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## (54) Continuous casting method and apparatus therefor

(57) The invention relates to a method and apparatus for continuous casting of metal, comprising pouring the molten metal from a tundish into a mould through a tap hole in a base wall of the tundish, and wherein first and second tundishes and associated corresponding first and second nozzle means, are used to enable the flow of molten metal to be continuous or nearly continuous, such that when one of the first tundish is required to be changed it is moved into a changeover position, wherein both the first and second tundishes are in position over the mould so that metal may flow from both tundishes simultaneously into the mould, with the nozzle means immersed in the molten metal in the mould.

The combined flow from the first and second tundishes is approximately equal to the required full flow from one tundish. The second tundish is moved with the first tundish, in the same direction such that a second tap hole is over the mould so that molten metal flows from the second tundish into the mould. The flow from the first and second tundishes is regulated so that the combined flow rate does not exceed a prescribed rate.

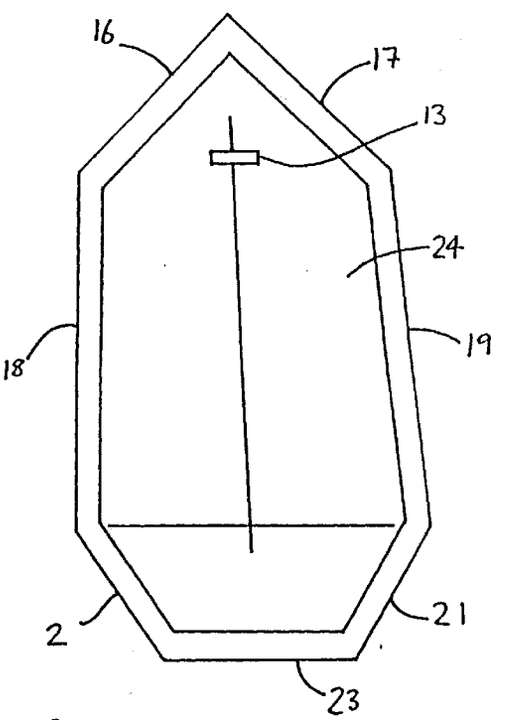


fig. 9.

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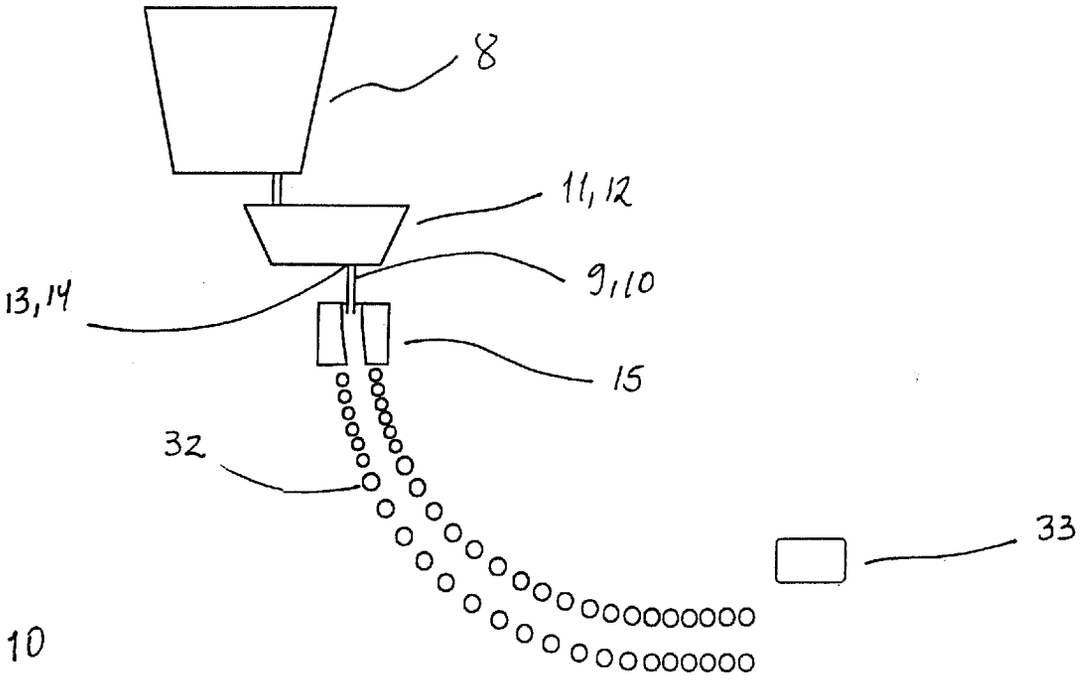


Fig. 10

## Description

The present invention relates to a continuous casting method and apparatus therefore including a new tundish design for ensuring the continuous casting method may be continued for long casting runs with minimised interruption.

In the continuous casting of metals and in particular steel it is advantageous to extend the length of the cast. This provides two main advantages. Firstly, it maximises the duration of the steady state conditions when the best product quality is achieved and this in turn reduces the amount of scrap steel produced typically from the beginning and end portions of a casting run which are not of sufficiently quality and it also improves the overall quality of the finished product. Secondly production levels are maximised and the existing plant and equipment is able to be utilised to a greater extent which improves the return on investment.

There is an additional advantage in that the length of the cast can be optimised with the duration of the available life from the wear components in the casting process which can be changed at the end of each cast. Thus if the cast is long enough the full life of the main wear components can be used which reduces downtime and the cost of replacement of the wear parts.

