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## (54) HOISTING TYPE CONTINUOUS CASTING DEVICE AND HOISTING TYPE CONTINUOUS CASTING METHOD

(57) A pulling-up-type continuous casting apparatus according to the present invention includes: a holding furnace that holds a molten metal; a draw-out part that draws out the molten metal from a molten-metal surface of the molten metal that is held in the holding furnace; a shape-defining member that defines a cross-sectional shape of a cast-metal article to be cast by applying an external force to a held molten metal which is an unsolidified molten metal that has been drawn out by the draw-out part, the shape-defining member being located in the vicinity of the molten-metal surface; and a temperature measurement unit that measures the temperature of the held molten metal, in which the temperature of the held molten metal is controlled based on the result of measurement in the temperature measurement unit.

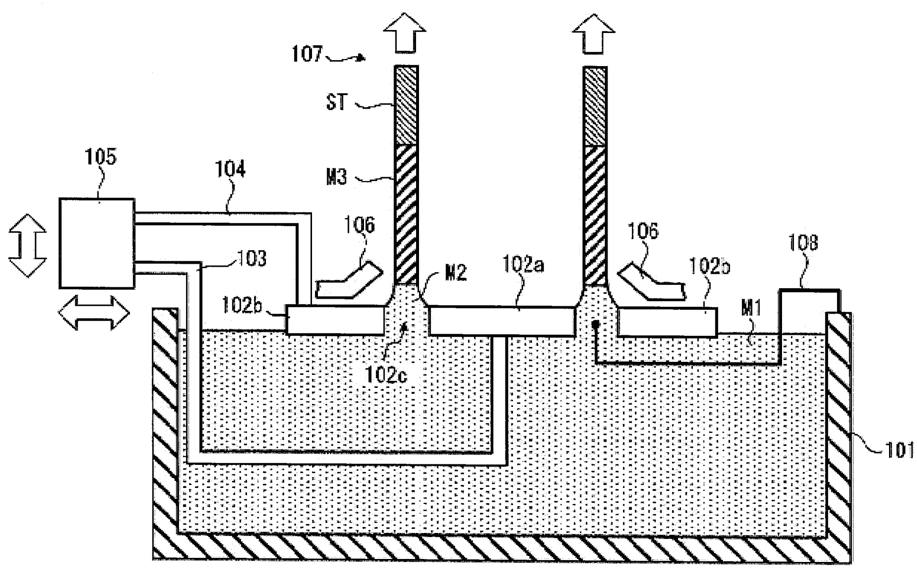


Fig. 1

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## Description

### Technical Field

**[0001]** The present invention relates to a pulling-up-type continuous casting apparatus and a pulling-up-type continuous casting method.

### Background Art

**[0002]** In Patent Literature 1, a free casting method is proposed by the present inventors as an epoch-making continuous casting method that does not require a mold. As shown in Patent Literature 1, when a starter is pulled up after it is immersed into the surface of a melted metal (molten metal) (in other words, the molten-metal surface), the molten metal is also drawn out following the starter by the surface film or surface tension of the molten metal. Here, by drawing out the molten metal through a shape-defining member that is located in the vicinity of the molten-metal surface and cooling the molten metal, a cast-metal article with a desired cross-sectional shape can be cast continuously.

**[0003]** In an ordinary continuous casting method, not only the cross-sectional shape but also the longitudinal shape is defined by a mold. In particular, the cast-metal article that is produced by a continuous casting method has a shape that is linearly elongated in its longitudinal direction because the solidified metal (in other words, the cast-metal article) must be passed through a mold.

**[0004]** In contrast, a shape-defining member that is used in a free casting method defines only the cross-sectional shape of the cast-metal article and does not define the longitudinal shape of the cast-metal article. In addition, because the shape-defining member is movable in directions parallel to the molten-metal surface (in other words, horizontal directions), cast-metal articles with different longitudinal shapes can be obtained. For example, a hollow cast-metal article (in other words, a pipe) that is formed to have a zigzag or spiral, not linear, configuration along its length is disclosed in Patent Literature 1.

### Citation List

### Patent Literature

**[0005]** **[Patent Literature 1]** Japanese Unexamined Patent Application Publication No. 2012-61518

### Summary of Invention

### Technical Problem

**[0006]** The present inventors have found the following problem.

**[0007]** According to the free casting method disclosed in Patent Literature 1, it is impossible to accurately control the temperature of the unsolidified molten metal that has been pulled up from the molten-metal surface following the starter (held molten metal). Thus, according to the free casting method disclosed in Patent Literature 1, it is impossible to accurately control the speed at which the starter is pulled up.

**[0008]** The present invention has been made in view of the above circumstances and aims to provide a pulling-up-type continuous casting apparatus and a pulling-up-type continuous casting method in which the speed at which the starter is pulled up can be accurately controlled by accurately controlling the temperature of the held molten metal.

### Solution to Problem

**[0009]** A pulling-up-type continuous casting apparatus according to one aspect of the present invention includes: a holding furnace that holds a molten metal; a draw-out part that draws out the molten metal from a molten-metal surface of the molten metal that is held in the holding furnace; a shape-defining member that defines a cross-sectional shape of a cast-metal article to be cast by applying an external force to a held molten metal which is an unsolidified molten metal that has been drawn out by the draw-out part, the shape-defining member being located in the vicinity of the molten-metal surface; and a temperature measurement unit that measures the temperature of the held molten metal, in which the temperature of the held molten metal is controlled based on the result of measurement in the temperature measurement unit. According to this structure, the temperature of the held molten metal can be accurately controlled, whereby it is possible to accurately control the speed at which the starter is pulled up.

**[0010]** It is preferable that the temperature measurement unit be a thermocouple and a temperature measuring junction of the temperature measurement unit be provided in the held molten metal.

**[0011]** It is preferable that the temperature measurement unit be a thermocouple and a temperature measuring junction of the temperature measurement unit be provided in the molten metal in the vicinity of the held molten metal.

**[0012]** It is preferable that the temperature measurement unit be a thermocouple and a temperature measuring junction of the temperature measurement unit be provided in the molten metal immediately below the held molten metal.

**[0013]** It is preferable that the temperature measurement unit be a thermocouple and a temperature measuring junction of the temperature measurement unit be provided in the vicinity of a contact surface between the shape-defining member and the held molten metal inside the shape-defining member.

**[0014]** It is preferable that the holding furnace control the temperature of the molten metal based on the result of measurement in the temperature measurement unit to control the temperature of the held molten metal.

**[0015]** It is preferable that the pulling-up-type continuous casting apparatus further include a temperature controller that controls the temperature of the held molten metal based on the result of measurement in the temperature measurement unit.

**[0016]** It is preferable that the temperature controller be provided in the molten metal in the vicinity of the held molten metal.

**[0017]** It is preferable that the temperature controller be provided in the molten metal immediately below the held molten metal.

**[0018]** It is preferable that the temperature controller be formed to surround the molten metal in the vicinity of the held molten metal.

**[0019]** It is preferable that the pulling-up-type continuous casting apparatus further include a separating part that surrounds the molten metal in the vicinity of the held molten metal.

**[0020]** It is preferable that the temperature controller include a protruding part that extends to the inside of the held molten metal.

**[0021]** It is preferable that the temperature controller be provided in the vicinity of a contact surface between the shape-defining member and the held molten metal inside the shape-defining member.

**[0022]** A pulling-up-type continuous casting method according to one aspect of the present invention includes the steps of: placing a shape-defining member that defines a cross-sectional shape of a cast-metal article to be cast in the vicinity of a molten-metal surface of a molten metal that is held in a holding furnace; pulling up the molten metal through the shape-defining member; and measuring the temperature of a held molten metal which is an unsolidified molten metal that has been pulled up; and controlling the temperature of the held molten metal based on the result of the measurement. According to this structure, the temperature of the held molten metal can be accurately controlled, whereby it is possible to accurately control the speed at which the starter is pulled up.

**[0023]** It is preferable that the pulling-up-type continuous casting method include providing a temperature measuring junction of a thermocouple in the held molten metal to measure the temperature of the held molten metal.

**[0024]** It is preferable that the pulling-up-type continuous casting method include providing a temperature measuring junction of a thermocouple in the molten metal in the vicinity of the held molten metal to measure the temperature of the held molten metal.

**[0025]** It is preferable that the pulling-up-type continuous casting method include providing a temperature measuring junction of a thermocouple in the molten metal immediately below the held molten metal to measure the temperature of the held molten metal.

**[0026]** It is preferable that the pulling-up-type continuous casting method include providing a temperature measuring junction of a thermocouple in the vicinity of a contact surface between the shape-defining member and the held molten metal inside the shape-defining member to measure the temperature of the held molten metal.

**[0027]** It is preferable that the pulling-up-type continuous casting method include controlling the temperature of the molten metal by the holding furnace to control the temperature of the held molten metal.

**[0028]** It is preferable that the temperature of the held molten metal be controlled by a temperature controller.

**[0029]** It is preferable that the temperature controller be provided in the molten metal in the vicinity of the held molten metal.

**[0030]** It is preferable that the temperature controller be provided in the molten metal immediately below the held molten metal.

**[0031]** It is preferable that the temperature controller be formed to surround the molten metal in the vicinity of the held molten metal.

**[0032]** It is preferable that a separating part that surrounds the molten metal in the vicinity of the held molten metal be further provided.

**[0033]** It is preferable that a protruding part extending to the inside of the held molten metal be provided in the temperature controller.

**[0034]** It is preferable that the temperature controller be provided in the vicinity of a contact surface between the shape-defining member and the held molten metal in the shape-defining member.

