

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
7 June 2007 (07.06.2007)

PCT

(10) International Publication Number
WO 2007/062476 A1

(51) International Patent Classification:
B22D 11/07 (2006.01)

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(21) International Application Number:
PCT/AU2006/001820

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(22) International Filing Date:
30 November 2006 (30.11.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2005906692 30 November 2005 (30.11.2005) AU

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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Published:

— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: A GAS AND LUBRICANT DELIVERY APPARATUS

(57) Abstract: A lubricant delivery element for delivering lubricant into a cavity, the lubricant distribution element comprising a thin element of porous material for delivering lubricant into the cavity through the element.

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A GAS AND LUBRICANT DELIVERY APPARATUS

Field of the Invention

The present invention relates to a gas and
5 lubricant delivery apparatus and more particularly to a
lubricant delivery element, in particular for direct chill
continuous casting hot top moulds.

Background of the Invention

10 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
15 vertically under gravity. The mould body is continuously
cooled using a coolant in a chamber around the mould, thus
chilling the molten metal to form the ingots. The mould
body also acts as an outlet for the direct chill water
spray.

20 A lubricant is introduced into the mould cavity
to improve the surface quality of the ingots by preventing
the sticking of the metal to the inside wall of the mould.

In US 4,157,728 it was found that the surface
quality of non-ferrous metal ingots cast using this method
25 is known to be improved by the introduction of gas into
the mould cavity just below the hot top containing the
molten metal bath. This was done using an array of small
holes which delivered oil to the molten metal entry end of
the mould cavity (ie. the top in the vertical case), with
30 radial slots used to deliver the air.

Subsequently, various means of delivering the
lubricant and gas into the mould cavity have been
disclosed. In one version, disclosed in US 4,598,763, air
and oil are introduced into the mould cavity through a
35 porous graphite ring whose primary function is to act as a
mould liner to form the casting surface. This arrangement
involves the introduction of the air and oil in contact

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with the molten metal at the point where the molten metal solidifies in the mould. This results in one significant problem, being that tar-like deposits build up within the graphite due to the vaporisation of the oil, thus

5 restricting the flow of both air and oil. A further problem with this arrangement is that high delivery pressures are required to force the oil through the graphite ring, increasing the manufacturing and operating costs of the hot top mould.

10 In another version, disclosed in US 5,320,159, oil and air are introduced into the mould cavity via grooves in the top and bottom of a distribution plate. Circumferential channels in the mould body are provided to deliver oil and air to the radial grooves in the
15 distribution plate. However, the grooves in the distribution plate may suffer from molten metal entry. After entering the grooves the metal solidifies, resulting in tearing of the billet surface and damage to the distribution plate. This problem may be minimised by
20 reducing the diameter of the grooves (to as little as 100-200 micron), however, the manufacturing required is costly and ultimately it is not sufficient to completely prevent metal entry should the gas pressure in the mould cavity be insufficient.

25 A further problem with using a distribution plate, is that because oil is introduced to the distribution plate at one point from the circumferential channel, this results in a region of low oil flow directly opposite the feed point and hence an uneven distribution
30 of oil occurs in the mould cavity. Similar problems may also occur with the air distribution.

Summary of the Invention

35 According to a first aspect of the present invention there is provided a lubricant delivery element for delivering lubricant into a cavity, the lubricant distribution element comprising a thin element of porous

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material for delivering lubricant into the cavity through the element.

Preferably, the lubricant distribution element has a thickness of less than approximately 5mm.

5 Preferably, the lubricant distribution element has a thickness of 0.1 to 5mm, more preferably, 1-5mm, more preferably 2-3mm.

Preferably, the lubricant distribution element has a thickness of approximately 1.5 mm.

10 The lubricant distribution element may however, have a thickness of less than 0.1mm.

The lubricant distribution element may have at least one groove formed in the surface of the element. When present, the groove may assist in the circumferential distribution of lubricant through the element for even flow of lubricant from the circumference or sides of the distribution element.

15 Preferably, the groove extends substantially around the circumference or the sides of the element.

20 Preferably, the groove is approximately 0.5mm deep.

Preferably, the porous material comprises an agglomerate of particles.

25 Preferably, the particles have an average diameter of less than approximately 0.25mm.

Preferably, the particles have an average diameter of 10 to 100 micron.

More preferably, the particles have an average diameter of 40 to 70 micron.

30 The average diameter of the particles may be less than 10 microns.

Preferably, the average diameter of the pores in the porous material is less than the size of the particles.

35 Preferably, the porous material has a porosity of 10 to 70%, more preferably 20 to 40%.

The porosity of the material may change across

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the width of the lubricant distribution element.

Preferably, the porous material is of the kind commonly used in powder metallurgy applications.

Preferably, the porous material is aluminium,
5 iron, copper or sintered bronze, more preferably, sintered bronze. In this embodiment, the thin element of porous material is manufactured by sintering bronze powder in a steel die at high temperature.

The porous material may be a porous ceramic.

10 The porous material may also be graphite. However, if the porous material is graphite, then the lubricant distribution element is preferably provided with a strengthening means. The strengthening means may be, for example, a thin element of metal laminated to the
15 graphite.

The porous material may be a porous plastic, such as polytetrafluoroethylene.

Preferably, the lubricant distribution element is shaped so that in use, it extends around the perimeter of
20 the cavity.

Typically, the lubricant distribution element is in the shape of an annular disc. The annulus of the annular disc may be round or non-round in shape.

The lubricant distribution element may comprise a
25 single element or a number of parts which, in use, abut one another to form the lubricant distribution element.

Preferably, the lubricant delivery element further comprises a sealant for sealing the lubricant distribution element.

30 Preferably, the sealant seals at least portions of the horizontal surfaces of the element. This forces the lubricant to flow through the element as opposed to over the surface.

Preferably, the sealant seals at least a portion
35 of the surface of the lubricant distribution element which is not arranged to be exposed to the cavity.

Preferably, the sealant comprises a layer of

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varnish on at least a portion of the surface of the lubricant distribution element.

Alternatively, the sealant may comprise a layer of impermeable foil on at least a portion of the surface
5 of the lubricant distribution element.

Alternatively, the sealant may comprise a layer of settable rubber. The settable rubber is applied as a paste which sets after application.

The sealant may comprise a combination of layers
10 of any two or more of varnish, impermeable foil and a settable rubber.

Alternatively, the sealant comprises a fibre gasket(s).

Alternatively, the sealant comprises an O-ring.
15 Alternatively, the sealant comprises a flat surface.

Preferably, the flat surface is provided by a metal plate. The flat surface may, alternatively, be provided by the top of the mould body.

20 According to a second aspect of the present invention there is provided a gas delivery element for delivering gas into a cavity, the element comprising a thin element of porous material for delivering gas into the cavity through the element.

25 Preferably, the gas distribution element has one or more of the features of the lubricant distribution element according to the first aspect.

According to a third aspect of the present invention there is provided a gas and lubricant delivery
30 apparatus for delivering gas and lubricant into a cavity, the apparatus comprising a lubricant distribution element according to the first aspect of the present invention, and a gas distribution element for delivering gas into the cavity.

