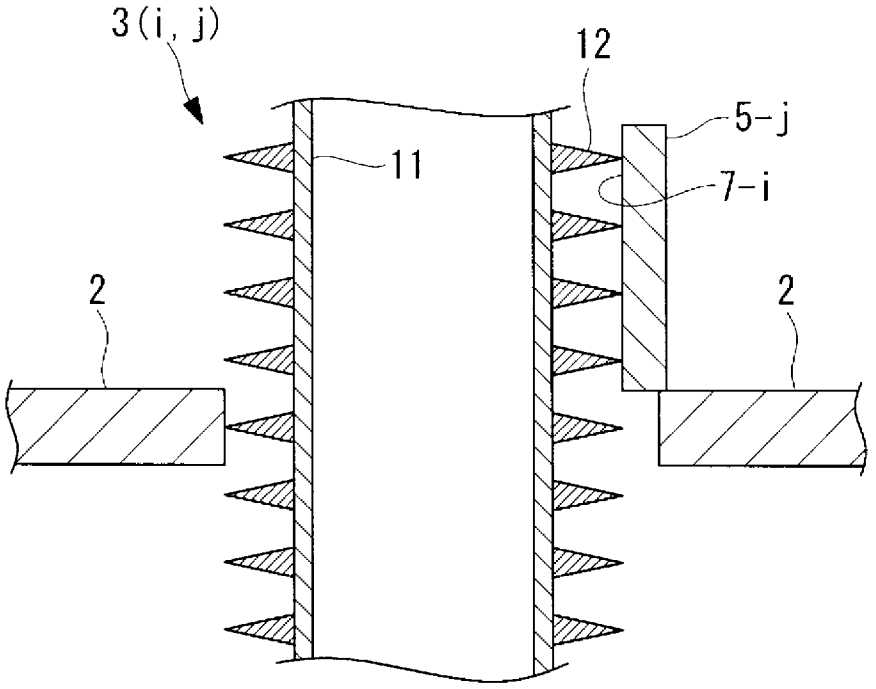


FIG. 4

HEAT TRANSFER PIPE SUPPORT STRUCTURE AND WASTE HEAT RECOVERY BOILER

TECHNICAL FIELD

[0001] The present invention relates to a heat transfer pipe support structure and a waste heat recovery boiler, and particularly relates to a heat transfer pipe support structure and a waste heat recovery boiler that are used to collect waste heat.

BACKGROUND ART

[0002] A waste heat recovery boiler is known that collects waste heat from high-temperature exhaust gas. In the above-described waste heat recovery boiler, a plurality of heat transfer pipes are provided in a flue. The waste heat recovery boiler transfers the heat of the exhaust gas to water, by causing the high-temperature exhaust gas to flow through the flue and causing the water to flow through the plurality of heat transfer pipes. The plurality of heat transfer pipes are supported by the flue as a result of being inserted through a plurality of through-holes formed in a heat transfer pipe support plate (see Patent Document 1).

CITATION LIST

Patent Literature

[0003] Patent Document 1: Japanese Unexamined Patent Application Publication No. 2002-295989A

SUMMARY OF INVENTION

Technical Problem

[0004] When the flow rate of the exhaust gas flowing through the flue is high, the plurality of heat transfer pipes may vibrate. As a result of the plurality of heat transfer pipes vibrating, sections that are in contact with the heat transfer pipe support plate may wear. It has been desired to appropriately support the plurality of heat transfer pipes and to reduce the wear of the plurality of heat transfer pipes.

[0005] An object of the present invention is to provide a heat transfer pipe support structure and a waste heat recovery boiler that support heat transfer pipes appropriately.

[0006] Another object of the present invention is to provide a heat transfer pipe support structure and a waste heat recovery boiler that reduce wear of heat transfer pipes.

[0007] Yet another object of the present invention is to provide a heat transfer pipe support structure and a waste heat recovery boiler that suppress vibration of heat transfer pipes.

Solution to Problem

[0008] A heat transfer pipe support structure according to a first aspect of the present invention includes a heat transfer pipe support plate having a first through-hole formed therein; a first heat transfer pipe configured to be inserted through the first through-hole; and a vibration-damping support plate formed in a belt-shape. In such a heat transfer pipe support structure, the edge of the vibration-damping support plate is joined to the surface of the heat transfer pipe support plate so that the first heat transfer pipe is held between the edge of the first through-hole and the vibration-damping support plate.