## Advantageous Effects of Invention

**[0035]** According to the present invention, it is possible to provide a pulling-up-type continuous casting apparatus and a pulling-up-type continuous casting method in which the speed at which the starter is pulled up can be accurately controlled by accurately controlling the temperature of the held molten metal.

## Brief Description of Drawings

**[0036]**

Fig. 1 is a cross-sectional view showing a configuration example of a free casting apparatus according to a first embodiment;

Fig. 2 is a plan view of an internal shape-defining member 102a and an external shape-defining member 102b;

Fig. 3 is a cross-sectional view showing a modified example of the free casting apparatus according to the first embodiment;

Fig. 4 is a cross-sectional view showing a configuration example of a free casting apparatus according to a second embodiment;

Fig. 5 is a cross-sectional view of a modified example of the free casting apparatus according to the second embodiment;

Fig. 6 is a cross-sectional view showing a first specific configuration example of a temperature controller 109;

Fig. 7 is a cross-sectional view showing a second specific configuration example of the temperature controller 109;

Fig. 8 is a cross-sectional view showing another configuration example of the free casting apparatus according to the present invention;

Fig. 9 is a cross-sectional view showing another configuration example of the free casting apparatus according to the present invention;

Fig. 10 is a cross-sectional view showing another configuration example of the free casting apparatus according to the present invention; and

Fig. 11 is a cross-sectional view showing a modified example of the free casting apparatus according to the present invention.

**Description of Embodiments**

**[0037]** Description is hereinafter made of specific embodiments to which the present invention is applied with reference to the drawings. It should be noted that the present invention is not limited to the following embodiments. The following description and the drawings are simplified as needed to clarify the description.

**[0038]** <First embodiment>

**[0039]** First, with reference to Fig. 1, a free casting apparatus (pulling-up-type continuous casting apparatus) according to a first embodiment will be described. Fig. 1 is a cross-sectional view showing a configuration example of the free casting apparatus according to the first embodiment. As shown in Fig. 1, the free casting apparatus according to the first embodiment includes a molten metal holding furnace (holding furnace) 101, an internal shape-defining member 102a, an external shape-defining member 102b, supporting rods 103 and 104, an actuator 105, a cooling gas nozzle 106, a draw-out part 107, and a thermocouple (temperature measurement unit) 108.

**[0040]** The molten metal holding furnace 101 holds a molten metal M1 of aluminum or an aluminum alloy, for example, and maintains the molten metal M1 at a prescribed temperature. In particular, in this embodiment, a case in which the molten metal holding furnace 101 holds the molten metal M1 at a temperature according to a result of measurement in the thermocouple 108 will be described as an example (described later). In the example that is shown in FIG. 1, the surface level of the molten metal M1 (in other words, the molten-metal surface) is lowered as the casting proceeds because the molten metal holding furnace 101 is not replenished with molten metal during casting. However, a configuration in which the molten metal holding furnace 101 is replenished with molten metal during casting to maintain the molten-metal surface level constant is also possible. It should be appreciated that the molten metal M1 may be a melt of a metal other than aluminum or an alloy thereof.

**[0041]** The internal shape-defining member 102a and the external shape-defining member 102b are made of ceramic or stainless steel, for example, and are located in the vicinity of the molten-metal surface. In the example shown in Fig. 1, the internal shape-defining member 102a and the external shape-defining member 102b are placed to contact the molten-metal surface. However, the internal shape-defining member 102a and the external shape-defining member 102b may be located with the principal surface thereof on its lower side (on the side that faces the molten-metal surface) away from the molten-metal surface. Specifically, a prescribed (approximately 0.5 mm, for example) gap may be provided between the principal surface of the internal shape-defining member 102a and the external shape-defining member 102b on its lower side and the molten-metal surface.

**[0042]** The internal shape-defining member 102a defines the internal shape of a cast metal M3 (or a cast-metal article M3) to be cast and the external shape-defining member 102b defines the external shape of the cast metal M3 to be cast. The cast metal M3 shown in Fig. 1 is a hollow cast-metal article that has a tubular shape (that is, a pipe) in a horizontal cross-section (which is hereinafter referred to as "transverse cross-section"). More specifically, the internal shape-defining member 102a defines the internal shape of the transverse cross-section of the cast metal M3 and the external shape-defining member 102b defines the external shape of the transverse cross-section of the cast metal M3.

**[0043]** Fig. 2 is a plan view of the internal shape-defining member 102a and the external shape-defining member 102b. The cross-sectional view of the internal shape-defining member 102a and the external shape-defining member 102b shown in Fig. 1 corresponds to a cross-sectional view that is taken along the line I-I in Fig. 2. As shown in Fig. 2, the external shape-defining member 102b has a rectangular planar shape, for example, and has a circular opening at its center. The internal shape-defining member 102a has a circular planar shape and is located at the center of the opening of the external shape-defining member 102b. The gap between the internal shape-defining member 102a and the external shape-defining member 102b is a molten metal passing part 102c through which the molten metal is passed. As described above, a shape-defining member 102 is constituted of the internal shape-defining member 102a, the external shape-defining member 102b, and the molten metal passing part 102c.

**[0044]** The draw-out part 107 includes a starter (draw-out member) ST that is immersed into the molten metal M1, and a lifter PL (not shown) that drives the starter ST in, for example, vertical directions.

**[0045]** As shown in Fig. 1, the molten metal M1 is joined to the starter ST that is immersed thereinto and then pulled up through the molten metal passing part 102c following the starter ST with its contour held by the surface film or surface tension thereof. The molten metal that is pulled up from the molten-metal surface following the starter ST (or the cast metal M3 that is formed by solidification of the molten metal M1 that has been drawn out by the starter ST) by the surface film or surface tension of the molten metal M1 is herein referred to as "held molten metal M2". The interface between the cast metal M3 and the held molten metal M2 is a solidification interface.

**[0046]** The starter ST is made of ceramic or stainless steel, for example. The surfaces of the starter ST may be covered with a protective coating (not shown), such as that of a salt crystal. In this case, because melt-bonding between the starter ST and the molten metal M1 can be prevented, the releasability between the starter ST and the cast metal M3 can be improved. This makes it possible to reuse the starter ST. In addition, the starter ST may have irregular surfaces. In this case, because the protective coating can be easily deposited (precipitated) on the surfaces of the starter ST, the releasability between the starter ST and the cast metal M3 can be further improved. At the same time, the binding force in the pull-up direction between the starter ST and the molten metal M1 during the draw-out of the molten metal can be improved.

**[0047]** The supporting rod 103 supports the internal shape-defining member 102a and the supporting rod 104 supports the external shape-defining member 102b. The positional relation between the internal shape-defining member 102a and the external shape-defining member 102b can be maintained by the supporting rods 103 and 104. By forming the supporting rod 103 having a pipe structure, causing cooling gas to flow through the supporting rod 103, and further providing a blow-out hole in the internal shape-defining member 102a, the cast metal M3 can be cooled from inside as well.

**[0048]** Both the supporting rods 103 and 104 are coupled to the actuator 105. The actuator 105 allows the supporting rods 103 and 104 to move up and down (in vertical directions) and in horizontal directions while keeping the positional relation between the internal shape-defining member 102a and the external shape-defining member 102b. According to this structure, the actuator 105 can move the internal shape-defining member 102a and the external shape-defining member 102b downward when the molten-metal surface level is lowered as the casting proceeds. In addition, because the actuator 105 can move the internal shape-defining member 102a and the external shape-defining member 102b in horizontal directions, the longitudinal shape of the cast metal M3 can be changed freely.

**[0049]** The cooling gas nozzle (cooling part) 106 is used to blow cooling gas (e.g., air, nitrogen, argon) onto the starter ST and the cast metal M3 to cool the starter ST and the cast metal M3. By cooling the starter ST and the cast metal M3 with the cooling gas while the cast metal M3 is being pulled up by the lifter PL (not shown) that has been coupled to the starter ST, the held molten metal M2 in the vicinity of the solidification interface is sequentially solidified and the cast metal M3 is formed continuously.

**[0050]** The thermocouple 108 is used to measure the temperature of the held molten metal M2. In the example shown in Fig. 1, a temperature measuring junction of the thermocouple is provided inside of the held molten metal M2. According to this structure, the thermocouple 108 is able to accurately measure the temperature of the held molten metal M2. The position where the temperature measuring junction of the thermocouple 108 is provided is not limited to the inside of the held molten metal M2 and the temperature measuring junction of the thermocouple 108 may be provided in the molten metal M1 which is in the vicinity of the held molten metal M2 or is immediately below the held molten metal M2, as shown in Fig. 3. Further, temperature measuring means other than the thermocouple 108 may be used as long as the temperature measuring means is able to measure the temperature of the held molten metal M2.

**[0051]** The molten metal holding furnace 101 controls the temperature of the molten metal M1 based on the result of measurement in the thermocouple 108 as described above. According to this structure, the temperature of the held molten metal M2 is accurately controlled. As a result, for example, the temperature of the held molten metal M2 can be reduced to about a melting point, whereby it is possible to improve the speed at which the starter ST is pulled up (that is, to accurately control the speed at which the starter ST is pulled up).

**[0052]** Next, with reference to Fig. 1, a free casting method according to this embodiment will be described.

**[0053]** First, the starter ST is moved downward and immersed into the molten metal M1 through the molten metal passing part 102c which is between the internal shape-defining member 102a and the external shape-defining member 102b.

**[0054]** Then, the starter ST starts to be pulled up at a prescribed speed. Here, even after the starter ST is separated from the molten-metal surface, the molten metal M1 is pulled up (drawn out) from the molten-metal surface following the starter ST by the surface film or surface tension thereof and forms a held molten metal M2. As shown in FIG. 1, the held molten metal M2 is formed in the molten metal passing part 102c which is between the internal shape-defining member 102a and the external shape-defining member 102b. In other words, a shape is imparted to the held molten metal M2 by the internal shape-defining member 102a and the external shape-defining member 102b.

