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(54) DEVICE AND METHOD FOR CONTINUOUSLY REMOVING IMPURITIES FROM MOLTEN METAL

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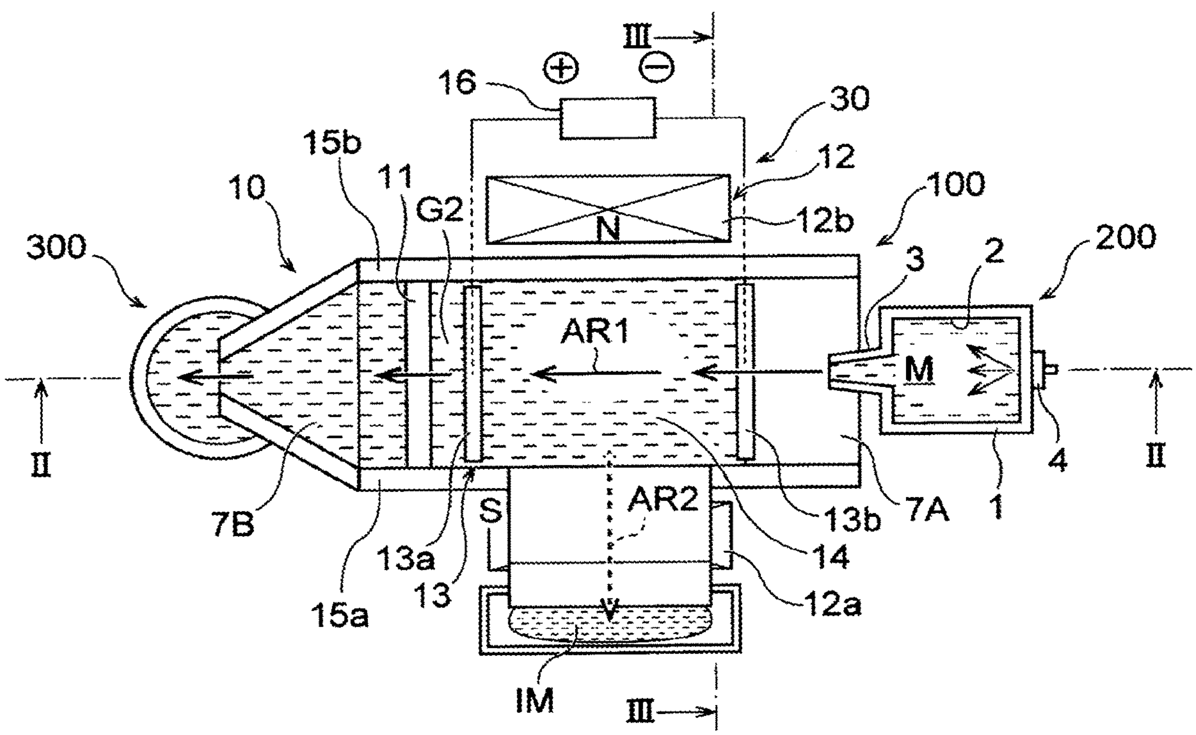
(57) **ABSTRACT**

A device for continuously removing impurities from molten metal includes a molten metal flow path body, an inlet-side closed end plate and an outlet-side closed end plate are provided in the molten metal flow path body so as to form an impurity removal space, an electrode device composed of an inlet-side electrode and an outlet-side electrode that face each other in a longitudinal direction of the molten metal flow path body, a magnetic field device composed of a pair of permanent magnets that face each other in a width direction, sandwich the impurity removal space, and an urging device composed of the electrode device and the magnetic field device applies a Lorentz force downward to molten metal in the impurity removal space so as to increase a density of the molten metal and cause impurities in the molten metal to rise up to a surface of the molten metal.



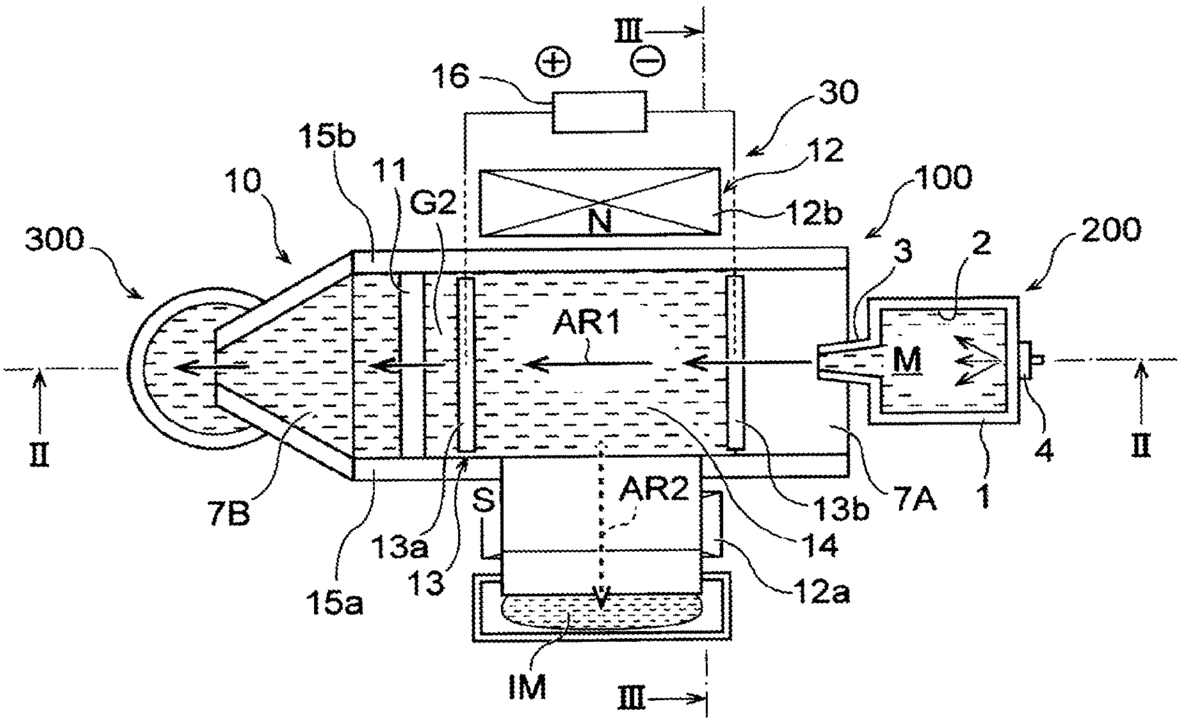

III
16
30
12
12b
N
10
15b
11
G2
100
300
3
2
200
AR1
M
II
II
4
7B
13a
13
15a
S
AR2
14
13b
7A
1
12a
IM
III