[0009] In the above-described heat transfer pipe support structure, as a result of the first heat transfer pipe being held between the edge of the first through-hole and the vibration-damping support plate, the clearance between the edge of the first through-hole and the first heat transfer pipe is reduced, enabling vibration of the first heat transfer pipe to be reduced. As a result of the reduction in the vibration of the first heat transfer pipe, a sliding movement of the first heat transfer pipe with respect to the edge of the first through-hole is reduced, and wear of the first heat transfer pipe is reduced due to the reduction of the sliding movement.

[0010] The vibration-damping support plate is formed so that a curvature of a contact surface of the vibration-damping support plate that is in contact with the first heat transfer pipe becomes equal to a curvature of the outer surface of the first heat transfer pipe.

[0011] In the above-described heat transfer pipe support structure, as a result of the curvature of the contact surface of the vibration-damping support plate being equal to the curvature of the outer surface of the first heat transfer pipe, it is possible to reduce a contact surface pressure with which the vibration-damping support plate presses the first heat transfer pipe, and to appropriately reduce the sliding movement of the first heat transfer pipe with respect to the edge of the first through-hole. Further, as a result of curving the vibration-damping support plate at the above-described curvature, when a distance between the edge of the first through-hole and the vibration-damping support plate increases due to thermal expansion or the like, it is possible to reduce an increase in the amount of clearance between the first heat transfer pipe and the first through-hole, compared with a case in which the vibration-damping support plate is a flat plate.

[0012] The heat transfer pipe includes a pipe and a fin joined to the outer side of the pipe. The vibration-damping support plate supports the first heat transfer pipe by being in contact with the fin.

[0013] The above-described heat transfer pipe support structure supports the first heat transfer pipe as a result of the vibration-damping support plate being in contact with the fin. Thus, it is possible to reduce a sliding movement of the fin with respect to the edge of the first through-hole, and to reduce wear of the fin. Specifically, the above-described heat transfer pipe can appropriately support the first heat transfer pipe provided with the fin.

[0014] The heat transfer pipe support structure according to the first aspect of the present invention further includes a second heat transfer pipe. In this heat transfer pipe support structure, the heat transfer pipe support plate further has a second through-hole formed therein, and the vibration-damping support plate is disposed so that the second heat transfer pipe is held between the edge of the second through-hole and the vibration-damping support plate.

[0015] Specifically, the vibration-damping support plate is provided so as to reduce vibration of the plurality of heat transfer pipes. The above-described heat transfer pipe support structure can be manufactured easily, compared with other heat transfer pipe support structures in which each of a plurality of vibration-damping support plates is provided for each of a plurality of heat transfer pipes.

[0016] A waste heat recovery boiler according to a second aspect of the present invention includes the heat transfer pipe support structure according to the first aspect of the present invention and a flue forming a flow path through which an exhaust gas flows. The heat transfer pipes are disposed in the flow path.

[0017] As a result of the heat transfer pipe support structure appropriately supporting the heat transfer pipe, the above-described waste heat recovery boiler can appropriately collect waste heat from the exhaust gas, while inhibiting the heat transfer pipe from vibrating due to the flow of the exhaust gas.

Advantageous Effects of Invention

[0018] In the heat transfer pipe support structure and the waste heat recovery boiler according to the present invention, the heat transfer pipe can be appropriately supported so as to reduce the wear of the heat transfer pipe by being held between the edge of the through-hole and the vibration-damping support plate.

BRIEF DESCRIPTION OF DRAWINGS

[0019] FIG. **1** is a diagram illustrating a heat transfer pipe support structure provided in a waste heat recovery boiler.

[0020] FIG. **2** is a perspective view of a vibration-damping support plate.

[0021] FIG. **3** is an enlarged view of the heat transfer pipe support structure.

[0022] FIG. **4** is a cross-sectional view of the heat transfer pipe support structure.

DESCRIPTION OF EMBODIMENTS

[0023] An embodiment of a heat transfer pipe support structure will be described below with reference to the accompanying drawings. As illustrated in FIG. **1**, a heat transfer pipe support structure **1** includes a heat transfer pipe support plate **2**, a plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*) (m=2, 3, 4, . . . , n=2, 3, 4, . . .), and a plurality of vibration-damping support plates **5**-**1** to **5**-*n*. The heat transfer pipe support plate **2** is formed in a planar shape. The heat transfer pipe support plate **2** is supported by a flue so as to be disposed along a plane substantially parallel with the vertical direction.

