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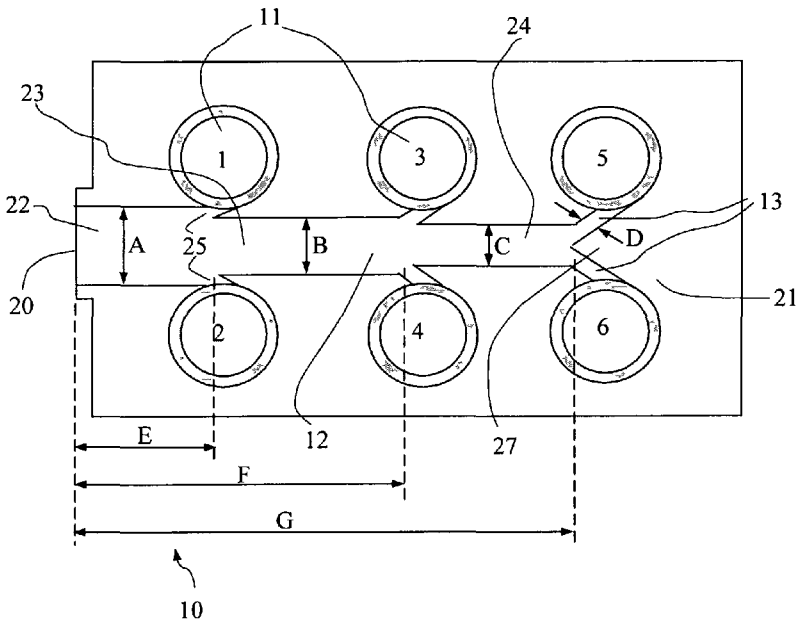

Figure 3.

(57) Abstract: An apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each channel having an inlet through which molten metal may enter the channel and an opposing end wall, wherein at least one of the channels reduces in width from its inlet to its end wall.

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AN APPARATUS FOR FEEDING MOLTEN METAL TO A PLURALITY OF MOULDS

Summary of the Invention

The present invention relates to an apparatus for feeding molten metal to a plurality of moulds.

Background of the Invention

One known method of casting metal ingots is that of direct chill continuous casting using a hot top mould. In this method, a bath of molten metal is located directly above or next to the mould cavity, through which the molten metal is either drawn horizontally or flows vertically under gravity. The mould body is continuously cooled in a chamber around the mould, thus chilling the molten metal to form ingots, billets or other shapes as desired. The mould body also acts as an outlet for the direct chill water spray.

Multiple hot top moulds may be fed with molten metal using a single apparatus, which may be referred to as a "mould table" or a "flooded table". An example of one known design for a flooded table apparatus is shown in Figure 1. The flooded table comprises a primary channel or trough, a plurality of secondary channels fluidly connected to the primary channel and a plurality of reservoirs arranged along the secondary channels. The multiple moulds are each connected to a reservoir of the flooded table so that molten metal can be fed to the mould from the reservoirs.

An advantage of the flooded or mould table is that control over only a single level of molten metal is required as opposed to controlling the molten metal level above each individual mould. The flooded table also allows for close packing of the moulds relative to one another, thus reducing the capital costs of the casting system. Furthermore, using the flooded table to feed the molten metal avoids oxide generation by a cascade effect inside

the mould. Recent developments in direct chill casting, in particular in respect of the flooded table, has led to the employment of large multi-strand mould tables with 60 to 80 moulds.

Delivery of the molten metal into each mould of the system, both at cast start and for steady state phase of the operation, has an important influence on the in-mould processes and hence on the product quality and the system productivity. One significant problem when using flooded tables is excessive variance in the time taken to fill all the moulds on the table at cast start. Another problem faced is too high a molten metal temperature distribution across the table. Typically, the larger the mould table, the greater the fill time variation at cast start and melt temperature variation from mould to mould.

For efficient production of sufficient quality castings, each mould must be filled with molten metal and a solid shell formed on the solidifying product within a given time. If this time is too short there is insufficient solid shell formed to support the product emerging from the mould and a bleed-out may occur. Conversely, should the time be too long and the solidifying product within the mould held too long prior to the lowering of the starting head, the solid may extend into the channel feeding the molten metal to the mould resulting in a hang-up, with the solidified product being unable to exit the bottom of the mould as the casting machine ram with the starting heads attached is lowered. In both these situations, excess scrap product is produced. More seriously these problems may result in damage to the casting equipment and exposure ofoperators to dangerous conditions.

It is therefore highly desirable that each mould within the system receives an initial fill of molten metal within a given time limit with respect to all of the other moulds in the table, and that the metal temperature be as uniform as possible across the table. It is further

desirable to avoid excessive turbulence of the molten metal as it enters each mould as this can increase the production of oxides and thereby reduce the quality of the cast product.

Various designs for the flooded or mould table have been developed, largely by empirical methods. An example of more recent flooded table designs is disclosed in US 6848497. However, whilst some recent designs have addressed some of the above problems, no present commercial flooded table casting system provide a completely satisfactory apparatus for feeding molten metal to a plurality of moulds. In present commercial casting systems, fill time differences of 20 to 30 seconds between each mould, fill times of greater than 10 seconds and temperature differences across the mould table of 20 to 30^0C are common. Such operating parameters can often result in the problems described above.

Summary of the Invention

According to a first aspect of the present invention, there is provided an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, wherein the ratio of the width of the entry port to the width of its respective reservoir for at least one of the reservoirs is less than 1:1.

In an embodiment, the ratio is less than 1:1 for most of the reservoirs.

In an embodiment, the ratio is less than 1:1 for each reservoir.

Preferably, the ratio is from 1:1 to 1:10, more preferably 1:3 to 1:8, more preferably approximately 1:5.

According to a second aspect of the present invention, there is provided an apparatus for feeding

molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, wherein the longitudinal extent of at least one of the entry ports is tangential to the perimeter of its reservoir.

In an embodiment, the longitudinal extent of most of the entry ports are tangential to the perimeter of their respective reservoirs.

In an embodiment, the longitudinal extent of each of the entry ports is tangential to the perimeter of their respective reservoirs .

In an embodiment, the, most or each reservoir is circular in cross-section and the longitudinal extent of its or their respective entry port(s) is tangential to its reservoir's circumference.

According to a third aspect of the present invention, there is provided an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each channel having an inlet through which molten metal may enter the channel and an opposing end wall, wherein at least one of the channels reduces in width from its inlet to its end wall.

In an embodiment, most of the channels reduce in width from their inlets to their end walls.

In an embodiment, each of the channels reduce in width from their inlets to their end walls.

In an embodiment, the width of the channel (s) reduces continuously from the inlet to the end wall.

In an embodiment, the width of the channel (s) reduces stepwise from the inlet to the end walls.

In an embodiment, each entry port has an opening in one of the channels for molten metal to enter the entry port from that channel.

In an embodiment, the at least one channel comprises a first channel portion and a second channel portion.

In an embodiment, the first channel portion is wider than the second channel portion.

In an embodiment, the first channel portion comprises the portion of the channel between its inlet and the opening(s) of the entry port(s) of the reservoir or opposing pair of reservoirs closest to the inlet.