FIG. 1

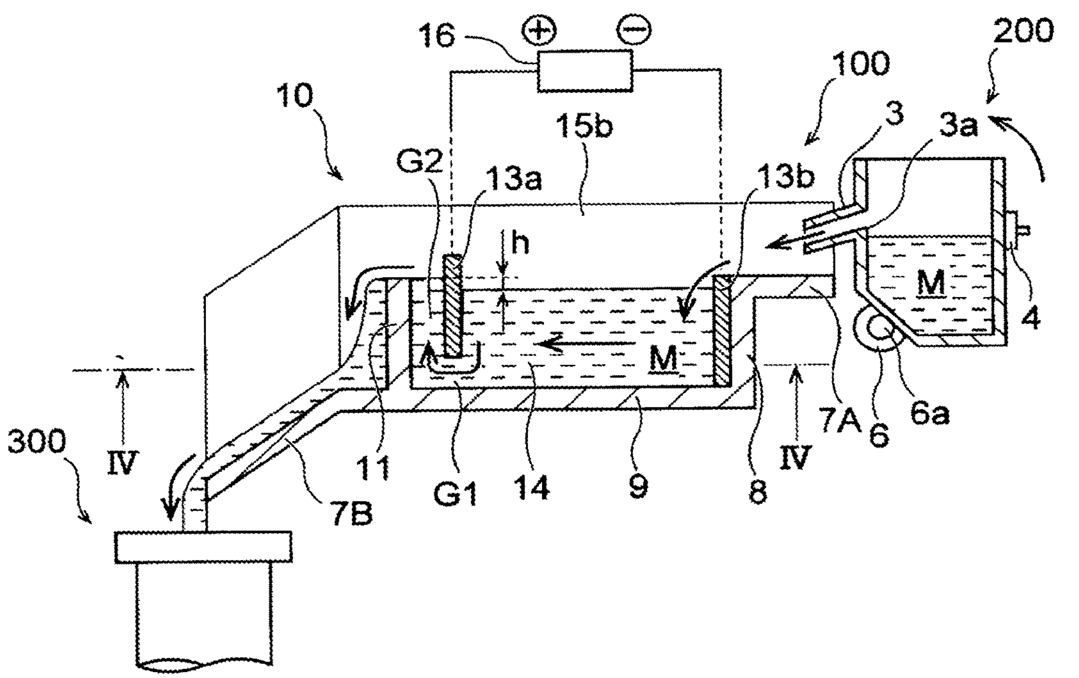

16
200
100
10
15b
3
3a
G2
13a
13b
h
M
M
4
IV
IV
7A
6
6a
300
11
G1
14
9
8
7B

FIG. 2

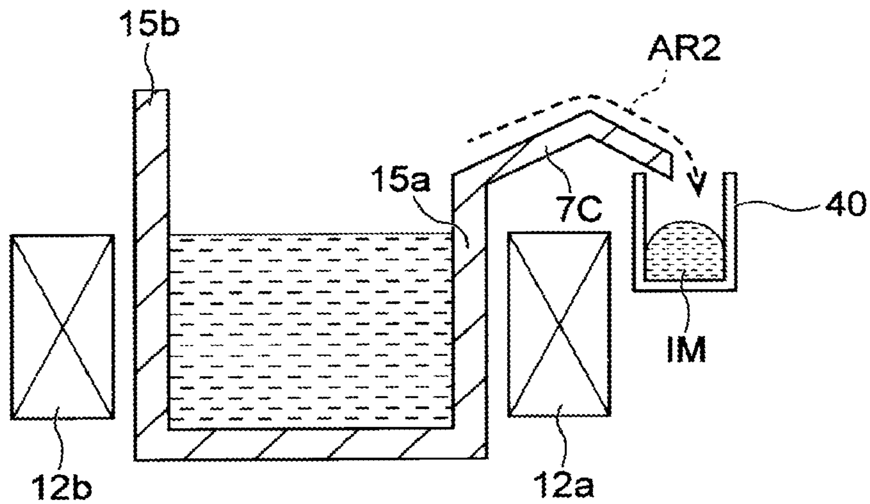

15b
AR2
15a
7C
40
IM
12b
12a

FIG. 3

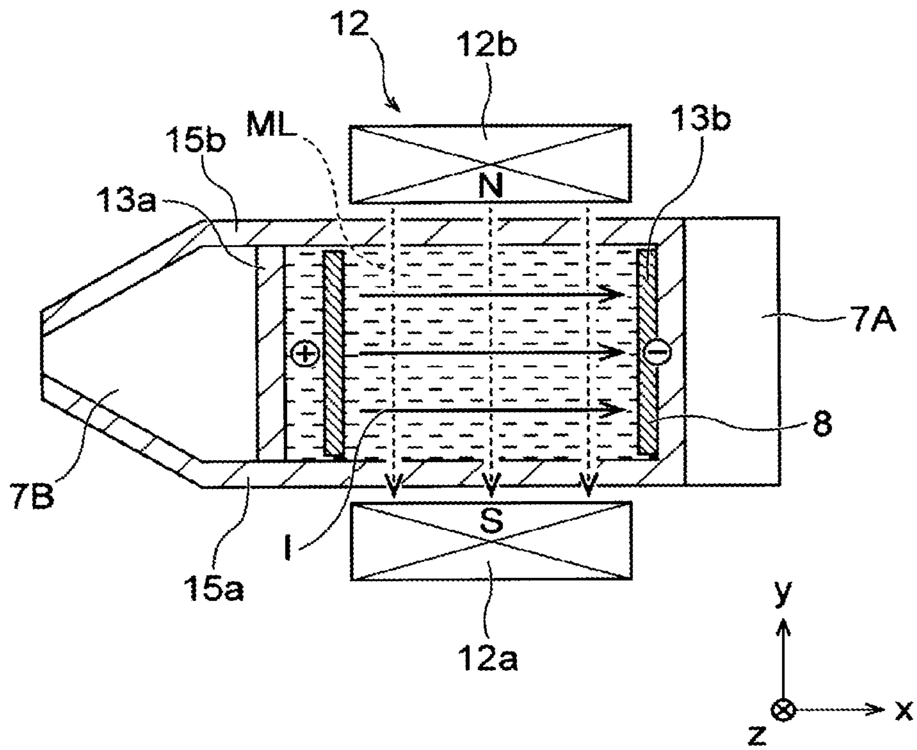

12
12b
ML
15b
13b
13a
N
7A
8
7B
S
I
15a
12a
y
x
z

FIG. 4

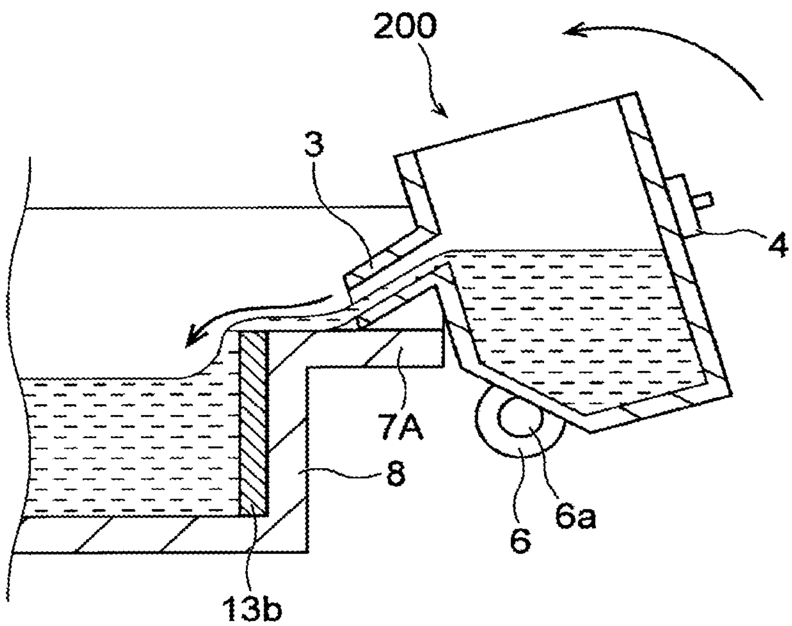


FIG. 5

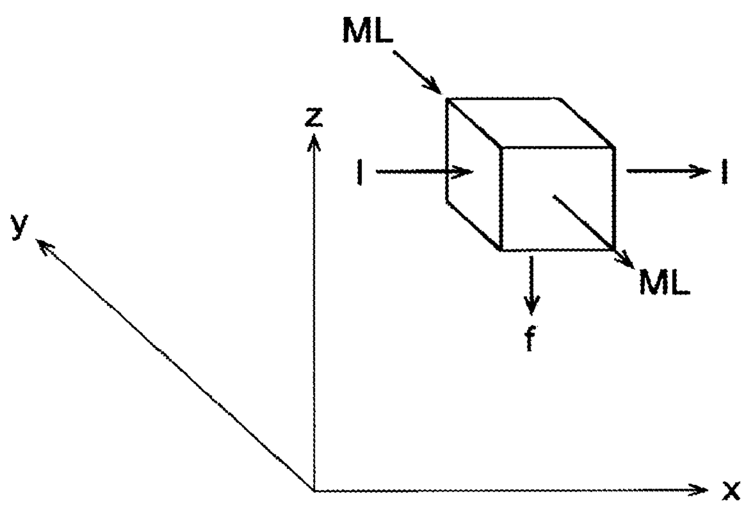


FIG. 6

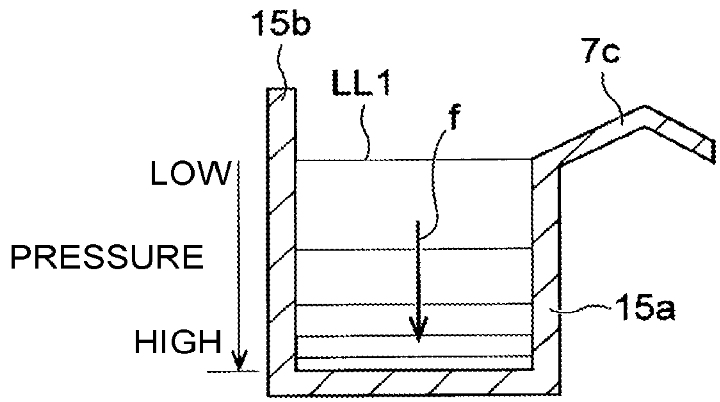

15b
LL1
f
7c
LOW
PRESSURE
HIGH
15a

FIG. 7a

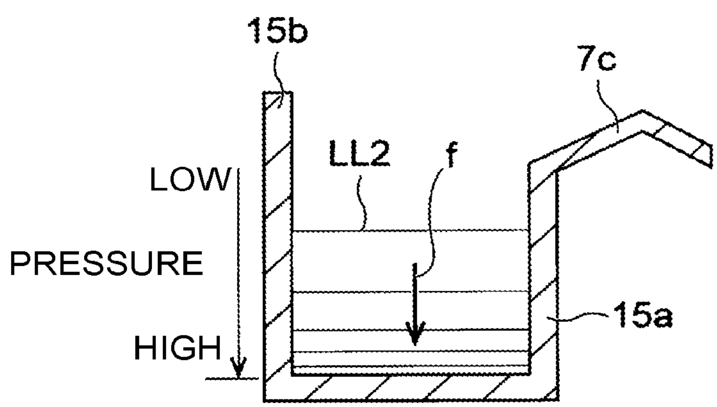

15b
7c
LL2
f
LOW
PRESSURE
HIGH
15a

FIG. 7b

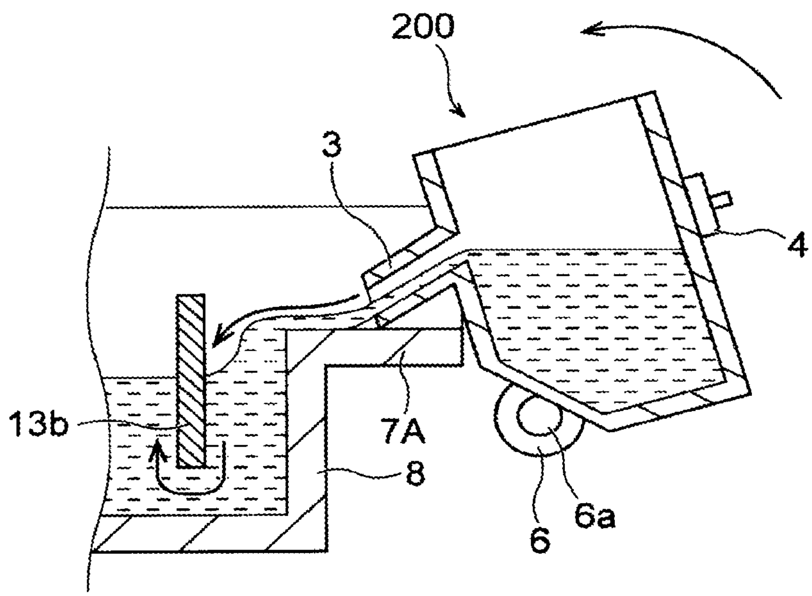


FIG. 8

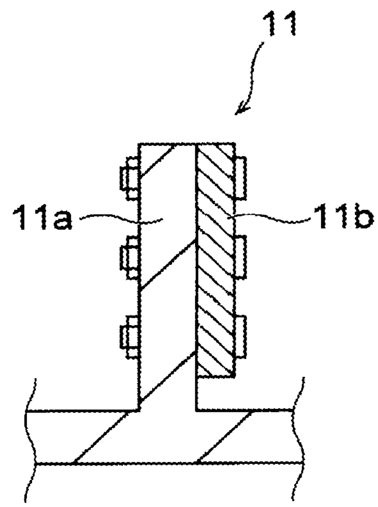


FIG. 9a

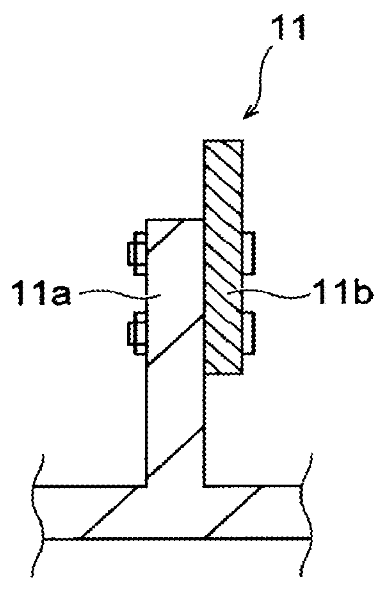


FIG. 9b

DEVICE AND METHOD FOR CONTINUOUSLY REMOVING IMPURITIES FROM MOLTEN METAL

TECHNICAL FIELD

[0001] The present invention relates to a device and a method for continuously removing impurities from molten metal.

BACKGROUND ART

[0002] Conventionally, productization from molten metal having electrical conductivity (conductivity), that is, non-ferrous molten metal (e.g., Al, Cu, Zn, or Si, alloy including at least two of these, Mg alloy, or the like) or molten metal other than non-ferrous molten metal includes, for example, steps of dissolving raw materials, adjusting components, removing impurities mixed in molten metal, and molding. Removal of impurities is generally referred to as purification of molten metal, and, for example, a ceramic filter is used therefor.

[0003] However, since an impurity removal method using a filter is, of course, a filtration method, clogging is likely to occur. Therefore, there is a problem such that the workability is deteriorated and the running cost is increased.

[0004] In other words, in a case of a filter type, how large the mesh is set to is actually an important point. In order to remove not only large impurities but also fine impurities, the mesh must be fine. However, if the mesh is made fine, clogging is more likely to occur. For example, clogging may occur instantaneously, and production may stop.