[0024] A plurality of through-holes **6**-(**1**, **1**) to **6**-(*m*, *n*) are formed in the heat transfer pipe support plate **2**. The plurality of through holes **6**-(**1**, **1**) to **6**-(*m*, *n*) are arranged in a lattice pattern. Specifically, the plurality of through-holes **6**-(**1**, **1**) to **6**-(*m*, *n*) overlap with one of a plurality of parallel lines, and a chosen straight line of the plurality of parallel lines overlaps with a plurality of through-holes **6**-(**1**, j) to **6**-(*m*, *j*) of the plurality of through-holes **6**-(**1**, **1**) to **6**-(*m*, *n*). Further, the plurality of through-holes **6**-(**1**, **1**) to **6**-(*m*, *n*) respectively correspond to the plurality of heat transfer pipes **3** -(**1**, **1**) to **3**-(*m*, *n*).

[0025] Each of the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*) is formed in a cylindrical shape. Each of the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*) is disposed along a straight line parallel with the normal direction of the heat transfer pipe support plate **2**, namely, disposed along a straight line parallel with the horizontal direction. A chosen heat transfer pipe **3**-(*i*, *j*) of the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*) is supported by the heat transfer pipe support plate **2** as a result of being inserted through a through-hole **6**-(*i*, *j*) of the plurality of through-holes **6**-(**1**, **1**) to **6**-(*m*, *n*) that corresponds to the heat transfer pipe **3**-(*i*, *j*).

[0026] A chosen vibration-damping support plate **5**-*j* (j=1, 2, 3, . . . , n) of the plurality of vibration-damping support plates **5**-**1** to **5**-*n* is formed in a belt-shape, as illustrated in FIG. **2**. The vibration-damping support plate **5**-*j* is curved, which forms a plurality of contact surfaces **7**-**1** to **7**-*m* therein. A chosen contact surface **7**-*i* (i=1, 2, 3, . . . , m) of the plurality of contact surfaces **7**-**1** to **7**-*m* is formed as a concave surface that follows the side surface of a cylinder.

[0027] As illustrated in FIG. **3**, the vibration-damping support plate **5**-*j* is disposed so that the contact surface **7**-*i* comes into contact with the outer surface of the heat transfer pipe **3**(*i*, *j*). The vibration-damping support plate **5**-*j* is joined to one surface of the heat transfer pipe support plate **2** by welding.

[0028] As illustrated in FIGS. **3** and **4**, the heat transfer pipe **3**-(*i*, *j*) includes a pipe **11** and a fin **12**. The pipe **11** is formed of a metal and formed in a tubular shape. A flow path **14** is formed inside the pipe **11**. The fin **12** is formed of a metal plate that is formed in a belt-shape. The fin **12** is joined to the pipe **11**, with one edge of the belt-shaped fin **12** spirally joined to the outer wall of the pipe **11**, so as to protrude to the outer side from the outer wall of the pipe **11**. The heat transfer pipe **3**-(*i*, *j*) is formed so that the edge of the fin **12** that is not joined to the pipe **11** follows the side surface of a cylinder.

[0029] At this time, the vibration-damping support plate **5**-*j* is formed so that a curvature of the contact surface **7**-*i* corresponding to the heat transfer pipe **3**-(*i*, *j*) becomes equal to a curvature of a surface along which the outer edge of the fin **12** of the heat transfer pipe **3**-(*i*, *j*) extends. The vibration-damping support plate **5**-*j* is disposed so that each of the plurality of contact surfaces **7**-**1** to **7**-*m* comes into contact with the outer edge of the fin **12** of each of the plurality of heat transfer pipes **3**-(**1**, j) to **3**-(*m*, *j*), and joined to the heat transfer pipe support plate **2**.

[0030] The heat transfer pipe support structure **1** is applied to a waste heat recovery boiler. The waste heat recovery boiler is provided with a duct that forms a flue, and the plurality of heat transfer pipe support structures **1** are disposed in the flue. The waste heat recovery boiler causes a high-temperature exhaust gas discharged from a combustion apparatus, such as a boiler, to flow through the flue, and causes water to flow through the flow path **14** of each of the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*). When the exhaust gas flows through the flue, the exhaust gas flows in the vicinity of the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*).

[0031] When the exhaust gas flows in the vicinity of the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*), the exhaust gas heats the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*) as a result of coming into contact with the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*), and then the exhaust gas is cooled by the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*). At this time, the heat transferred from the exhaust gas to the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*) is transferred to the water flowing through the flow path **14**. Specifically, while being in contact with the exhaust gas, the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*) heats the water by transferring the heat of the exhaust gas to the water flowing through the flow path **14**.

