(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 540 407 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
02.01.2013 Bulletin 2013/01

(21) Application number: **11809748.4**

(22) Date of filing: **22.07.2011**

(51) Int Cl.:
B21B 45/02 *(2006.01)*

(86) International application number:
PCT/JP2011/066742

(87) International publication number:
WO 2012/011578 (26.01.2012 Gazette 2012/04)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **19.10.2010 JP 2010234715**
22.07.2010 JP 2010164522

(71) Applicant: **Nippon Steel & Sumitomo Metal Corporation**
Tokyo 100-8071 (JP)

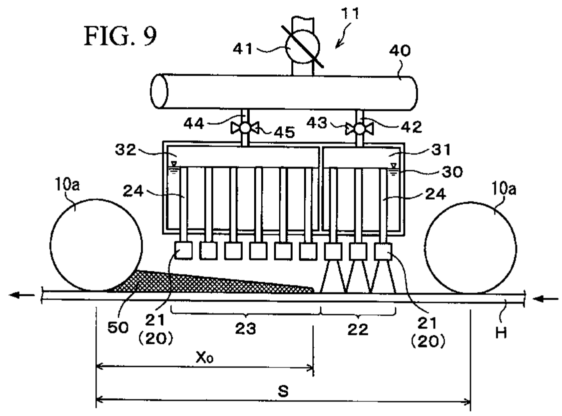
(72) Inventors:
- **YAMAMOTO, Ryuji**
  Tokyo 100-8071 (JP)
- **SERIZAWA, Yoshihiro**
  Tokyo 100-8071 (JP)
- **ODA, Tomoya**
  Tokyo 100-8071 (JP)
- **KAWAMURA, Naonori**
  Tokyo 100-8071 (JP)
- **TAWARA, Naotaka**
  Tokyo 100-8071 (JP)
- **AGARIO, Hidetaka**
  Tokyo 100-8071 (JP)
- **OGAWA, Kenichi**
  Tokyo100-8071 (JP)
- **SHUTOU, Kouji**
  Tokyo 100-8071 (JP)

(74) Representative: **Vossius & Partner**
Siebertstrasse 4
81675 München (DE)

(54) STEEL PLATE COOLING SYSTEM AND STEEL PLATE COOLING METHOD

(57) Disclosed is a steel plate cooling system including a plurality of constraining roll pairs that allows a steel plate to pass restrictively therebetween; and an upper cooling apparatus and a lower cooling apparatus that are arranged between the constraining roll pairs so as to be opposed to each other with the steel plate interposed therebetween and have a plurality of spray nozzle rows. The plurality of spray nozzle rows is formed in a plate passing direction of the steel plate, and each of the spray nozzle rows has a plurality of identical spray nozzles lined up in a width direction of the steel plate. When viewed in the plate passing direction, the spray nozzle rows are each classified into an upstream spray nozzle row group located on a relative upstream side and a downstream spray nozzle row group located on a relative downstream side. A number of spray nozzles that belong to the upstream spray nozzle row group is smaller than a number of spray nozzles that belong to the downstream spray nozzle row group.

FIG. 9



EP 2 540 407 A1

Description

Technical Field

[0001] The present invention relates to a steel plate cooling system and a steel plate cooling method that cool a steel plate obtained by hot rolling while allowing the steel plate to pass horizontally and restrictively between constraining rolls. Priority is claimed on Japanese Patent Application No. 2010-164522, filed July 22, 2010 and Japanese Patent Application No. 2010-234715, filed October 19, 2010, the content thereof is incorporated herein by reference.

Background Art

[0002] A hot steel plate after finish rolling of hot rolling is cooled to a predetermined temperature while being constrained and conveyed between constraining rolls after a finish rolling machine. A cooling system, for example, a plurality of spray nozzles that sprays cooling water to the upper and lower surfaces, respectively, of the hot steel plate, is arranged between respective constraining roll pairs, and the hot steel plate is cooled using the cooling water. In the hot rolling of the hot steel plate, the aspect of cooling after this finish rolling becomes an important factor that determines the mechanical properties of the steel plate, workability, and weldability, and it is thus important to uniformly cool the hot steel plate to a predetermined temperature.

[0003] However, in a case where the hot steel plate is cooled using cooling water as described above, on the upper surface side of the hot steel plate, it is difficult to uniformly cool the hot steel plate due to the influence of water flow on a surface that accumulates on the hot steel plate. That is, although the water on the surface on the hot steel plate is discharged in the width direction of the hot steel plate, the water on the surface interferes with a water jet stream of the cooling water sprayed onto the hot steel plate. This makes the cooling water non-uniform in the width direction of the hot steel plate.

[0004] Thus, Patent Document 1 discloses a cooling method of adjusting the collision area of the water jet stream from the spray nozzle or adjusting the spread angle of the water jet stream, causing the water jet stream to sufficiently reach the upper surface of the hot steel plate. In the case of this method, cooling capacity can be sufficiently secured and the hot steel plate can be uniformly cooled.

[0005] Here, in the hot rolling, the cooling capacity required for the cooling system differs depending on the type, usage, or the like of the steel plate. Accordingly, the cooling system is desired to be able to uniformly cool the hot steel plate as described above, and select a cooling capacity control range across a broad range.

[0006] For example, in a case where a required cooling capacity is low under this situation, that is, in a case where the amount of cooling water sprayed onto the hot steel plate is small, the nozzle load pressure of the spray nozzle becomes small. It is thereby difficult to secure the area of a collision portion (hereinafter, referred to as a "spray pattern") of the water jet stream from the spray nozzle to the hot steel plate. For this reason, in the cooling method described in Patent Document 1, the water jet stream from a spray nozzle is influenced by the water on the surface in the case where the cooling water amount is small, and it is difficult to uniformly cool the hot steel plate.

[0007] Thus, Patent Document 2 discloses a cooling system that has spray nozzles that have different amounts of cooling water to be sprayed, and uses the spray nozzles separately according to the required cooling capacity (cooling water amount). However, since a water jet stream with a large amount of cooling water from a spray nozzle affects a water jet stream with a small amount of cooling water in a case where the difference between the amounts of cooling water sprayed from the respective spray nozzles is large when the upper surface of the hot steel plate is cooled, the cooling water becomes non-uniform in the width direction of the hot steel plate. Since non-uniformity of cooling occurs if the spray nozzles with different amounts of cooling water in this way are simultaneously used, the conditions that the cooling system can be applied are limited and the cooling capacity range may not be sufficiently broadened.

[0008] Additionally, Patent Document 3 discloses a cooling system including air-water spray nozzles that spray two fluids (air and cooling water) in order to secure a spray pattern. However, the air-water spray nozzles need an air compressor, air piping, or the like for supplying air, and thus the manufacturing costs of the cooling system become high. Additionally, since the nozzle structure of the air-water spray nozzles is complicated, and is apt to clog, maintenance costs also become high in addition to the manufacturing costs of the cooling system. Moreover, the pressure control of air and water is complicated, it is difficult to keep the air-water ratio constant, and the cooling capacity changes depending on the air-water ratio. As such, the cooling system has a problem of too many influencing factors, and it is difficult to perform precise cooling capacity control.

Citation List

Patent Literature

[0009]

[Patent Document 1] Japanese Unexamined Patent Application, First Publication No. 2006-82115
[Patent Document 2] Japanese Unexamined Patent Application, First Publication No. 2007-301568
[Patent Document 3] Japanese Unexamined Patent Application, First Publication No. 2006-219732

Summary of Invention

Problem to be Solved by the Invention

[0010] The present invention has been invented in view of the above-described problems, and an object thereof is to provide a steel plate cooling system and a steel plate cooling method that uniformly cool the hot steel plate after hot rolling while broadly controlling cooling capacity when the steel plate is cooled.

Means for solving the Problem

[0011] The present invention has adopted the following means in order to solve the above problems and achieve the relevant object.
That is,
(1) a steel plate cooling system related to one aspect of the present invention is a steel plate cooling system including a plurality of constraining roll pairs that allows a steel plate to pass restrictively therebetween; and an upper cooling apparatus and a lower cooling apparatus that are arranged between the constraining roll pairs so as to be opposed to each other with the steel plate interposed therebetween and have a plurality of spray nozzle rows. The plurality of spray nozzle rows is formed in a plate passing direction of the steel plate, and each of the spray nozzle rows has a plurality of identical spray nozzles lined up in a width direction of the steel plate. When viewed in the plate passing direction, the spray nozzle rows are each classified into an upstream spray nozzle row group on a relative upstream side and a downstream spray nozzle row group located on a relative downstream side. A number of spray nozzles that belong to the upstream spray nozzle row group is smaller than a number of spray nozzles that belong to the downstream spray nozzle row group.
[0012] (2) In the steel plate cooling system described in the above (1), preferably, a ratio of a total number of the respective spray nozzle rows and the number of spray nozzle rows that belong to the upstream spray nozzle row group is equal to or an integer ratio approaching the ratio of the maximum spraying amount and minimum spraying amount of each spray nozzle that belongs to the spray nozzle rows.
[0013] (3) The steel plate cooling system described in the above (1) preferably further includes a control unit that controls a cooling water to be sprayed toward the steel plate from the plurality of spray nozzle rows, and the control unit preferably controls the spraying of the cooling water so that the cooling water is caused to be sprayed from both the upstream spray nozzle row group and the downstream spray nozzle row group in a case where a total amount of water to be sprayed toward the steel plate is equal to or larger than a maximum spraying amount of the upstream spray nozzle row group, and the cooling water is caused to be sprayed only from the upstream spray nozzle row group in a case where the total amount of water is smaller than the maximum spraying amount of the upstream spray nozzle row group.
[0014] (4) The steel plate cooling system described in the above (3) preferably further includes a water supply header that supplies the cooling water to the upstream spray nozzle row group and the downstream spray nozzle row group; a flow rate regulating valve that regulates the flow rate of the cooling water to be supplied to the water supply header; a first control valve that controls a permission or prohibition of supply of the cooling water to be supplied from the water supply header to the upstream spray nozzle row group; and a second control valve that controls a permission or prohibition of supply of the cooling water to be supplied from the water supply header to the downstream spray nozzle row group.
[0015] (5) The steel plate cooling system described in the above (1) preferably further includes a first water supply header that supplies a cooling water to the upstream spray nozzle row group; a second water supply header that supplies a cooling water to the downstream spray nozzle row group; a first flow rate regulating valve that regulates a flow rate of the cooling water to be supplied to the first water supply header; a second flow rate regulating valve that regulates a flow rate of the cooling water to be supplied to the second water supply header; and a control unit that controls the cooling water to be sprayed toward the steel plate from the plurality of spray nozzle rows. The control unit preferably controls the spraying of the cooling water so that the cooling water is caused to be sprayed from both the upstream spray nozzle row group and the downstream spray nozzle row group in a case where a total amount of water to be

sprayed toward the steel plate is equal to or larger than a maximum spraying amount of the upstream spray nozzle row group, and the cooling water is caused to be sprayed only from the upstream spray nozzle row group in a case where the total amount of water is smaller than the maximum spraying amount of the upstream spray nozzle row group.

[0016] (6) In the steel plate cooling system described in any one of the above (1) to (5), preferably, a mutually adjacent intervals, in the plate passing direction, of the respective spray nozzle rows that belong to the upstream spray nozzle row group are the same, and wherein a mutually adjacent intervals, in the plate passing direction, of the respective spray nozzle rows that belong to the downstream spray nozzle row group are the same.

[0017] (7) In the steel plate cooling system described in any one of the above (1) to (5), preferably, all the adjacent intervals of the respective spray nozzle rows in the plate passing direction are the same.

[0018] Incidentally, in a case where the total amount of cooling water to be sprayed onto the upper surface of the steel plate is smaller than the maximum water amount of the upstream spray row group, the amount of the water on the surface on the steel plate becomes small, and the water on the surface is discharged in the plate passing direction of the steel plate, that is, to the downstream side of the steel plate, with the movement of the steel plate, and does not accumulate on the upstream side as much. For this reason, the cooling water sprayed to the upstream side of the steel plate can cool the steel plate uniformly without being influenced by the water on the surface.

In such a case and in a case where the water on the surface on the steel plate accumulates on the constraining roll pair side on the downstream side of the steel plate, (8) in the steel plate cooling system described in any one of the above (1) to (5), the upstream spray nozzle row group may be arranged so that a cooling water is sprayed from the upstream spray nozzle row group toward a position of the upstream side in the plate passing direction not overlapped with a region of water on the surface that accumulates on the steel plate when a maximum spraying amount is caused to be sprayed from the upstream spray nozzle row group.

[0019] (9) When a steel plate is cooled using the steel plate cooling system described in any one of the above (1) to (5), the spraying of the cooling water may be controlled by the control unit so that the cooling water is caused to be sprayed from both the upstream spray nozzle row group and the downstream spray nozzle row group in a case where the total amount of water to be sprayed toward the steel plate is equal to or larger than the maximum spraying amount of the upstream spray nozzle row group, and the cooling water is caused to be sprayed only from the upstream spray nozzle row group in a case where the total amount of water is smaller than the maximum spraying amount of the upstream spray nozzle row group.

[0020] (10) In the steel plate cooling method described in the above (9), a region of water on the surface that accumulates on the steel plate when the cooling water is caused to be sprayed with the maximum spraying amount from the upstream spray nozzle row group may be obtained in advance, and the upstream spray nozzle row group may be arranged so that the cooling water is sprayed from the upstream spray nozzle row group toward a position of the upstream side in the plate passing direction not overlapped with the region.

Effects of the Invention

[0021] According to the present invention, uniform cooling can be performed in a wide cooling capacity range with a smaller number of spray nozzles, a smaller number of nozzle rows, and a smaller number of flow rate regulating valves. Additionally, since the facility configuration is simple, and there is one type of nozzle, reduction in facility construction costs or reduction in maintenance costs can be achieved.