[0005] Thus, conventionally, flux is previously introduced into the molten metal prior to removal with a filter. By such introduction, impurities are changed into substances having a large particle size. As a result, it becomes possible to remove impurities while keeping the mesh large to some extent, and it is possible to increase the removal efficiency (trap efficiency) of the filter. However, it is not preferable to introduce flux into the molten metal in terms of product quality in many cases.

SUMMARY OF INVENTION

Technical Problem

[0006] As described above, according to a conventional method, it is actually impossible to continuously produce products without stopping production of products while removing impurities, including fine impurities, from molten metal.

[0007] The present invention has been made in view of such circumstances, and it is an object thereof to provide a device and a method for continuously removing impurities for enabling continuous manufacture of products while removing impurities from non-ferrous metal or other molten metal containing impurities with high accuracy.

Solution to Problem

[0008] An embodiment of the present invention is

[0009] a device for continuously removing impurities from molten metal, which sends electrically conductive molten metal to a metal product manufacturing device in a next stage, the device including:

[0010] a molten metal flow path body having a molten metal flow path for flowing electrically conductive molten metal that has flown from outside toward the metal product manufacturing device;

[0011] an inlet-side closed end plate and an outlet-side closed end plate that are provided in the molten metal flow path body so as to partition a front and a rear of the molten metal flow path and form an impurity removal space;

[0012] an electrode device composed of an inlet-side electrode and an outlet-side electrode that are provided in the impurity removal space, face each other in a longitudinal direction in which molten metal flows, and can be put into electrical contact with molten metal in the impurity removal space; and

[0013] a magnetic field device composed of a pair of permanent magnets that are provided outside the molten metal flow path forming body, face each other in a width direction intersecting the longitudinal direction, sandwich the impurity removal space of the molten metal flow path forming body in the width direction, have opposite poles facing each other, and can form a magnetic field in molten metal in the impurity removal space,

