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(11) **EP 0 780 176 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
25.06.1997 Bulletin 1997/26

(51) Int. Cl.⁶: **B22D 11/04**, B22D 11/06,
B22D 11/10, B22D 11/16

(21) Application number: **96119789.4**

(22) Date of filing: **10.12.1996**

(84) Designated Contracting States:
DE GB IT

(30) Priority: **13.12.1995 JP 324203/95**
04.04.1996 JP 82324/96
20.05.1996 JP 124672/96

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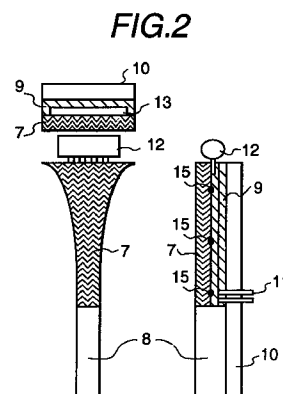
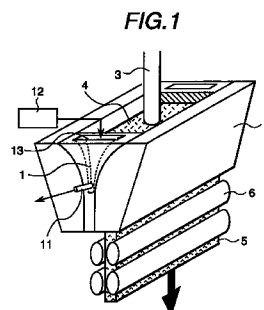
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(54) **Apparatus for and process of continuous casting**

(57) A continuous casting apparatus of a reduction type in which a mold is composed of long-side mold elements (2) and short-side mold elements (1), each short-side mold element (1) including a reduction portion (7) widened at its upper portion and narrowed at its lower portion and a straight portion (8), so that reduction is performed in a state that solidification is suppressed on a short-side mold element (1) side. The reduction portion (7) is made of a refractory member, and the straight portion (8) is made of a water-cooled copper plate. The refractory member (7) may be made from a material mainly containing ZrB_2 , and it may be divided in a plurality of parts. To control a temperature distribution of the short-side mold element (1), a high temperature supply passage (13) is provided in a back surface portion of the short-side mold element (1). An elastically deformable frame is arranged at a contact portion between a reduction portion (7) made of a refractory member and a long-side mold element (2) for preventing formation of gaps between the short-side mold element (1) and the long-side mold element (2). Also, a seal member is provided at a contact portion between the short-side mold element (1) and the long-side mold element (2) for improving a sliding therebetween.



EP 0 780 176 A2

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an apparatus for and a process of continuously producing a long-sized ingot having a specified cross-section by solidifying molten metal in a lead-through mold and continuously drawing the solidified shell.

2. Description of the Prior Art

(1) Apparatuses and processes for continuously producing a long-sized ingot having a specified cross-section by continuously solidifying molten metal in a lead-through type mold and continuously drawing a shell solidified in the mold have been described, for example, in Japanese Patent Laid-open Nos. Sho 58-218353 and Hei 3-8541, and WO 94/07628.

In general, steel sheets are produced by rolling a steel slab which is cast from molten steel by continuous casting. The thickness of the slab is generally set at about 200 mm, and accordingly, many rolling steps are required to obtain a steel sheet having a thickness of 100 mm or less using such a slab.

On the contrary, in recent years, a technique called "mini-hot" has been proposed, in which a steel sheet is rolled using a slab having a thickness reduced to a value of about from 30 to 80 mm for omitting a heating step and rough rolling in a hot-rolling step, thereby reducing an equipment cost and an operation cost, shortening a lead time from a raw material to a product, and saving an energy required for rolling.

It is essential to shorten a distance between opposed long-side mold elements for producing a thin slab; however, when the distance between opposed long-side mold elements is shortened, it becomes difficult to ensure a space in which a pouring nozzle for supplying molten metal is to be inserted. To cope with such an inconvenience, a technique has been proposed, which adopts a mold formed in such a shape that the width is widened at an upper portion thereof and is substantially equal to the cross-section of a slab at a lower end thereof.

(2) In general, metal sheets are produced by rolling a slab (plate-like ingot) produced from molten metal by continuous casting. The thickness of a slab is generally set at about 200 mm, and accordingly many rolling steps are required to obtain a metal sheet having a thickness of 10 mm or less using such a slab. On the other hand, the number of rolling steps can be reduced using a thin slab produced by a sheet continuously casting process; however, in this process, the casting speed must be

increased for ensuring a production. Additionally, in the case of producing a thin slab, since a mold space into which a pouring nozzle for pouring molten metal in the mold is to be inserted is made smaller, a pouring nozzle insertion portion of the mold must be widened. Such a technique has been disclosed, for example, in Japanese Patent Laid-open No. Sho 63-26244, WO 94/07628, and Japanese Patent Laid-open Nos. Hei 7-232241 and Hei 7-256399.

(3) In general, a steel sheet is produced by rolling a plate-like ingot or a slab having a thickness of about 200 mm produced by continuously supplying molten steel in a lead-through mold and continuously drawing a shell solidified in the mold. In this case, many rolling steps are required to obtain a steel sheet having a thickness of 10 mm or less using such a slab.

If a thin slab having a thickness of from 30 to 100 mm is produced, it is possible to reduce the number of the rolling steps using such a thin slab and hence to lower a production cost; however, in such a process of producing a thin slab, the casting speed must be increased for ensuring a production comparable to that obtained using the conventional thick slab. Moreover, in such a process, the short-side mold element is narrowed for producing a thin slab, and consequently a space of the mold on the molten metal supply side is also narrowed. This makes it difficult to ensure a space into which a pouring nozzle is to be inserted.

To cope with such an inconvenience, a thin slab continuously casting process (hereinafter, referred to sometimes to a reduction casting type) has been disclosed, for example, in Japanese Patent Laid-open No. Sho 58-218360, Sho 64-2764, Hei 2-147151, Hei 3-8541, and WO 94/07628, in which a pouring nozzle can be easily inserted in a mold space using a reduction type mold including short-side mold elements in each of which the width (in the thickness direction of a slab) is widened at its upper portion and is narrowed at its lower portion. Such a mold also takes a suitable measure for ensuring stable casting without breakage of a solidified shell, that is, for preventing production of a solidified shell on the surface, being in contact with molten metal, of the short-side mold element at the reduction step. Concretely, a refractory member is used for a reduction portion of the short-side mold element for keeping the short-side mold element being in contact with molten metal at a reduction step in a high temperature state.

On the other hand, differently from the thin slab continuously casting process using the above-described reduction type mold, a modification of the conventional thick slab continuously casting process is disclosed in Japanese Utility Model Laid-open No. Sho 55-11201, in which a portion, being in contact with a long-side mold element, of the short-

side mold element is applied with a metal plating for improving a wear resistance of the contact portion.

(4) In general, steel sheets are manufactured by rolling a slab (flat ingot) produced from molten steel by continuous casting. The thickness of a slab is generally set at about 200 mm, and accordingly many rolling steps are required to obtain a steel sheet having a thickness of 10 mm or less using such a slab.

The number of rolling steps in manufacturing a steel sheet can be reduced using a thin slab produced by a thin slab continuously casting process; however, in this case, the casting speed must be increased for ensuring a production. Additionally, in the process of producing a thin slab, since a space of a mold into which a pouring nozzle for pouring molten metal in the mold is inserted is made smaller, a pouring nozzle insertion portion of the mold must be widened.

Such a technique has been disclosed, for example, in Japanese Patent Laid-open Nos. Hei 3-8541, Sho 58-3255, Sho 62-64458 and Hei 2-155543, and WO 94/07628.

(5) In general, a steel sheet is produced by rolling a plate-like ingot or a slab having a thickness of about 200 mm produced by continuously supplying molten steel in a lead-through mold and continuously drawing a shell solidified in the mold. In this case, many rolling steps are required to obtain a steel sheet having a thickness of 10 mm or less using such a slab.

If a thin slab having a thickness of from 30 to 100 mm is produced, it is possible to reduce the number of the rolling steps using such a thin slab and hence to lower a production cost; however, in such a process of producing a thin slab, the casting speed must be increased for ensuring a production comparable to that obtained using the conventional thick slab. Moreover, in such a process, the short-side mold element is narrowed for producing a thin slab, and consequently a space of the mold on the molten metal supply side is also narrowed. This makes it difficult to ensure a space into which a pouring nozzle is to be inserted.

To cope with such an inconvenience, a thin slab continuously casting process (hereinafter, referred to sometimes to a reduction casting type) has been disclosed, for example, in Japanese Patent Laid-open No. Hei 3-8541, WO 94/07628, and Japanese Patent Laid-open Nos. Hei 7-232241 and Hei 7-256399, in which a pouring nozzle can be easily inserted in a mold space using a reduction type mold including short-side mold elements in each of which the width (in the thickness direction of a slab) is widened at its upper portion and is narrowed at its lower portion.

(6) Thin slab continuously casting apparatuses for continuously producing a thin slab from molten metal (for example, molten steel) have been vari-

ously proposed. Of these apparatuses, a reduction type is classified into a synchronously moving mold type such as a twin-belt type or a twin-roll type and an oscillating fixed mold type. The reduction type thin slab continuously casting apparatus has a disadvantage that a solidified shell produced on the surface of a short-side mold element causes an excess drawing resistance, leading to operational troubles such as breakout. Accordingly, in the reduction type thin slab continuously casting apparatus, it becomes important to suppress production of a solidified shell on the surface of a reduction portion of the short-side mold element. In this regard, there have been proposed various methods of using a refractory member being in low in thermal conductivity for the short-side mold element or providing a heating means in the short-side mold element. For example, continuous casting apparatuses of an oscillating fixed mold type in which a short-side mold element is made of a refractory member, have been disclosed in Japanese Patent Laid-open Nos. Hei 3-8541 and Hei 7-232241.

In the continuous casting apparatus of a reduction type in which reduction is performed in a state that a solidified shell is not produced on the surface of a short-side mold element, it is of course important to prevent a solidified shell from being produced on a reduction portion of a short-side mold element; however, since solidification is slower on the surface of the short-side mold element than on the surface of the long-side mold element, there is a possibility that breakout occurs at a portion directly under the mold if the growth of the solidified shell on the short-side mold element is insufficient. Also if no breakout occurs, bulging of a slab occurring on the short-side mold element exerts adverse effect on the quality of the slab. For this reason, the continuous casting apparatus disclosed in Japanese Patent Laid-open No. Hei 7-232241 is so configured that a reduction portion of a short-side mold element is made of a refractory member for suppressing production of a short-side solidified shell, and a straight portion of the short-side mold element is made of a water-cooled metal plate for ensuring a strength of the solidified shell on the short-side mold element by strongly cooling the straight portion. Moreover, in Japanese Patent Laid-open No. Hei 3-8541, a water-cooled metal plate is used for not only a straight portion but also part of a reduction portion of a short-side mold element for significantly increasing the strength of the solidified shell on the short-side mold element side.

Moreover, a process of producing a high quality slab using a mold directly connected to a tundish has been disclosed in Rev. Metall. Cah. Inf. Tech. : Vol. 92, No. 6 (1995), P. 781, in which a ceramic member is used for an upper portion of an inner surface of the mold being in contact with molten steel, and a water-cooled copper plate is used for a

lower portion of the inner surface of the mold.

The above-described prior arts have the following problems:

(1) In the above-described prior art (for example, Japanese Patent Laid-open No. Sho 58-218353), a thin slab is produced by supplying molten metal in a mold space formed of long-side mold elements moving in synchronization with the slab and approximately fan-shaped short-side mold elements not moving in synchronization with the slab.

According to such a technique, even in the case where the short-side mold elements are not heated, since a slab is moved in synchronization with the long-side mold elements, it can be cast on the basis of a rolling phenomenon even if a solidified shell is produced on the surfaces of the short-side mold elements. In this technique, however, there occurs a disadvantage that since a slab is moved in synchronization with the long-side mold elements, a mold powder floating on a molten metal surface is entrapped in the long-side mold elements moving in synchronization with the slab, as a result of which the mold powder is difficult to stably remain on the molten metal surface. In other words, it is practically impossible to use a mold powder for such a synchronously moving type mold.

The above technique thus cannot obtain important effects of a mold powder, of preventing oxidation of a molten metal surface, catching inclusions and the like, resulting in the deteriorated quality of a slab. The use of a mold powder is effective to obtain a high quality slab.

A technique of producing a thin slab using a mold powder has been proposed, which adopts a so-called oscillating type mold in which long-side mold elements and short-side mold elements do not move in synchronization with a slab and are made to vertically oscillate in a fixed state, wherein the short-side mold element is formed in an approximately fan-shape.

The techniques disclosed for example in WO 94/07628 and Japanese Patent Laid-open No. Hei 3-8541, which are different from the above-described synchronously moving mold type, fail to examine a temperature distribution of a short-side refractory member at the time of casting and a non-uniform reduction in temperature of the short-side refractory member with time in the case of a long-period casting, and consequently, they cannot positively prevent production of a solidified shell on the surfaces of the short-side mold elements and thereby cannot perform stable casting.

(2) According to the above-described prior arts, the pouring nozzle insertion portion of the mold is widened, so that the pouring nozzle can be easily inserted in the mold space, enabling production of a thin slab. On the other hand, it is desirable to supply

a mold powder on a molten metal surface during casting for improving the quality of a slab; however, in the prior art, Japanese Patent Laid-open No. Sho 63-26244 in which long-side mold elements are moved at the same speed as a drawing speed of a slab, it is difficult to use a mold powder. The apparatuses disclosed in the prior arts, WO 94/07628, and Japanese Patent Laid-open Nos. Hei 7-232241 and Hei 7-256399 are of an oscillating mold type, and thereby they can use a mold powder. A mold powder mainly contains oxides such as CaO, SiO₂, MgO, and Al₂O₃ which are generally added with additives for reducing the viscosity, such as Li₂O, NaF, and CaF. A refractory member mainly containing Al₂O₃ or SiO₂, which is represented by a pouring nozzle, is liable to be corroded by a mold powder. Accordingly, a mold made from such a refractory member is corroded by a mold powder, and exhibits only a service life similar to that of a pouring nozzle. The above prior arts fail to sufficiently examine corrosion of a material of a short-side mold element due to a mold powder.

(3) The prior arts disclosed in Japanese Patent Laid-open No. Sho 58-218360, Sho 64-2764 and Hei 2-147151 are of a reduction casting type in which circulating metal belts are used for long-side mold elements arranged in the width direction of a slab and fixed side plates are used as short-side mold elements. In this mold, a refractory member is used for a reduction portion of the short-side mold element for keeping the reduction portion in a high temperature state, and a metal frame is provided for supporting each side edge of the refractory member of the short-side mold element being in slide-contact with the long-side mold element (metal belt). The structure for supporting the refractory material with such a frame is intended to lower a sliding resistance of the refractory member in sliding with the long-side mold element (metal belt); however, it fails to examine thermal deformation of the refractory member. More specifically, the metal frame is water-cooled from the back surface so as to be suppressed in thermal deformation; while the refractory member is not cooled and thereby it is thermally deformed in a rigid body, that is, in the frame. Gaps are thus formed between the refractory member and the metal frame resulting from thermal deformation (expansion) of the refractory member, to create casting fins due to insertion of molten metal in the gap. This causes damages of the mold, surface defects of a slab, restrictive breakout due to the presence of casting fins in the mold and the like, thus obstructing stable casting and also giving a potential danger to an operator.

The prior art described in Japanese Patent Laid-open No. Hei 3-8541 is of a reduction type using a fixed mold plate as a long-side mold element and a fixed side plate as a short-side mold element. Even in this mold, a refractory member is

used for a reduction portion of the short-side mold element for keeping the short-side mold element in a high temperature state, and a side edge of the short-side mold element, being in slide-contact with the long-side mold element, is supported by a metal frame. The short-side mold element in this prior art has basically the same configuration as that described in Japanese Patent Laid-open No. Sho 58-218360, and thereby it has the same inconvenience.

The prior art described in WO 94/07628 is of a reduction type in which a fixed mold plate is used as a long-side mold element and a fixed side plate is used as a short-side mold element. In this mold, a reduction portion of the short-side mold element is made of a refractory member, but the short-side mold element is brought in direct-contact with the long-side mold element. As a result, each edge of the refractory member tends to be damaged at the contact portion between the short-side mold element and the long-side mold element. In particular, when the short-side mold element moves along the long-side mold element for changing the width of a slab, the sliding resistance becomes larger, and thereby the degree of the damages of the refractory member is increased. Moreover, in the case where the surface of the short-side mold element is applied with a plating, the short-side mold element moves while grinding the plating, to significantly damage the long-side mold element, thereby obstructing stable casting.

On the other hand, the prior art described in Japanese Utility Model Laid-open No. Sho 55-11201, which is not of a reduction type, is so configured that a short-side mold element is applied with a metal plating so that the wear of the mold is somewhat suppressed. However, since the refractory made mold is not applied with a metal plating, the reduction type in which a refractory member is used for a reduction portion of the short-side mold element cannot adopt the prior art described in Japanese Utility Model Laid-open No. Sho 55-11201. If the surface of the refractory member can be applied with a metal plating, the metal plating is possibly peeled from the refractory material of the short-side mold element at the boundary therebetween due to a difference in thermal deformation between the refractory member and the metal plating, as a result of which there is a possibility in breaking the short-side mold element and obstructing stable casting.

(4) The prior art (Japanese Patent Laid-open No. Hei 3-8541) adopts a short-side mold element made from a material having a low thermal conductivity. Such a material, however, is insufficient for preventing production of a solidified shell on the surface of the short-side mold element. A solidified shell is thus produced on the surface of the short-side mold element during casting, to cause a large drawing resistance in the reduction step, thereby

degrading a quality of a short-side portion of a slab and also causing breakout. The technique, therefore, is difficult to obtain stable casting.

In the prior arts (Japanese Patent Laid-open Nos. Sho 58-3255 and Sho 62-64458), a heater is provided in a refractory member of each short-side mold element for preventing production of a solidified shell on the surface of the refractory member. On the other hand, the prior art (Japanese Patent Laid-open No. Hei 2-155543) has a configuration in which a high frequency heating coil is provided in association with a refractory member of a short-side mold element for re-melting a solidified shell produced on the surface of the refractory member or preventing production of the solidified shell by controlling a power applied to the high frequency heating coil, thereby reducing a drawing resistance due to production of the solidified shell on the surface of the short-side mold element in the reduction step.

Such a prior art, however, has a disadvantage in that since any solidified shell is not produced on the surface of the refractory member of the reduction portion of the short-side mold element at all, the molten metal side of the refractory member is entirely brought in contact with molten metal, thereby causing casting fins due to insertion of molten metal in gaps at each contact portion between the short-side mold element (refractory member) and the long-side mold element.

WO 94/07628 discloses a continuous casting mold used for producing a thin slab with a simple structure, in which a mold passage is formed of two metal plates and two side wall assemblies each of which is divided into upper and lower regions; and a heating means is provided for heating the above upper region and a cooling means is provided for cooling the above lower region. The technique, however, has a disadvantage in that since the upper region has a structure in which any solidified shell is not produced at all, the molten metal side of the side wall assembly is entirely brought in contact with molten metal, thereby causing casting fins due to insertion of molten metal in gaps at each contact portion between the side wall assembly and the metal plate. In other words, although this technique is intended to form a temperature distribution in the vertical direction (drawing direction of a slab) by heating the upper portion and cooling the lower portion for improving a drawing performance of the slab, it does not examine suppression of creation of casting fins.

The casting fins thus formed cause damages of the mold, surface defects of a slab, and restrictive breakout due to the casting fins remaining in the mold, thereby obstructing stable casting.

In this technique, furthermore, when a solidified shell is produced on the surface of a short-side mold element by a lower side water-cooled copper

plate portion of the short-side mold element, molten metal on the short-side mold element side rounds over a solidified shell produced on the long-side mold element side. The rounding of molten metal causes surface defects on a slab.

As described above, the prior arts fail to achieve stable casting because of creation of casting fins and rounding of molten metal. Moreover, surface defects formed on a slab tend to harm quality of the slab, and casting fins cause damages of a mold, resulting in the shortened life of the mold.

In addition, the prior arts do not sufficiently examine movement of the short-side mold element in the width direction of a slab at an arbitrary time during casting or not during casting, that is, they do not sufficiently examine the change in width of a slab.

(5) According to the above-described prior arts, a thin slab can be produced using a reduction type mold including short-side mold elements in each of which the width is widened at its upper portion and is narrowed at its lower portion for making easy insertion of a pouring nozzle in a mold space. Each of these prior arts is intended to prevent formation of a solidified shell on the surface of the short-side mold element at a reduction step for casting a slab without any breakage of the solidified shell. More specifically, a refractory member is used for the reduction portion of the short-side mold element for keeping the short-side mold element being in contact with molten metal at the reduction step in a high temperature state.

Each of the above-described prior arts uses a refractory member for the upper reduction portion of the short-side mold element; however, it fails to examine thermal deformation of the refractory member due to a difference in temperature between a molten metal side of the refractory member and the opposed side thereof.

(6) The above-described prior arts, however, are disadvantageous in that since solidification on the short-side mold element is rapidly started from the water-cooled metal member of the short-side mold element, there occurs cracks and thereby a surface quality of a short-side portion of a slab is degraded. In particular, when the reduction portion of the short-side mold element is made of the water-cooled metal plate as described in Japanese Patent Laid-open No. Hei 3-8541, a short-side solidified shell produced on the reduction portion causes an excess drawing resistance, leading to breakout, thus harming operational stability. Moreover, since the refractory member is different in material from the water-cooled metal member, there occurs a step at the connection portion therebetween when the mold is set up. A difference in thermal expansion coefficient between the refractory member and the water-cooled metal member is one of causes for forming such a step. In the case where a step is

formed in such a manner that the water-cooled metal member projects toward the inner surface of the mold more than the refractory member does, a long-side solidified shell is restricted at the step, thereby causing breakout. The step of the short-side mold element must be thus set such that the refractory member projects more than the water-cooled metal member does. However, when the step is enlarged, molten steel rounds over the long-side mold element side at the step. The rounding of molten steel degrades the quality of the corner or a long-side portion of the slab, and in the worst case, it causes breakout. Consequently, it becomes important to suitably adjust the value of the step; however, since the step must be adjusted in the order of 1/10 mm, there occurs a problem in increasing the manufacturing cost of the short-side mold element and the set-up time required for setting the mold. Japanese Patent Laid-open No. Hei 7-232241 discloses a technique intended to prevent the rounding of molten steel, in which the entire surface, on the molten steel side, of the short-side mold element is made of the same refractory member to eliminate the above step. In this technique, however, there is a possibility that breakout occurs at a portion directly under the mold because a solidifying speed cannot be increased on the short-side mold element side. Also, this technique is not preferable for high speed casting because it cannot increase the solidifying speed on the short-side mold element side.

Rev. Metall. Cah. Inf. Tech.: Vol. 92, No. 6(1995), P. 781 describes a means for solving withdrawal mark and hot tear liable to be produced for a mold directly connected to a tundish. However, such casting is largely different from the reduction type continuous casting in which reduction is performed in a state that molten metal is not solidified on the surface of the short-side mold element. Firstly, in this casting, solidification starting point is not positioned at the uppermost portion of the molten metal surface, and thereby it is impossible to lubricate a boundary between the mold and a solidified shell by a mold powder. This makes it difficult to reduce a friction between the mold and solidified shell. On the contrary, in the reduction type continuous casting, a long-side solidified shell is produced from the uppermost portion of the molten metal surface, and thereby it is possible to lubricate a boundary between the mold and a solidified shell by a mold powder. Secondly, in the casting, solidification starts simultaneously both on the long-side mold element and on the short-side mold element, just as the conventional casting. Thus, a drawing force is applied to each of the long-side solidified shell and the short-side mold element, which is thin and weak, produced by moderate solidification at a ceramic portion of the mold. In the case of using such a mold, it is difficult to achieve high speed

casting at a casting speed more than 2 m/min. On the contrary, in the reduction type continuous casting, the upper portion, on the molten metal side, of the straight portion of the short-side mold element is moderately cooled, and accordingly, even when the thickness of the short-side solidified shell becomes thin, a long-side solidified shell produced from the uppermost portion of the molten metal surface is sufficiently large in thickness and is also strong. The reduction type continuous casting process, therefore, can realize high speed casting in which a large drawing force is applied to the solidified shell. Thirdly, in this casting, solidification simultaneously starts around the entire periphery of a slab, just as the conventional casting, so that there never occurs rounding of molten steel. As a result, the description in Rev. Metall. Cah. Inf. Tech.: Vol. 92, No. 6(1995), P. 781 does not solve the problems of the reduction type continuous casting.

SUMMARY OF THE INVENTION

A first object of the present invention is to provide an apparatus and a process for performing stable continuous casting by uniformly heating short-side mold elements with a simple equipment for a long-period of time for stably suppressing production of a solidified shell on the surface of each short-side mold element throughout casting.

A second object of the present invention is to provide a continuous casting apparatus for performing stable continuous casting for a long period of time by suppressing corrosion of a short-side mold element due to a mold powder.

A third object of the present invention is to provide a continuous casting apparatus of a reduction type in which the short-side mold element is kept in a high temperature state, which is capable of preventing formation of any gap, into which molten metal is possibly inserted, between the short-side mold element and the long-side mold element even by thermal deformation of a refractory member of the short-side mold element, and preventing damages of the mold, thereby ensuring stable casting.

A fourth object of the present invention is to provide an apparatus and a process for continuous casting a high quality slab by forming a solidified shell at each corner of a contact portion between a short-side mold element and a long-side mold element in such a manner as to be continuous to a solidified shell produced on the surface of the long-side mold element, thereby suppressing creation of casting fins and rounding of molten metal.

A fifth object of the present invention is to provide a continuous casting apparatus for performing stable casting by reducing thermal deformation of a refractory member of a short-side mold element due to a difference in temperature between a molten metal side of the

refractory member and the opposed side thereof.

A sixth object of the present invention is to provide a continuous casting apparatus capable of producing such a short-side solidified shell as to increase a surface quality of a short-side portion of a slab and to exhibit a strength sufficient for high casting, preventing rounding of molten metal at a step portion of the short-side mold element, and reducing a manufacturing cost of the short-side mold element and significantly shortening a set-up time required for setting the mold.

To achieve the above first object, according to the present invention, there is provided a continuous casting apparatus for continuously producing a slab by continuously supplying molten metal in a space of a mold including opposed long-side mold elements and opposed short-side mold elements and continuously drawing a shell solidified in the mold,

the improvement wherein

the short-side mold element has in a back surface portion a passage allowing a high temperature gas to pass therethrough, the passage being formed in such shape that the width is widened at its upper portion and is narrowed at its lower portion; and the short-side mold element has a high temperature gas supply means for supplying the high temperature gas into the passage from top to bottom of the short-side mold element.

According to the present invention, there is also provided a continuous casting apparatus for continuously producing a slab by continuously supplying molten metal in a space of a mold including opposed long-side mold elements and opposed short-side mold elements and continuously drawing a shell solidified in the mold,

the improvement wherein

the short-side mold element has in a back surface portion a passage allowing a high temperature gas to pass therethrough; and the short-side mold element has a plurality of high temperature gas supply means arranged in the casting direction.

According to the present invention, there is also provided a continuous casting process for continuously producing a slab by continuously supplying molten metal in a space of a mold including opposed long-side mold elements and opposed short-side mold elements and continuously drawing a shell solidified in the mold,

the improvement wherein

a high temperature gas is supplied, from top to bottom of the short-side mold element, into a passage provided in a back surface portion of the short-side mold element for allowing a high temperature gas to pass therethrough.

According to the present invention, there is also provided a continuous casting process for continuously producing a slab by continuously supplying molten metal in a space of a mold including opposed long-side mold elements and opposed short-side mold elements and continuously drawing a shell solidified in the mold, the improvement wherein

a passage allowing a high temperature gas to pass therethrough is provided in a back surface portion of the short-side mold element; and the high temperature gas is supplied in the passage independently through a plurality of positions arranged in a casting direction.

To achieve the above second object, according to the present invention, there is provided a continuous casting apparatus for continuously producing a slab by continuously supplying molten metal in a space of a mold including opposed long-side mold elements and opposed short-side mold elements and continuously drawing a shell solidified in the mold, wherein a level of a molten metal pool is kept constant and a mold powder is floated on the molten metal pool, the improvement wherein

a portion of the short-side mold element, in which at least a mold powder, molten metal and a solidified shell coexist, is made from a material mainly containing zirconium diboride (ZrB_2).

To achieve the above third object, according to the present invention, there is provided a continuous casting apparatus for continuously producing a slab by continuously supplying molten metal in a space of a mold including opposed long-side mold elements and short-side mold elements and continuously drawing a shell solidified in the mold, the improvement wherein

the short-side mold element has a reduction portion made of a refractory member, the reduction portion being formed in a shape that the width is gradually narrowed in the casting direction from the upper surface of the molten metal; the short-side mold element has a heating means for heating the short-side mold element in such a manner that the molten metal is not solidified on the surface of the short-side mold element; the short-side mold element has a cooling metal plate constituting a parallel portion positioned under the reduction portion of the short-side mold element; the short-side mold element has a heat-resisting metal member including a frame disposed at a contact portion between the reduction portion of the refractory member and the long-side mold element, and a back surface portion connected to the frame on an anti-molten metal side of the refractory mem-

ber; and

the short-side mold element has a thermal insulating member disposed between the anti-molten metal side of the refractory member and the back surface portion.

According to the above fourth object, according to the present invention, there is provided a continuous casting apparatus having a mold including opposed long-side mold elements and opposed short-side mold elements, the improvement wherein

each of the long-side mold element and the short-side mold element has a means for adjusting its temperature; the short-side mold element includes an upper reduction portion having a width gradually narrowed from top to bottom and a lower side parallel portion; and the reduction portion has a means for cooling the vicinity of each corner portion between the long-side mold element and the short-side mold element;

wherein a solidified shell is produced only at the corner portion at the reduction portion and a solidified shell is produced over the entire surface at the parallel portion, the solidified shell produced at the corner portion at the reduction portion being continuous to the solidified shell produced at the parallel portion.

According to the present invention, there is also provided a continuous casting apparatus for continuously producing a slab by continuously supplying molten metal in a space of a mold having opposed long-side mold elements and opposed short-side mold elements and continuously drawing a shell solidified in the mold, wherein the short-side mold element has a width gradually narrowed in the casting direction from the molten metal surface and a heating means is provided for heating the short-side mold element, whereby the reduction is completed in a state in which molten metal is not solidified on the surface of the short-side mold element,

the improvement wherein

a means for cooling the vicinity of each corner portion between the long-side mold element and the short-side mold element is provided so that a solidified shell produced on the surface of the long-side mold element is continuously formed at the corner portion between the long-side mold element and the short-side mold element.

According to the present invention, there is also provided a continuous casting process using a continuous casting apparatus having a mold including opposed long-side mold elements and opposed short-side mold elements,

the improvement wherein

the short-side mold element includes an upper reduction portion and a lower side parallel portion; the reduction portion has a width gradually narrowed from top to bottom and the parallel portion has a substantially uniform width; and both ends in the width direction of the short-side mold element are adjusted at temperatures not more than a shell forming temperature.

According to the present invention, there is also provided a continuous casting process using a continuous casting apparatus having a mold including opposed long-side mold elements and opposed short-side mold elements,

the improvement wherein

the short-side mold element includes an upper reduction portion and a lower side parallel portion; the reduction portion has a width gradually narrowed from top to bottom and the parallel portion has a substantially uniform width; and the reduction portion of the short-side mold element is adjusted in temperature so as to have such a temperature distribution in the width direction that a center portion in the width direction of the short-side mold element is set at a temperature more than a shell forming temperature and both ends in the width direction of the short-side mold element are set at temperatures not more than the shell forming temperature.

To achieve the fifth object, according to the present invention, there is provided a continuous casting apparatus for continuously producing a slab by continuously supplying molten metal in a space of a mold including opposed long-side mold elements and opposed short-side mold elements and continuously drawing a shell solidified in the mold,

the improvement wherein

the short-side mold element is made of a refractory member divided into a plurality of parts in the casting direction.