During the casting process metal is poured through a tap hole in a vessel and this vessel is typically in the form of a tundish. In order to extend the desired casting time it is necessary to replace the tundish a number of times after each time its life is expended. In particular for the casting of ferrous metals such as steel, the high temperature chemical aggression and physical erosion of the refractory material of the tundish permits the tundish to run continuously for only short periods before they have to be exchanged cleaned of slag and relined. Thus it is necessary to changeover the tundish a number of times in order to continuously cast the steel over a long period. Such tundish changes are sometimes known as flying tundish changes.

A known method of changing over tundishes and a tundish used is shown in figures 1 to 3. In figure 1 the first tundish is in the casting position over the mould and the second tundish 2 is in a "waiting to cast" position to one side. When it is time to change the first tundish 1, the first tundish 1 remains in the casting position until all the metal in the first tundish 1 is poured into the mould 5. The tap hole is then closed and the first tundish 1 is moved sideways to a parking position as shown in figure 2. Simultaneously the second tundish is moved sideways from a pre-fill position into the casting position over the mould 5. When it is in the desired casting position, as shown in figure 3, it is filled with metal and its tap hole is opened and casting can recommence.

This conventional tundish changeover method is acceptable for standard conventional continuous casting runs. In such runs a strand which is essentially parallel is formed during the solidification process of the continuous casting operation. With this process, because of the maximum length allowed in the continuous casting machine for solidification and because the strand is essentially parallel, there is enough flexibility to slow down the machine to allow a strand stoppage. Typically such a conventional continuous casting machine would have sufficient flexibility to allow a strand stoppage of up to three minutes which allows the tundish change to takes place.

GB 1145860 discloses an apparatus and method for the continuous casting of metal having tundishes which, as the time for changeover of the tundish approaches, pour metal continuously into the mould. This is achieved by the use of refractory chutes which, in this simultaneous pouring stage, transfers the molten metal from the nozzle of the tundishes to the mould. Thus metal is continuously poured whilst the tundish is changed over. The problem with this method however is that the chutes get clogged up with molten metal because it is difficult to maintain a sufficiently high temperature in the chute. Also oxidation of the metal occurs in the chute which results in diminished quality of the final product and loss of yield. The molten metal falls from the chute into the mould through the opening 90.

There are additional significant disadvantages with all the above conventional methods. It is not possible to increase the casting speed significantly without causing significant interruption problems. Additionally there are interruption problems with lower strand thicknesses. Additionally, and more recently casting machines have been developed which are tapered such that the cast section is gradually reduced after initial forming in the mould and before final solidification. These circumstances mean that it is not possible to slow down or stop the casting process for a sufficient length of time to allow the conventional flying tundish change method and therefore long runs are not possible for these specific circumstances.

It is therefore an objective of the invention to provide a tundish change method and an apparatus therefore and tundish shape which enables long casting runs for reduced strand thickness as well as for tapering of the casting machine. It is also an objective of the invention to provide a tundish change method and tundish therefore which allows long casting runs to be continuous and uninterrupted at increased speeds.

According to the invention there is provided a method of continuous casting of metal, comprising pouring the molten metal from a tundish into a mould through a tap hole in a base wall of the tundish, and wherein first and second tundishes each comprising a corresponding first and second tap hole and associated first and second nozzle means, are used to enable the flow of molten metal to be continuous or nearly continuous, such that when one of the first tundish is required to be changed it is moved into a first tundish changeover position, and the second tundish is moved into a second tundish changeover position, and wherein in the changeover po-

sition both the first and second tundishes are in position over the mould so that metal may flow from both tundishes simultaneously into the mould, characterised in that in the changeover position the first and second nozzle means of the first and second tundishes are immersed in the molten metal in the mould.

In the first stage of the preferred method of the invention a first tundish in the casting position is positioned over the mould so that molten metal can flow through the tap hole into the mould. The first tundish is typically located 400 mm above the mould and a pouring tube directs the flow of metal from the tundish into the mould. A second tundish is in a position alongside the first tundish in the plan view.

In the second stage of the method of the invention, which occurs when the level of the molten metal in the first tundish has reached a pre-determined low level, the second tundish is lowered to the level of the fill position, which is in a preferred embodiment approximately 400 mm above the mould. Then both the first and second tundishes are positioned so that the tap hole of the second tundish is also located over the mould. Although the first tap hole has been moved sideways with the first tundish, it nevertheless is still in a position over the mould and molten metal is still flowing into the mould from the first tundish. The tap hole of the second tundish is then opened so that molten metal flows from the second tundish into the mould. Preferably the flow from the first and second tundishes will be regularised so that is does not exceed a prescribed rate which is preferably the same rate as a single tap hole when fully open. The flow rate is preferably regulated by tap hole valves which may be controlled by suitable control systems. Preferably this stage is maintained until the first tundish is emptied at which point the flow from its tap hole is zero and the flow from the second tundish tap hole is correspondingly regulated to the required full flow.

Preferably the tap holes of the fist and second tundishes are arranged symmetrically on either side of a centreline of the mould.

According to a subsequent third stage of the method of the invention, when the first tundish is empty its tap hole is closed and it is raised above the level of the fill position and moved to a park position. The second tundish is then able to be moved sideways to a position where the tap hole of the second tundish is positioned centrally in the mould. This is the preferred position when the whole of the flow is coming from a single tundish.