[0014] in which the electrode device and the magnetic field device constitute an urging device that can apply a Lorentz force downward to molten metal in the impurity removal space so as to increase a density of the molten metal and cause impurities in the molten metal to rise up to a surface of the molten metal.

[0015] Furthermore, an embodiment of the present invention is

[0016] a continuous impurity removal method for removing impurities from molten metal in sending electrically conductive molten metal to a metal product manufacturing device in a next stage, the method including:

[0017] preparing a molten metal flow path body having a molten metal flow path for flowing electrically conductive molten metal that has flown from outside toward the metal product manufacturing device;

[0018] providing an inlet-side closed end plate and an outlet-side closed end plate in the molten metal flow path body so as to partition a front and a rear of the molten metal flow path and form an impurity removal space;

[0019] providing, in the impurity removal space, an electrode device composed of an inlet-side electrode and an outlet-side electrode that face each other in a longitudinal direction in which molten metal flows and can be put into electrical contact with molten metal in the impurity removal space;

[0020] providing, outside the molten metal flow path forming body, a magnetic field device composed of a pair of permanent magnets that face each other in a width direction intersecting the longitudinal direction, sandwich the impurity removal space of the molten metal flow path forming body in the width direction, have opposite poles facing each other, and can form a magnetic field in molten metal in the impurity removal space; and

[0021] causing an urging device composed of the electrode device and the magnetic field device to apply a Lorentz force downward to molten metal in the impurity removal space so as to increase a density of the molten metal and cause impurities in the molten metal to rise up to a surface of the molten metal.