To achieve the sixth object, according to the present invention, there is provided a continuous casting apparatus of a reduction type in which a mold is composed of long-side mold elements and short-side mold elements, each short-side mold element including a reduction portion widened at its upper portion and narrowed at its lower portion and a straight portion, so that reduction is performed in a state that solidification is suppressed on a short-side mold element side,

the improvement wherein

a surface portion, on a molten metal side, of an upper portion of the straight portion is made of a

member other than a water-cooled metal member; and

a surface portion, on a molten metal side, of a lower portion of the straight portion is made of a water-cooled metal member.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will be apparent from the following detailed description of the preferred embodiments of the invention in conjunction with the accompanying drawings, in which:

Fig. 1 is a view showing a continuous casting apparatus in a first embodiment of the present invention; Fig. 2 is a view showing a structure of a short-side mold element used in the first embodiment; Fig. 3 is a view showing a short-side mold element used in a comparative test; Fig. 4 is a diagram showing a temperature distribution of a short-side refractory member used in the first embodiment; Fig. 5 is a view showing a structure of another short-side mold element used in the first embodiment; Fig. 6 is a diagram showing a temperature distribution of a short-side refractory member used in the first embodiment; Fig. 7 is a view showing a structure of a further short-side mold element used in the first embodiment; Fig. 8 is a view showing a structure of a further short-side mold element used in the first embodiment; Fig. 9 is a view showing a structure of a further short-side mold element used in the first embodiment; Fig. 10 is a view showing a structure of a further short-side mold element used in the first embodiment; Fig. 11 is a typical view of a continuous casting apparatus used in a second embodiment of the present invention; Figs. 12 and 13 are views showing a structure of a short-side mold element used in the second embodiment; Fig. 14 is a diagram showing a relationship between a wear amount and an erosion amount (due to molten metal) for a short-side mold element in the second embodiment; Fig. 15 is a view showing a structure of another short-side mold element used in the second embodiment; Fig. 16 is a further short-side mold element used in the second embodiment; Fig. 17 is a view showing a structure of a dummy bar head used in the second embodiment; Fig. 18 is a view showing a structure of a prior art

duly bar head;

Fig. 19 is a view showing a configuration of a straightforward rolling system used in the second embodiment;

Fig. 20 is a view showing a concept of a continuous casting apparatus in a first example of a third embodiment of the present invention;

Figs. 21(a) to 21(c) are views showing a short-side mold element used for the continuous casting apparatus shown in Fig. 20; wherein Fig. 21(a) is a view seen from a molten metal side showing the short-side mold element; Fig. 21(b) is a sectional view taken on line B-B of Fig. 21(a); and Fig. 21(c) is a sectional view taken on line C-C of Fig. 21(a);

Figs. 22(a) to 22(c) are views showing a second example of the third embodiment; wherein Fig. 22(a) is a view seen from a molten metal side showing the short-side mold element; Fig. 22(b) is a sectional view taken on line B-B of Fig. 22(a); and Fig. 22(c) is a sectional view taken on line C-C of Fig. 22(a);

Figs. 23(a) to 23(d) are views showing a third example of the third embodiment; wherein Fig. 23(a) is a view seen from a molten metal side showing the short-side mold element; Fig. 23(b) is a sectional view taken on line B-B of Fig. 23(a); Fig. 23(c) is a sectional view taken on line C-C of Fig. 23(a); and Fig. 23(d) is a sectional view taken on line D-D of Fig. 23(a);

Figs. 24(a) to 24(d) are views showing a fourth example of the third embodiment; wherein Fig. 24(a) is a view seen from a molten metal side showing the short-side mold element; Fig. 24(b) is a sectional view taken on line B-B of Fig. 24(a); Fig. 24(c) is a sectional view taken on line C-C of Fig. 24(a); and Fig. 24(d) is a sectional view taken on line D-D of Fig. 24(a);

Figs. 25(a) to 25(c) are views showing a fifth example of the third embodiment; wherein Fig. 25(a) is a view seen from a molten metal side showing the short-side mold element; Fig. 25(b) is a sectional view taken on line B-B of Fig. 25(a); and Fig. 25(c) is a sectional view taken on line C-C of Fig. 25(a);

Fig. 26 is a view showing a configuration of a twin-belt type continuous casting apparatus as a sixth example of the third embodiment, in which a short-side mold element is seen from a molten metal side;

Fig. 27 is a view showing a configuration of a twin-roll type continuous casting apparatus as a seventh example of the third embodiment, in which a short-side mold element is seen from a molten metal side;

Fig. 28 is a view showing a concept of a continuous casting apparatus used in a fourth embodiment;

Fig. 29 is a view showing a structure of a short-side mold element used in the fourth embodiment;

Fig. 30 is a view showing the progress of solidification in a mold (at a reduction portion) in the fourth

embodiment;

Fig. 31 is a view showing the progress of solidification in the mold (at a parallel portion after completion of reduction) in the fourth embodiment;

Fig. 32 is a view showing a cooling structure provided at a portion, in the vicinity of a contact portion with a short-side mold element, of a long-side mold element in the fourth embodiment;

Fig. 33 is a view showing a cooling structure provided at a portion, in the vicinity of a long-side mold element, of a short-side mold element in the fourth embodiment;

Fig. 34 is a view showing another structure of a short-side mold element used in the fourth embodiment (a molten metal contact surface portion is formed of a refractory member at a reduction portion and is formed of a water-cooled metal plate at a parallel portion);

Fig. 35 is a view showing a further structure of a short-side mold element, in which a seal member is disposed at a contact portion of a short-side mold element with a long-side mold in the fourth embodiment;

Fig. 36 is a twin-belt type continuous casting apparatus used in the fourth embodiment;

Fig. 37 is a twin-roll type continuous casting apparatus used in the fourth embodiment;

Fig. 38 is a view showing a solidified shell formed on a short-side mold element in the fourth embodiment;

Fig. 39 is a diagram showing a temperature distribution in the width direction of a short-side mold element in the fourth embodiment of the present invention;

Fig. 40 is a view showing a concept of a continuous casting apparatus in a fifth embodiment of the present invention;

Fig. 41 is a view showing an outer structure of a short-side mold element used in the fifth embodiment;

Fig. 42 is a view showing an inner structure of the short-side mold element shown in Fig. 41;

Fig. 43 is a diagram showing a thermal expansion and thermal stress of a refractory member in the casting direction in the fifth embodiment, in which a divided type refractory member is compared with an integral type refractory member;

Fig. 44 is a diagram showing a relationship between an erosion amount due to molten metal of a short-side mold element and a casting time in the fifth embodiment;

Fig. 45 is a view showing a structure of another short-side mold element used in the fifth embodiment;

Fig. 46 is a view showing a configuration of a twin-belt type continuous casting apparatus used in the fifth embodiment;

Fig. 47 is a view showing a configuration of a twin-roll type continuous casting apparatus used in the

fifth embodiment;

Fig. 48 is a view showing a concept of a continuous casting apparatus in a sixth embodiment of the present invention;

Figs. 49(a) to 49(c) are views showing a short-side mold element in the sixth embodiment; wherein Fig. 49(a) is a front view of the short-side mold element; Fig. 49(b) is a vertical sectional view of the short-side mold element; and Fig. 49(c) is a horizontal vertical view taken on A-A, B-B and C-C of Fig. 49(a);

Figs. 50(a) and 50(b) are a horizontal sectional view of a short-side mold element in the sixth embodiment, and a typical view showing a reduction type continuous casting in which reduction is performed in a state solidification is suppressed on a short-side mold element, respectively;

Fig. 51 is a diagram showing a relationship between a surface temperature of a surface, on the molten steel side, of a straight portion of a short-side mold element and a thickness of a short-side solidified shell;

Figs. 52(a) and 52(b) are views, each illustrating a production state of a short-side mold element in the vicinity of RS, wherein Fig. 52(a) is for a short-side mold element in which a surface, on a molten steel side, of a straight portion is entirely made of a water-cooled copper plate; and Fig. 52(b) is for a short-side mold element of the present invention;

Figs. 53 and 54 are sectional views of a continuous casting apparatus in the sixth embodiment;

Figs. 55(a) and 55(b) are a front view and a vertical sectional view showing a short-side mold element in which a front surface portion on a molten steel side is manufactured by lamination in the sixth embodiment;

Fig. 56 is a view showing a concept of a twin-belt type continuous casting apparatus; and

Fig. 57 is a view showing a concept of a twin-roll type continuous casting apparatus.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, preferred embodiments of the present invention will be described with reference to the drawings.

Embodiment 1

A continuous casting apparatus in this embodiment is of a type in which a slab is continuously produced by continuously supplying molten metal into a space of a mold including opposed long-side mold elements and opposed short-side mold elements and continuously drawing a shell solidified in the mold. In the above mold, a passage allowing a high temperature gas to pass therethrough is provided in a back surface portion of each short-side mold element. The passage is also

tapered such that the width is widened at its upper portion and is narrowed at its lower portion. With this configuration, an upper portion of the short-side mold element can be heated with a high temperature gas directly after being burned by supplying the high temperature gas in the short-side mold element from top to bottom by way of the passage.

The temperature of the burning gas is gradually reduced as the burning gas flows closer to a lower portion of the short-side mold element because the thermal energy of the burning gas is gradually absorbed by the short-side mold element.

On the other hand, the passage for a high temperature gas, provided in the short-side mold element, is formed in such a shape that the width is widened at its upper portion and is narrowed at its lower portion; and accordingly, although the temperature of the burning gas is reduced as the burning gas flows closer to the narrowed lower portion of the short-side mold element, the temperature of the lower portion of the short-side mold element is not extremely reduced because the flow velocity of the burning gas becomes larger at the narrowed lower portion of the short-side mold element to make larger a heat transfer coefficient of the lower portion of the short-side mold element.

A plurality of the passages for supplying the high temperature gas may be provided in the short-side mold element along the casting direction for suppressing a temperature drop of the burning and easily performing uniform heating.

The high temperature gas can be obtained by burning a mixed gas of a combustible gas and an air, which is low in burning temperature as compared with a high temperature gas obtained by burning a mixed gas of a combustible gas and oxygen. Such a burning gas at a low temperature makes it possible to enlarge the flow rate thereof without occurrence of erosion of the short-side refractory member due to molten metal, and hence to uniformly heat the short-side refractory member.

A plurality of high temperature gases can be independently supplied into a plurality of the passages provided in the short-side mold element. In this case, it is possible to adjust temperatures of the portions at which the passages are provided by controlling temperatures or flow rates of the high temperature gases independently supplied in the passages, and hence to easily adjust a temperature distribution of the short-side refractory member.

A burning gas having a temperature higher than that obtained by burning a mixed gas of a combustible gas and air can be supplied in accordance with the following manner.

When a large amount of a mixed gas of a combustible gas and oxygen is supplied and burned, the short-side refractory member is locally heated at a high temperature, and in the worst case, the refractory member may suffer damages from erosion due to molten metal.

Accordingly, in the case where a mixed gas of a combustible gas and oxygen is burned, the flow rate

thereof must be adjusted in a suitable range; however, such a suitable range is often insufficient to uniformly heat the short-side refractory member.

In this embodiment, the short-side refractory member can be uniformly heated at a high temperature by allowing a suitable amount of a high temperature burning gas to flow from each of a plurality of high temperature gas supply portions.

In this case, a passage for supplying a high temperature gas may be divided into a plurality of parts in the casting direction in such a manner as to be matched with a plurality of the high temperature gas supply portions, and a discharge port for discharging the high temperature gas may be provided for each divided part of the passage. With this configuration, it is possible to supply the high temperature gas in the short-side mold element while independently changing the temperature or flow rate of the high temperature gas in the casting direction, and hence to adjust a temperature distribution of the short-side mold element in the casting direction.

It is desirable to measure an actual temperature distribution of the short-side mold element in the casting direction, and to independently change the temperature or flow rate of the high temperature gas in the casting direction so as to obtain a desirable temperature distribution.

The short-side mold element may be made of a material satisfying a relationship of $\lambda/\delta \leq 0.02$ ($\text{cal/cm}^2 \times \text{sec} \times ^\circ\text{C}$) where λ is a thermal conductivity and δ is a thickness of the material. This is effective to make smaller a calorie transmitted to the back surface of the short-side mold element during casting than that sufficient to produce a solidified shell on the front surface, on the molten metal side, of the short-side mold element, and hence to further suppress production of the solidified shell on the surface of the short-side mold element.

The short-side mold element may be continuously heated during casting for preventing the temperature of the short-side mold element from being gradually reduced during casting.

The continuous heating of the short-side mold element makes it possible to prevent production of a solidified shell on the surface of the short-side mold element for a long-period of time, and hence to stably perform long-term casting.

The heating temperature of the short-side mold element may be suppressed to be in a range between a value being 0.7 time a liquidus temperature of a metal to be cast and the liquidus temperature. This is effective to stably suppress production of a solidified shell on the surface of the short-side mold element throughout casting, and hence to perform stable casting.

Hereinafter, the present invention will be more fully described with reference to an embodiment.

Fig. 1 is a typical view showing a continuous casting apparatus used in this embodiment.

In this embodiment, molten metal is supplied through a pouring nozzle 3 into a fixed mold including

short-side mold elements 1 and long-side mold elements 2, to form a molten pool 4. The short-side mold element 1 is formed in such an approximately fan-shape that the width is widened at its upper portion and is narrowed at its lower portion. The molten metal is cooled in the mold, and is solidified into a slab 5. The slab 5 is then drawn downward from the mold while being supported by supporting rolls 6. A gap 13, which is a passage for a high temperature gas, is formed in such a shape that the width is widened at its upper portion and is narrowed at its lower portion. A high temperature gas is supplied from a gas burner 12 into the gap 13 as shown in Fig. 1, and is discharged from a discharge pipe 11 as a discharge port of the high temperature gas.

In this embodiment, the short-side mold element 1 is formed in such an approximately fan-shape that the width is widened at its upper portion and is narrowed at its lower portion, and the gap 13 as a passage for a high temperature gas is also formed in such a shape that the width is widened at its upper portion and is narrowed at its lower portion. The passage is, as shown in Fig. 7, in a relationship of $L1 > L2$, where $L1$ is a distance (in the width direction of the short-side mold element) at the upper portion and $L2$ is a distance (in the width direction of the short-side mold element) at the lower portion. The ratio between $L1$ and $L2$ is desirable to be suitably determined in accordance with casting conditions (molten metal temperature, solidifying temperature of a material to be cast, casting speed, and the like). With this configuration, a distance from the gap 13 to the long-side mold element 2 is rendered substantially constant in the casting direction, thereby making easy uniform heating of the short-side mold element. However, the short-side mold element may be formed in such a shape that the widths of the upper and lower portion are substantially equal to each other, and the gap 13 as a passage for a high temperature gas is formed in such a shape that the width is widened at its upper portion and is narrowed at its lower portion.

Fig. 2 is a view showing a structure of a short-side mold element used in this embodiment.

A surface portion, being in contact with molten metal, of the short-side mold element is composed of a short-side refractory member 7 and an internally water-cooled type short-side copper plate 8 made of a copper alloy. The short-side refractory member 7 is bonded to a molten silica made short-side refractory frame 9 and is mounted to a short-side back plate 10. Moreover, in this embodiment, thermocouples 15 are mounted in the short-side mold element 1 at three portions arranged in the casting direction for measuring a temperature distribution of the short-side mold element 1 in the casting direction. A gas burner nozzle 12 is mounted over the short-side mold element 1 for allowing a burning gas to flow in the gap 13 formed between the short-side refractory member 7 and the short-side refractory frame 9.

As shown in Fig. 8, such a burning gas at a high temperature is supplied from the gas burner nozzle 12 provided over the short-side mold element 1, passing

through the gap 13, and is discharge from a discharge pipe 11. In this embodiment, the burning gas is obtained by burning a mixed gas of a combustible gas and oxygen. The short-side mold element 1 is made of a material satisfying the following equation:

$$\lambda/\delta \leq 0.02 \text{ (cal/cm}^2 \times \text{sec} \times \text{°C)} \quad (1)$$

where λ is a thermal conductivity and δ is a thickness of the material.

For example, the short-side mold element 1 may be made of a material having a thickness (δ) of 2 cm and a thermal conductivity (λ) of $0.035 \text{ cal/cm}^2 \times \text{sec} \times \text{°C}$, these values satisfying the above relationship.

The high temperature burning gas flows through the gap 13 from top to bottom, and is discharged from the discharge pipe 11 mounted at the lower portion of the short-side refractory member 7. This is called a top-to-bottom heating type, which is distinguished from the following bottom-to-top heating type.

Fig. 3 shows a structure of a short-side mold element used for a comparative test.

The structure of the short-side mold element shown in Fig. 3 is the same as that shown in Fig. 2, except that the gas burner nozzle 14 is mounted at the lower portion of the short-side mold element 7 for allowing a burning gas to flow through the short-side mold element 1 from bottom to top. This is called a bottom-to-top heating type. Here, the burning gas is obtained by burning a mixed gas of propane gas and air. Methane and butane may be similarly used as combustible gases; however, propane gas is advantageous in terms of availability and simplicity of equipment.

A casting test was carried out using the casting apparatus including the short-side mold element having the above structure.

The short-side mold elements were heated for 10 minutes before casting, and molten steel was continuously cast into a slab having a size of 70 mm (thickness) $\times$ 1200 mm (width). The temperature of the short-side refractory member 7 was measured by the thermocouples 15 mounted in the back surface portion of the short-side refractory member 7. The temperature of the short-side refractory member 7 reached a stationary value after an elapse of 15 minutes since starting of heating. This shows that the heating for the short-side mold element is desirable to be performed earlier by 15 minutes than casting starts. More preferably, the heating for the short-side mold element may be performed earlier by 30 - 60 minutes than casting starts.

Fig. 4 shows a temperature distribution in the casting direction of the short-side refractory member 7, which is measured directly before casting.

As is apparent from Fig. 4, the top-to-bottom heating type can obtain a substantially uniform temperature distribution of the short-side refractory member 7, in which the temperature of a portion near the meniscus is 1300°C and the temperature of a lower portion of the short-side refractory member is 1000°C , that is, the

upper side is higher in temperature than the lower side only by about 300°C . On the contrary, the bottom-to-top heating type exhibits a non-uniform temperature distribution of the short-side refractory member 7, in which the temperature of the portion near the meniscus is 600°C and the lower portion of the short-side refractory layer is 1100°C , that is, the upper side is very lower in temperature than the lower side by about 500°C , and further the temperature gradient is undesirably sharp.

The casting tests using the top-to-bottom heating type and the bottom-to-top heating type were started.

The production was set at 10 ton/charge, and the casting speed was set at a value of from 2 to 6 m/min. The short-side refractory member 7 was continuously heated during casting. As a result, in the test using the top-to-bottom heating type, casting was usually stable; however, in the test using the bottom-to-top heating type, there frequently occurred breakout after an elapse of about one minute since starting of casting. In this casting tests, various kinds of steels such as a low carbon steel, medium carbon steel, high carbon steel, and stainless steel were cast; however, the casting state was not dependent on the kinds of steels.

As described above, according to the configuration using the top-to-bottom heating type, there can be provided an apparatus and a process for performing stable continuous casting irrespective of kinds of steels by uniformly heating short-side mold elements for a long-period of time with a simple equipment for stably suppressing production of a solidified shell on the surface of each short-side mold element throughout casting.

Fig. 5 is a view showing a structure of another short-side mold element used in this embodiment.

Gas burner nozzles 16 are mounted in the short-side refractory member 7 from the back surface side thereof at three portions arranged in the casting direction, for heating the short-side refractory member 7 with a high temperature gas obtained by burning a mixed gas of a propane gas and oxygen. This is called a three-stage heating type. As shown in Fig. 9, the burning gas passes through the gap 13, and is discharged from the upper portion of the short-side mold element. A plurality of the gas burner nozzles 16 may be arranged at equal intervals in the casting direction; however, in order to further equalize a temperature distribution from top to bottom, the gas burner nozzles 16 are preferably arranged such that a distance of a passage allowing the high temperature gas supplied from the gas burner nozzle 16 mounted at the upper portion is made shorter and a distance of a passage allowing a high temperature gas supplied from the gas burner nozzle 16 mounted at the lower portion is made longer. Namely, the distances $L3$, $L4$, $L5$ in Fig. 9 may be set to satisfy a relationship of $L3 < L4 < L5$.

A casting test was carried out using the same simple apparatus as that in the previous test except for the structure of the short-side mold element. The dimensions of a slab were set such that the thickness was 40 mm and the width was 1,200 mm.

Fig. 6 shows a temperature distribution of a short-side refractory member in a stationary state before starting of casting. The temperature distribution of the top-to-bottom heating type shown in Fig. 4 is also shown in this diagram for comparison. For the three-stage heating type, the heating temperature is about 1500°C at a portion near the meniscus and about 1450°C at the lower portion of the short-side refractory member 7. As compared with the top-to-bottom heating type, the three-stage heating type can obtain a uniform temperature distribution of the short-side mold element in which a high temperature can be ensured and a temperature difference between the upper and lower sides is only about 50°C. Moreover, the temperature distribution in the casting direction by the three-stage heating type is more uniform than that of the top-to-bottom heating type. As a result from casting at a production of 10 ton/charge, it was confirmed that the casting using the three-stage heating type was usually stable.

The temperature distribution of the short-side mold element can be adjusted by means of a short-side mold element temperature control means for controlling a temperature or flow rate of a high temperature gas in such a manner that a temperature T of the short-side mold element satisfies the following equation:

$$0.7 \times TL < T \leq TL \text{ (}^\circ\text{C)} \quad (2)$$

where TL indicates a liquidus temperature of molten metal.

Additionally, a plurality of passages allowing high temperature gases to individually flow therethrough, shown in Fig. 10, may be provided. Moreover, as a temperature distribution detecting means for detecting a temperature distribution of the short-side mold element, for example, thermocouples 15 may be provided as shown in Fig. 5, and a control means for adjusting a temperature or flow rate of a high temperature gas on the basis of the measured values detected by the temperature distribution detecting means may be provided. With this configuration, it is possible to further uniformly keep the temperature distribution of the short-side mold element for a long-period of time.

As described above, according to the configuration using the three-stage heating type, there can be provided an apparatus and a process for performing stable continuous casting irrespective of kinds of steels by uniformly heating short-side mold elements for a long-period of time with a simple equipment for stably suppressing production of a solidified shell on the surface of each short-side mold element throughout casting.

Embodiment 2

In general, a portion of a pouring nozzle used for continuous casting, positioned at a powder line, is made from a material mainly containing ZrO₂ incorporated with C, SiC and the like. Such a material exhibits a high corrosion resistance against a mold powder, as com-

pared with a refractory member mainly containing Al₂O₃, SiO₂, or MgO which is used for an inner wall of a tundish or the like. However, even the pouring nozzle made from such a material mainly containing ZrO₂ exhibits a damage of about 4 mm/hr due to erosion of molten metal, and must be exchanged for each period of 6-8 hours. Accordingly, a continuous casting mold made from such a material must be also exchanged at a frequency substantially equal to that of a pouring nozzle. In this case, however, since the exchange of the mold takes a lot of time as compared with a pouring nozzle, there occurs a trouble in the casting operation. The material of the mold must be also selected in terms of wear resistance because an inner surface of a mold is susceptible to wear due to sliding with a solidified shell. The inventors have examined materials being small in corrosion due to a mold powder and in erosion due to molten steel and being large in wear resistance, and found that a material mainly containing ZrB₂ is excellent in the above properties.

On the basis of the above knowledge, a portion of a short-side mold element, in which the width is narrowed in the casting direction from a molten metal surface, may be made from a material mainly containing ZrB₂ for preventing corrosion of the short-side mold element due to a mold powder or the like and for reducing wear due to sliding with a solidified shell, thereby prolonging a service life of the mold. The content of ZrB₂ is desirable to be 90% or more. A material containing 90% or less of ZrB₂ added with C, BN and the like exhibits a strong resistance against corrosion; however, it is insufficient in terms of wear resistance because of its low strength. More preferably, the content ZrB₂ is set at 100%.

The short-side mold element may be divided into an upper side reduction part (R-section) formed in an approximately fan-shape and a lower side straight part (S-section) having a width substantially equal to the thickness of a slab, wherein the R-section is made from a material containing ZrB₂ and the S-section is made of a copper alloy plate having an internally water-cooled structure. Such a structure of the short-side mold element is effective to accelerate the growth of a solidified shell on the lower side of the short-side mold element.

A heating means may be provided in the short-side mold element for heating the upper portion of the short-side mold element. This is effective to prevent production of a solidified shell on the upper portion of the short-side mold element, and hence to perform stable casting by reducing a drawing resistance at a reduction step in which a distance between the long-side mold elements in the thickness direction of a slab is reduced in the casting direction.

The fixed mold may be made to oscillate by an oscillation applying means. This is effective to accelerate flow-in of a mold powder, and hence to improve the quality of a slab and stability of casting.

The short-side mold elements may be movable in the width direction of a slab at an arbitrary time during casting or not during casting. This is effective to contin-

uously produce slabs having various widths.

A metal member (hereinafter, referred to as frame) may be provided for portions, being in contact with the long-side mold elements, of the short-side mold element. This is effective to prevent ZrB_2 of the short-side mold element from being brought in direct-contact with the long-side mold elements, and hence to reduce damages of both the mold elements due to friction therebetween when the width of a slab is changed.

In the configuration that a high temperature gas is used for heating the short-side mold element, the discharged gas may be used to be blasted to the slab after being solidified. This is effective to prevent a reduction in temperature of the slab after completion of the solidification, and hence to eliminate or reduce an energy required for reheating the slab upon direct rolling of the slab.

Moreover, part of a dummy bar used at starting of casting may be provided with a projection extending along the curve of the approximately fan-shape of the short-side mold element. When the heating temperature of the short-side mold element is lower than the melting point of molten metal, a solidified shell is easy to be produced on the surface of the short-side mold element. In this case, a large drawing resistance is generated and the solidified shell is broken in the mold, tending to cause breakout of a slab. With this configuration, the breakout generated at the beginning of casting can be reduced because the projection provided on the dummy bar is integrated with the solidified shell, to apparently increase the strength of the solidified shell.

The above-described continuous casting apparatus capable of producing a thin slab can constitute a straightforward rolling system in which the casting apparatus is directly connected to a rolling mill. This is effective to enhance the total heat efficiency on a small scale, and hence to reduce the cost of rolled sheets as final products.

The above description for the continuous casting apparatus of an oscillating mold type is also effective for a belt caster or a drum caster in which long-side mold elements move in synchronization with a slab.

Hereinafter, an embodiment of the present invention will be described with reference to the drawings. Fig. 11 is a typical view of a continuous casting apparatus used in this embodiment. Molten metal is supplied through a pouring nozzle 3 into a fixed mold including short-side mold elements 1 and long-side mold elements 2, to form a molten metal pool 4. The short-side mold element 1 is formed in such an approximately fan-shape that the width is widened at its upper portion and is narrowed at its lower portion. The molten metal is cooled in the mold, and is solidified into a slab 5. The slab 5 is drawn downward from the mold while being supported by supporting rolls 6. Figs. 12, 13 are views showing a structure of a short-side mold element used in this embodiment. The short-side mold element 1 is composed of an upper short-side section 17 and a lower short-side section 18 made of a copper plate hav-

ing an internally water-cooled structure. A high temperature burning gas was supplied from a gas burner 20 into a gap 19 formed in a short-side rear plate 21 provided on the back surface of the upper short-side section 17 of the short-side mold element 1 for heating the upper short-side section 17. A mixed gas of a propane gas and a compression air was burned by the gas burner 20. In this embodiment, the upper short-side section 17 was made from 100% of ZrB_2 . For comparison, the upper short-side section 17 was also made from a material mainly containing Al_2O_3 , SiO_2 or ZrO_2 generally used for a pouring nozzle.

Fig. 14 shows a relationship between a wear amount and an amount of erosion due to molten metal after an elapse of two hours since starting of casting. In this test, a casting speed was set at a value of from 3 to 5 m/min and a mold powder was supplied on the upper surface of a molten metal pool during casting. The wear amount was about 0.4 mm for the material containing ZrB_2 ; while it was about 1 mm for the comparative material. In other words, the material containing ZrB_2 is superior to the comparative material in wear resistance by twice or more. On the other hand, the amount of erosion due to molten metal was about 0.5 mm for the material containing ZrB_2 ; while it was about 10 mm. In other words, the material containing ZrB_2 is superior to the comparative material in erosion due to molten metal by 20 times.

Fig. 15 is a view showing a structure of another short-side mold element used in this embodiment, in which the use of the material mainly containing ZrB_2 is limited for lowering a running cost for casting in consideration of the fact that the material mainly containing ZrB_2 is higher in cost than a material mainly containing AlO_2 , SiO_2 or ZrO_2 . A powder line portion 25 of an upper short-side section 24 was made from a material containing 100% of ZrB_2 and other portions thereof were made from a material mainly containing AlO_2 , SiO_2 or ZrO_2 . The powder line portion 25 was bonded at an angle-shaped mating surface with the other portion using a ceramic based adhesive. This structure was satisfactory to reduce the cost of the upper short-side section to be about 1/10 as compared with one entirely made of the material containing 100% of ZrB_2 . Even in this structure, stable casting was carried out without any leakage of molten steel from the above bonded portion.

Fig. 16 is a view showing a structure of a short-side mold element used in this embodiment. The material mainly containing ZrB_2 having a high hardness tends to damage the surface of the long-side mold element when the width of a slab is changed. To cope with such an inconvenience, a frame 26 was provided for a portion at which the upper short-side section 17 is brought in contact with the long-side mold element 2. The frame 26 may be made from a material having a high temperature resistance such as a stainless steel. With this configuration, it is possible to make smooth sliding with the long-side mold element when the width of a slab is changed and hence to prevent the long-side mold element from

being damaged, and also to prevent the brittle material, ZrB_2 from being chipped off. In addition, in this embodiment, the frame 26 is not provided with any cooling means and is cooled by contact with the long-side mold element.

Fig. 17 is a view showing a structure of a dummy bar head used in this embodiment, and Fig. 18 is a view showing a structure of a prior art dummy bar head. A projection 29 was mounted on the dummy bar head 28 in such a manner as to be brought in contact with the surface of each long-side mold element. The dimension of the projection 29 in the width direction of a slab was set to be substantially equal to that of the slab. In the case where the dummy bar head with the projections shown in Fig. 17 is used, it is possible to make larger the thickness of a solidified shell on the surface of each long-side mold element at the beginning of casting. This is effective to prevent breakage of the solidified shell at the beginning of casting, and hence to reduce occurrence of breakout of a slab.

Fig. 19 is a view showing a configuration of a straightforward rolling system used in this embodiment. A slab 5 produced by a continuous casting apparatus 30 is bent in the horizontal state, and is subjected to descaling by a descaler 31 for removing oxide scales from the surface of the slab 5, after which it is rolled to a specified thickness by a rough-rolling mill 32 and a finishing rolling mill 33. After that, the sheet thus rolled is cooled by a cooling apparatus 34 into a coil 35. The slab 5 is blasted with the discharged gas having used for heating the short-side mold elements through a discharge gas pipe 36 at an inlet of the descaler 31. The gas discharged from the discharge gas pipe 36 can be set to be in a range of from 900 to 1100°C. This makes it possible to moderate the cooling for the slab as compared with air cooling.

As described above, according to the above configuration, since the portion of the short-side mold element in which the width is narrowed in the casting direction from the molten metal surface can be made from a material containing ZrB_2 , it is possible to reduce the degree of corrosion of the short-side mold element due to a mold powder, and hence to prolong the service life of the mold.

The short-side mold element can be divided into an upper side reduction part (R-section) formed in an approximately fan-shape and a lower side straight part (S-section) having a width substantially equal to the thickness of a slab, wherein the R-section is made from a material containing ZrB_2 and the S-section is made of a copper alloy plate having an internally water-cooled structure. Such a structure of the short-side mold element makes it possible to accelerate the growth of a solidified shell on the lower side of the short-side mold element.

A heating means can be provided in the short-side mold element for heating the upper portion of the short-side mold element. This makes it possible to prevent production of a solidified shell on the upper portion of

the short-side mold element, and hence to perform stable casting by reducing a drawing resistance at a reduction step in which a distance between the long-side mold elements in the thickness direction of a slab is reduced in the casting direction.

The fixed mold can be made to oscillate by an oscillation applying means. This makes it possible to accelerate flow-in of a mold powder, and hence to improve the quality of a slab and stability of casting.

The short-side mold elements can be movable in the width direction of a slab at an arbitrary time during casting or not during casting. This makes it possible to continuously produce slabs having various widths.

A metal member (frame) can be provided for portions, being in contact with the long-side mold elements, of the short-side mold element. This makes it possible to prevent ZrB_2 of the short-side mold element from being brought in direct-contact with the long-side mold elements, and hence to reduce damages of both the mold elements due to friction therebetween when the width of a slab is changed.

In the configuration that a high temperature gas is used for heating the short-side mold element, the discharged gas can be used to be blasted to the slab after being solidified. This makes it possible to prevent a reduction in temperature of the slab after completion of the solidification, and hence to eliminate or reduce an energy required for re-heating the slab upon direct rolling of the slab.

The material containing 90% or more of ZrB_2 can exhibit a strong resistance against corrosion and keep a high strength. This makes it possible to reduce wear due to sliding with a solidified shell.

Moreover, part of a dummy bar used at starting of casting can be provided with a projection extending along the curve of the approximately fan-shape of the short-side mold element. When the heating temperature of the short-side mold element is lower than the melting point of molten metal, a solidified shell is easy to be produced on the surface of the short-side mold element. In this case, a large drawing resistance is generated and the solidified shell is broken in the mold, tending to cause breakout of a slab. With this configuration, the breakout generated at the beginning of casting can be reduced because the projection provided on the dummy bar is integrated with the solidified shell, to apparently increase the strength of the solidified shell.

The above-described continuous casting apparatus capable of producing a thin slab can constitute a straightforward rolling system in which the casting apparatus is directly connected to a rolling mill. This makes it possible to enhance the total heat efficiency on a small scale, and hence to reduce the cost of rolled sheets as final products.

Embodiment 3

A frame, which is part of a heat-resisting member, can be arranged at a contact portion between a reduc-

tion portion made of a refractory member and a long-side mold element, that is, at each edge of the reduction portion made of a refractory member. This is effective to prevent formation of gaps between the short-side mold element and the long-side mold element by allowing the frame to be elastically deformed in accordance with thermal deformation of the refractory member of the short-side mold element. The metal plating described in the previous prior art, Japanese Utility Model No. Sho 55-11201 has not any elasticity, and thereby even if the surface of the refractory member can be applied with the metal plating in place of the frame, the metal plating is possibly peeled from the refractory member of the short-side mold element at the boundary therebetween due to a difference in thermal deformation between the refractory member and the metal planting, as a result of which there is a possibility in breaking the short-side mold element and obstructing stable casting.

According to the present invention, the provision of the frame is effective to prevent formation of gaps between the short-side mold element and the long-side mold element, and hence to prevent creation of casting fins due to insertion of molten metal into the gaps. This makes it possible to safely perform stable casting without occurrence of inconveniences such as damages of the mold, surface defects of a slab, and restrictive breakout. Also, since the refractory member of the upper reduction portion of the short-side mold element is indirectly brought in contact with the long-side mold element through the frame made from a heat-resisting metal, a sliding resistance is made smaller so that it is possible to prevent damages at the edges of the refractory member of the short-side mold element and the surface of the long-side mold element when the short-side mold moves along the long-side mold element.

Moreover, a thermal insulating member can be provided between an anti-molten metal side of the refractory member and the back surface portion thereof for reducing a temperature rise of the back surface portion due to heating of the refractory member. Also, it is possible to eliminate the need of cooling the frame and the back surface portion by the presence of the heat-resisting metal member having a high heat-resistance, and hence to simplify the structure thereof.

In the above continuous casting apparatus, the frame preferably has a thickness allowing the frame to be elastically deformed in accordance with the shape of the reduction portion of the short-side mold element and thermal deformation of the short-side mold element. With this configuration, it is possible to make more effective the elastic deformation of the heat-resisting metal made frame of the present invention.