According to a fourth stage of the method of the invention, the first tundish is located in the side ways to a parking position above the fill level which permits a third tundish to be moved into position ready for the cycle to be repeated again.

According to the invention there is also provided a continuous casting apparatus for carrying out the method described above. The apparatus comprises the two tundishes which are so shaped as to each have top sides which when the tundishes are arranged so that the corresponding sides of each tundishes are abutting, the tap holes of the corresponding tundishes are close to each other. This enables pouring to occur simultaneously from both of the tap holes into the mould for casting strands with a strand width which is at least as wide as the distance between the respective tap holes.

According to the invention there is also provided a tundish which comprises sides two front sides, two long sides, two short sides and a rear side, a base and an open or closed top. The tap hole is arranged at the top end of the tundish in the base so that molten metal flows out downwardly, into the paper as shown, into the mould. The base comprises slightly angled surfaces, angled towards the tap hole, to enable the molten metal to flow towards the tap hole. The tundish is so arranged so that the tap hole is a close as possible to the front sides so that the distance between the tap holes of corresponding tundishes when in the position when both tundishes are pouring simultaneously, is minimised. The front sides could be arranged to be non-symmetrical and at any desired angle.

One side may be more acute angle to make that side closer to the tap hole. Preferably the top sides are symmetrical and forming an apex of 90 degrees.

There now follows a more detailed description of a specific embodiment of the method and apparatus according to the invention with the help of the attached drawings in which:

Fig. 1 is a plan view of a first stage the existing tundish change method,

Fig. 2 is a plan view of a second stage of the existing tundish change method,

Fig. 3 is a plan view of a third stage of the existing tundish change method,

Fig. 4 is a plan view of the apparatus of the embodiment of the invention in a first stage of the method of the invention,

Fig. 5 is a plan view of the apparatus of the embodiment of the invention in a second stage of the method of the invention,

Fig. 6 is a plan view of the apparatus of the embodiment of the invention in a third stage of the method of the invention,

Fig. 7 is a plan view of the apparatus of the embodiment of the invention in a fourth stage of the method of the invention,

Fig. 8 is an enlarged plan view of the apparatus of the embodiment of the invention,

Fig. 9 is an enlarged plan view of the tundish of the apparatus of the embodiment of the invention, and

Fig. 10 is an elevation of the casting apparatus of the present invention.

Figures 1 to 3 showing a conventional method of tundish changeover as described above. When the first tundish 1 is expended the tap hole 3 is closed and the first tundish 1 is moved to the left to a parking position. Simultaneously the second tundish 2 is moved into the moulding position and its tap hole 4 is opened and the flow of molten metal into the mould recommences. It is clear to see that with this method the flow of molten metal into the mould is actually stopped for the period of time it takes to carry out these steps from the closing of the tap hole 3 to the opening of the tap hole 4.

Referring now to figures 4 to 7, the apparatus according to the embodiment of the invention is shown as well as four stages of the method of the invention. In figure 4 a first tundish 11 is shown in the casting position and is positioned over the mould 15 so that molten metal can flow through the tap hole 13 into the mould 15. The first tundish 11 is typically located 400 mm above the mould and a pouring tube, or nozzle means, directs flow to the mould. In this casting position the first tundish is arranged so that the pouring tube is arranged centrally in the mould and is immersed in the molten metal. The tap hole 13 is fully open. A second tundish 12 is in a position alongside the first tundish 11 in the plan view. This position is called a pre-casting position.

Referring now to figure 5 a second stage in the method of the invention is shown which occurs when the level of the molten metal in the first tundish 11 has reached a pre-determined low level. The second tundish 12 is then positioned at a mould filling position, which is approximately 400 mm above the mould. Additionally both the first and second tundishes are moved sideways to corresponding changeover position, in which the tap hole 14 of the second tundish 12 is also positioned over the mould 15. Although the first tap hole 13 has been moved sideways with the first tundish 11, it nevertheless is still also in a position over the mould 15 and molten metal is still flowing into the mould from the first tundish 11. The tap hole 14 of the second tundish 12 is then opened so that molten metal flows from the second tundish into the mould 15. At this point molten metal is flowing from both the first and second tundishes into the mould. The flow will be regularised so that is does not exceed a prescribed rate which is preferably the same rate as a single tap hole when fully open. So the flow rate will be made up of a portion of the flow rate from tap hole 13 and a portion of the flow rate from tap hole 14. This could be for example half of the normal flow rate from each of the tap holes 13, 14. The flow rate is regulated by tap hole valves which are known in the art and which may be controlled by suitable control systems, which would also be apparent to the person skilled in the art, so that the desired flow from any one tap hole and hence the total flow can be controlled. This stage is maintained until the first tundish 11 is emptied at which point the flow from tap hole 13 is zero and the flow from tap hole 14 is correspondingly increased to full flow, i.e. it is opened completely. The flow of the molten metal into the mould has therefore been maintained at a constant flow rate and there has been no interruption, or essentially no interruption, in the flow rate during the changeover of the tundishes.

Referring now to figure 6, the first tundishes 11 is moved upwardly above the fill level out of the paper in figure 6 to permit the second tundish 12 to move to a position where the tap hole 14 of the second tundish 12 is positioned centrally in the mould 15. This is the preferred position when the whole of the flow is coming from a single tundish.

Referring now to figure 7, the first tundish 11 is then moved side ways (to the left in figure 7) to a parking position so that a third tundish can be moved into position ready for the cycle to be repeated again.