[0022] Furthermore, an embodiment of the present invention is

[0023] a device for continuously removing impurities from molten metal, which sends electrically conductive molten metal to a metal product manufacturing device in a next stage, the device including:

[0024] a molten metal flow path body having a molten metal flow path for flowing electrically conductive molten metal that has flown from outside toward the metal product manufacturing device;

[0025] an inlet-side closed end plate and an outlet-side closed end plate that are provided in the molten metal flow path body so as to partition a front and a rear of the molten metal flow path and form an impurity removal space;

[0026] an electrode device composed of an inlet-side electrode and an outlet-side electrode that are provided in the impurity removal space, face each other in a longitudinal direction in which molten metal flows, and can be put into electrical contact with molten metal in the impurity removal space; and

[0027] a magnetic field device composed of a pair of permanent magnets that are provided outside the molten metal flow path forming body, face each other in a width direction intersecting the longitudinal direction, sandwich the impurity removal space of the molten metal flow path forming body in the width direction, have opposite poles facing each other, and can form a magnetic field in molten metal in the impurity removal space,

[0028] in which the outlet-side electrode is provided in a floating state in the impurity removal space so that a first gap opened vertically is formed between the outlet-side electrode and a bottom surface of the molten metal flow path forming body and a second gap opened in the longitudinal direction is formed between the outlet-side electrode and the outlet-side closed end plate, and

[0029] the electrode device and the magnetic field device constitute an urging device that can apply a Lorentz force downward to molten metal in the impurity removal space so as to increase a density of the molten metal and cause impurities in the molten metal to rise up to a surface of the molten metal, and can send molten metal on an inner side than the outlet-side electrode in the impurity removal space through the first gap to the second gap.

[0030] Furthermore, an embodiment of the present invention is

[0031] a continuous impurity removal method for removing impurities from molten metal in sending electrically conductive molten metal to a metal product manufacturing device in a next stage, the method including:

[0032] preparing a molten metal flow path body having a molten metal flow path for flowing electrically conductive molten metal that has flown from outside toward the metal product manufacturing device;

[0033] providing an inlet-side closed end plate and an outlet-side closed end plate in the molten metal flow path body so as to partition a front and a rear of the molten metal flow path and form an impurity removal space;

[0034] providing, in the impurity removal space, an electrode device composed of an inlet-side electrode and an outlet-side electrode that face each other in a longitudinal direction in which molten metal flows and can be put into electrical contact with molten metal in the impurity removal space;

[0035] providing, outside the molten metal flow path forming body, a magnetic field device composed of a pair of permanent magnets that face each other in a width direction intersecting the longitudinal direction, sandwich the impurity removal space of the molten metal flow path forming body in the width direction, have opposite poles facing each other, and can form a magnetic field in molten metal in the impurity removal space;

[0036] providing the outlet-side electrode in a floating state in the impurity removal space so that a first gap opened vertically is formed between the outlet-side electrode and a bottom surface of the molten metal flow path forming body and a second gap opened in the longitudinal direction is formed between the outlet-side electrode and the outlet-side closed end plate; and

[0037] causing an urging device composed of the electrode device and the magnetic field device to apply a Lorentz force downward to molten metal in the impurity removal space so as to increase a density of the molten metal and cause impurities in the molten metal to rise up to a surface of the molten metal, and send molten metal on an inner side than the outlet-side electrode through the first gap to the second gap.

BRIEF DESCRIPTION OF DRAWINGS

[0038] FIG. **1** is an explanatory plan view illustrating the overall configuration of a device for continuously removing impurities from molten metal according to an embodiment of the present invention.

[0039] FIG. **2** is an explanatory sectional view taken along line II-II of FIG. **1**.

[0040] FIG. **3** is an explanatory sectional view taken along line III-III of FIG. **2**.

[0041] FIG. **4** is an explanatory sectional view taken along line IV-IV of FIG. **2**.

[0042] FIG. **5** is an explanatory view illustrating a usage state corresponding to a part of FIG. **2**.

[0043] FIG. **6** is an explanatory view for explaining generation of a Lorentz force.

[0044] FIG. **7***a* is an explanatory view for explaining a pressure state in molten metal.

[0045] FIG. **7***b* is an explanatory view for explaining a pressure state in molten metal.

[0046] FIG. **8** is an explanatory partial view illustrating a modified example corresponding to FIG. **5**.

[0047] FIG. **9***a* is an explanatory longitudinal sectional view illustrating a specific example of an outlet-side closed end plate.

[0048] FIG. **9***b* is an explanatory longitudinal sectional view illustrating a specific example of an outlet-side closed end plate.

DESCRIPTION OF EMBODIMENTS

[0049] Hereinafter, embodiments of the present invention will be described with reference to the drawings.

[0050] FIG. **1** is an explanatory plan view illustrating the entire configuration of an embodiment of a device **100** for continuously removing impurities from molten metal according to the present invention. The metal is a non-ferrous metal having electrical conductivity or another metal. The non-ferrous metal or another metal is a non-ferrous metal of a conductor (electric conductor) such as Al, Cu, Zn, an alloy including at least two of these, or an Mg alloy, or a metal other than the non-ferrous metal.

[0051] In FIG. **1**, the flow of molten metal M is indicated by a solid arrow AR**1**, and the movement of impurities IM is indicated by a broken arrow AR**2**. That is, it is shown that the impurities IM are removed laterally while the molten metal M is flowing along the arrow AR**1**.

[0052] More specifically, FIG. **1** illustrates a case where a tilting type melting furnace is used as an example. As can be seen from FIG. **1**, the impurity removing device **100** receives molten metal M from a melting furnace **200** in the preceding stage, allows the molten metal M flow inside the impurity removing device **100**, causes impurities in the molten metal M to positively rise up to the vicinity of the liquid surface during the molten metal M is flowing so that the impurities can be removed by arbitral means, and causes the molten metal M to flow into a mold **300** in the following stage after impurities are removed, so that a product (ingot) such as a billet or a slab, for example, can be manufactured from high-quality molten metal M. A general-purpose melting furnace **200** and a general-purpose mold **300** can be employed. Therefore, for example, the impurity removing device **100** of the present invention can be additionally provided to an existing melting furnace **200** and an existing mold **300** later.

[0053] The melting furnace **200** is a general-purpose tilting type melting furnace as described above. That is, the melting furnace **200** includes a container-shaped melting furnace main body **1** having an opening **2** at the top. A spout **3** for the molten metal M is formed at a side wall on the front side (left side in the figure) of the tilting type melting furnace main body **1**. A general-purpose gas burner **4** is attached to a rear side wall. The raw material of the electrically conductive metal introduced from the opening **2** is heated by the gas burner **4** to be molten metal M and is housed in the melting furnace main body **1**.

