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(54) CONTINUOUS STEEL CASTING APPARATUS.

(57) A continuous steel casting apparatus which is usable for manufacturing a cast steel piece having excellent surface condition by hardening molten steel without bringing the same into contact with solid casting mold walls, and which has simple construction. A high-temperature lead chamber holding molten lead the temperature of which is higher than the solidifying point of steel and a low-temperature lead chamber holding molten lead the temperature of which is lower than the solidifying point of steel are connected to each other via a partition wall. The high-temperature molten lead and low-temperature molten lead are held in the respective chambers so that the liquid levels thereof exceed the upper end of the partition wall, and a communicating layer of the molten lead is formed on the upper side of the partition wall. Two parallel side weirs (side walls) are provided so as to extend between an upstream side of the partition wall and a downstream side thereof. When molten steel is fed continuously between the side weirs of the high-temperature molten lead chamber, it floats on the surface of the molten lead and spreads between the side weirs to flow above the partition wall into the low-temperature molten lead chamber, the molten steel then floating on the surface of the molten lead in the low-temperature molten lead chamber to be solidified and turn into a thin cast steel piece.

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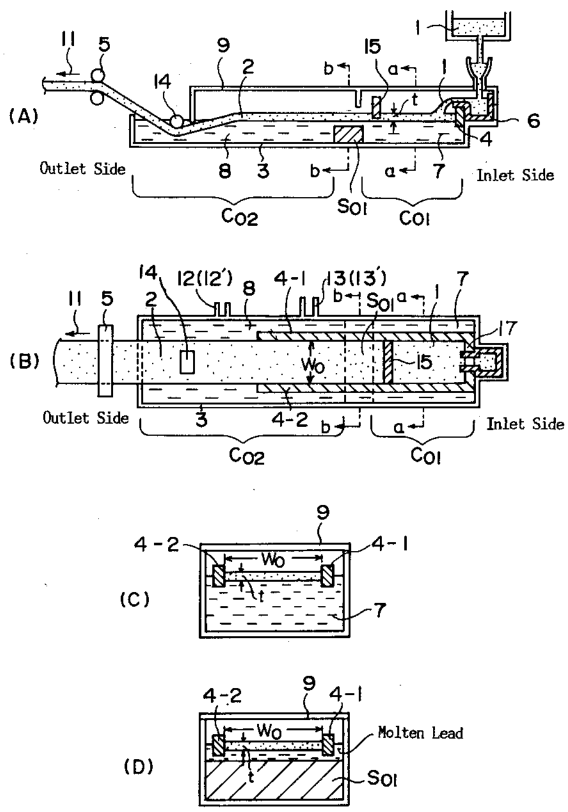
Fig. 1


(A)
11
5
14
9
2
b
15
a
t
1
6
4
Outlet Side
8
3
b
a
7
Inlet Side
C02
S01
C01
(B)
14
12(12')
8
4-1
13(13')
b
S01
a
1
7
17
11
5
2
W0
15
Outlet Side
3
4-2
b
a
Inlet Side
C02
C01
(C)
9
4-2
W0
4-1
t
7
(D)
4-2
9
4-1
W0
Molten Lead
t
S01

[Technical Field]

This invention relates to a continuous steel casting apparatus.

[Background Art]

Thin cast steel slab is advantageous for the manufacture of steel sheet because such slab can simplify the rolling operation and efforts have been paid for developing more efficient continuous steel casting apparatuses. Known continuous steel casting apparatuses are so designed as to use moving casting mold made of solid metal and to form a solidified shell on the wall of a casting mold.

Such a continuous steel casting apparatus is, however, costly because it requires vibrating, traveling and/or rotating members that move the wall of the casting mold. Additionally, with the apparatus, the surface temperature of the solidified shell falls and the shell contracts to produce an air gap between the wall of the casting mold and the solidified shell that can eventually give rise to an unevenly cooled cast slab having cracks on the surface because of the uneven thickness and a poor thermal conductivity of the air gap. The surface of the cast slab can often become scratched as it is scraped by the wall of the casting mold.

Japanese Patent Publications Nos. 58-74249, 59-42163 and 61-147947 disclose continuous steel casting apparatus that do not use any casting mold made of a solid metal. More specifically, Japanese Patent Publication No. 58-74249 relates to a method of pouring molten steel into a molten lead tank from an end thereof, spreading the poured molten steel over the surface of the molten lead in the tank, cooling and solidifying the poured molten steel by means of the same molten lead and taking out the solidified steel from the opposite end of the molten lead tank.

On the other hand, Japanese Patent Publication No. 59-42163 teaches a continuous steel casting method of pouring molten steel onto a molten lead bath containing molten lead moving more fast than the feeding speed of molten steel.

Finally, Japanese Patent Publication No. 61-147947 describes a continuous steel casting method of feeding molten steel as a turbulence-free stratum to an end of a molten lead tank containing molten lead at a temperature sufficiently lower than the solidifying point of steel, cooling and solidifying the molten steel without significantly spreading it and taking out the solidified steel from the opposite end of the molten lead tank. However, none of these methods have been commercialized to date.

[Disclosure of Invention]

With a continuous steel casting apparatus according to the invention, molten steel is made to contact with molten lead without using casting mold of solid metal and the cast steel slab produced there floats and moves on the molten lead. Molten steel is poured at about 1,600 °C and the cast steel slab produced may conveniently be handled at about 600 °C.

On the other hand, metal lead has a boiling point of 1,740 °C and a solidifying point of about 330 °C. Thus, during the continuous casting operation, the metal lead remains in a totally molten state. The specific gravity of molten lead is 10 to 11, whereas that of steel is about 7. Therefore, molten steel and the cast steel slab formed in the apparatus remain floating on the molten lead during the operation of continuous casting.

Additionally, molten steel and molten lead can hardly dissolve each other and the alloy components in molten steel can hardly be dissolved into molten lead. Thus, the chemical composition of the molten steel and that of the produced cast steel slab can hardly change during the operation of continuous casting.

Fig. 1 of the accompanying drawings illustrates a continuous steel casting apparatus according to the invention. Fig. 1 (A) shows a longitudinal cross sectional view and (B) shows a plan view without sealing cover (9), whereas (C) and (D) respectively shows longitudinal cross sectional views taken along a-a and b-b in (A) and (B).