**[0055]** Next, the starter ST (and the cast metal M3) are cooled by the cooling gas blown out of the cooling gas nozzle 106. As a result, the held molten metal M2 is sequentially solidified from top to bottom and the cast metal M3 grows. In this way, the cast metal M3 can be cast continuously.

**[0056]** While casting is being carried out, the thermocouple 108 measures the temperature of the held molten metal M2. The molten metal holding furnace 101 controls the temperature of the molten metal M1 based on the result of measurement in the thermocouple 108. According to this structure, the temperature of the held molten metal M2 is accurately controlled. As a result, for example, the temperature of the held molten metal M2 can be lowered to about the melting point, whereby it is possible to improve the speed at which the starter ST is pulled up (that is, to accurately control the speed at which the starter ST is pulled up).

**[0057]** As described above, the free casting apparatus according to this embodiment includes the thermocouple 108 that measures the temperature of the held molten metal M2 and accurately controls the temperature of the held molten metal M2 based on the result of measurement in the thermocouple 108. According to this structure, the free casting apparatus according to this embodiment is able to lower the temperature of the held molten metal M2 to about the melting point, whereby it is possible to improve the speed at which the starter ST is pulled up (that is, to accurately control the speed at which the starter ST is pulled up).

**[0058]** While the case in which the temperature of the held molten metal M2 is constantly measured while the casting is being carried out has been described in the above embodiment, the present invention is not limited to this case. The temperature of the held molten metal M2 may not be measured, for example, after the speed at which the starter ST is pulled up is determined. Accordingly, for example, the temperature measuring junction of the thermocouple 108 may be provided inside the held molten metal M2 or in the vicinity of the held molten metal M2 with the start of the casting and may be removed after the speed at which the starter ST is pulled up is determined.

<Second embodiment>

**[0059]** Fig. 4 is a cross-sectional view showing a configuration example of a free casting apparatus according to a second embodiment. In the free casting apparatus shown in Fig. 1 stated above, the molten metal holding furnace 101 controls the temperature of the held molten metal M2 by controlling the temperature of the molten metal M1 based on the result of measurement in the thermocouple 108. Meanwhile, the free casting apparatus shown in Fig. 4 further includes a temperature controller 109 that controls the temperature of the held molten metal M2 (or the molten metal M1 in the vicinity of the held molten metal M2) based on the result of measurement in the thermocouple 108.

**[0060]** The temperature controller 109 is provided in the molten metal M1 which is in the vicinity of the held molten metal M2 or is immediately below the held molten metal M2 and controls the temperature of the molten metal M1 which is in the vicinity of the held molten metal M2 or is immediately below the held molten metal M2 based on the result of measurement in the thermocouple 108. For example, the temperature controller 109 heats the molten metal M1 by a heater or the like or cools the molten metal M1 by causing refrigerant to flow through a refrigerant circuit. According to this structure, it is possible to control the temperature of the held molten metal M2 with higher accuracy.

**[0061]** Since the other structures of the free casting apparatus shown in Fig. 4 is similar to those of the free casting apparatus shown in Fig. 1, the description thereof will be omitted. Note that the position where the temperature measuring junction of the thermocouple 108 is provided is not limited to the inside of the held molten metal M2 and the temperature measuring junction of the thermocouple 108 may be provided in the molten metal M1 which is in the vicinity of the held molten metal M2 or is immediately below the held molten metal M2, as shown in Fig. 5.

(First Specific Configuration Example of Temperature Controller 109)

**[0062]** Fig. 6 is a cross-sectional view showing a first specific configuration example of the temperature controller 109. In the example shown in Fig. 6, the temperature controller 109 is formed to surround the molten metal M1 which is in the vicinity of the held molten metal M2 or is immediately below the held molten metal M2.

**[0063]** More specifically, in the example shown in Fig. 6, the temperature controller 109 is constituted of a main body part and protruding parts. The main body part of the temperature controller 109 is provided immediately below the held molten metal M2. The protruding parts of the temperature controller 109 are provided to protrude upwardly from both ends of the main body part so as to separate the molten metal M1 which is in the vicinity of the held molten metal M2 or is immediately below the held molten metal M2 from the other area of the molten metal M1. However, the molten metal M1 which is in the vicinity of the held molten metal M2 or is immediately below the held molten metal M2 and the other area of the molten metal M1 are not completely separated from each other.

**[0064]** According to this structure, the temperature of the held molten metal M2 can be controlled with further accuracy.

(Second Specific Configuration Example of Temperature Controller 109)

**[0065]** Fig. 7 is a cross-sectional view showing a second specific configuration example of the temperature controller 109. In the example shown in Fig. 7, the temperature controller 109 is formed to surround the molten metal M1 which is in the vicinity of the held molten metal M2 or is immediately below the held molten metal M2 and includes a protruding part extending to the inside of the held molten metal M2.

**[0066]** More specifically, in the example shown in Fig. 7, the temperature controller 109 is constituted of a main body part, a first protruding part, and a second protruding part. The main body part of the temperature controller 109 is provided immediately below the held molten metal M2. The first protruding part of the temperature controller 109 is provided to protrude upwardly from both ends of the main body part so as to separate the molten metal M1 which is in the vicinity of the held molten metal M2 or is immediately below the held molten metal M2 from the other area of the molten metal M1. However, the molten metal M1 which is in the vicinity of the held molten metal M2 or is immediately below the held molten metal M2 and the other area of the molten metal M1 are not completely separated from each other. Further, the second protruding part of the temperature controller 109 is provided to protrude upwardly from the central part of the upper surface of the main body part. This second protruding part extends to the inside of the held molten metal M2.

**[0067]** According to the above structure, it is possible to directly control the temperature of the held molten metal M2 (to control the temperature of the held molten metal M2 further accurately).

**[0068]** As described above, the free casting apparatus according to this embodiment includes the thermocouple 108 that measures the temperature of the held molten metal M2 and the temperature controller 109 that controls the temperature of the held molten metal M2 based on the result of measurement in the thermocouple 108. Accordingly, the free casting apparatus according to this embodiment is able to control the temperature of the held molten metal M2 further accurately, whereby it is possible to further improve the speed at which the starter ST is pulled up (that is, to control the speed at which the starter ST is pulled up further accurately).

<Third

**[0069]** In this embodiment, another configuration example of the free casting apparatus according to the present invention will be described.

(Another Configuration Example of Free Casting Apparatus According to Present Invention (Case 1))

**[0070]** Fig. 8 is a cross-sectional view showing another configuration example of the free casting apparatus according to the present invention. In the free casting apparatus shown in Fig. 8, the temperature measuring junction of the thermocouple 108 is provided in the vicinity of the contact surface between the shape-defining member 102 and the held molten metal M2 inside the shape-defining member 102 (in the example shown in Fig. 8, external shape-defining member 102b). Since the other structures of the free casting apparatus shown in Fig. 8 are similar as those of the free casting apparatus shown in Fig. 4, the description thereof will be omitted.

(Another Configuration Example of Free Casting Apparatus According to Present Invention (Case 2))

**[0071]** Fig. 9 is a cross-sectional view showing another configuration example of the free casting apparatus according to the present invention. In the free casting apparatus shown in Fig. 9, the temperature controller 109 is provided in the vicinity of the contact surface between the shape-defining member 102 and the held molten metal M2 inside the shape-defining member 102. In other words, in the free casting apparatus shown in Fig. 9, a function of the temperature controller 109 is added to the shape-defining member 102. Since the other structures of the free casting apparatus shown in Fig. 9 are similar to those of the free casting apparatus shown in Fig. 4, the descriptions thereof will be omitted.

(Another Configuration Example of Free Casting Apparatus According to Present Invention (Case 3))

**[0072]** Fig. 10 is a cross-sectional view showing another configuration example of the free casting apparatus according to the present invention. In the free casting apparatus shown in Fig. 10, besides the temperature controller 109, a separating part 110 formed to surround the molten metal M1 which is in the vicinity of the held molten metal M2 or is immediately below the held molten metal M2 is further provided. Since the other structures of the free casting apparatus shown in Fig. 10 are similar to those of the free casting apparatus shown in Fig. 4, the descriptions thereof will be omitted.

**[0073]** As described above, the free casting apparatus according to the first to third embodiments above includes the thermocouple 108 that measures the temperature of the held molten metal M2 and the temperature controller 109 (or the molten metal holding furnace 101) that controls the temperature of the held molten metal M2 based on the result of measurement in the thermocouple 108. Accordingly, the free casting apparatus according to the first to third embodiments is able to accurately control the temperature of the held molten metal M2, whereby it is possible to improve the speed at which the starter ST is pulled up (that is, to accurately control the speed at which the starter ST is pulled up).

**[0074]** While the case in which the cast-metal article having a cylindrical shape (hollow cast-metal article) is formed has been described as an example in the above embodiments, the present invention is not limited thereto. The present invention is also applicable to a case in which a cast-metal article with a shape of a circular column is formed as shown in Fig. 11 or cases in which cast-metal articles having other shapes are formed.

**[0075]** Note that the present invention is not limited to the above embodiments and may be changed as needed without departing from its scope. For example, the above-mentioned configuration examples may be used in combination.