Brief Description of Drawings

[0022]

FIG. 1 is a side view showing a schematic configuration of a portion of a hot-rolling facility having a cooling system related to a first embodiment of the present invention.

FIG. 2 an explanatory view showing a schematic configuration in a longitudinal cross-sectional view of an upper cooling apparatus of the cooling system.

FIG. 3 an explanatory view showing a schematic configuration in a horizontal cross-sectional view of the upper cooling apparatus of the cooling system.

FIG. 4 is an explanatory view showing the condition in which cooling water is sprayed from a spray nozzle of the cooling system.

FIG. 5 is a graph showing the relationship between nozzle load pressure and spray angle of the spray nozzle of the cooling system.

FIG. 6 is a graph showing the relationship between nozzle load pressure and cooling water amount of the spray nozzle of the cooling system.

FIG. 7 is an explanatory view showing the relationship between the nozzle load pressure of the spray nozzle of the

cooling system, and the water amount density of the cooling water supplied from the upper cooling apparatus.
FIG. 8 is an explanatory view showing the condition in which a steel plate is cooled in a case where required cooling capacity is high.
FIG. 9 is an explanatory view showing the condition in which the steel plate is cooled in a case where the required cooling capacity is low.
FIG. 10 is an explanatory view of a case where cooling water is sprayed only from a downstream spray nozzle row group.
FIG. 11 is a graph that shows cooling rates in respective positions in the width direction of the steel plate cooled using the cooling system.
FIG. 12 is a side view showing an overall cooling system related to a second embodiment of the present invention.
FIG. 13 is a perspective view schematically showing a nozzle header of the cooling system.
FIG. 14 is a plan view showing the arrangement of cooling water spray nozzles attached to the nozzle header of the cooling system.
FIG. 15 is a graph showing the relationship between water supply amount density and nozzle water supply pressure from a small-flow-rate nozzle header and a large-flow-rate nozzle header.

Description of Embodiments

[First Embodiment]

[0023] A first embodiment of the present invention will be described below. FIG. 1 is a side view showing a schematic configuration of a portion of a hot-rolling facility having a cooling system 1 related to the present embodiment.
[0024] As shown in FIG. 1, a finish rolling machine 2, a hot correcting device 3, and the cooling system 1 are provided in this order in a plate passing direction of a steel plate (hot steel plate) H in the hot-rolling facility. The rolling mill 2 hot-rolls the steel plate H that is discharged from a heating furnace (not shown) and is rolled by a roughing rolling machine (not shown). The hot correcting device 3 corrects the shape of the steel plate H after finish rolling. The cooling system 1 cools the steel plate H after hot correction to a predetermined temperature, for example, 350°C. This allows the steel plate H rolled in the finish rolling machine 2 to be shape-corrected in the hot correcting device 3 and then cooled by the cooling system 1 during conveyance.
In addition, a layout in which correction is made after cooling may be adopted, that is, the hot correcting device 3 may be located on the downstream side (rear surface side) of the cooling system 1. Otherwise, the hot correcting devices 3 may be provided on both sides of the upper side and the lower side with the steel plate H of the cooling system 1 interposed therebetween.
[0025] The cooling system 1 includes a plurality of constraining roll pairs 10, upper cooling apparatuses 11, and lower cooling apparatuses 12, and a control unit 5.
The plurality of constraining roll pairs 10 includes constraining rolls 10a arranged above the steel plate H, and the conveying rolls 10b arranged below the steel plate. The constraining rolls 10a and the conveying rolls 10b are lined up in the horizontal direction in the plate passing direction of the steel plate H, and allow the steel plate H to pass restrictively therebetween. Each constraining roll pair 10 is constituted by two constraining rolls arranged up and down. The steel plate H is conveyed in a state where the steel plate is sandwiched between the upper and lower constraining rolls. In addition, the lower constraining roll may be referred to as a conveying roll.
Additionally, the constraining rolls 10a and the conveying rolls 10b sandwich the steel plate H.
[0026] An upper cooling apparatus 11 that cools the upper surface side of the steel plate H and a lower cooling apparatus 12 that cools the lower surface side of the steel plate H are arranged, respectively, between adjacent constraining roll pairs 10 and 10. Specifically, the upper cooling apparatus 11 and the lower cooling apparatus 12 are arranged so as to be opposed to each other with the steel plate H interposed therebetween. This configuration enables the cooling system 1 to cool the upper and lower surfaces of the steel plate H. Additionally, the upper cooling apparatus 11 and the lower cooling apparatus 12 have a plurality of spray nozzle rows 21. The spray nozzle rows 21 are arranged in the plate passing direction of the steel plate H, and each of the spray nozzle rows 21 has a plurality of identical spray nozzles 20 lined up in the width direction of the steel plate H.
[0027] The lower cooling apparatus 12 is provided with a plurality of spray nozzles arranged side by side in the plate passing direction and width direction of the steel plate H, for example, full cone spray nozzles (not shown). Although the full cone nozzles of the lower cooling apparatus 12 are not shown, these nozzles have a slightly larger amount of ejected water than the full cone spray nozzles of the upper cooling apparatus 11 shown in FIG. 2. Cooling water is sprayed onto the steel plate H from the full cone spray nozzles, and the steel plate H is cooled by a water jet stream of the cooling water from the lower surface side.
[0028] The upper cooling apparatus 11, as shown in FIGS. 2 and 3, has a plurality of spray nozzles that sprays cooling water onto the upper surface of the steel plate H, that is, the full cone spray nozzles 20 in the present embodiment. The

full cone spray nozzle 20, as shown in FIG. 4, can spray a conic water jet stream.

[0029] A plurality of full cone spray nozzles 20, as shown in FIGS. 2 and 3, forms nozzle rows in the width direction of the steel plate H, and a plurality of the nozzle rows is lined up in the plate passing direction. For example, in FIGS. 2 and 3, the spray nozzle rows 21 arranged side by side in nine rows are configured. In each of the spray nozzle rows 2 1 a to 21i, the plurality of spray nozzles 20 is arranged side by side in the width direction of the steel plate H. That is, the plurality of full cone nozzles 20 is alternately arranged in a horizontal cross-sectional view. This configuration allows the cooling water sprayed from the full cone spray nozzles 20 to be sprayed onto the upper surface of the steel plate H.

[0030] The nine spray nozzle rows 21 a to 21i, as shown in FIGS. 2 and 3, are classified into the spray nozzle rows 21 a to 21c that are respective spray nozzle rows 21 located on the relative upstream side and the spray nozzle rows 21 d to 21i that are respective spray nozzle rows located on the relative downstream side, when viewed in the plate passing direction. Specifically, the spray nozzle rows are grouped into two nozzle row group 22 and nozzle row groups 23 that are arranged in the plate passing direction of the steel plate H. Hereinafter, a nozzle row group arranged on the upstream side (the upstream side of the steel plate H) of the steel plate H is referred to as an upstream spray nozzle row group 22, and a nozzle row group arranged on the downstream side (the downstream side of the steel plate H) of the steel plate H is referred to as a downstream spray nozzle row group 23. As described above, the upstream spray nozzle row group 22 is constituted by, for example, three spray nozzle rows 21 a to 21 c, and the downstream spray nozzle row group 23 is constituted by, for example six spray nozzle rows 21d to 21i. In addition, a method of setting the number of rows of the spray nozzle rows 21a to 21 i in the upstream spray nozzle row group 22 and the downstream spray nozzle row group 23 will be described below. Additionally, the arrangement position of the upstream spray nozzle row group 22 will be described below.

[0031] One end portion of a supply pipe 24 that supplies cooling water to each of the full cone spray nozzles 20 is connected to the full cone spray nozzle 20. The supply pipe 24 extends vertically upward from the full cone spray nozzle 20, and the other end portion of the supply pipe 24 is arranged within a nozzle box 30 that can store cooling water.

[0032] The inside of the nozzle box 30 is partitioned into two storage chambers 31 and 32. The supply pipes 24 of the full cone spray nozzles 20 of the upstream spray nozzle row group 22 are accommodated in the upstream storage chamber 31 arranged on the upstream side of the steel plate H. Additionally, the supply pipes 24 of the full cone spray nozzles 20 of the downstream spray nozzle row group 23 is accommodated in the downstream storage chamber 32 arranged on the downstream side of the steel plate H. Cooling water is always stored up to the positions of the other end portions of the supply pipes 24 in each of the storage chambers 31 and 32. Thereby, if cooling water is supplied from a header 40 to be described below to the storage chambers 31 and 32, the cooling water is supplied to the full cone spray nozzles 20 via the supply pipes 24. Accordingly, the reaction of an upper cooling section 11 becomes rapid, and the steel plate H can be suitably cooled. Additionally, even in a case when cooling is not performed, damage caused by the heating of the nozzle box 30 (from the hot steel plate) can be prevented by the cooling water stored in the respective storage chambers 31 and 32.

[0033] A supply header 40 that supplies cooling water to the nozzle box 30 (the upstream spray nozzle row group 22 and the downstream spray nozzle row group 23) is arranged above (on the upstream side of) the nozzle box 30. A flow rate regulating valve 41 is provided above (on the upstream side of) the supply header 40. The opening or closing of the flow rate regulating valve 41 allows cooling water to circulate through the inside of the supply header 40, and the flow rate of the cooling water to be supplied to the inside of the supply header 40 to be adjusted (controlled). Piping 42 communicated with the supply header 40 is connected to the upstream storage chamber 31. An on-off control valve (first control valve) 43 is interposed in the piping 42, and the permission or prohibition (on or off, or opening or closing of the valve) of supply of the cooling water from the supply header 40 to the upstream storage chamber 31 (upstream spray nozzle row group 22) is controlled by the on-off control valve 43. Similarly, piping 44 communicating with the supply header 40 is also connected to the downstream storage chamber 32. An on-off control valve (second control valve) 45 is interposed in the piping 44, and the permission or prohibition (on or off, or opening or closing of the valve) of supply of the cooling water from the supply header 40 to the downstream storage chamber 32 (downstream spray nozzle row group 23) is controlled by the on-off control valve 45.

Additionally, the flow rate regulating valve 41, the on-off control valve 43, and the on-off control valve 45 are connected to the control unit 5. The control unit 5 controls the cooling water sprayed toward the steel plate H from the plurality of spray nozzle rows 21.

[0034] Additionally, as shown in FIG. 2, it is preferable that the mutually adjacent intervals a are the same in the plate passing direction of the respective spray nozzle rows 21 that belong to the upstream spray nozzle row group 22. It is preferable that the mutually adjacent intervals b are the same in the plate passing direction of the respective the spray nozzle rows 21 that belong to the downstream spray nozzle row group 23. Moreover, it is preferable that the adjacent interval c between the spray nozzle rows 21c arranged closest to the downstream spray nozzle row group 23 side among the respective the spray nozzle rows 21 that belong to the upstream spray nozzle row group 22 and the spray nozzle row 21 d arranged closest to the upstream spray nozzle row group 22 side among the respective spray nozzle rows 21 that belong to the downstream spray nozzle row group 23 is equal to the adjacent interval a and the adjacent interval

b. That is, it is preferable that all the adjacent intervals of the respective spray nozzle rows 21 in the plate passing direction are the same.

Moreover, it is preferable that all the mutually adjacent intervals of the respective spray nozzle rows 21 in the width direction of the steel plate are the same.

[0035] In the upper cooling apparatus 11 of the above configuration, first, a required cooling water amount is determined from a cooling rate or cooling stop temperature required for the steel plate H. The flow rate regulating valve 41 is controlled by the control unit 5 and the flow rate of the cooling water to be supplied to the supply header 40 is regulated so that the cooling water of the cooling water amount is supplied. At this time, it is determined in the control unit 5 whether both the on-off control valves 43 and 45 are opened or only the on-off control valve 43 is opened, as described below. At this time, in a case where the required cooling water amount is larger than the maximum water amount of the upstream spray nozzle row group 22, both the on-off control valves 43 and 45 are opened by the control unit 5. On the other hand, in a case where the required cooling water amount is smaller than the maximum water amount of the upstream spray nozzle row group 22, only the on-off control valve 43 is opened by the control unit 5. Then, cooling water is supplied to the upstream storage chamber 31 from the supply header 40, for example by opening the on-off control valve 43. The cooling water within the upstream storage chamber 31 is sprayed onto the steel plate H via the supply pipes 24 of the upstream spray nozzle row group 22, and the full cone spray nozzles 20. Similarly, cooling water is sprayed onto the steel plate H via the downstream storage chamber 32, the supply pipes 24 of the downstream spray nozzle row group 23, and the full cone spray nozzles 20 from the supply header 40, for example by opening the on-off control valve 45. In this way, in the upper cooling apparatus 11, spraying of cooling water is controlled in every nozzle row group 22 or 23.

[0036] Next, a method of setting the numbers of rows of the spray nozzle rows 21 a to 21i in the nozzle row groups 22 and 23 described above, and the arrangement position of the upstream spray nozzle row group 22 will be described above together with a method of cooling the steel plate using the upper cooling apparatus 11.

[0037] In setting the numbers of rows of the spray nozzle rows 21 a to 21 i, and the arrangement position of the upstream spray nozzle row group 22, first, the characteristics of a full cone spray nozzle 20 to be used in an embodiment to be described below will be described using this full cone spray nozzle as an example. The rated maximum load pressure of the full cone nozzle 20 is 0.3 MPa.