The frame and the back surface portion can be separately provided and be fastened by a fastening member. With this configuration, the frame and the back surface portion can be separately, easily machined upon manufacturing the heat-resisting member composed of the frame and the back surface portion. They can be integrated with each other by fastening, and can

achieve the function of the integral heat-resisting member described above.

Molten metal, which is not solidified at the upper reduction portion of the short-side mold element, is preferably solidified to a sufficient thickness on a lower side parallel portion positioned under the upper reduction portion by positively cooling the lower side parallel portion. Concretely, a cooling mechanism may be provided for a cooling metal plate constituting the parallel portion for positively cooling the parallel portion. Additionally, according to the present invention, the frame and the back surface portion are not required to be cooled, and thereby the cooling mechanism may be configured to cool only the cooling metal plate and not to cool the heat-resisting metal member.

The cooling metal plate and the heat-resisting metal member may be separately provided, so that the cooling metal plate can be made from a metal capable of sufficiently exhibiting the cooling function differently from a metal constituting the heat-resisting metal member.

The short-side mold element may be movable in the width direction of a slab at an arbitrary time during casting or not during casting. In the present invention, since the frame disposed at each edge of the reduction portion made of the refractory member is connected to the back surface portion on the anti-molten metal side of the refractory member, the short-side mold element can be easily moved without shifting of the frame in the direction of the width of a slab at an arbitrary time during casting or not during casting.

Moreover, according to the present invention, a seal member can be provided between the short-side mold element and the long-side mold element for further reducing a sliding resistance between the short-side mold element and the long-side mold element, thereby positively preventing damages of the short-side mold element and long-side mold element and further positively blocking gaps between the short-side mold element and the long-side mold element. In particular, the provision of the seal member is effective when the short-side mold element moves along the long-side mold element for changing the width of a slab.

According to the present invention, preferably, the seal member provided between the upper reduction portion of the short-side mold element and the long-side mold element may be made from a metal material such as copper or a copper alloy, and the seal member provided between the lower side water-cooled metal plate of the short-side mold element and the long-side mold element may be made from a non-metal material such as teflon.

The seal member provided between the reduction portion of the short-side mold element and the long-side mold element may be made from a high temperature material such as fine ceramics, and the seal member provided between the lower side cooling metal plate and the long-side mold element may be made from a low temperature material such as teflon.

More preferably, the long-side mold element may be formed of a fixed type mold element made from a metal having a high thermal conductivity for enhancing an effect of cooling molten metal from the long-side mold element side, thereby accelerating production of a solidified shell on the surface of the long-side mold element.

In the above description, preferably, the long-side molds may be formed of a pair of movable belts circulating while keeping a gap corresponding to the reduction portion of the short-side mold element, molten metal being kept in such a mold; or the long-side mold elements may be formed of a pair of movable rolls rotating while keeping a gap corresponding to the reduction portion of the short-side mold.

A first example of the present invention will be described in detail with reference to Fig. 20 and Figs. 21(a) to 21(c). Fig. 20 is a view showing a concept of a continuous casting apparatus in this example. A mold 1 used in this continuous casting apparatus is a fixed type mold including short-side mold elements 2 and long-side mold elements 3. The short-side mold element 2 is formed in such an approximately fan-shape that the width (in the direction of the width of a slab) is gradually narrowed in the casting direction from the upper surface of a molten metal 5 in order to make easy insertion of a pouring nozzle 4 in a mold space and to reduce the degree of a wavy state of the molten metal surface in the mold 1. The molten metal 5 is supplied from a tundish 6 in the mold 1 through the pouring nozzle 4, to form a molten metal pool. The molten metal 5 is cooled in the mold 1, and is solidified into a slab 69. The slab 69 is drawn downward from the mold 1 while being supported by supporting rolls 68. The long-side mold element 3 is made from a metal having a high thermal conductivity, such as copper or a copper alloy, for enhancing a cooling effect and accelerating production of a solidified shell on the surface thereof. The short-side mold element 2 is movable in the width direction of a slab by a short-side mold element driving unit 101 under the control by a short-side width changing unit 100.

Figs. 21 (a) to 21(c) are views showing a structure of the short-side mold element 2 used for the continuous casting apparatus in this example, wherein Fig. 21(a) is a view seen from the molten metal 5 side, showing the short-side mold element 2; Fig. 21(b) is a sectional view taken on line B-B of Fig. 21(a); and Fig. 21(c) is a sectional view taken on line CC of Fig. 21(a). As shown in Figs. 21(a) to 21(c), the portion, being in contact with the molten metal 5, of the reduction portion of the short-side mold element 2 is made of a refractory member 70, and a thermal insulating member 71 is provided on the back surface of the refractory member 70. The refractory member 70 can be directly or indirectly heated by an electric heating (such as current-carrying heating or induction heating) means represented by a refractory member heating unit 72 at an arbitrary time during casting or not during casting.

A frame 74a is disposed at a contact portion between the refractory member 70 of the short-side mold element 2 and the long-side mold element 3, that is, at each edge of the refractory member 70. The frame 74a is integrated with a back surface portion 74b disposed on the anti-molten metal side of the thermal insulating member 71. The frame 74a and the back surface portion 74b, made from a heat-resisting metal such as a stainless steel (SUS 310 or SUS 314), constitutes a heat-resisting metal member 74. The frame 74a disposed between the refractory member 70 and the long-side mold element 3 has a thickness of about from 2 to 5 mm along the shape of the reduction portion of the refractory member 70 of the reduction portion.

A water-cooled metal plate 73 containing a water-cooled mechanism (not shown) is disposed at a parallel portion positioned under the refractory member 70. In addition, the water-cooled mechanism may be replaced with an air-cooled mechanism. The water-cooled metal plate 73 and the heat-resisting metal member 74 are separately provided, and are mounted on a back plate 75 for suppressing thermal deformation of the water-cooled metal plate 73 and the heat-resisting metal member 74.

As described above, since the frame 74a is provided at the contact portion between the refractory member 70 and the long-side mold element 3, even when the refractory member 70 is thermally deformed, the frame 74a is elastically deformed in accordance with the deformation thereof, to prevent formation of gaps between the short-side mold element 2 and the long-side mold element 3. The thickness of the frame 74a is preferably set such that the frame 74a is elastically deformable in accordance with thermal deformation of the refractory member 70. For this reason, it is set at a value of from 2 to 5 mm.

Although the frame 74a has a thickness being as thin as a value of from 2 to 5 mm, it can sufficiently withstand high temperature because it is made from a heat-resisting metal. Accordingly, the frame 74a is not required to have a cooling groove such as a water-cooled mechanism in its interior 5. Moreover, since the thermal insulating member 71 is disposed between the back surface portion 74b and the refractory member 70, it is possible to reduce a temperature rise due to heating for the refractory member 70. Additionally, the back surface portion 74b, which is made from the heat-resisting metal, is not required to be cooled. Namely, the heat-resisting member 74 including the frame 74a and the back surface portion 74b is not required to be provided with any cooling mechanism such as a water-cooled mechanism, differently from the water-cooled metal plate 73. Consequently, the structure of the heat-resisting metal member 74 is made simple. In addition, the frame 74a is indirectly cooled by the long-side mold element 3.

Each of the long-side mold element 3 and the water-cooled metal plate 73 at the lower parallel portion of the short-side mold element 2 is preferably made

from a metal having a high thermal conductivity such as copper or a copper alloy, and the contact surface thereof with the molten metal 5 and a solidified shell 76 may be applied with Cr plating or a double-layer plating (lower layer: Ni plating, upper layer: Cr plating), or thermal spraying of a heat-resisting metal.

If the frame 74a is independently disposed on each edge of the refractory member 70 at the reduction portion, when the short-side mold element 2 is moved in the width direction of a slab by the short-side mold element driving unit 101, the frame 74a is possibly shifted along with movement of the short-side mold element 2. However, in this example, since the frame 74a is connected to the back surface portion 74b on the anti-molten metal side of the refractory member 70, it is not shifted. As a result, it is possible to easily move the short-side mold element 2 in the width direction of a slab without shifting of the frame 74a at an arbitrary time during casting or not during casting.

In the case of casting a slab using such a mold 1, there is a temperature distribution in the width direction of the refractory member 70 of the short-side mold element 2. More specifically, the center portion in the width direction of the refractory member 70 is high in temperature and a portion, in the vicinity of the long-side mold element 2, of the refractory member 70 is relatively low in temperature. Accordingly, the solidified shell 76 is not produced at the center portion in the width direction of the refractory member 70; while it is produced at the portion, in the vicinity of the long-side mold element 3, of the refractory member 70 continuously to the solidified shell 76 produced on the surface of the long-side mold element 3.

For example, as a result of a simulation carried out by the inventor in which a slab 8 having a thickness of 30 mm and a width of 2,100 mm was cast from carbon steel (carbon content: 0.05%) at a casting speed of 10 m/min in a state that the refractory members 70 of the short-side mold elements 2 were pre-heated for 10 minutes before starting of casting, the temperature of the center in the width direction of the refractory member 70 of the short-side mold element 2 was 1520°C and the temperature of each edge, in the vicinity of the long-side mold element 3, of the refractory member 70 was 900°C. Namely, since the solidified shell 76 is not formed at the reduction portion continuously in the width direction (thickness direction of the slab 69) on the entire surface (molten metal 5 side) of the short-side mold element 2, a drawing resistance functioning as a wedge effect is not applied to the long-side mold element 3 at the reduction step. Also, since the frame 74a is present at each edge of the refractory member 70 of the short-side mold element 2, a contact area between the refractory member 70 and the solidified shell 76 is made smaller, so that a sliding resistance liable to cause a sliding wear between the short-side mold element 2 and the solidified shell 6 is reduced, as a result of which it becomes possible to perform stable casting without breakage of the solidified shell 76 formed on the

surface of the long-side mold element 3, and hence to prolong the service life of the short-side mold element.

As described above, according to this example, since the frame 74a connected to the refractory member 70 and the thermal insulating member 71 on the anti-molten metal side is disposed at the contact portion between the refractory member 70 of the short-side mold element 2 and the long-side mold element 3, it is possible to prevent formation of gaps between the short-side mold element 2 and the long-side mold element 3 and hence to prevent creation of casting fins by insertion of molten metal into the gaps, and also to prevent inconveniences such as damages of the surface of the mold 1, surface defects of the slab 69, and restrictive breakout, and hence to safely perform stable casting.

Since the thermal insulating member 71 is disposed between the back surface portion 74b and the refractory member 70, it is possible to reduce a temperature rise of the back surface portion 74b. Moreover, since the frame 74a and the back surface portion 74b are made from a heat-resisting metal, it is possible to eliminate the needs of cooling them by a cooling mechanism such as a water-cooling mechanism, and hence to simplify the structure thereof.

Since the refractory member 70 is indirectly brought in contact with the long-side mold element 3 through the frame 74a made from a heat-resisting metal, it is possible to reduce a sliding resistance when the short-side mold element 2 is moved along the long-side mold element 3 for changing the width of the slab 69, and hence to prevent occurrence of damages of the edges of the refractory member 70 and the surface of the long-side mold element 3. Also, since the frame 74a made of a heat-resisting metal is provided at each edge of the refractory member 70, it is possible to reduce the contact area between the solidified shell 76 formed on the surface of the long-side mold element 3 and the refractory member 70 and hence to reduce a sliding resistance therebetween. This is effective to perform stable casting, and to reduce a sliding wear during casting and prolong the service life of the short-side mold element 2.

Since the frame 74a is connected to the refractory member 70 on the anti-molten metal side, it is possible to prevent the shifting of the frame 74a, and hence to easily move the short-side mold element 2 in the width direction of the slab at an arbitrary time during casting or not during casting.

Next, a second example of the present invention will be described with reference to the drawings.

Figs. 22(a) to 22(c) are views showing a configuration of a short-side mold element 2A in the continuous casting apparatus used in this example; wherein Fig. 22(a) is view seen from a molten metal 3 side, showing the short-side mold element 2A; Fig. 22(b) is a sectional view taken on line B-B of Fig. 22(a); and Fig. 22(c) is a sectional view taken on line C-C of Fig. 22(a). In these figures, parts corresponding to those shown in Figs.

21(a) to 21(c) are indicated by the same characters. This example has a basic configuration being similar to that of the first example, except that a space 77 is provided between a refractory member 70 and a thermal insulating member 71 and a burner 72a as a heating means is provided in the space 77. A high temperature gas from the burner 72a is introduced in the space 77 for heating the refractory member 70 at an arbitrary time during casting or not during casting. Even in this example, the same effect as that in the first example can be obtained.

A third example and a fourth example of the present invention will be described with reference to Figs. 23(a) to 23(d) and Figs. 24(a) to 24(d).

Figs. 23(a) to 23(d) and Figs. 24(a) to 24(d) show configurations of short-side mold elements 2 and 2A of the third and fourth examples, respectively. Figs. 23(a), 24(a) are views seen from a molten metal 5 side, showing the short-side mold elements 2 and 2A, respectively; Figs. 23(b), 24(b) are sectional views taken on line B-B of Figs. 23(a), 24(a), respectively; Figs. 23(c), 24(c) are sectional views taken on line C-C of Figs. 23(a), 24(a), respectively; and Fig. 23(d), 24(d) are sectional views taken on line D-D of Figs. 23(a), 24(a), respectively. The third example shown in Figs. 23(a) to 23(d) is a modification of the first example in which a seal member 78 is provided between a frame 74a and a long-side mold element 3; and the fourth example shown in Figs. 24(a) to 24(d) is a modification of the second example in which the seal member 78 is provided between the frame 74a and the long-side mold element 3. In these figures, parts corresponding to those shown in Figs. 21(a) to 21(c) and Figs. 22(a) to 22(c) are indicated by the same characters.

Since the seal member 78 is provided between the frame 74a of the short-side mold element 2 or 2A and the long-side mold element 3, the frame 74a is not directly brought in contact with the long-side mold elements 3. This is effective to further reduce a sliding resistance between the short-side mold element 2 or 2A and the long-side mold element 3 and hence to positively prevent occurrence of damages of the refractory member 70 and the long-side mold element 3, and also to positively block the gaps between the short-side mold element 2 or 2A and the long-side mold element 3, particularly, when the short-side mold element 2 or 2A is moved along the long-side mold element 3 for changing the width of the slab 69. Moreover, the seal member 78 may be extended between a cooling metal plate 73 at the lower portion of the mold 1 and the long-side mold element 3, as shown in Figs. 23(a) to 23(d) and Figs. 24(a) to 24(d), for further reducing the sliding resistance.

The seal member 78 may be made from a non-metal material such as teflon; however, preferably, the seal member 78 provided between the upper reduction portion of the short-side mold element 2 or 2A and the long-side mold element 3 is made from a metal such as copper or a copper alloy, and the seal member 78

between the cooling metal plate 73 at the lower side parallel portion and the long-side mold element 3 is made from a non-metal material such as teflon. Alternatively, preferably, the seal member 78 provided between the reduction portion of the short-side mold element 2 or 2A and the long-side mold element 3 is made from a high temperature material such as fine ceramics, and the seal member 78 provided between the water-cooling metal plate 73 at the lower side parallel portion and the long-side mold element 3 is made from a low temperature material such as teflon.

As described above, according to the third and fourth examples, in addition to the effects of the first and second examples, since the seal member 78 is provided between the frame 74a and the long-side mold element 3, it is possible to further reduce a sliding resistance between the short-side mold element 2 or 2A and the long-side mold element 3 and hence to positively prevent occurrence of damages of the short-side mold element 2 or 2A and the long-side mold element 3, and also to positively block gaps therebetween.

A fifth example of the present invention will be described with reference to Figs. 25(a) to 25(c).

Figs. 25(a) to 25(c) are views showing a configuration of a short-side mold element 2B in a continuous casting apparatus in this example, wherein Fig. 25(a) is a view seen from a molten metal 3 side, showing the short-side mold element 2B; Fig. 25(b) is a sectional view taken on line B-B of Fig. 25(a); and Fig. 25(c) is a sectional view taken on line C-C of Fig. 25(a). In these figures, parts corresponding to those shown in Figs. 21(a) to 21(c) are indicated by the same characters. In this example, a frame 74c and a back surface portion 74d of a heat-resisting metal member 74A are provided separately from each other, and they are fastened to each other by means of bolts 91 as fastening members at several positions arranged in the vertical direction (casting direction) as shown in Fig. 25(b). Of holes formed in the frame 74c, through which the bolts 91 pass, the lowermost hole has a diameter being substantially the same as that of the bolt 91, and other holes are all in the form of slots 92 for absorbing a difference in thermal deformation between the frame 74c and the back surface portion 74d during casting or during preheating of the refractory member 70. The other configurations are the same as those in the first example. Parts corresponding to those shown in Figs. 21(a) to 21(c) are indicated by the same characters.

Since the frame 74a and the back surface portion 74d are provided separately from each other, they can be independently, easily machined upon manufacturing the heat-resisting metal member 74A. In particular, a stainless steel such as SUS 310 or SUS 314 preferable as a heat-resisting metal is difficult to be machined, and thereby the above configuration is advantageous in simplifying the manufacture. In addition, the frame 74c is integrated with the back surface portion 74d after being fastened by the bolts 91, and the same effect as that in the first example can be obtained. Moreover, since the

hole formed at the lowermost portion of the frame 74c has a diameter being substantially the same as that of the bolt 91 and other holes are all in the form of the slots 92, it is possible to absorb a difference in thermal deformation between the frame 74c and the back surface portion 74d. In addition, the head of the bolt 91 formed in a disk-shape can be buried in the bolt hole formed in the frame 74c. This is effective to prevent occurrence of damages on the surface of the long-side mold element 3 by the head of the bolt 91.

A sixth and a seventh examples of the present invention will be described with reference to Figs. 26 and 27. Fig. 26 shows a twin-belt type continuous casting apparatus in the sixth example, and Fig. 27 shows a twin-roll type continuous casting apparatus in the seventh example. The structures of a short-side mold element and a long-side mold element shown in Figs. 26 and 27 are equivalent to those shown in Fig. 21(a). In addition, like parts in Figs. 26 and 27 are indicated by the like characters.

In each of the continuous casting apparatuses shown in Figs. 26 and 27, a short-side mold element 81 has the same shape and structure as those of the short-side mold element shown in Figs. 21(a) to 21(c), Figs. 22(a) to 22(c) and Figs. 25(a) to 25(c). Namely, the short-side mold element 81 is formed in such an approximately fan-shape that the width is gradually narrowed in the casting direction from the upper surface of molten metal, and a reduction portion of the short-side mold element 81 is formed of a refractory member 82 having a heating means while a parallel portion positioned under the reduction portion is formed of a water-cooled metal plate 83. Long-side mold elements of the twin-belt type continuous casting apparatus shown in Fig. 26 are formed of a pair of movable belts 84a circulating while keeping a gap corresponding to the reduction portion of the short-side mold element 81; and long-side mold elements of the twin-roll type continuous casting apparatus shown in Fig. 27 are formed of a pair of movable rolls 84b rotating while keeping a gap corresponding to the reduction portion of the short-side mold element 81. Moreover, in the twin-belt type continuous casting apparatus shown in Fig. 26, a cooling body 85 for cooling a slab 80 is provided along the movable belt 84a.

Even in the sixth and seventh examples, a frame 86 made from a heat-resisting metal is provided along the shape of the reduction portion at a contact portion between the refractory member 82 of the short-side mold element 81 and the movable belt 84a or movable roll 84b as the long-side mold element, that is, at each edge of the refractory member 82. The frame 86 is connected to a back surface portion (not shown) equivalent to that shown in Fig. 19 on the anti-molten metal side of the refractory member 82. Moreover, a thermal insulating member (not shown) is disposed between the back surface portion and the refractory member 82. The frame 86 and the back surface portion may be configured to be similar to those shown in the first to fifth

examples.

As described above, according to the sixth and seventh examples, since the frame 86 connected to the anti-molten metal side of the refractory material 82 is disposed at the contact portion between the refractory member 82 of the short-side mold element 81 and the movable belt 84a or movable roll 84b as the long-side mold element, there can be the same effect as those described in the previous examples, that is, it is possible to prevent formation of gaps between the short-side mold element 81 and the movable belt 84a or movable roll 84b and hence to prevent creation of casting fins due to insertion of molten metal into the gaps. This is effective to perform stable casting without occurrence of inconveniences such as damages of the mold, surface defects of a slab, and restrictive breakout. Moreover, since the refractory member 82 is indirectly brought in contact with the movable belt 84a or movable roll 84b through the frame 86, it is possible to reduce a sliding resistance, and hence to prevent damages of the refractory member 82, movable belt 84a or movable roll 84b. Additionally, it is possible to change the width of a slab at an arbitrary time during casting or not during casting. The other effects similar to those described in the previous examples can be also obtained.

Even in the sixth and seventh examples, a seal member may be provided between the frame 86 and the movable belt 84a or movable roll 84b. In this case, it is possible to further reduce a sliding resistance between the short-side mold element 81 and the movable belt 84a or movable roll 84b, and hence to positively prevent damages of the mold, and also to positively block the gaps therebetween.

According to the present invention, since the frame 86 connected to the anti-molten metal side of the refractory member is provided at the contact portion between the reduction portion of the short-side mold element and the long-side mold element, it is possible to prevent formation of gaps between the short-side mold element and the long-side mold element and hence to prevent creation of casting fins due to insertion of molten metal into the gaps. This is effective to prevent occurrence of inconveniences such as damages of the mold, surface defects of a slab, and restrictive breakout, and hence to perform stable casting.

Embodiment 4

Fig. 28 is a schematic view showing a concept of a continuous casting apparatus used in this embodiment.

In the continuous casting apparatus in this embodiment, molten metal 4 is supplied through a pouring nozzle 3 into a fixed mold composed of short-side mold elements 1 and long-side mold elements 2, to form a molten pool 4. The short-side mold element 1 is formed in such an approximately fan-shape that the width in the thickness direction of a slab is widened at an upper portion and is narrowed at a lower portion for making easy insertion of the pouring nozzle 3 and reducing the

degree of a wavy state of a molten metal surface in the mold.

The molten metal 4 is supplied from a tundish 60 into the mold. Specifically, the molten metal 4 stored in the tundish 60 is allowed to pass through the pouring nozzle 3 mounted to the lower portion of the tundish 60 by adjustment of a stopper 61 and to be supplied into the fixed mold.

The molten metal 4 is cooled in the mold to be solidified into a slab 5. The slab 5 is drawn downward from the mold while being supported by a plurality of supporting rolls 6.

Each of the short-side mold elements 1 and the long-side mold elements 2 has a cooling water feeder, and thereby it can be suitably cooled during casting or the like. The short-side mold element 1 also has a temperature controller, and thereby it can be controlled in its temperature.

Fig. 29 is a view showing a structure of the short-side mold element 1 used in this embodiment. As shown in Fig. 29, the short-side mold element 1 includes a reduction portion 62 having a width gradually narrowed from top to bottom and a parallel portion 63 having a substantially uniform width.

The short-side mold element 1 has a refractory member 47 disposed at a molten metal contact surface 64, a high heat-insulating refractory member 48 disposed at a reduction portion behind the refractory member 47, an internally water-cooled metal plate 49 disposed behind the refractory member 48 and at the lower side parallel portion 63; and a back plate 50 mounted on the metal plate 49 for suppressing thermal deformation of the metal plate 49.

The refractory member 47 is heated by applying a current from lead wires 51 through electrodes 52. A temperature change of the refractory member 47 is measured by means of thermocouples 53 mounted on the back surface of the refractory member 47, and is fed-back to the temperature controller provided on the short-side mold element. As a result, the temperature of the refractory member 47 can be controlled before or during casting.

Here, the refractory member 47 may be heated by a heating means such as a burner, other than the above-described electric heating.

With the above-described configuration of the present invention, a pouring basin is widened at its upper portion and is narrowed at its lower portion, so that a solidified shell is produced on the surface of each short-side mold element as shown in Fig. 38.

Fig. 38 shows a shape of a solidified shell produced on the surface of the short-side mold element.

A solidified shell 54 is produced at the upper reduction portion continuously at each corner portion between the short-side mold element 1 and the long-side mold element 2 in an area lower than the molten metal surface.

On the other hand, the solidified shell 54 is produced over the entire surface at the lower side parallel

portion.

In order to form the solidified shell 54 as described above, temperature adjustment of the short-side mold element 1 in the width direction is required to be suitably performed.

Fig. 39 shows one example of the temperature adjustment of the short-side mold element 1 in the width direction.

With respect to the upper reduction portion, the center in the width direction of the short-side mold element 1 is heated up to a temperature higher than a solidified shell forming temperature (T), that is, it is heated at $T_2 (>T)$ in Fig. 39; while each end of the short-side mold element 1 is adjusted at a temperature lower than the solidified shell forming temperature (T), that is, it is adjusted at $T_1 (\leq T)$ in Fig. 39. At this time, preferably, the temperature curve between the center and each end of the short-side mold element is moderately changed; however, it may be changed stepwise or linearly.

Such a temperature adjustment can be performed by heating the center in the width direction of the short-side mold element 1 at the upper reduction portion by electric heating or heating using a burner, and by cooling both the ends of the short-side mold element 1.

Both the ends of the short-side mold element 1 can be cooled by allowing cooling water to flow in cooling water grooves provided in the mold.

At this time, both the ends of the short-side mold element 1 are cooled either from the short-side mold element 1 side or from the long-side mold element 2 side.

For example, cooling water grooves may be provided in the short-side mold element 1 on the side opposed to molten metal, whereby an effect of cooling both the ends of the short-side mold element 1 is enhanced by setting a flow rate of cooling water flowing in both the ends of short-side mold element 1 more than that of cooling water flowing in the center of the short-side mold element 1.

On the other hand, cooling water grooves may be provided in the long-side mold element 2, whereby an effect of cooling both the ends of the short-side mold element 1 is enhanced by setting a flow rate of cooling water flowing in the vicinities of contact portions between the long-side mold element 2 and the short-side mold element 1 more than that of cooling water flowing in the other portions of the long-side mold element 2.

The above-described heating and the cooling make it possible to obtain the above-described temperature distribution in the width direction of the short-side mold element, and hence to produce the solidified shell shown in Fig. 38 in accordance with such a temperature distribution.

With respect to the upper reduction portion, the solidified shell 54 is not produced at the center in the width direction of the short-side mold element because the center is high in temperature.

On the other hand, the solidified shell 54 already produced on the surface of the long-side mold element 2 is continuously produced at the corner portion between the long-side mold element 2 and the short-side mold element 1 because each end, in the vicinity of the long-side mold element 2, of the short-side mold element 1 is low in temperature.

Accordingly, at the upper reduction portion, the solidified shell 54 is formed only at each corner portion and is not continuously formed in the width direction over the entire surface of the short-side mold element 1, and thereby there is not generated a drawing resistance due to reduction performed along the short-side mold elements.

Moreover, since the solidified shell 54 is produced at the corner portion between the short-side mold element 1 and the long-side mold element 2 continuously from the long-side mold element 2 side, it is possible to prevent creation of casting fins by insertion of molten metal in gaps between the short-side mold element 1 and the long-side mold element 2. This is effective to prevent occurrence of restrictive breakout, and to prevent rounding of the molten metal 4 over the long-side solidified shell 54 from the short-side mold element 1 side upon production of the short-side solidified shell 54 on the lower side water-cooled metal plate 49 of the short-side mold element 1. On the other hand, the solidified shell 54 is formed over the entire surface of the parallel portion of the short-side mold element 1.

At this time, preferably, the upper reduction portion of the short-side mold element 1 is formed of a refractory member and the lower side parallel portion is formed of a metal member. With this configuration, a suitable temperature distribution is formed at the upper reduction portion, and the cooling for molten metal is accelerated at the lower side parallel portion, as a result of which the solidified shell can be produced only at each corner portion at the upper reduction portion and it is produced over the entire surface at the lower side parallel portion as shown in Fig. 38.

In this way, according to this embodiment, since the solidified shell 54 is not continuously grown over the entire surface of the short-side mold element 1 in the width direction, the reduction can be smoothly performed, and after completion of the reduction, the solidified shell 54 can be produced on the surface of the short-side mold element 1 by cooling the short-side mold element 1, to thus continuously produce the slab 5.

According to the configuration of this embodiment, a solidified shell is produced on the surface of the short-side mold element of the mold having a pouring basin being wide at its upper portion and narrow at its lower portion in such a manner that at the upper reduction portion, the solidified shell is not produced at the center of the short-side mold element and is produced at each end, in the vicinity of the contact portion with the long-side mold element, of the short-side mold element by heating the short-side mold element at a high tempera-

ture and cooling the vicinity of the contact portion between the short-side mold element and the long-side mold element. This is effective to reduce a drawing resistance of the reduction portion due to production of the short-side solidified shell and also prevent creation of casting fins due to insertion of molten metal into gaps between the short-side mold element and the long-side mold element, and hence to prevent occurrence of restrictive breakout.

A simulation was carried out to confirm a production state of a solidified shell 54 in the case of casting using the above-described continuous casting apparatus.

In this simulation, the refractory member 47 of each short-side mold element 1 was pre-heated for about 10 minutes before casting, and molten carbon steel (carbon content: 0.05 wt%) was continuously cast at a casting speed of 10 m/min into a slab having a size (thickness: 30 mm, width: 2,100 mm).

Figs. 30 and 31 show the production states, in this casting, of the solidified shell 54 at a certain cross-section A-A' at the reduction portion 62 and at a certain cross-section B-B' at the parallel portion 63, respectively.

Fig. 30 shows the production state of the solidified shell 54 at the reduction portion 62, in which a temperature difference exists in the short-side mold element 1 in the width direction. The temperature difference is due to cooling for both the ends in the width direction of the short-side mold element 1 by allowing cooling water to flow in the cooling water grooves 55 formed in the long-side mold element 2.

In the simulation of this embodiment, the center in the width direction of the refractory member 47 of the short-side mold element 1 is set at a high temperature of 1520°C and the portion, in the vicinity of the long-side mold element 2, of the refractory member 47 of the short-side mold element 1 is set at a temperature of 900°C, which is lower than that at the center in the width direction by about 420°C.

The solidified shell 54 is not produced at the center portion in the width direction of the short-side mold element 1 because the center portion is set at a high temperature.

On the other hand, the solidified shell 54 produced on the surface of the long-side mold element 2 is continuously produced at the corner portion between the long-side mold element 2 and the short-side mold element 1 because the portion, in the vicinity of the long-side mold element 2, of the short-side mold element 1 is set at a low temperature.

Consequently, the solidified shell 54 is not continuously produced in the width direction over the entire surface of the short-side mold element 1, so that it is possible to prevent generation of a drawing resistance due to reduction performed along the short-side mold elements 1.

Moreover, since the solidified shell 54 is produced at the corner portion between the short-side mold ele-

ment 1 and the long-side mold element 2 continuously from the long-side mold element 2 side, it is possible to prevent creation of casting fins by insertion of molten metal in gaps between the short-side mold element 1 and the long-side mold element 2. This is effective to prevent occurrence of restrictive breakout, and to prevent rounding of the molten metal 4 over the long-side solidified shell 54 from the short-side mold element 1 side upon production of the short-side solidified shell 54 on the lower side water-cooled metal plate 49 of the short-side mold element 1. On the other hand, as shown in Fig. 31, the solidified shell 54 is produced over the entire surface of the short-side mold element 1 at a region subsequent to the reduction portion, that is, at the parallel portion 63 because the parallel portion 63 is cooled by the metal plate 49 of the short-side mold element 1.

In this way, according to the present invention, since the solidified shell 54 is not continuously grown over the entire surface of the short-side mold element 1 in the width direction, the reduction can be smoothly performed, and after completion of the reduction, the solidified shell 54 is produced on surface of the short-side mold element 1 by cooling the short-side mold element 1, to thus continuously produce the slab 5.

Figs. 32 and 33 show structures for cooling a portion, in the vicinity of the long-side mold element 2, of the short-side mold element 1 of the continuous casting apparatus used in this embodiment.

Fig. 32 shows the structure in which an effect of cooling a contact portion of the long-side mold element 2 with the short-side mold element 1 is set to be more than an effect of cooling the other portions of the long-side mold element 2 by increasing a flow rate of cooling water flowing in cooling water grooves 55 in a portion, in the vicinity of the contact portion with the short-side mold element 1, of the long-side mold element 2, so that the solidified shell 54 produced on an inner surface of the long-side mold element 2 is accelerated to be continuously produced at the corner portion between the short-side mold element 1 and the long-side mold element 2. Specifically, in this embodiment, the size of only the cooling water groove 55 provided in the vicinity of the contact portion with the short-side mold element 1 is made larger for increasing the flow rate of cooling water flowing in the cooling water groove, thereby accelerating the cooling at each end of the short-side mold element 1.

In this case, the cooling ability in the vicinity of the contact portion with the short-side mold element 1 can be improved by increasing the velocity or decreasing the temperature of cooling water flowing in the cooling water groove 55 provided in the vicinity of the contact portion, other than by increasing the size of the cooling water groove 55.

Fig. 33 shows the structure in which the metal plate 49 behind the refractory members 47, 48 of the short-side mold element 1 has a plurality of cooling water grooves 55, and of these cooling water grooves 55, one

provided in the vicinity of each contact portion with the long-side mold element 2 is allowed to flow cooling water therethrough at a large flow rate. This gives a temperature distribution (temperature gradient) in the width direction to the short-side mold element 1. Namely, the center in the width direction of the short-side mold element 1 is set at a high temperature and a portion, in the vicinity of the long-side mold element 2, of the short-side mold element 1 is set at a low temperature, so that the solidified shell 54 produced on the long-side mold element 2 is accelerated to be continuously produced at the corner portion between the short-side mold element 1 and the long-side mold element 2.

In the cooling structure shown in Fig. 33, three pieces of the cooling water grooves 55 are formed on the short-side mold element 1, and the flow rate of cooling water flowing in the side grooves 55 is made larger than that of cooling water flowing in the center groove 55. In this case, the cooling ability can be enhanced by positioning the surface, on the molten metal 4 side, of the cooling water groove 55 closer to the molten metal 4.