**Reference Signs List**

**[0076]**

| | |
|---|---|
| 101 | MOLTEN METAL HOLDING FURNACE |
| 102 | SHAPE-DEFINING MEMBER |
| 102a | INTERNAL SHAPE-DEFINING MEMBER |
| 102b | EXTERNAL SHAPE-DEFINING MEMBER |
| 102c | MOLTEN METAL PASSING PART |
| 103, 104 | SUPPORTING ROD |
| 105 | ACTUATOR |
| 106 | COOLING GAS NOZZLE |
| 107 | DRAW-OUT PART |
| 108 | THERMOCOUPLE |
| 109 | TEMPERATURE CONTROLLER |
| 110 | SEPARATING PART |
| M1 | MOLTEN METAL |
| M2 | HELD MOLTEN METAL |
| M3 | CAST METAL |
| ST | STARTER |
| PL | LIFTER |

**Claims**

1. A pulling-up-type continuous casting apparatus, comprising:

    a holding furnace that holds a molten metal;
    a draw-out part that draws out the molten metal from a molten-metal surface of the molten metal that is held in the holding furnace;
    a shape-defining member that defines a cross-sectional shape of a cast-metal article to be cast by applying an external force to a held molten metal which is an unsolidified molten metal that has been drawn out by the draw-out part, the shape-defining member being located in the vicinity of the molten-metal surface; and
    a temperature measurement unit that measures the temperature of the held molten metal,
    wherein the temperature of the held molten metal is controlled based on the result of measurement in the temperature measurement unit.

2. The pulling-up-type continuous casting apparatus according to Claim 1, wherein the temperature measurement unit is a thermocouple and a temperature measuring junction of the temperature measurement unit is provided in the held molten metal.

3. The pulling-up-type continuous casting apparatus according to Claim 1, wherein the temperature measurement unit is a thermocouple and a temperature measuring junction of the temperature measurement unit is provided in the molten metal in the vicinity of the held molten metal.

4. The pulling-up-type continuous casting apparatus according to Claim 1, wherein the temperature measurement unit is a thermocouple and a temperature measuring junction of the temperature measurement unit is provided in the molten metal immediately below the held molten metal.

5. The pulling-up-type continuous casting apparatus according to Claim 1, wherein the temperature measurement unit is a thermocouple and a temperature measuring junction of the temperature measurement unit is provided in the vicinity of a contact surface between the shape-defining member and the held molten metal inside the shape-defining member.

6. The pulling-up-type continuous casting apparatus according to any one of Claims 1 to 5, wherein the holding furnace controls the temperature of the molten metal based on the result of measurement in the temperature measurement unit to control the temperature of the held molten metal.

7. The pulling-up-type continuous casting apparatus according to any one of Claims 1 to 5, further comprising a temperature controller that controls the temperature of the held molten metal based on the result of measurement in the temperature measurement unit.

8. The pulling-up-type continuous casting apparatus according to Claim 7, wherein the temperature controller is provided in the molten metal in the vicinity of the held molten metal.

9. The pulling-up-type continuous casting apparatus according to Claim 7, wherein the temperature controller is provided in the molten metal immediately below the held molten metal.

10. The pulling-up-type continuous casting apparatus according to any one of Claims 7 to 9, wherein the temperature controller is formed to surround the molten metal in the vicinity of the held molten metal.

11. The pulling-up-type continuous casting apparatus according to any one of Claims 7 to 9, further comprising a separating part that surrounds the molten metal in the vicinity of the held molten metal.

12. The pulling-up-type continuous casting apparatus according to according to any one of Claims 7 to 11, wherein the temperature controller includes a protruding part that extends to the inside of the held molten metal.

13. The pulling-up-type continuous casting apparatus according to Claim 7, wherein the temperature con-

troller is provided in the vicinity of a contact surface between the shape-defining member and the held molten metal inside the shape-defining member.

**14.** A pulling-up-type continuous casting method comprising the steps of:

placing a shape-defining member that defines a cross-sectional shape of a cast-metal article to be cast in the vicinity of a molten-metal surface of a molten metal that is held in a holding furnace;
pulling up the molten metal through the shape-defining member; and
measuring the temperature of a held molten metal which is an unsolidified molten metal that has been pulled up; and
controlling the temperature of the held molten metal based on the result of the measurement.

**15.** The pulling-up-type continuous casting method according to Claim 14, comprising providing a temperature measuring junction of a thermocouple in the held molten metal to measure the temperature of the held molten metal.

**16.** The pulling-up-type continuous casting method according to Claim 14, comprising providing a temperature measuring junction of a thermocouple in the molten metal in the vicinity of the held molten metal to measure the temperature of the held molten metal.

**17.** The pulling-up-type continuous casting method according to Claim 14, comprising providing a temperature measuring junction of a thermocouple in the molten metal immediately below the held molten metal to measure the temperature of the held molten metal.

**18.** The pulling-up-type continuous casting method according to Claim 14, comprising providing a temperature measuring junction of a thermocouple in the vicinity of a contact surface between the shape-defining member and the held molten metal inside the shape-defining member to measure the temperature of the held molten metal.

**19.** The pulling-up-type continuous casting method according to any one of Claims 14 to 18, comprising controlling the temperature of the molten metal by the holding furnace to control the temperature of the held molten metal.

**20.** The pulling-up-type continuous casting method according to any one of Claims 14 to 18, comprising controlling the temperature of the held molten metal by a temperature controller.

**21.** The pulling-up-type continuous casting method according to Claim 20, comprising providing the temperature controller in the molten metal in the vicinity of the held molten metal.

**22.** The pulling-up-type continuous casting method according to Claim 20, comprising providing the temperature controller in the molten metal immediately below the held molten metal.

**23.** The pulling-up-type continuous casting method according to any one of Claims 20 to 22, comprising forming the temperature controller to surround the molten metal in the vicinity of the held molten metal.

**24.** The pulling-up-type continuous casting method according to any one of Claims 20 to 22, further comprising forming a separating part that surrounds the molten metal in the vicinity of the held molten metal.

**25.** The pulling-up-type continuous casting method according to any one of Claims 20 to 24, comprising providing a protruding part that extends to the inside of the held molten metal in the temperature controller.

**26.** The pulling-up-type continuous casting method according to Claim 20, comprising providing the temperature controller in the vicinity of a contact surface between the shape-defining member and the held molten metal in the shape-defining member.