The spray angle α of a water jet stream from the full cone spray nozzle 20 shown in FIG. 4 depends on the nozzle load pressure of the full cone spray nozzle 20. The results that the inventors have investigated regarding this point are shown in FIG. 5. The horizontal axis of FIG. 5 represents the nozzle load pressure, and the vertical axis represents the change rate of the spray angle. Referring to FIG. 5, it can be seen that the change rate of the spray angle of the full cone spray nozzle 20 decreases abruptly when the nozzle load pressure is equal to or lower than about 0.04 MPa (dotted line in FIG. 5). This shows that, in a case where the nozzle load pressure is equal to or lower than 0.04 MPa, the area of a collision portion of a water jet stream onto the steel plate H from the full cone spray nozzle 20, that is, a so-called spray pattern cannot be secured. Accordingly, in order to suitably cool the steel plate H, it can be seen that the nozzle load pressure of the full cone spray nozzle 20 is required to be equal to or higher than 0.04 MPa. In addition, in the present embodiment, although the nozzle load pressure is set to be equal to or higher than 0.04 MPa, this is just an example.

[0038] Additionally, the inventors have investigated the cooling water amount of the full cone spray nozzle 20 that is required to secure a nozzle load pressure of 0.04 MPa or higher, that is, to secure the spray pattern. The results are shown in FIG. 6. The horizontal axis of FIG. 6 represents the nozzle load pressure, and the vertical axis represents the cooling water amount of the full cone spray nozzle 20. Referring to FIG. 6, as for the range of the cooling water amount that secures the spray pattern, it can be seen that the range of the ratio of the maximum water amount and minimum water amount of the full cone spray nozzle 20 is within a range of about 3:1.

[0039] Here, the cooling of the steel plate H using the upper cooling apparatus 11 of the cooling system 1 will be described. FIG. 7 shows the relationship between the nozzle load pressure of the full cone spray nozzle 20, and the water amount density of the cooling water supplied from the upper cooling apparatus 11. In addition, the water amount density represents the cooling water amount per unit area of the cooling water sprayed onto the steel plate H between the constraining roll pair 10a and 10b arranged with the steel plate H interposed therebetween. Accordingly, although the water amount density or the cooling water amount may be described hereinbelow, both have the same meaning.

[0040] As described above, in the hot rolling, the cooling capacity required for the cooling system 1, that is, the required cooling water amount, (water amount density) differs depending on the type, usage, or the like of the steel plate H. For example, in a case where the required cooling water amount is larger than the maximum water amount of the upstream spray nozzle row group 22 (the range of an upper solid line in the graph of FIG. 7), in order to secure this high water amount density, cooling water is sprayed onto the upper surface of the steel plate H from both the upstream spray nozzle row group 22 and the downstream spray nozzle row group 23, for example, as shown in FIG. 8. In this case, since the cooling water amount is larger than the maximum water amount of the upstream spray nozzle row group 22, the water on the surface 50 that accumulates on the steel plate H spreads to the entire upper surface of the steel plate H between the constraining roll pairs 10 and 10. Specifically, since the water on the surface 50 and the cooling water sprayed from the upstream spray nozzle row group 22 and the downstream spray nozzle row group 23 are forcedly stirred on the whole surface of the steel plate H, the steel plate H is uniformly cooled at least in the width direction of the steel plate H. Accordingly, in order to avoid the influence of the water on the surface 50, it is necessary to secure the spray pattern of each full cone spray nozzle 20. That is, as described above, the nozzle load pressure of the full cone spray nozzle 20 is required to be equal to or higher than 0.04 MPa. In the graph of FIG. 7, in the range of the upper solid line, this nozzle load pressure can be secured and the steel plate H can be suitably cooled.

[0041] On the other hand, if the required cooling water amount (water amount density) decreases as shown in FIG. 7, the nozzle load pressure of the full cone spray nozzle 20 also decreases. For example, in a case where the required water amount density is equal to or lower than about 0.55 $m^3/m^2/min$ in FIG. 7, that is, lower than the maximum water amount of the upstream spray nozzle row group 22, if the cooling water is supplied from both the upstream spray nozzle row group 22 and the downstream spray nozzle row group 23, the nozzle load pressure of 0.04 MPa cannot be secured in each of the full cone spray nozzles 20.

[0042] Therefore, cooling water is sprayed onto the upper surface of the steel plate H only from the upstream spray nozzle row group 22, and the spraying of the cooling water from the downstream spray nozzle row group 23 is stopped. Here, in a case where the required water amount density is a water amount density that is equal to or lower than about 0.55 $m^3/m^2/min$ (the range of the lower solid line in the graph of FIG. 7), that is, lower than the maximum water amount of the upstream spray nozzle row group 22, as shown in FIG. 9, the water on the surface 50 on the steel plate H becomes a small amount, and the water on the surface 50 flows in the plate passing direction of the steel plate H, that is, toward the downstream side of the steel plate H, with the movement of the steel plate H. Accordingly, the spraying of the cooling water from the downstream spray nozzle row group 23 is stopped as described above. Thereby, as shown in the graph of FIG. 7, the upper solid line shifts to the lower solid line, and the nozzle load pressure of the full cone spray nozzle 20 in the upstream spray nozzle row group 22 rises abruptly. Accordingly, the spray pattern of the full cone spray nozzle 20 can be secured, and the steel plate H can be suitably cooled.

[0043] In a case where the spraying of the cooling water from the downstream spray nozzle row group 23 is stopped, as in the present embodiment, it is most preferable that the ratio of the number (nine rows) of rows of all the spray nozzle rows 2 1 a to 21i and the number (three rows) of rows of the spray nozzle rows 21 a to 21c of the upstream spray nozzle row group 22 be the ratio of the maximum water amount and minimum water amount of the full cone spray nozzle 20, that is, the above-described 3:1. For example, in a case where the number of rows of the spray nozzle rows 21 of the upstream spray nozzle row group 22 is equal to or higher than four, the nozzle load pressure of each full cone spray nozzle 20 becomes small compared to a case where the number of rows of the upstream spray nozzle row group 22 is three. Then, in a case where the required cooling water amount has further decreased, and the number of rows of the upstream spray nozzle row group 22 is three, the spray pattern can be secured. However, in a case where the number of rows of the upstream spray nozzle row group 22 is equal to or higher than four, a case where the spray pattern cannot be secured occurs. That is, the range of the water amount density in which the spray pattern can be secured and the steel plate H can be suitably cooled in a case where the number of rows of the upstream spray nozzle row group 22 is equal to or higher than four becomes narrow compared to the range of the water amount density in a case where the number of rows of the upstream spray nozzle row group 22 is three. Incidentally, in the present embodiment, the ratio of the maximum water amount density and minimum water amount density, that is, the cooling capacity control range, of controllable cooling water becomes a wide range of 9:1. On the other hand, if the number of rows of the upstream spray nozzle row group 22 becomes equal to or lower than two, the amount of the cooling water sprayed from each full cone spray nozzle 20 exceeds the maximum water amount, and the required water amount density cannot be secured. Accordingly, as described above, it is most preferable that the ratio of the number of rows of all the spray nozzle rows 2 1 a to 21i and the number of rows of the spray nozzle rows 21a to 21c of the upstream spray nozzle row group 22 be an integer ratio that is the same as or approaches the ratio of the maximum water amount and minimum water amount of the full cone spray nozzle 20.

[0044] In addition, in the present embodiment, the ratio of the maximum water amount and minimum water amount of the full cone spray nozzle 20 is 3:1. Thus, the ratio of the number of rows of all the spray nozzle rows 21a to 21i and the number of rows of the spray nozzle rows 21 a to 21 c of the upstream spray nozzle row group 22 is set to 3:1. However, the ratio of the numbers of the spray nozzle rows is not limited to this. If the ratio of the numbers of the spray nozzle rows is the ratio of the maximum water amount and minimum water amount of a spray nozzle as described above, the ratio of the numbers of the spray nozzle rows can be set to various values. For example, in a case where the spray nozzles to be used for the cooling system is changed and the ratio of the maximum water amount and minimum water amount is 7:3, the ratio of the number (seven rows) of rows of all the spray nozzle rows and the number (three rows) of rows of the spray nozzle rows of the upstream spray nozzle row group is also set to 7:3.

[0045] Additionally, in a case where the ratio of the maximum water amount and minimum water amount of the full cone spray nozzle 20 is not expressed by an integer ratio, the ratio of the number of rows of all the spray nozzle rows 21a to 21i and the number of rows of the spray nozzle rows 21a to 21c of the upstream spray nozzle row group 22 may be set to an integer ratio approaching the ratio of the maximum water amount and minimum water amount of the full cone spray nozzle 20. Specifically, the ratio of the maximum water amount in a case where the minimum water amount

is set to 1 is set to an integer by rounding off to the closest integer. For example, in a case where the ratio of the maximum water amount and minimum water amount of the full cone spray nozzle is 1:3.1, the ratio can be 1:3 by rounding off 3.1 to the closest integer. The integer ratio of the maximum water amount and minimum water amount of the full cone spray nozzle 20 obtained in this way may be set to an integer ratio to approach the above.
It is not preferable that an uncontrollable water amount density range be between the maximum water amount density and the minimum water amount density. Therefore, it is preferable to approximate the ratio of the number of rows of all the spray nozzle rows and the number of rows of the spray nozzle rows of the upstream spray nozzle row group 22 so as to become smaller than the ratio of the maximum water amount and minimum water amount of a spray nozzle.
In the present invention, it is not necessary to provide an upper limit to the ratio of the numbers of the spray nozzle rows. However, even if the nozzle load pressure is raised to about 0.7 MPa, the ratio of the maximum water amount and the minimum water amount is about four, and may be equal to or lower than four. If needed, the upper limit may be 3.5, 3, or 2.5.
[0046] Additionally, as described above with reference to FIG. 9, the water on the surface 50 may flow to and accumulate on the downstream side of the steel plate H depending on a required cooling water amount. In this case, it is preferable that the upstream spray nozzle row group 22 be arranged so that the cooling water sprayed from the upstream spray nozzle row group 22 does not interfere with the water on the surface 50. Specifically, when a maximum spraying amount is sprayed from the upstream spray nozzle row group 22, it is preferable that the upstream spray nozzle row group 22 be arranged so that cooling water is sprayed from the upstream spray nozzle row group 22 toward a position of the upstream side in the plate passing direction not overlapped with the region of the water on the surface 50 that accumulates on the steel plate H.
[0047] Moreover, the inventors keenly studied the range over which the water on the surface 50 is present on the steel plate H in a case where cooling water is sprayed only from the upstream spray nozzle row group 22. Specifically, first, the cooling water of the water amount density W of the maximum water amount of the upstream spray nozzle row group 22 was sprayed from the upper cooling apparatus H to the steel plate H in a state where the steel plate H is made stationary, and the height hc of the water on the surface at the center in the plate width direction was derived through experiments. Next, in a case where the cooling water of the same water amount density W as the steel plate H passed at a plate passing speed Ls was sprayed, an experiment was performed regarding the range over which cooling water spreads on the steel plate H as the water on the surface 50 as shows in FIG. 9. Then, the height distribution of the water on the surface 50 on the steel plate H was assumed to be secondary distribution in the width direction. As a result, the inventors obtained the knowledge that the range X_0 where the water on the surface 50 shown in FIG. 9 is present is expressed by the following Formula (1). In addition, the range X_0 represents the distance from the center of the downstream constraining roll pair 10 of the steel plate H to the end portion of the water on the surface 50. Additionally, the water on the surface height hc in Formula (1) represents the height of the water on the surface 50 at the center of the steel plate H in the width direction, and is expressed by the following Formula (2).
[0048]

[Formula 1]

$$X_0 = \frac{29.4 \times hc \times S}{Ls^2} \quad \cdots\cdots \quad (1)$$

[0049] Here, X_0: Horizontal range of water on the surface 50 (m), hc: Height (m) of water on the surface 50 at center in plate width direction in a case where steel plate H is in a stationary state, S: Distance m between centers of constraining roll pairs 10 and 10, Ls: Plate passing speed (m/min) of steel plate H
Additionally, in the above Formula (1), "29.4" is a constant having a dimension of (m/min^2).
[0050]

[Formula 2]

$$hc = 0.04 \times (W \times B)^{\frac{2}{3}} \quad \cdots\cdots \quad (2)$$

[0051] Here, W: Water amount density ($m^3/m^2/min$) of cooling water sprayed from upper cooling apparatus 11, B:

Width (m) of steel plate H.
Additionally, in the above Formula (2), "0.04" is a constant having a dimension of ($m^{(-1/3)}/min^{(2/3)}$).

[0052] As described above, the range X_0 where the water on the surface 50 is present on the steel plate H is calculated by the above Formula (1). In addition, the position of an upstream end portion of the range X_0 where the water on the surface 50, as shown in FIG. 9, is almost the same as the position of an upstream end portion of the downstream spray nozzle row group 23. The upstream spray nozzle row group 22 is arranged at a position where a water jet stream of the cooling water sprayed from the downstream spray nozzle row 21 c does not interfere with the water on the surface 50, that is, at a position where a downstream end portion of the water jet stream is apart from the center of downstream constraining roll pair 10 by the range X_0 or higher. Thereby, since the upstream spray nozzle row group 22 sprays cooling water to a place with almost no water on the surface 50, the region of the steel plate H that the sprayed cooling water hits is uniformly cooled. That is, since the direction in which the water on the surface 50 flows is the same as the plate passing direction of the steel plate H, the water on the surface 50 is seldom stirred. By suppressing stirring of the water on the surface 50 in this way, the steel plate H can be uniformly cooled.

[0053] According to the above embodiment, the spraying of the cooling water onto the upper surface of the steel plate H is controlled in each nozzle row group 22 or 23. For example, in a case where the required cooling capacity is high, that is, in a case where the required cooling water amount is smaller than the maximum water amount of the upstream spray nozzle row group 22 (the range of the upper solid line in the graph of FIG. 7), the cooling water of which the flow rate has been controlled by the flow rate regulating valve 41 is first supplied to the supply header 40. Then, both the on-off control valves 43 and 45 are opened, and cooling water is sprayed onto the upper surface of the steel plate H from all the nozzle row groups 22 and 23. In this case, since the nozzle load pressure of the full cone spray nozzle 20 is high, even if the water on the surface 50 accumulates on the steel plate H, the spray pattern of each full cone spray nozzle 20 can be secured and the water on the surface 50 is forcibly stirred as a whole. Thus, the steel plate H can be uniformly cooled. Accordingly, the steel plate H can be uniformly cooled to a predetermined temperature.