Referring now to figure 8 an enlarged view of the continuous casting apparatus of the invention is shown in the changeover position when both tundishes are pouring molten metal, into the mould just before one of them is emptied and moved out of position. It can be seen from the figure that the apparatus comprises the two tundishes 11, 12 which are so shaped as to each have top sides 16, 17 which when the tundishes are arranged so that the corresponding sides of each tundishes are abutting, the tap holes 13, 14 of the corresponding tundishes are close to each other. It will be appreciated that when the tundishes are compared to the tundishes of the prior art it can be seen that the distance between the corresponding tap holes of the prior art tundishes is much greater. This enables pouring to occur simultaneously from both of the tap holes into the mould 15 for casting strands with a strand width which is at least as wide as the distance between the respective tap holes 13, 14.

Referring to figure 9 an enlarged view of a single tundish of the invention is shown which comprises sides two front sides 16, 17, two long sides 18, 19 two short sides 21, 22 and a rear side 23. The tap hole is arranged at the top end of the tundish 11 in the base so that molten metal flows out downwardly, into the paper as shown, into the mould. The base 24 comprises surfaces which are angled towards the tap hole. The tundish is so arranged so that the tap hole 13 is a close as possible to the front sides 16, 17 so that the distance between the tap holes 13, 14 of corresponding tundishes when in the position in figure 8, is minimised. It will be appreciated that within the scope of the invention the top sides could be arranged to be non-symmetrical and at any desired angle. One side could for instance be made at and significantly more acute angle to make that side closer to the tap hole 13 so that when it is abutted against a cor-

responding side of a second tundish the distance between the corresponding tap holes is reduced. The embodiment shown however, with the top sides symmetrical and forming an apex of 90 degrees, has the advantage that the tundishes can be used from either side which simplifies the changeover operation and reduces the required inventory of spare tundishes. It will be appreciated that the apex could be at an alternative desired angle.

In order that even narrower strands of mould can be accommodated using the present invention to avoid any interruptions to the flow, it is possible to provide an angled pouring tube which directs the flow of molten metal from the tap hole inwardly into the narrow mould. Thus moulds for strands which are narrower than the distance between the tap holes of corresponding tundishes can be used.

Referring now to fig. 10 a side elevation of the apparatus, is shown to show the complete operation of the casting apparatus and method of the invention. The tundishes 11, 12 are charged from a ladle 8 as shown schematically in fig.10. In the 11, 12 have corresponding pouring tubes 9, 10 which are immersed in the molten metal in the mould 15. The tundishes are shown in fig. 10 in their corresponding changeover positions with both tundishes 11, 12 discharging metal and both pouring tubes 9, 10 immersed in the molten metal in the mould 15. When the first tundish 11 is empty it is closed and moved upwards in figure 10 and then sideways out of the page in fig. 10 to a parking position allowing the second tundish to adopt a central poring position over the mould and a new tundish to ready to be moved into the moulding positions when the second tundish is nearly empty. So in the same way as with the second tundish the new tundish adopts a changeover position when the second tundish is nearly empty with both tundishes pouring, followed by a central pouring position when the second tundish has moved off to its parking position.

After exiting the mould 15 the molten metal enters a series of casting rolls forming a strand support 32 during which the metal solidifies completely and then enters the subsequent operational steps 33 as a fully cast strand or slab.

## Claims

1. A method of continuous casting of metal, comprising pouring the molten metal from a tundish into a mould through a tap hole in a base wall of the tundish, and wherein first and second tundishes, each comprising a corresponding first and second tap hole and associated corresponding first and second pouring nozzle means, are used to enable the flow of molten metal to be continuous or nearly continuous, such that when the first tundish nears the time when it is required to be changed, it is moved into a first tundish changeover position, and the second tundish is moved into a second tundish changeover position, and wherein in the corresponding changeover positions both the first and second tundishes are in position over the mould so that metal may flow from both tundishes simultaneously into the mould, characterised in that during pouring in the corresponding changeover positions the first and second nozzle means of the first and second tundishes remain immersed in the molten metal in the mould.

2. A method of continuous casting of metal, comprising pouring the molten metal from a tundish into a mould through a tap hole in a base wall of the tundish, and wherein first and second tundishes each comprising a corresponding first and second tap hole and associated corresponding first and second pouring nozzle means, are used to enable the flow of molten metal to be continuous or nearly continuous, such that in a first stage, the first tundish is arranged in a casting position with its pouring nozzle arranged essentially centrally over the mould and metal is cast from the first tundish into the mould, and in a second stage, when the first tundish nears the time when it is required to be changed it is moved into a first tundish changeover position, and the second tundish is moved into a second tundish changeover position, and wherein in the corresponding changeover positions both the first and second tundishes are in position over the mould so that metal may flow from both tundishes simultaneously into the mould until, in a third stage, when the first tundish is emptied, it is moved from its changeover position and the second tundish is moved to the casting position with its pouring tube arranged centrally in the mould.

3. A method according to claim 1 or 2 characterised in that the combined flow from the first and second tundishes is approximately equal to the required full flow from one tundish.

4. A method according to claim 1, characterised in that the flow from the first and second tundishes is maintained until the first tundish is emptied at which point the flow from its tap hole is zero and the flow from the second tundish tap hole is correspondingly regulated to the required full flow.