Fig. 33 shows another structure of the short-side mold element 1 of the continuous casting apparatus used in this embodiment. A refractory member 47 is disposed at a surface, being in contact with molten metal, of an upper reduction portion of a short-side mold element 1; a heat-insulating refractory member 48 is disposed behind the refractory member 47; and a water-cooled metal plate 49 is disposed behind the refractory member 48. In this case, the water-cooled metal plate 49 is exposed to a surface, being in contact with the molten metal 4, of a lower side parallel portion.

In the case of providing the refractory member 47 at the surface, being in contact with the molten metal 4, of the lower side parallel portion of the short-side mold element 1, the thickness of a solidified shell 54 at the parallel portion of the short-side mold element 1 is about 4 mm in the above-described simulation; however, in this embodiment, it can be set at about 7 mm.

Accordingly, it is possible to make larger the growth amount of the solidified shell 54 at the lower side parallel portion of the short-side mold element 1. This is advantageous in prevention of occurrence of breakout.

Here, each of the long-side mold element 2 and the water-cooled metal plate of the short-side mold element 1 is made from a metal having a high thermal conductivity such as copper or a copper alloy, and it is applied on the contact surface with the molten metal 4 with Cr plating or Ni-Cr plating (lower layer: Ni plating, upper layer: Cr plating).

Fig. 35 shows a further structure of the short-side mold element 1 of the continuous casting apparatus used in this embodiment.

As shown in Fig. 35, a seal member 56 is provided at a contact surface between the short-side mold element 1 and a long-side mold element 2 for eliminating direct contact between the short-side mold element 1 and the long-side mold element 2, thereby reducing a

sliding resistance of the short-side mold element 1 with respect to the long-side mold element 2 when the width of a slab is changed.

Furthermore, since a refractory member 47 used for a reduction portion is not brought in direct-contact with the long-side mold element 2 by the presence of the seal member 56, it is possible to reduce the possibility of damaging the refractory member 47 upon mold setting or change in width of a slab.

Accordingly, even in the case of on-line change of width of a slab performed during casting as well as before casting, it is possible to reduce the possibility of occurrence of troubles and to prevent damages on the contact surface of the long-side mold element 2 with the molten metal 4.

Here, the seal member 56 made of a metal seal material such as copper or a copper alloy, or a high temperature seal material such as fine ceramics may be used for the refractory member 47 of the short-side mold element 1; while the seal member 56 made of a non-metal seal material such as teflon may be used for a water-cooled metal plate 49 of the lower side parallel portion of the short-side mold element 1.

Fig. 36 shows a twin-belt type continuous casting apparatus used in this embodiment, and Fig. 37 shows a twin-roll type continuous casting apparatus used in this embodiment.

In the twin-belt type continuous casting apparatus shown in Fig. 36, belts moving in synchronization with a slab 5 are used as long-side mold elements 57; while in the twin-roll type continuous casting apparatus shown in Fig. 37, rolls moving in synchronization with a slab 5 are used as the long-side mold elements 58. Each casting apparatus commonly uses fixed type short-side mold elements 1, each of which has a width gradually narrowed in the casting direction from the molten metal surface.

The short-side mold element 1 used for each casting apparatus has the same configuration as shown in any of Figs. 29 to 35. In operation, the refractory member 47 of the upper reduction portion of the short-side mold element 1 is heated and a portion, in the vicinity of each contact portion with the twin-belt type long-side mold element 57 or twin-roll type long-side mold element 58, of the refractory member 47 is strongly cooled. As a result, any solidified shell 54 is not produced at the center in the width direction of the refractory member 47 because the center is set at a high temperature.

On the other hand, a portion, in the vicinity of the long-side mold element 2, of the short-side mold element 1 is low in temperature, so that the solidified shell 54 produced on the inner surface of the long-side mold element 2 is continuously produced at the corner portion between the short-side mold element 1 and the twin-belt type long-side mold element 57 or the twin-roll type long-side mold element 58.

Consequently, the solidified shell 54 is not continuously produced in the width direction over the entire surface of the short-side mold element 1. This is effective

to prevent generation of a drawing resistance due to reduction along the short-side mold elements 1.

Moreover, since the solidified shell 54 is produced at the corner portion, it is possible to prevent creation of casting fins by insertion of molten metal in gaps between the short-side mold element 1 and the twin-belt type long-side mold element 57 or the twin-roll type long-side mold element 58. This is effective to prevent occurrence of restrictive breakout, and to prevent rounding of the molten metal 4 over the long-side solidified shell 54 from the short-side mold element 1 side upon production of the short-side solidified shell 54 on the lower side water-cooled metal plate 49 of the short-side mold element 1.

In this way, since the solidified shell 54 is not continuously grown over the entire surface of the short-side mold element 1 in the width direction, the reduction can be smoothly performed, and after completion of the reduction, the solidified shell 54 can be produced on the surface of the short-side mold element 1 by cooling the short-side mold element 1, to thus continuously produce a slab.

The present invention can be applied to the twin-belt type continuous casting apparatus or the twin-type continuous casting apparatus using short-side mold elements each including an upper reduction portion with a width gradually narrowed from top to bottom and a lower side parallel portion having a substantially uniform width. In other words, the present invention is effective for a continuous casting apparatus using short-side mold elements each including an upper reduction portion with a width gradually narrowed from top to bottom and a lower side parallel portion having a substantially uniform width.

In this embodiment, it is possible to prevent rounding of molten metal over a solidified shell on a long-side mold element from a short-side mold element side upon production of a short-solidified shell on a lower side water-cooled metal portion of the short-side mold element.

With the configuration of the present invention, since a seal member is provided at a contact portion between a short-side mold element and a long-side mold element, it is possible to prevent direct contact between the short-side mold element and the long-side mold element when the short-side mold element is moved in the width direction of a slab at an arbitrary time during casting or not during casting, and hence to smoothly move the short-side mold element in the width direction of the slab.

According to this embodiment using a mold having a width being widened at its upper portion and gradually narrowed in the casting direction, the reduction is performed in a state that molten steel in the mold is not solidified on a short-side mold element by heating the upper portion of the short-side mold element and cooling a portion in the vicinity of a contact portion between a long-side mold element and the short-side mold element, and the solidified shell on the long-side mold ele-

ment can be continuously produced at the corner portion between the long-side mold element and the short-side mold element.

This makes it possible to reduce creation of casting fins by insertion of non-solidified molten steel in gaps at a contact portion between a long-side mold element and a short-side mold element at the reduction step, and hence to reduce restrictive breakout caused by the casting fins remaining in the mold during casting. This is effective to achieve stable casting at a high speed.

The reduction in creation of casting fins lowers creation of surface defects of a slab, resulting in the improved quality of the slab, and also it lowers damages of a mold due to casting fins, resulting in the prolonged service life of the mold.

According to this embodiment, it is possible to prevent rounding of molten metal over a solidified shell produced on a long-side mold element from a short-side mold element side upon production of a solidified shell produced on a lower side water-cooled metal portion of the short-side mold element, and hence to achieve stable casting at a high speed.

In addition, according to this embodiment, since a seal member is provided at a contact portion between a short-side mold element and a long-side mold element, it is possible to prevent direct contact between the short-side mold element and the long-side mold element when the short-side mold element is moved in the width direction of a slab at an arbitrary time during casting or not during casting, and hence to smoothly move the short-side mold element in the width direction of a slab.

According to the present invention, there can be provided an apparatus and a process for continuously casting a high quality slab at a high speed by producing a solidified shell at a corner portion of a contact portion between a short-side mold element and a long-side mold element continuously to a solidified shell on the long-side mold element, thereby suppressing creation of casting fins and rounding of molten metal.

Embodiment 5

An upper reduction portion of a short-side mold element can be made of a refractory member divided into a plurality of parts in the casting direction. This is effective to reduce thermal deformation of the refractory member due to a temperature difference between a molten metal contact side of the refractory member and the opposed side thereof, and to substantially eliminate a difference in taper amount of the mold between in the assembled state and in the casting state. As a result, it is possible to perform stable casting using the mold having a taper kept in the assembled state, and hence to prevent breakout due to restriction of a solidified shell in the mold. In addition, the divided type refractory member can be easily manufactured using small pieces of refractory member at a low cost.

The refractory member can be made from a mate-

rial mainly containing ZrB_2 . This is effective to reduce corrosion of a short-side mold element due to a mold powder, and to prolong the service life of the mold.

The upper reduction portion of the short-side mold element, which is made of a refractory member, can be heated by a heating means. This is effective to prevent production of a solidified shell on the surface of the upper portion of the short-side mold element. Accordingly, it is possible to reduce a drawing resistance in the casting direction at a reduction step in which the thickness of a slab is made thinner, and hence to perform stable casting.

The lowermost piece of the above divided type refractory member can be extended up to a portion having a constant width and positioned downwardly adjacent to the upper reduction portion, and a cooling means can be provided at the lowermost piece for cooling it. With this configuration, a solidified shell can be produced at the portion provided with the lowermost piece of the refractory member on the molten metal contact side, though no solidified shell has been produced at the upper reduction portion on the molten metal contact side. Also, the lower straight portion downwardly adjacent to the above portion provided with the lowermost piece of the refractory member, which has a width substantially equal to the thickness of a slab, can be made of a copper alloy plate having an internally water-cooled structure. This is effective to accelerate the growth of the solidified shell.

The fixed type mold can be made to oscillate by means of an oscillation applying means. This is effective to accelerate the flow-in of a mold powder and keep a preferable lubrication state between the mold and a solidified shell, and hence to improve quality of a slab and stability of casting.

A frame can be provided at a contact portion between the short-side mold element and the long-side mold element for preventing direct contact between the long-side mold element and a refractory member of the short-side mold element. This is effective to reduce damages of both the mold elements due to a sliding friction therebetween upon change of the width of a slab, and hence to stably perform the slab width changing operation at an arbitrary time during casting or not during casting.

In the above description, the long-side mold elements can be formed of a pair of movable belts circulating while keeping a gap corresponding to the reduction portion of the short-side mold element, in which molten metal is held in the mold including the long-side mold elements (movable belts) and the short-side mold elements. Alternatively, the long-side mold elements can be formed of a pair of movable rolls rotating while keeping a gap corresponding to the reduction portion of the short-side mold element, in which molten metal is held in the mold including the long-side mold elements (movable rolls) and the short-side mold elements.

Hereinafter, a preferred embodiment of the present invention will be described with reference to the draw-

ings.

Fig. 40 is a view showing a concept of a continuous casting apparatus used in this embodiment. Molten metal 4 is supplied through a pouring nozzle 3 into a fixed type mold including opposed short-side mold elements 1 and opposed long-side mold elements 2, to form a molten metal pool. The short-side mold element 1 is formed in such an approximately fan-shape that the width (in the thickness direction of a slab) is widened at its upper portion and is narrowed at its lower portion for making easy insertion of the pouring nozzle in a mold space and reducing the degree of a wavy state of a molten metal surface in the mold. The molten metal 4 is cooled in the type mold, and is solidified into a slab 5. The slab 5 is drawn downward from the mold while being supported by supporting rolls 6.

Figs. 41 and 42 show a structure of a short-side mold element used in this embodiment. The short-side mold element 1 includes an upper short-side mold section 107 made of a refractory member and a lower short-side mold section 108 made of a copper plate having an internally water-cooled structure. A high temperature burning gas is supplied from a heating means 110 such as a gas burner into a gap 115 between the upper short-side mold section 107 and a short-side rear plate 108 provided on the back surface of the upper short-side mold section 107, to heat the upper short-side mold section 107. In this embodiment, the gas burner for burning a mixed gas of a propane gas and a compression air is used as the heating means 110; however, a current-carrying heating system for electrically heating the upper short-side mold section 107 may be used. A temperature change of the upper short-side mold section 107 is measured by means of thermocouples 112 mounted in the upper short-side mold section 107 on the anti-molten metal side, and the measured result is fed-back to control the temperature of the upper short-side mold section 107 before and during casting. This is effective to prevent production of a solidified shell on the molten metal contact surface of the upper short-side mold section (upper reduction portion) 107, and hence to prevent occurrence of restrictive breakout.

In this embodiment, the upper short-side mold section 107 is made of a refractory member divided into a plurality of parts in the casting direction, and the refractory member is made from 100% of ZrB_2 . The use of the divided type refractory member for the upper short-side mold section 107 is effective to reduce the cost by about one-tenth, as compared with the use of one large-sized refractory member. Also, the lowermost piece of the refractory member of the upper short-side mold section 107 is extended up to a portion having a constant width and positioned downwardly adjacent to the upper short-side mold section (upper reduction portion) 107, and a cooling means is provided at the lowermost piece for cooling it. With this configuration, a solidified shell can be produced at the portion provided with the lowermost piece of the refractory member on the molten metal contact side, though no solidified shell has been pro-

duced at the upper reduction portion on the molten metal contact side. As a result, it becomes possible to prevent rounding of molten metal over the long-side mold element side from the short-side mold element side. Also, a lower straight portion downwardly adjacent to the above portion provided with the lowermost piece of the refractory member, which has a width substantially equal to the thickness of a slab, is made of a copper alloy plate having an internally water-cooled structure for accelerating the growth of the solidified shell. This makes it possible to ensure the thickness of the short-side solidified shell and increase the strength thereof, and hence to prevent breakout due to bulging occurring directly under the mold.

Deformation of a slab in the width direction (thickness direction of a refractory member) is dependent on a difference in thermal expansion, generated during casting, between the molten metal side and its opposed side of the upper short-side mold section 107 made of the refractory member. Fig. 43 is a diagram showing the result of a test carried out for examining the above deformation of a slab depending on a difference in thermal expansion of the refractory member with the presence or absence of division of the refractory member taken as a parameter. In this test, a divided type refractory member divided into six pieces in the casting direction was compared with an integral type refractory member. Each refractory member is made from 100% of ZrB_2 and has an entire length of 600 mm. In addition, it is assumed that the upper short-side mold section 107 has a uniform temperature distribution. As is apparent from Fig. 43, for the integral type refractory member, the deformed amount of a slab is maximized (about 1.15 mm) at a point being 300 mm apart in the casting direction from the top of the upper short-side mold section 107, and the width of the mold which is set upon assembly of the mold is narrowed by about 2.3 mm on both sides of a slab in the width direction. The mold is usually assembled to have a taper of about 1 - 1.2% of the width of a slab such that the width of the mold is widened at its upper portion and is narrowed in the casting direction (toward the bottom of the mold) in consideration of the contraction of the width of the slab in the mold. For a slab having a width of 1,200 mm, the mold (length: 1,000 mm) is assembled to have a taper of about 12 - 15 mm over the entire length of the mold. In the case of using the integral type refractory member for the short-side mold section 107, since the width of the mold is narrowed by about 2.3 mm at the point 300 mm apart from the top of the mold, the taper becomes 1.47% in an upper area having a distance of 300 mm apart from the top of the mold, and becomes 0.19% in a lower area downwardly adjacent to the upper area and having a distance of 600 mm. As a result, the taper in the upper area is about 1.47 times larger than the necessary taper for contraction of the width of the slab. Such a large taper possibly restricts a solidified shell in the mold, leading to breakout. Besides, the taper in the lower area is about 0.19 time smaller than the necessary taper for

the contraction of the width of the slab. Such a small taper tends to excessively enlarge a gap between the solidified shell in the mold and the mold surface, and hence to break the solidified shell by bulging due to static pressure of the molten steel in the mold, leading to breakout. On the other hand, in the case of using the divided type refractory member of the present invention for the upper short-side section 107, the deformed amount of a slab in the width direction (thickness direction of the refractory member) is as small as about 0.03 mm at maximum (about 2.6% of the deformed amount of the slab measured in the case of using the integral type refractory member). In other words, the taper of the mold set upon assembly of the mold is little changed during casting. This makes it possible to perform stable casting using the mold having a taper kept in the assembled state, and hence to prevent occurrence of breakout due to restriction of the solidified shell in the mold.

Fig. 44 shows an erosion amount (due to molten metal) of the upper short-side mold section 107 with time (testing time: 2 hours after casting). In this test, the upper short-side mold section 107 was made from 100% of ZrB_2 , and for comparison, it was also made from a material generally used for a pouring nozzle, containing 76% of Al_2O_3 , 10% of SiO_2 and 12% of ZrO_2 . A slab having a thickness of 40 mm and a width of 1,200 mm was cast from carbon steel (carbon content: 0.19%) at a casting speed of 5.0 m/min. In this casting, the upper short-side mold section 107 was pre-heated for about 10 minutes before casting, as a result of which the upper short-side mold section 107 exhibited a temperature distribution in the casting direction in which the temperature of the central portion in the width direction was 1350°C and the temperature of a portion in the vicinity of the long-side mold element was 950°C at a certain cross-section in the casting direction on the anti-molten metal side. As is seen from Fig. 44, the comparative sample cannot be repeatedly used because the erosion amount at the powder line on the molten metal surface after casting becomes excessively larger; however, the inventive sample of ZrB_2 can be repeatedly used because the erosion amount is 1/40 or less that of the comparative sample, and also it enables stable casting by preventing restrictive breakout due to the presence of the solidified shell in the eroded portion.

Fig. 45 is a view showing a structure of a short-side mold element used in this embodiment. A frame 113 made of a band-like metal having a thickness of about 2 to 5 mm is provided along an edge portion at which the upper short-side mold section 107 is brought in contact with the long-side mold element 2. The frame 113, which is made from a heat-resisting metal such as SUS 316 or SUS 310, is not provided with any cooling means and cooled by contact with the long-side mold element 2 and by air cooling on the back surface side. By provision of the frame 113, it is possible to eliminate direct contact between the refractory member of the upper short-side mold section 107 and the long-side mold ele-

ment 2, and hence to prevent damages on the surface of the long-side mold element 2 upon change of the width of a slab, and also to prevent occurrence of chipping of the refractory member of the upper short-side mold section 107. Moreover, when a refractory member divided into a plurality of parts in the casting direction is assembled into the upper short-side mold section 107 as the upper-side mold element 1, the frame 113 can be used as a mounting guide, to thereby shorten the assembling time of the mold by one-tenth as compared with the conventional assembling time.

Figs. 46, 47 show a twin-belt type continuous casting apparatus and a twin-roll type continuous casting apparatus to which the present invention is applied. The twin-belt type continuous casting apparatus shown in Fig. 46 uses belts moving in synchronization with a slab 5 as long-side mold elements 114, and the twin-roll type continuous casting apparatus shown in Fig. 47 uses rolls moving in synchronization with the slab 5 as long-side mold elements 115. Each of the apparatuses uses as the short-side mold element 1 a fixed mold of a reduction type in which the width (thickness direction of a slab) is widened at its upper portion and is narrowed in the casting direction. As a result, the short-side mold element 1 described above can be applied to these apparatuses shown in Figs. 46 and 47, which ensures stable casting.

According to this embodiment, an upper reduction portion of a short-side mold element can be made of a refractory member divided into a plurality of parts in the casting direction. This is effective to reduce thermal deformation of the refractory member due to a temperature difference between a molten metal contact side of the refractory member and the opposed side thereof, and to substantially eliminate a difference in taper amount of the mold between in the assembled state and in the casting state. As a result, it is possible to perform stable casting using the mold having a taper kept in the assembled state, and hence to prevent breakout due to restriction of a solidified shell in the mold. In addition, the divided type refractory member can be easily manufactured using small pieces of refractory member at a low cost.

The refractory member can be made from a material mainly containing ZrB_2 . This is effective to reduce corrosion of a short-side mold element due to a mold powder, and to prolong the service life of the mold.

The upper reduction portion of the short-side mold element, which is made of a refractory member, can be heated by a heating means. This is effective to prevent production of a solidified shell on the surface of the upper portion of the short-side mold element. Accordingly, it is possible to reduce a drawing resistance in the casting direction at a reduction step in which the thickness of a slab is made thinner, and hence to perform stable casting.

The lowermost piece of the above divided type refractory member can be extended up to a portion having a constant width and positioned downwardly adja-

cent to the upper reduction portion, and a cooling means can be provided at the lowermost piece for cooling it. With this configuration, a solidified shell can be produced at the portion provided with the lowermost piece of the refractory member on the molten metal contact side, though no solidified shell has been produced at the upper reduction portion on the molten metal contact side. Also, the lower straight portion downwardly adjacent to the above portion provided with the lowermost piece of the refractory member, which has a width substantially equal to the thickness of a slab, can be made of a copper alloy plate having an internally water-cooled structure. This is effective to accelerate the growth of the solidified shell.

The fixed type mold can be made to oscillate by means of an oscillation applying means. This is effective to accelerate the flow-in of a mold powder and keep a preferable lubrication state between the mold and a solidified shell, and hence to improve quality of a slab and stability of casting.

A frame can be provided at a contact portion between the short-side mold element and the long-side mold element for preventing direct contact between the long-side mold element and a refractory member of the short-side mold element. This is effective to reduce damages of both the mold elements due to a sliding friction therebetween upon change of the width of a slab, and hence to stably perform the slab width changing operation at an arbitrary time during casting or not during casting.

Embodiment 6

Hereinafter, a preferred embodiment of a thin slab continuously casting apparatus of the present invention will be described in detail, but not exclusively.

Fig. 48 is a schematic view of a continuous casting apparatus of a reduction type using an oscillating mold, in which reduction is performed in a state in which solidification is suppressed on a short-side mold element. A long-side mold element 3 is entirely formed of a water-cooled copper plate. On the other hand, a short-side mold element is composed of a reduction portion formed in such an approximately fan-shape that the width is widened at its upper portion and is narrowed at its lower portion, and a straight portion having the upper portion partially made of a refractory member 2 and the lower portion made of a water-cooled copper plate 1. As shown in Fig. 48, the short-side mold element is applied with a clamping force from the long-side mold element side, and accordingly it is required to have a compressive strength larger than a stress caused by clamping. Molten steel is supplied in the mold through a pouring nozzle 5 provided in a tundish, to form a molten steel pool 4. The molten steel is cooled in the mold, and is solidified into a thin slab 7. The thin slab 7 is drawn downward from the mold while being supported by supporting rolls 6.

Figs. 49(a) to 49(c) show a structure of a short-side

mold element used for the continuous casting apparatus shown in Fig. 48, wherein Fig. 49(a) is a front view of the short-side mold element; Fig. 49(b) is a vertical sectional view of the short-side mold element; and Fig. 49(c) is a horizontal sectional view taken on lines A-A, B-B, and C-C of Fig. 49(a). The short-side mold element has the reduction portion with a widened upper portion and a narrowed lower portion, and the straight portion. The reduction portion has a length of from 300 to 1,000 mm (preferably, from 400 to 600 mm), and the straight portion has a length of from 200 to 1,000 mm (preferably, from 300 to 500 mm). The length of each portion is determined depending on the thickness of a slab to be produced. The length of the straight portion is set to be 30-60% (preferably, 40-50%) of the entire length of the mold, and the reduction portion has a radius of curvature of from 1,500 to 5,000 mm (preferably, from 2,500 to 3,500 mm). The extension of the upper portion of the mold is 0.1 to 0.4 time (preferably, 0.1 to 0.3 time) the length of the reduction portion on both the sides of the mold.

Each of the reduction portion 128 and an upper portion 129 of the straight portion is made of a refractory member 2 having a high thermal resistance, such as molten silica, and a lower portion 130 of the straight portion is made of the water-cooled copper plate 1. Each of the water-cooled copper plate 1 and the long-side mold element 3 is made from a high strength and high hardness Cu-alloy containing 5 wt% or less (preferably, 1 - 3 wt%) of additional elements such as Zr, Cr, Ti and V, and it is formed, at least on the molten steel side, with a seizure preventive plating such as Ni plating or Cu plating.

The refractory structure differs on the upper and lower sides with respect to a boundary portion (hereinafter, referred to as "RS portion") between the reduction portion and the straight portion. The upper side (reduction portion) from the RS portion is composed of the hollow refractory member 2 having a low thermal conductivity formed on the molten metal side (front surface) and the water-cooled copper plate 1 formed on the back surface thereof, as shown in the cross-section A-A. The reason why the refractory member 2 has a hollow structure 131 is that it is heated by a gas burner. As shown in the cross-section B-B, the upper portion 129 of the straight portion lower than the RS portion is composed of a solid refractory member 2 having a low thermal conductivity formed on the molten metal side (front surface) and the water-cooled copper plate 1 formed on the back surface thereof. The reason why the upper portion 129 is made of the solid refractory member is that it is not required to be heated. The upper portion 129 of the straight portion has a length of from 20 to 600 mm (preferably, from 50 to 300 mm), which is 5 - 90% (preferably, 10 - 30%) of the entire length of the straight portion. The thickness of the refractory member 2 constituting the upper portion 129 of the straight portion is gradually reduced in the drawing direction of a slab. As shown in the cross-section C-C, the lower portion

130 of the straight portion is entirely composed of a water-cooled copper plate 1. The water-cooled plate 1 is provided behind the refractory members constituting the reduction portion 128 and the upper portion 129 of the straight portion for imparting a strength withstanding a fastening force applied to the short-side mold element from the long-side mold element side.

Thermocouples are disposed in the refractory member 2 to usually monitor the temperature of the surface thereof on the molten metal side. The reduction portion 128 is heated by the gas burner during casting in such a manner that the temperature of the surface thereof on the molten steel side is kept more than a liquidus temperature of molten steel. On the contrary, the upper portion 129 of the straight portion is cooled through the water-cooled copper plate 1 in such a manner that the temperature thereof is kept less than the liquidus temperature of molten steel. By the control of the temperatures of the reduction portion 128 and the upper portion 129 of the straight portion as described above, it is possible to start production of a short-side solidified shell at the upper portion 129 of the straight portion, and hence to obtain a high quality slab.

A short-side edge portion 137 having a width of from 1 to 4 mm (preferably, from 2 to 3 mm) is provided at a contact portion between the short-side mold element 2 and the long-side mold element 3 in a range of from the reduction portion 128 to the upper portion 129 of the straight portion. The short-side edge portion 137 is made from the same material as that of the long-side mold element 3, that is, a copper alloy. The surface, being in contact with molten steel, of the short-side edge portion 137 is applied with a double-layer plating (lower layer: Ni plating, upper layer: Cr plating). The provision of the short-side edge portion 137 in the short-side mold element 2 is effective to improve the strength, particularly, toughness of the contact portion with the long-side mold element 3, and hence to prevent breakage of the short-side mold element 2 due to sliding with the long-side mold element 3 upon change of the width of a slab. As a result, it is possible to reduce a possibility in causing troubles even upon on-line change of the width of a slab during casting.

Figs. 50(a) and 50(b) are typical views showing a continuous casting process of a reduction type using the continuous casting apparatus shown in Fig. 48, in which solidification is suppressed on the short-side mold element side; wherein Fig. 50(a) is a vertical sectional view of a mold during casting; and Fig. 50(b) is a horizontal sectional view of each position of the mold shown in Fig. 50(a). As shown in the cross-section A-A, the front surface (molten steel side) of the refractory member 2 is kept at a high temperature by allowing a high temperature gas heated by the gas burner to flow in the gap 131. As a result, a short-side solidified shell 133 is not produced on the surface of the short-side mold element during casting, and a long-side solidified shell 132 is produced only on the surface of the long-side mold element 3 composed of the water-cooled copper plate 1.

The long-side solidified shell 132 is reduced in the state that any short-side solidified shell 133 is not produced on the surface of the short-side mold element, and it reaches the upper portion 129 of the straight portion. As shown in the cross-section B-B, since the refractory member 2 is not heated at the upper portion 129 of the straight portion and is cooled by the water-cooled copper plate 1, the short-side solidified shell 133 is gradually produced on the front surface (molten metal side). In this case, since the thickness of the refractory member 2 is reduced in the casting direction and the temperature of the front surface (molten metal side) is gradually lowered, the short-side solidified shell 133 is gradually grown. As shown in the cross-section C-C, when reaching the lower portion 130 of the straight portion, the short-side solidified shell 133 is strongly cooled, to be made thick. The short-side solidified shell 133 has, at the lower end of the mold, a sufficient strength to achieve stable casting.

Fig. 51 shows a relationship between a surface temperature of the surface, on a molten metal side, of a straight portion of a short-side mold element and a thickness of a short-side solidified shell, which is obtained by simulation in the case of casting using the above continuous casting apparatus. For comparison, the result of a simulation in the case of using the short-side mold element in which the surface, on the molten steel side, of a straight portion is entirely made of the water-cooled copper plate (disclosed in Japanese Patent Laid-open No. Hei 7-232241) is also shown in Fig. 51. Although the surface, on the molten steel side, of the straight portion of the short-side mold element has a temperature distribution, a temperature at the widthwise central portion is substituted for such a temperature distribution. In this test, a slab having a width of 1,500 mm and a thickness of 40 mm was cast from carbon steel (carbon content: 0.25%) at a casting speed of 4 m/min. With respect to the mold, the entire length of the straight portion was set at 500 mm, and the length of the upper portion 129 (made of a refractory member) of the straight portion of the short-side mold element of the present invention was set at 70 mm. In addition, the surface temperature at the widthwise central portion on the surface, on the molten steel side, of the short-side mold element at the lower end (directly over the RS portion) of the reduction portion was 1520°C.

Figs. 52(a) and 52(b) are vertical sectional views showing production states of the short-side solidified shell 133 in the vicinity of the RS portion; wherein Fig. 52(a) is for the case using the short-side mold element in which the surface, on the molten steel side, of the straight portion is entirely made of a water-cooled copper plate (described in Japanese Patent Laid-open No. Hei 7-232241); and Fig. 52(b) is for the case of using the short-side mold element of the present invention. As shown in Fig. 52(a), in the case of using the short-side mold element in which the surface, on the molten steel side, of the straight portion is entirely made of a water-cooled copper plate, a step between the short-side

refractory member and the water-cooled copper plate is present at the RS portion, and it is taken as a solidification starting point. The surface temperature of the water-cooled copper plate 1 at the RS portion is 420°C, and thereby a temperature difference more than 1000°C exists at the RS portion. The molten steel 4 is rapidly cooled by the water-cooled copper plate 1, and consequently there occur cracks, resulting in the degraded surface quality of a short-side portion of a slab. In addition, when the step at the RS portion increases, the molten steel 4 rounds over a long-side portion of a slab already solidified. The rounding of the molten steel degrades the quality of the slab at corners and on the long-side mold side, and in the worst case, there occurs breakout due to the rounding of the molten steel. For this reason, it is required to machine and set up the short-side mold element in such a manner as to reduce such a step as more as possible.

On the contrary, as shown in Fig. 52(b), in the case of using the short-side mold element of the present invention, the surface temperature of the refractory member at the RS portion is 1155°C and thereby a temperature difference is suppressed to be less than 400°C, to thus prevent rapid cooling. Also, as shown in Figs. 49(a) and 49(b), since the thickness of the refractory member is gradually reduced toward the bottom of the mold, the surface temperature is smoothly dropped at the upper portion 129, made of the refractory member, of the straight portion. As a result, a temperature difference between the upper portion 129 and the lower water-cooled copper plate 130 of the straight portion becomes only about 300°C, and consequently, it is possible to obtain a slab having a short-side portion excellent in surface quality without any crack. Also, since the solidification starting point on the short-side mold element is shifted up to the upper portion 129 of the straight portion which is lower than the RS portion, and a step between the short-side refractory member 2 and the water-cooled copper plate 1 is also shifted up to a portion lower than the upper portion 129. Since the short-side solidified shell 133 is already grown to a thickness of about 0.4 mm at the step portion, it is not required to manage the size of the step at a high accuracy, and it is possible to perfectly prevent rounding of the molten steel. There is only a difference of about 0.8 mm in the thickness of the short-side solidified shell 133 at the end of the straight portion (the lower end of the mold) between in the case of using the short-side mold element in which the surface, on the molten steel side, of the straight portion is entirely made of a water-cooled copper plate and in the case of using the short-side mold element of the present invention. Namely, in both the cases, the short-side solidified shell 133 has a sufficiently large strength to realize high speed casting.

In the short-side mold element used for the thin slab continuously casting apparatus of the present invention, the short-side refractory member is divided into a portion to be heated and a portion not to be heated with respect to the RS portion; however, the

same effect can be obtained if the boundary between the portions to be heated and not to be heated is positioned upwardly or downwardly of the RS portion.

In this embodiment, the mold is made to vertically oscillate at an amplitude of 20 mm or less (preferably, 3 to 15 mm) and at a frequency of from 1 to 40 Hz (preferably 2.5 to 8 Hz). The amplitude and the frequency are particularly dependent on a casting speed, and more specifically, they are made larger with an increasing casting speed. In addition, the casting speed is made larger with a decrease in thickness of a slab. The casting speed becomes a value of from 2.5 to 4.5 m/min for a slab having a thickness of 70 mm; it becomes a value of from 3 to 6.5 mm/min for a slab having a thickness of 50 mm; and it becomes a value of from 4.5 to 8 m/min for a slab having a thickness of 30 mm. The amplitude and the frequency are suitably combined with this casting speed.

In this embodiment, a mold powder is added when molten steel is poured in the mold, and the molten steel is continuously cast in a state in which the mold powder is floated on the molten steel surface. The mold powder has fine particle sizes less than 200 μm (preferably, 5 to 50 μm), and has an effect for keeping the temperature of the molten steel. The mold powder has another effect to react with non-metallic inclusions suspended in the molten steel and to absorb and remove them. The use of a mold powder makes it possible to obtain a high quality slab containing less inclusions. A mold powder in a molten state flows in a gap between a long-side solidified shell and a long-side mold element, and exhibits a resistance against heat release and performs lubrication between the mold and the long-side solidified shell, thus contributing to stable operation as well as improvement in quality. A mold powder contains components functioning as a flux, such as CaO , CaF_2 , SiO_2 , Al_2O_3 and NaCO_3 .

In this embodiment, as shown in Fig. 48, the slab 7 is drawn while being supported by the supporting rolls 6, and at the same time, it is cooled from both sides thereof by a jet of an water-air mixture directly after being discharged from the mold and between a plural rows of the supporting rolls 6. The slab, which is vertically cast, is guided by a plural rows (preferably, 5 to 12 rows) of the supporting rolls 6 in such a manner as to be moved in the horizontal direction. The supporting roll 6 has an internally water-cooled structure and is made from heat-resisting steel.