[0054] On the other hand, for example, in a case where the required cooling capacity is low, that is, in a case where the required cooling water amount is smaller than the maximum water amount of the upstream spray nozzle row group 22 (the range of the lower solid line in the graph of FIG. 7), the flow rate of cooling water is first controlled by the flow rate regulating valve 41, and this cooling water is supplied to the supply header 40. Then, only the on-off control valve 43 is opened, for example cooling water is sprayed onto the upper surface of the steel plate H only from the upstream spray nozzle row group 22 of the steel plate H, and the spraying of the cooling water from the downstream spray nozzle row group 23 of the steel plate is stopped. In this case, with the nozzle load pressure of the full cone spray nozzle 20 high and the spray pattern maintained, the amount of cooling water sprayed onto the steel plate H can be set to a predetermined water amount. Additionally, the water on the surface 50 on the steel plate H becomes a small amount, and the water on the surface 50 flows in the plate passing direction of the steel plate H, that is, to the downstream side of the steel plate H, with the movement of the steel plate H. For this reason, the cooling water sprayed to the upstream side of the steel plate H can cool the steel plate H uniformly without being influenced by the water on the surface 50. Accordingly, the steel plate H can be uniformly cooled to a predetermined temperature. According to the present embodiment as described above, the steel plate H can be uniformly cooled to a predetermined temperature while controlling the cooling capacity over a broad range.

[0055] Here, disadvantages in a case where cooling water is sprayed only from the downstream spray nozzle row group 23 will be described.
In this case, as shown in FIG. 10, the water on the surface 50 flows to the upstream side from a spraying region. Since the direction in which the water on the surface 50 flows and the plate passing direction of the steel plate H are reverse, an irregular flow occurs in the water on the surface 50, and cooling of the steel plate H becomes uneven in the width direction or the longitudinal direction on the upstream side of the spraying region. Accordingly, it is not preferable to spray cooling water only from the downstream spray nozzle row group 23.

[0056] Next, advantages in a case where the same full cone spray nozzles 20 are arranged in all the spray nozzle rows 21 a to 21i will be described. In this case, the cooling capacities of all the full cone spray nozzles 20 are the same in the upper cooling apparatus 11. As described above, in a case where spray nozzles different cooling capacities are used, cooling water becomes uneven with respect to the steel plate H. However, in the present embodiment, cooling water does not become uneven with respect to the steel plate H because the cooling water sprayed from the full cone spray nozzles 20 can be kept from affecting each other. For this reason, spraying of cooling water can be controlled in each of the downstream spray nozzle row group 23 and the upstream spray nozzle row group 22 to cope with a case where the required cooling capacity is high, a case where low or even a case at the boundary of the cooling capacity. Accordingly, the cooling capacity control range can be selected over a broad range. In addition, since the cooling capacities of all the full cone spray nozzles 20 are the same, there is also an effect that the control of the full cone spray nozzles 20 when cooling the steel plate H becomes easy.

[0057] Moreover, the ratio of the number of rows of all the spray nozzle rows 21a to 21 i and the number of rows of the spray nozzle rows 21a to 21c of the upstream spray nozzle row group 22 is set to the ratio of the maximum water amount and minimum water amount of each full cone spray nozzle 20. For this reason, in a case where the required cooling capacity has decreased, as described above, the spraying of the cooling water from the downstream spray nozzle row group 23 can be stopped at a suitable timing. Accordingly, the cooling capacity control range can be maximized, while securing the required cooling capacity.

[0058] Additionally, since the upstream spray nozzle row group 22 is arranged at a position where a water jet stream of the cooling water sprayed from the upstream spray nozzle row group 22 does not interfere with the water on the surface 50, the cooling water sprayed from the spray nozzle rows 21c of the downstream is not influenced by the water on the surface 50. Moreover, the spray pattern of each full cone spray nozzle 20 can be secured as described above. Accordingly, even in a case where the required cooling capacity is low, the steel plate H can be suitably cooled.

[0059] Although the steel plate H can be uniformly cooled in the present embodiment as described above, the inventors have verified this effect. Specifically, in a case where the required cooling water amount is smaller than the maximum water amount of the upstream spray nozzle row group 22, as shown in FIG. 9, cooling water was sprayed onto the steel plate H only from the upstream spray nozzle row group 22.

[0060] Then, the results when the width-direction distribution of the cooling rate from 750 to 600°C in a case where the steel plate H was cooled to 100°C or lower was measured are shown in FIG. 11. The horizontal axis of FIG. 11 represents the positions of the steel plate H in the width direction, and the vertical axis represents the cooling rates of the steel plate H in the respective positions in the width direction. Referring to FIG. 11, it is confirmed that the cooling rates become almost uniform in the width direction of the steel plate H, and the steel plate H can be uniformly cooled.

[Second Embodiment]

[0061] Next, a cooling system of a second embodiment of the present invention will be described.

FIGS. 12 to 15 show a second embodiment, and show a steel plate cooling system. Hereinafter, steel materials are thick plates, and members and apparatuses above a steel plate will be described. In the following description, the description of the same members as those of the first embodiment is omitted.

Additionally, the second embodiment is different from the first embodiment in that water supply headers are provided in the upstream spray nozzle row group and downstream spray nozzle row group, respectively, and that the flow rate regulating valve is provided in each water supply header.

[0062] A steel plate cooling system 100 includes an upper cooling apparatus 111 and a lower cooling apparatus 112. The upper cooling apparatus 111, as shown in FIG. 12, includes a small-flow-rate cooling unit (upstream spray nozzle row group) 110 and a large-flow-rate nozzle cooling unit (downstream spray nozzle row group) 130. The small-flow-rate cooling unit 110 and the large-flow-rate nozzle cooling unit 130 are arranged above the steel plate H.

The small-flow-rate cooling unit 110 includes a small-flow-rate water supply header (first water supply header) 117. The small-flow-rate water supply header 117 supplies cooling water to the small-flow-rate cooling unit 110. Additionally, the large-flow-rate nozzle cooling unit 130 includes a large-flow-rate water supply header (second supply header) 137. The large-flow-rate water supply header 137 supplies cooling water to the large-flow-rate nozzle cooling unit 130.

Additionally, the steel plate cooling system 100 includes a flow rate regulating valve (first flow rate regulating valve) 114 that adjusts the flow rate of the cooling water to be supplied to the small-flow-rate water supply header 117, and a flow rate regulating valve (second flow rate regulating valve) 134 that adjusts the flow rate of the cooling water to be supplied to the large-flow-rate water supply header 137.

Moreover, the flow rate regulating valves 114 and 134 are connected to a flow rate adjusting unit (control unit) 149. Moreover, a channel switching three-way valve 115 or 135 that is one of on-off control valves is connected to the flow rate adjusting unit 149.

The flow rate adjusting unit 149 controls the opening or closing of the flow rate regulating valves 114 and 134 and the channel switching three-way valves 115 and 135, and controls the cooling water made to be sprayed toward the steel plate H from a plurality of cooling water spray nozzles 126.

[0063] The small-flow-rate water supply header 117 is connected to a cooling water tank (not shown) via a small-flow-rate cooling water supply pipe 112. The flow rate regulating valve 114 and the channel switching three-way valve 115 are attached to the small-flow-rate cooling water supply pipe 112. One outlet of the channel switching three-way valve 115 is connected to the small-flow-rate water supply header 117 via the small-flow-rate cooling water supply pipe 112. Hereinafter, switching of this direction is referred to as opening. Additionally, the outer outlet of the channel switching three-way valve 115 is connected to the cooling water tank (not shown) via a return pipe (not shown). Hereinafter, switching of this direction is referred to as closing.

Similarly, the large-flow-rate nozzle cooling unit 130 also includes the large-flow-rate cooling water supply pipe 132, the flow rate regulating valve 134, and the channel switching three-way valve 135.

[0064] The flow rate regulating valve 114 of the small-flow-rate cooling unit 110 and the flow rate regulating valve 134 of the large-flow-rate nozzle cooling unit 130 preferably have degrees of opening that become a water supply amount density proportional to the ratio of the number of cooling water spray nozzles of the large-flow-rate nozzle cooling unit

130 to the number of cooling water spray nozzles of the small-flow-rate cooling unit 110. Thereby, the amount of cooling water from the cooling water spray nozzles 126 of the small-flow-rate cooling unit 110 and the amount of cooling water from cooling water spray nozzles 146 of the large-flow-rate nozzle cooling unit 130 are uniformly maintained, so that the steel plate H can be uniformly cooled.

[0065] The small-flow-rate cooling unit 110 includes a small-flow-rate nozzle header 122, and the large-flow-rate nozzle cooling unit 130 includes a large-flow-rate cooling water nozzle header 142. As shown in FIG. 13, small-flow-rate nozzle water supply pipes 119 are connected to the small-flow-rate nozzle header 122, and large-flow-rate nozzle water supply pipes 139 are connected to the large-flow-rate nozzle header 142. Moreover, the small-flow-rate cooling water spray nozzles 126 are attached to the small-flow-rate nozzle header 122, and the large-flow-rate cooling water spray nozzles 146 are attached to the large-flow-rate nozzle header 142.

[0066] The small-flow-rate cooling water spray nozzles 126 and the large-flow-rate cooling water spray nozzles 146 are the same. Additionally, the intervals of the small-flow-rate cooling water spray nozzles 126 and the large-flow-rate cooling water spray nozzles 146 in the plate passing direction are equal. Moreover, the intervals of the cooling water spray nozzles 126 and 146 of the adjacent small-flow-rate cooling unit 110 and large-flow-rate nozzle cooling unit 130 in the plate passing direction are also equal to the intervals of the other cooling water spray nozzles 126 and 146 in the plate passing direction. Thereby, deviation decreases in the accumulated amount of the water on the surface, and the steel plate is uniformly cooled.

[0067] As shown in FIG. 13, the small-flow-rate cooling water spray nozzles 126 penetrates through a bottom plate 124 of the small-flow-rate nozzle header 122, cooling water inlets 127 of upper ends thereof are located near a top plate 123, and jetting ports 28 of lower ends thereof protrude downward from the bottom plate 124. The large-flow-rate nozzle header 142 has the same structure as the small-flow-rate nozzle header 122, and the large-flow-rate cooling water spray nozzles 146 have the same structure as the small-flow-rate cooling water spray nozzles 126.

[0068] It is preferable that the interval g between the top plate 123 of the small-flow-rate nozzle header 122 and the cooling water inlets 127 of the small-flow-rate cooling water spray nozzles 126 and the interval g between the top plate 143 of the large-flow-rate nozzle header 142 and cooling water inlets 147 of the large-flow-rate cooling water spray nozzles 146 be set to 3 to 8 mm. If the interval g is less than 3 mm, the pressures applied to the cooling water inlets do not become equal, and water is apt to come out in the cooling water spray nozzles nearest to the nozzle water supply pipes 119 and 139. Thereby, the difference between the amounts of water sprayed from the respective spray nozzles 126 and 146 may occur. Additionally, if the interval g exceeds 8 mm, excessive time is taken until the small-flow-rate nozzle header 122 and the large-flow-rate nozzle header 142 are filled with water after water filling begins. Moreover, if the interval g exceeds 8 mm, when the water filling from the cooling water spray nozzles 126 and 146 is stopped, water will drip from the cooling water spray nozzles 126 and 146 until all the water accumulated between the cooling water inlets 127 and 147 and the top plates 123 and 142 of the headers is exhausted.

Additionally, a small-flow-rate cooling unit 150 and a large-flow-rate nozzle cooling unit 170 below the steel plate H that are the same as the small-flow-rate cooling unit 110 and the large-flow-rate nozzle cooling unit 130 are arranged above the steel plate H. In the small-flow-rate cooling unit 150 and the large-flow-rate nozzle cooling unit 170, the intervals g are respectively the interval g between a bottom plate 164 of a small-flow-rate nozzle header 162 and cooling water inlets 167 of small-flow-rate cooling water spray nozzles 166 and the interval g between a bottom plate 184 of a large-flow-rate nozzle header 182 and cooling water inlets 187 of large-flow-rate cooling water spray nozzles 186.

[0069] FIG. 14 schematically shows the arrangement of the small-flow-rate cooling water spray nozzles 126 (166) and the large-flow-rate cooling water spray nozzles 146 (186). As shown in FIG. 14, a number of the small-flow-rate cooling water spray nozzles 126 (166) and a number of the large-flow-rate cooling water spray nozzles 146 (186) are arranged at regular intervals, respectively, in the steel plate width direction and the steel plate conveying direction. Additionally, the small-flow-rate cooling water spray nozzles 126 (166) and the large-flow-rate cooling water spray nozzles 146 (186) have the same nozzle diameter, and the number of the small-flow-rate cooling water spray nozzles is smaller than the number of the large-flow-rate cooling water spray nozzles.

[0070] FIG. 15 shows the relationship between the water supply amount density ($m^3/m^2/min$) and the nozzle water supply pressure (MPa).

[0071] A spray pattern securing limit pressure is a nozzle water supply pressure (for example, 30 kPa) of whether or not a predetermined spray pattern determined according to the nozzle can be secured. In order to cool a hot steel plate uniformly, it is necessary to set the nozzle water supply pressure to be equal to or higher than the spray pattern securing limit pressure. For this reason, in the cooling of the steel plate (steel material) H, a water supply amount density for obtaining a required cooling rate (determined depending on the constituents of the steel material and the material quality to be secured) is determined. This determines whether water is supplied to both the small-flow-rate nozzle header 122 and the large-flow-rate nozzle header 142 or to any one of the headers, using the flow rate adjusting unit 149, in a region in which the nozzle water supply pressure is equal to or higher than the spray pattern securing limit pressure with reference to the water supply amount density and FIG. 15.