35 Preferably, the gas distribution element is substantially similar to the lubricant distribution element. In this embodiment gas is delivered into the

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cavity through the gas distribution element.

The gas distribution element may be integrally formed with the lubricant distribution element.

In this embodiment, the gas distribution element
5 preferably comprises radial grooves and at least one circumferential groove formed in the upper surface of the lubricant distribution element.

Alternatively, the gas distribution element may take the form of a distribution plate, which may be part
10 of the top of the cavity wall or be a separate plate.

In this embodiment, preferably, the distribution plate has a first set of grooves formed in the top surface of the plate for delivery of gas into the cavity.

Preferably, the distribution plate also has a
15 second set of grooves formed in the top surface to connect the first set of grooves to one another for distribution of the gas to all the grooves in the first set.

Preferably, the distribution plate is manufactured from a metal, such as, for example steel or
20 aluminium.

Alternatively, the distribution plate is manufactured from a ceramic.

Alternatively, the distribution plate is manufactured from a plastic, such as polytetrafluoro-
25 ethylene.

Preferably, the gas distribution element is shaped to extend around the perimeter of the cavity.

Preferably, the gas distribution element is of a similar shape to the lubricant distribution element.

Typically, the gas distribution element is in the
30 shape of an annular disc. The annulus of the annular disc may be round or non-round in shape.

Preferably, the gas distribution element is arranged, in use, to be located above the lubricant
35 distribution element.

Preferably, the gas distribution element has a cut away portion in its lower surface into which the

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lubricant distribution element is adapted to fit snugly.

The gas distribution element may comprise a single element or a number of parts which, in use, abut one another to form the gas distribution element.

5 Preferably, the apparatus for delivering gas and lubricant further comprises a sealant for sealing the lubricant distribution element and the gas distribution element.

10 Preferably, the sealant seals the gas distribution element from the lubricant distribution element.

Preferably, the sealant seals at least a portion of the surface of the gas and lubricant distribution elements.

15 Preferably, the sealant comprises a layer of varnish and/or impermeable foil and/or settable rubber and/or a fibre gasket(s) on at least some of the surface of the gas and lubricant elements.

20 Alternatively, the sealant may comprise an O-ring.

Alternatively, the sealant may comprise a flat surface.

25 Preferably, the sealant further comprises a sealing plate overlaying the gas distribution element for sealing the top of the gas distribution element.

30 According to a fourth aspect of the present invention, there is provided a hot top mould for direct chill continuous casting of metal ingots comprising a mould having a mould body and a cavity defined in the mould body and a gas and lubricant delivery apparatus for delivering gas and lubricant to the mould cavity according to any one or more features of the third aspect of the invention.

35 Preferably, the gas and lubricant delivery apparatus is located proximate the molten metal entry end of the mould.

Preferably, the gas and lubricant delivery

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apparatus is located above the level of the mould body at which the molten metal solidifies.

Preferably, the gas and lubricant delivery apparatus is located on top of the mould body.

5 Preferably, the mould body has a space therein for the flow of coolant through the mould body.

Preferably, the space for the flow of coolant is shaped to flow the coolant close to the gas and lubricant delivery apparatus.

10 Preferably, the hot top mould further comprises a supply mechanism for supplying gas and lubricant to the gas and lubricant delivery apparatus.

Preferably, the supply mechanism comprises gas and lubricant supply channels formed separately in the top
15 of the mould, the supply channels being in fluid connection with the gas and lubricant delivery apparatus.

Alternatively, the supply mechanism may comprise pipe fittings through the mould body and connected directly to the gas and lubricant delivery apparatus.

20 Preferably, the hot top mould further comprises a molten metal bath for feeding molten metal to the mould cavity.

Preferably, the hot top mould further comprises an orifice plate, which spaces the molten metal bath from
25 the mould.

The mould body may or may not have a graphite insert located just below the gas and lubricant delivery apparatus.

Preferably, the metal is a non-ferrous metal such
30 as aluminium, magnesium, copper or zinc and their alloys.

According to a fifth aspect of the present invention, there is provided a hot top mould for direct chill continuous casting of metal ingots comprising a mould having a mould body and a cavity defined in the
35 mould body, and a lubricant delivery element for delivering lubricant to the mould cavity according to the first aspect of the present invention.

Brief Description of the Drawings

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

Figure 1 is a schematic view of a gas and lubricant delivery apparatus for delivering gas and lubricant according to one embodiment of the present invention located in a hot top mould;

10 Figure 2 is a top plan view of a gas distribution element of the apparatus of Figure 1;

Figure 3 is a view of the gas distribution element of Figure 2 through axis A-A;

Figure 4 is a schematic view of a gas and lubricant delivery apparatus for delivering gas and lubricant according to an alternative embodiment of the present invention located in a hot top mould;

Figure 5 is a schematic view of a gas and lubricant delivery apparatus for delivering gas and lubricant according to another alternative embodiment of the present invention located in a hot top mould;

Figure 6A is a top plan view of a hot top mould incorporating a gas and lubricant delivery apparatus for delivering gas and lubricant according to another
25 embodiment of the present invention;

Figures 6B, 6C, 6D and 6E are schematic views of the hot top mould of Figure 6A through sections A-A, B-B, C-C and D-D, respectively;

Figure 7 is an image of the surface of a metal
30 ingot cast using a hot top mould comprising a gas and lubricant delivery apparatus for delivering gas and lubricant according to preferred embodiments of the present invention;

35 Detailed Description of the Drawings

Referring firstly to Figure 1, a section of a hot top mould 10 for use in direct chill continuous casting of

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non-ferrous metals such as aluminium, magnesium, copper, zinc and their alloys, for example, is shown. The hot top mould 10 comprises a molten metal bath 11 located above a mould 12 in a vertical arrangement, ie. so molten metal will flow substantially vertically through the mould 12. The mould 12 and molten metal bath 11 may be arranged so that flow through the mould 12 is substantially horizontal.

The hot top mould 10 also comprises a gas and lubricant delivery apparatus 13 according to preferred embodiments of the present invention located at the top of the mould body 14 (ie. proximate the molten metal entry end of the mould 12 and above the level of the mould body 14 at which the molten metal contacts the mould body 14) for the delivery of gas (typically air) and lubricant (typically oil) to the mould cavity 15.

The mould body 14 in use is cooled using a coolant (typically water) flowing through a space 17 in the mould body 14 in order to solidify the molten metal. The mould body 14 preferably, but not necessarily, has an insert 27 manufactured of graphite.

The gas and lubricant delivery apparatus 13 comprises a lubricant distribution element 20 and a gas distribution element 21. The lubricant distribution element 20 is an annular disc of porous material through which lubricant is delivered to the mould cavity 15. Although the annulus of the annular disc is shown as being round, it may be non-round. Furthermore, the lubricant distribution element 20 may comprise a single element or a number of parts which, in use, abut one another to form the lubricant distribution element 20. The porous annular disc is thin, having a thickness of approximately 1 to 5mm. This range represents a balance between the disc being as thin as practical to fit into the hot top mould 10 and the pressure required to force the oil through the disc into the mould cavity 15. However, it may be possible to use a much thinner disc of, for example, less

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than 0.1mm. In an alternative embodiment (not shown here) the disc has a thickness of at least approximately 1.5mm with a 0.5mm groove formed in the top surface of the disc to further improve the distribution of oil around the circumference of the disc for even circumferential flow of lubricant and gas from the apparatus 13.