In an embodiment, the second channel portion comprises the portion of the channel between the opening(s) of the entry port(s) of the reservoir or opposing pair of reservoirs closest to the inlet and the opening(s) of the entry port(s) of the next closest reservoir or opposing pair of reservoirs.

In an embodiment, where the apparatus comprises four reservoirs arranged about each channel, the next closest pair of reservoirs to the inlet is also the pair furthermost from the inlet.

In an embodiment, the at least one channel comprises a third channel portion.

In an embodiment, the second channel portion is wider than the third channel portion.

In an embodiment, the third channel portion comprises the portion of the channel between the opening(s) of the entry port(s) of the next closest reservoir or opposing pair of reservoirs and the opening(s) of the entry port(s) to the following closest reservoir or opposing pair of reservoirs.

In an embodiment, where the apparatus comprises six reservoirs, the first channel portion is shorter in length than the second channel portion.

In an embodiment, the third channel portion is shorter in lengths than the second channel portion.

However, in an embodiment, where the apparatus comprises four reservoirs, the first channel portion is longer in length than the second channel portion.

In an embodiment, the third channel portion is shorter in lengths than the first channel portion.

In an embodiment, where the apparatus comprises six reservoirs arranged about each channel, the following closest reservoir or opposing pair of reservoirs to the inlet is also the pair furthermost from the inlet.

According to a fourth aspect of the present invention, there is provided an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each channel having an inlet through which molten metal may enter the channel and an opposing end wall, wherein the end wall comprises an angular portion for reducing backflow of molten metal from the end wall.

In an embodiment, the angular portion is triangular shaped.

In an embodiment, the angular portion extends towards the channel inlet.

The apex of the triangular shaped angular portion may project in to the channel, preferably towards the channel inlet .

In an embodiment, sides of the angular portion are formed by entry ports of an opposing pair of reservoirs.

In another arrangement, a side of the angular portion may be formed by the entry port of a reservoir.

According to a fifth aspect of the present invention, there is provided an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at

least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each channel having an inlet through which molten metal may enter the channel and an opposing end wall, the reservoirs located on one or both longitudinal sides of one of the channels, wherein the entry ports of the reservoirs which are closer to the inlet of their respective channel are narrower than entry ports of reservoirs further from the inlet of that channel.

According to a sixth aspect of the present invention, there is provided an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each channel having an inlet through which molten metal may enter the channel and an opposing end wall, the reservoirs located on one or both longitudinal sides of one of the channels, wherein the entry ports of the reservoirs which are closer to the inlet of their respective channel have a longitudinal extent which is closer to the perpendicular with respect to the longitudinal extent of that channel, than entry ports of reservoirs further from the inlet of that channel.

According to a seventh aspect of the present invention, there is provided an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity, and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each reservoir being in fluid communication with their respective mould through a feed tube, wherein at least a portion of at least one of the reservoirs has a cross-sectional area which is 20 to 80% of the cross-sectional area of its respective feed tube.

Preferably, at least a portion of most of the reservoirs has a cross-sectional area which is 20 to 80% of the cross-sectional area of its respective feed tubes.

Preferably, at least a portion of all of the reservoirs has a cross-sectional area which is 20 to 80% of the cross-sectional area of its respective feed tube.

Preferably, the entire at least one reservoir has a cross-sectional area which is 20 to 80% of the cross-sectional area of its respective feed tube.

Preferably, the portion of the at least one reservoir has a cross-sectional area which is 30 to 70% of the cross-sectional area of its respective feed tube, more preferably 40 to 60%, more preferably approximately 50%.

In an embodiment, the at least one reservoir is non-concentric with its respective mould below.

According to an eighth aspect of the present invention, there is provided an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising any combination of the first, second, third, fourth, fifth, sixth and seventh aspects of the present invention.

In an embodiment, the apparatus also comprises a primary trough for supplying molten metal to the at least one channel.

The molten metal may be supplied to the at least one channel from the primary trough through each channel's inlet.

In an embodiment, the primary trough has at least one molten metal feed position at which molten metal is fed into the primary trough.

In an embodiment, the primary trough has two molten metal feed positions, located preferably at either end of the trough.

In an embodiment, the width of the channel inlets is dependent on their proximity to the at least one molten metal feed position of the primary trough.

In an embodiment, the width of those channel

inlets closer to the at least one molten metal feed position are narrower than those channel inlets which are further from the at least one molten metal feed position.

Brief Description of the Drawings

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a prior art apparatus for feeding molten metal to a plurality of moulds;

Figure 2 is a cut-away side view of a conventional direct chill continuous casting mould connected to a reservoir for supplying molten metal to the mould;

Figure 3 is a plan view of an apparatus for feeding molten metal to a plurality of moulds according to an embodiment of the invention;

Figure 4 is a perspective view of an apparatus for feeding molten metal to a plurality of moulds according to another embodiment of the present invention;

Figure 5 is a perspective view of an apparatus for feeding molten metal to a plurality of moulds according to another embodiment of the invention; and

Figure 6 is a perspective view of an apparatus for feeding molten metal to a plurality of moulds according to a further embodiment of the invention.

Detailed Description of Embodiments

Referring to Figure 3, an apparatus 10 for feeding molten metal to a plurality of moulds according to an embodiment of the present invention is shown. The apparatus 10 comprises a plurality of reservoirs 11 for supplying molten metal to the plurality of moulds under gravity and a channel 12 for supplying molten metal to the plurality of reservoirs 11 through an entry port 13 in each reservoir. It is noted that the reservoirs 11 may be

referred to in the art as "refractories". In the embodiment shown in Figure 3, the apparatus 10 comprises six reservoirs 11, arranged on both longitudinal sides of the channel 12. However, in variations of this embodiment, the apparatus may comprise more or less reservoirs arranged on one or both longitudinal sides of the channel and at one or both ends of the channel. The apparatus 10 may be used in the casting of any suitable metals including aluminium, magnesium and their respective alloys.

When the apparatus 10 is used in a direct chill casting system, moulds are attached to each reservoir 11 in an arrangement the same or similar to that shown in Figure 2. The mould 15 shown in Figure 2 comprises top and bottom sections, but may be formed as a unitary mould. The reservoir 11 is arranged in fluid communication with the mould 15 through a feed tube 16, which is often referred to in the art as an "orifice plate" or a "transition plate". The mould 15 may also incorporate a graphite ring 17 as well as a gas and/or oil distribution system 18 as shown in Figure 2. It is noted also that Figure 2 shows the reservoir 11 comprising a lower connection portion 19, which connects the reservoir 11 to the feed tube 16 (orifice plate).

Level A is typically the level of molten metal during the run phase of the casting operation in the reservoir 11, Level B is typically the level taken to be the reservoir full level at cast start and Level C is the typical level or position of the top of the starting head inside the mould 15 at cast start. The space between Level C and Level B is the space that constitutes the initial mould fill.

At cast start, the mould 15 is closed from below by a starting head with the top level of the starting head typically set at level C. The reservoir 11 is filled by the incoming molten metal to a typical level marked by level B. When this level is reached the cast start

procedure is actuated and after a pre-set time delay the starting head is lowered and the withdrawal of the cast product with a solid surface layer commenced. Filling of the reservoir 11 to a pre-set level (typically as indicated by level A) continues with the molten metal flow then being controlled to maintain this level throughout the cast.