A continuous steel casting apparatus according to the invention comprises a molten lead tank (3) which is divided into lead chambers (C01) and (C02) by a partition wall (S01) arranged between the inlet side and the outlet side of the tank (3). The inlet side lead chamber (C01) contains molten lead (7) having a temperature higher than the solidifying point of steel, that may be 1,600 °C for instance, while the outlet side lead chamber (C02) contains molten lead (8) having a temperature lower than the solidifying point of steel, that may be 800 °C for instance.

The tank (3) is filled with molten lead to a level higher than the upper end of the partition wall (S01). As a result, while the high-temperature molten lead (7) in the lead chamber (C01) and the low-temperature molten lead (8) in the lead chamber (C02) would not mix together at and near the bottom of the tank (3), they communicate with each other above the partition wall (S01) to show a same liquid level.

A continuous steel casting apparatus according to the invention additionally comprises a pair of side weirs (4-1) and (4-2) having lower portions immersed into the molten lead (7) and (8) and connected with each other by a connecting weir (17) at the inlet side ends thereof. The side weirs (4-1) and (4-2) extend sufficiently long from the partition wall (S01) toward both the inlet side and the outlet side of the tank and arranged in parallel with each other, having been separated from each other with a distance of (W0).

A continuous steel casting apparatus according to the invention further comprises a taking out device (5) arranged adjacent to the outlet side of the molten lead tank, which may be a pinch roll or some other appropriate device.

While the side weirs (4-1) and (4-2) may be arranged in parallel with each other and separated by a distance of (W0) in Fig. 1 they may alternatively be arranged being flared its distance to be more wide toward the outlet side at art angle of not exceeding 20° so that the average distance between them is held equal to (W0).

With a continuous steel casting apparatus according to the invention, molten steel is poured into the lead chamber (C01) and then moves to the lead chamber (C02) so that the poured molten steel is cooled by the low-temperature molten lead in the lead chamber (C02) until it is solidified to make a cast steel slab (2), which is subsequently taken out of the tank (3) by means of the taking out device in a continuous operation.

In the operation of continuous steel casting illustrated in Fig. 1, a molten steel layer is formed in the lead chamber (C01) to a thickness of t(mm). The molten steel layer is immersed into the molten lead by about 70% of its thickness while the remaining 30% of its thickness is exposed out of the surface level of the molten lead.

Thus, the lower ends of the side weirs (4-1) and (4-2) of the apparatus needs to be located more deep than $0.7 \times t$(mm) from the surface level of the molten lead. On the other hand, the upper ends of the side weirs (4-1) and (4-2) needs to be sufficiently above $0.3 \times t$(mm) from the surface level of the molten lead.

Thus, with such an arrangement, when a layer of molten steel is formed in the lead chamber (C01) to a thickness of t(mm), molten steel would not leak out under the lower ends of the side weirs, nor overflows over the upper ends thereof.

While a molten lead layer is formed above the partition wall (S01), the molten lead layer has to have a thickness sufficiently greater than $0.7 \times t$(mm) by the same token. With this arrangement, the bottom of the molten steel layer would never touch the partition wall (S01) so that the molten steel layer would smoothly flow from the lead chamber (C01) into the lead chamber (C02).

Now, the operation of a continuous steel casting apparatus according to the invention will be described. Prior to actual casting, a guide sheet (not shown) typically made of steel and having a width of (WO) is laid in the lead chamber (CO2) in such a way that it extends between a position close to the partition wall (S01) and the taking out device (5). Thereafter, molten steel (1) is poured into the space defined by the side weirs of the lead chamber (C01).

The poured molten steel (1) spreads over the surface of the high-temperature molten lead (7) and, as more molten steel (1) is poured continuously, the foremost portion of the spreading molten steel (1) is made to advance under the static pressure of the molten steel layer in (C01), passing over the partition wall (S01), until it gets to the tail end of the guide sheet, where it is solidified thereon.

Once the foremost portion of the molten steel is solidified at the tail end of the guide sheet, the guide sheet is moved forward along arrow (11) by moving the taking out device (5) so that the following molten steel (1) in the lead chamber (C01) is successively made to pass over the partition wall (S01) and move into the lead chamber (C02), where it is cooled and solidified by the low-temperature molten lead (8) to make a cast steel slab (2) with a width of (W0), which is then guided by the guide sheet and taken out by the taking out device (5).

Assume that molten steel is continuously poured at a rate of M (tons/min), it then moves forward between the side weirs (4-1) and (4-2) at the rate of M (tons/min). When the distance between the side weirs (4-1) and (4-2) is W(m), the thickness of the cast steel slab is T(m), the cast steel slab is taken out at a rate of V(m/min) and the specific gravity of the cast steel slab is ρ, equation (1) below hold true.

$$W \cdot T \cdot V \cdot \rho = M \qquad (1)$$

where M, W and ρ are constants.

It will be understood from the equation (1) above that , as the rate V(m/min) of taking out the cast steel slab is raised, the thickness T(m) of the cast steel slab is reduced and vice versa.

For terminating the operation of continuous casting, the supply of molten steel (1) is stopped and the taking out device (5) is stopped. Then the high-temperature molten lead (7) in the lead chamber (C01) is cooled to a temperature below the solidifying point of steel, which is typically 1,400°C,for example by feeding solid lead pellets into the lead chamber (C01) in order to solidify the molten steel in the lead chamber (C01). Then, all the steel in the apparatus can be taken out as a cast steel slab by operating the taking out device (5).

During the operation of continuous casting, the high temperature molten lead (7) in the lead chamber (C01) is kept to the temperature of molten steel (1) without any heating device since the molten lead is constantly kept in contact with high temperature molten steel that is continuously being poured.

The low-temperature molten lead (8) in the lead chamber (C02) has to be cooled because its temperature will rise if it is not cooled. The cooling is realized by means of a heat exchanger arranged in the lead chamber (C02). Alternatively, it may be realized by causing the low-temperature molten lead (8) to circulate through a cooling apparatus seperately arranged from the lead chamber (C02). Reference numeral (12) in Fig. 1 (B) denotes a example of an outlet port of molten lead for this circulation whereas (13) denotes an inlet port.