The space 17 in the mould body 14 for the coolant is shaped to flow the coolant close to the gas and lubricant delivery apparatus 13. Because the lubricant distribution element 20 is so thin it is readily cooled by the coolant cooling the mould body 14. This substantially prevents the lubricant, while it is inside the distribution element 20, from reaching a temperature where it will vaporise and decompose into tar-like deposits and thus restrict its flow through the lubricant distribution element 20.

The lubricant distribution element 20 in the form of a porous annular disc may be manufactured from any materials commonly used in powder metallurgy applications; such as aluminium, iron, copper or sintered bronze. Sintered bronze is a preferable material as it provides the required strength and flexibility and is readily and cost effectively manufactured into any shape, including thin annular discs by sintering bronze powder in a steel die at high temperatures. In addition, sintered bronze allows for good control over the porosity and pore size, particularly compared to graphite. Use of porous ceramic materials to form the disc may also be possible. Another alternative material which could be used is a porous plastic such as polytetrafluoroethylene. Furthermore, it may also be possible to form the thin disc of graphite of adequate porosity. In this case, the graphite would need to be strengthened by, for example, lamination to a thin metal support disc as of itself, graphite would not have the required strength.

In forming the disc, it has been found that as the particle size of the material forming the porous disc

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increases, the uniformity of circumferential oil distribution throughout the disc, in use, decreases. The diameter of the particles used to form the disc is therefore less than approximately 0.25mm. Particles
5 smaller than approximately 10-20 micron in diameter may be used to form a disc, however, at smaller particle sizes, the pressure required to force the oil through the porous disc may become too high for effective operation of the lubricant and gas delivery apparatus 13. The diameter of
10 the pores is generally approximately 20 - 40 micron. However, for discs manufactured of smaller particles, this diameter may be reduced. The porosity of the thin disc is 10 to 70%, preferably, 20 to 40%. In an alternative embodiment, the disc has a gradient of changing porosity
15 across its width.

Because the diameter of the pores/porosity is so small the surface tension of the molten metal acts to prevent it from entering the pores and damaging the lubricant distribution element 20.

20 Referring now also to Figures 2 and 3, in one embodiment of the gas and lubricant delivery apparatus 13 of the present invention, the gas distribution element 21 is in the form of an annular distribution plate, shown in detail in Figures 2 and 3. The gas distribution element 21
25 may comprise a single element or a number of parts which, in use, abut one another to form the gas distribution element 21. The distribution plate has radial grooves 40 on its top surface 41 for delivering the gas to the mould cavity 15. The distribution plate also has at least one
30 circumferential groove 42 connecting the radial grooves 40 for distribution of the gas to all the grooves 40. The distribution plate is preferably manufactured from a metal such as, for example, steel or aluminium. The gas distribution element 21 in the form of an annular
35 distribution plate also has a cut away portion 43 in its lower surface 44 into which the lubricant distribution element 20 in the form of the annular porous disc is

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adapted to fit snugly.

In an alternative embodiment (not shown), the gas distribution element 21 is integrally formed with the lubricant distribution element 20 by forming radial
5 grooves and at least one circumferential groove on the upper surface of the lubricant distribution element 20 which is in the form of an annular disc of porous material.

Referring more specifically again to Figure 1, as
10 described above, the gas and lubricant delivery apparatus 13 comprising the lubricant distribution element 20 and the gas distribution element 21 is located on top of the mould body 14. In use, an orifice plate 25 spaces the top of the gas distribution element 21 from the bottom of the
15 molten metal bath 11, with the entire arrangement fixed into position by a locking plate 26. Part of the mould body 14 comprises a graphite liner 27, located immediately beneath the gas distribution element 21. The purpose of the graphite liner 27 is to provide a casting surface upon
20 which the molten metal initially begins to solidify. In the embodiment shown in Figure 1, the orifice plate 25 has an overhang portion 28 extending into the mould cavity 15 past the lubricant and gas distribution elements 20,21. The overhang portion 28 creates a space 29 between the
25 orifice plate 25 and the mould body 14, which is the entry point to the mould cavity 15 for the gas and lubricant delivered by the gas and lubricant delivery apparatus 13.

Thus, the gas and lubricant delivery apparatus 13 is arranged so that it is highly unlikely to be contacted
30 by molten metal. Instead, the molten metal meniscus will contact the graphite liner 27 which is below the gas and lubricant delivery apparatus 13. This means that the apparatus 13 is not directly heated by the molten metal and hence the likelihood of lubricant vaporisation is
35 further reduced. In use, the lubricant is allowed to enter the mould cavity 15 as a liquid and flow down a part of the mould body 15 before reaching the solidifying

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molten metal.

The supply of gas and lubricant to the gas and lubricant delivery apparatus 13 is provided by gas and lubricant supply channels 30,31 respectively formed in the top of the mould body 14. Alternatively, pipe fittings through the mould body 14 may be used to supply lubricant and/or gas directly to the gas and lubricant delivery apparatus 13. A first O-ring 32 seals the lubricant and gas supply channels 30,31 from one another. A second O-ring 33 seals the entire gas and lubricant delivery apparatus 13 at the boundary between the locking plate 26 and the top of the mould body 14.

Further sealing of the lubricant and gas distribution elements 20,21 may be provided. In Figure 1, sealing of the top surface 41 of the gas distribution element 21 in the form of an annular distribution plate is provided by a sealing ring 34 overlaying the plate. The bottom surface of the lubricant distribution element 20, in the form of the annular porous disc, is sealed by a thin coat of varnish. Alternatively, a layer of thin, impermeable foil or an O-ring or a layer of settable rubber, applied as a paste, or a flat surface in the form of a metal plate or the top of the mould body 14 could be used. Sealing of the lubricant and gas distribution elements 20,21 guards against loss of lubricant and/or gas into other parts of the mould 12 providing controlled flow both radially and circumferentially.

Referring now to Figure 4, an alternative embodiment of the gas and lubricant delivery apparatus 113 is shown. Similar features to those described in the previous embodiment have been referenced with the same numbers, but are prefixed with the numeral 1.

In the embodiment shown in Figure 4, the gas distribution element 121 is in the form of an annular porous disc similar to the lubricant distribution element 120. The disc forming the gas distribution element 121 is sandwiched between the lubricant distribution element 120

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and the orifice plate 125. A layer 135 of either impermeable foil or varnish separates and seals the discs forming the lubricant and gas distribution elements 120,121 from one another. The, gas is therefore delivered
5 to the mould cavity 115 through the porous disc forming the gas distribution element 121 without substantial mixing with the lubricant being delivered to the mould cavity 115, through the porous disc forming the lubricant distribution element 120.

10 Rear surfaces 136 of both the lubricant and gas distribution elements 120,121 are sealed selectively using an impermeable foil, varnish layer, or a thin fibre gasket. The lower surface 132 of the lubricant distribution element 120 is similarly sealed. Notably, the
15 lower surface 137 is not sealed where it is located above the lubricant supply channel 132 so that lubricant can be fed to the lubricant distribution element 120 from the channel 132.

Figure 4 also discloses an alternative supply
20 mechanism of supplying gas to the gas distribution element 121, whereby an air supply line 145 through an air supply plate 136 located behind the delivery apparatus 113 (ie. away from the mould cavity 115) on top of the mould body 114 supplies the gas from the gas supply channel 131.

25 Figure 4 also shows the molten metal meniscus 150 where it contacts the graphite liner 127.

Referring now to Figure 5, another alternative embodiment of the gas and lubricant delivery apparatus 213
30 of the present invention is shown. Similar features to those described in the previous embodiments have been referenced with the same numbers, but are prefixed with the numeral 2.

In this embodiment of the gas and lubricant delivery apparatus 213, the gas and lubricant distribution
35 elements 220,221 are shown extending beyond the mould body 214 defined by the graphite liner 227 into the mould cavity 215. Furthermore, the gas distribution element 221

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overhangs the lubricant distribution element 220. This assists in directing the flow of gas perpendicular to the mould bodies 214. The gas distribution element 221 in Figure 5 may be in the form of either an annular
5 distribution plate or an annular porous disc.

Figure 5 also shows the gas and lubricant delivery apparatus 213 in use with an orifice plate 225 which does not have an overhang extending into the mould cavity 215 past the lubricant and gas delivery apparatus
10 213.

Referring now to Figures 6A to 6E, a further alternative embodiment of the gas and lubricant delivery apparatus 313 of the present invention is shown. Similar features to those described in the previous embodiments
15 have been referenced with the same numbers, but are prefixed with the numeral 3.

The delivery apparatus 313 comprises lubricant and gas distribution elements 320 and 321, respectively. The top and bottom surfaces of the lubricant distribution
20 element 320 are sealed by thin fibre gaskets 355, 356.

The gas distribution element 321 is different from previously described embodiments in that the radial and circumferential grooves 340, 342 for delivering the gas to the mould cavity 315 are formed in the lower
25 surface 344 of the gas distribution element 321 as opposed to the top surface. As shown specifically in Figure 6E, the gas distribution element 321 comprises two circumferential grooves 342 in the form of chambers, connected by a plurality of radial grooves 340, also in
30 the form of chambers. One of the circumferential chambers 342 is located on the inside wall of the mould cavity 315, slightly vertically spaced away from the other such that the radial channels 340 are slightly angled with respect to the horizontal. The gas supply channels 330 are
35 provided through the locking plate 326 as opposed to through the mould body 314 as shown in Figure 6B in particular.

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The delivery apparatus 313 is also shown comprising a locating pin 357 for correctly positioning the gas and lubricant distribution elements 320, 321 within the hot top mould 310.

5

EXAMPLES

Example 1

A hot top mould 10 according to preferred embodiments of the invention was used to cast a billet of aluminium alloy 6063. The lubricant distribution element 20 in the form of an annular disc was formed from particles of sintered bronze of between 45 and 63 micron in diameter. The resulting disc had a porosity of 45-50%. The disc had a thickness of approximately 1.5 mm. The gas distribution element 21 comprised a metal disc having radial grooves machined on one surface. Air was used as the gas and oil as the lubricant.

A single billet with a diameter of 152mm was cast under the following conditions:

- 20 • Casting Speed: 150mm/min
- Coolant Water Flowrate: 75L/min
- Metal Head: 75mm
- Air Pressure: 2.5kPa
- Melt Temperature: 670-710°C
- 25 • Oil Flowrate: 5mL/min

The resulting casting had a surface which was free of any defects as shown in Figure 7.

30 Example 2

A test mould was set up in the lab to test a gas and lubricant delivery apparatus 13 according to embodiments of the present invention, in which the lubricant distribution element 20 and the gas distribution element 21 are formed of a porous plastic material, specifically polytetrafluoroethylene ("PTFE"). Figure 13 shows a schematic view of the test mould used. Notably,

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the steps machined into the top of the mould body 14 in which the gas and lubricant distribution elements sit are of a depth which is 0.1 mm less than the thickness of the distribution elements so as to provide a compressive force to the horizontal surfaces of the distribution elements 20, 21 by the sealing ring 34. The distribution elements 20, 21 were formed by cutting annular rings from 1.5 mm thick sheets of a porous PTFE plastic (having pores of 50 micron) supplied by Porex. The diameters of the elements 20, 21 were such as to provide a 5 and 10 mm radial section through which the lubricant and gas, respectively, would flow to the inner surface of the mould 12. The inner surface diameter of the mould was 150 mm. The two distribution elements 20, 21 were stuck together using Dow-Corning Silastic 732, which is a silicon adhesive/sealant. The top surface of the gas distribution element 21 and the lower surface of the lubricant distribution element 20 were also coated with silicon prior to assembly into the mould. The gas supplied to the gas distribution element 21 was dry air from a cylinder, through a regulator to a needle valve for accurately controlling the flow. The gas flow rate was measured using an Aalborg digital gas flow meter. The gas flow meter was kept in the gas delivery line and the flow around the circumference of the mould was detected using a soap solution. The lubricant supplied to the lubricant distribution element 20 was Exal45 as supplied by ODT Engineering. The circumferential flow of the lubricant in the mould was observed through the test mould which was formed from transparent Perspex for the purposes of this test.

A very uniform circumferential distribution of gas was obtained at a flow rate of 2.0 litres per minute. The gas pressure required to achieve this flow was low, approximately 20 - 30 mbar. High gas flows did not change the distribution which remained uniform around the circumference of the mould.

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On initial connection of the lubricant supplied to the mould, gas was found to be bubbling back through the lubricant supply. This was traced to the gas supply and was due to a portion of the surface of the gas distribution element 21 not being coated with silicon. This portion of the surface was subsequently coated and as a result no bypass of gas to the oil supply line occurred. At a head height of 1000 mm, a flow rate of 1 ml/min of lubricant to the lubricant distribution element 21 was obtained. Even circumferential flow was obtained after about 10 minutes.

Example 3

A hot top mould 10 according to a preferred embodiment of the invention was used to cast a billet of magnesium alloy AZ80. The mould diameter was 203 mm. The nominal composition for AZ80 is 8.5% Aluminium and 0.5% Zinc, with the balance magnesium. Table 1 below provides details of the operating conditions used for the casting of the AZ80 billet.

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Table 1 - Conditions for AZ80 alloy cast

Parameter	Unit	Setting/Actual
Furnace set point	°C	740
Metal temperature in hot top box	°C	720-730
Pump start power	%	120
Pump start power hold time	seconds	25
Pump run power	%	38
Cast speed	mm/minute	90
Water flow	litres/minute	160
Mould gas flow rate	litres/minute	3
Metal level - hot top box	mm	60
Orifice plate material & coating		N17 + graphite

5 The alloy was successfully cast to a length of approximately 1380 mm. Figure 14 shows the surface of the cast billets which have a satisfactory cast surface and are not cracked.

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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
5 "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 clearly understood that although
10 prior art publication(s) are referred to herein, this reference does not constitute an admission that any of these documents forms part of the common general knowledge in the art in Australia or in any other country.