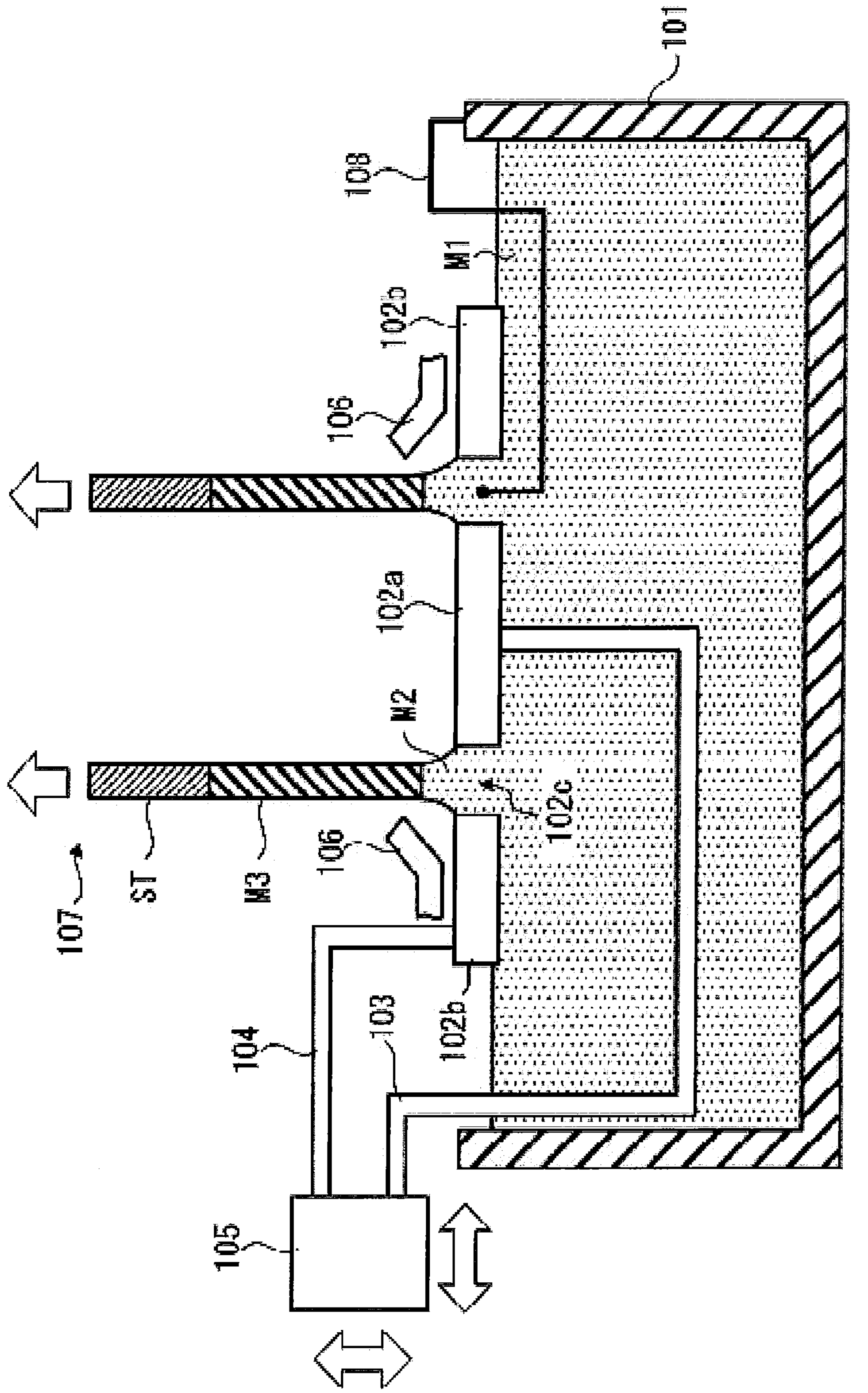


Fig. 1

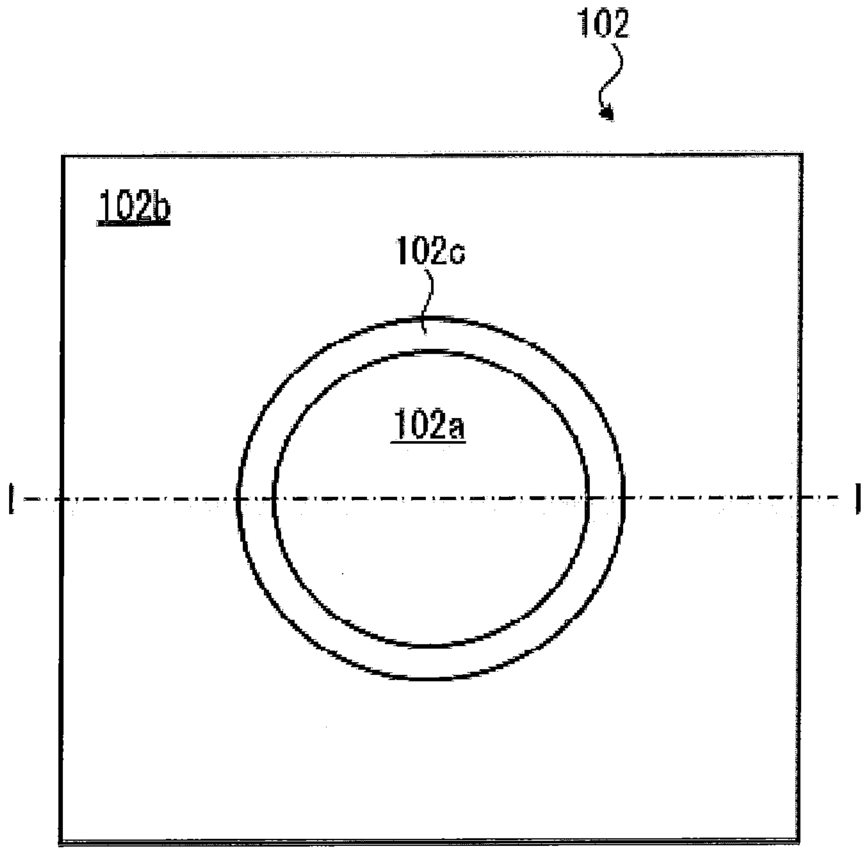


Fig. 2

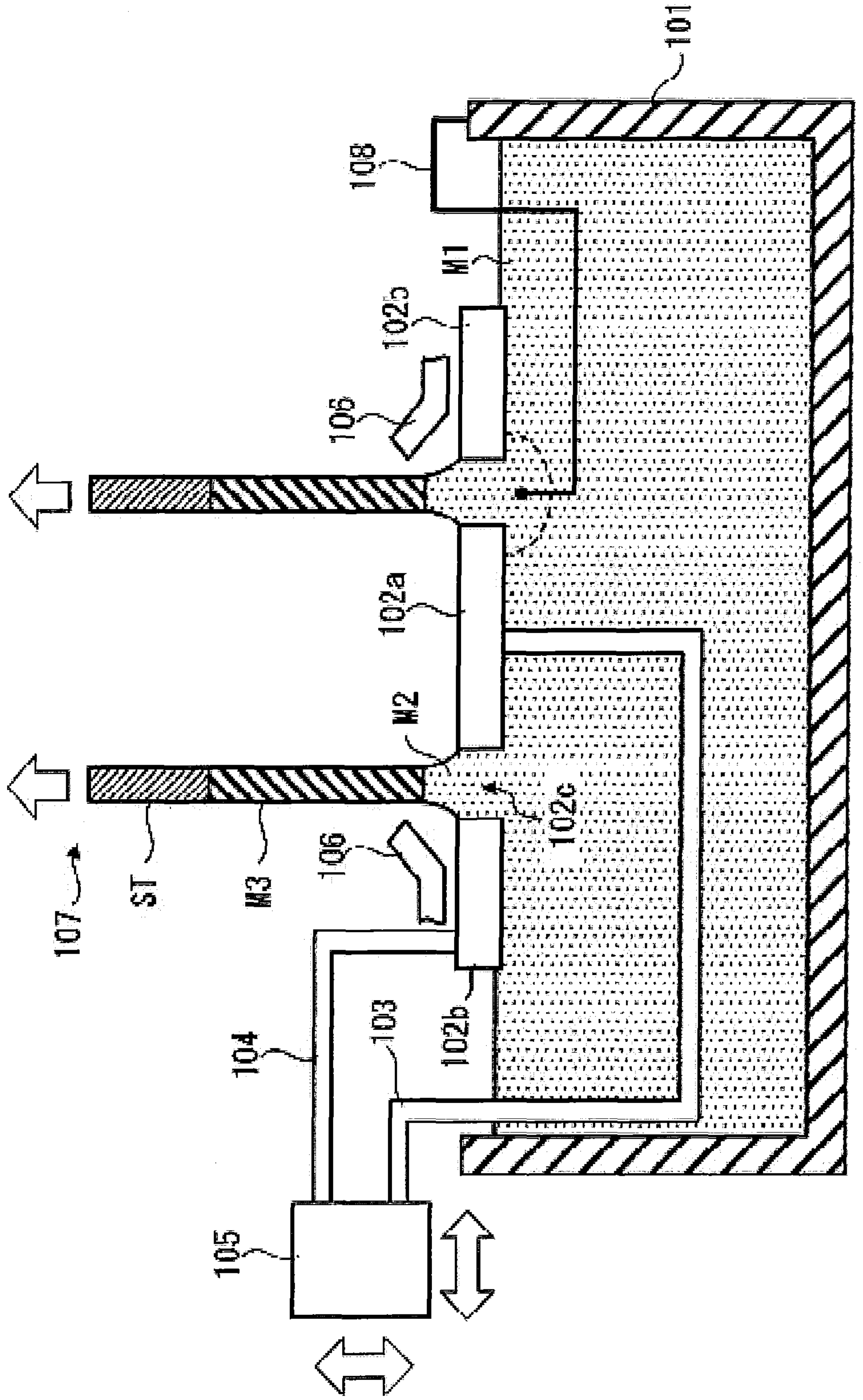


Fig. 3

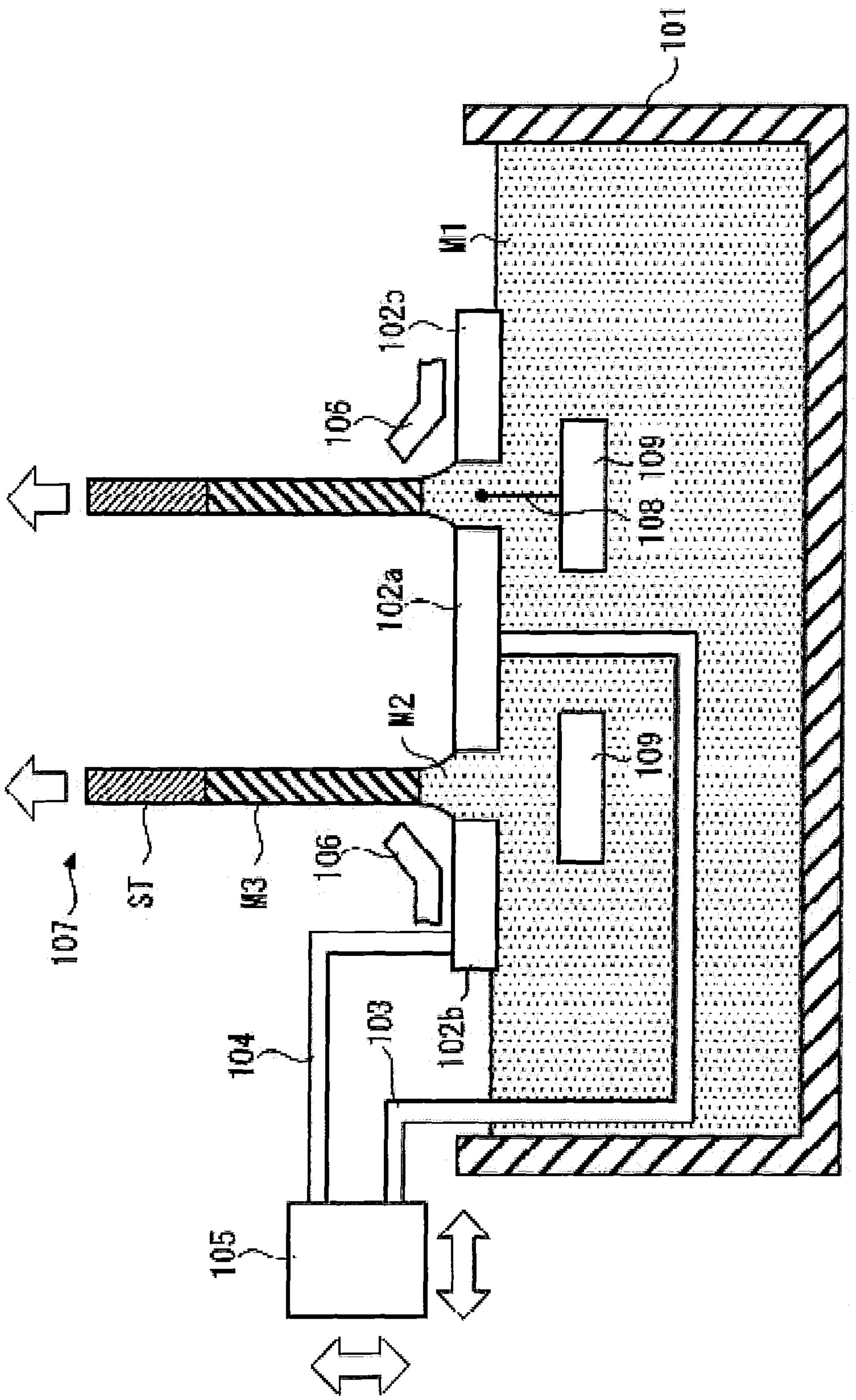
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Fig. 4