[0054] FIG. **2** is an explanatory longitudinal sectional view taken along line II-II of FIG. **1**. As can be seen from FIG. **2**, a hinge mechanism **6** is provided at an outer bottom portion of the melting furnace main body **1** so as to be able to derrick and rotate. As a result, it is configured to be able to derrick and rotate on a horizontal shaft **6***a* from an upright state to an inclined pouring state. This melting furnace main body **1** can adjust the amount of molten metal supplied to a gutter main body **10**. The molten metal M is poured from the spout **3** to the impurity removing device **100** in the next stage by tilting the melting furnace main body **1**. This state is illustrated in FIG. **5**. By adjusting the angle at which the melting furnace main body **1** is inclined, the head h illustrated in FIG. **2** is changed, and the flow rate of the molten metal M from the melting furnace main body **1** to the gutter main body **10** can be changed. It is to be noted that the level of the molten metal M in the gutter main body **10** is performed by changing the height of an outlet-side closed end plate **11**. Moreover, as illustrated in FIG. **8**, one electrode **13***b*, which will be described later, can be provided separately from the inlet-side closed end plate **8**. The flow of the molten metal M at this time is as illustrated in FIG. **8**.

[0055] The impurity removing device **100** that receives the molten metal M from the melting furnace **200** is configured to have a function as a so-called gutter that allows the received molten metal M flow from right to left in FIG. **1** and give the molten metal M to the mold **300** in the next stage, and a selective accumulation function of selectively accumulating impurities in the molten metal M that are caused to rise up to the vicinity of the liquid surface during the flow.

[0056] That is, as can be seen particularly from FIG. **2**, the impurity removing device **100** includes the gutter main body (sorting tank) (molten metal flow path body) **10**, and a magnetic field device **12** that sandwiches the gutter main body **10** in the width direction. Furthermore, as can be seen particularly from FIG. **1**, the impurity removing device **100** has an electrode device **13** composed of a pair of electrodes **13***a* and **13***b* that are housed inside the gutter main body **10** (molten metal flow path) and face each other. The magnetic field device **12** and the electrode device **13** constitute an urging device **30** that applies a Lorentz force f downward to the molten metal M, as will be described later in detail.

[0057] As can be seen from FIG. **1**, the gutter main body **10** is configured to guide the molten metal M from the melting furnace **200** to the mold **300**, and the gutter main body **10** is made of a refractory material and has a substantially U-shaped cross section as can be seen from FIG. **3**. The gutter main body **10** can be installed with a gradient so that the left side becomes lower than the right side in FIG. **2** in order to make the flow of the molten metal M smooth.

[0058] As can be seen from FIG. **2**, the gutter main body **10** has an inflow auxiliary plate **7**A that receives the molten metal M from the melting furnace **200**, and an inlet-side closed end plate **8**, a main flow path bottom plate **9**, and the outlet-side closed end plate **11** that follow. Furthermore, there are right and left side plates **15***a* and **15***b* sandwiching these members in the width direction. The right and left side plates **15***a* and **15***b*, the inlet-side closed end plate **8**, and the outlet-side closed end plate **11** form a main flow path (impurity removal space) **14** as an impurity removal portion.

[0059] The outlet-side closed end plate **11** can be configured such that the height thereof can be adjusted. Arbitral configuration configured such that the height thereof can be adjusted can be employed. For example, as can be seen from FIGS. **9***a* and **9***b*, the outlet-side closed end plate **11** may be composed of a main body **11***a* and an auxiliary plate **11***b* which are bolted to each other, and the auxiliary plate **11***b* may be vertically shifted with respect to the main body **11***a*.

[0060] The inlet-side electrode **13***a* in the electrode device **13** is provided in close contact with the inlet-side closed end plate **8**, and the outlet-side electrode **13***b* is spaced from the outlet-side closed end plate **11** with a gap (second gap) G**2** in the longitudinal direction and is provided in a floating state of floating with a gap (first gap) G**1** in the depth direction. As a result, the molten metal M flows through the gaps G**1** and G**2**, flows over the outlet-side closed end plate **11**, or so-called overflows, and flows out from the main flow path **8** through an outflow auxiliary plate **7**B toward the mold **300** as will be described later.

[0061] A power supply **16** is connected between the pair of electrodes **13***a* and **13***b* in the electrode device **13**. This power supply **16** is configured to be able to pass an alternating current as well as a direct current. Furthermore, it is configured to switch the polarity of a direct current.

[0062] The magnetic field device **12** is provided on both right and left sides of the gutter main body **10** as can be seen from FIGS. **1** and **4**. This magnetic field device **12** includes a pair of right and left permanent magnets **12***a* and **12***b*, and the gutter main body **10** is sandwiched between the pair of permanent magnets **12***a* and **12***b*. The pair of permanent magnets **12***a* and **12***b* have opposite poles facing each other, and in this embodiment, the inner sides of the pair of permanent magnets **12***a* and **12***b* are magnetized respectively to an S pole and an N pole. As a result, the lines of magnetic force ML from an upper permanent magnet **12***b* in FIG. **4** penetrate the molten metal M in the gutter main body

10 and reach a lower permanent magnet **12***a*. Thus, in actual use, a current I flows between the pair of electrodes **13***a* and **13***b* as can be seen from FIG. **4**. Therefore, the lines of magnetic force ML and the current I intersect each other. As a result, a Lorentz force f to push the molten metal M downward is generated in the molten metal M as illustrated in FIG. **6**. It is to be noted that the magnetic field device **12** can be constituted of an electromagnet.

[0063] Next, the operation of the embodiment of the present invention will be described.

[0064] As can be seen from FIGS. **1** and **2**, when electrically conductive metal is introduced into the melting furnace **200** and is heated and molten, the molten metal M is caused to flow from the melting furnace **200** into the main flow path **14** by increase of the molten metal M and the tilt illustrated in FIG. **5**.

[0065] In this main flow path **14**, the lines of magnetic force ML and the current I intersect each other as can be seen from FIG. **4**. This concept is illustrated in FIG. **6** described above. As a result, a Lorentz force f is generated and acts on the molten metal M as a force in a direction to push the molten metal M downward. As a result, the pressure inside the molten metal M increases as it goes from the surface to a bottom portion. The state of pressure distribution in this case is illustrated in FIG. **7***a*. That is, the density of the molten metal M becomes larger toward the bottom portion due to the gravity in addition to the Lorentz force f. This density affects greatly the buoyancy of impurities IM contained in the molten metal M. That is, when the density is high, a large buoyancy acts on impurities IM.