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Claims

1. A lubricant delivery element for delivering lubricant into a cavity, the lubricant distribution element comprising a thin element of porous material for delivering lubricant into the cavity through the element.
2. A lubricant delivery element as claimed in claim 1, wherein the lubricant distribution element has a thickness of less than approximately 5mm.
3. A lubricant delivery element as claimed in claim 1, wherein the lubricant distribution element has a thickness of 0.1 to 5mm.
4. A lubricant delivery element as claimed in claim 1, wherein the lubricant distribution element has a thickness of 1 to 5mm.
5. A lubricant delivery element as claimed in any one of the preceding claims, wherein the porous material comprises an agglomerate of particles, the particles having an average diameter of less than approximately 0.25mm.
6. A lubricant delivery element as claimed in any one of claims 1 to 5, wherein the porous material comprises an agglomerate of particles, the particles having an average diameter of 10 to 100 micron.
7. A lubricant delivery element as claimed in any one of the preceding claims, wherein the porous material has a porosity of 10 to 70%.
8. A lubricant delivery element as claimed in any one of claims 1 to 7, wherein the porous material has a porosity of 20 to 40%.

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9. A lubricant delivery element as claimed in any one of the preceding claims, wherein the porosity of the material changes across the width of the lubricant distribution element.
- 5 10. A lubricant delivery element as claimed in any one of the preceding claims, wherein the porous material is sintered bronze.
- 10 11. A lubricant delivery element as claimed in any one of claims 1 - 9, wherein the porous material is polytetrafluoroethylene.
12. A lubricant delivery element as claimed in any
15 one of the preceding claims, further comprising a sealant for sealing at least a portion of the surface of the lubricant distribution element which is not arranged to be exposed to the cavity.
- 20 13. A lubricant delivery element as claimed in claim 12, wherein the sealant comprises a layer of varnish, impermeable foil or settable rubber, or a fibre gasket(s), or an O-ring(s), or any combination thereof.
- 25 14. A gas and lubricant delivery apparatus for delivering gas and lubricant into a cavity, the apparatus comprising a lubricant distribution element as claimed in any one of the preceding claims, and a gas distribution element for delivering gas into the cavity.
- 30 15. A gas and lubricant delivery apparatus as claimed in claim 14, wherein the gas distribution element is integrally formed with the lubricant distribution element.
- 35 16. A gas and lubricant delivery apparatus as claimed in claim 14 or 15, wherein the gas distribution element is substantially similar to the lubricant distribution

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element.

17. A gas and lubricant delivery apparatus as claimed in claim 14 or 15, wherein the gas distribution element
5 comprises radial grooves and at least one circumferential groove formed in the upper surface of the lubricant distribution element.

18. A gas and lubricant delivery apparatus as claimed
10 in claim 14 or 15, wherein the gas distribution element is in the form of a distribution plate, the distribution plate having a first set of grooves formed in the top surface of the plate for delivery of gas into the cavity.

15 19. A gas and lubricant delivery apparatus as claimed in claim 18, wherein, the distribution plate also has a second set of grooves formed in the top surface to connect the first set of grooves to one another for distribution of the gas to all the grooves in the first set.

20 20. A gas and lubricant delivery apparatus as claimed in any one of claims 14 to 19, wherein the gas distribution element has a cut away portion in its lower surface into which the lubricant distribution element is
25 adapted to fit snugly.

21. A gas and lubricant delivery apparatus as claimed in any one of claims 14 to 20, wherein the apparatus further comprises sealant for sealing the lubricant
30 distribution element from the gas distribution element.

22. A hot top mould for direct chill continuous casting of metal ingots comprising a mould having a mould body and a cavity defined in the mould body and a gas and
35 lubricant delivery apparatus for delivering gas and lubricant to the mould cavity as claimed in any one of claims 14 to 21.

- 25 -

23. A hot top mould as claimed in claim 22, wherein the gas and lubricant delivery apparatus is located proximate the molten metal entry end of the mould.

5

24. A hot top mould as claimed in claim 22 or 23, wherein the gas and lubricant delivery apparatus is located on top of the mould body.

10 25. A hot top mould as claimed in any one of claims 22 to 24, wherein the mould body has a space therein for the flow of coolant through the mould body.

26. A hot top mould as claimed in claim 25, wherein
15 the space for the flow of coolant is shaped to flow the coolant close to the gas and delivery apparatus.

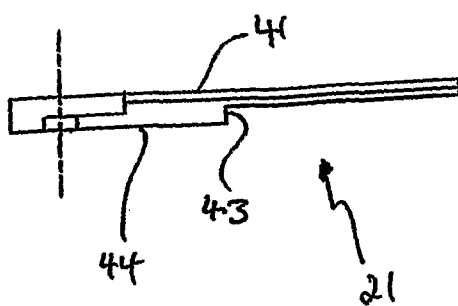
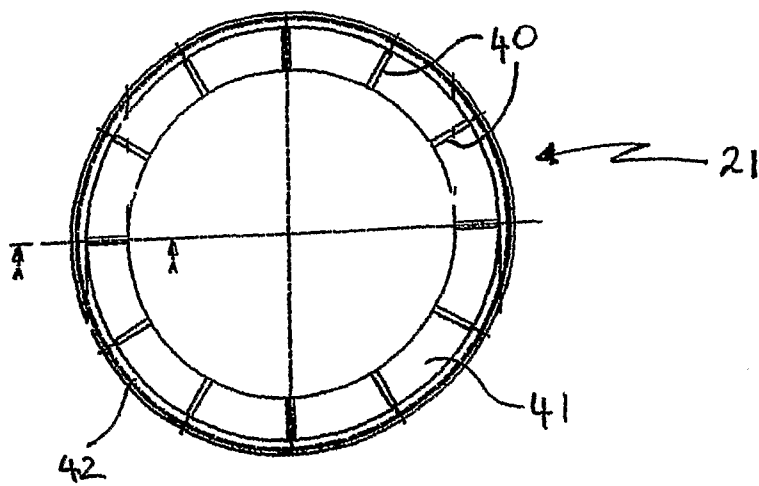
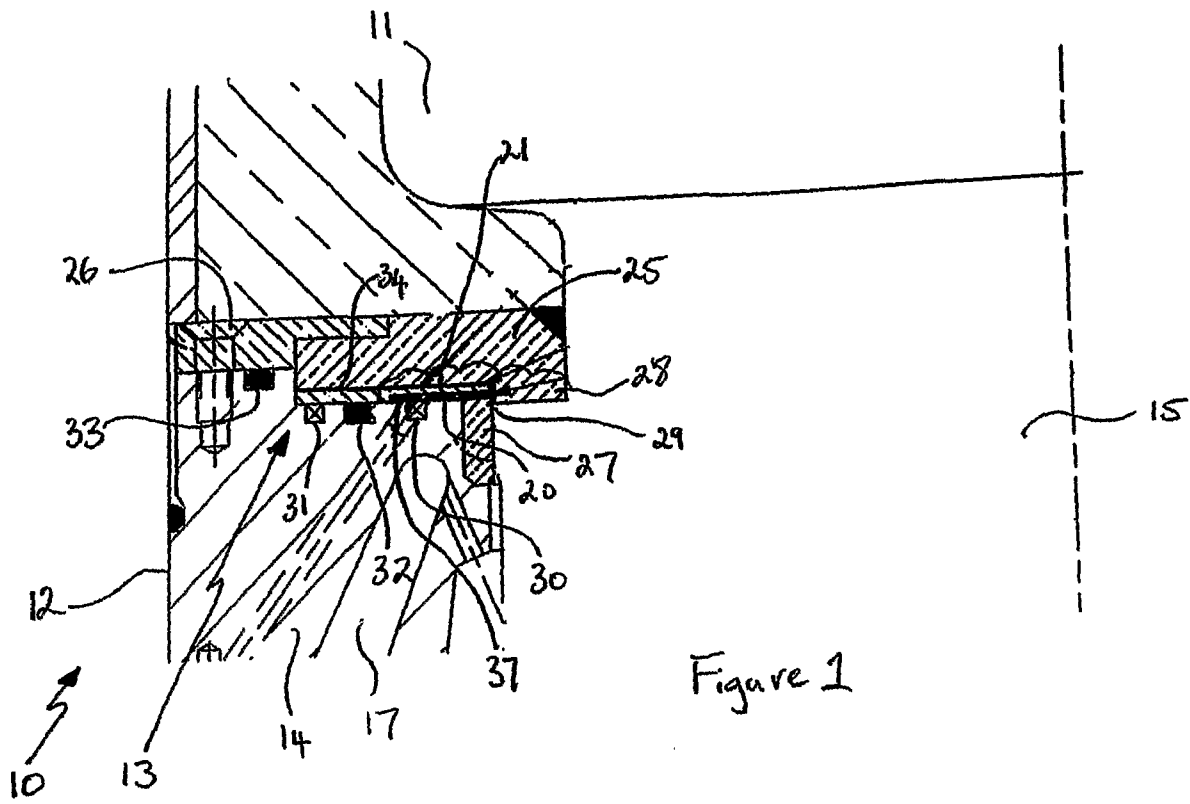
27. A hot top mould as claimed in any one of claims 22 to 26, wherein the hot top mould further comprises a
20 supply mechanism for supplying gas and lubricant to the gas and lubricant delivery apparatus.