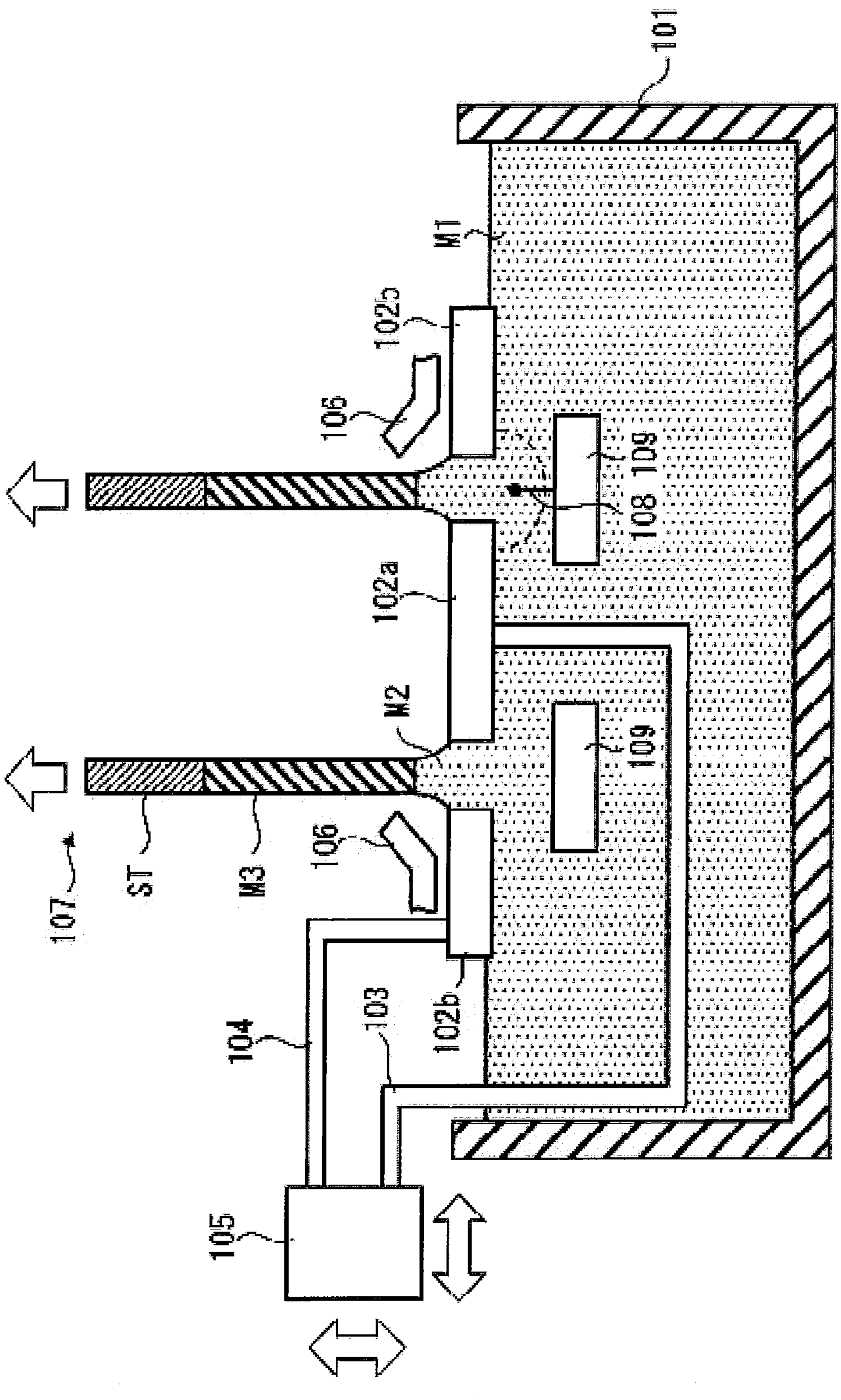
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Fig. 5