[0032] The heat transfer pipe support structure **1** can reduce a clearance between the edge of the through-hole **6**-(*i*, *j*) and the heat transfer pipe **3**-(*i*, *j*) by supporting the heat transfer pipe **3**-(*i*, *j*) through holding the heat transfer pipe **3**-(*i*, *j*) between the vibration-damping support plate **5**-*j* and the edge of the through-hole **6**-(*i*, *j*). The plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*) vibrate as a result of being subject to a force from the exhaust gas, particularly when the flow rate of the exhaust gas flowing through the flue is sufficiently high. The vibration of the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m*, *n*) is reduced as a result of the clearance between the edge of the through-hole **6**-(*i*, *j*) and the heat transfer pipe **3**-(*i*,

j) being reduced. Specifically, providing the plurality of vibration-damping support plates **5**-**1** to **5**-*n* in the heat transfer pipe support structure **1** reduces the clearance between the edge of the through-hole **6**-(*i, j*) and the heat transfer pipe **3**-(*i, j*), enabling the vibration of the heat transfer pipe **3**-(*i, j*) to be reduced. The reduction of the vibration of the heat transfer pipe **3**-(*i, j*) in the heat transfer pipe support structure **1** reduces a sliding movement of the outer side of the fin **12** of the heat transfer pipe **3**-(*i, j*) with respect to the edge of the through-hole **6**-(*i, j*), enabling the fin **12** of the heat transfer pipe **3**-(*i, j*) to be inhibited from wearing.

[0033] At this time, the vibration-damping support plate **5**-*j* formed so that the curvature of the contact surface **7**-*i* becomes equal to the curvature of the surface along which the outer side of the heat transfer pipe **3**-(*i, j*) extends allows the contact surface **7**-*i* to be in intimate contact with the outer side of the heat transfer pipe **3**-(*i, j*). The intimate contact of the contact surface **7**-*i* with the outer side of the heat transfer pipe **3**-(*i, j*) in the heat transfer pipe support structure **1** can reduce a contact surface pressure received by a section of the heat transfer pipe **3**-(*i, j*) that comes into contact with the contact surface **7**-*i*. In addition, the intimate contact of the contact surface **7**-*i* with the outer side of the heat transfer pipe **3**-(*i, j*) in the heat transfer pipe support structure **1** can support the heat transfer pipe **3**-(*i, j*) appropriately so as to inhibit the heat transfer pipe **3**-(*i, j*) from vibrating in the longitudinal direction of the vibration-damping support plate **5**-*j*.

[0034] Further, compared with a case in which the heat transfer pipe **3**-(*i, j*) is supported by a flat plate instead of the vibration-damping support plate **5**-*j*, when a distance between the edge of the through-hole **6**-(*i, j*) and the vibration-damping support plate **5**-*j* only slightly increases due to thermal expansion and the like, as a result of the contact surface **7**-*i* of the vibration-damping support plate **5**-*j* having the curvature equal to that of a surface on the outer side of the heat transfer pipe **3**-(*i, j*), it is possible to suppress an increase in the amount of clearance between the heat transfer pipe **3**-(*i, j*) and the through-hole **6**-(*i, j*), and further to reduce the sliding movement of the heat transfer pipe **3**-(*i, j*) and thereby the wear of the fin **12**.

[0035] The plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m, n*) may be replaced by a plurality of other heat transfer pipes that are arranged in a pattern different from the lattice pattern. Examples of the plurality of other heat transfer pipes may include a plurality of heat transfer pipes arranged in a zigzag pattern. In this case also, the plurality of vibration-damping support plates **5**-**1** to **5**-*n* are disposed so as to reduce the clearances between the edges of the through-holes and the plurality of heat transfer pipes and joined to the heat transfer pipe support plate **2**. The above-described heat transfer pipe support structure, to which the plurality of other heat transfer pipes are applied, can also reduce the vibration and wear of the plurality of heat transfer pipes, in the same manner as of the heat transfer pipe support structure **1** of the above-described embodiment.

[0036] In the heat transfer pipe support structure **1**, a plurality of other vibration-damping support plates may be further joined to a surface of the heat transfer pipe support plate **2**, on the reverse side of the surface to which the plurality of vibration-damping support plates **5**-**1** to **5**-*n* of the heat transfer pipe support plate **2** are joined. The plurality of other vibration-damping support plates are disposed so as to reduce the clearances between the edges of the plurality of through-holes **6**-(**1**, **1**) to **6**-(*m, n*) and the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m, n*), in the same manner as the plurality of vibration-damping support plates **5**-**1** to **5**-*n*. The above-described heat transfer pipe support structure further provided with the plurality of other vibration-damping support plates can also reduce the wear of the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m, n*), in the same manner as of the heat transfer pipe support structure **1** of the above-described embodiment. Further, compared with the above-described heat transfer pipe support structure **1**, the heat transfer pipe support structure further provided with the plurality of other vibration-damping support plates can support the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m, n*) more firmly and also can reduce the wear of the plurality of heat transfer pipes **3**-(**1**, **1**) to **3**-(*m, n*) more reliably.