Figs. 53 and 54 are sectional views showing a continuous casting apparatus in this embodiment. Long-side mold elements 3 and short-side mold elements 140 are contained in a mold outer frame 141. Both sides of the mold outer frame 141 are each supported by oscillating cylinders 142 for vertically oscillating the mold at the above-described amplitude and frequency. The oscillating cylinder 142 mounts an electric-hydraulic servo valve 143. The right and left oscillating cylinders 142 are oscillated synchronously by a synchronization control circuit 145 to which a signal having a desirable

waveform (sine wave, biased sine wave, triangular wave, or the like) is inputted from a high cycle oscillation indicator 146. In addition, reference numeral 144 indicates a balance cylinder, to which a specified pressure is enclosed so as to take a balance of an oscillating weight of the mold and the like by making use of a lower rod of the oscillating cylinder 142. Reference numeral 147 indicates a width changing cylinder.

In the short-side mold element used for the thin slab continuously casting apparatus, the upper portion 129 of a straight portion is made of the same refractory member 2 as that of the reduction portion of the short-side mold element, and is integrated with the reduction portion. However, as shown in Figs. 55(a) and 55(b), the upper portion 129 of the straight portion of the short-side mold element may be composed of a front portion (molten steel side) made from a material 134 having a high conductivity and excellent strength and wear resistance, such as SiC based ceramic or intermetallic compound, and a rear portion made of the same refractory member 2 as that of the reduction portion 2. The above both portions of the upper portion 129 may be laminated to each other. Fig. 55(a) is a front view of the above laminated type short-side mold element thus manufactured, and Fig. 55(b) is a vertical sectional view of the laminated type short-side mold element shown in Fig. 55(a). In comparison with the integral type short-side mold element, the laminated type short-side mold element has a disadvantage in reducing the strength of the laminated portion and in requiring management of a step formed at the laminated portion; however, it is advantageous in that the shape of the water-cooled copper plate 1 disposed for imparting a strength can be simplified as compared with the structure shown in Figs. 49(a) to 49(c). Moreover, since the refractory member 2 has a constant thickness, it is possible to suppress a thermal stress due to a difference in thermal expansion caused by a temperature difference in the thickness direction, and hence to reduce a possibility in breakage of the refractory member 2. Also, since the portion at which there occurs a sliding with the short-side solidified shell is made from the material 134 excellent in wear resistance, it is possible to prolong the service life of the short-side mold element. According to the present invention, by suppressing a temperature change on the front surface portion, on the molten steel side, of the short-side mold element and specifying the solidification starting point of the short-side solidified shell at a position different from the step, it is possible to obtain a slab having a high surface quality. Accordingly, in the case of using the laminated type short-side mold element, it is desirable to reduce a temperature change at the front surface portion, on the molten steel side, of the short-side mold element by bringing the front surface portion, on the molten steel side, of the short-side mold element with the water-cooled copper plate 1 without provision of any heating means, as shown in Figs. 55(a) and 55(b). Also, as shown in Figs. 55(a) and 55(b), it is desirable that the upper portion to be heated,

of the straight portion, is simultaneously heated together with the reduction portion. With this structure, it is possible to simplify the shape of the short-side mold element and to make easy manufacture of the short-side mold element, and hence to reduce the manufacturing cost.

Fig. 56 is a schematic view of a twin-belt type continuous casting apparatus to which the present invention is applied. A belt 135 moving in synchronization with a slab is used as a long-side mold element, and a fixed plate is used as a short-side mold element.

Fig. 57 is a schematic view of a twin-roll type continuous casting apparatus to which the present invention is applied. A roll 138 moving in synchronization with a slab is used as a long-side mold element, and a fixed plate is used as a short-side mold element. The above two apparatuses are common to each other in that the width of the short-side mold element is gradually narrowed in the casting direction from the molten metal surface. Such an apparatus may adopt each of the short-side mold elements shown in Figs. 49(a) to 49(c) or Fig. 55 in which the reduction portion and the upper portion of the straight portion are made of a refractory member and the lower portion of the straight portion is made of a water-cooled copper plate, and also a heating means is provided for only a portion including the reduction portion. This is effective to improve the surface quality of a slab and prevent rounding of molten steel at the step portion of the short-side mold element, and hence to cast a high quality slab at a high speed.

As described above, according to the apparatus and process for continuously producing a thin slab, which is of a reduction type in which reduction is performed in a state in which solidification is suppressed on a short-side mold element side, there can be obtained excellent effects of producing such a short-side solidified shell as to increase a surface quality of a short-side portion of a slab and to exhibit a strength sufficient for high speed casting, preventing rounding of molten metal at a step portion of the short-side mold element, and reducing a manufacturing cost of the short-side mold element and significantly shortening a set-up time required for setting the mold. The apparatus and process of the present invention can be applied to other apparatuses and processes of not reduction type, so long as a long-side mold element or a short-side mold element is made of a plurality of materials.

The apparatus and process of the present invention are effective to improve production of a solidified shell for suppressing occurrence of breakout, and hence to perform stable casting for a long-period of time.

Claims

1. In a continuous casting apparatus for continuously producing a slab (5) by continuously supplying molten metal (4) in a space of a mold including opposed long side mold elements (2) and opposed short-side mold elements (1) and continuously

drawing a shell solidified in the mold,
the improvement wherein

said short-side mold element (1) has in a back surface portion a passage (13) allowing a high temperature gas to pass therethrough, said passage (13) being formed in such shape that the width is widened at its upper portion and is narrowed at its lower portion; and
said short-side mold element (1) has a high temperature gas supply means (12) for supplying the high temperature gas into said passage (13) from top to bottom of said short-side mold element (1).

2. In a continuous casting apparatus for continuously producing a slab (5) by continuously supplying molten metal (4) in a space of a mold including opposed long-side mold elements (2) and opposed short-side mold elements (7, 8) and continuously drawing a shell solidified in the mold,
the improvement wherein

said short-side mold element (7, 8) has in a back surface portion a passage (13) allowing a high temperature gas to pass therethrough; and
said short-side mold element (7, 8) has a plurality of high temperature gas supply means (16) arranged in the casting direction.

3. A continuous casting apparatus according to claim 1 or 2, wherein said high temperature gas supply means (12; 16) includes a means for burning a mixed gas of a combustible gas and air.
4. A continuous casting apparatus according to any of claims 1 to 3, wherein said short-side mold element (1; 7, 8) is made of a material satisfying the following relationship:

$$\lambda/\delta \leq 0.02 \text{ (cal/cm}^2 \times \text{sec} \times ^\circ\text{C)}$$

where λ is a thermal conductivity and δ is a thickness of the material.

5. A continuous casting apparatus according to any of claims 1 to 4, further including a short-side mold element (1; 7, 8) temperature control means (15) for controlling a temperature or flow rate of the high temperature gas such that a temperature T of said short-side mold element (1; 7, 8) satisfies the following equation:

$$0.7 \times TL < T \leq TL \text{ (}^\circ\text{C)}$$

where TL is a liquidus temperature.

6. A continuous casting apparatus according to any of

claims 1 to 5, wherein said passage (13) allowing a high temperature gas to pass therethrough is divided into a plurality of parts in the casting direction, and each of said divided parts of said passage (13) includes said high temperature gas supply means (12) and a discharge port (11) for discharging the high temperature gas.

7. A continuous casting apparatus according to any of claims 1 to 6, further including a temperature distribution detecting means (15) for detecting a temperature distribution of said short-side mold element (1; 2), and a control means for controlling a temperature or flow rate of the high temperature gas on the basis of a value detected by said temperature distribution detecting means (15) in such a manner that a desirable temperature distribution is obtained.

8. In a continuous casting apparatus for continuously producing a slab (5) by continuously supplying molten metal (4) in a space of a mold including opposed longside mold elements (2) and opposed short-side mold elements (1) and continuously drawing a shell solidified in the mold, wherein a level of a molten metal pool (4) is kept constant and a mold powder is floated on the molten metal pool (4),
the improvement wherein

a portion (7) of the short-side mold element (1), in which at least a mold powder, molten metal and a solidified shell coexist, is made from a material mainly containing zirconium diboride (ZrB_2).

9. A continuous casting apparatus according to claim 8, wherein said short-side mold element (1) is formed in such an approximately fan-shape that the width is widened at its upper portion and is narrowed at its lower portion.

10. A continuous casting apparatus according to claim 8 or 9, wherein said short-side mold element (1) is divided into an upper reduction portion (7) and a lower straight portion (8), and said upper reduction portion (7) is formed in an approximately fan-shape and made from a material mainly containing ZrB_2 , and said lower straight portion (8) is formed in a shape with a constant width and made of a copper alloy plate having an internally water-cooled structure.

11. In a continuous casting apparatus for continuously producing a slab (69) by continuously supplying molten metal (5) in a space of a mold (1) including opposed longside mold elements (3) and short-side mold elements (2) and continuously drawing a shell (76) solidified in the mold (1),
the improvement wherein

said short-side mold element (2) has a reduction portion (7) made of a refractory member (70), said reduction portion (7) being formed in a shape that the width is gradually narrowed in the casting direction from the upper surface of the molten metal (5);

said short-side mold element (1) has a heating means (72) for heating said short-side mold element (2) in such a manner that the molten metal (5) is not solidified on the surface of said short-side mold element (2);

said short-side mold element (2) has a cooling metal plate (73) constituting a parallel portion positioned under said reduction portion of said short-side mold element (2);

said short-side mold element (2) has a heat-resisting metal member (74) including a frame (74a) disposed at a contact portion between said reduction portion of said refractory member (70) and said long-side mold element (3), and a back surface portion (74b) connected to said frame (74a) on an anti-molten metal side of said refractory member (70); and

said short-side mold element (2) has a thermal insulating member (71) disposed between said anti-molten metal side of said refractory member (70) and said back surface portion (74b).

12. A continuous casting apparatus according to claim 11, wherein said frame (74a) has a thickness allowing said frame to be elastically deformed in accordance with the shape of said reduction portion of said short-side mold element (2) and thermal deformation of said short-side mold element (2).

13. A continuous casting apparatus according to claim 11 or 12, wherein said frame (74a) and said back surface portion (74b) are provided separately from each other, and they are fastened to each other by means of a fastening member (91).

14. A continuous casting apparatus according to claim 11, wherein said cooling metal plate (73) has a cooling mechanism for cooling only said cooling metal plate (73) and not cooling said heat-resisting metal member (74).

15. A continuous casting apparatus according to claim 11, wherein said cooling metal plate (73) is provided separately from said heat-resisting metal member (74).

16. A continuous casting apparatus according to claim 11, wherein said short-side mold element (2) is movable in the width direction of the slab (69) at an arbitrary time during casting or not during casting.

17. A continuous casting apparatus according to any one of claims 1 to 6, wherein a seal member (78) is

provided between said short-side mold element (2, 2A) and said long-side mold element (3).

18. A continuous casting apparatus according to claim 17, wherein said seal member (78) provided between said reduction portion of said short-side mold element (2, 2A) and said long-side mold element (3) is made from a metal material, and said seal member (78) provided between said cooling metal plate (73) and said long-side mold element (3) is made from a non-metal material.

19. A continuous casting apparatus according to claim 17, wherein said seal member (78) provided between said reduction portion of said short-side mold element (2, 2A) and said long-side mold element (3) is made from a high temperature material, and said seal member (78) provided between said cooling metal plate (73) and said long-side mold element (3) is made from a low temperature material.

20. A continuous casting apparatus according to claim 11, wherein said long-side mold element (3) is a fixed type long-side mold element made from a metal having a high thermal conductivity.

21. A continuous casting apparatus according to any one of claims 11 to 19, wherein said long-side mold elements are a pair of movable belts (84a) circulating while keeping a gap corresponding to said reduction portion of said short-side mold element (81).

22. A continuous casting apparatus according to any one of claims 11 to 19, wherein said long-side mold elements are a pair of movable rolls (84b) rotating while keeping a gap corresponding to said reduction portion of said short-side mold element (81).

23. In a continuous casting apparatus for continuously producing a slab (5) by continuously supplying molten metal (4) in a space of a mold including opposed shortside mold elements (1) and opposed long-side mold elements (2) and continuously drawing a shell solidified in the mold, wherein said short-side mold element (1) is formed in such an approximately fan-shape that the width is widened at its upper portion and is narrowed at its lower portion,

the improvement wherein

part (29) of a dummy bar head (28) used at the time of starting of casting projects along the curve of said approximately fan-shape of said short-side mold element (1).

24. In a continuous casting apparatus having a mold including opposed long-side mold elements (2) and

opposed short-side mold elements (1),
the improvement wherein

each of said long-side mold elements (2) and
said short-side mold elements (1) has a means
for adjusting its temperature;
said short-side mold element (1) includes an
upper reduction portion (7) having a width
gradually narrowed from top to bottom and a
lower side parallel portion (8); and
said reduction portion (7) has a means for cool-
ing the vicinity of each corner portion between
said long-side mold element (2) and said short-
side mold element (1);

wherein a solidified shell is produced only at
the corner portion at said reduction portion (7) and
a solidified shell is produced over the entire surface
at said parallel portion (8), the solidified shell pro-
duced at the corner portion at said reduction por-
tion (7) being continuous to the solidified shell
produced at said parallel portion (8).

25. In a continuous casting apparatus for continuously
producing a slab (5) by continuously supplying mol-
ten metal (4) in a space of a mold having opposed
long-side mold elements (2) and opposed short-
side mold elements (1) and continuously drawing a
shell solidified in said mold, wherein said short-side
mold element (1) has a width gradually narrowed in
the casting direction from the molten metal surface
and a heating means (72) is provided for heating
said short-side mold elements (1), whereby the
reduction is completed in a state in which molten
metal is not solidified on the surface of said short-
side mold element (1),
the improvement wherein

a means for cooling the vicinity of each corner
portion between said long-side mold element
(2) and said shortside mold element (1) is pro-
vided so that a solidified shell produced on the
surface of said long-side mold element (2) is
continuously formed at the corner portion
between said long-side mold element (2) and
said short-side mold element (1).

26. A continuous casting apparatus according to claim
24 or 25, wherein a portion in the vicinity of the con-
tact portion between said reduction portion (7) of
said short-side mold element (1) and said long-side
mold element (2) is more intensely cooled than a
molten metal contact portion of said short-side
mold element (1) is cooled, from the side of said
long-side mold element (2).
27. A continuous casting apparatus according to claim
24 or 25, wherein a portion in the vicinity of the con-
tact portion between said reduction portion (7) of

said short-side mold element (1) and said long-side
mold element (2) is cooled from the side, opposed
to molten metal (4), of said short-side mold element
(1) and from said long-side mold element (2) side.

28. A continuous casting apparatus according to any of
claims 24 to 27, wherein said upper reduction por-
tion (7) of said short-side mold element (1) is made
of a refractory member and said lower side parallel
portion (8) of said short-side mold element (1) is
made from a metal material.
29. A continuous casting machine according to any of
claims 24 to 28, wherein said short-side mold ele-
ment (1) is movable along said long-side mold ele-
ment (2) at an arbitrary time during casting or not
during casting.
30. A continuous casting apparatus according to any of
claims 24 to 29, wherein a seal member (78) is pro-
vided at a contact portion between said short-side
mold element (1) and said long-side mold element
(2) for making movable said short-side mold ele-
ment (1) along said long-side mold element (2) at
an arbitrary time during casting or not during cast-
ing.
31. A continuous casting apparatus according to any of
claims 24 to 30, wherein a seal member (78) is pro-
vided at a contact portion between said short-side
mold element (1) and said long-side mold element
(2) in a state being mounted on said short-side
mold element (1), for making movable said short-
side mold element (1) along said long-side mold
element (2) at an arbitrary time during casting or
not during casting.
32. A continuous casting apparatus according to claim
30 or 31, wherein said seal member (78) is made of
a metal seal material such as copper or a copper
alloy, which is used for said upper reduction portion
(7) of said short-side mold element (1), while said
seal member (78) is made of a non-metal seal
material such as teflon, which is used for a lower
side metal plate portion (8) of said short-side mold
element (1).
33. A continuous casting apparatus according to claim
30 or 31, wherein said seal member (78) is made of
a high temperature seal material such as fine
ceramics, which is used for said upper reduction
portion (7) of said short-side mold element (1),
while said seal member (78) is made of a non-metal
seal material such as teflon, which is used for a
lower side metal plate portion (8) of said short-side
mold element (1).
34. A continuous casting apparatus according to any of
claims 24 to 33, wherein said long-side mold ele-

ment (2) is formed of a fixed type metal mold element made from copper or a copper alloy.

35. A continuous casting apparatus according to any of claims 24 to 34, wherein said long-side mold elements (2) are formed of a pair of opposed movable belts (84a) circulating while keeping a gap therebetween over a specified distance for holding molten steel. 5
36. A continuous casting apparatus according to any of claims 24 to 34, wherein said long-side mold elements are formed of a pair of opposed movable rolls (84b) rotating while keeping a gap therebetween over a specified distance for holding molten steel. 10
37. In a continuous casting apparatus for continuously producing a slab (5) by continuously supplying molten metal (4) in a space of a mold including opposed longside mold elements (2) and opposed short-side mold elements (1) and continuously drawing a shell solidified in the mold, the improvement wherein 20

said short-side mold element (1) is made of a refractory member divided into a plurality of parts in the casting direction. 25
38. A continuous casting apparatus according to claim 37, wherein the material of said short-side mold element (1) mainly contains ZrB_2 . 30
39. A continuous casting apparatus according to claim 37 or 38, wherein said short-side mold element (1) is of a reduction type in which the width is widened at an upper portion and is gradually narrowed in the casting direction. 35
40. A continuous casting apparatus according to any of claims 37 to 39, wherein an upper portion (7) of said short-side mold element (1) is formed in a reduction shape in which the width is narrowed in the casting direction and is made of a refractory member divided into a plurality of CO parts, and a lower portion (8) of said short-side mold element (1) has a constant width and is made of a copper alloy plate having an internally water-cooled structure. 40 45
41. A continuous casting apparatus according to any of claims 37 to 40, wherein a lowermost piece of a plurality of said refractory member parts of said short-side mold element (1) is used for a width constant portion (8) positioned under said reduction portion (7). 50 55
42. A continuous casting apparatus according to any of claims 37 to 41, wherein said upper reduction portion (7) of said refractory member of said short-side

mold element (1) has a heating means.

43. A continuous casting apparatus according to any of claims 37 to 42, wherein said lowermost piece of said refractory member parts of said short-side mold element (1) has a cooling means on a side opposed to the molten metal (4). 5
44. A continuous casting apparatus according to any of claims 37 to 43, wherein said short-side mold element (1) has a means (15) for measuring a temperature of said refractory member (7) of said short-side mold element (1). 10
45. A continuous casting apparatus according to any of claims 37 to 44, wherein said mold includes an oscillation applying means for oscillating said mold. 15
46. A continuous casting apparatus according to any of claims 37 to 45, wherein said short-side mold element (1) is movable in the width direction of a slab at an arbitrary time during casting or not casting. 20
47. A continuous casting apparatus according to any of claims 37 to 46, wherein a metal frame (74a) is provided at each edge, being in contact with said long-side mold element (2), of said refractory member (7) of said short-side mold element (1). 25
48. A continuous casting apparatus according to any of claims 37 to 46, wherein said long-side mold elements are formed of a pair of belts (84a) circulating while keeping a gap corresponding to said reduction portion (7) of said short-side mold element (1). 30
49. A continuous casting apparatus according to any one of claims 37 to 46, wherein said long-side mold elements are formed of a pair of movable rolls (84b) circulating while keeping a gap corresponding to said reduction portion of said short-side mold element (1). 35
50. In a continuous casting process for continuously producing a slab (5) by continuously supplying molten metal (4) in a space of a mold including opposed longside mold elements (2) and opposed short-side mold elements (1) and continuously drawing a shell solidified in the mold, the improvement wherein 40 45

a high temperature gas is supplied, from top to bottom of said short-side mold element (1), into a passage (13) provided in a back surface portion of said short-side mold element (1) for allowing a high temperature gas to pass there-through.
51. In a continuous casting process for continuously producing a slab (5) by continuously supplying mol-

ten metal (4) in a space of a mold including opposed long-side mold elements (2) and opposed short-side mold elements (1) and continuously drawing a shell solidified in the mold,

the improvement wherein

5

a passage (13) allowing a high temperature gas to pass therethrough is provided in a back surface portion of said short-side mold element (1); and
said high temperature gas is supplied in said passage (13) independently through a plurality of positions (16) arranged in a casting direction.

10

52. A continuous casting process according to claim 50 or 51, wherein said high temperature gas is obtained by burning a mixed gas of a combustible gas and air.

15

53. A continuous casting process according to any of claims 50 to 52, wherein a temperature or flow rate of said high temperature gas is controlled such that a temperature T of said short-side mold element satisfies the following equation:

20

$$0.7 \times TL < T \leq TL \text{ (}^{\circ}\text{C)}$$

25

where TL is a liquidus temperature.

30

54. In a continuous casting process using a continuous casting apparatus having a mold including opposed long-side mold elements (2) and opposed short-side mold elements (1),
the improvement wherein

35

said short-side mold element (1) includes an upper reduction portion (7) and a lower side parallel portion (8);

said reduction portion (7) has a width gradually narrowed from top to bottom and said parallel portion (8) has a substantially uniform width; and

40

both ends in the width direction of said short-side mold element (1) are adjusted at temperatures not more than a shell forming temperature.

45

55. In a continuous casting process using a continuous casting apparatus having a mold including opposed long-side mold elements (2) and opposed short-side mold elements (1),
the improvement wherein

50

said short-side mold element (1) includes an upper reduction portion (7) and a lower side parallel portion (8);

55

said reduction portion (7) has a width gradually narrowed from top to bottom and said parallel

portion (8) has a substantially uniform width; and

said reduction portion of said short-side mold element (1) is adjusted in temperature so as to have such a temperature distribution in the width direction that a center portion in the width direction of said short-side mold element (1) is set at a temperature more than a shell forming temperature and both ends in the width direction of said short-side mold element (1) are set at temperatures not more than the shell forming temperature.

56. In a continuous casting apparatus of a reduction type in which a mold is composed of long-side mold elements (2) and short-side mold elements (1), each short-side mold element (1) includes a reduction portion (7) widened at its upper portion and narrowed at its lower portion and a straight portion (8), so that reduction is performed in a state that solidification is suppressed on a short-side mold element side,

the improvement wherein

a surface portion, on a molten metal side, of an upper portion of said straight portion (8) is made of a member other than a water-cooled metal member; and

a surface portion, on a molten metal side, of a lower portion of said straight portion (8) is made of a watercooled metal member.