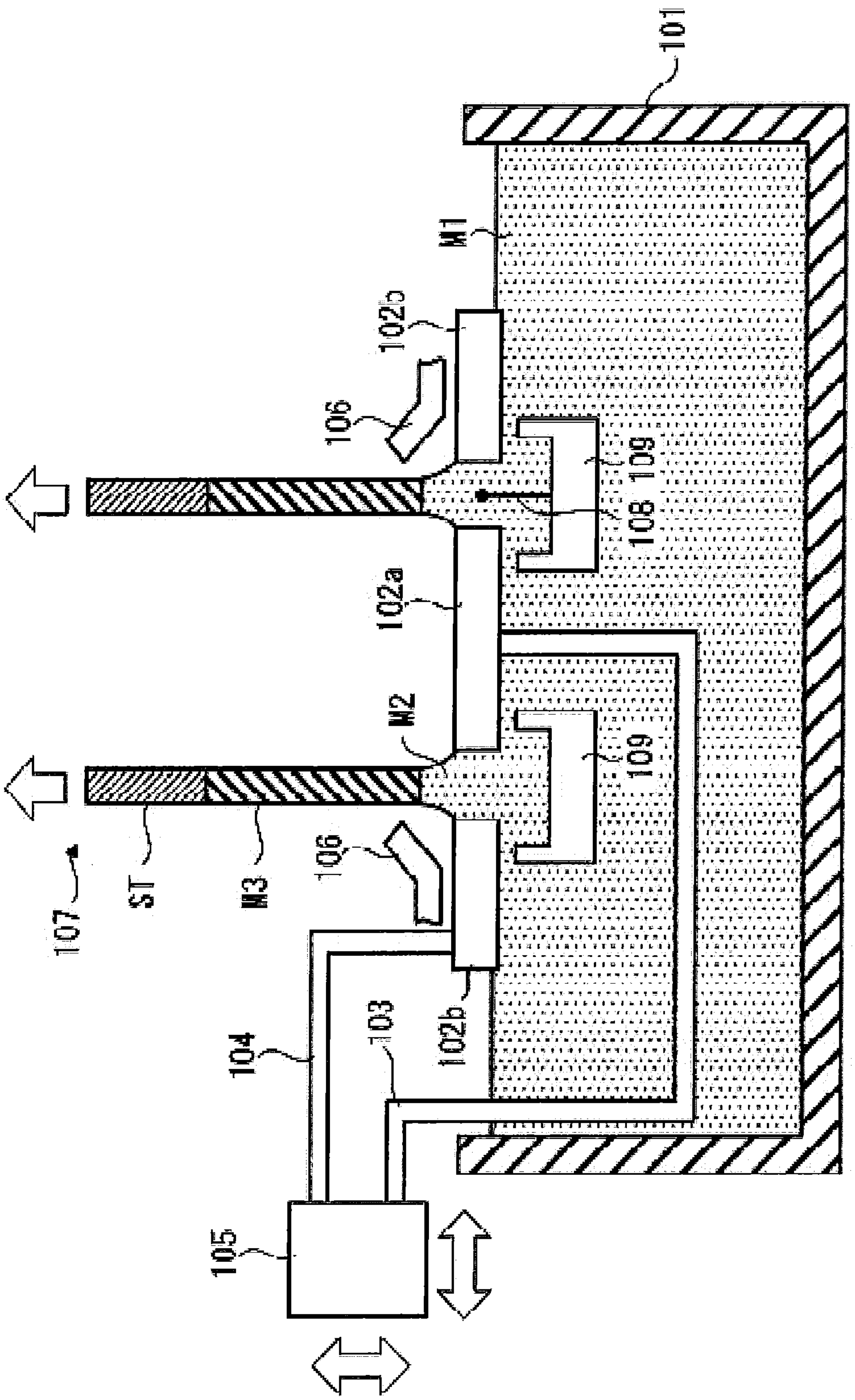


Fig. 6

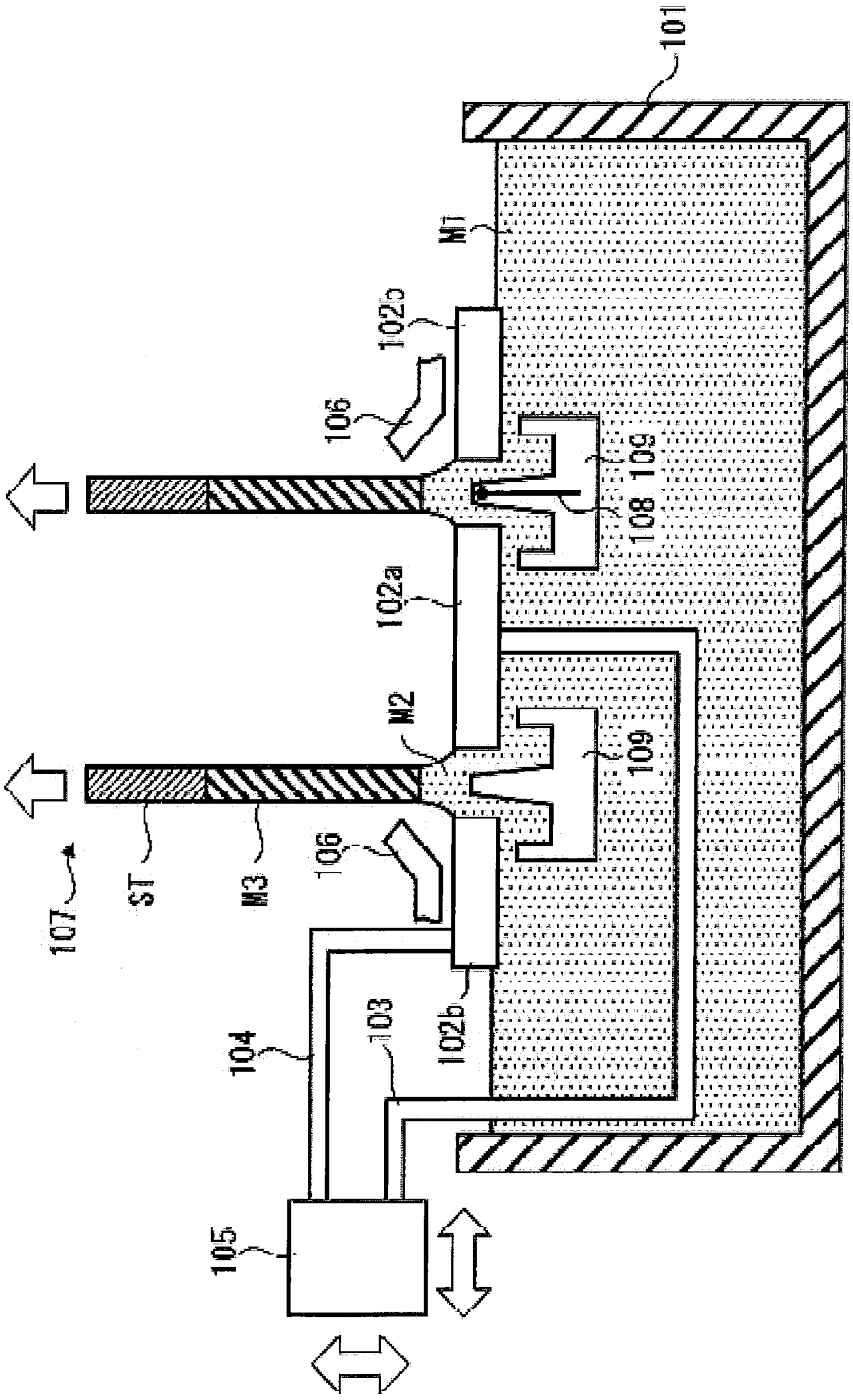
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Fig. 7

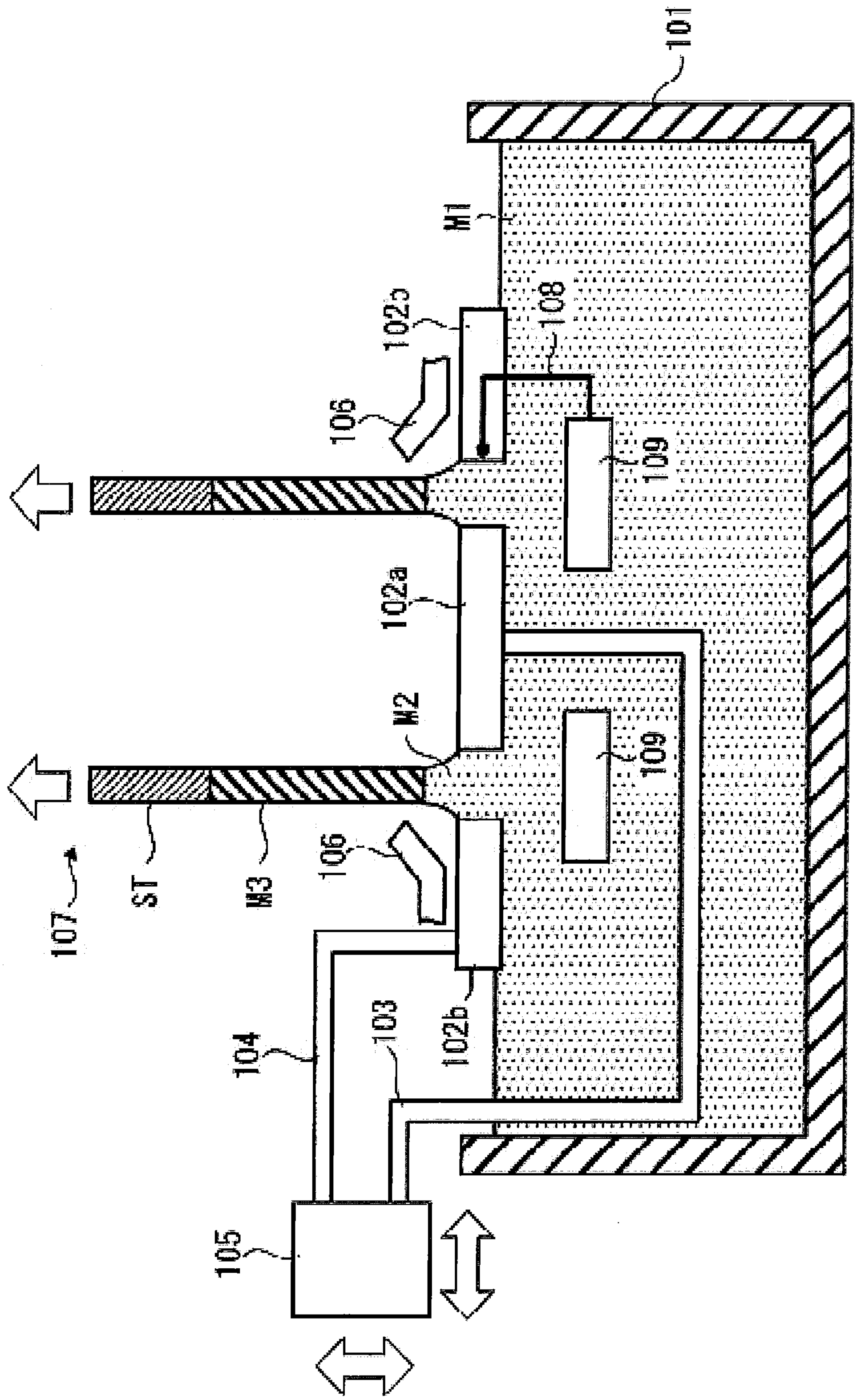
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Fig. 8