[0072] Specifically, cooling water is supplied to both the small-flow-rate nozzle header 122 and the large-flow-rate nozzle header 142 if the determined water supply amount density is within a range of b to c as shown in FIG. 15, and cooling water is supplied only to the small-flow-rate nozzle header 122 if the water supply amount density is within a range of a to b. Additionally, the spraying water amount and fuel spraying pressure from the respective nozzles via the small-flow-rate nozzle header 122 and the large-flow-rate nozzle header 142 are adjusted by the flow rate regulating valves 114 and 134 so as to become constant.

[0073] The steel plate cooling system 100, as shown in FIG. 12, includes the flow rate adjusting unit 149 on the steel plate upper surface side. The flow rate adjusting unit 149 controls the cooling water to be sprayed toward the steel plate H from the small-flow-rate cooling water spray nozzles 126 and the large-flow-rate cooling water spray nozzles 146. In the flow rate adjusting unit 149, a cooling rate is determined by, for example, a host computer from the constituents of a target steel plate, mechanical properties (material quality), or the like, and a zone water supply amount density is obtained from this cooling rate and the plate thickness of the target steel plate. Moreover, in the flow rate adjusting unit 149, a nozzle header (both the large-flow-rate water supply header 137 and the small-flow-rate water supply header 117, or only the small-flow-rate water supply header 117) to be used is determined from the zone water supply amount density and FIG. 15.

[0074] The zone water supply amount density obtained in this way, and the information on a nozzle header to supply water are input to the flow rate adjusting unit 149. Here, in a case where the nozzle header information relates to using both the large-flow-rate water supply header 137 and the small-flow-rate water supply header 117, a water supply amount density ratio is further input to the flow rate adjusting unit 149. Then, the flow rate adjusting unit 149 input the valve opening signals of the flow rate regulating valves 114 and 134, and the signals for opening the channel switching three-way valves 115 and 135, on the basis of the input zone water supply amount density, nozzle header information, and water supply amount density ratio. Additionally, in a case where the nozzle header information relates to using only the large-flow-rate water supply header 137, the flow rate adjusting unit 149 closes the channel switching three-way valve 115, and opens the channel switching three-way valve 135, and outputs the valve opening signal of the flow rate regulating valve 134. Additionally, in a case where the nozzle header information relates to using only the small-flow-rate water supply header 117, the flow rate adjusting unit 149 closes the channel switching three-way valve 135, and opens the channel switching three-way valve 115, and outputs the valve opening signal of the flow rate regulating valve 114. Additionally, a flow rate adjusting unit 189 on the lower surface side of the steel plate H (control unit) is also the same.

[0075] Although the cooling units 110 and 130 (upper cooling apparatus 111) above the steel plate have been described above, the cooling units 150 and 170 (lower cooling apparatus 112) below the steel plate H also have the same structure as the upper cooling apparatus. That is, a cooling water supply pipe 152, a water supply header 157, a nozzle water supply pipe 159, the nozzle header 162, the cooling water spray nozzles 166, and a cooling water supply pipe 172, a water supply header 177, a nozzle water supply pipe 179, the nozzle header 182, and the cooling water spray nozzles 186 have the same structure as the upper cooling apparatus 111 above the steel plate H. Additionally, the flow rate regulating valves 154 and 174, the channel switching three-way valves 155 and 175, and the flow rate adjusting unit 189 also have the same structure as the upper cooling apparatus 111 above the steel plate H.

[0076] Here, an example of the manipulation and operation of the steel plate cooling system 100 configured as described above will be described.

[0077] Before the steel plate cooling system 100 receives a rolled hot steel plate H, the zone water supply amount density (For example, 1.5 $m^3/m^2/min$) of a cooling zone where the steel plate cooling system 100 is arranged, information on a nozzle header to supply water (for example, the large-flow-rate water supply header 137 and the small-flow-rate water supply header 117), and the water supply amount density ratio (for example, 2.0) of the large-flow-rate nozzle cooling unit 130 to the small-flow-rate cooling unit 110 are input to the flow rate adjusting unit 189 above the steel plate H top from the host computer. Thereby, the flow rate adjusting unit 149 determines the respective water supply amount densities (For example, small-flow-rate cooling unit: 0.5 $m^3/m^2/min$, and large-flow-rate nozzle cooling unit: 1.0 $m^3/m^2/min$) of the small-flow-rate cooling unit 110 and the large-flow-rate nozzle cooling unit 130, determines the opening degrees of the flow rate regulating valves 114 and 134 on the basis of the determined respective water supply amount densities, and outputs to the flow rate regulating valves 114 and 134 the opening degree information from which the above water supply amount densities are obtained. The flow rate regulating valves 114 and 134 operate if this opening degree information is input, and have opening degrees corresponding to the information. Thereby, the cooling water of the small-flow-rate cooling water supply pipe 112 passes sequentially through the small-flow-rate water supply header 117 and the small flow rate nozzle water supply pipes 119, and flows into the small flow rate unit 122. Additionally, the cooling water of the large-flow-rate cooling water supply pipe 132, similar to above, passes sequentially through the large-flow-rate water supply header 137 and the large-flow-rate nozzle water supply pipes 139, and flows into the large flow rate unit 142. The small flow rate unit 122 and the large flow rate unit 142 are filled with cooling water in a short time, and the cooling water is sprayed almost simultaneously from the small-flow-rate-side cooling water spray nozzles 126 of the small flow rate unit 122, and the large-flow-rate-side cooling water spray nozzles 146 of the large flow rate unit 142.

[0078] In addition, the water supply amount density ratio to be output from the above host computer to the flow rate adjusting units 149 and 189 is calculated from the cooling zone water supply amount density. However, although it is preferable that the water supply amount density ratio be a water supply amount density ratio proportional to the number of nozzles of the large-flow-rate nozzle header 142 to the number of nozzles of the small-flow-rate nozzle header 122 or a value close thereto, in either case, it is necessary to set the pressures within both the headers 122 and 142 to a value equal to or higher than the spray pattern securing limit pressure. Additionally, the cooling units 150 and 170 below the steel plate H are similarly adjusted.

[0079] If the hot steel plate H is passed in the above state and its cooling is started, when the hot steel plate H passes through the steel plate cooling system 100, water filling stop information is input from the host computer to the flow rate adjusting unit 149. Thereby, by outputting the closing signals of the channel switching three-way valves 115 and 135 from the flow rate adjusting unit 149, the channel switching three-way valves 115 and 135 are closed to stop water supply. Accordingly, the spraying of the cooling water from the small-flow-rate cooling water spray nozzle 122 and the large-flow-rate cooling water spray nozzles 146 stops immediately.

[0080] Although a case where cooling water is sprayed from both the small flow rate cooling unit 110 and the large flow rate cooling unit 130 has been described above, in a case where cooling water is sprayed only from the small flow rate unit 110, the zone water supply amount density in the cooling zone where the steel plate cooling system 100 is arranged, and the information on a nozzle header (small-flow-rate water supply header 117) to supply water are input from the host computer to the flow rate adjusting units 149 and 189. Thereby, the opening degree of the flow rate regulating valve 114 of the unit 110 that is a water supply target is determined, and actuating signals are output from the host computer to the flow rate adjusting units 149 and 189, similar to above, with respect to the flow rate regulating valve 114 and the channel switching three-way valve 115.

[0081] The present invention is not limited to the above first and the second embodiments. That is,

(A) although the plate thickness has been described in the embodiments, the present invention is may also be used for a thin plate and a shaped steel. Additionally, a thick plate is also available for a roller quencher that is a cooling facility after heat treatment.
(B) Although the flow rate adjusting units (control units) 149 and 189 are provided in the upper cooling apparatus and the lower cooling apparatus, respectively, one flow rate adjusting unit may control both the upper cooling apparatus and the lower cooling apparatus.
(C) Although the full cone nozzles have been described in the above embodiments, other types of nozzles can also be used in the present invention.
(D) In the above respective embodiment, the nozzle types and number of rows of the upper cooling apparatus and the lower cooling apparatus may differ.

[0082] Although the preferred first and second embodiments of the present invention have been described above referring to the accompanying drawings, the present invention is not limited to these embodiments. It is apparent to those skilled in the art that various alterations or modifications are conceivable in the category of the idea set forth in the claims, and it will be understood that these alterations or modifications naturally belongs to the technical scope of the present invention.

Industrial Applicability

[0083] The present invention is useful when a steel plate obtained by hot rolling is cooled while allowing the steel plate to pass horizontally and restrictively between constraining rolls.

Reference Signs List

[0084]

H:	STEEL PLATE
1:	COOLING SYSTEM
2:	FINISH ROLLING MACHINE
3:	HOT CORRECTING DEVICE
10a:	CONSTRAINING ROLL

10b: CONVEYING ROLL

10: CONSTRAINING ROLL PAIR

11: UPPER COOLING APPARATUS

12: LOWER COOLING APPARATUS

20: FULL CONE SPRAY NOZZLE

21a to 21i: SPRAY NOZZLE ROW

22: UPSTREAM SPRAY NOZZLE ROW GROUP

23: DOWNSTREAM SPRAY NOZZLE ROW GROUP

24: SUPPLY PIPE

30: NOZZLE BOX

31: UPSTREAM STORAGE CHAMBER

32: DOWNSTREAM STORAGE CHAMBER

40: HEADER

41: FLOW RATE REGULATING VALVE

42: PIPING

43: ON-OFF CONTROL VALVE

44: PIPING

45: ON-OFF CONTROL VALVE

50: WATER ON THE SURFACE

100: STEEL PLATE COOLING SYSTEM

110, 150: SMALL-FLOW-RATE COOLING UNIT

112, 152: SMALL-FLOW-RATE COOLING WATER SUPPLY PIPE

114, 154: FLOW RATE REGULATING VALVE

115, 155: CHANNEL-SWITCHING THREE-WAY VALVE

117, 157: SMALL-FLOW-RATE WATER SUPPLY HEADER

119, 159: SMALL-FLOW-RATE NOZZLE WATER SUPPLY PIPE

122, 162: SMALL-FLOW-RATE NOZZLE HEADER

126, 166: SMALL-FLOW-RATE COOLING WATER SPRAY NOZZLE

130, 170: LARGE-FLOW-RATE NOZZLE COOLING UNIT

132, 172: LARGE-FLOW-RATE COOLING WATER SUPPLY PIPE

134, 174: FLOW RATE REGULATING VALVE

135, 175: CHANNEL SWITCHING THREE-WAY VALVE

137, 177: LARGE-FLOW-RATE WATER SUPPLY HEADER

139, 179: LARGE-FLOW-RATE NOZZLE WATER SUPPLY PIPE

142, 182: LARGE-FLOW-RATE NOZZLE HEADER

146, 186: LARGE-FLOW-RATE COOLING WATER SPRAY NOZZLE

149, 189: FLOW RATE ADJUSTING UNIT

Claims

1. A steel plate cooling system comprising:

a plurality of constraining roll pairs that allows a steel plate to pass restrictively therebetween; and
an upper cooling apparatus and a lower cooling apparatus that are arranged between the constraining roll pairs so as to be opposed to each other with the steel plate interposed therebetween and have a plurality of spray nozzle rows,
wherein the plurality of spray nozzle rows is formed in a plate passing direction of the steel plate, and each of the spray nozzle rows has a plurality of identical spray nozzles lined up in a width direction of the steel plate,
wherein when viewed in the plate passing direction, the spray nozzle rows are each classified into an upstream spray nozzle row group located on a relative upstream side and a downstream spray nozzle row group located on a relative downstream side, and
wherein a number of spray nozzles that belong to the upstream spray nozzle row group is smaller than a number of spray nozzles that belong to the downstream spray nozzle row group.

2. The steel plate cooling system according to Claim 1,
wherein a ratio of a total number of the respective spray nozzle rows and a number of spray nozzle rows that belong to the upstream spray nozzle row group is equal to or an integer ratio approaching the ratio of a maximum spraying amount and minimum spraying amount of each spray nozzle that belongs to the spray nozzle rows.

3. The steel plate cooling system according to Claim 2, further comprising a control unit that controls a cooling water to be sprayed toward the steel plate from the plurality of spray nozzle rows,
wherein the control unit controls the spraying of the cooling water so that the cooling water is caused to be sprayed from both the upstream spray nozzle row group and the downstream spray nozzle row group in a case where a total amount of water to be sprayed toward the steel plate is equal to or larger than a maximum spraying amount of the upstream spray nozzle row group, and the cooling water is caused to be sprayed only from the upstream spray nozzle row group in a case where the total amount of water is smaller than the maximum spraying amount of the upstream spray nozzle row group.

4. The steel plate cooling system according to Claim 3, further comprising:

a water supply header that supplies the cooling water to the upstream spray nozzle row group and the downstream spray nozzle row group;
a flow rate regulating valve that regulates the flow rate of the cooling water to be supplied to the water supply header;
a first control valve that controls a permission or prohibition of supply of the cooling water to be supplied from the water supply header to the upstream spray nozzle row group; and
a second control valve that controls a permission or prohibition of supply of the cooling water to be supplied from the water supply header to the downstream spray nozzle row group.