Still alternatively, the molten lead (8) in the lead chamber (C02) may be cooled efficiently by such means as described below. The molten lead (8) is partly taken out through a molten lead outlet port (12') of the lead chamber (C02) and a corresponding amount of solid lead in the form of pellets for example is fed into the lead chamber (C02) through a inlet port (13') in order to cool the molten lead in the chamber (CO2). It may be clear that the molten lead (8) taken out through the outlet port (12') may be pelletized and used as a coolant.

Since the vapor pressure of molten lead at 1,000 °C is less than about 0.1KPa, less lead vapor can arise from the low temperature molten lead in the lead chamber (C02). On the other hand, lead vapor can arise from the high-temperature molten lead in the lead chamber (C01) since the vapor pressure of molten lead at 1,600 °C is about 25KPa.

A sealing cover (9) is provided at least on the lead chamber (C01) of the continuous steel casting apparatus according to the invention in order to prevent lead vapor from being dissipated into the atmosphere and also prevent lead oxide from being produced in the chamber.

The inside of the lead chamber closed by the sealing cover (9) can easily be held under an airtight condition by arranging for example a sink roll (14) and a outlet wall of the sealing cover (9), where the lower edge of the outlet wall is immersed into the molten lead and the cast steel slab is taken out under the sink roll and the outlet wall as illustrated in Fig.1 (A).

Dissipation and generation of lead vapor and production of lead oxide can be effectively prevented from for example by feeding the airtightly sealed space of the apparatus with non-oxidizing gas such as nitrogen gas. The prevention of the formation of a thick oxide scale on the upper surface of cast steel slab can also be archived by keeping the inside of the sealed space under highly non-oxidizing condition.

Reference numeral (15) in Fig. 1 denotes a scum weir which is used for removing scum from the molten steel. The molten steel poured into the lead chamber (C01) flows under the scum weir (15) and then toward the partition wall (S01). The scum floating on the surface of the molten steel in the lead chamber (C01) is mostly blocked by the scum weir (15) because it cannot move under the bottom of the scum weir (15) so that the produced cast steel slab may be substantially free from so-called scum-scars.

With a continuous steel casting apparatus according to the invention, the surface temperature of the molten steel in the lead chamber (C01) may be raised or maintained to a more high temperature by additionally arranging a heater (not shown) somewhere in the upper space of the lead chamber (C01) or by spraying heat insulating flux over the surface of the molten steel (1).

While it may be irrelevant to directly compare the invention with a process described below , there is known a so-called float process with which molten glass is made to spread over molten tin in a bath and cooled by the molten tin to produce plate glass. Since plate glass is non-crystalline and highly fluid over a wide temperature range from 1,050 °C down to 600 °C, it can keep on spreading on the molten tin for a prolonged period of time.

Steel is, on the other hand, crystalline and a molten steel having a temperature of 1600 °C loses its fluidity when it is cooled down to its solidifying point of 1,450 °C. In other words, the temperature range in which molten steel can spread over molten lead is rather narrow and hence molten steel can quickly lose its fluidity.

Apart from the present invention, it may be conceivable to pour molten steel into a tank containing molten lead from an end of thereof, spreading the poured molten steel over the surface of the molten lead in the tank, cooling and solidifying the poured molten steel by means of the same molten lead and taking out the solidified steel from the opposite end of the molten lead tank.

With such a technique, however, it is difficult to maintain the temperature of the poured molten steel above the solidifying point for a prolonged period of time and the poured molten steel can become solidified well before it spreads well. Thus, it is not feasible to produce cast steel slab of thin thickness with such a technique.

With a continuous steel casting apparatus according to the invention as illustrated in Fig. 1, molten steel stays in the lead chamber (C01) for a sufficiently long period of time. During this stay, the molten steel is held to a temperature well above the solidifying point of steel and therefore satisfactorily spreads over the molten lead so that wide and thin cast steel slab can be manufactured on a stable basis.

Since the high-temperature molten lead (7) and the low temperature molten lead (8) communicate with each other above the partition wall (S01) in Fig. 1, they can mix with each other. However, such mixing of the high-temperature molten lead (7) and the low-temperature molten lead (8) can be eliminated by making the partition wall (S01) sufficiently thick and/or reducing the thickness of the molten lead layer on the partition wall (S01).

Also apart from the present invention, it may be conceivable to feed molten steel as a turbulence-free stratum to an end of a molten lead tank containing molten lead at a temperature sufficiently lower than the solidifying point of steel, cooling and solidifying the molten steel without significantly spreading it and taking out the solidified steel from the opposite end of the molten lead tank.

With such an arrangement, however, since the surface tension of molten steel is greater than that of molten lead, the flowing stratum of molten steel can be easily deformed by molten lead and, since about 70% of the overall height of the molten steel layer sinks under the surface of the molten lead in the tank, turbulences of stratum of molten steel can generated in this sinking.

Additionally, the inlet port of the tank for feeding molten steel can be easily deformed by abrasive flow of molten steel and/or solidified steel sticking thereof, and making it difficult to keep a turbulence-free stratum of molten steel in the molten lead tank.

In the continuous steel casting apparatus of Fig. 1 the molten steel layer is fed to the lead chamber (C02), however molten steel layer has been formed already partly sunk into the molten lead in the lead chamber (C01), it would not further sink into the molten lead in the lead chamber (C02) and, therefore, the molten steel layer can remain turbulence-free there.

Additionally, if a tundish (6)-inlet port for feeding a molten steel-may deformed , the floating layer of the molten steel fed to the lead chamber (C02) is not affected by such defrom and, since the bottom of the layer of the molten steel moving from (C01) to (C02) is supported by molten lead, no abrasion nor sticking of the molten steel thereto so that the the molten steel layer formed in the lead chamber (C01) can maintain its shape and size also in the lead chamber (C02).

If the pair of side weirs is flared toward the outlet side by an angle less than 20°, the produced cast steel slab can be easily separated from the side weirs (4-1) and (4-2) because a cast steel piece contracts and reduces its width (W0) as it is cooled and solidified. However it the angle of flare is greater than 20°, the molten steel layer is tend to spread sharply during its solidification and can generate turbulences in it.