[0037] The vibration-damping support plate **5**-*j* may be replaced by a plurality of other vibration-damping support plates corresponding to the plurality of heat transfer pipes **3**-(**1**, j) to **3**-(*m, j*). The plurality of other vibration-damping support plates corresponding to the heat transfer pipe **3**-(*i, j*) are joined to the heat transfer pipe support plate **2** so as to reduce the clearance between the edge of the through-hole **6**-(*i, j*) and the heat transfer pipe **3**-(*i, j*). In this case also, the heat transfer pipe support structure can reduce the vibration and wear of the plurality of heat transfer pipes **3**-(**1**, j) to **3**-(*m, j*).

[0038] However, in the above-described heat transfer pipe support structure, it is necessary to join the same number of the plurality of vibration-damping support plates as that of the plurality of heat transfer pipes **3** -(**1**, j) to **3**-(*m, j*) to the heat transfer pipe support plate **2**. On the other hand, in the heat transfer pipe support structure **1** of the above-described embodiment, because the number of the plurality of vibration-damping support plates **5**-**1** to **5**-*n* joined to the heat transfer pipe support plate **2** is smaller than the number of the plurality of heat transfer pipes **3**-(**1**, j) to **3**-(*m, j*), the heat transfer pipe support structure **1** can be manufactured easily compared with the above-described heat transfer pipe support structure provided with the plurality of other vibration-damping support plates.

[0039] The heat transfer pipe **3**-(*i, j*) may be replaced by another heat transfer pipe on which the fin **12** is not formed. In this case also, the heat transfer pipe support structure reduces the sliding movement of the heat transfer pipe with respect to the edge of the through-hole **6**-(*i, j*), enabling the heat transfer pipe to be inhibited from wearing.

REFERENCE SIGNS LIST

[0040] **1**. Heat transfer pipe support structure

[0041] **2**. Heat transfer pipe support plate

[0042] **3**-(**1**, **1**) to **3**-(*m, n*). Plurality of heat transfer pipes

[0043] **5**-**1** to **5**-*n*. Plurality of vibration-damping support plates

[0044] **6**-(**1**, **1**) to **6**-(*m, n*). Plurality of through-holes

[0045] **7**-**1** to **7**-*m*. Plurality of contact surfaces

1. A heat transfer pipe support structure comprising:

a heat transfer pipe support plate having a first through-hole formed therein;

a first heat transfer pipe configured to be inserted through the first through-hole; and

a vibration-damping support plate formed in a belt-shape;

an edge of the vibration-damping support plate being joined to a surface of the heat transfer pipe support plate so that the first heat transfer pipe is held between an edge of the first through-hole and the vibration-damping sup-

port plate as a result of a contact surface of the vibration-damping support plate different from the edge thereof coming into contact with an outer surface of the first heat transfer pipe.

2. The heat transfer pipe support structure according to claim **1**, wherein the vibration-damping support plate is formed so that a curvature of a contact surface of the vibration-damping support plate that is in contact with the first heat transfer pipe becomes equal to a curvature of an outer surface of the first heat transfer pipe.

3. The heat transfer pipe support structure according to claim **1**, wherein

the first heat transfer pipe includes a pipe and a fin joined to an outer side of the pipe, and

the vibration-damping support plate supports the first heat transfer pipe by being in contact with the fin.

4. The heat transfer pipe support structure according to claim **1**, further comprising:

a second heat transfer pipe; wherein

the heat transfer pipe support plate further has a second through-hole formed therein, and the vibration-damping support plate is disposed so that the second heat transfer pipe is held between an edge of the second through-hole and the vibration-damping support plate.

5. A waste heat recovery boiler comprising:

the heat transfer pipe support structure according to claim **1**; and

a flue forming a flow path through which an exhaust gas flows;

the first and second heat transfer pipes being disposed in the flow path.

6. A waste heat recovery boiler comprising:

the heat transfer pipe support structure according to claim **2**; and

a flue forming a flow path through which an exhaust gas flows;

the first and second heat transfer pipes being disposed in the flow path.

7. A waste heat recovery boiler comprising:

the heat transfer pipe support structure according to claim **3**; and

a flue forming a flow path through which an exhaust gas flows;

the first and second heat transfer pipes being disposed in the flow path.

8. A waste heat recovery boiler comprising:

the heat transfer pipe support structure according to claim **4**; and

a flue forming a flow path through which an exhaust gas flows;

the first and second heat transfer pipes being disposed in the flow path.

* * * * *