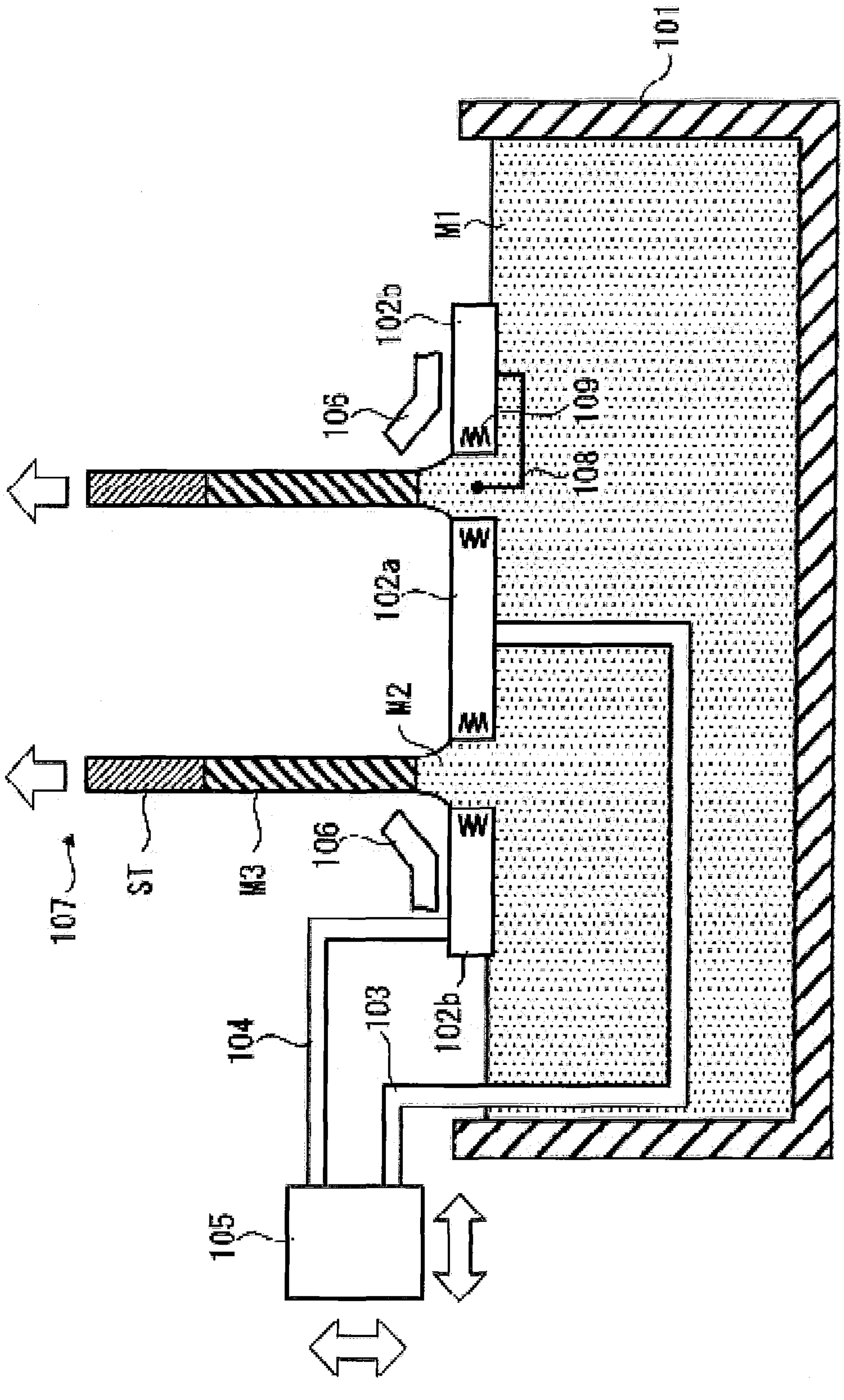


Fig. 9

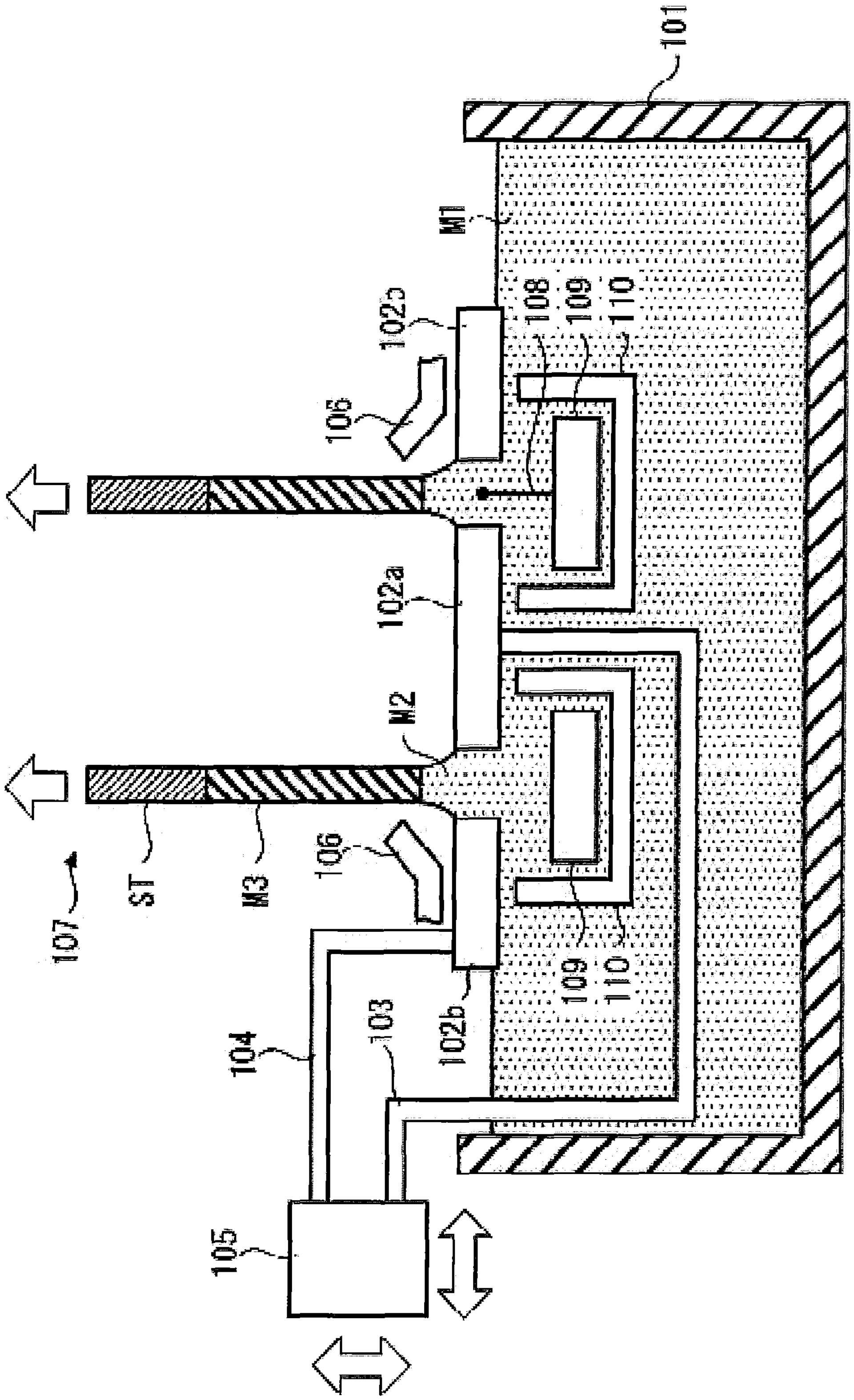
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Fig. 10

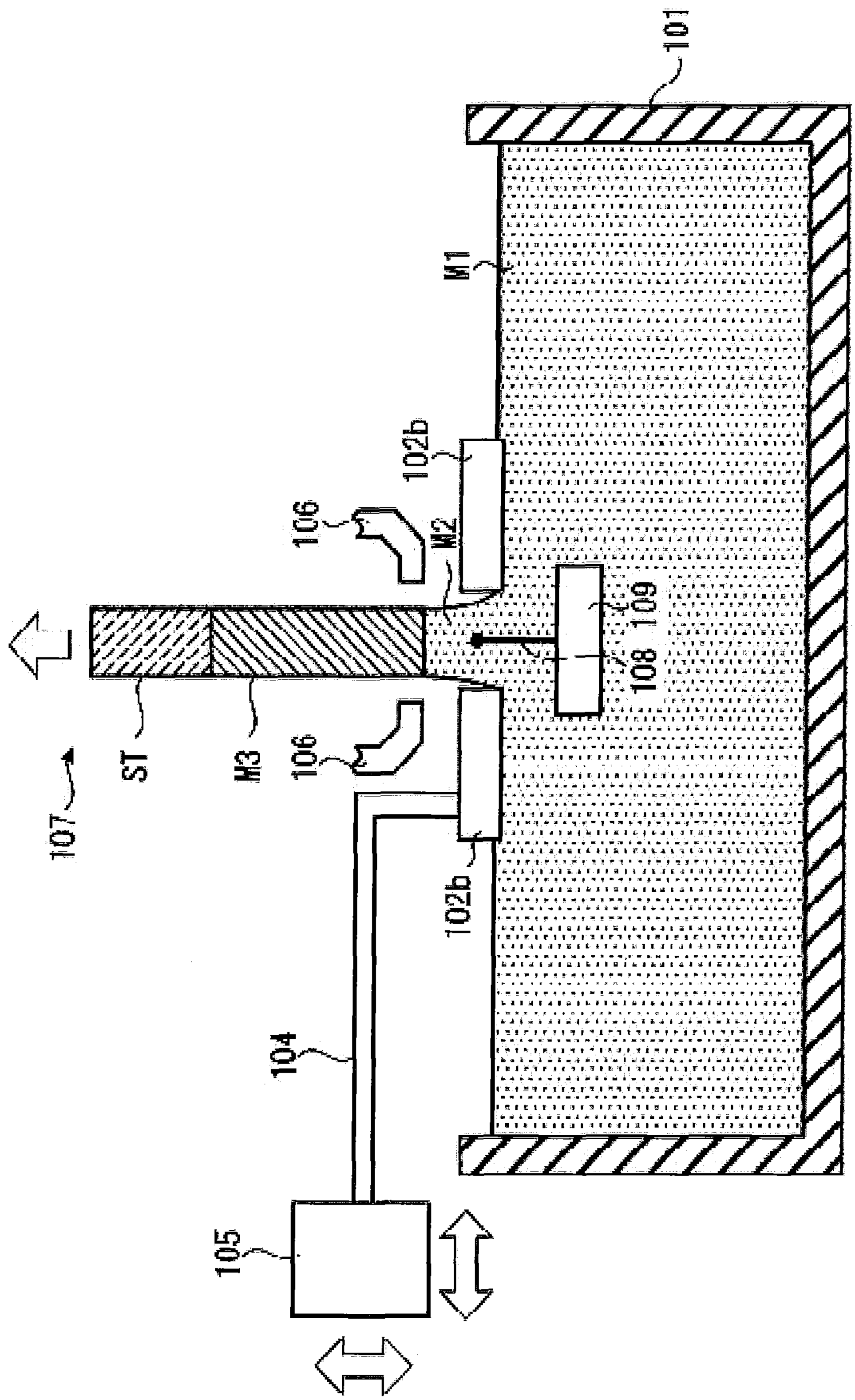


Fig. 11

**INTERNATIONAL SEARCH REPORT**

International application No. PCT/JP2013/002456

A. CLASSIFICATION OF SUBJECT MATTER
*B22D11/01*(2006.01)i, *B22D11/04*(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)
B22D11/01, B22D11/04

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 | 1996-2013 |
| Kokai Jitsuyo Shinan Koho | 1971-2013 | Toroku Jitsuyo Shinan Koho | 1994-2013 |

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. |
|---|---|---|
| A | JP 2012-61518 A (Toyota Central Research and Development Laboratories, Inc.), 29 March 2012 (29.03.2012), entire text & WO 2012/035752 A1 | 1-26 |
| A | JP 2-205232 A (Director General of National Research Institute for Science and Technology Agency), 15 August 1990 (15.08.1990), entire text (Family: none) | 1-26 |

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

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"P" document published prior to the international filing date but later than the priority date claimed
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"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 |
|---|---|
| 24 April, 2013 (24.04.13) | 14 May, 2013 (14.05.13) |

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

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

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2013/002456

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | JP 63-199049 A (Sumitomo Electric Industries, Ltd.), 17 August 1988 (17.08.1988), entire text (Family: none) | 1-26 |

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## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- JP 2012061518 A **[0005]**