5. A method according to claim 4, characterised in that the first tundish is then closed and raised and moved away to a parking position, in which position a further third tundish can be moved into position over the mould ready for the cycle to be repeated again.

6. A continuous casting apparatus for carrying out the method described in claim 1, the apparatus com-

prising at least two tundishes which are so shaped as to each have front sides which, when the tundishes are arranged so that the corresponding front sides of each tundishes are abutting, the tap holes of the corresponding tundishes are close enough to each other to enable pouring to occur simultaneously from both of the tap holes into the mould for casting strands with a strand width which is at least as wide as the distance between the respective tap holes.

**7.** An apparatus according to claim 6, characterised in that a tap hole valve is arranged to correspond with the tap holes of each tundish to control the flow rate.

**8.** An apparatus according to claim 6, characterised in that at least one of the tundishes comprises two front sides, two long sides and a rear side, a base and an open or closed top and a tap hole arranged at the top end of the tundish in the base so that molten metal flows out downwardly, into the mould, the base comprising at least one angled surface, angled towards the tap hole, to enable the molten metal to flow towards the tap hole, the tundish is so arranged so that the tap hole is as close as possible to the top sides so that the distance between the tap holes of corresponding tundishes when in the position when both tundishes are pouring simultaneously, is minimised.

**9.** A tundish according to claim 6, characterised in that the front sides are symmetrical.

**10.** A tundish according to claim 6, characterised in that the front sides form an apex of 90 degrees.

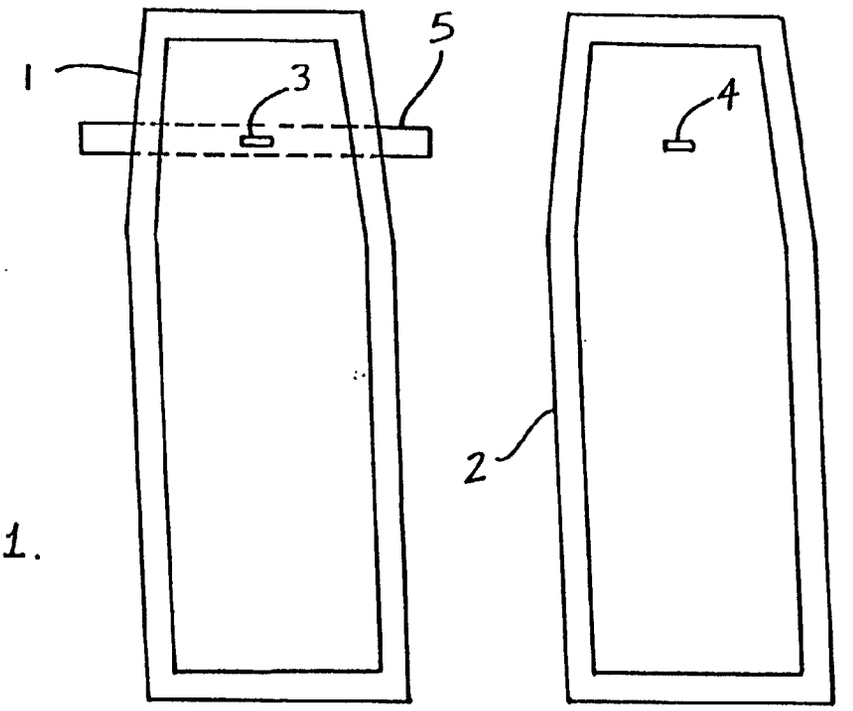


fig. 1.

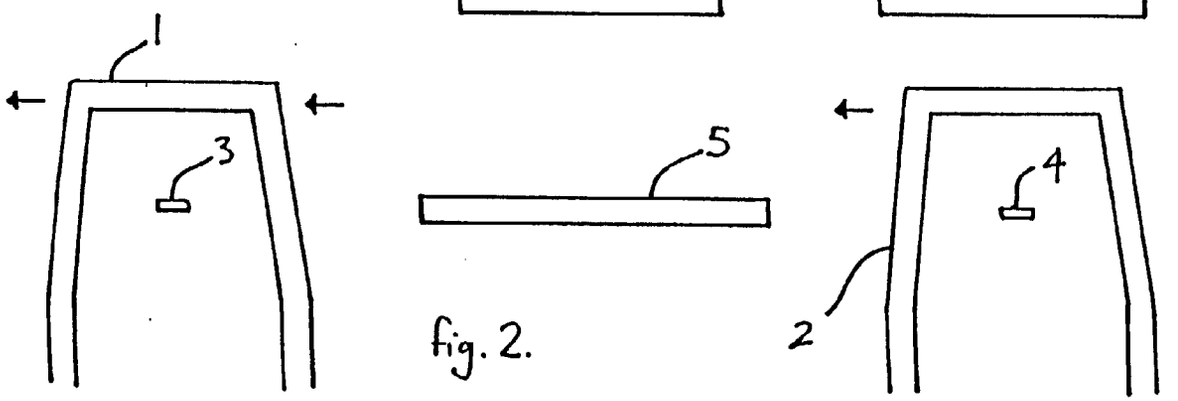


fig. 2.

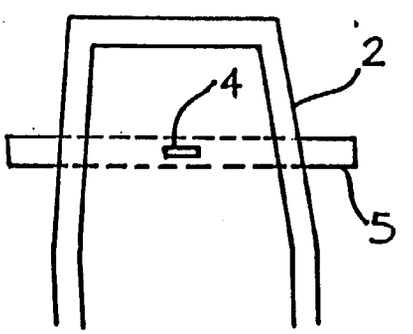


fig. 3.