5. The steel plate cooling system according to Claim 1, further comprising:

a first water supply header that supplies a cooling water to the upstream spray nozzle row group;
a second water supply header that supplies a cooling water to the downstream spray nozzle row group;
a first flow rate regulating valve that regulates a flow rate of the cooling water to be supplied to the first water supply header;
a second flow rate regulating valve that regulates a flow rate of the cooling water to be supplied to the second water supply header; and
a control unit that controls the cooling water to be sprayed toward the steel plate from the plurality of spray nozzle rows,
wherein the control unit controls the spraying of the cooling water so that the cooling water is caused to be sprayed from both the upstream spray nozzle row group and the downstream spray nozzle row group in a case where a total amount of water to be sprayed toward the steel plate is equal to or larger than a maximum spraying amount of the upstream spray nozzle row group, and the cooling water is caused to be sprayed only from the upstream spray nozzle row group in a case where the total amount of water is smaller than the maximum spraying amount of the upstream spray nozzle row group.

6. The steel plate cooling system according to any one of Claims 1 to 5,
wherein a mutually adjacent intervals, in the plate passing direction, of the respective spray nozzle rows that belong to the upstream spray nozzle row group are the same, and
wherein a mutually adjacent intervals, in the plate passing direction, of the respective spray nozzle rows that belong to the downstream spray nozzle row group are the same.

7. The steel plate cooling system according to any one of Claims 1 to 5,
wherein all the adjacent intervals of the respective spray nozzle rows in the plate passing direction are the same.

8. The steel plate cooling system according to any one of Claims 1 to 5,
wherein the upstream spray nozzle row group is arranged so that a cooling water is sprayed from the upstream spray nozzle row group toward a position of the upstream side in the plate passing direction not overlapped with a region of a water flow on a surface that accumulates on the steel plate when a maximum spraying amount is caused to be sprayed from the upstream spray nozzle row group.

9. A steel plate cooling method, when a steel plate is cooled using the steel plate cooling system according to any one of Claims 3 to 5,
the spraying of the cooling water is controlled by the control unit so that the cooling water is caused to be sprayed from both the upstream spray nozzle row group and the downstream spray nozzle row group in a case where the total amount of water to be sprayed toward the steel plate is equal to or larger than the maximum spraying amount of the upstream spray nozzle row group, and the cooling water is caused to be sprayed only from the upstream spray nozzle row group in a case where the total amount of water is smaller than the maximum spraying amount of the upstream spray nozzle row group.

10. The steel plate cooling method according to Claim 9,
wherein a region of a water flow on a surface that accumulates on the steel plate when the cooling water is caused to be sprayed with the maximum spraying amount from the upstream spray nozzle row group is obtained in advance, and
wherein the upstream spray nozzle row group is arranged so that the cooling water is sprayed from the upstream spray nozzle row group toward a position of the upstream side in the plate passing direction not overlapped with the region.

FIG. 1

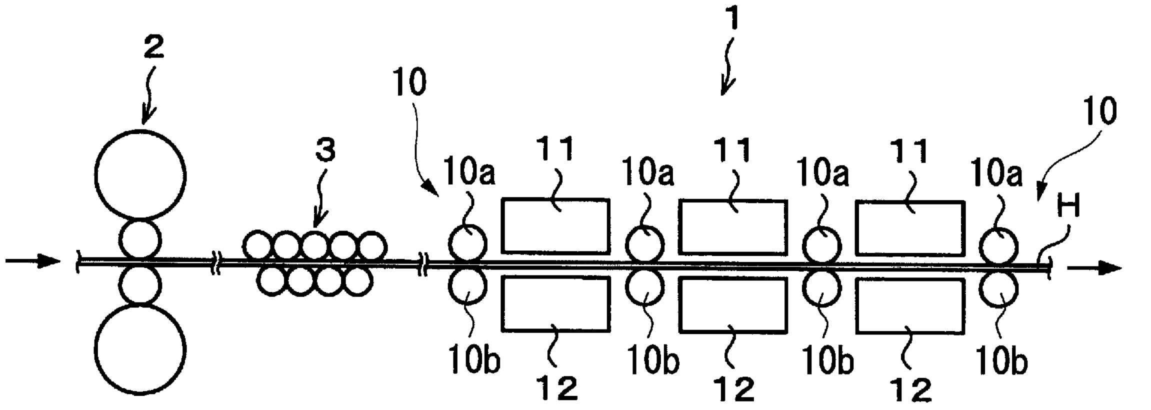

2
3
10
1
10
10a
11
10a
11
10a
11
10a
H
10b
12
10b
12
10b
12
10b

FIG. 2

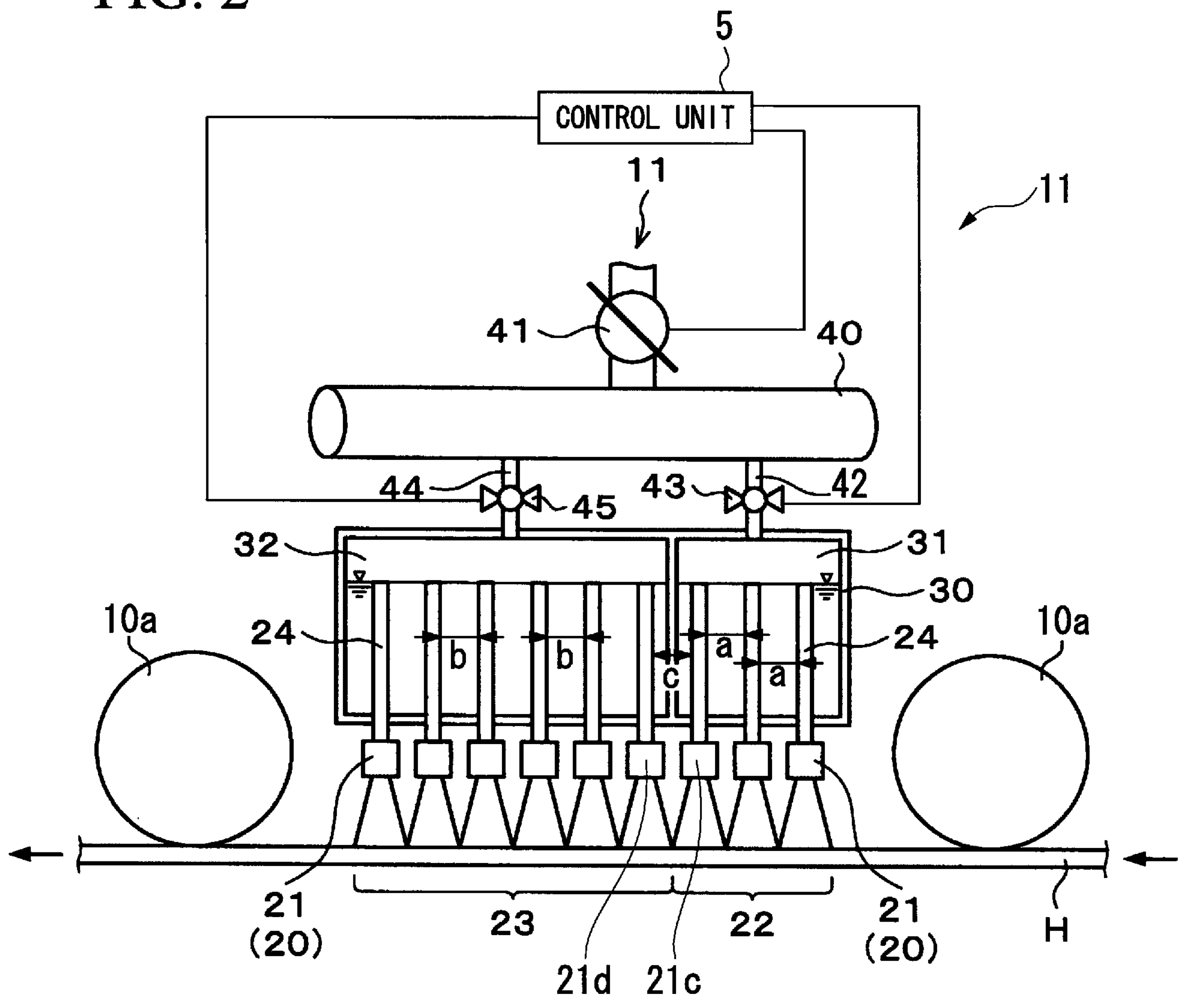

5
CONTROL UNIT
11
11
41
40
44
45
43
42
32
31
30
10a
24
b
b
c
a
a
24
10a
21
(20)
23
22
21
(20)
H
21d
21c

FIG. 3

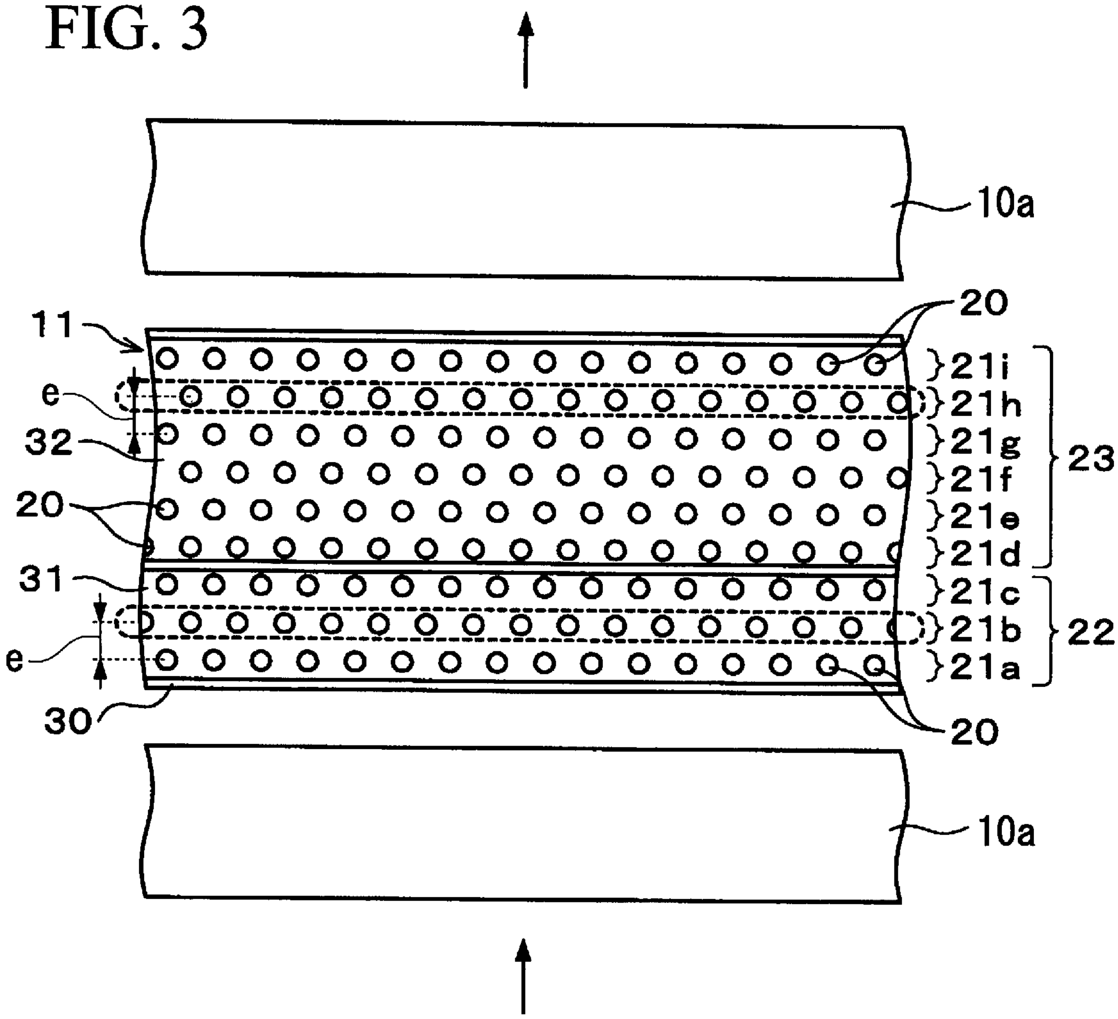

10a
11
20
e
32
20
31
e
30
21i
21h
21g
21f
21e
21d
21c
21b
21a
23
22
20
10a

FIG. 4

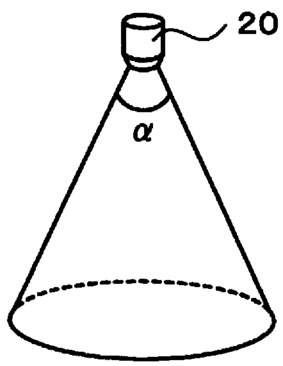

20
α

FIG. 5

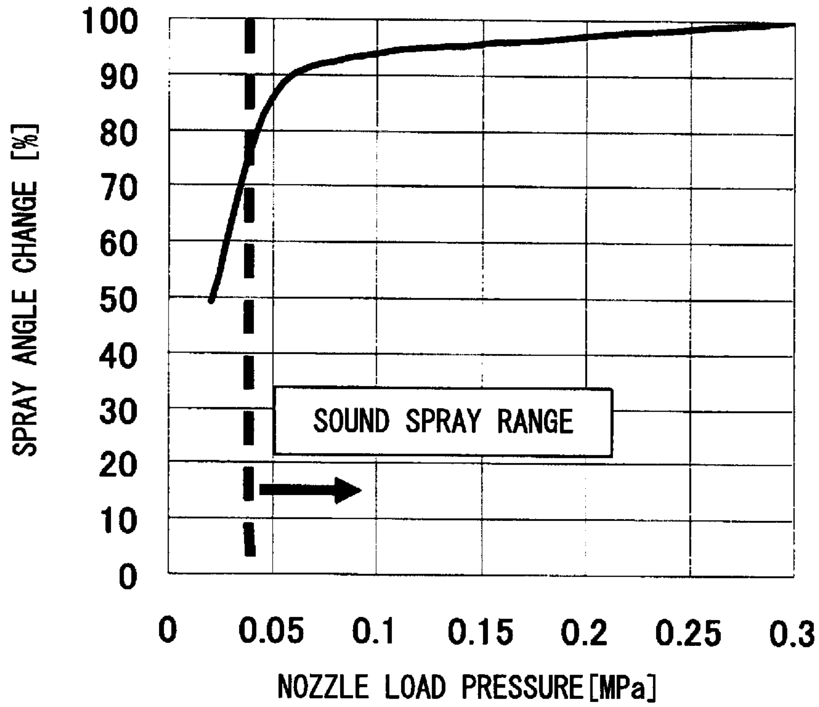

100
90
80
70
60
50
40
30
20
10
0
SPRAY ANGLE CHANGE [%]
SOUND SPRAY RANGE
0
0.05
0.1
0.15
0.2
0.25
0.3
NOZZLE LOAD PRESSURE[MPa]

FIG. 6

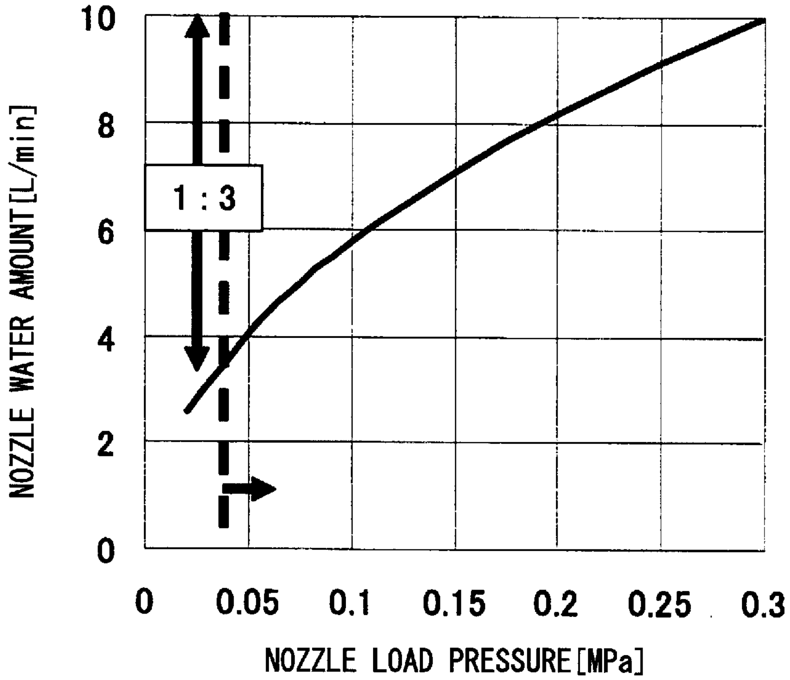

10
8
6
4
2
0
NOZZLE WATER AMOUNT[L/min]
1 : 3
0
0.05
0.1
0.15
0.2
0.25
0.3
NOZZLE LOAD PRESSURE[MPa]

FIG. 7

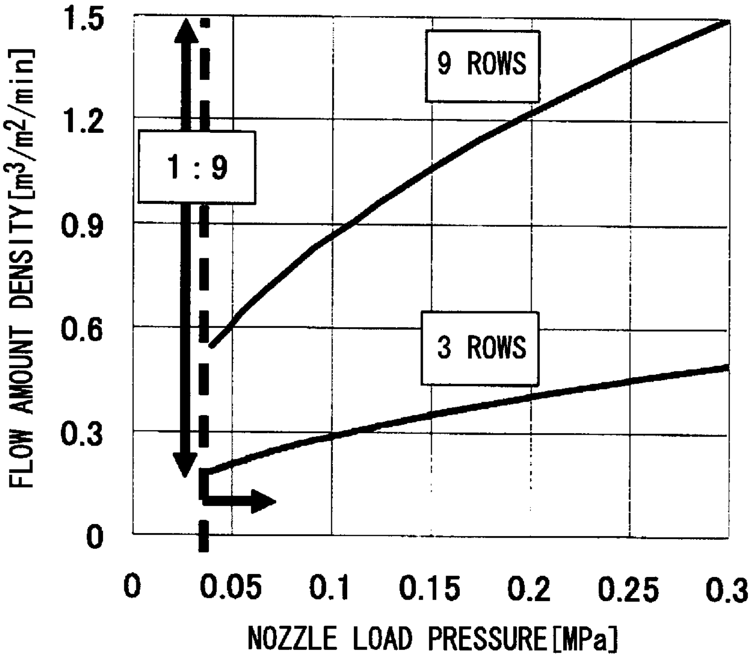

FLOW AMOUNT DENSITY[m3/m2/min]
NOZZLE LOAD PRESSURE[MPa]
1.5
1.2
0.9
0.6
0.3
0
0
0.05
0.1
0.15
0.2
0.25
0.3
9 ROWS
3 ROWS
1 : 9

FIG. 8

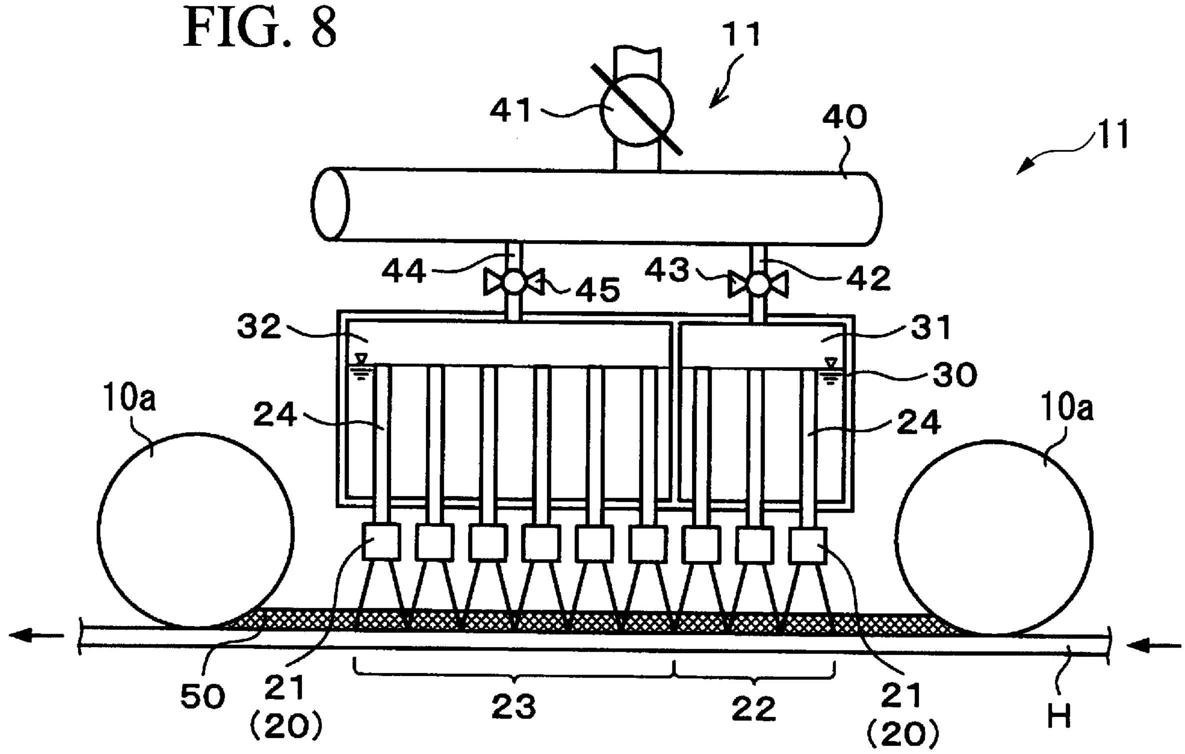

11
41
40
11
44
45
43
42
32
31
30
10a
24
24
10a
50
21
(20)
23
22
21
(20)
H

FIG. 9

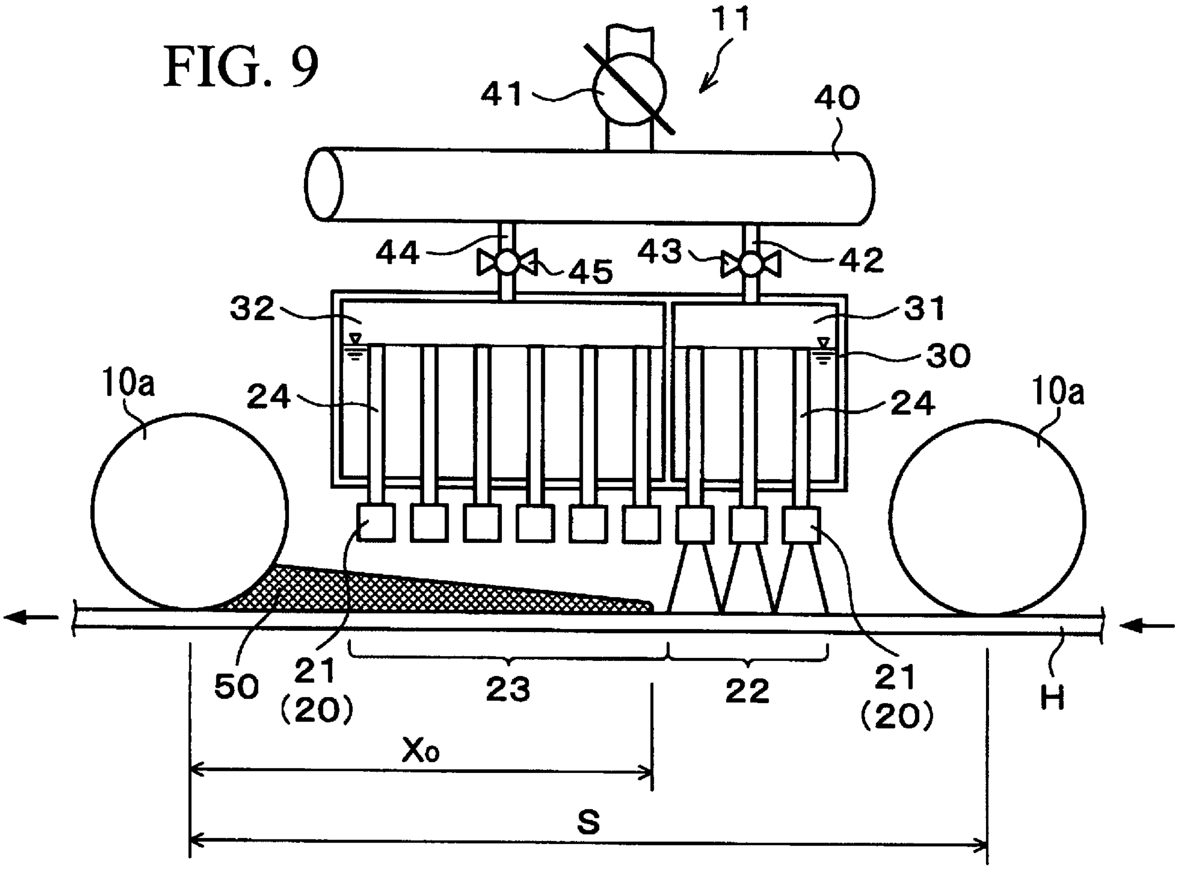


FIG. 10

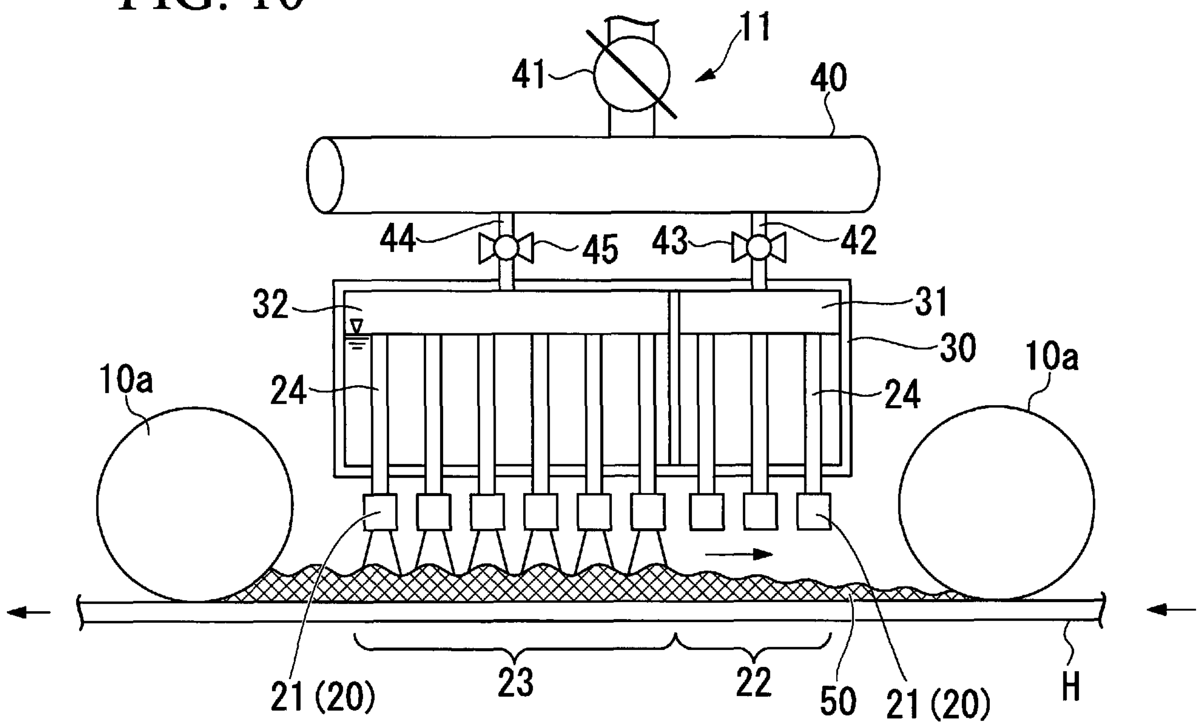

11
41
40
44
45
43
42
32
31
30
10a
24
24
10a
21 (20)
23
22
50
21 (20)
H

FIG. 11

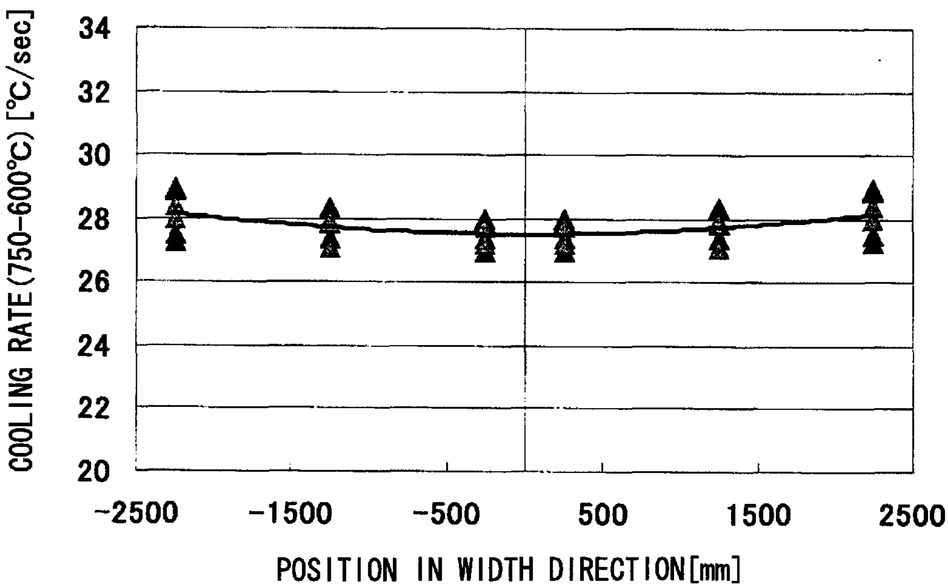

COOLING RATE (750-600°C) [°C/sec]
34
32
30
28
26
24
22
20
-2500
-1500
-500
500
1500
2500
POSITION IN WIDTH DIRECTION[mm]

FIG. 12

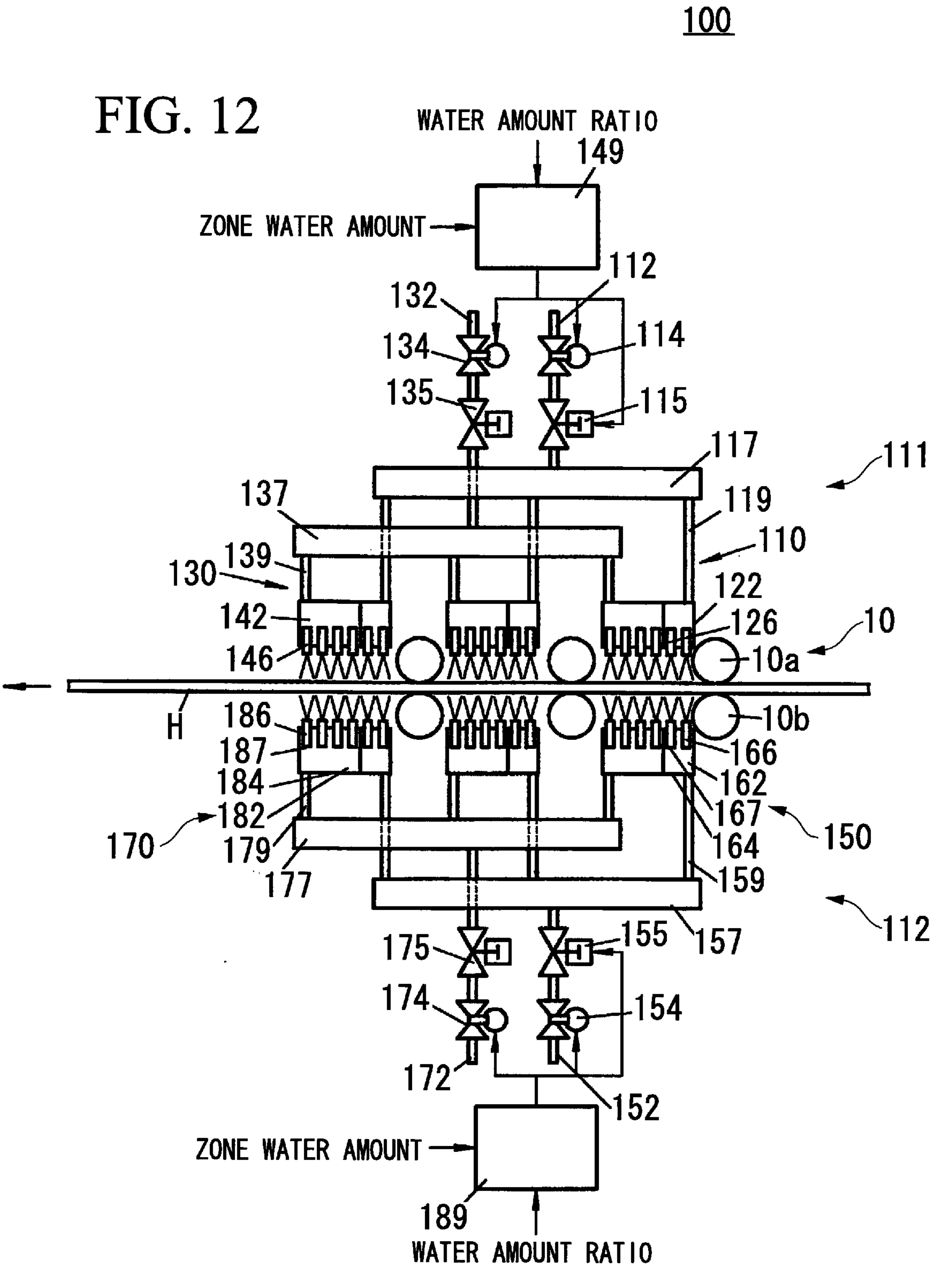

100
WATER AMOUNT RATIO
149
ZONE WATER AMOUNT
112
132
114
134
135
115
117
111
137
119
110
139
130
122
142
126
10
146
10a
H
186
10b
187
166
184
162
182
167
150
170
179
164
177
159
157
112
175
155
174
154
172
152
ZONE WATER AMOUNT
189
WATER AMOUNT RATIO

FIG. 13

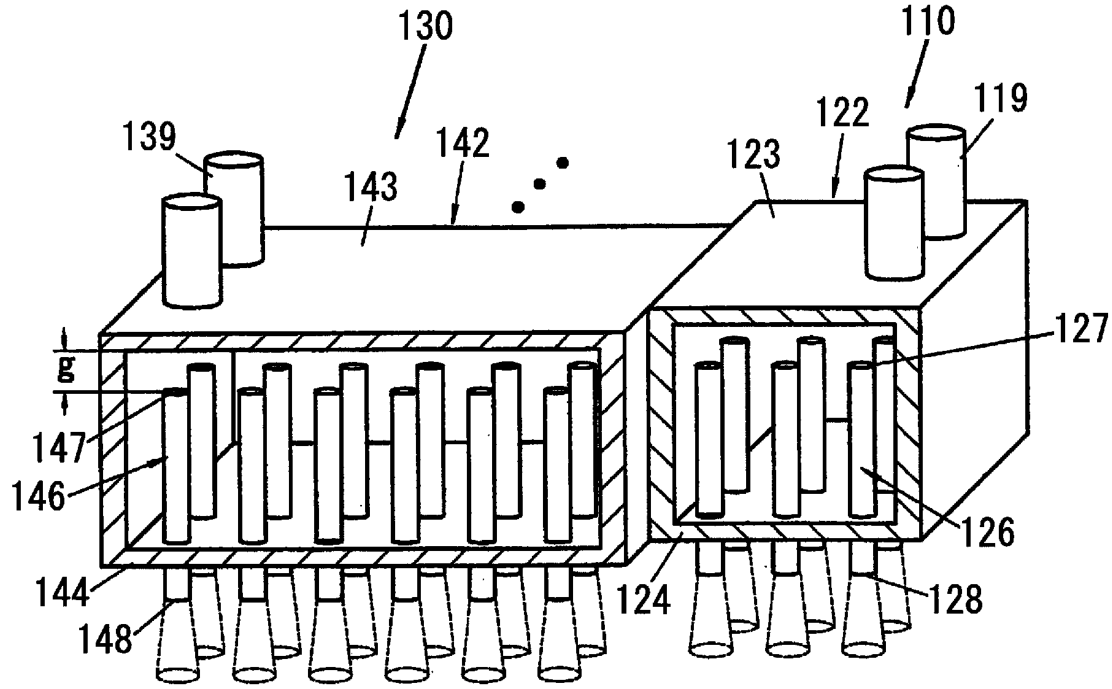

130
110
139
142
143
122
123
119
127
g
147
146
126
144
124
128
148

FIG. 14

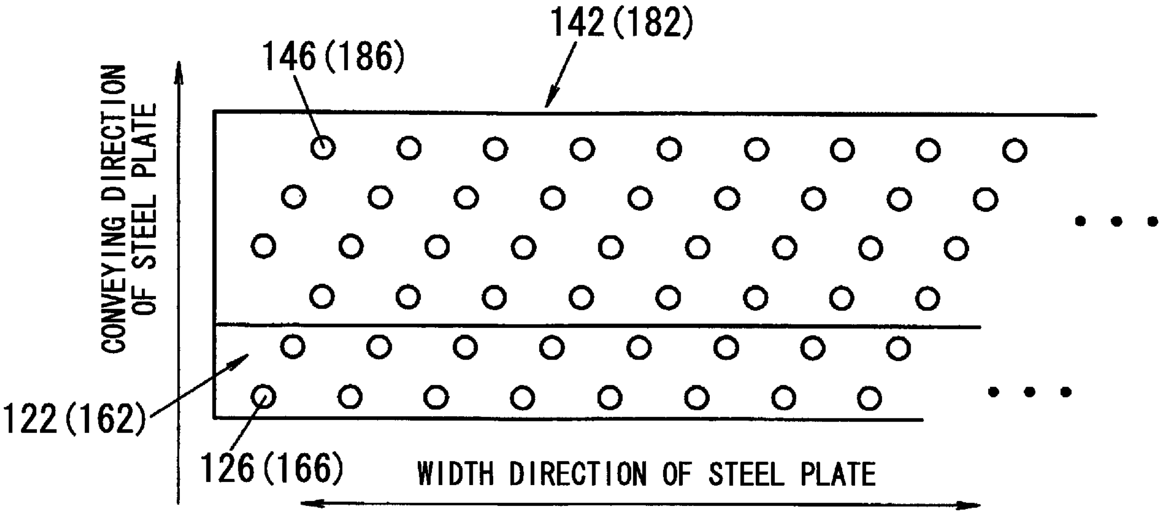
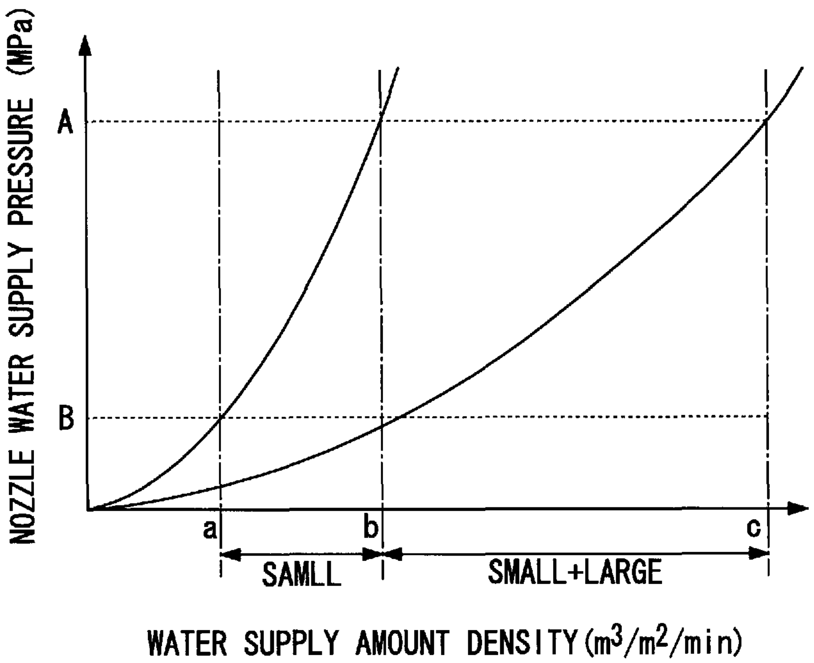

142 (182)
146 (186)
CONVEYING DIRECTION OF STEEL PLATE
122 (162)
126 (166)
WIDTH DIRECTION OF STEEL PLATE

FIG. 15


NOZZLE WATER SUPPLY PRESSURE (MPa)
A
B
a
b
c
SAMLL
SMALL+LARGE
WATER SUPPLY AMOUNT DENSITY(m3/m2/min)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/066742

A. CLASSIFICATION OF SUBJECT MATTER
B21B45/02(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B21B45/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	WO 2008/35510 A1 (Nippon Steel Corp.), 27 March 2008 (27.03.2008), fig. 2(a) & US 2009/0121396 A1 & EP 1944099 A1 & WO 2008/035510 A1 & KR 10-2008-0089600 A & CN 101374613 A & RU 2008129687 A	1,6,7 2-5,8-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 August, 2011 (04.08.11)	16 August, 2011 (16.08.11)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2010164522 A **[0001]**
- JP 2010234715 A **[0001]**
- JP 2006082115 A **[0009]**
- JP 2007301568 A **[0009]**
- JP 2006219732 A **[0009]**