FIG. 1

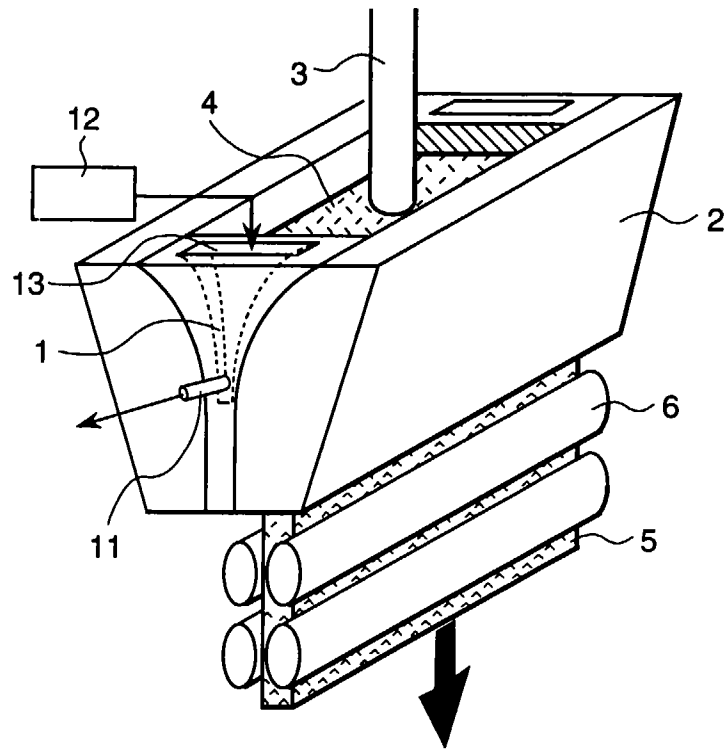


FIG. 2

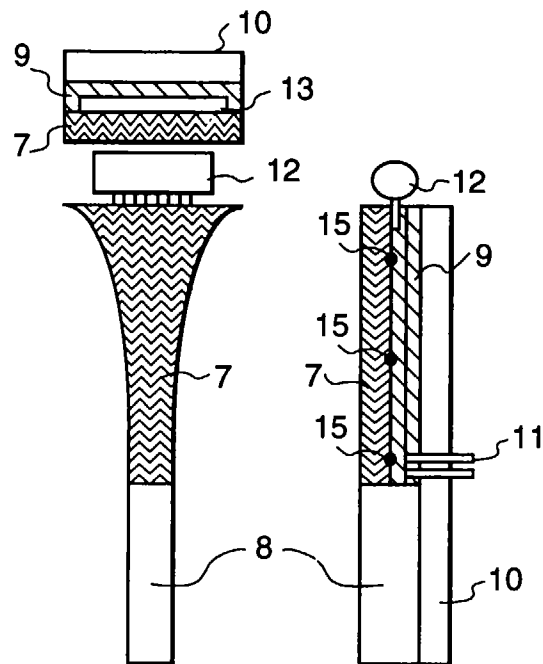


FIG.3

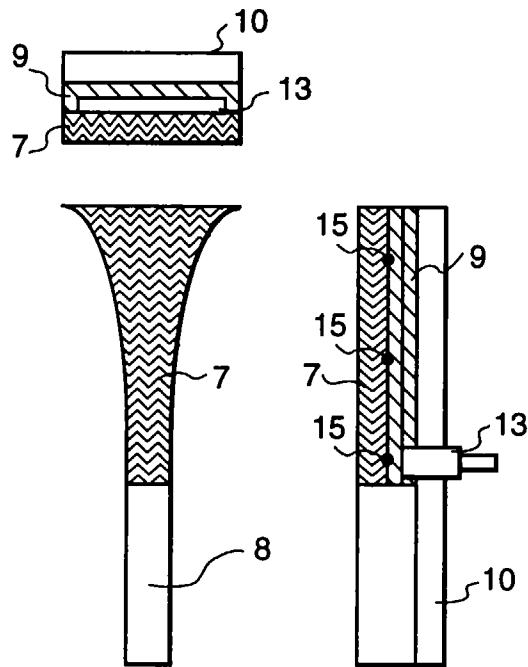


FIG.4

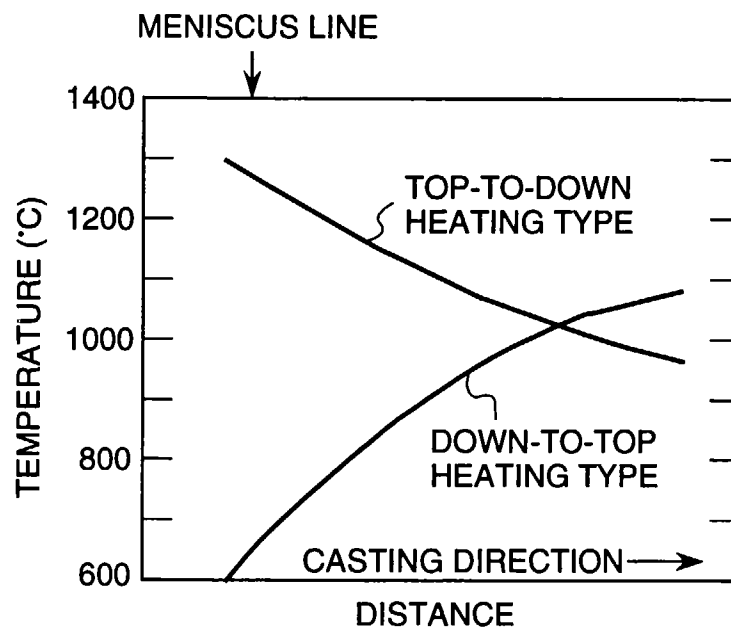


FIG.5

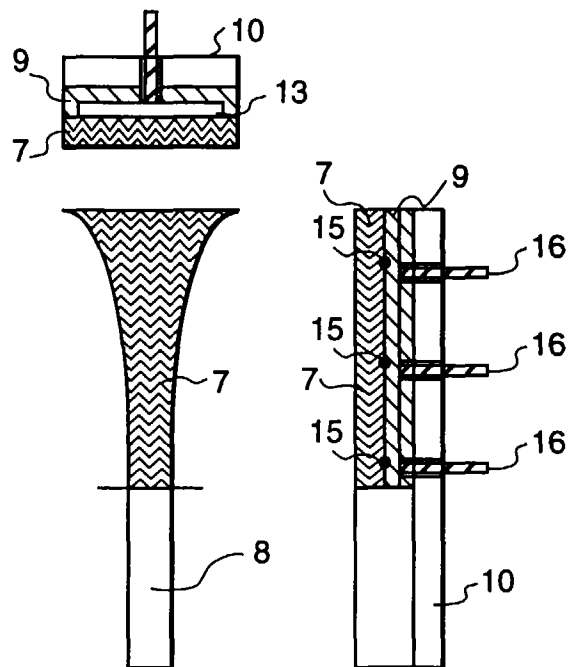


FIG.6

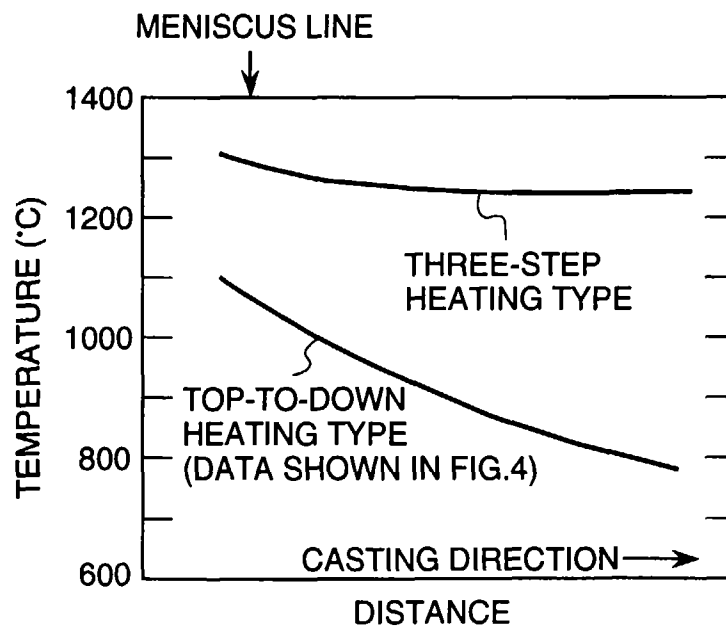


FIG.7

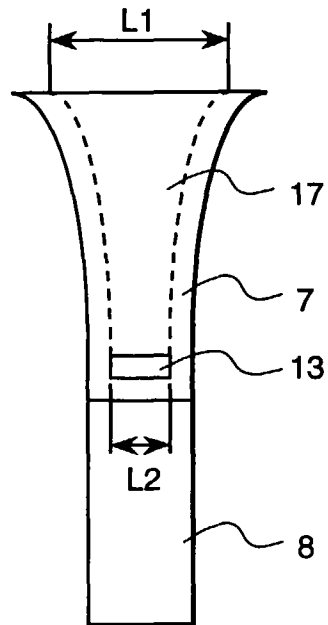


FIG.8

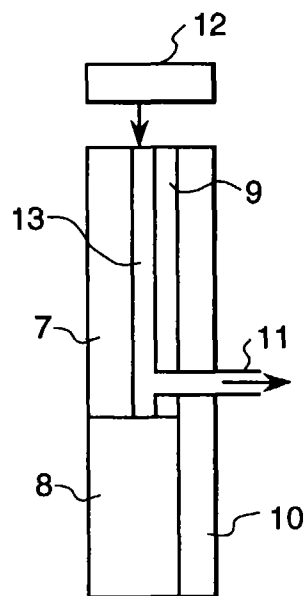


FIG.9

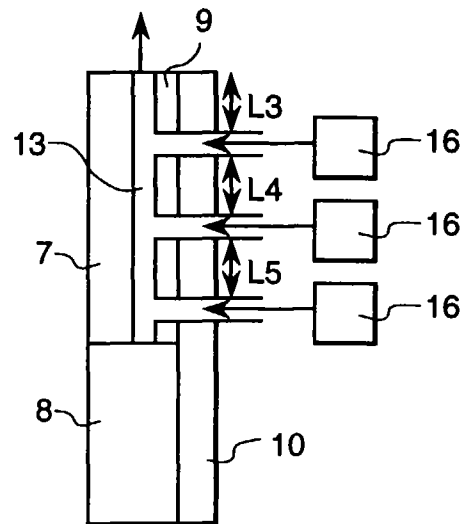


FIG.10

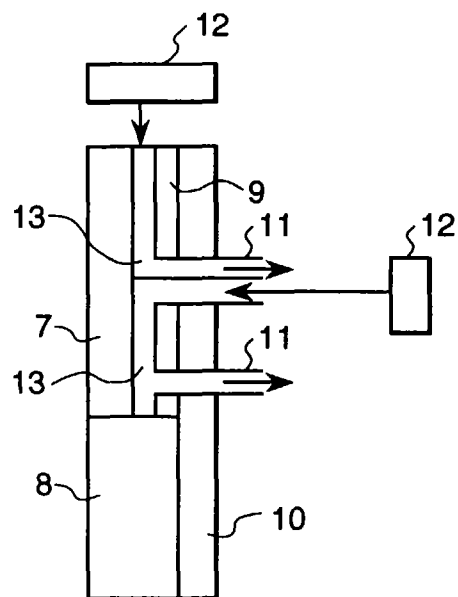


FIG. 11

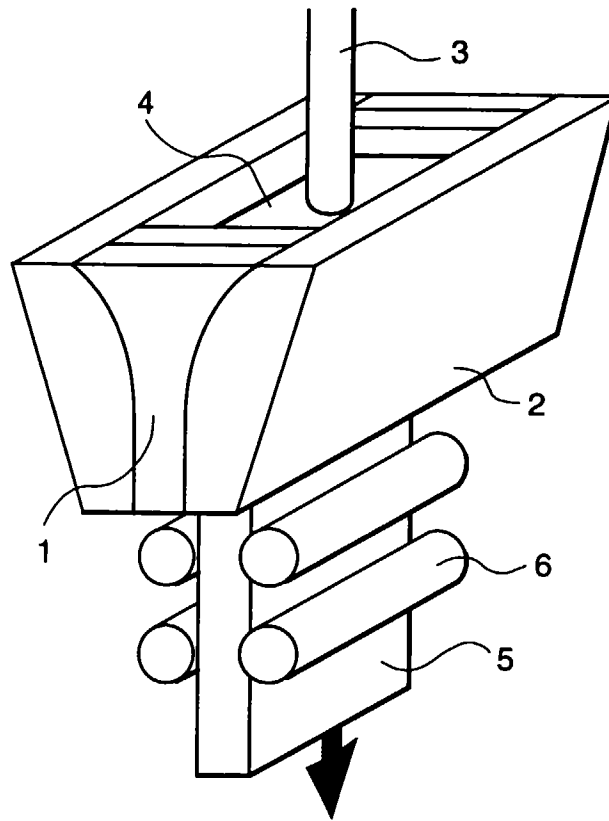


FIG. 12

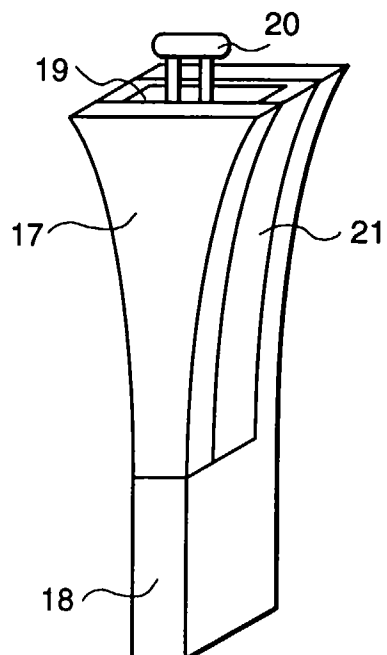


FIG. 13

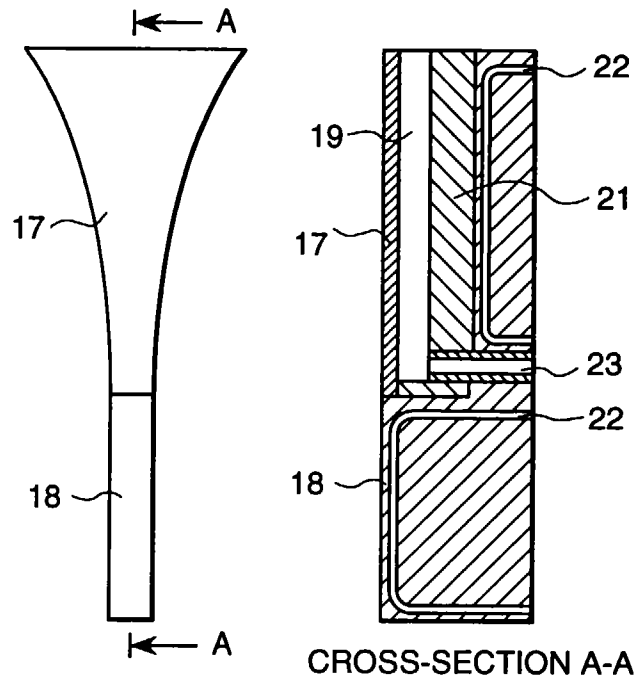


FIG. 14

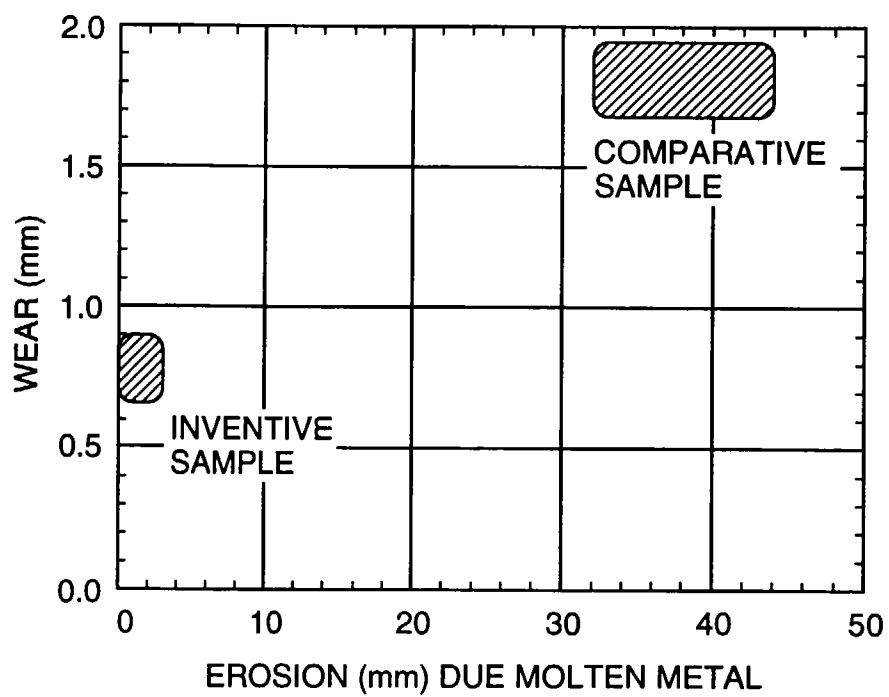


FIG. 15

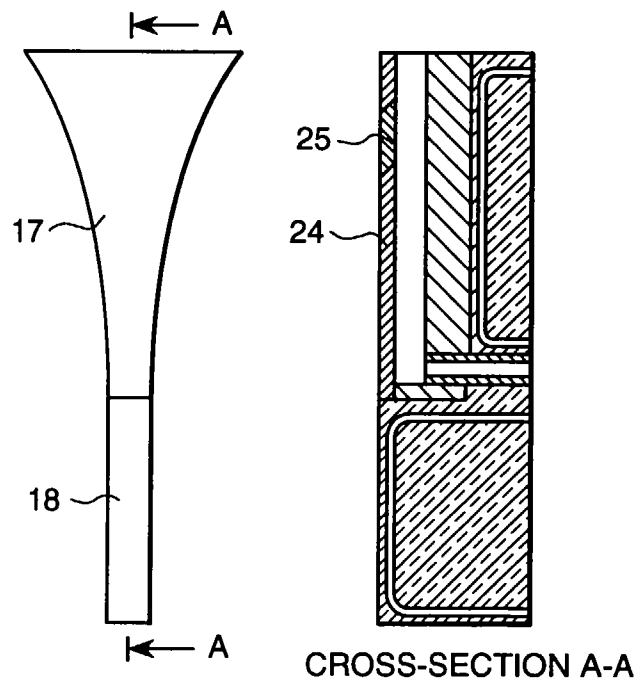


FIG. 16

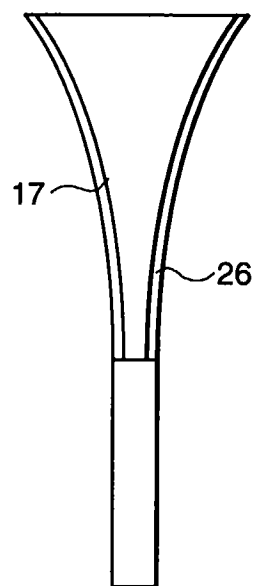


FIG.17

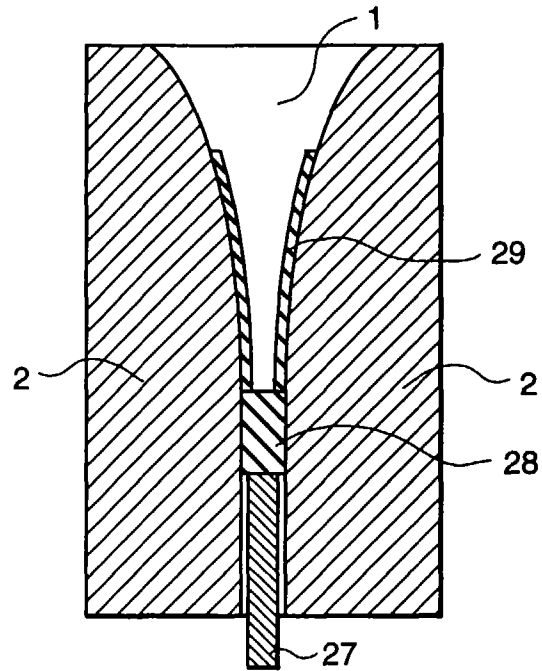


FIG.18

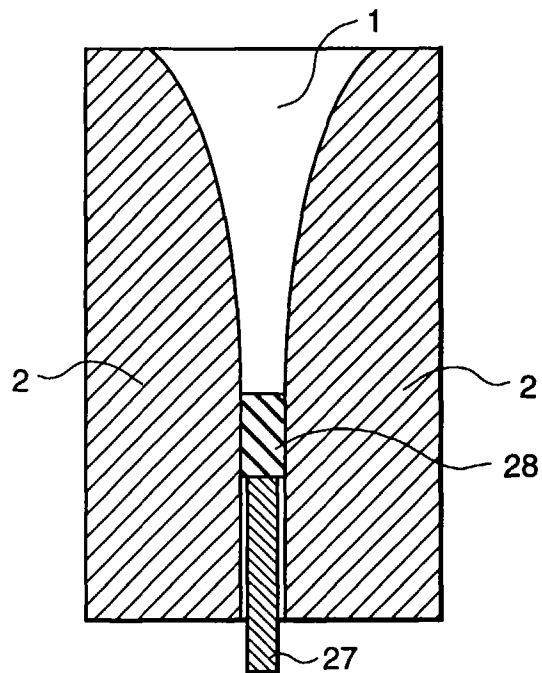


FIG. 19

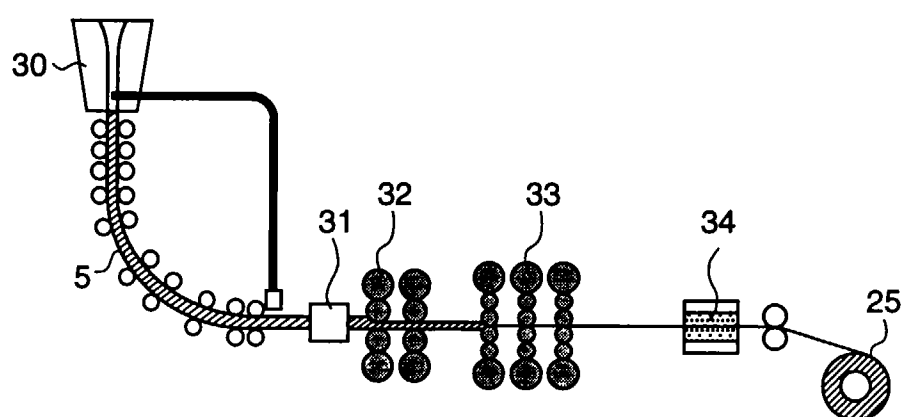


FIG.20

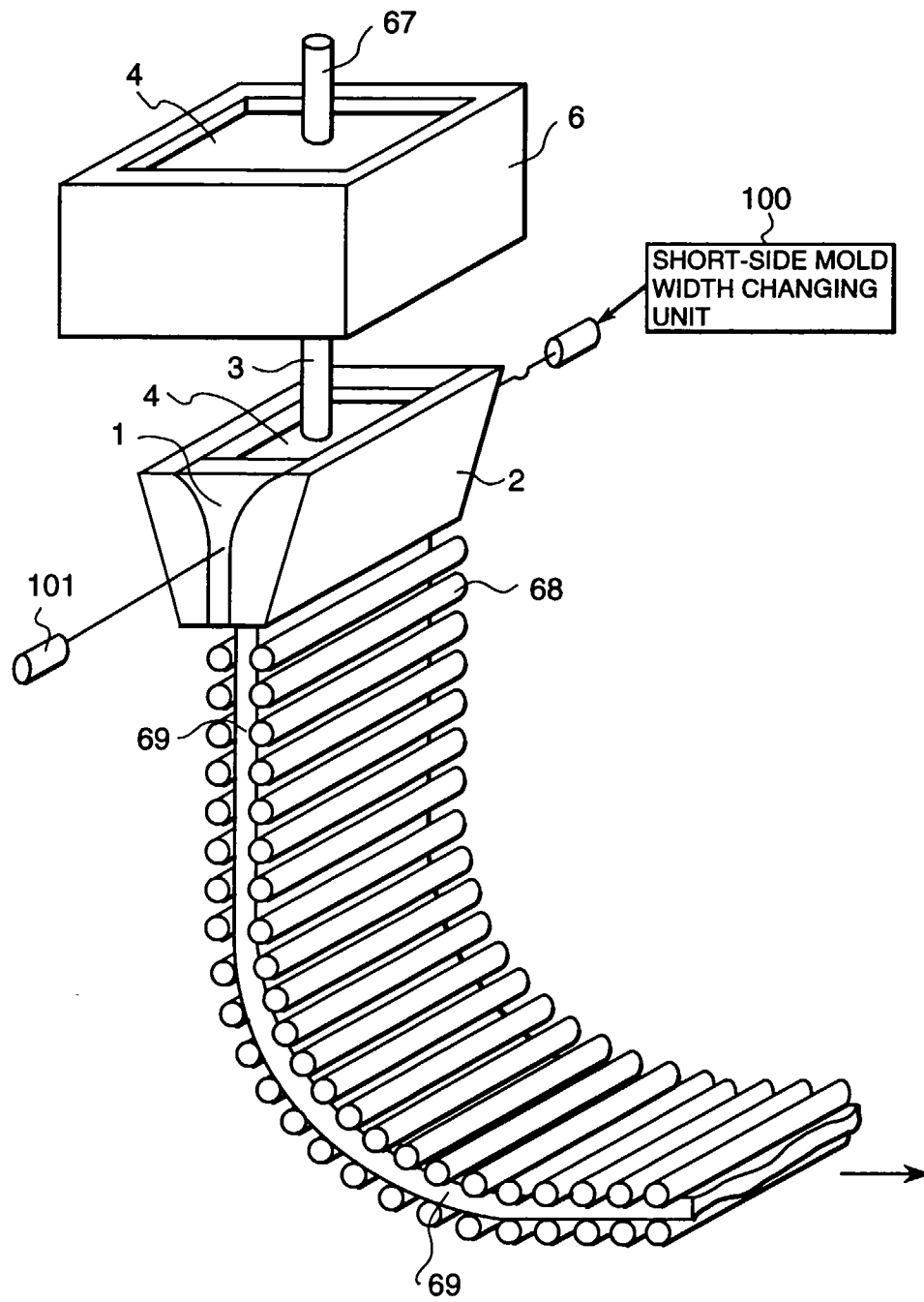


FIG.21A

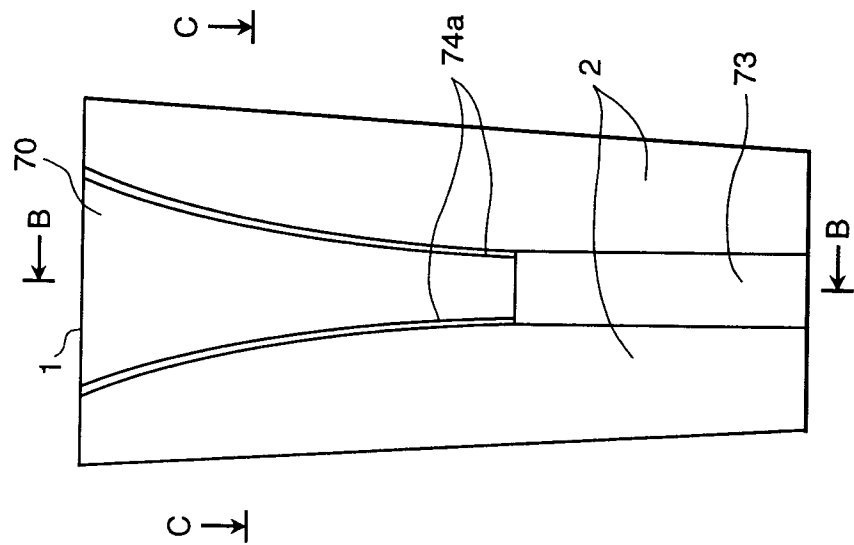


FIG.21B

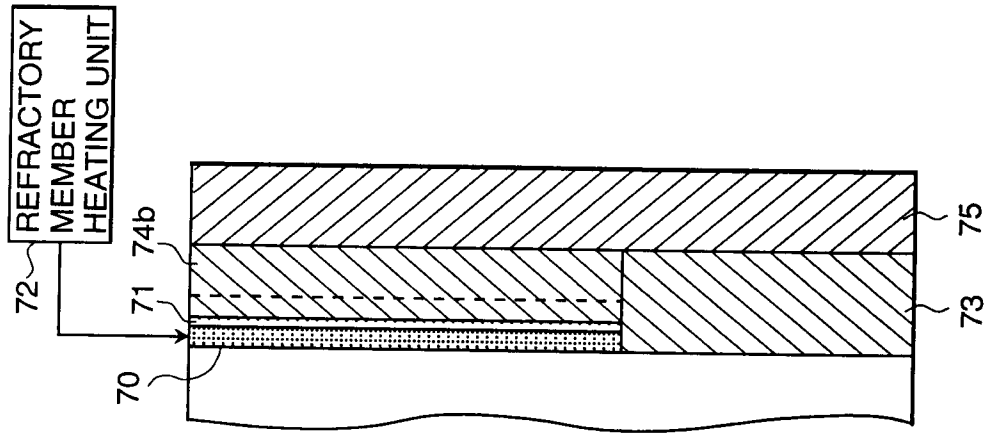


FIG.21C

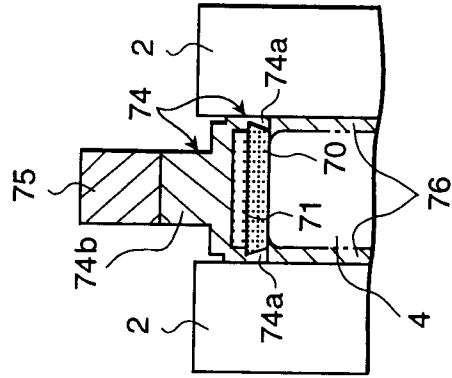


FIG.22A

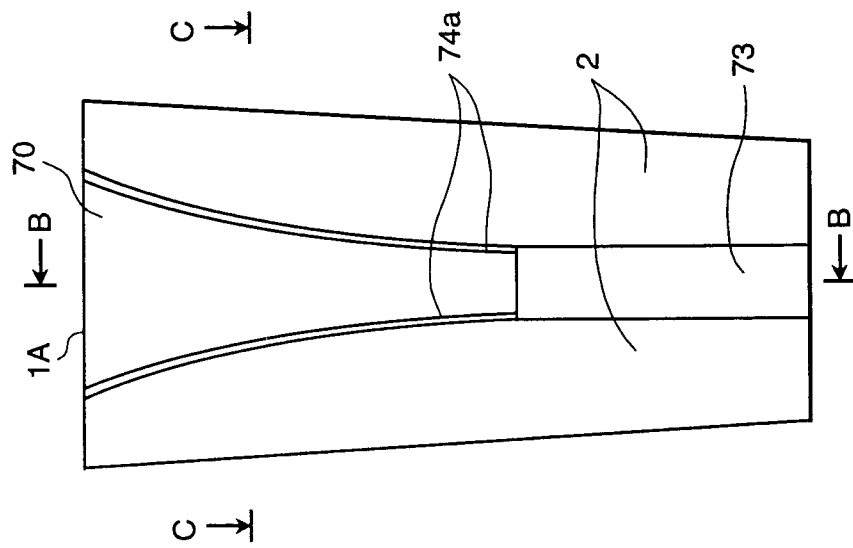


FIG.22B

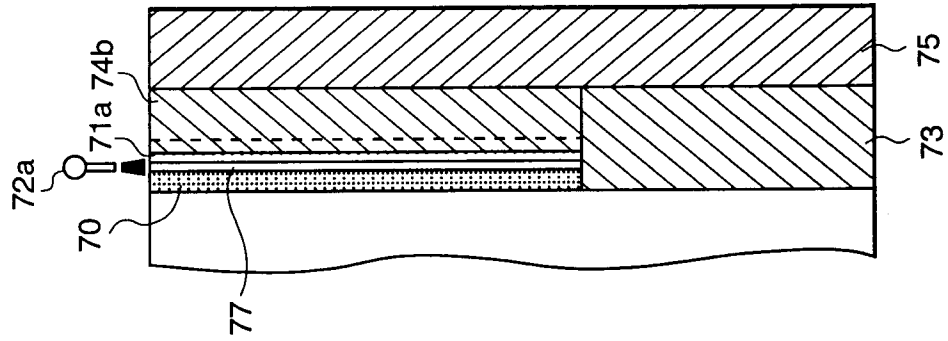


FIG.22C