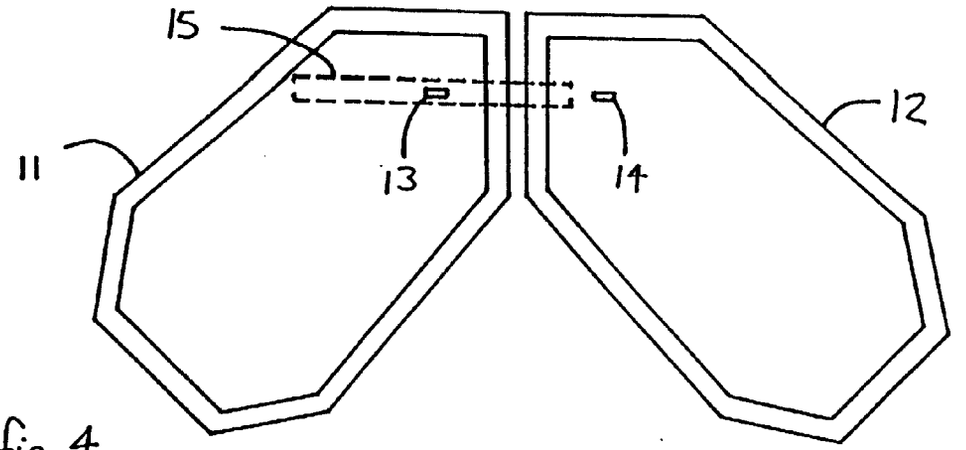


fig. 4.

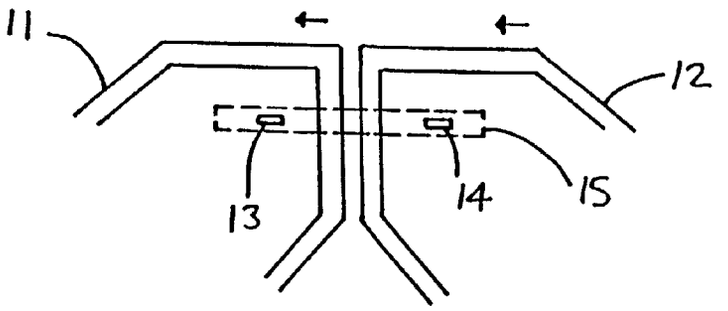


fig. 5.

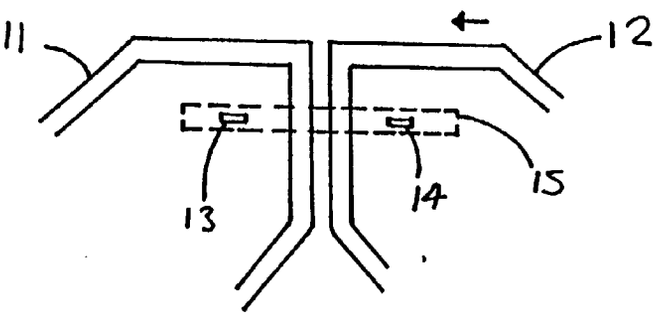


fig. 6.

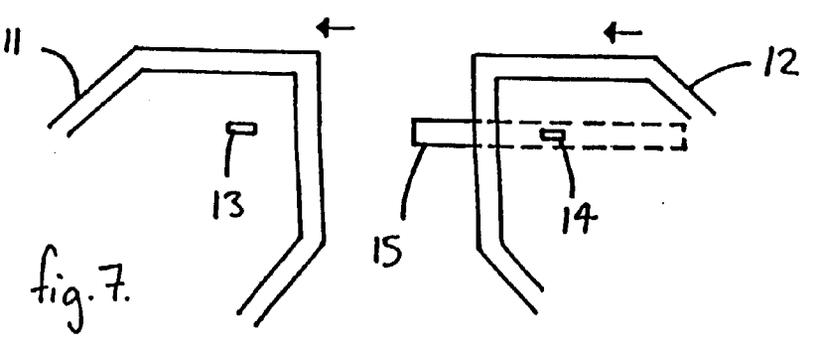


fig. 7.

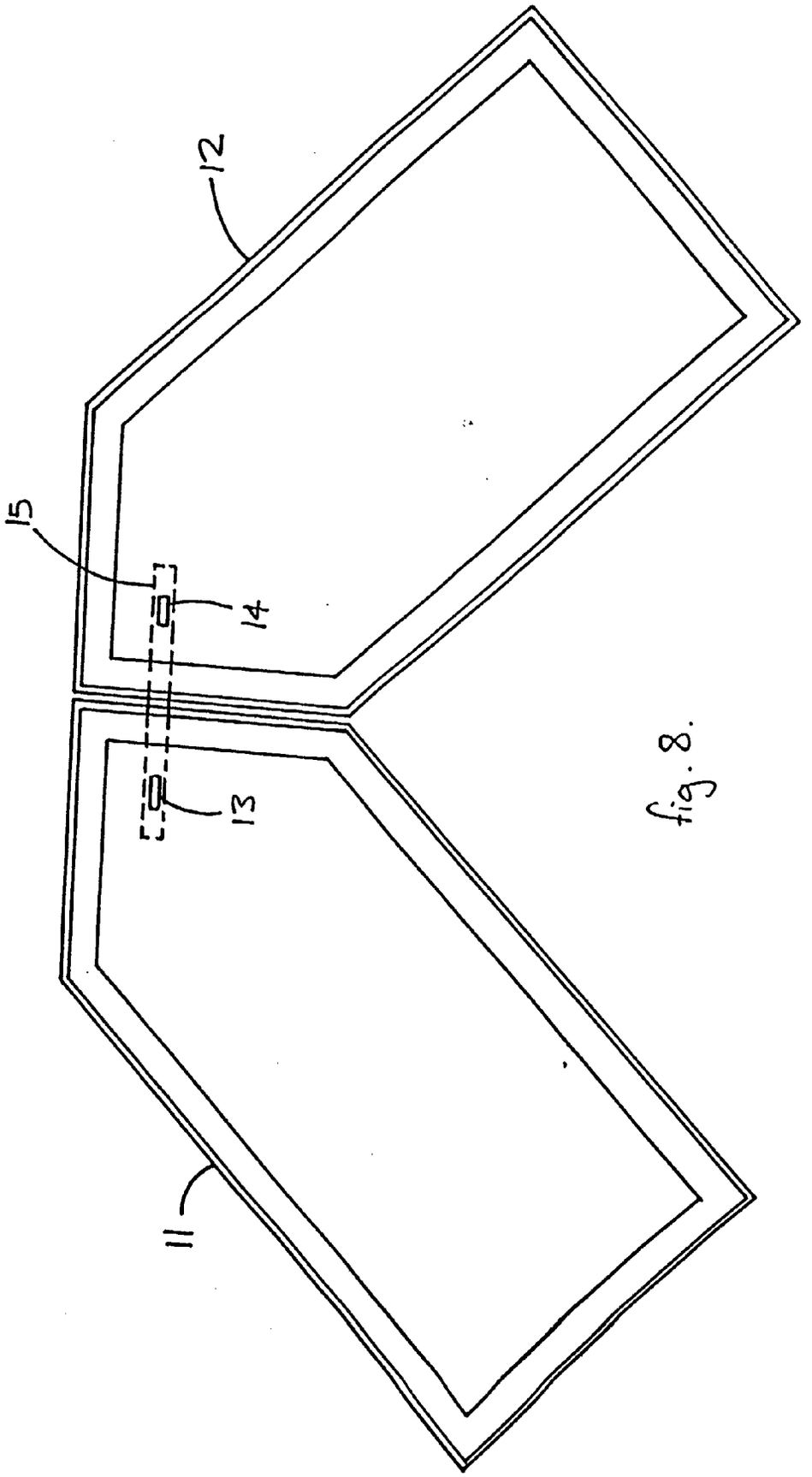


fig. 8.

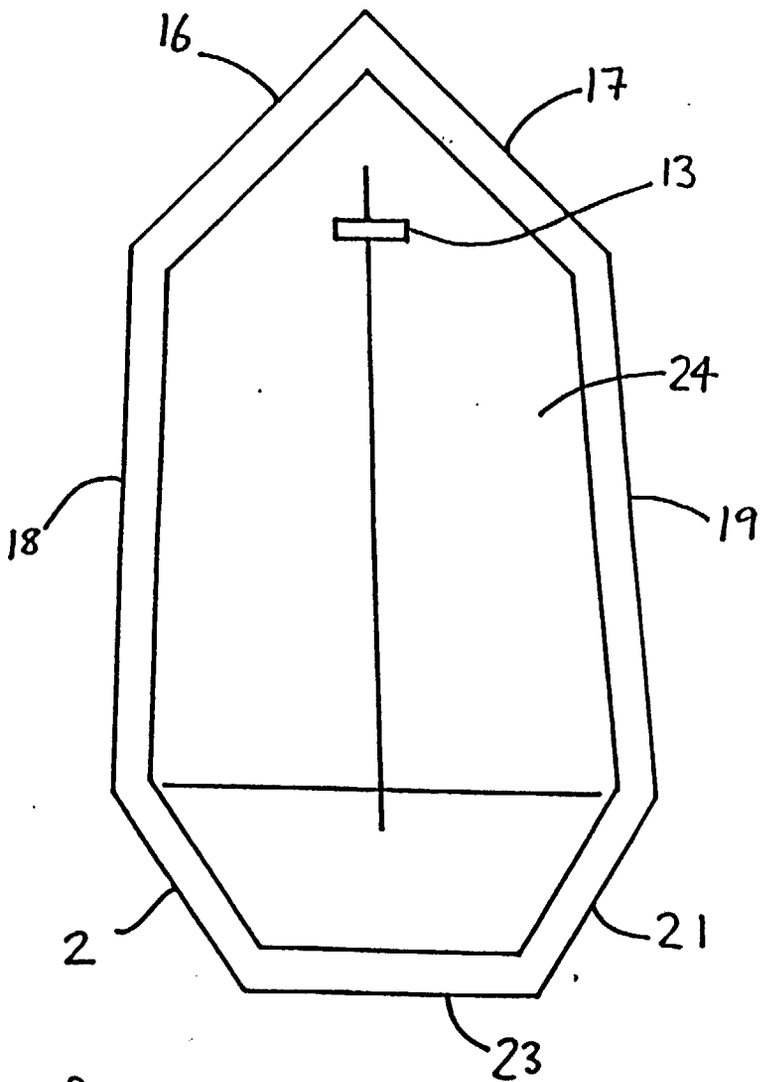


fig. 9.