Referring again to Figure 3, the channel 12 has an inlet 20 through which molten metal may enter the channel 12 and an opposing end wall 21. The channel 12 reduces in width from its inlet 20 to its end wall 21. In the embodiment shown in Figure 3, the width of the channel 12 reduces stepwise from the inlet 30 to the end wall 21. However, in other embodiments, the width of the channel 12 may reduce continuously from the inlet 20 to the end wall 21. Advantageously, the reducing width of the channel 12 reduces the volume of molten metal which can be held in the apparatus 10. Furthermore, the reducing width of the channel 12 "accelerates" flow of molten metal from the channel's inlet 20 towards it's end wall 21 and thus to the reservoirs 11 furthest from the channel inlet 20. As a result, the reducing width of the channel 12 reduces the time taken and the differential in time taken between reservoirs 11 to fill with molten metal.

The channel 12 comprises first, second and third channel portions, 22, 23 and 24 respectively. The first channel portion 22 is wider than the second channel portion 23 which is wider than the third channel portion, thus providing the step-wise reduction in the width of the channel 12. The first channel portion 22 is shorter in length than the second channel portion 23. The first channel portion 22 should be as short as possible to reduce overall fill time of the apparatus 10 but not so short that an undesirably large fill time differential between reservoirs Il is created. The third channel portion 24 is shorter than the second channel portion 23. Advantageously, this reduces the fill time differential

between the reservoirs 11, in particular those in the middle and those furthermost from the channel inlet 20.

Each entry port 13 has an opening 25 in the channel 12 for molten metal to enter the entry port 13 from the channel 12. The first channel portion 22 comprises the portion of the channel 12 between its inlet 20 and the openings 25 of the entry ports 13 of the opposing pair of reservoirs 11 closest to the inlet 20. The second channel portion 23 comprises the portion of the channel 12 between the openings of the entry ports opposing pair of reservoirs 11 closest to the inlet 20 and the opening of the entry port of the next closest (ie. middle) opposing pair of reservoirs 11. The third channel portion 24 comprises the portion of the channel 12 between the openings 25 of the entry ports 13 of the middle opposing pair of reservoirs 11 and the openings 25 of the entry ports 13 to the furthermost opposing pair of reservoirs 11 from the channel's inlet 20.

The entry ports 13 are designed to have a height to accommodate the desired operational molten metal level for the apparatus 10 including adequate additional height to allow for variations in the molten metal supply to and outflow from the apparatus 10.

Compared to conventional apparatuses for feeding molten metal to a plurality of moulds, such as that shown in Figure 1, the entry ports 13 of the reservoirs 11 are significantly narrower. The ratio of the width of each entry port 13 to the width of its respective reservoir 11 is less than 1:1. Preferably, the ratio is from 1:1 to 1:10, more preferably 1:3 to 1:8, more preferably approximately 1:5. The narrower entry ports 13 reduce the volume of molten metal which can be held in the apparatus 10 (as compared to a conventional apparatus for feeding molten to a plurality of moulds). The width of the entry ports 13 is designed to provide the appropriate molten metal flow rate to their respective reservoirs 11, given the diameter of that reservoir.

The longitudinal extent of each of the entry-ports 13 is tangential to the perimeter of its respective reservoir 11. In the embodiment shown in Figure 3 the reservoirs 11 are circular in cross-section and the longitudinal extent their respective entry ports 13 are tangential to their respective reservoir's circumference. This feature of the apparatus 10 encourages laminar flow of the molten metal into the reservoirs 11, reducing turbulence and the associated problems with turbulence in the molten metal. This in turn reduces the time taken to fill the reservoirs 11.

The end wall 21 comprises an angular portion 27 for reducing backflow of molten metal from the end wall 21. The angular portion 27 is triangular shaped and has an apex which projects into the channel 12 and extends towards the channel inlet 20. The sides of the angular portion 27 are formed by the entry ports 13 of the opposing pair of reservoirs 11 furthermost from the channel inlet 20. The angular portion 27 reduces the backflow of molten metal from the end wall by directing any flow of molten metal towards the sides of the channel 12 and most advantageously into the reservoirs 11 furthermost from the channel inlet 20. This not only reduces the turbulence in the molten metal in the apparatus 10 (and hence the formation of oxides) but also improves the rate of flow of molten metal into the reservoirs furthermost from the channel inlet 20, consequently reducing the time taken to fill these reservoirs with molten metal.

Referring now to Figure 4, an apparatus 110 for feeding molten metal to a plurality of moulds according to another embodiment of the present invention is shown. The apparatus 110 has similar features to the apparatus 10 shown in Figure 3. These similar features have been given the same reference numbers but are prefixed with the numeral 1.

The apparatus 110 of Figure 4 comprises a

plurality of reservoirs 111 for supplying molten metal to the plurality of moulds under gravity and a channel 112 for supplying molten metal to the plurality of reservoirs 111 through an entry port 113 in each reservoir 111. Each channel 112 has an inlet 120 through which molten metal may enter the channel 112 and an opposing end wall 121. The reservoirs 111 are located on both longitudinal sides of the channels 112.

The entry ports 113 of the reservoirs 111 which are closer to the inlet 120 of the channel 112 are narrower than entry ports of reservoirs further from the inlet 120 of the channel 112.

Furthermore, the entry ports 113 of the reservoirs which are closer to the inlet 120 of the channel 112 have a longitudinal extent which is closer to the perpendicular with respect to the longitudinal extent of the channel 112, than entry ports of reservoirs further from the inlet 120 of the channel 112.

Both of the above described features reduce the time differential between filling of the reservoirs 11 which are located at different positions relative to the channel inlet 120. Without wishing to be bound by any particular theory, fluid flow dynamics are used to determine the width of the entry ports 113 and the arrangement of the longitudinal extent of the entry ports 113 relative to the longitudinal extent of the channel 112 are designed so as to enable the volumetric flow rate of the molten metal into each of the reservoirs 11 to be closely similar. As a result the time taken to the fill each of the reservoirs 11 is similar and the time differential reduced.

The arrangement of the entry ports 113, in particular their openings 125 in the channel 112 relative to the central axis of their respective reservoirs 111, in the embodiment shown in Figure 4 is dependent on the position of each reservoir relative to the inlet 120 of the channel 112. The arrangement of the entry port

openings 125 is designed to minimise the generation of whirlpool type turbulence in the reservoirs 111. Such turbulence can create a vortex within the reservoirs 111, which may subsequently entrap oxides and other contaminants within the molten metal entering the mould. For those reservoirs closest to the channel inlet 120, the entry port openings 125 are further away from the channel inlet 120 than the central axis of their respective reservoirs. Conversely, for those reservoirs which are furthermost from the channel inlet 120, the entry port openings 125 are closer to the channel inlet 120 than the central axis of their respective reservoirs.