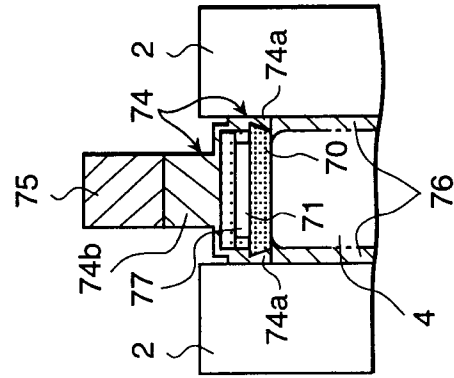


FIG.23A

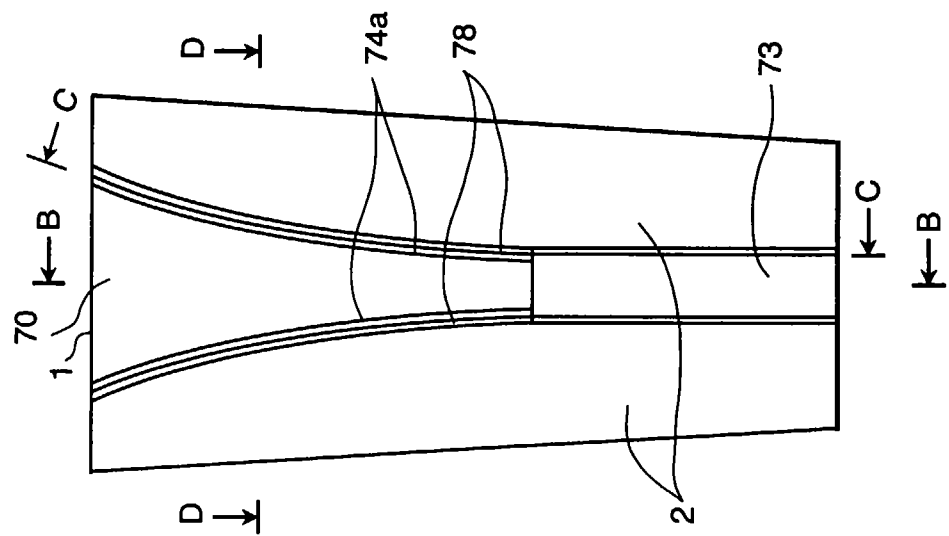


FIG.23B

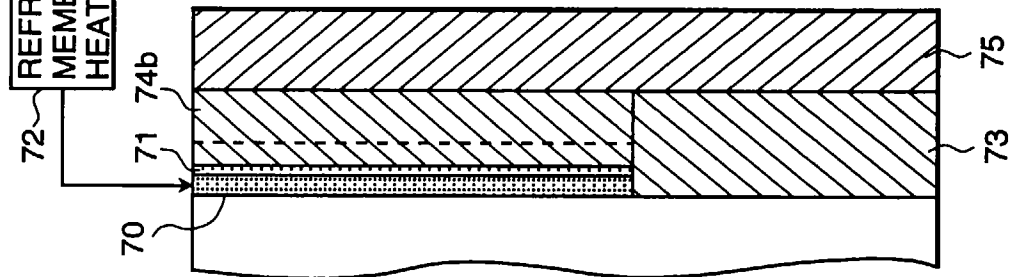


FIG.23C

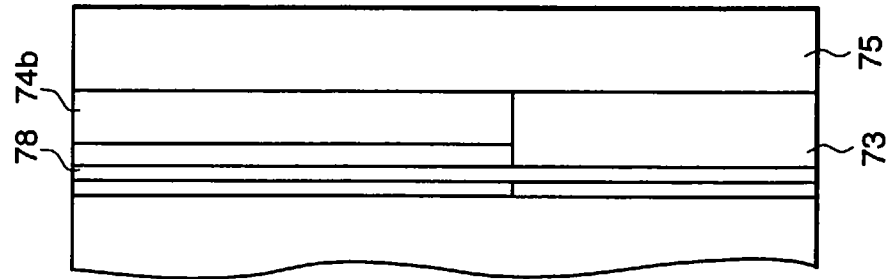


FIG.23D

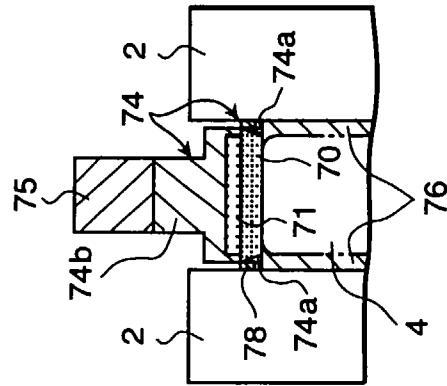


FIG.24A

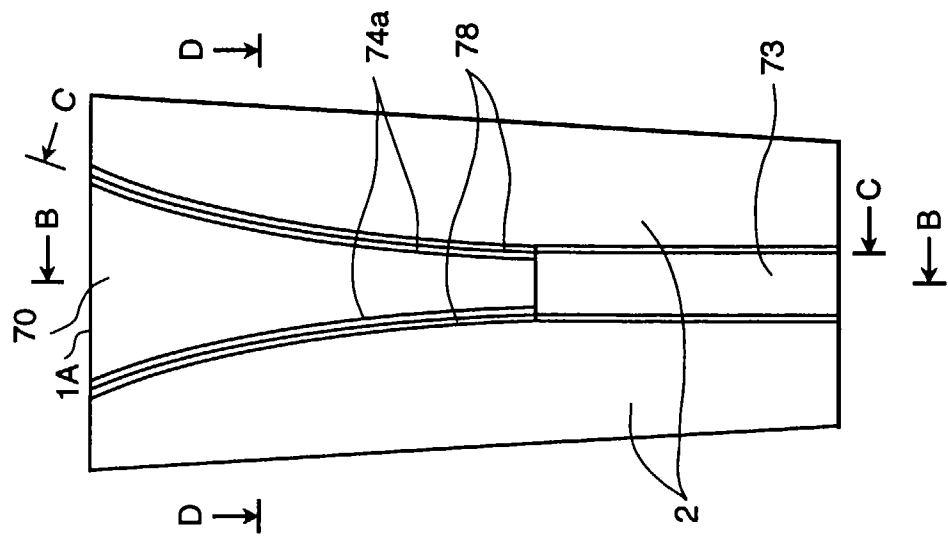


FIG.24B

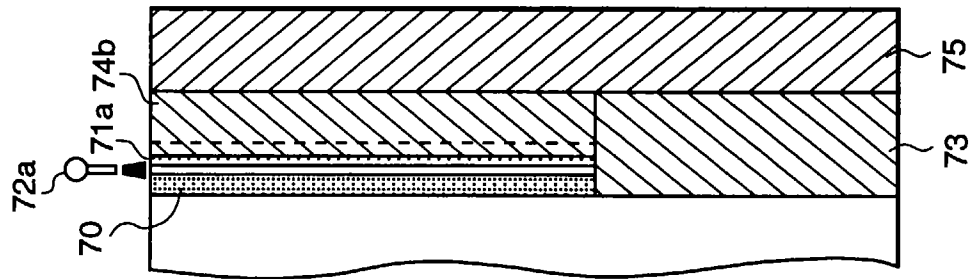


FIG.24C

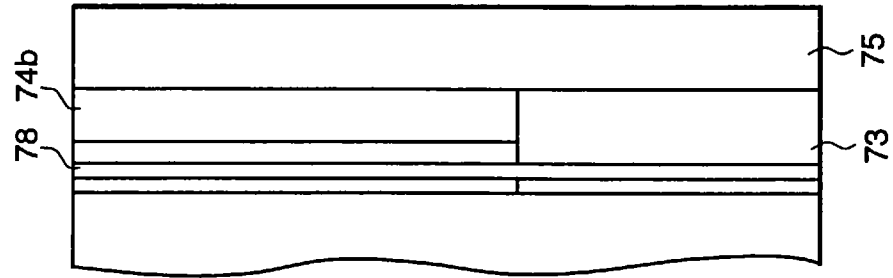


FIG.24D

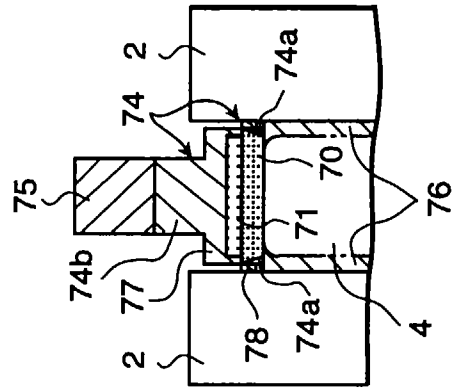


FIG.25A

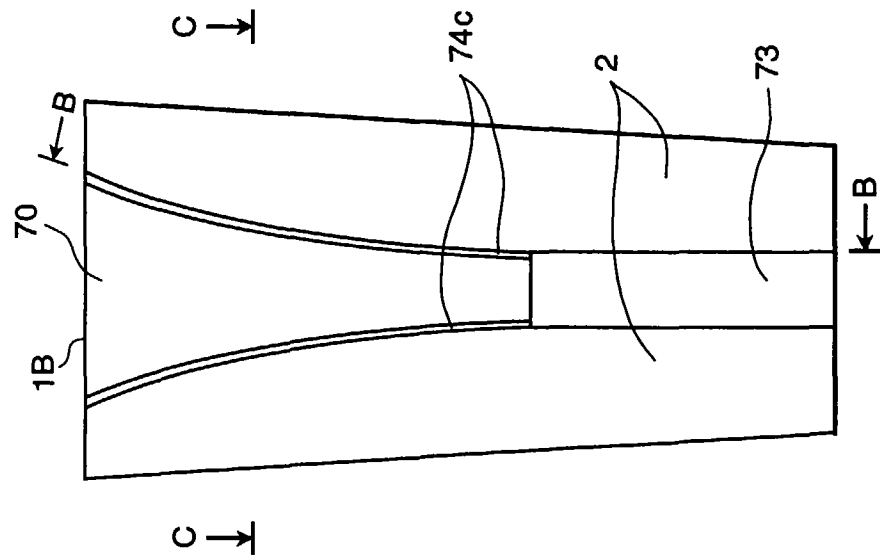


FIG.25B

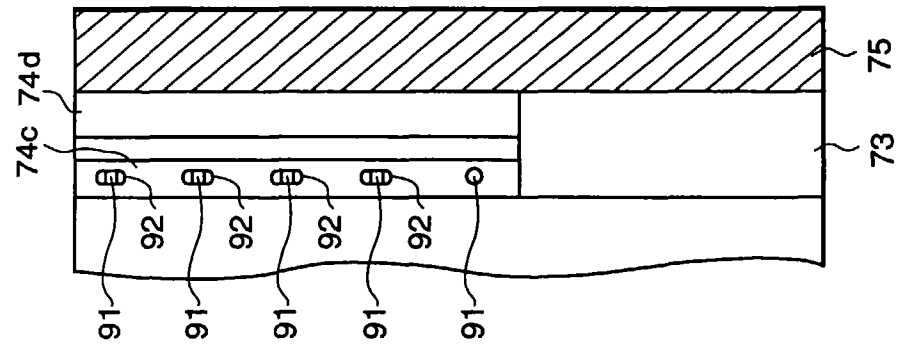


FIG.25C

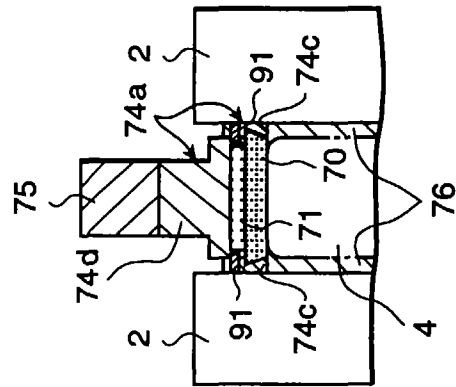


FIG.26

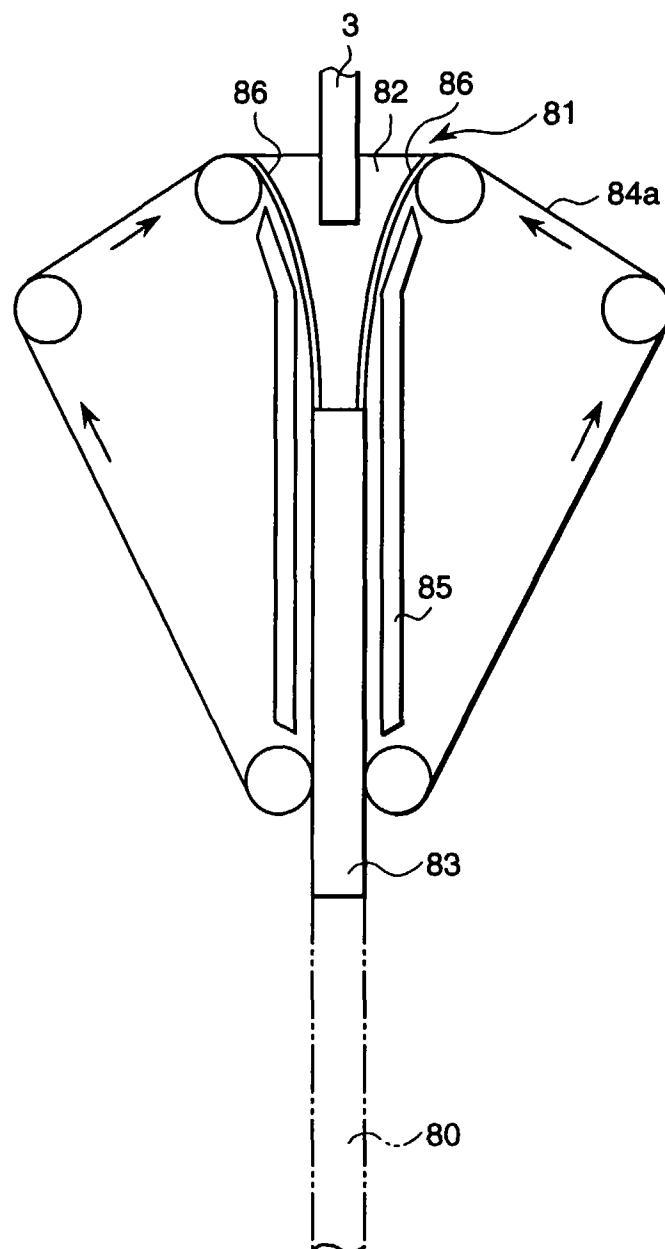


FIG.27

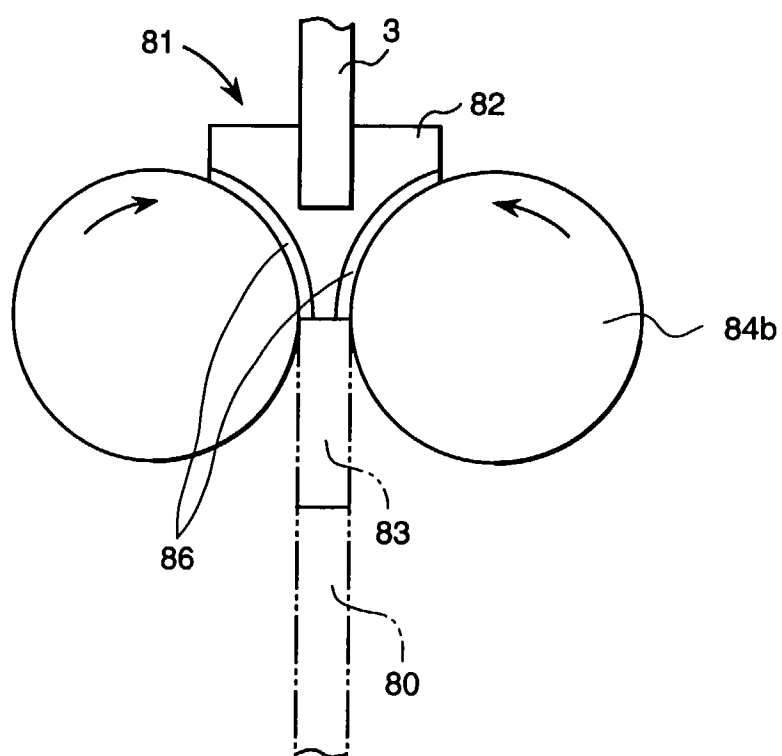


FIG.28

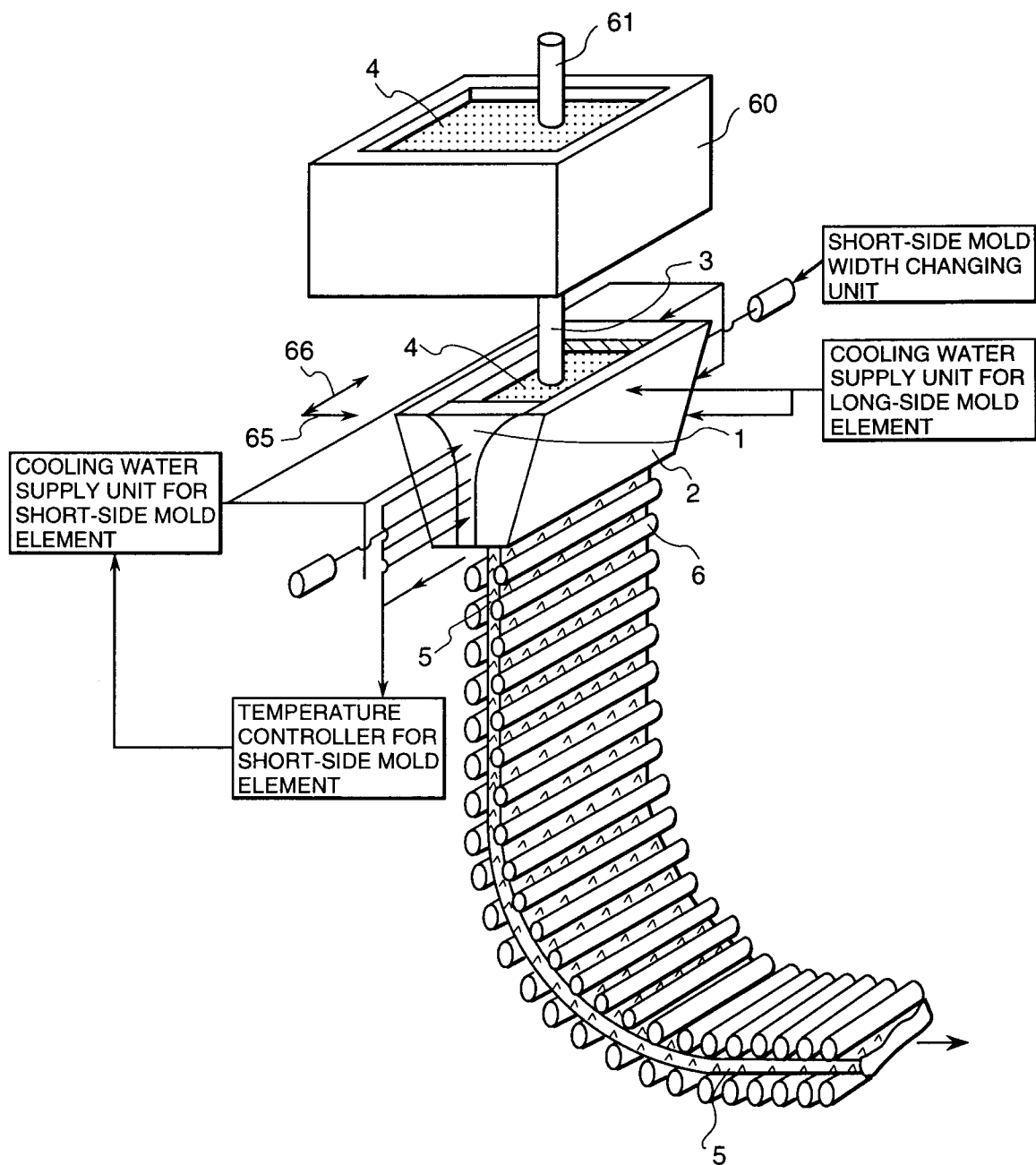


FIG.29

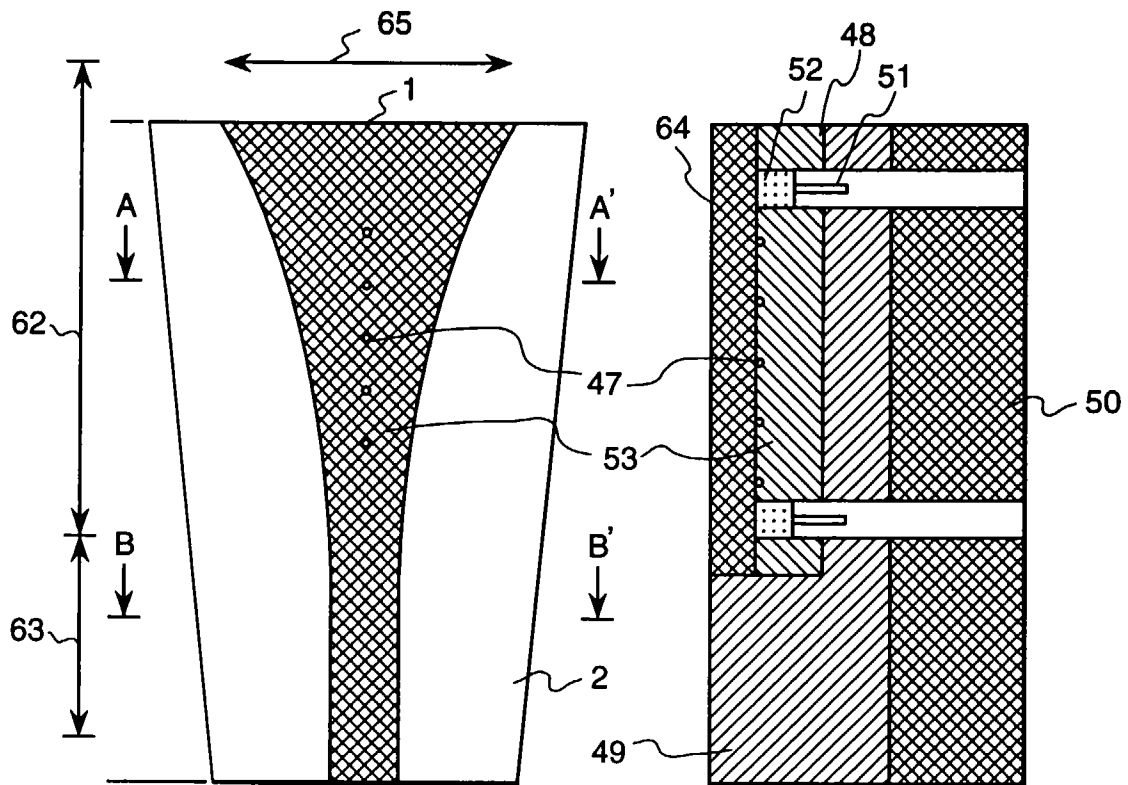


FIG.30

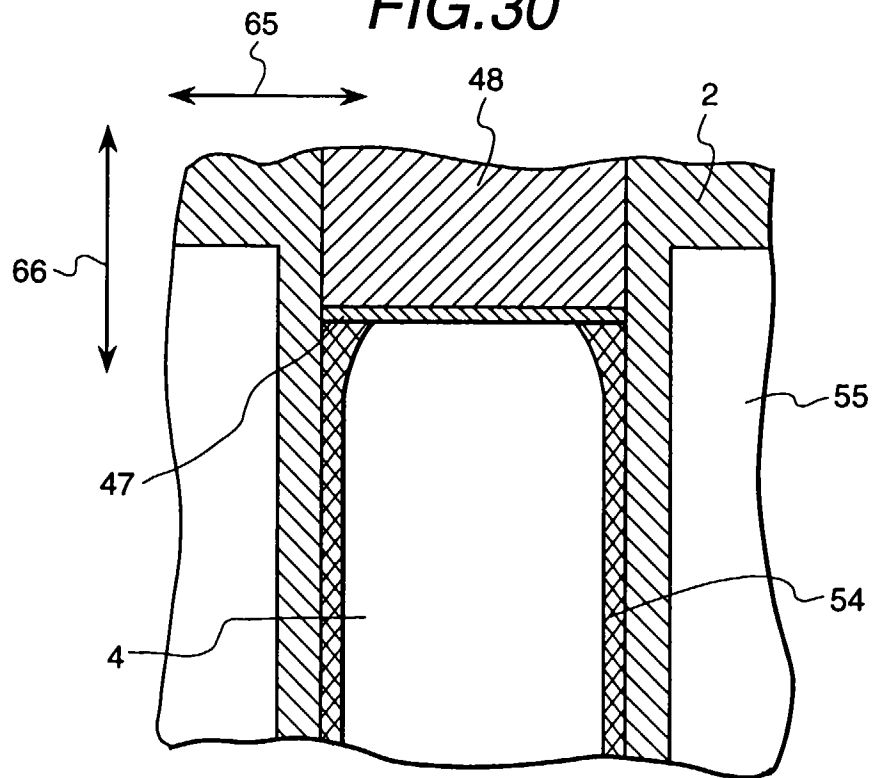


FIG.31

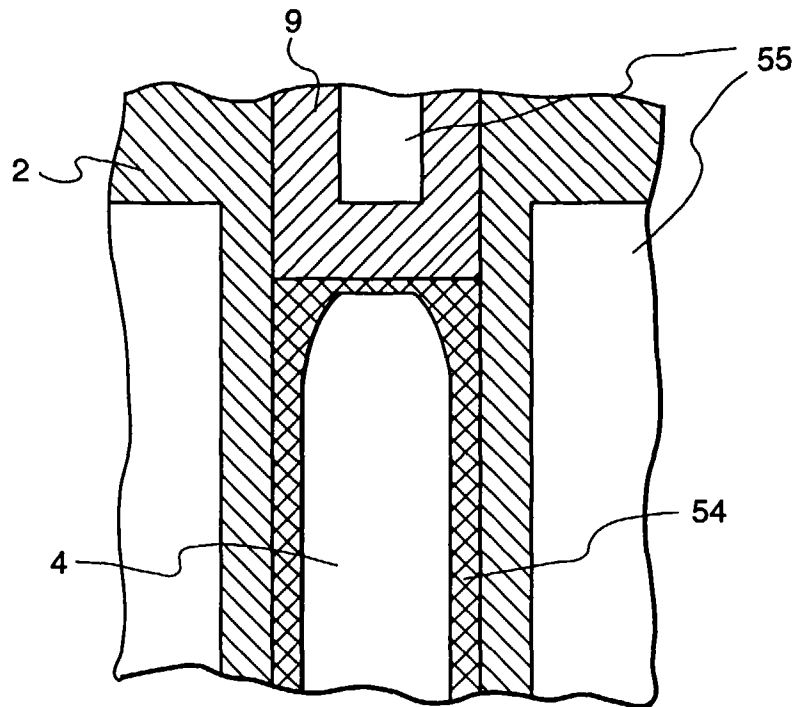


FIG.32

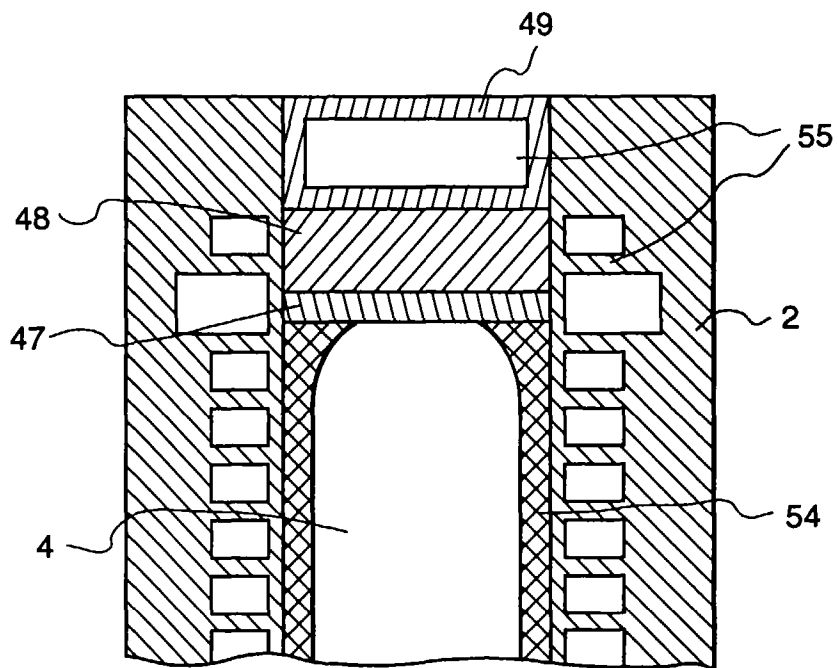


FIG.33

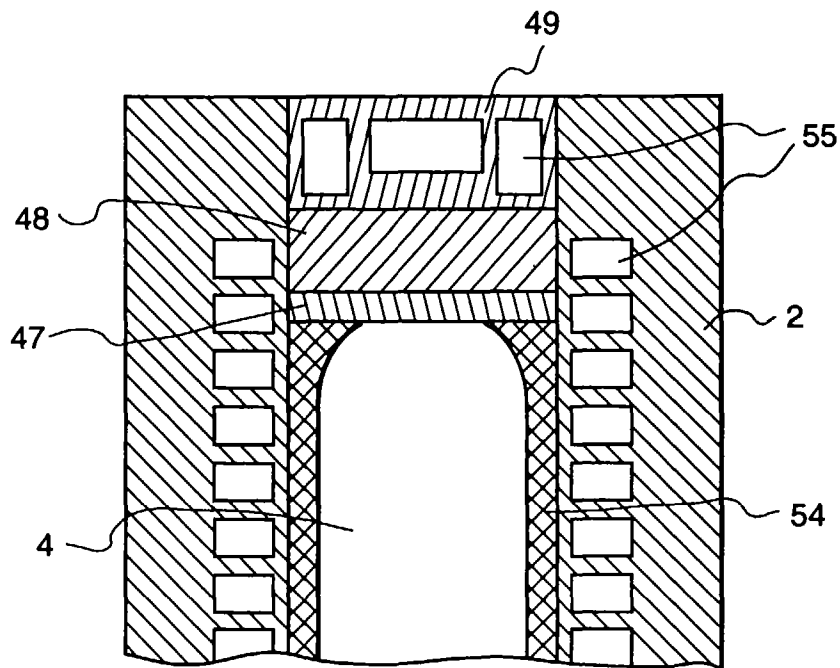


FIG.34

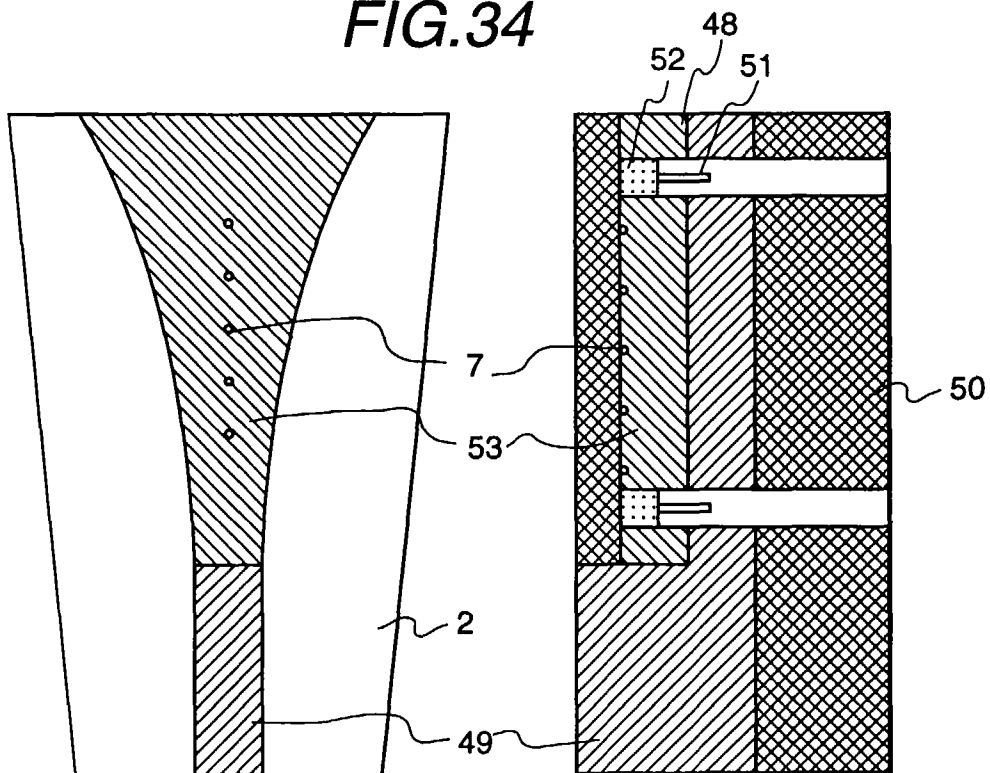


FIG.35

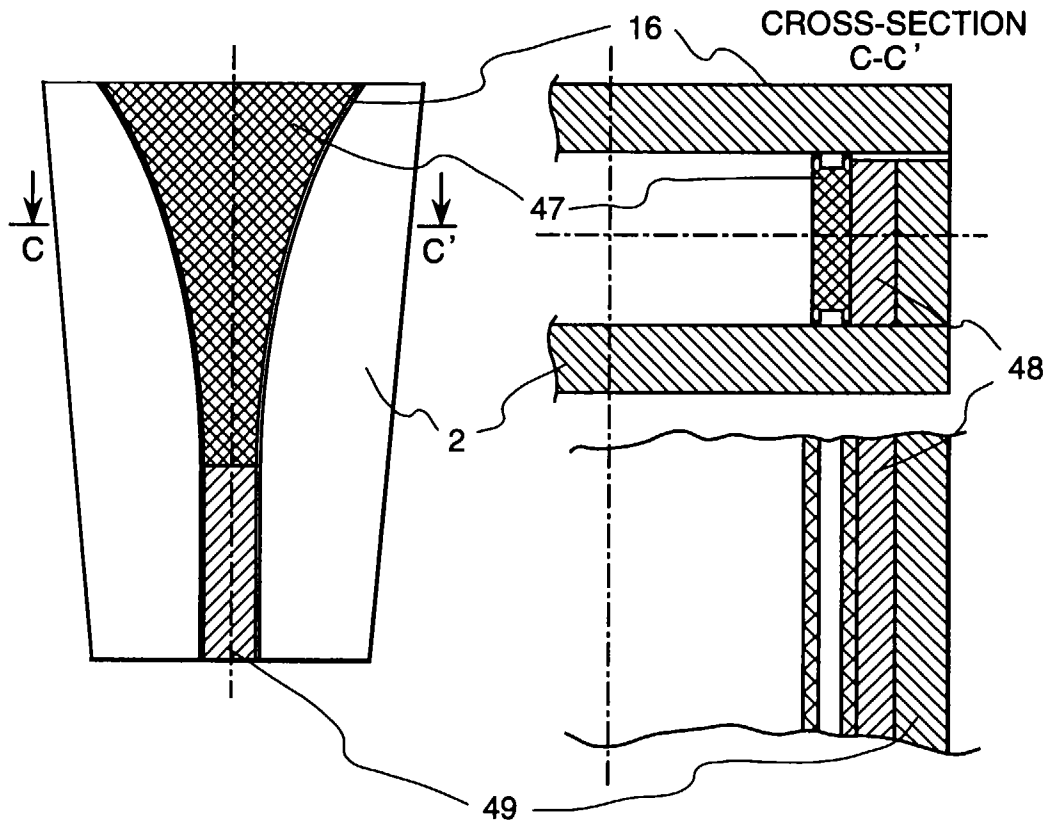


FIG.36

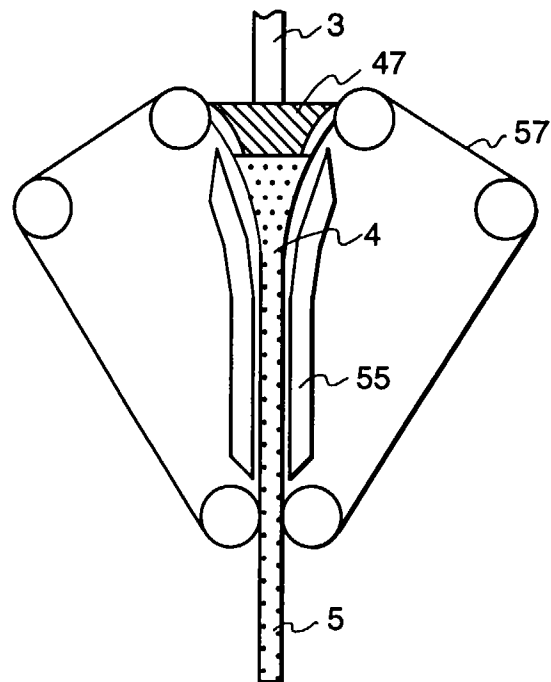


FIG.37

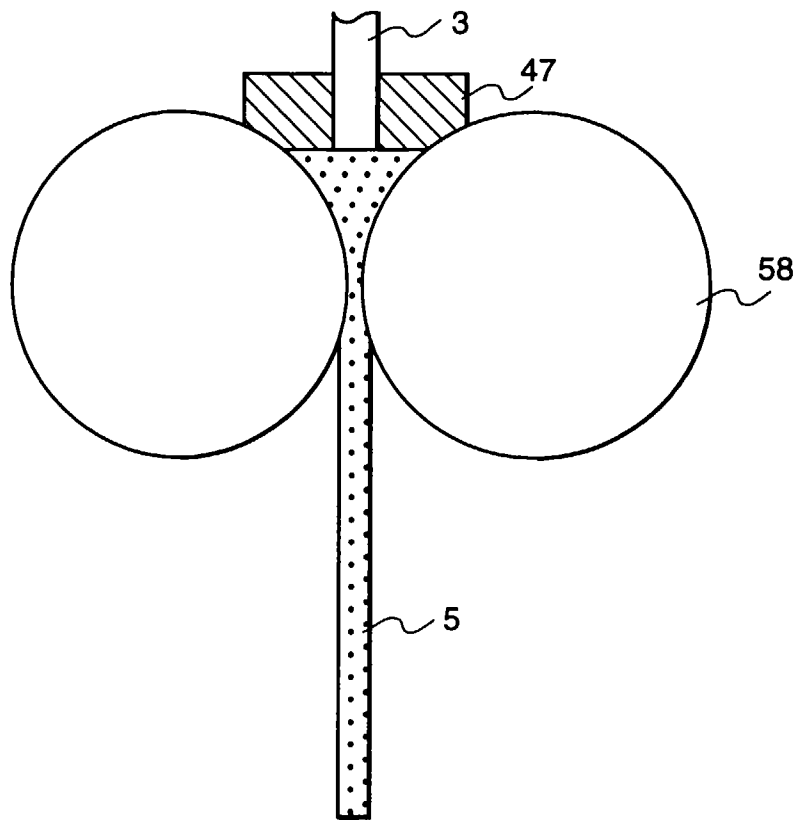


FIG.38

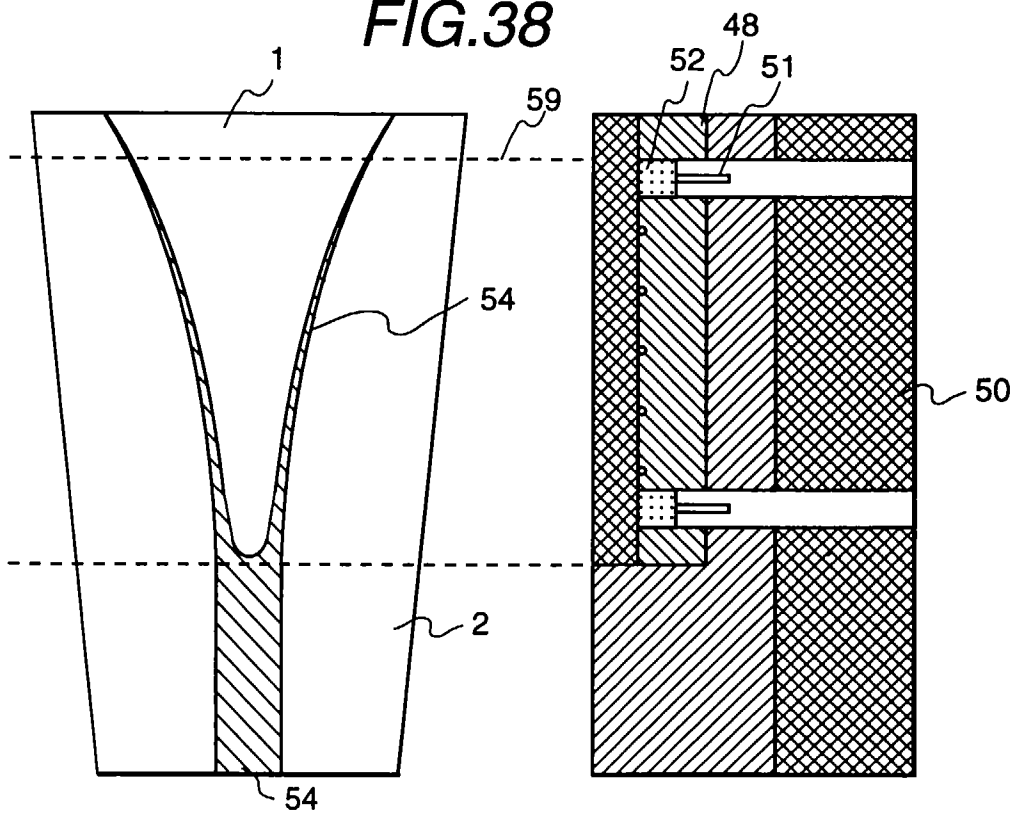


FIG.39

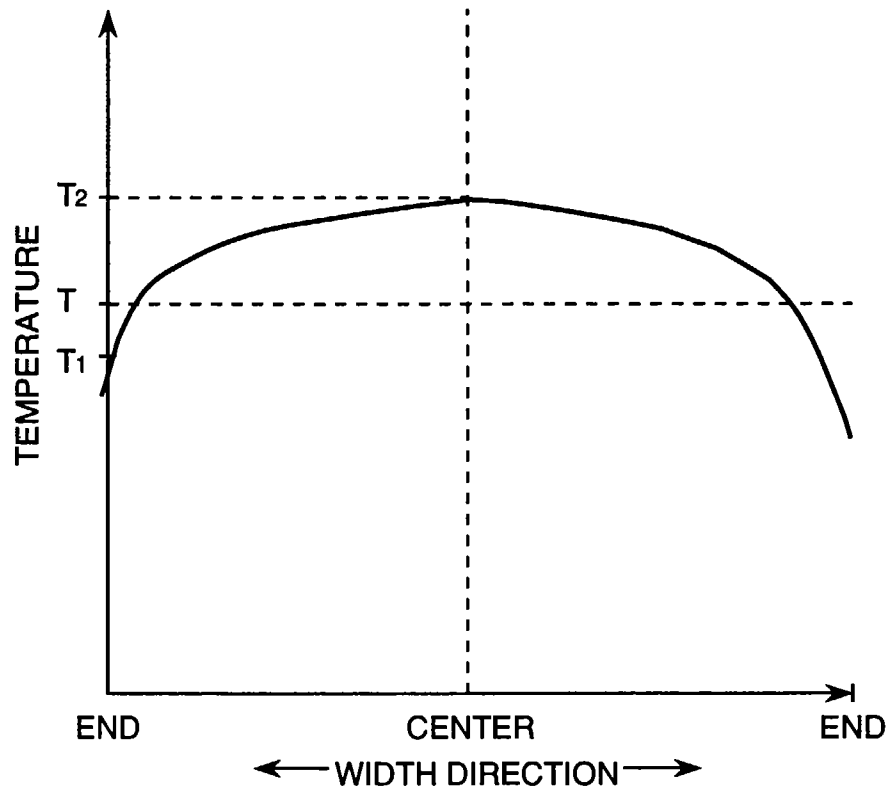


FIG.40

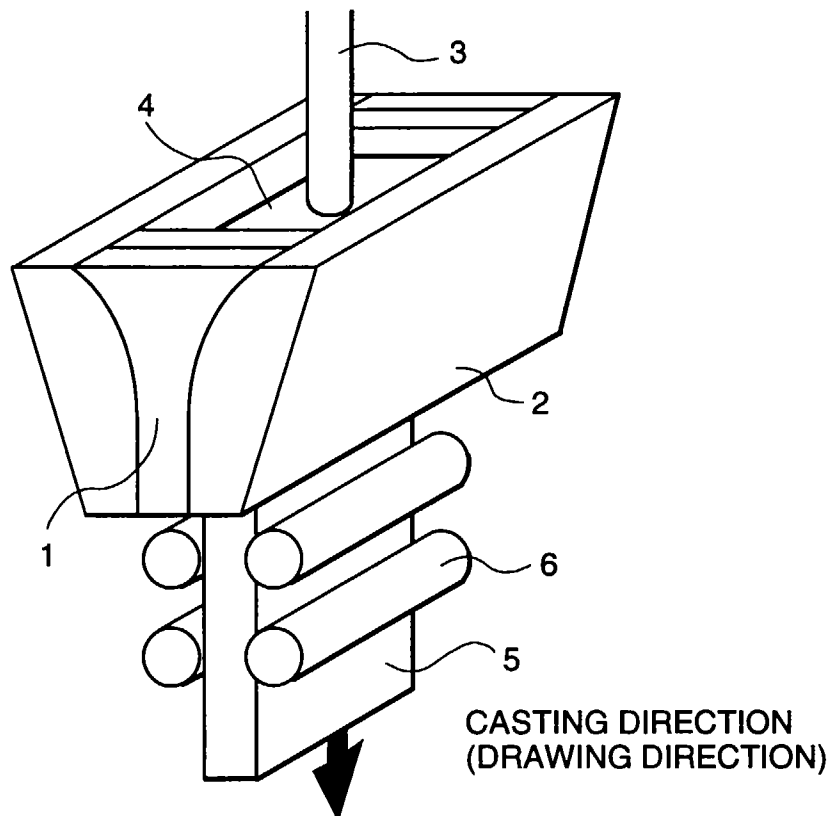


FIG.41

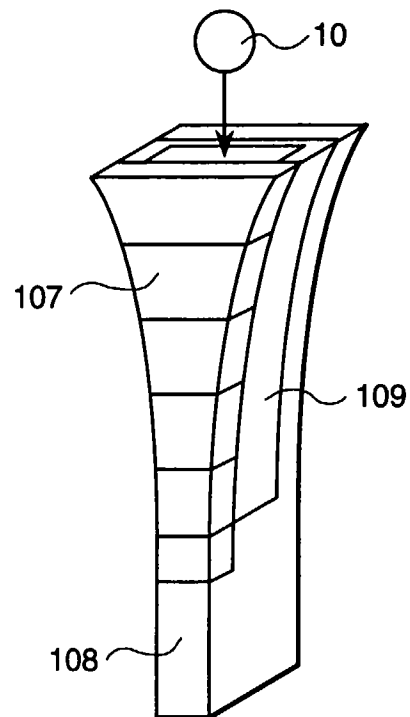


FIG.42

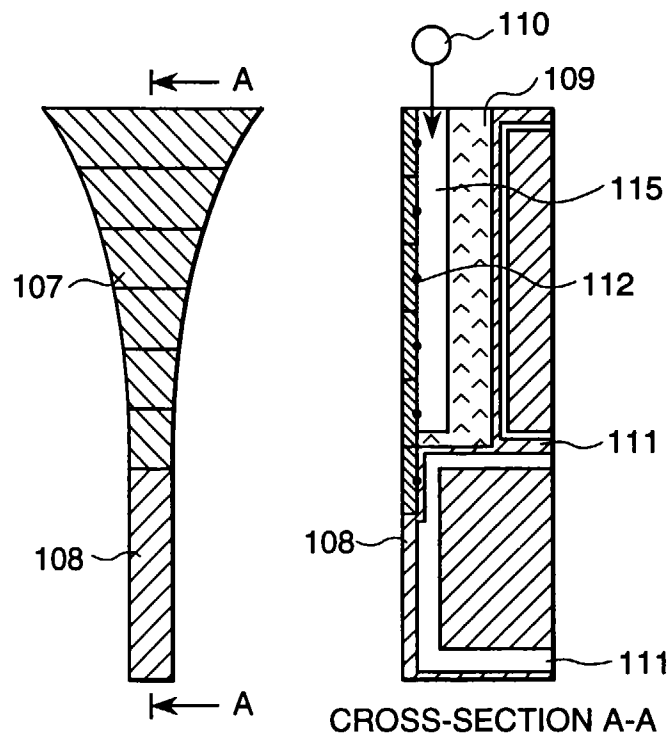


FIG.43

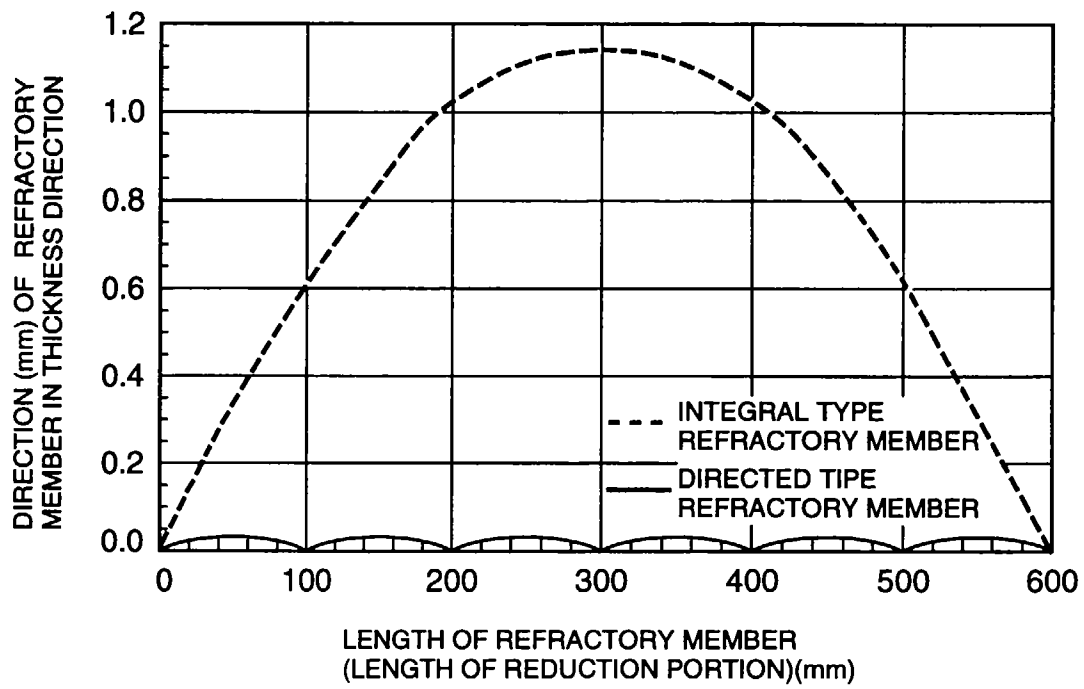


FIG.44

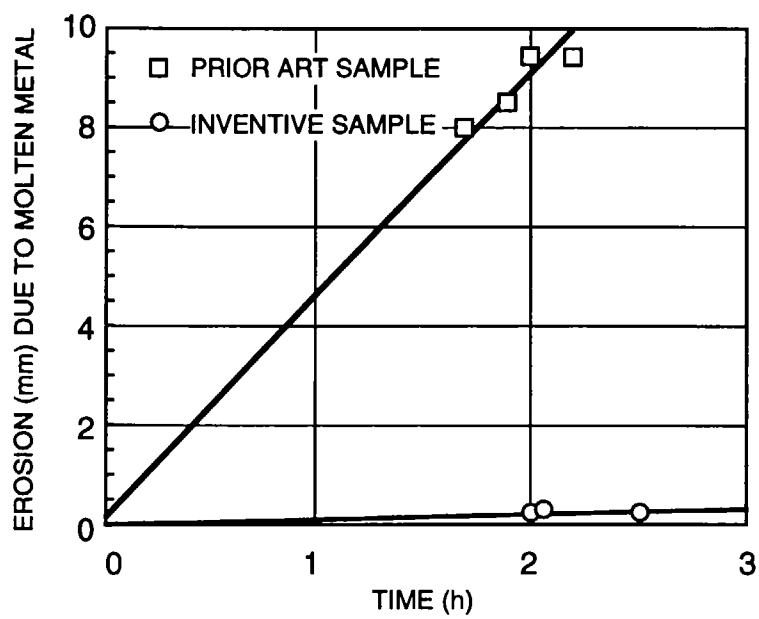


FIG.45

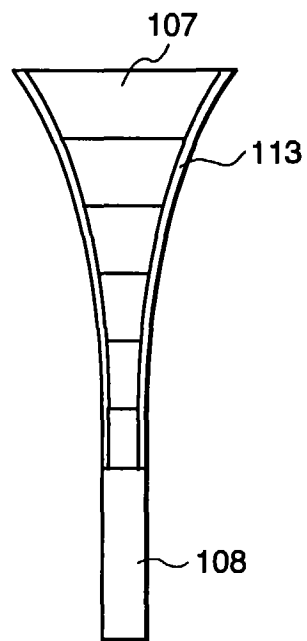


FIG.46

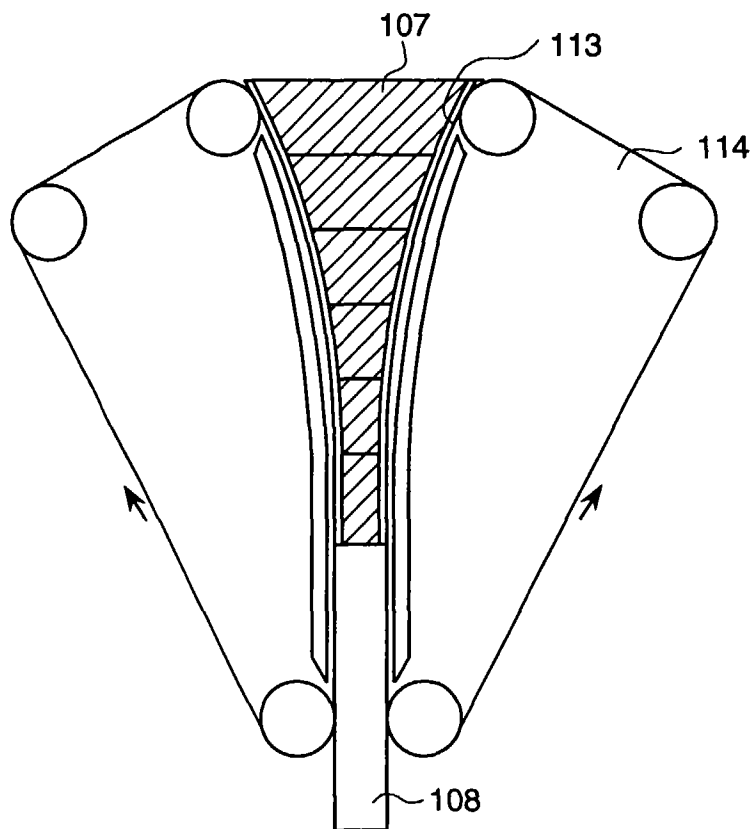


FIG.47

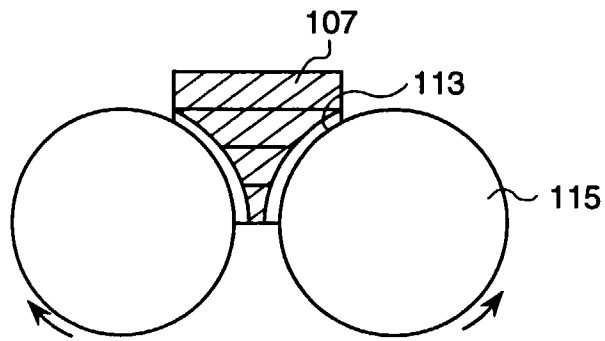


FIG.48

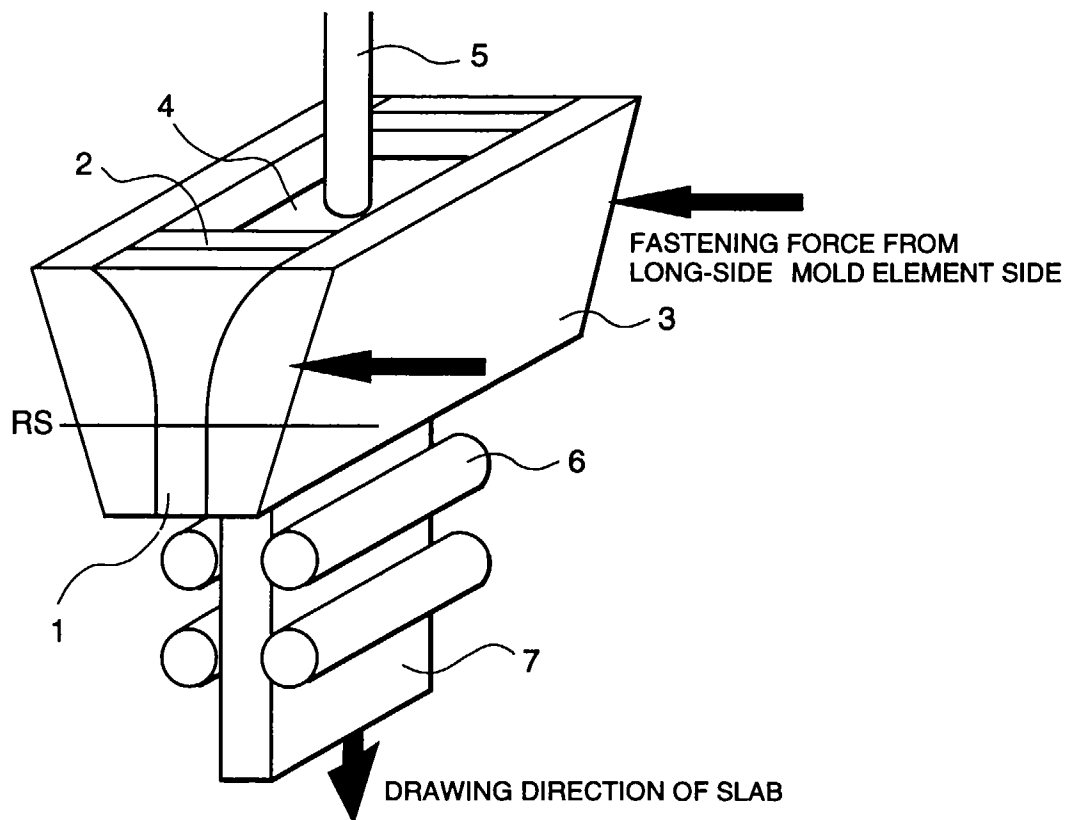


FIG.49A

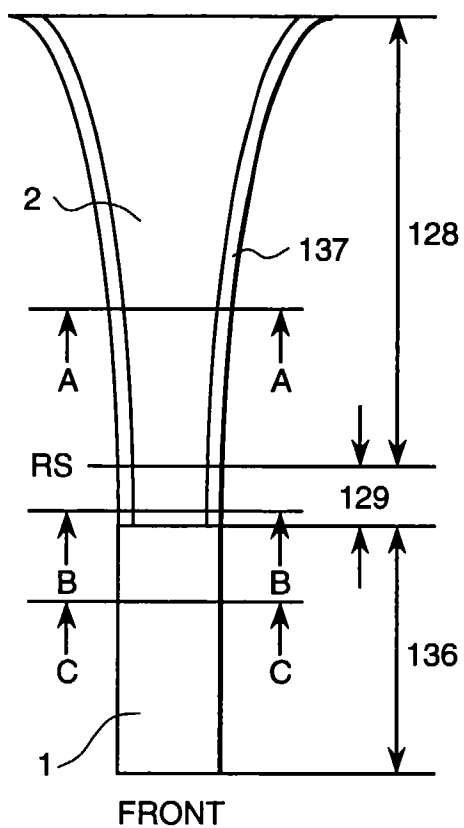


FIG.49B

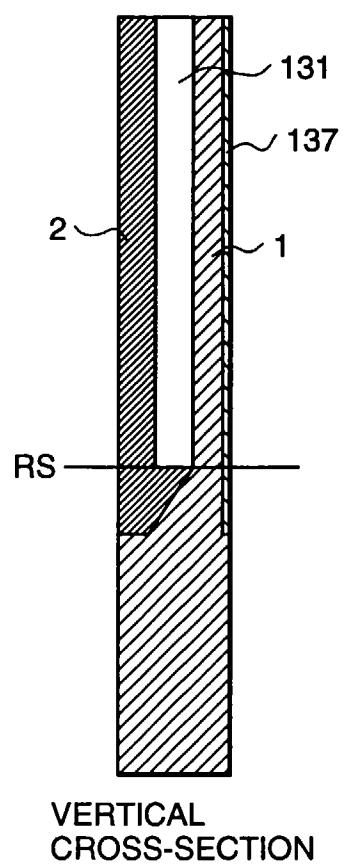


FIG.49C

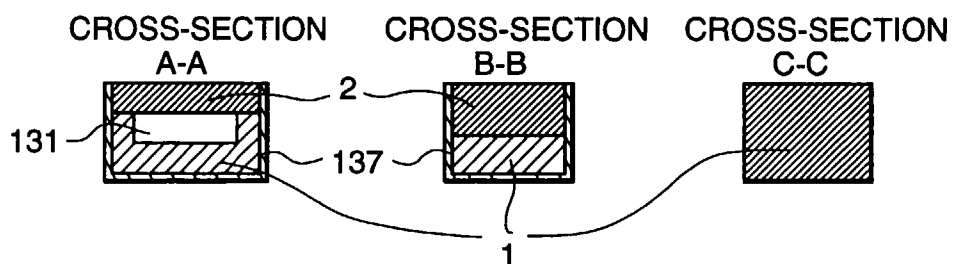


FIG.50A

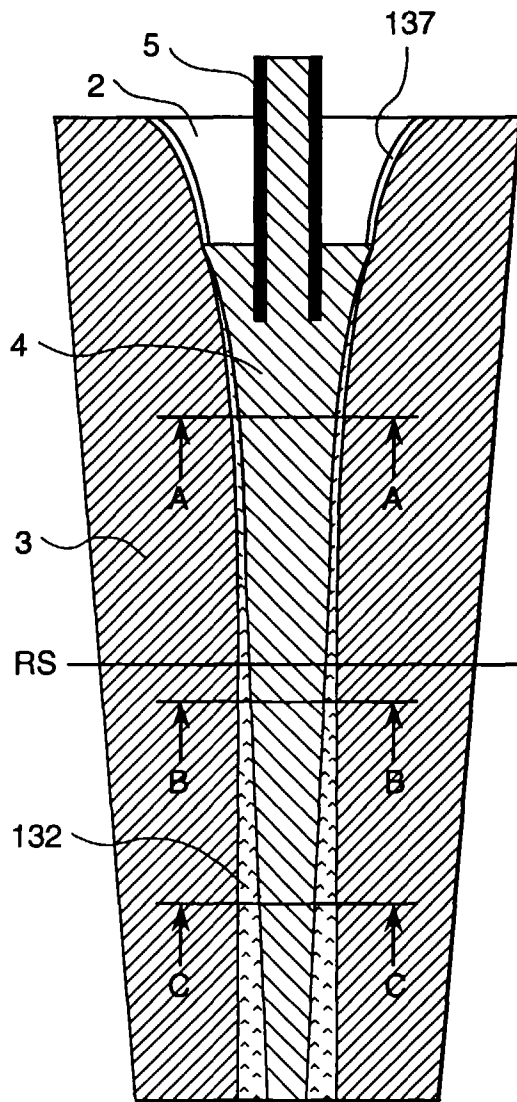
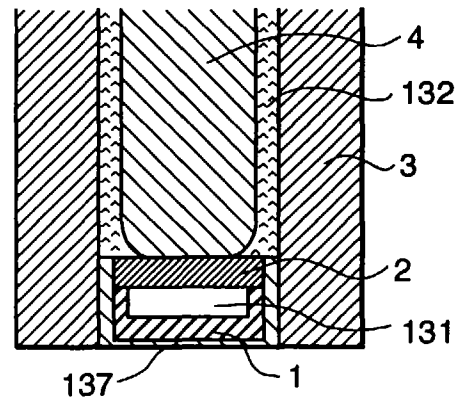
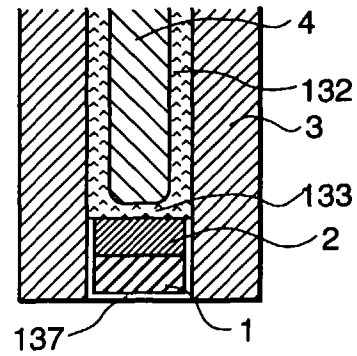


FIG.50B

CROSS-SECTION A-A



CROSS-SECTION B-B



CROSS-SECTION C-C

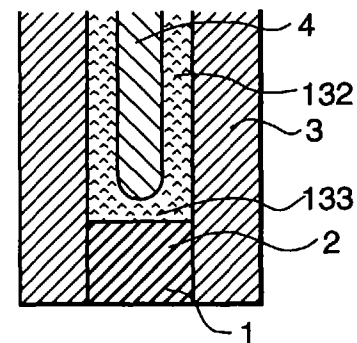


FIG.51

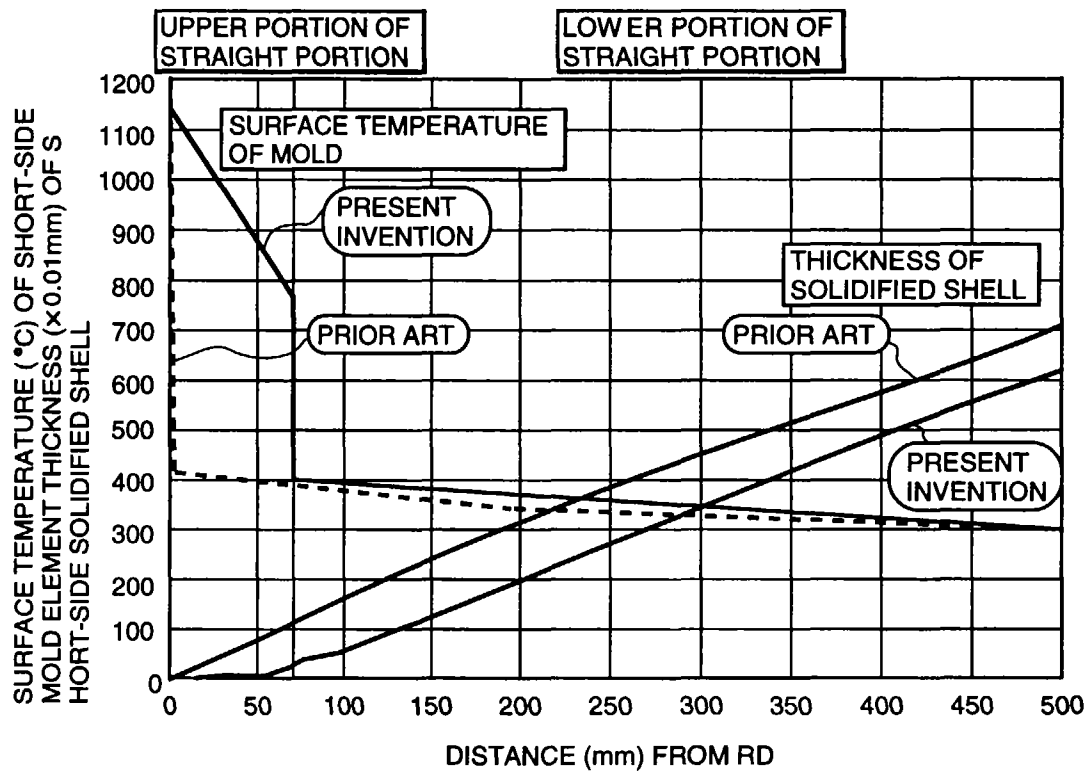
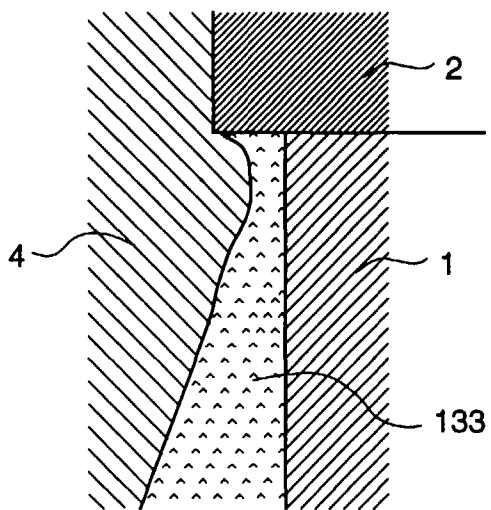
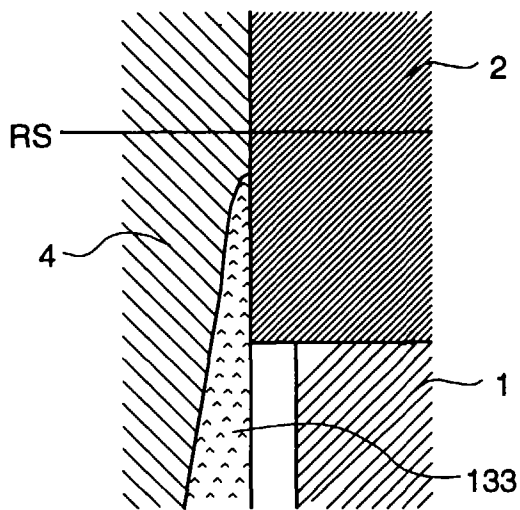


FIG.52A



PRIOR ART

FIG.52B



PRESENT INVENTION

FIG.53

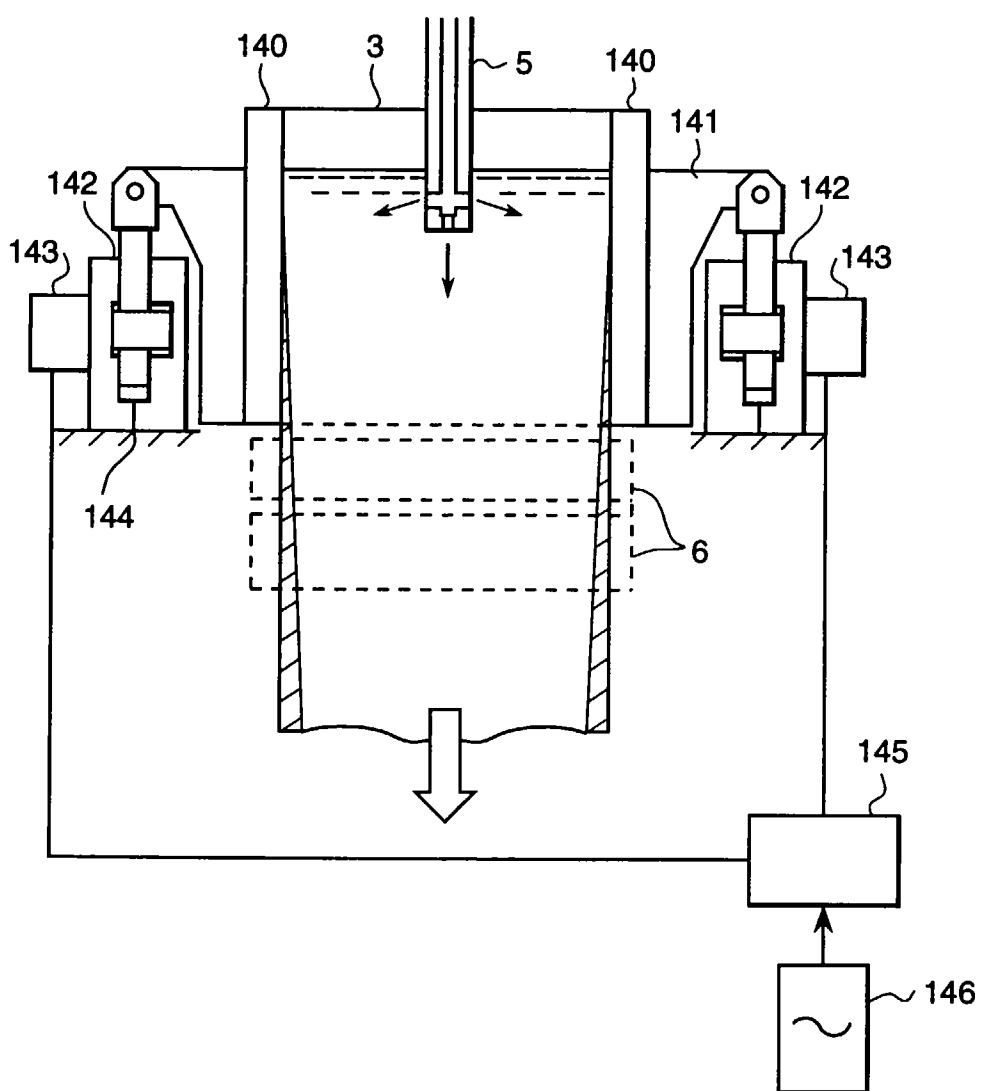


FIG. 54

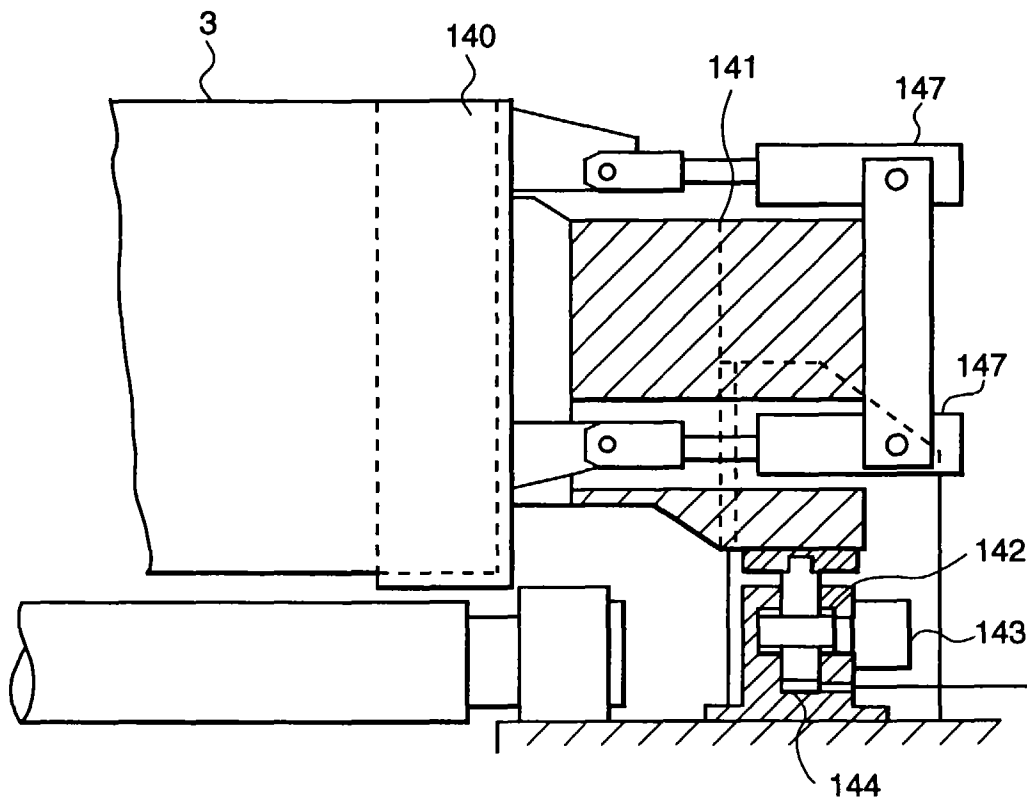


FIG.55

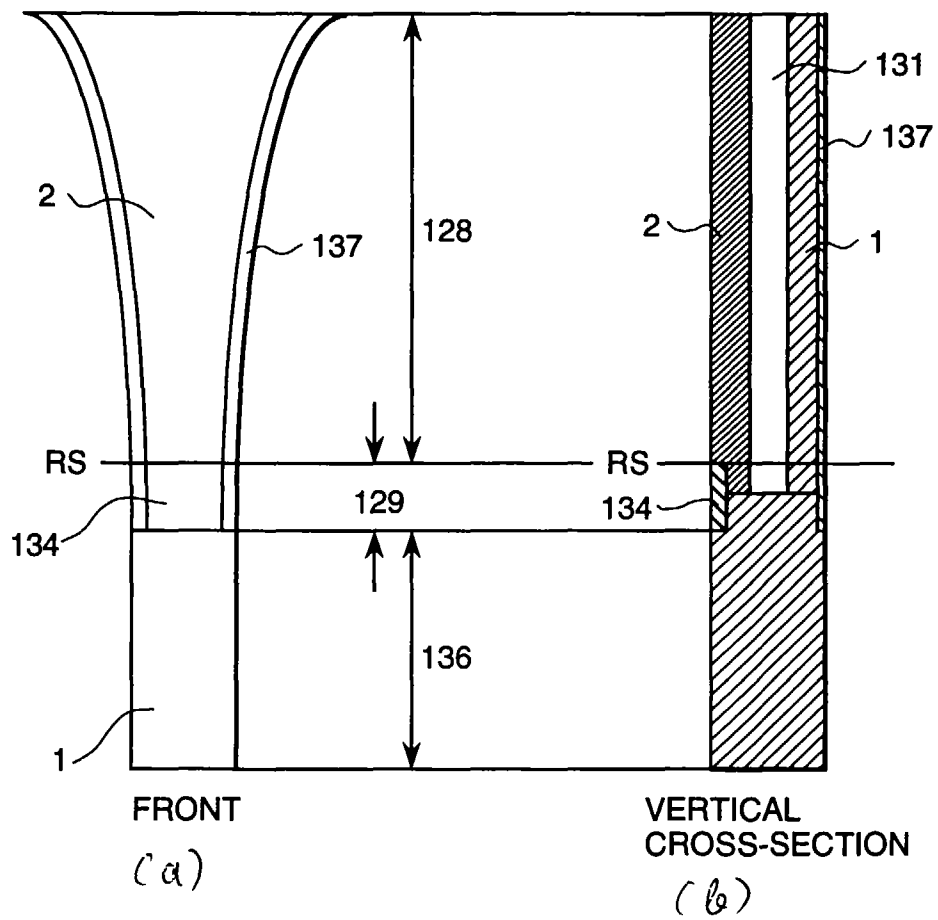


FIG.56

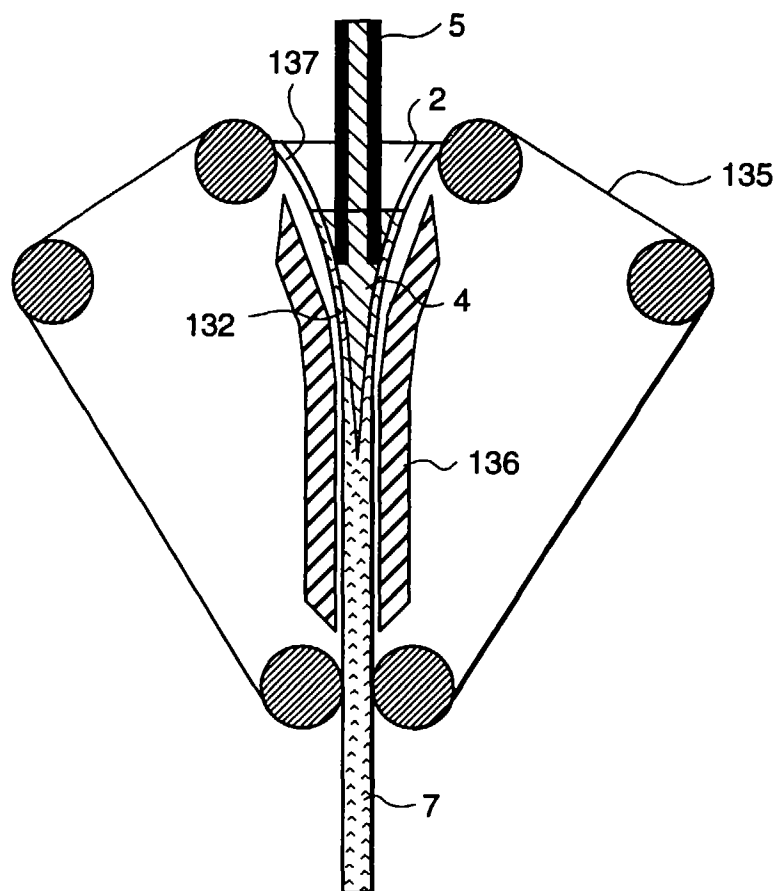


FIG.57