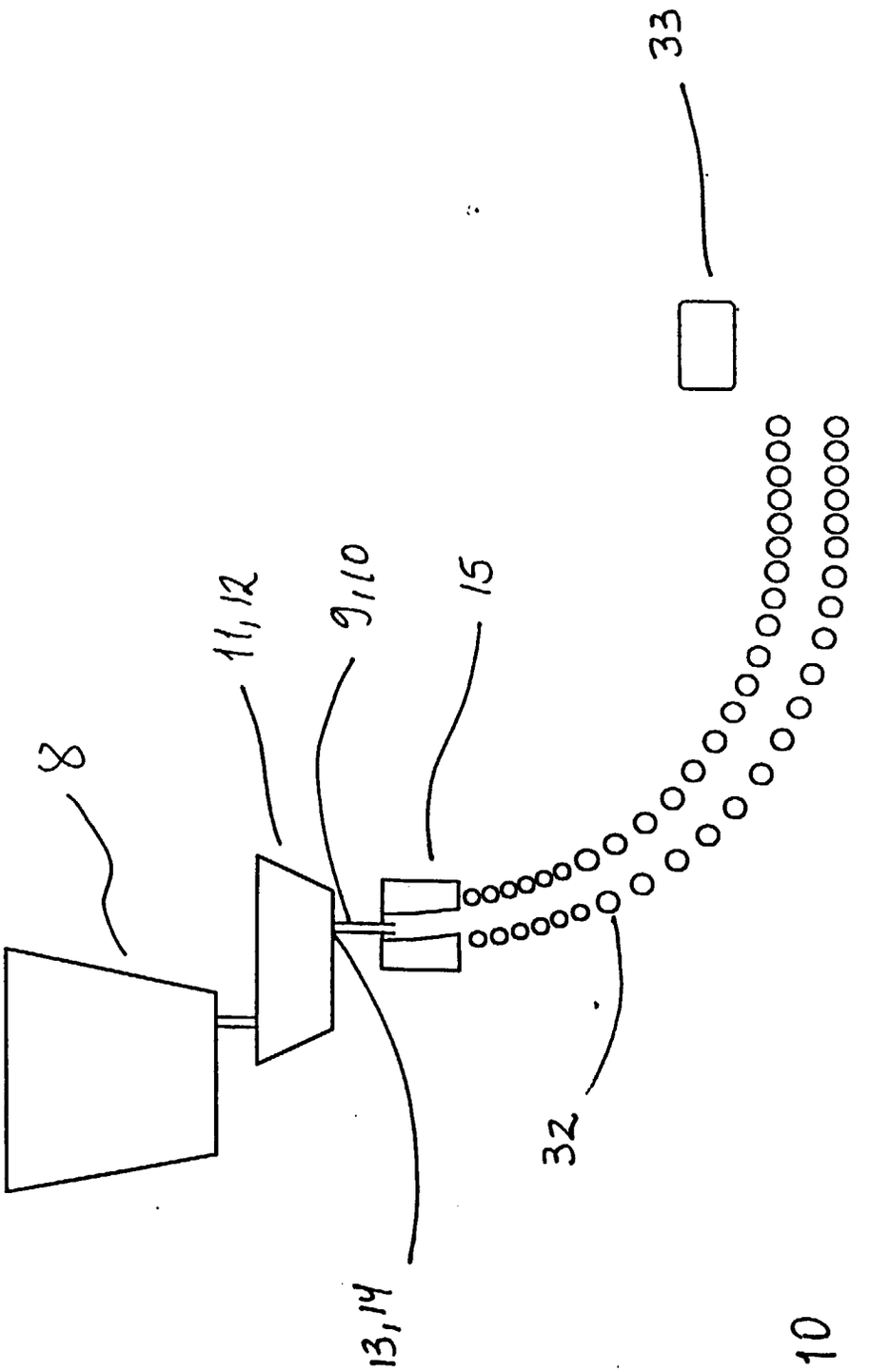


Fig. 10

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number
EP 98 30 1250

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
|---|---|---|---|
| A,D | GB 1 145 860 A (E. W. BLISS COMPANY) * claim 1; figures 1-5 * | 1 | B22D11/10 |
| X | DE 903 024 C (DR.-ING. E. H. SIEGFRIED JUNGHANS) * page 3, line 48 - line 78; claim 14; figure 5 * | 1,6 | |
| A | WO 90 01383 A (ROKOP CORPORATION) 22 February 1990 * claim 1; figure 1 * | 1 | |
| A | DE 35 05 612 A (CONTINUA INTERNATIONAL CONTINUOUS CASTING S.P.A. ) 29 August 1985 * claim 1; figures 4-6 * | 1 | |
| A | US 3 333 746 A (G. R. COPE ET AL.) 1 August 1967 * figure 4 * | 6 | |
| A | US 3 707 183 A (L. DANIELI) 26 December 1972 * figure 6 * | 6 | TECHNICAL FIELDS SEARCHED (Int.Cl.6) |
| A | US 3 583 470 A (F. BOHLER) 8 June 1971 * figures 1,2,6 * | 6 | B22D |
| A | US 3 741 277 A (E. BACHNER ET AL.) 26 June 1973 * claim 1 * | 1 | |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| BERLIN | 13 May 1998 | Sutor, W |

CATEGORY OF CITED DOCUMENTS

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