The apparatus 110 shown in Figure 4 has reservoirs 111 which are restricted in volume as compared to the conventional cylindrical reservoirs such as those shown in Figure 1. This shaping of the reservoirs 111 reduces the volume of the molten metal which can be held in the apparatus 110. As a result, the temperature differential across the apparatus 110 during casting operation is reduced. Furthermore, as less molten metal is required to fill the apparatus 110 (and the reservoirs 111), the time taken to fill the reservoirs 111 and the time to fill differential betweeen the reservoirs at the start of casting operating is also reduced. An additional advantage from the reduced volume of molten metal is the reduced thermal load placed on the apparatus 10.

The restricted volume of the reservoirs 111 is such that at least a portion, but preferably the entirety, of each reservoir is 20 to 80% of the cross-sectional area of its respective feed tube. Preferably, the portion of each reservoir 111 has a cross-sectional area which is 30 to 70% of the cross-sectional area of its respective feed tube, more preferably 40 to 60%, more preferably approximately 50%. It is also noted that the reservoirs 111 of the apparatus 110 shown in Figure 4 are shaped such that they are not concentric with their respective moulds below as is the case conventionally. This does not

adversely affect the characteristics of the cast billets, nor the casting operation using the apparatus 110.

It is noted that any one or more of the features shown and discussed above in relation to the apparatus 110 of Figure 4 may be incorporated in the apparatus 10 of Figure 3 and vice versa.

Referring now to Figure 5, an apparatus 210 for feeding molten metal to a plurality of moulds according to another embodiment of the present invention is shown. The apparatus 210 has similar features to the apparatus 10 shown in Figure 3. These similar features have been given the same reference numbers but are prefixed with the numeral 2. The embodiment in Figure 5 shows a variation in which the entry ports 213 are curved, as opposed to being linear as is the case for the embodiments shown in Figures 3 and 4.

Referring now to Figure 6, an apparatus 300 for feeding molten metal to a plurality of moulds according a further embodiment of the invention is shown. The apparatus 300 is designed for feeding molten metal to a much greater number of moulds than the apparatuses 10, 110 and 210 discussed above in relation to Figures 3 to 5. A plurality of the apparatuses 10, 110, 210 of either Figures 3, 4 and/or 5 form units or modules of the apparatus 300 of Figure 6. The apparatus 300 also comprises a primary trough 301 for supplying molten metal to the channels 12, 112, 212 through each channel's inlet 20, 120, 220.

Flow to each of the channels 12, 112, 212 from the primary trough is controlled by gates (not shown) on the channel inlets 20, 120, 220 as would be known to a person skilled in the art. Generally, during cast start using the apparatus 300 of Figure 6, the gates are closed, preventing any flow of molten metal from entering any of the channels 12, 112, 212. Only the primary trough 301 receives molten metal at start-up until a specified level or "head" of molten metal is attained in the primary

trough 301. The gates on all of the channels 12, 112, 212 are subsequently opened to enable molten metal to flow into the channels 12, 112, 212. This may or may not occur simultaneously for all of the channels 12, 112, 212. In some embodiments, it may be necessary to have staged opening of the gates.

The primary trough 301 has at least one molten metal feed position 302 at which molten metal is fed into the primary trough. The primary trough 301 of the apparatus 300 of Figure 6 has two molten metal feed positions 302 at either end of the trough 301. The width of the channel inlets 20, 120, 220 may be determined by their proximity to the molten metal feed positions 302 of the primary trough 301. In such an embodiment, the width of those channel inlets closer to the molten metal feed positions 302 of the primary trough 301 are typically narrower than those channel inlets which are further from the molten metal feed positions 302. Advantageously, this feature acts against the channels closer to the molten metal feed positions 302 of the primary trough 301 during normal casting operation of the apparatus 300 from starving the channels further away from the molten metal feed positions of molten metal.

EXAMPLES

Example 1

A model apparatus which was similar to the apparatus 10 shown in Figure 3 was constructed for use in water flow modelling. The reservoirs of the model apparatus had a diameter of 152mm. Table 1 below provides details of dimensions A-G for the model apparatus as indicated on Figure 3. All values are in millimetres.

Table 1

Mould diameter	A	B	C	D	E	F	G
152	60	50	50	30	240	485	585

Water was released into the channel of the model apparatus from a predetermined head height .

The resulting fill time for all of the reservoirs across the model apparatus showed a fill time difference of less than 5 seconds. Table 2 below provides fill times for reservoirs 1 to 6 (as indicated on Figure 3).

Table 2

Water headheight (mm)	Time to fill individual reservoir number (seconds)					
	1	2	3	4	5	6
76	3.8	3.7	4.8	4.8	3.5	3.4
97	5.4	5.5	4.1	4.6	3.3	3.3
110	5.2	5.3	3.1	3.7	3.2	3.0

Example 2

A model apparatus for feeding molten metal to a plurality of moulds was modelled on a computer using Flow 3D software. The model apparatus was similar to the apparatus 300 shown in Figure 6 comprising ten modules each having six reservoirs connected to a primary trough. Such an apparatus may be referred to in the industry as a 60 strand mould table. The reservoirs of the model apparatus had a diameter of 152 mm and each module had the same geometric dimensions as the model apparatus discussed in Example 1.

The channel inlets for each of the modules was the same and the modules were spaced eguidistantly apart along the primary trough.

The primary trough of the model apparatus was filled with molten metal to a height of 70 mm prior to release of the molten metal simultaneously into each of the channels of each of the modules through their inlet. It is noted that this height may be varied according to requirements. The simultaneous release of the molten metal to all of the modules is achieved using conventional

molten metal control technology typical of which is hydraulic or numerically activated sliding refractory dam system.

The computer modelling was run for only one half of the table to reduce processing time. Table 3 below provides fill times for reservoirs 1 to 6 of modules A to E (as indicated on Figure 6).

Table 1. Results obtained from the Flow 3D modelling of the half table (Δt = maximum time difference).

Mould No.	Module					Δt - between modules
	A	B	C	D	E	
	Mould fill time - seconds					
1	4.4	5.2	5	5.8	5.6	**1.4**
2	5	5	5	5.2	5.6	**0.6**
3	5.6	6.8	6.4	7.2	7.2	**1.6**
4	6	5.8	6.4	7.2	7.2	**1.4**
5	4	4.2	4.4	4.4	4.4	**0.4**
6	4	4.2	4.4	4.4	4.4	**0.4**
Δt - within module	**2**	**2.6**	**2**	**2.8**	**2.8**	
Δt - across table		**3.2**				

The computer model was shown to closely follow the flow patterns and fill times observed in the water modelling described in Example 1 above.

The fill time differentials within a single module, between modules and across the entire apparatus were all less than 5 seconds. Upon further modelling, the fill times for reservoirs 3 and 4 were reduced by reducing the length and/or width of the entry ports for these reservoirs.

Further studies using the computer model also found that the fill time for an individual reservoir is dependent upon the molten metal head height in the primary trough prior to release of the metal from the primary trough to each of the modules and the width of the channel

inlet of each module. A head height of approximately 80 mm was found to provide an acceptable compromise between reservoir fill time and turbulence during the reservoir filling process. A metal head greater than 100 mm provided a shorter reservoir fill time but with excessive turbulence, whilst a head height of less than 70 mm gave an unacceptably long reservoir fill time.