[0066] Therefore, in a state in which the Lorentz force f is generated, impurities IM in the molten metal M rise in the molten metal M and reach the liquid level. That is, impurities IM tend to settle in the molten metal M by its own weight. Moreover, a buoyancy due to the molten metal M acts on impurities IM. Thus, when the density of the molten metal M increases, a large buoyancy acts on impurities IM in the molten metal M. Therefore, impurities IM rise or fall according to a difference between the buoyancy and the settlement force. Thus, by setting the Lorentz force f to an expected value, the buoyancy becomes larger than the settlement force, and impurities IM rise in the molten metal M and reach the vicinity of the liquid surface. This operation is continuously performed in the process of flow of the molten metal M through the main flow path **14**.

[0067] In this way, impurities IM rise up to the vicinity of the surface of the molten metal M. Impurities IM that have risen up are automatically or artificially discharged to an impurity receiver **40** via the impurity removing plate **7**C as can be seen from FIG. **3** by arbitral means. As illustrated in FIG. **3**, the impurity removing plate **7**C has a mountain-shaped cross section.

[0068] Moreover, in the gutter main body **10**, the molten metal M is pushed down by application of pressure as illustrated in FIG. **7***b* as described above to decrease the liquid level. Along with this, the molten metal M flows through the gap G**1** and reaches the gap G**2** as can be seen from FIG. **2**. As a result, a head h is generated, and a pressure corresponding to the head h is applied to the molten metal M in the gutter main body **10** as illustrated in FIG. **2**. Here, since impurities IM rise in the molten metal M and gather in the vicinity of the liquid surface, the molten metal M flowing through the gap G**1** contains substantially no impurity IM. That is, molten metal M substantially containing no impurity IM exists in the gap G**2**. Thus, the liquid level of the molten metal M rises in the gap G**2**. Therefore, the substantially purified molten metal M flows over the outlet-side closed end plate **11** and flows into the mold **30** via the outflow auxiliary plate **7**B. As a result, a high-quality product with less impurities IM can be obtained. In FIG. **2**, h denotes a head of two liquid levels.

[0069] The above-described fact that application of the Lorentz force f can cause impurities IM in the molten metal M to rise in the molten metal M will be described below in detail.

[0070] The magnetic field strength in the molten metal M in FIG. **4** will be denoted by B. Here, as can be seen from FIGS. **7***a* and **7***b*, it is assumed that a Lorentz force f is generated downward. At this time, a force F that acts on a bottom portion of the gutter main body **10** is the sum of a force fg due to the gravity and a force fm due to the Lorentz force f, and is expressed as the following expression.

$$F=fg+fm$$

[0071] Here, since the horizontal area A of the gutter main body **10** is A=l×a (l: the length of the gutter main body **10**, a: the width of the gutter main body **10**), the pressure P at a bottom portion of the gutter main body **10** is expressed as the following expression.

[0072] P=F/A Furthermore, assuming here that the current density between the pair of electrodes **13***a* and **13***b* is constant, the Lorentz force f becomes zero at the surface of the molten metal, and I×B×l (N) at a bottom portion. Thus, the pressure is highest at a bottom portion. This state is illustrated in FIGS. **7***a* and **7***b*.

[0073] Furthermore, the apparent density of the molten metal M affected by two influences of the Lorentz force f and the gravity is denoted by ρm, the density of mixed impurity particles is denoted by ρs, and the particle size is denoted by V. The buoyancy fa received from the molten metal M and the force fg due to the gravity simultaneously act on the impurity particles. At this time, assuming that the force received by the impurity particles is denoted by Fs, the following expression is satisfied.

$$\begin{aligned} Fs &= fa - fg \\ &= \rho m \times V - \rho s \times V \\ &= (\rho m - \rho s) \times V \end{aligned}$$

Accordingly, the impurity particles move in the molten metal M as follows.

[0074] (a) $\rho m - \rho s > 0$ Rise

[0075] (b) $\rho m - \rho s < 0$ Settlement

[0076] (c) $\rho m - \rho s = 0$ Floating

[0077] With the embodiment of the present invention described above, the following advantages can be obtained.

[0078] (1) Continuous purification of molten metal M is possible, which is consistent with a continuous casting method that has become a standard technology in the industry.

[0079] (2) Although the rise speed of impurities varies depending on the particle size, density, and the like of impurities, the residence time of the molten metal M in the gutter main body (sorting tank) may be increased by slowing down the flow speed or lengthening the gutter main body, for example, in the case of separating objects (having small particle size) having a low rise speed.

[0080] (3) Since the purification is neither physical nor mechanical, there is no need to replace a filter, which not only improves the work efficiency but also reduces costs.

[0081] (4) The specific gravity of the molten metal can be easily changed by changing the magnetic field strength or the current value, and an impurity removing operation can be performed according to the type of the molten metal M to be subjected to impurity removal.

1. A device for continuously removing impurities from molten metal, which sends electrically conductive molten metal to a metal product manufacturing device in a next stage, the device comprising:

a molten metal flow path body having a molten metal flow path for flowing electrically conductive molten metal that has flown from outside toward the metal product manufacturing device;

an inlet-side closed end plate and an outlet-side closed end plate that are provided in the molten metal flow path body so as to partition a front and a rear of the molten metal flow path and form an impurity removal space;

an electrode device composed of an inlet-side electrode and an outlet-side electrode that are provided in the impurity removal space, face each other in a longitudinal direction in which molten metal flows, and can be put into electrical contact with molten metal in the impurity removal space; and

a magnetic field device composed of a pair of permanent magnets that are provided outside the molten metal flow path forming body, face each other in a width direction intersecting the longitudinal direction, sandwich the impurity removal space of the molten metal flow path forming body in the width direction, have opposite poles facing each other, and can form a magnetic field in molten metal in the impurity removal space,

wherein the electrode device and the magnetic field device constitute an urging device that can apply a Lorentz force downward to molten metal in the impurity removal space so as to increase a density of the molten metal and cause impurities in the molten metal to rise up to a surface of the molten metal.

2. The device for continuously removing impurities from molten metal according to claim **1**, wherein a power supply that can adjust an amount of current so as to adjust the Lorentz force is connected with the pair of electrodes in the electrode device.