With a continuous steel casting apparatus according to the invention, solidification of the molten steel layer can start anywhere between in front of the partition wall (S01) and behind it depending on the operating conditions, a cast steel slab having a width corresponding to the distance of (WO) can be obtained regardless of the exact point at which molten steel layer starts solidification, because the side weirs (4-1) and (4-2) extend sufficiently long from the partition wall (S01) toward both the inlet side and the outlet side of the tank and arranged substantially in parallel with each other with an average distance of (W0) separating them. Note that the side weirs (4-1) and (4-2) should extend toward the outlet side well beyond the point at which the molten steel layer completes its solidification.

A solidified shell of steel is fragile by itself. However, the solidified shell produced in a continuous steel casting apparatus according to the invention is moved by the static pressure of molten steel continuously poured into the lead chamber (C01) and the tension exerted by the taking out device (5) where the static pressure and the tension are in good balance so that the fragile solidified shell may not be broken easily.

Additionally, the molten lead held in contact with the solidified shell moves with the movement of the solidified shell. Thus, the solidified shell of the continuous steel casting apparatus according to the invention is never subjected to an excessive force and hence kept sound so that the molten steel layer may gradually solidify as it moves in the apparatus.

A continuous steel casting apparatus according to the invention may additionally be provided with another molten lead chamber or a heating furnace of the cast steel slab to the outlet side of the lead chamber (C02). With a continuous steel casting apparatus according to the invention, a cast steel slab having a fine texture can be prepared by appropriately regulating the temperature of the molten lead in the lead chamber (C02). Likewise, a cast steel slab prepared in the apparatus can be immediately hot-rolled by regulating the temperature of the lead chamber (C02) and the additional lead chamber or the heating furnace to a temperature suitable for hot rolling or heat-treating of the cast steel slab.

[Brief Description of the Drawings]

Fig. 1 schematically illustrates an embodiment of apparatus according to the invention.

Fig. 2 schematically illustrates an embodiment of side weirs used in the apparatus according to the invention.

Fig. 3 schematically illustrates another embodiment of apparatus according to the invention.

Fig. 4 schematically illustrates still another embodiment of apparatus according to the invention.

[Best Mode for Carrying out the Invention]

Preferably, a continuous steel casting apparatus is so designed as to be able to manufacture cast steel slabs with several different widths. Fig. 2 illustrates a pair of side weirs suitable to manufacture cast steel slabs with different widths. In Fig. 2 (A1), (A2) and (A3) show longitudinal cross sectional views of three different profiles of the side weirs.

Referring particularly to (A1) of Fig. 2 the distance separating the side weirs (4-1) and (4-2) is (W1) when the level of molten lead surface there is set to (L1). Then, a cast steel slab having a width of (W1) is prepared in the apparatus. Similarly, a cast steel slab having a width of (W2) is prepared when the level of molten lead surface is raised to (L2).

Referring now to Fig. 1(A2) a cast steel slab having a width of (W1'), (W2') or (W3') can be prepared by setting a level of molten lead surface to (L1'), (L2') or (L3') respectively. Similarly, in Fig.1(A3) a cast steel slab having a width of (W1''), (W2'') or (W3'') can be prepared with the stepped profiles of the side weirs (4-1) and (4-2). In other words, with a pair of side weirs (4-1) and (4-2) having the profiles of any of (A1), (A2) or (A3), cast steel slabs having different widths can be manufactured.

Referring to Fig. 2 (A1), the height of the molten lead above the partition wall (S01) is (D1) when (L1) is selected for the level of molten lead surface On the other hand, Fig.2 (B1) shows a cross sectional view when (L3) is selected for the level of molten lead surface, using the same side weirs. Then, the height of the molten lead above the partition wall (S01) will be (D2), which is too large and can significantly reduce the effect of the partition wall (S01).

If such is the case, a partition block (10) as shown in Fig. 2 (B2) may be made to sink into the molten lead in the apparatus between the side weirs (4-1) and (4-2) in such a way that the direction indicated by arrows (C-C) is held in parallel with the side weirs (4-1) and (4-2) and rotated by 90° in the molten lead before the pushing force applied to it is released. Then, the partition block (10) is tend to move upward by the buoyancy exerted to it by the molten lead and caught by the side weirs (4-1) and (4-2) as shown in Fig. 1 (B1) so that the effective height of the partition wall (S01) is increased and the height of the molten lead above the partition wall (S01) is reduced to (D1).

Note that, in Fig. 2 (B2), (16-1) and (16-2) denote projections that are engaged with the respective side weirs (4-1) and (4-2) to anchor the partition block (10) in place.

Fig. 3 schematically illustrates another embodiment of continuous steel casting apparatus according to the invention. This embodiment is adapted to manufacture cast steel slabs with different widths. In Fig. 3 (A) shows a longitudinal cross sectional view and (B) shows a plan view without the sealing cover (9).

This embodiment comprises a molten lead tank (3) with a plurality of partition walls S1, ..., Sp (S1, S2, S3, S4) that define a plurality of lead chambers C1, ..., Cp+1 (C1, C2, C3, C4, C5) , which are filled with molten lead in such a way that the temperature of the molten lead in lead chamber Cm (e.g., C3) is higher than the solidifying point of steel and all the lead chambers located downstream to the lead chamber Cm (C4, C5) are filled with molten lead having a temperature lower than the solidifying point of steel while all the lead chambers located upstream to the lead chamber Cm (C1, C2) are filled with molten lead having a temperature higher or lower than the solidifying temperature of steel. The level of molten lead surfaces set exceeding the upper ends of all the partition walls (S1, S2, S3, S4) of the molten lead tank (3).

The embodiment also comprises a pair of side weirs (4-1) and (4-2) having lower portions immersed in molten lead and connected with each other at the inlet side ends via a connecting weir (17), said side weirs having stepped profiles and in each step they are arranged in parallel with each other or flared toward the outlet side end at an angle of less than 20° being separated from each other by distances W1, ..., Wp (W1<...<Wp) at the respective steps and in each step it extends sufficiently long from the corresponding partition wall Sn (e.g., S2) toward both the inlet side and the outlet side of the tank. The embodiment is additionally provided with a taking out device (5) arranged adjacent to the outlet side of the molten lead tank (3).