Additional studies found that the channel inlets needed to be greater than 50 mm for the model apparatus based on the 152 mm diameter reservoirs to achieve acceptable fill times.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, ie. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

It is to be understood that, if any prior art publication is referred to herein, such reference does not constitute an admission that the publication forms a part of the common general knowledge in the art, in Australia or any other country.

CLAIMS

1. An apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each channel having an inlet through which molten metal may enter the channel and an opposing end wall, wherein at least one of the channels reduces in width from its inlet to its end wall.

2. An apparatus as claimed in claim 1, wherein the ratio of the width of the entry port to the width of its respective reservoir for at least one of the reservoirs is less than 1:1.

3. An apparatus as claimed in claim 1, wherein the ratio of the width of the entry port to the width of its respective reservoir for at least one of the reservoirs is from 1:1 - 1:10.

4. An apparatus as claimed in claim 1, wherein the ratio of the width of the entry port to the width of its respective reservoir for at least one of the reservoirs is 1:3 - 1:8.

5. An apparatus as claimed in any one of the preceding claims, wherein the longitudinal extent of at least one of the entry ports is tangential to the perimeter of its reservoir.

6. An apparatus as claimed in any one of the preceding claims, wherein at least one reservoir is circular in cross-section and the longitudinal extent of

its respective entry port is tangential to that reservoir's circumference.

7. An apparatus as claimed in any one of the preceding claims, wherein the width of at least one of the channels reduces continuously from its inlet to its end wall.

8. An apparatus as claimed in any one of the preceding claims, wherein the width of at least one of the channels reduces stepwise from its inlet to its end wall.

9. An apparatus as claimed in any one of the preceding claims, wherein the at least one channel comprises a first channel portion and a second channel portion, the first channel portion being wider than the second channel portion.

10. An apparatus as claimed in claim 9, wherein the at least one channel also comprises a third channel portion, wherein in the second channel portion is wider than the third channel portion.

11. An apparatus as claimed in either claims 9 or 10, wherein the first channel portion is shorter in length than the second channel portion.

12. An apparatus as claimed in claim 10, wherein the third channel portion is shorter than the first and second channel portion.

13. An apparatus as claimed in claim 9, wherein the first channel portion is longer in length than the second channel portion.

14. An apparatus as claimed in any one of the preceding claims, wherein each entry port has an opening

in one of the channels for molten metal to enter the entry-port from that channel .

15. An apparatus as claimed in claim 14 when dependent upon any one of claims 9-13, wherein the first channel portion comprises the portion of the channel between its inlet and the opening (s) of the entry port(s) of the reservoir or opposing pair of reservoirs closest to the inlet .

16. An apparatus is claimed in either claim 14 or 15, when dependent upon any one of claims 9-13, wherein the second channel portion comprises the portion of the channel between the opening (s) of the entry port(s) of the reservoir or opposing pair of reservoirs closest to the inlet and the opening (s) of the entry port(s) of the next closest reservoir or opposing pair of reservoirs.

17. An apparatus as claimed in any one of claims 14-16, when dependent upon claim 10, wherein the third channel portion comprises the portion of the channel between the opening (s) of the entry ports (s) of the next closest reservoir or opposing pair of reservoirs and the opening (s) of the entry ports (s) to the following closest reservoir or opposing pair of reservoirs.

18. An apparatus as claimed in any one of the preceding claims, wherein each channel has an inlet through which molten metal may enter the channel and an opposing end wall, and wherein the end wall comprises an angular portion for reducing back flow of molten metal from the end wall .

19. An apparatus as claimed in claim 18 wherein the angular portion extends towards the channel inlet.

20. An apparatus as claimed in either claims 18 or 19, wherein the angular portion is triangular shaped and the apex of the triangular shaped angular portion projects into the channel.

21. An apparatus as claimed in any one of claims 18-20, wherein sides of the angular portion are formed by entry ports of an opposing pair of reservoirs.

22. An apparatus as claimed in any one of the preceding claims, wherein each channel has an inlet through which molten metal may enter the channel at an opposing end wall, the reservoirs located on one or both longitudinal sides of one of the channels, and wherein the entry ports of the reservoirs which are closer to the inlet of their respective channel are narrower than entry ports of reservoirs further from the inlet of that channel.

23. An apparatus as claimed in any one of the preceding claims, wherein each channel has an inlet through which molten metal may enter the channel and an opposing end wall, the reservoirs located on one or both longitudinal sides of one of the channels, and wherein the entry ports of the reservoirs which are closer to the inlet of their respective channel have a longitudinal extent which is closer to the perpendicular with respect to the longitudinal extent of that channel, than entry ports to reservoirs further from the inlet of that channel.

24. An apparatus as claimed in any one of the preceding claims, wherein each reservoir is in fluid communication with their respective mould through a feed tube, and wherein at least a portion of at least one of the reservoirs has a cross-sectional area which is 20-80% of the cross-sectional area of its respective feed tube.

25. An apparatus as claimed in claim 24, wherein the entire at least one reservoir has a cross-sectional area which is 20-80% of the cross-sectional area of its respective feed tube.

26. An apparatus as claimed in either claim 24 or 25, wherein the portion of the at least one reservoir has a cross-sectional area which is 30-70% of the cross-sectional area of its respective feed tube.

27. An apparatus as claimed in any one of claims 24-26, wherein the portion of the at least one reservoir has a cross-sectional area which is 40-60% of the cross-sectional area of its respective feed tube.

28. An apparatus as claimed in any one of the preceding claims, wherein the at least one reservoir is non-concentric with its respective mould below.

29. An apparatus as claimed in any one of the preceding claims, wherein the apparatus also comprises a primary trough for supplying molten metal to the at least one channel through each channel's inlet.

30. An apparatus as claimed in claim 29, wherein the primary trough has at least one molten metal feed position at which molten metal is fed into the primary trough.

31. An apparatus as claimed in claim 30, wherein the width of the channel inlets closer to the at least one molten metal feed position are narrower than those channel inlets which are further from the at least one molten feed position.

32. An apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality

of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, wherein the longitudinal extent of at least one of the entry ports is tangential to the perimeter of its reservoir.

33. An apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, wherein the ratio of the width of the entry port to the width of its respective reservoir for at least one of the reservoirs is less than 1:1.

34. An apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each channel having an inlet through which molten metal may enter the channel and an opposing end wall, wherein the end wall comprises an angular portion for reducing backflow of molten metal from the end wall.

35. An apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each channel having an inlet through which molten metal may enter the channel and an opposing end wall, the reservoirs located on one or both longitudinal sides of one of the channels.

wherein the entry ports of the reservoirs which are closer to the inlet of their respective channel are narrower than entry ports of reservoirs further from the inlet of that channel .

36. An apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each channel having an inlet through which molten metal may enter the channel and an opposing end wall, the reservoirs located on one or both longitudinal sides of one of the channels, wherein the entry ports of the reservoirs which are closer to the inlet of their respective channel have a longitudinal extent which is closer to the perpendicular with respect to the longitudinal extent of that channel, than entry ports of reservoirs further from the inlet of that channel.