3. The device for continuously removing impurities from molten metal according to claim **1**, wherein the outlet-side closed end plate is configured to be capable of adjusting a mounting position in the molten metal flow path body in the longitudinal direction so as to adjust a length of the impurity removal space.

4. The device for continuously removing impurities from molten metal according to claim **1**, wherein the outlet-side electrode is provided in a floating state in the impurity removal space so that a first gap opened vertically is formed between the outlet-side electrode and a bottom surface of the molten metal flow path forming body and a second gap opened in the longitudinal direction is formed between the outlet-side electrode and the outlet-side closed end plate.

5. The device for continuously removing impurities from molten metal according to claim **1**, wherein the outlet-side closed end plate is configured such that a height of the outlet-side closed end plate can be adjusted so that an amount of molten metal that overflows can be adjusted.

6. The device for continuously removing impurities from molten metal according to claim **1**, wherein a molten metal supply device that supplies molten metal to the molten metal flow path body and can adjust a supply amount is provided in a preceding stage of the molten metal flow path body.

7. A continuous impurity removal method for removing impurities from molten metal in sending electrically conductive molten metal to a metal product manufacturing device in a next stage, the method comprising:

preparing a molten metal flow path body having a molten metal flow path for flowing electrically conductive molten metal that has flown from outside toward the metal product manufacturing device;

providing an inlet-side closed end plate and an outlet-side closed end plate in the molten metal flow path body so as to partition a front and a rear of the molten metal flow path and form an impurity removal space;

providing, in the impurity removal space, an electrode device composed of an inlet-side electrode and an outlet-side electrode that face each other in a longitudinal direction in which molten metal flows and can be put into electrical contact with molten metal in the impurity removal space;

providing, outside the molten metal flow path forming body, a magnetic field device composed of a pair of permanent magnets that face each other in a width direction intersecting the longitudinal direction, sandwich the impurity removal space of the molten metal flow path forming body in the width direction, have opposite poles facing each other, and can form a magnetic field in molten metal in the impurity removal space; and

causing an urging device composed of the electrode device and the magnetic field device to apply a Lorentz force downward to molten metal in the impurity removal space so as to increase a density of the molten metal and cause impurities in the molten metal to rise up to a surface of the molten metal.

8. The method for continuously removing impurities from molten metal according to claim **7**, further comprising adjusting an amount of current applied from a power supply to the pair of electrodes in the electrode device so as to adjust the Lorentz force.

9. The method for continuously removing impurities from molten metal according to claim **7**, further comprising a step of adjusting a mounting position of the outlet-side closed end plate in the molten metal flow path body in the longitudinal direction so as to adjust a length of the impurity removal space.

10. The method for continuously removing impurities from molten metal according to claim **7**, wherein the outlet-side electrode is provided in a floating state in the impurity removal space so that a first gap opened vertically is formed between the outlet-side electrode and a bottom surface of the molten metal flow path forming body and a second gap opened in the longitudinal direction is formed between the outlet-side electrode and the outlet-side closed end plate.

11. The method for continuously removing impurities from molten metal according to claim **7**, wherein the outlet-side closed end plate is configured such that a height of the outlet-side closed end plate can be adjusted and an amount of molten metal that overflows can be adjusted.

12. The method for continuously removing impurities according to claim **7**, wherein a molten metal supply device provided in a preceding stage of the molten metal flow path body adjusts an amount of molten metal supplied to the molten metal flow path body.

13. A device for continuously removing impurities from molten metal, which sends electrically conductive molten metal to a metal product manufacturing device in a next stage, the device comprising:

a molten metal flow path body having a molten metal flow path for flowing electrically conductive molten metal that has flown from outside toward the metal product manufacturing device;

an inlet-side closed end plate and an outlet-side closed end plate that are provided in the molten metal flow path body so as to partition a front and a rear of the molten metal flow path and form an impurity removal space;

an electrode device composed of an inlet-side electrode and an outlet-side electrode that are provided in the impurity removal space, face each other in a longitudinal direction in which molten metal flows, and can be put into electrical contact with molten metal in the impurity removal space; and

a magnetic field device composed of a pair of permanent magnets that are provided outside the molten metal flow path forming body, face each other in a width direction intersecting the longitudinal direction, sandwich the impurity removal space of the molten metal flow path forming body in the width direction, have opposite poles facing each other, and can form a magnetic field in molten metal in the impurity removal space,

wherein the outlet-side electrode is provided in a floating state in the impurity removal space so that a first gap opened vertically is formed between the outlet-side electrode and a bottom surface of the molten metal flow path forming body and a second gap opened in the longitudinal direction is formed between the outlet-side electrode and the outlet-side closed end plate, and

the electrode device and the magnetic field device constitute an urging device that can apply a Lorentz force downward to molten metal in the impurity removal space so as to increase a density of the molten metal and cause impurities in the molten metal to rise up to a surface of the molten metal, and can send molten metal on an inner side than the outlet-side electrode in the impurity removal space through the first gap to the second gap.

14. A continuous impurity removal method for removing impurities from molten metal in sending electrically conductive molten metal to a metal product manufacturing device in a next stage, the method comprising:

preparing a molten metal flow path body having a molten metal flow path for flowing electrically conductive molten metal that has flown from outside toward the metal product manufacturing device;

providing an inlet-side closed end plate and an outlet-side closed end plate in the molten metal flow path body so as to partition a front and a rear of the molten metal flow path and form an impurity removal space;

providing, in the impurity removal space, an electrode device composed of an inlet-side electrode and an outlet-side electrode that face each other in a longitudinal direction in which molten metal flows and can be put into electrical contact with molten metal in the impurity removal space;

providing, outside the molten metal flow path forming body, a magnetic field device composed of a pair of permanent magnets that face each other in a width direction intersecting the longitudinal direction, sandwich the impurity removal space of the molten metal flow path forming body in the width direction, have opposite poles facing each other, and can form a magnetic field in molten metal in the impurity removal space;

providing the outlet-side electrode in a floating state in the impurity removal space so that a first gap opened vertically is formed between the outlet-side electrode and a bottom surface of the molten metal flow path forming body and a second gap opened in the longitudinal direction is formed between the outlet-side electrode and the outlet-side closed end plate; and

causing an urging device composed of the electrode device and the magnetic field device to apply a Lorentz force downward to molten metal in the impurity removal space so as to increase a density of the molten metal and cause impurities in the molten metal to rise up to a surface of the molten metal, and send molten metal on an inner side than the outlet-side electrode through the first gap to the second gap.

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