Assume that the chamber (C3) contains hot molten lead showing a temperature higher than the solidifying point of steel and molten steel is poured into the chamber (C3). Then, the molten steel in the chamber (C3) flows into the chamber (C4) and then into the chamber (C5) to make a cast steel slab having a width of (W3).

Although the molten steel poured into the chamber (C3) may partly flows into the chambers

(C1) and (C2) also, it will then flows back toward the chamber (C4) after the chambers (C1) and (C2) become full. If the chambers (C1) and (C2) contains molten lead having a temperature higher than the solidifying point of steel, molten steel in those chambers remains molten state during the operation of continuous casting whereas, if the chambers (C1) and (C2) contains molten lead having a temperature lower than the solidifying point of steel, molten steel in those chambers are solidified there.

In any case, however, the steel in the chambers (C1) and (C2) can be fully collected by means of the taking out device (5) in a manner as described earlier by referring to the embodiment of Fig. 1 because it is floating on the surface of the molten lead in the chambers (C1) and (C2). In the similar manner, a cast steel slab having a width of (W1) is obtained when the chambers (C2) and (C3) are filled with low temperature molten lead and molten steel is poured into the chamber (C1), whereas a cast steel slab having a width of (W3) is produced when the chambers (C2) and (C3) are filled with hot molten lead and molten steel is poured into the chamber (C1).

While a pair of side weirs (4-1) and (4-2) in the molten lead tank of Figs. 1 and 3 are separated from lateral wall of the tank, the lateral walls of the tank may be partly or wholly used as side weirs alternatively. Fig. 4 illustrates such an embodiment of continuous steel casting apparatus. In Fig. 4 (A1) through (A4) show that the apparatus comprises a single partition wall. Fig. 4 (B1) shows that the apparatus comprising four partition walls. The embodiment of Fig. 4 is functionally equivalent to those of Figs. 1 and 3.

Hot molten lead having a temperature higher than the solidifying point of steel has to be prepared before starting a casting operation. Such hot molten lead can be obtained by means of a lead heating furnace arranged separately or by a lead heater arranged in the lead chamber.

Alternatively, hot molten lead can be obtained by pouring low temperature molten lead with a temperature of, for example, 600 °C into a ladle containing a molten steel. As molten lead falls through molten steel in the ladle, the lead is heated by the steel in the ladle and gets to the same temperature with the steel in the ladle which is higher than the solidifying point of steel when it reaches to the bottom of the ladle.

Therefore, when the bottom of the ladle is opened, hot molten lead having a temperature higher than the solidifying point of steel flows out first and is followed by molten steel. In this way, hot molten lead having a temperature higher than the solidifying temperature of molten steel can be easily obtained. In this method, a hundred tons of molten steel is cooled by about 2.5 °C to heat a ton of molten lead from 600 °C to 1,600 °C.

[Industrial Applicability]

A continuous steel casting apparatus according to the invention is simple in structure, less expensive for installation and practically free from mechanical trouble because it does not use any traveling or rotating mold wall. Additionally, the solidified shell in the apparatus is not subject to any excessive force and the produced cast steel slab is not scraped since it does not contact with the a solid metal member. Thus, high quality cast steel slab can be manufactured with a continuous steel casting apparatus according to the invention. Finally, cast steel slab manufactured by a continuous steel casting apparatus according to the invention can be directly brought to a hot rolling process because they are hot and heat is evenly distributed in them.

List of Reference Numerals, Symbols, and Items

1:
molten steel
2:
cast steel slab
3:
molten lead tank
4-1, 4-2:
side weir
5:
taking out device
6:
tundish
7:
high-temperature molten lead above the solidifying point of steel
8:
low-temperature molten lead below the solidifying point of steel
9:
sealing cover
10:
partition block
11:
moving direction of cast steel slab (guide sheet)
12, 12':
outlet port of molten lead
13:
inlet port of molten lead
13':
inlet port of coolant
14:
sink roll
15:
scum weir
16-1, 16-2:

projection for anchoring partition block
17:
connecting weir
S01:
partition wall
S1, S2, S3, S4:
partition wall
C01, C02:
lead chamber
C1, C2, C3, C4, C5:
lead chamber

Claims

1. A continuous steel casting apparatus characterized in that it comprises a molten lead tank having 2 lead chambers (C01) and (C02) being divided by a partition wall (S01) arranged between the inlet side and the outlet side of the molten lead tank, the inlet side lead chamber (C01) containing molten lead having a temperature higher than the solidifying point of steel, the outlet side lead chamber (C02) containing molten lead having a temperature lower than the solidifying point of steel, the molten lead tank being filled with molten lead to a level higher than the upper end of the partition wall (S01), a pair of side weirs having lower portions immersed into the molten lead and connected with each other at the inlet side ends thereof, the pair of side weirs extending sufficiently long from the partition wall (S01) toward both the inlet side and the outlet side of the molten lead tank and being arranged in parallel with each other with a distance of (WO) separating them from each other or flared toward the outlet side at an angle of not exceeding 20° with a mean distance of (W0) separating them from each other, and a taking out device arranged adjacent to the outlet side of the molten lead tank, and the upper space of the lead chamber (C01) is held in a non-oxidizing atmosphere.

2. A continuous steel casting apparatus according to claim 1, characterized in that the inner surface of either one or both of the pair of side weirs is a stepped surface receding toward the top or the bottom.

3. A continuous steel casting apparatus characterized in that it comprises a molten lead tank having a plurality of lead chambers C1, ..., Cp+1 being divided by a plurality of partition walls S1, ..., Sp arranged between the inlet side and the outlet side of the molten lead tank, one of said lead chambers Cm being filled with molten lead having a temperature higher than the solidifying point of steel, all the lead chambers located downstream to the lead chamber Cm being filled with molten lead having a temperature lower than the solidifying point of steel, all the lead chambers located upstream to the lead chamber Cm being filled with molten lead having a temperature higher or lower than the solidifying temperature of steel, the molten lead tank being filled with molten lead to a level higher than the upper ends of all the partition walls , a pair of side weirs having lower portions immersed into the molten lead and connected with each other at the inlet side ends thereof, the side weirs having stepped configurations of separating them each other with a successively formed stepwise distances of W1, ..., Wp (W1<...<Wp) from the inlet side to the outlet side of the molten lead tank, each step of W1, ..., Wp width being arranged in parallel with each other or flared toward the outlet side at an angle of less than 20° , each step extending sufficiently long from the corresponding partition wall Sn toward both the inlet side and the outlet side of the lead tank, and a taking out device arranged adjacent to the outlet side of the molten lead tank and the upper space of the lead chambers containing high-temperature molten lead is held in a non-oxidizing atmosphere.

4. A continuous steel casting apparatus according to claim 1, 2 or 3, characterized in that part or all of the side walls of the molten lead tank are constituted by side weirs.

Fig. 1

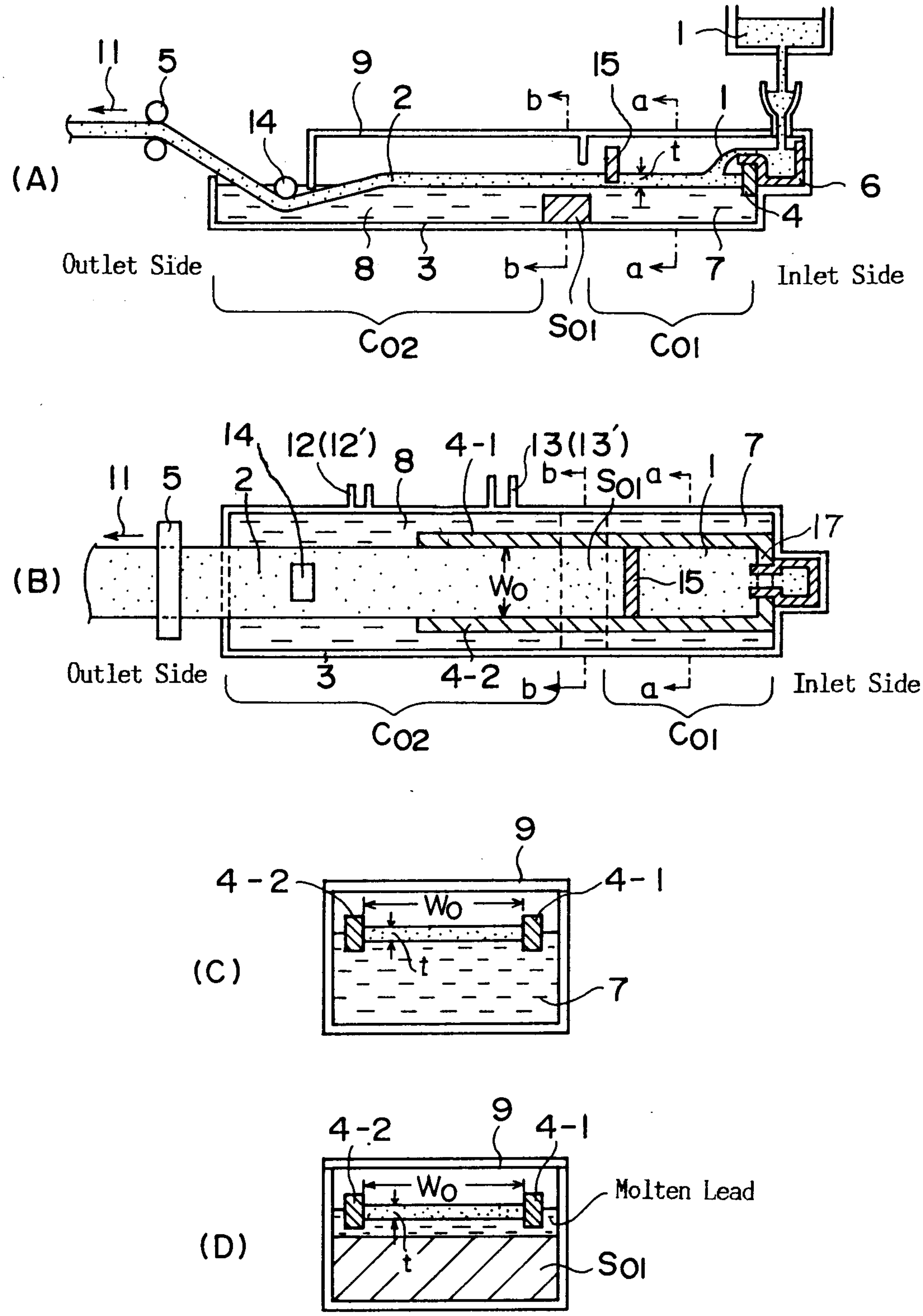

(A)
11
5
9
2
14
15
b
a
t
1
6
4
Outlet Side
8
3
b
a
7
Inlet Side
Co2
So1
Co1
(B)
14
12(12')
8
4-1
13(13')
7
11
5
2
b
So1
a
1
17
Wo
15
Outlet Side
3
4-2
b
a
Inlet Side
Co2
Co1
(C)
9
4-2
4-1
Wo
t
7
(D)
9
4-2
4-1
Wo
Molten Lead
t
So1

Fig.2

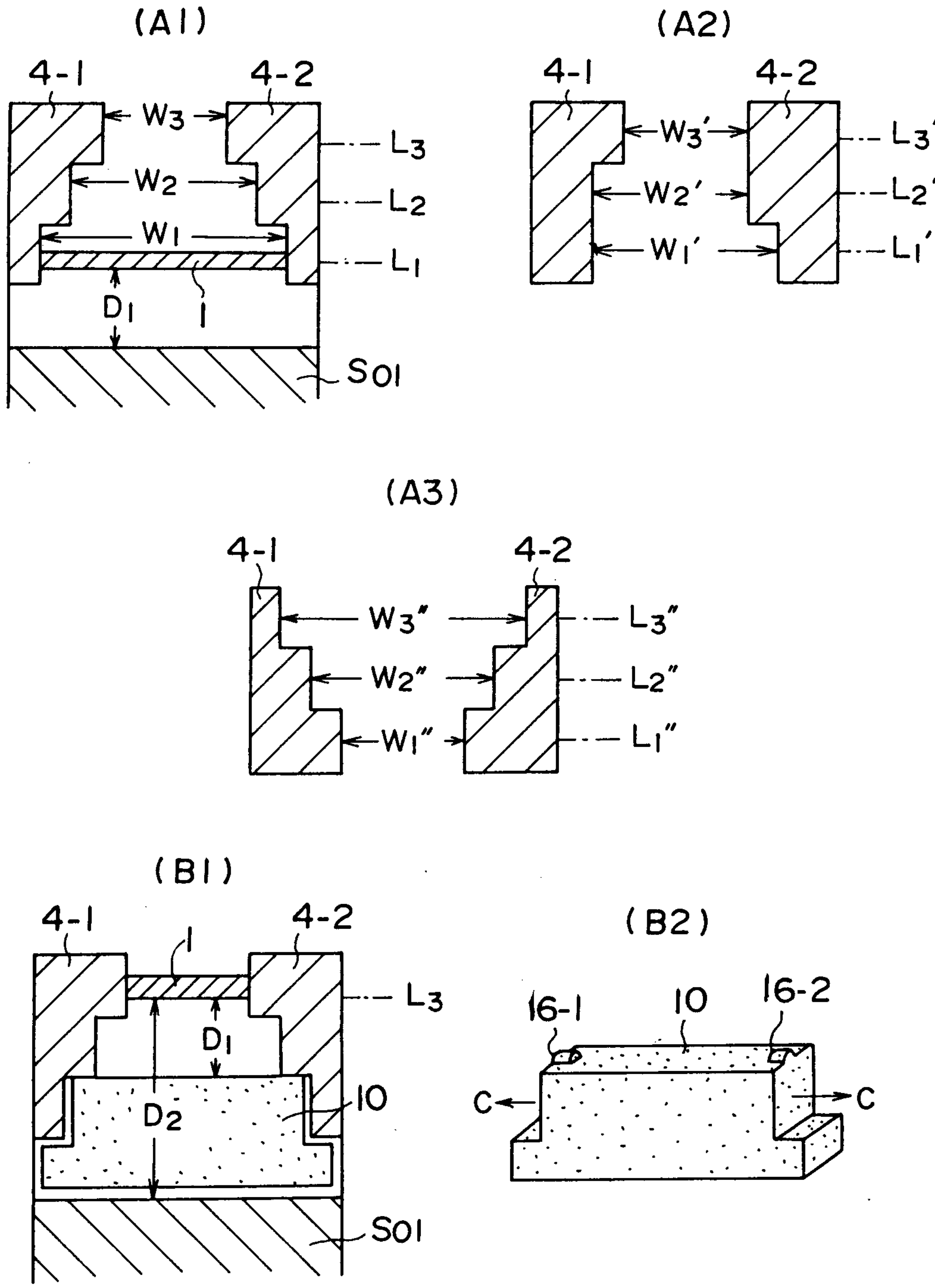
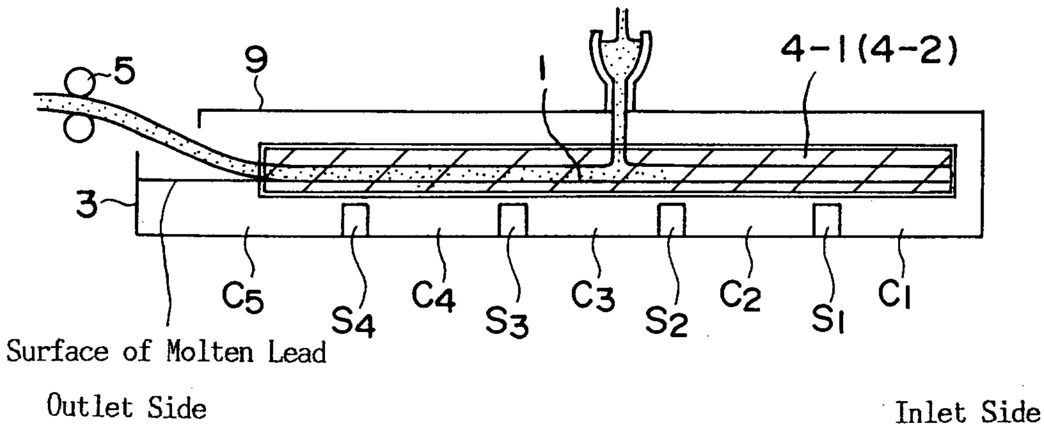

(A1)
4-1
4-2
W3
W2
W1
L3
L2
L1
D1
1
S01
(A2)
4-1
4-2
W3'
W2'
W1'
L3'
L2'
L1'
(A3)
4-1
4-2
W3"
W2"
W1"
L3"
L2"
L1"
(B1)
4-1
4-2
1
L3
D1
D2
10
S01
(B2)
16-1
10
16-2
C
C

Fig.3

(A)


5
9
1
4-1(4-2)
3
C5
S4
C4
S3
C3
S2
C2
S1
C1
Surface of Molten Lead
Outlet Side
Inlet Side

(B)

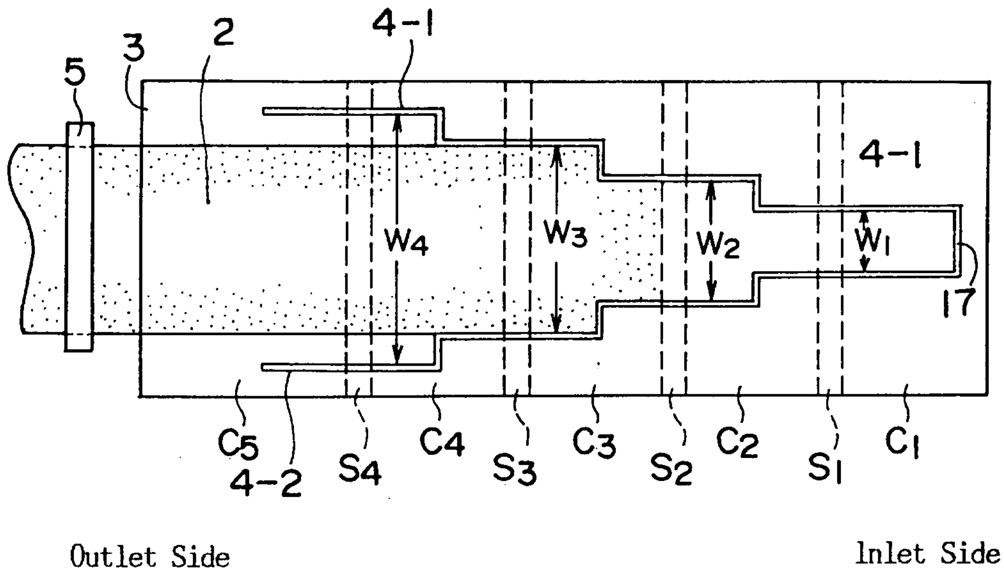
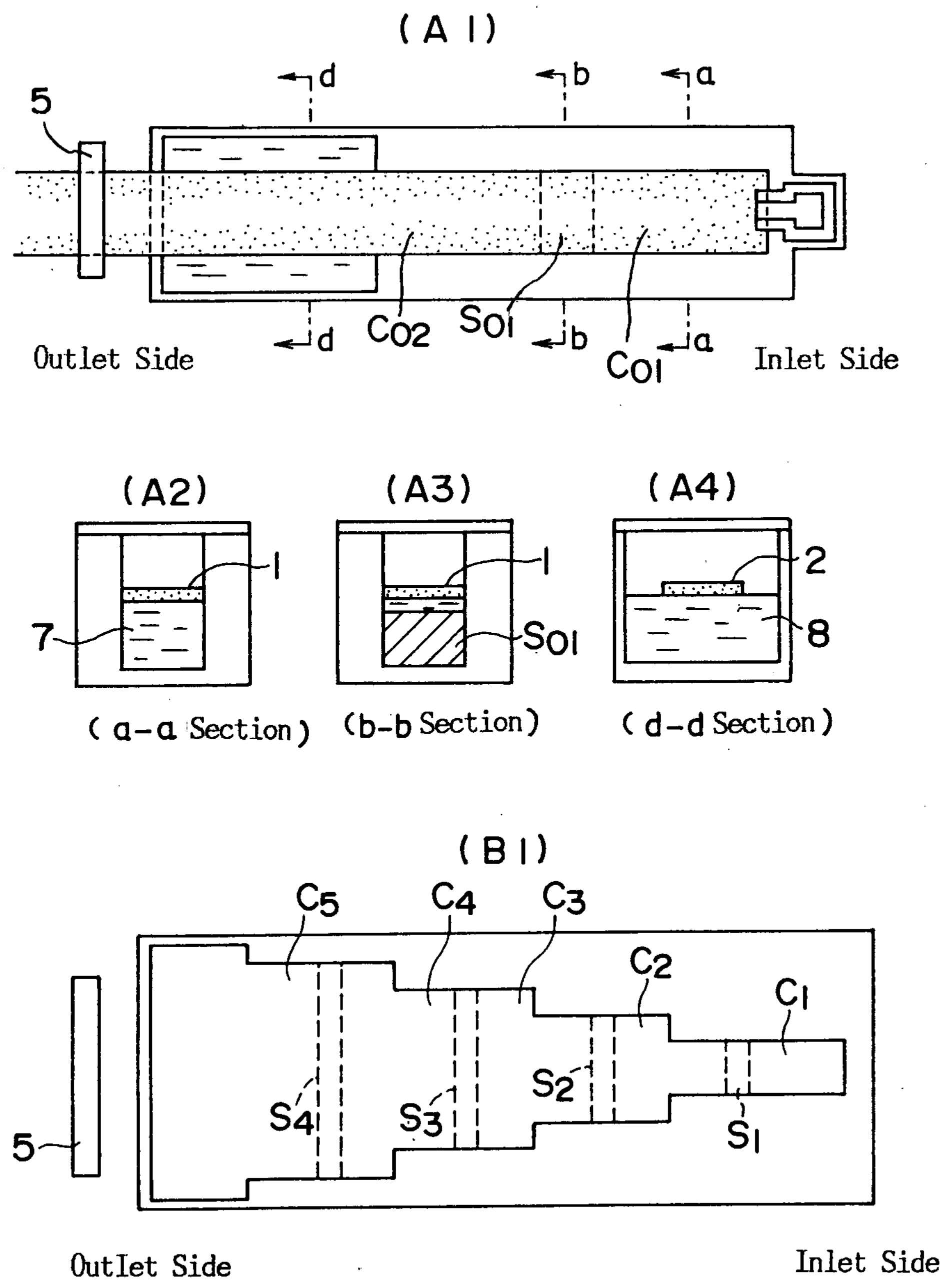

5
3
2
4-1
4-1
W4
W3
W2
W1
17
C5
4-2
S4
C4
S3
C3
S2
C2
S1
C1
Outlet Side
Inlet Side

Fig.4


(A1)
d
b
a
5
CO2
SO1
CO1
Outlet Side
Inlet Side
(A2)
(A3)
(A4)
1
7
SO1
2
8
(a-a Section)
(b-b Section)
(d-d Section)
(B1)
C5
C4
C3
C2
C1
S4
S3
S2
S1
5
Outlet Side
Inlet Side

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP93/01659

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^5 B22D11/01

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl^5 B22D11/01

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

Jitsuyo Shinan Koho 1926 - 1993
Kokai Jitsuyo Shinan Koho 1971 - 1993

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, A, 59-42163 (Nippon Steel Corp.), March 8, 1984 (08. 03. 84), (Family: none)	1-4
A	JP, A, 58-74249 (Mitsubishi Heavy Industries, Ltd.), May 4, 1983 (04. 05. 83), (Family: none)	1-4
A	US, A, 3,845,811 (Terrell Co.) November 5, 1974 (05. 11. 74), (Family: none)	1-4

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
January 13, 1994 (13. 01. 94)	February 1, 1994 (01. 02. 94)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.