37 . An apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity, and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each reservoir being in fluid communication with their respective mould through a feed tube, wherein at least a portion of at least one of the reservoirs has a cross-sectional area which is 20 to 80% of the cross-sectional area of its respective feed tube.

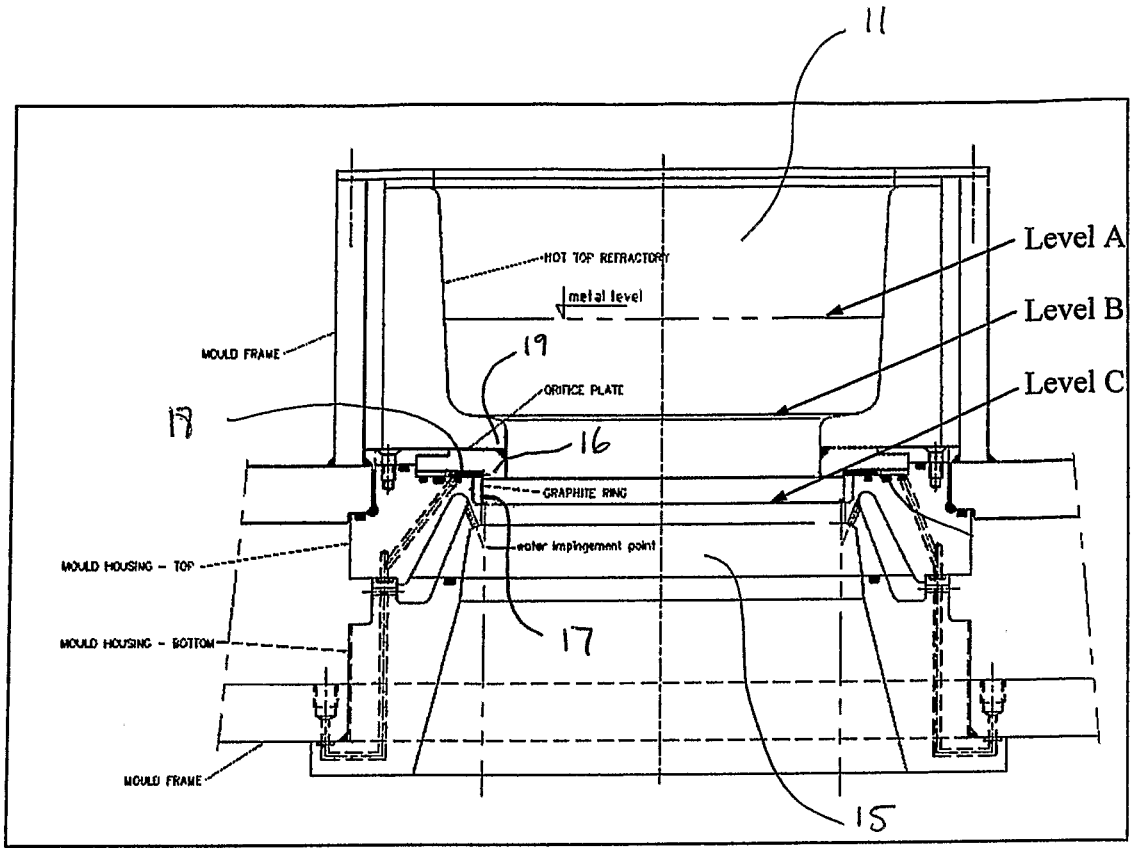

Figure 2

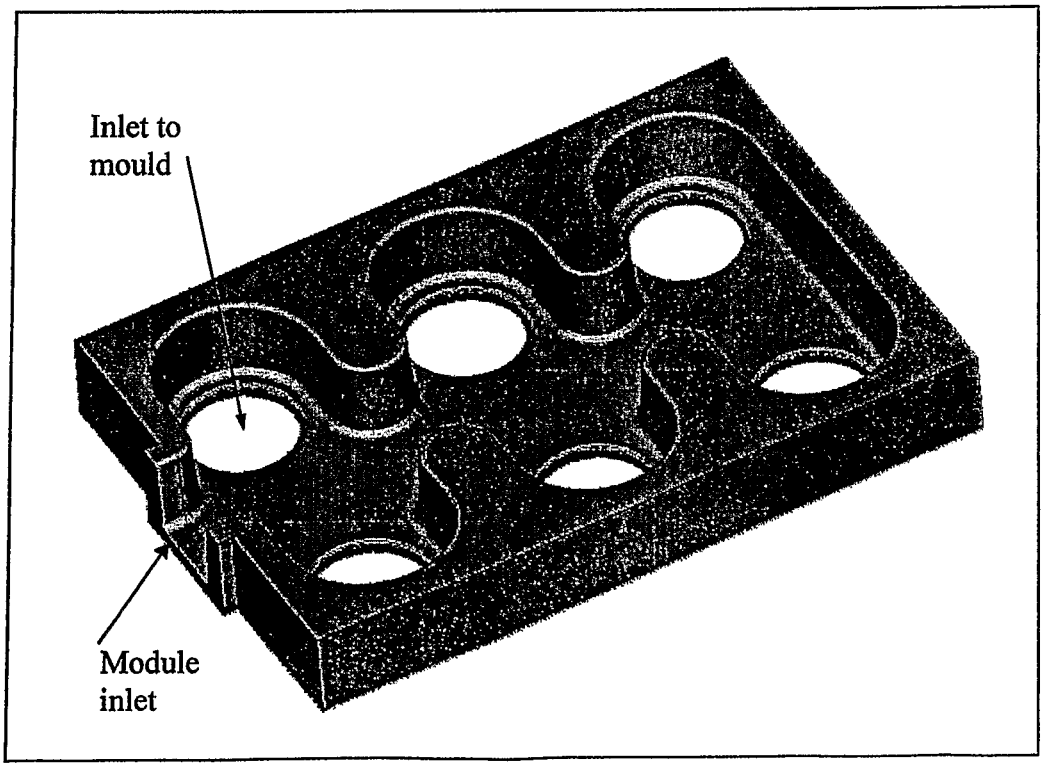