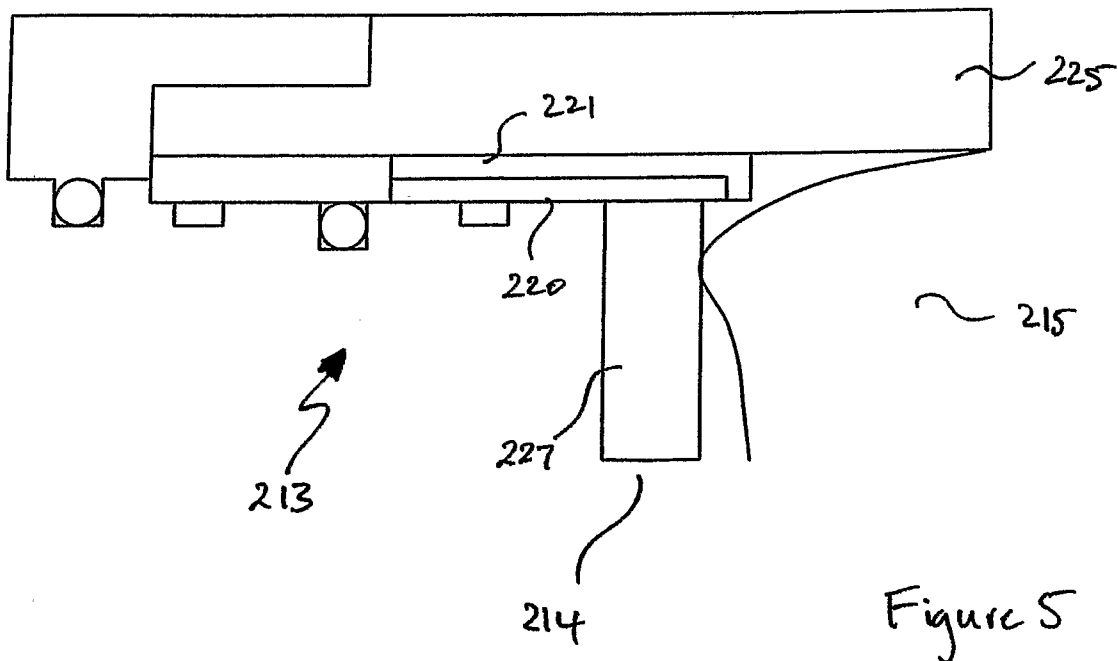
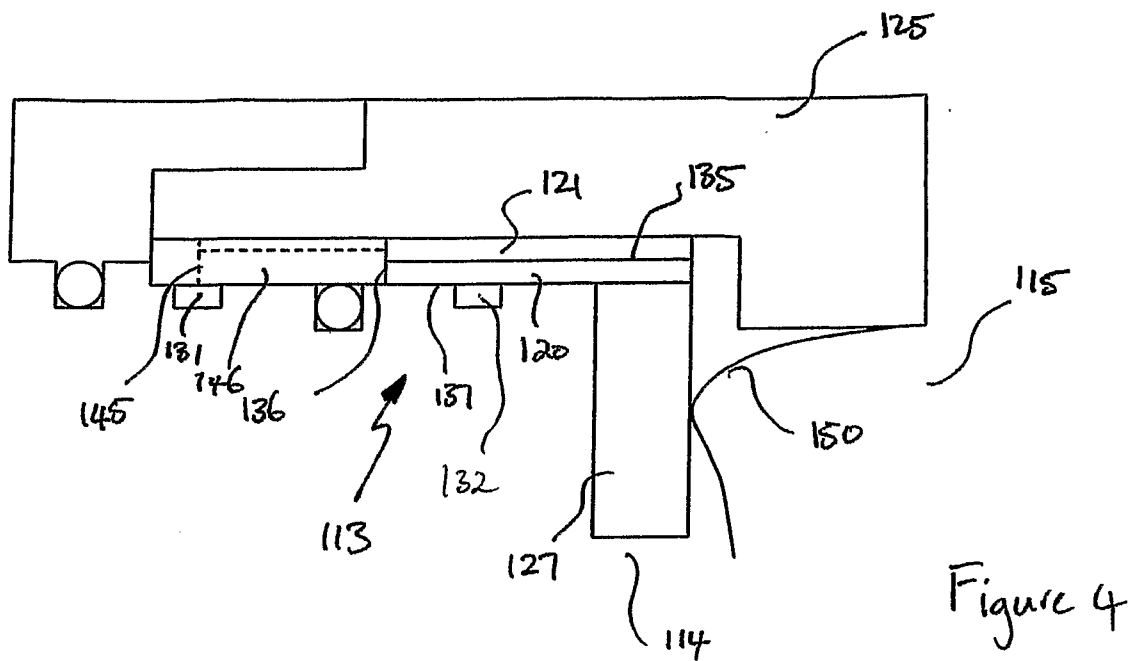
28. A gas delivery element for delivering gas into a cavity, the element comprising a thin element of porous
25 material for delivering gas into the cavity through the element.

29. A gas delivery element as claimed in claim 28, wherein the gas distribution element is substantially
30 identical to the lubricant distribution element as claimed in any one of claims 1 to 13.

30. A hot top mould for direct chill continuous casting of metal ingots comprising a mould having a mould
35 body and a cavity defined in the mould body, and a lubricant delivery element for delivering lubricant to the mould cavity according to any one of claims 1 to 13.

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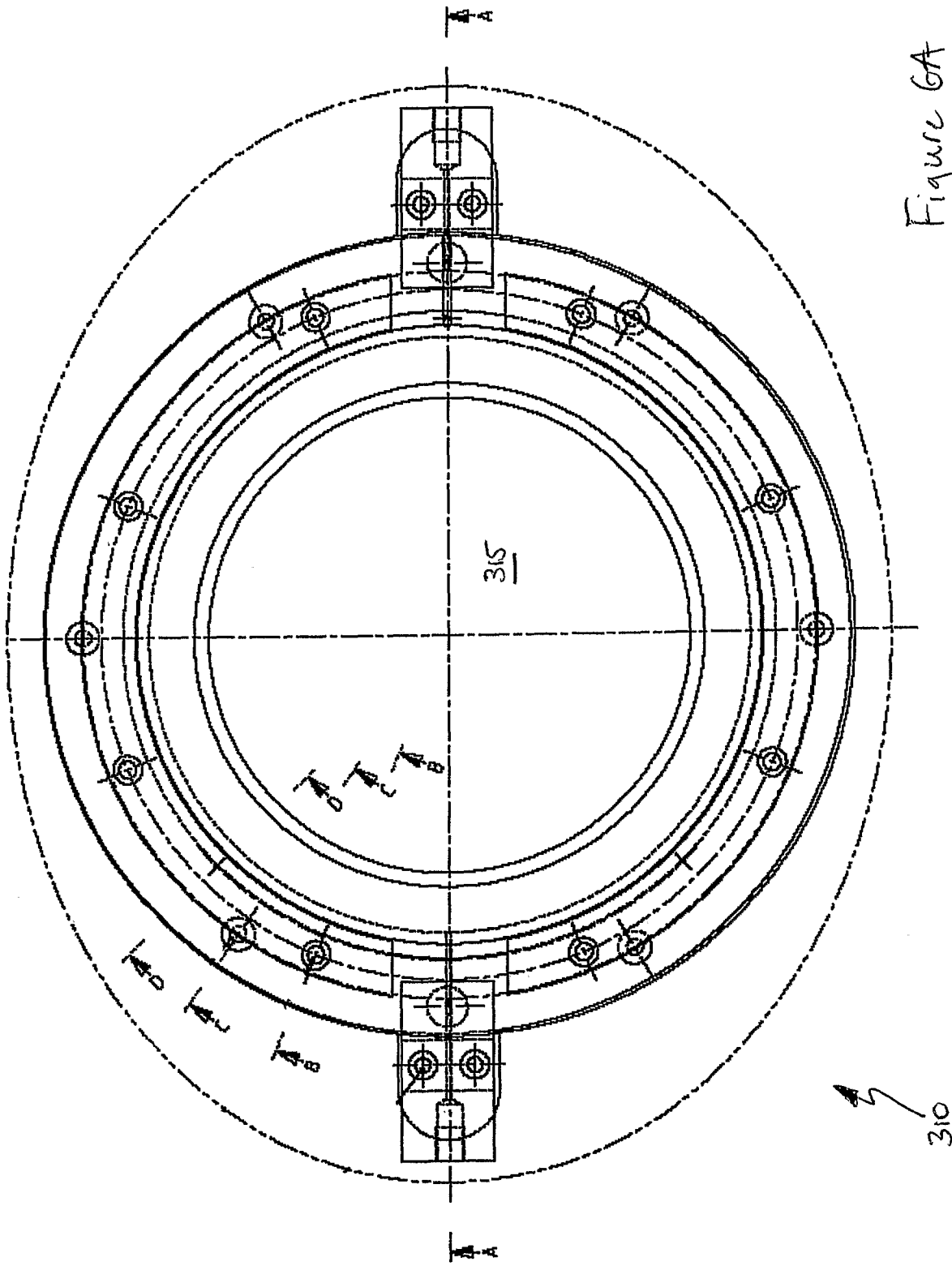
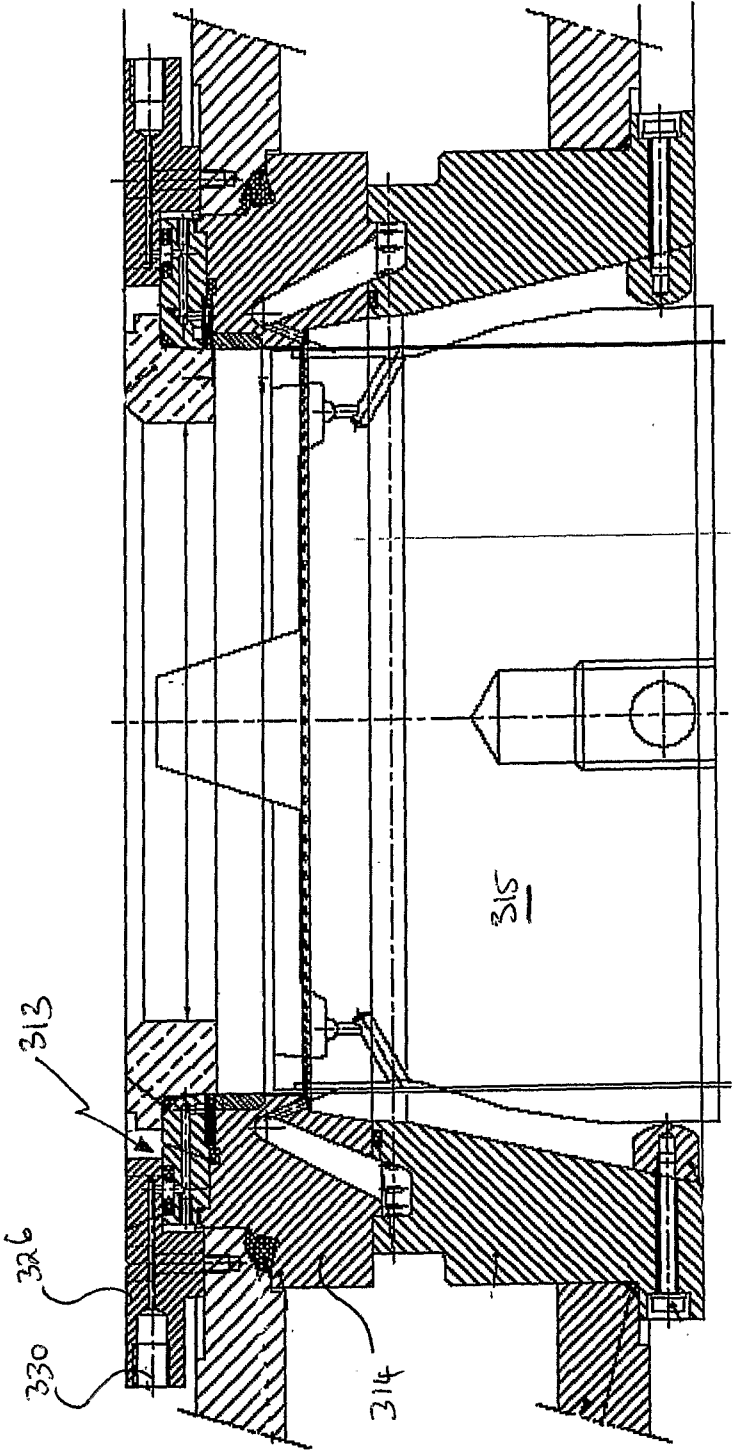


Figure 6A



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Figure 6B

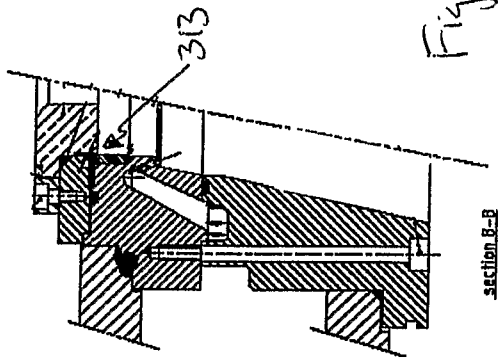


Figure 6C

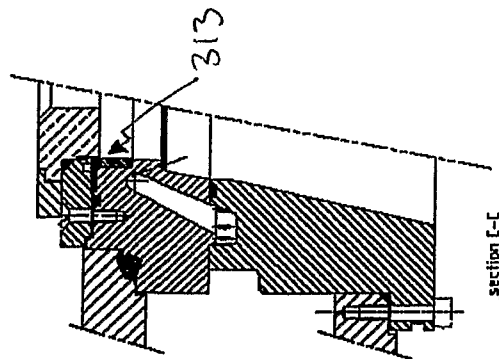


Figure 6D

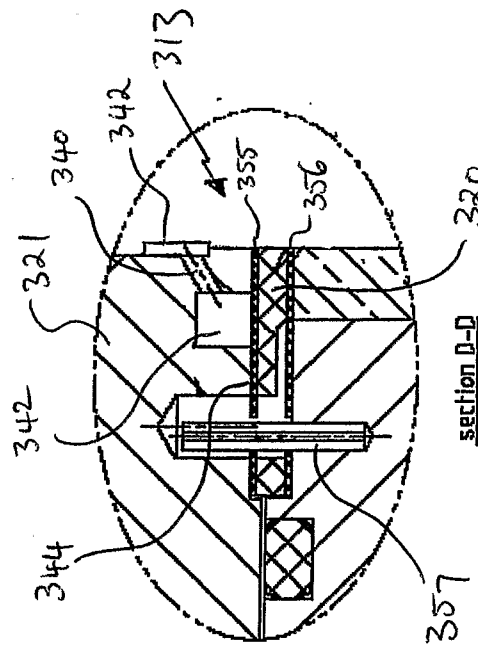


Figure 6E

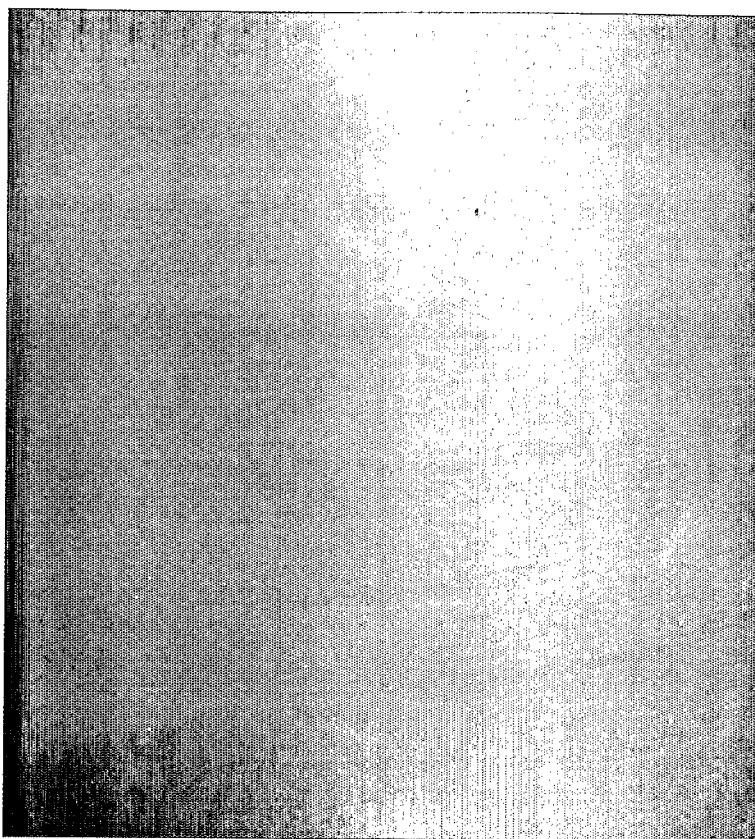


FIGURE 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2006/001820

A. CLASSIFICATION OF SUBJECT MATTER		
Int. Cl.		
B22D 11/07 (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)		
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)		
DWPI: B22D and key words: Lubrica+, Pore+, Porous+, Deliver+ and similar terms		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4437508 A (PRYOR ET AL) 20 March 1984	
Y	Whole document (particularly pages 2-3, 6 and 11; claim 8)	1-13 & 28-30
	Whole document (particularly pages 2-3, 6 and 11; claim 8)	14-27
X	EP 0060359 A1 (OLLN CORPORATION) 22 September 1982	
Y	Whole document (particularly pages 2-3, 6 and 11; claim 8)	1-13 & 28-30
	Whole document (particularly pages 2-3, 6 and 11; claim 8)	14-27
X	US 4501317 A (SOKOLOWSKI) 26 February 1985	
Y	Whole document (particularly abstract; columns 2-5)	1-13 & 28-30
	Whole document (particularly abstract; columns 2-5)	14-27
X	EP 0119734 B1 (KABUSHIKI KAISHA KOBE SEIKO SHO) 16 August 1989	
Y	Whole document (particularly cols 2, 5 & 6; column 9, line 58-column 12, line 37)	1-13 & 28-30
	Whole document (particularly cols 2, 5 & 6; column 9, line 58-column 12, line 37)	14-27
☒ 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 19 January 2007		Date of mailing of the international search report 29 JAN 2007
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaaustralia.gov.au Facsimile No. (02) 6285 3929		Authorized officer Mike Bremers Telephone No : (02) 6283 2052

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2006/001820

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	GB 2222792 A (SHOWA DENKO KABUSHIKI KAISHA) 21 March 1990 Whole Document (particularly pages 10-11, 16-22)	14-27

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2006/001820

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	4437508	US	4287937
		US	4420030
EP	0060359	JP	57152353
US	4501317	NONE	
EP	0119734	AU	24510/84
		JP	60040655
GB	2222792	AU	22208/88
		DE	3832306
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.			
END OF ANNEX			