Figure 1

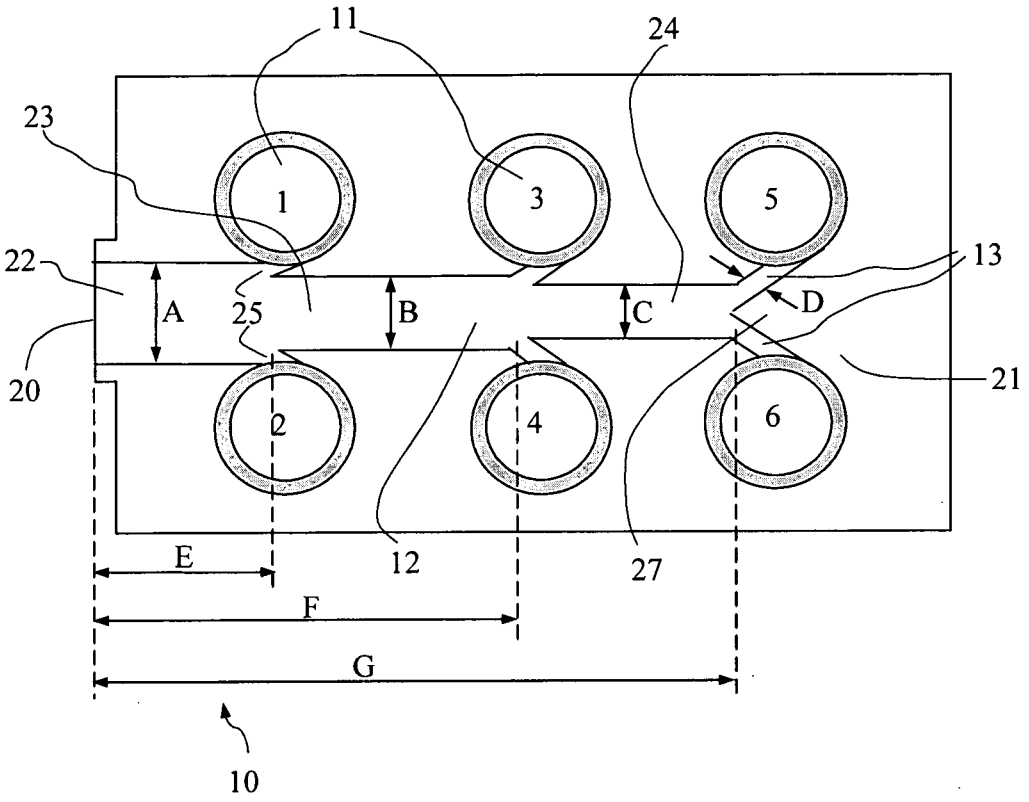

Figure 3.

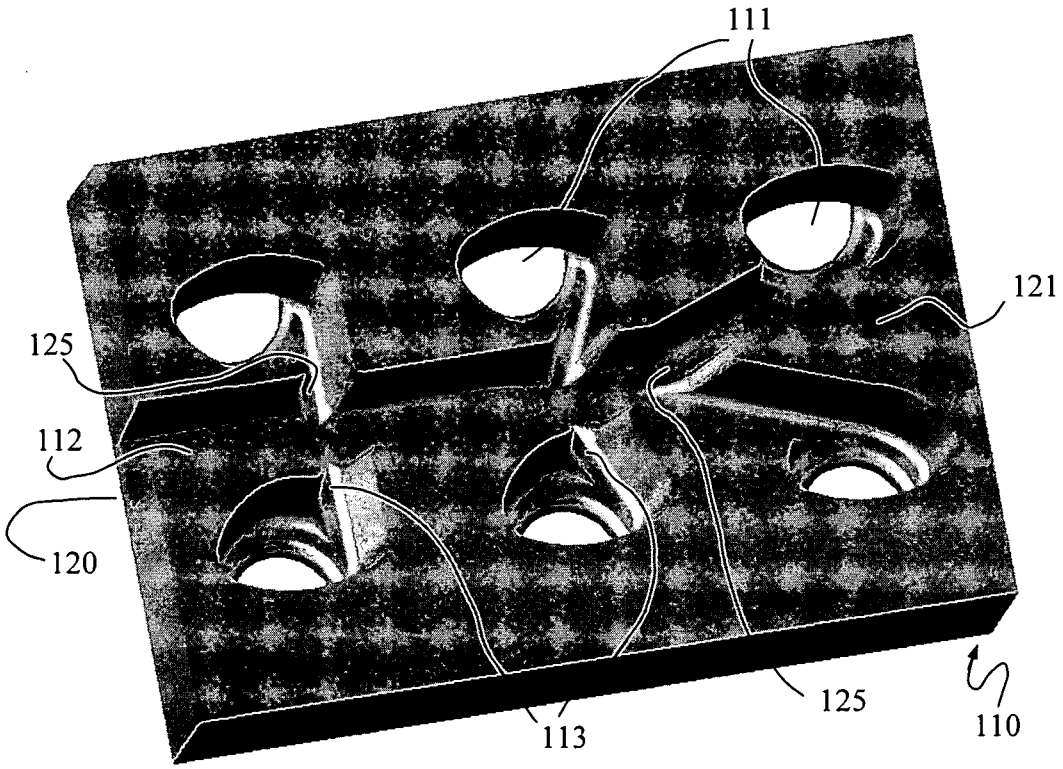

Figure 4.

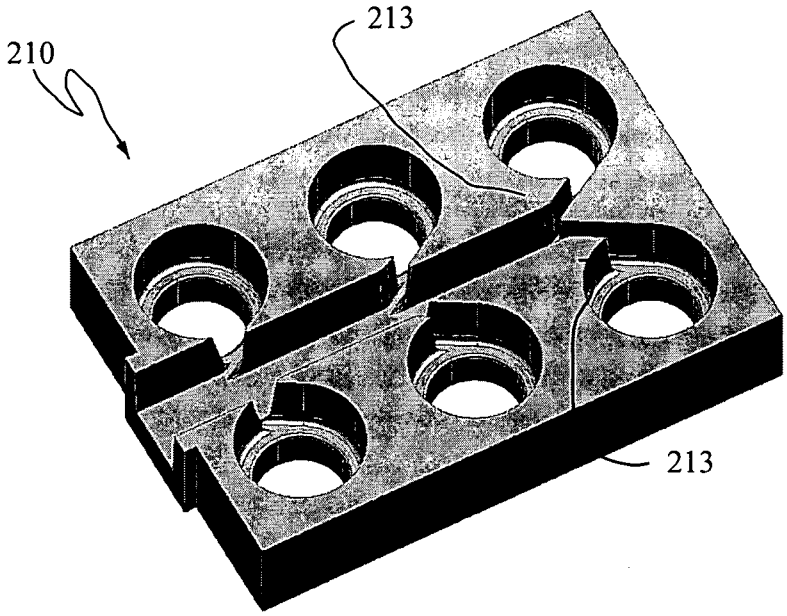

Figure 5

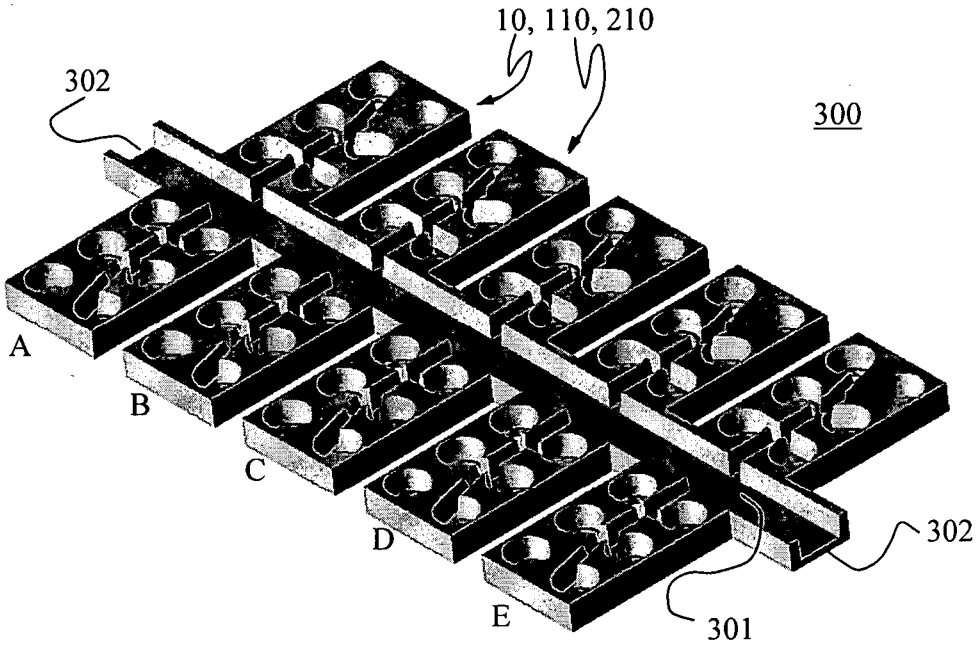

Figure 6.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2008/001381

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

B22D 11/10(2006.01) *B22D 11/103 (2006.01)* *B22D 35/00* (2006.01)
B22D 9/00 (2006.01) *B22D 11/18* (2006.01)

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)
IPC B22D1 1/10, B22D1 1/103, B22D35/00, B22D9/00

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPODOC, WPI, TXTUSl, TXTUS2, TXTUS3. TXTEPl, TXTGBl, TXTWOl, TXTAUl, TXTCAl and keywords (mould+ or mold+, reservoir+, bucket+, refract+, ceramic+, vessel÷, tray+, channel+, path+, groov+, passage÷, conduit+, molten metal, feed, convey+, distribut+, pour+, suppl+, circl+, port, gravi+)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	US 6848497 B2 (SALE ET AL.) 1 February 2005	
X	Column 1 lines 9 -31; column 2 line 66 - column 5 line 7; Figures 1 - 5	1, 5 - 10, 13 - 15, 17 - 21, 23, 29, 30, 32, 34, 36
Y	Figures 2, 4	3, 4, 24 - 27, 37
	US 7059383 Bl (TREMBLAY ET AL.) 13 June 2006	
X	Column 3 line 33 - column 5 line 50; Figures 1 - 5	1, 5 - 10, 13 - 15, 17 - 21, 23, 29, 30, 32, 34, 36
Y	Figures 2, 4	3, 4, 24 -27, 37
	US 6491087 Bl (TILAK) 10 December 2002	
X	Column 2 line 60 - 4 line 45, column 10 line 50 - 65, column 12 line 59 -- column 14 line 54; Figures 1, 2, 4, 6, 7, 8	1, 2, 7 - 9, 13 - 15, 29, 30, 33
Y	Figures 1, 4, 6, 8	3, 4, 24 - 27, 37

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

• Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 October 2008	**10 NOV 20DB**
Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	**MILKA WENAS** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 2593

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2008/001381

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. Ill Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. Claim 1: An apparatus for feeding molten metal to a plurality of moulds comprising reservoirs, at least one channel, entry port in each reservoir, each channel having an inlet and an opposing wall wherein at least one of the channel reduces in width from its inlet to its end wall.
2. Claim 32: wherein the longitudinal extent of the entry port is tangential to the perimeter of its reservoir.
3. Claim 33: wherein the ratio of the width of the entry port to the width of its respective reservoir is less than 1:1
4. Claim 34: wherein the angular wall comprises an angular portion for reducing backflow of molten metal from the end wall.
5. Claim 35: wherein the entry ports of the reservoirs which are closer to the inlet of their respective channel are narrower than the entry ports of reservoirs further from the inlet of that channel-.
6. Claim 36: wherein the entry ports of the reservoirs which are closer to the inlet of their respective channel have a longitudinal extent which is closer to the perpendicular with respect to the longitudinal extent of that channel than entry ports of reservoirs further from the inlet of that channel.
7. Claim 37: wherein the cross-sectional area of the reservoirs is 20 to 80% of the cross-sectional area of its respective feed tube

As reasoned on the Continuation of Box No: III

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Supplemental Box
(To be used when the space in any of Boxes 1to IV is not sufficient)

Continuation of Box No: III

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. There are 7 different inventions as follows:

1. Claim 1 is directed to an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each channel having an inlet through which molten metal may enter the channel and an opposing end wall, wherein at least one of the channels reduces in width from its inlet to its end wall. It is considered that the above integers comprise a first "special technical feature".
2. Claim 32 is directed to an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, wherein the longitudinal extent of at least one of the entry ports is tangential to the perimeter of its reservoir. It is considered that the above integers comprise a second "special technical feature".
3. Claim 33 is directed to an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, wherein the ratio of the width of the entry port to the width of its respective reservoir for at least one of the reservoir is less than 1:1. It is considered that the above integers comprise a third "special technical feature".
4. Claim 34 is directed to an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each channel having an inlet through which molten metal may enter the channel and an opposing end wall, wherein the end wall comprises an angular portion for reducing backflow of molten metal from the end wall. It is considered that the above integers comprise a fourth "special technical feature".
5. Claim 35 is directed to an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each channel having an inlet through which molten metal may enter the channel and an opposing end wall, the reservoirs located on one or both longitudinal sides of one of the channels, wherein the entry ports of the reservoirs which are closer to the inlet of their respective channel are narrower than the entry ports of reservoirs further from the inlet of that channel. It is considered that the above integers comprise a fifth "special technical feature".
6. Claim 36 is directed to an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each channel having an inlet through which molten metal may enter the channel and an opposing end wall, the reservoirs located on one or both longitudinal sides of one of the channels, wherein the entry ports of the reservoirs which are closer to the inlet of their respective channel have a longitudinal extent which is closer to the perpendicular with respect to the longitudinal extent of that channel, than the entry ports of reservoirs further from the inlet of that channel. It is considered that the above integers comprise a sixth "special technical feature".

Supplemental Box
(To be used when the space in any of Boxes I to VIII is not sufficient)

Continuation of Box No: ITJ

7. Claim 37 is directed to an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir, each reservoir being in fluid communication with their respective mould through a feed tube, wherein at least a portion of at least one of the reservoirs has a cross-sectional area which is 20 to 80% of the cross-sectional area of its respective feed tube. It is considered that the above integers comprise a seventh "special technical feature".

The common concept linking-together these groups of claims is relate to an apparatus for feeding molten metal to a plurality of moulds, the apparatus comprising a plurality of reservoirs for supplying molten metal to the plurality of moulds under gravity and at least one channel for supplying molten metal to the plurality of reservoirs through an entry port in each reservoir.

However, this concept is not novel in the light of:

D1 US 6848497 B2 (SALE ET AL.) 1 February 2005
D2 US 7059383 B1 (TREMBLAY ET AL.) 13 June 2006
D3 US 6491087 B1 (TILAK) 10 December 2002

This means that the common feature can not constitute a special technical feature within the meaning of PCT Rule 13.2, second sentence, since it makes no contribution over the prior art.

Since the common feature does not satisfy the requirement for being a special technical feature, it cannot provide the necessary technical relationship between the identified inventions. Therefore the claims do not satisfy the requirement of unity of invention ***a posteriori.***

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2008/001381

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member			
US	6491087	US	6675870	US	2002148593
US	6848497	US	2004206473		
US	7059383	NONE			

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX