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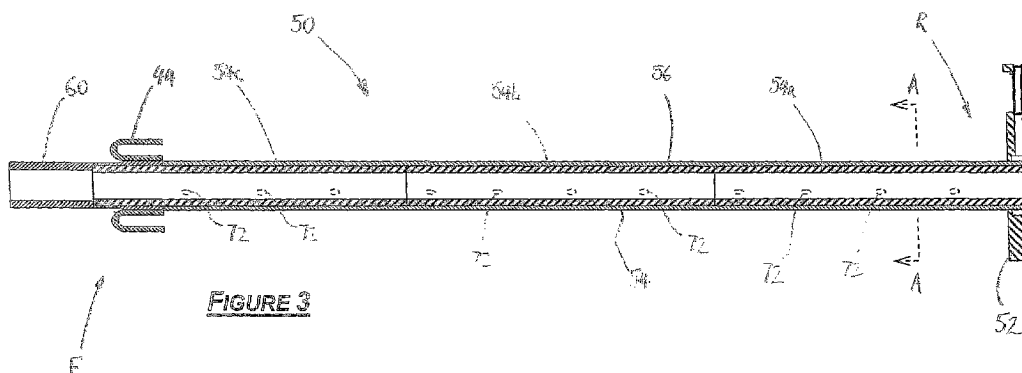


FIGURE 3

(57) Abstract: An apparatus for injecting solid material into a vessel, such as a direct smelting vessel. The apparatus has a central tube comprising: a core tube assembly that defines a passageway for solid material, the core tube assembly having at least one core tube and having an inlet for receiving solid material at a rear end and an outlet at a forward end; an outer sheath that extends over at least a portion of the core tube assembly, the outer sheath having an internal diameter that is greater than the outer diameter of the core tube assembly such that a substantially annular clearance is provided between the core tube assembly and the outer sheath; and a cementing agent that fills the annular clearance and forms a bond that secures the core tube assembly within the outer sheath.

APPARATUS FOR INJECTING SOLID MATERIAL INTO A VESSELField of the invention

5 The present invention relates to an apparatus for injecting solid material into a vessel, such as a direct smelting vessel.

Background

10

A known direct smelting process, which relies principally on a molten bath as a reaction medium, and is generally referred to as the HIs melt process, is described in International application PCT/AU96/00197 (WO 96/31627) in the name of the applicant.

15

The HIs melt process as described in the International application in the context of producing molten iron includes:

- 20 (a) forming a bath of molten iron and slag in a vessel;
- (b) injecting into the bath:
- (i) a metalliferous material, typically iron oxides; and
- 25 (ii) a solid carbonaceous material, typically coal, which acts as a reductant of the iron oxides and a source of energy; and
- (c) smelting metalliferous material to iron in
- 30 the metal layer.

The term "smelting" is herein understood to mean thermal processing wherein chemical reactions that reduce metal oxides take place to produce molten metal.

5 The Hismelt process also includes post-combusting reaction gases, such as CO and H₂ released from the bath, in the space above the bath with oxygen-containing gas and transferring the heat generated by the post-combustion to the bath to contribute to the thermal
10 energy required to smelt the metalliferous materials.

 The Hismelt process also includes forming a transition zone above the nominal quiescent surface of the bath in which there is a favourable mass of ascending and
15 thereafter descending droplets or splashes or streams of molten metal and/or slag which provide an effective medium to transfer to the bath the thermal energy generated by post-combusting reaction gases above the bath.

20 In the Hismelt process the metalliferous material and solid carbonaceous material is injected into the molten bath through a number of lances/tuyeres which are inclined to the vertical so as to extend downwardly and inwardly through the side wall of the smelting vessel
25 and into a lower region of the vessel so as to deliver at least part of the solids material into the metal layer in the bottom of the vessel. To promote the post-combustion of reaction gases in the upper part of the vessel, a blast of hot air, which may be oxygen enriched, is injected into
30 an upper region of the vessel through a downwardly extending hot air injection lance. Off gases resulting from the post-combustion of reaction gases in the vessel are taken away from the upper part of the vessel through

an off gas duct. The vessel includes refractory-lined water cooled panels in the side wall and the roof of the vessel, and water is circulated continuously through the panels in a continuous circuit.

5

The HIs melt process enables large quantities of molten iron to be produced by direct smelting of metalliferous material. To enable such levels of production, large quantities of both metalliferous material and carbonaceous material must be supplied to the vessel.

One example of the construction of a solids injection lance for use in a direct smelting vessel can be found in U.S. Patent No. 6,398,842 (assigned to the present Applicant). This form of lance can be used to inject solid particulate material, such as metalliferous material or carbonaceous material, into the direct smelting vessel. In that construction, the solid particulate material is passed through a central core tube which is fitted closely within an outer annular cooling jacket. A forced internal cooling water system is provided within the outer annular cooling jacket to allow the lance to operate successfully when exposed to the high temperatures encountered within a direct smelting vessel, which can be in excess of 1400°C.

Metalliferous material and carbonaceous material can be particularly abrasive. When the direct smelting vessel is used to produce molten iron, typically the metalliferous material comprises iron ore fines. It is desirable that the components of the direct smelting plant

can withstand exposure to these abrasive materials over a smelting campaign, which can be 12 months or longer.

The present invention provides an effective and
5 reliable solids injection lance for the injection of metalliferous material and/or carbonaceous material into a direct smelting vessel.

Summary of the invention

10

The present invention provides an apparatus for injecting solid material into a vessel, such as a direct smelting vessel, the apparatus having a central tube comprising:

15

a core tube assembly that defines a passageway for solid material, the core tube assembly having at least one core tube formed of a hard, wear resistant material and having an inlet for receiving solid material at a rear end and an outlet at a forward end;

20

an outer sheath that extends over at least a portion of the core tube assembly, the outer sheath having an internal diameter that is greater than the outer diameter of the core tube assembly such that a substantially annular clearance is provided between the
25 core tube assembly and the outer sheath; and

a cementing agent that fills the annular clearance and forms a bond that secures the core tube assembly within the outer sheath.

30

The outer sheath provides mechanical support to the core tube assembly and the cementing agent provides bonding across a substantial portion of the external surface of the core tube assembly.

Preferably, the core tube assembly comprises at least two core tubes that are arranged such that the ends of adjacent core tubes abut one another, and such that the
5 hollows of the core tubes are in alignment.

The cementing agent provides resistance to shear forces arising between adjacent core tubes due to pneumatic conveying of material through the core tube
10 assembly.

Preferably, the internal surface of the outer sheath is provided with a plurality of ribs that provide an interference with the cementing agent.
15

Preferably, the ribs extend circumferentially about the internal surface of the outer sheath. Preferably, each rib of said plurality of ribs extends over a partial circumference of the internal surface of
20 the outer sheath.

Preferably, said plurality of ribs are spaced circumferentially about a common diameter of said inner surface of said outer sheath, with clearance between at
25 least two adjacent ribs.

Preferably, the plurality of ribs extend partly longitudinally with respect to the elongate direction of the core tube assembly.
30

Preferably, the ribs include one or more sets of ribs.

Preferably, the ribs of a respective set of ribs are arranged in longitudinally spaced apart subsets of ribs.

5 Preferably, there are three ribs within each subset.

Preferably, a first set of ribs is located adjacent the forward end of the outer sheath and a second
10 set of ribs is located adjacent the rear end of the outer sheath.

Preferably, in an embodiment in which the core tube assembly comprises at least two core tubes, the
15 central tube further comprises one or more joiners on an outer surface of the core tube assembly that extend across the abutting ends of adjacent core tubes and join together the adjacent core tubes.

20 Preferably, the joiners are secured to the core tubes by an adhesive.

Preferably, the joiners have a thickness that is substantially equal to the radial thickness of the annular
25 clearance.

Preferably, the joiners are in the form of an elongate strip that extends in the elongate direction of the core tube assembly across the abutting ends of
30 adjacent core tubes.

Preferably, one of the sets of ribs has a passage that allows the joiners to slide through the

respective set of ribs during assembly of the central tube.

Preferably, the central tube further comprises
5 an extension piece that extends over a portion of the forward end of the core tube assembly.

Preferably, the extension piece is secured to the forward end of the outer sheath.
10

Preferably, the rear end of the core tube assembly is flush with the rear end of the outer sheath.

Preferably, the core tube assembly further
15 comprises a flange that extends about the rear end of the outer sheath.

Preferably, a rear surface of the flange is flush with the rear end of the outer sheath and/or the
20 core tube assembly.

Preferably, the cementing agent is a grout.

Preferably, the apparatus is a solids injection
25 lance.

Preferably, the apparatus further comprises an annular water cooling jacket that extends over a substantial portion of the centre tube.
30

The present invention further provides a direct smelting plant that comprises at least one apparatus as described above.

The present invention further provides a method of assembling the apparatus described above, comprising the steps of:

- 5 (a) inserting a core tube assembly into the outer sheath such that an annular clearance is established between the outer sheath and the core tube assembly;
- 10 (b) filling the annular clearance with the cementing agent; and
- (c) allowing the cementing agent to harden to form a bond that secures the core tube assembly within the outer sheath.

15 Preferably step (a) further comprises forming the core tube assembly by aligning a plurality of core tubes such that the ends of adjacent core tubes are in abutment and the hollow cores are in alignment.

20 Preferably, step (b) comprises introducing the cementing agent into the annular clearance adjacent one of the rear end and forward end of the core tube assembly.

 Preferably, the method further comprises

25 elevating the other of the forward end and the rear end prior to filling the annular clearance with the cementing agent.

 Preferably, the method further comprises forming

30 a hole in the outer sheath for introducing the cementing agent through the outer sheath into the annular clearance.

Preferably, the method further comprises securing an attachment point to the outer surface of the outer sheath about the hole, the attachment point for facilitating connection with a cementing agent delivery system.

Preferably, the attachment point is removed from the outer sheath after the annular clearance has been filled with the cementing agent.

Preferably, the method further comprises providing a plurality of ribs on the internal surface of the outer sheath prior to inserting the core tubes into the outer sheath.

Preferably, the method further comprises providing a plurality of ribs on the internal surface of the outer sheath adjacent forward and rear ends of said outer sheath, and affixing an extension piece to the forward end of the outer sheath after providing said ribs at said forward end and prior to inserting the core tube assembly into the outer sheath.

Preferably, the method further comprises joining abutting core tubes with one or more joiners that extend across the abutting ends of adjacent core tubes on an outer surface of the core tubes to join the adjacent core tubes.

Preferably, step (b) of inserting the core tube assembly into the outer sheath further comprises bringing the rear end of the core tube assembly flush with the rear end of the outer sheath.

Preferably, the method further comprises
securing a flange to the rear end of the outer sheath,
such that the rear end of the outer sheath is flush with
5 the rear surface of the flange.

Preferably, the method further comprises
securing a blank to the rear surface of the flange prior
to inserting the core tube assembly into the outer sheath.
10

Preferably, the method further comprises forming
breather holes in the outer sheath after the cementing
agent is sufficiently hard.

15

Brief description of the drawings

The present invention is described further by
way of example only with reference to the accompanying
20 drawings, of which:

Figure 1 is a vertical cross-section through a
direct smelting vessel that forms part of embodiments of a
direct smelting plant in accordance with the present
25 invention;

Figure 2 is a longitudinal partial cross-section
view of a prior art solids injection lances for injecting
ore into the vessel;

30

Figure 3 is a cross section view of a central
tube in accordance with an embodiment of the present
invention;

Figure 4A is a view of one embodiment of the forward end of the central tube of Figure 3;

5 Figure 4B is a view of an alternative embodiment of the forward end of the central tube of Figure 3;

Figure 5 is a cross section view of the central tube of Figure 3, as viewed along the line A-A in Figure
10 3;

Figure 6 is a partial bottom view of core tube assembly used in the central tube of Figure 3;

15 Figure 7 is a cross section view of the core tube assembly of Figure 6, as viewed along the line B-B in Figure 6; and

Figure 8A is a longitudinal cross section view
20 of the forward end of the outer sheath of the central tube of Figure 3;

Figure 8B is a longitudinal cross section view of the rear end of the outer sheath of the central tube of
25 Figure 3; and

Figure 9 is a cross section view of the outer sheath, as viewed along the line C-C in Figure 8A.

30 Detailed description

Figure 1 shows a direct smelting vessel 11 that is suitable particularly to be used to carry out the

HIs melt process as described in International patent application PCT/AU96/00197. The following description is in the context of smelting iron ore fines to produce molten iron in accordance with the HIs melt process.

- 5 However, it will be appreciated that the present invention is applicable to smelting any metalliferous material, including ores, partly reduced ores, and metal-containing waste streams. It will also be appreciated that the ores can be in the form of iron ore fines.

10

The vessel 11 has a hearth that includes a base 12 and sides 13 formed from refractory bricks, side walls 14, which form a generally cylindrical barrel extending upwardly from the sides 13 of the hearth, and a roof 17.

- 15 Water-cooled panels (not shown) are provided for transferring heat from the side walls 14 and also from the roof 17. The vessel 11 is further provided with a forehearth 19, through which molten metal is continuously discharged during smelting, and a tap-hole 21, through
20 which molten slag is periodically discharged during smelting. The roof 17 is provided with an outlet 18 through which process off gases are discharged.

- In use of the vessel 11 to smelt iron ore fines
25 to produce molten iron in accordance with the HIs melt process, the vessel 11 contains a molten bath of iron and slag, which includes a layer 22 of molten metal and a layer 23 of molten slag on the metal layer 22. The position of the nominal quiescent surface of the metal
30 layer 22 is indicated by arrow 24. The position of the nominal quiescent surface of the slag layer 23 is indicated by arrow 25. The term "quiescent surface" is

understood to mean the surface when there is no injection of gas and solids into the vessel 11.

The vessel 11 is provided with solids injection lances 27 that extend downwardly and inwardly through openings (not shown) in the side walls 14 of the vessel and into the slag layer 23. In use, iron ore fines, solid carbonaceous material (such as, for example, coal or coke breeze) and fluxes are injected through outlet ends 28 of the lances 27 into the metal layer 22. The iron ore fines, solid carbonaceous material, and fluxes are entrained in an oxygen-deficient carrier gas.

The outlet ends 28 of the lances 27 are above the surface of the metal layer 22 during quiescent operating conditions within the vessel. This position of the lances 27 reduces the risk of damage through contact with molten metal and also makes it possible to cool the lances by forced internal water cooling without significant risk of water coming into contact with the molten metal in the vessel 11.

The vessel 11 also has a gas injection lance 26 for delivering a hot air blast into an upper region of the vessel 11. The lance 26 extends downwardly through the roof 17 of the vessel 11 into the upper region of the vessel 11. In use, the lance 26 receives an oxygen-enriched hot air flow through a hot gas delivery duct (not shown), which extends from a hot gas supply station (also not shown).

Figure 2 illustrates the general construction of a known prior art solids injection lance 27. As shown in

Figure 2, the lance 27 is provided with a central tube 31 that defines a passageway for metalliferous material or carbonaceous material to pass from an inlet end to a forward end of the lance 27. The lance 27 is also
5 provided with an annular cooling jacket 32 that surrounds the central tube 31 and extends over a substantial part of the length of the central tube 31.

The annular cooling jacket 32 is in the form of
10 a long hollow annular structure 41 having outer and inner tubes 42, 43 interconnected by a front end connector piece 44. An elongate tubular structure 45 is disposed within the hollow annular structure 41 so as to divide the interior of the structure 41 into an inner elongate
15 annular water flow passage 46 and an outer elongate annular water flow passage 47.

The rear end (not shown) of annular cooling jacket 32 is provided with a water inlet (also not shown)
20 through which a flow of cooling water can be directed into the inner annular water flow passage 46 and a water outlet (also not shown) from which water is extracted from the outer annular passage 47 at the rear end of the lance 27. Accordingly, in use of the lance 27, cooling water flows
25 forwardly down the lance through the inner annular water flow passage 46, radially outward through the connector piece 44, and then backwardly through the outer annular passage 47 along the lance 27. Thus, cooling water provides effective cooling of the lance 27 when exposed to
30 the heat generated within the smelting vessel 11, when in use.

Figures 3 to 9 show a solids injection lance 27 according to an embodiment of the present invention.

The solids injection lance 27 comprises a
5 central tube 50 that has a flange 52 provided at the rear end (indicated by arrow R) of the central tube 50. The flange 52 facilitates connection of the central tube 50 with other components of the solids injection lance 27.

10 The central tube 50 also has three core tubes 54a, 54b, 54c that are arranged in series in an end-to-end relationship to form a core tube assembly 54. Core tube 54a is positioned at the rear end of the central tube 50 and receives solid material. Core tube 54c is positioned
15 at the forward end of the central tube 50 and delivers solid material into the vessel. Core tube 54b is positioned between core tubes 54a and 54c. Core tubes 54a, 54b, 54c are formed of a hard, wear resistant material, such as white cast iron, in particular, high
20 chromium white cast iron. Such white cast irons can be difficult to weld.

The solids injection lance 27 also comprises an outer sheath 56. As shown in Figure 5, the core tube
25 assembly 54 is mounted concentrically within the outer sheath 56, which extends substantially along the combined length of the core tube assembly 54. The inner diameter of the outer sheath 56 is greater than the outer diameter of core tubes 54a, 54b, 54c, such that an annular
30 clearance extends between the core tube assembly 54 and the outer sheath 56.

The annular clearance is filled with a cementing agent that, once hardened, bonds the core tube assembly 54 within the outer sheath 56. In this embodiment, the cementing agent is grout 58.

5

The forward end F of the central tube 50 is provided with an extension piece 60, which is received over the forward end of core tube 54c. In the embodiment depicted in Figure 4A, a rear portion of the extension piece 60 envelops the forward end of core tube 54c and is connected to the forward end of the outer sheath 56. The extension piece 60 has a first inner diameter 62a that is approximately equal to the outer diameter of core tube 54c, and a second inner diameter 62b that is less than the outer diameter of core tube 54c. Accordingly, the internal surface of the extension piece 60 has a shoulder 63 that abuts the forward end of core tube 54c. A forward portion of the extension piece 60 extends beyond the forward end of core tube 54c.

20

In the embodiment depicted in Figure 4B, the extension piece 60 is of the same external and internal diameter as the outer sheath 56 and is joined to the outer sheath 56 by means of a circumferential weld 90. Core tube 54c bridges the outer sheath 56 and the extension piece 60. A series of partially circumferential ribs 92 (similar to those described below in relation to Figures 8A and 8B) are provided at the forward end F of the outer sheath 56 and another series 94 at the forward end F2 of the extension piece 60. The outer sheath 56 is of such length that the forward end F thereof and associated ribs 66 are located at the forward end of, but internal to, the annular cooling jacket 32 of the lance 27. The extension

30

piece 60 extends externally of the of the annular cooling jacket 32 of the lance 27. Should the extension piece 60 and associated portion of core tube 54c melt, there remains a set of ribs 66 at the forward end of the outer
5 sheath 56 that resists relative movement of grout 58 located intermediate the outer sheath 56 and the core tube 54c.

Figure 3 shows the front end connector piece 44
10 of the annular water cooling jacket 32 to indicate the relative position of the annular water cooling jacket 32 with respect to the central tube 50, when assembled within a lance 27. As indicated in figure 3, the extension piece 60 projects beyond the forward end of the annular water
15 cooling jacket 32.

It is preferable that the core tubes 54a, 54b, 54c be arranged such that the hollow cores 55 are aligned. Any misalignment of the core tubes 54a, 54b, 54c may
20 result in increased wear occurring at the interface between adjacent core tubes 54a, 54b, 54c, which will substantially reduce the service life of the central tube 50. In addition, it is preferable that the core tubes 54 be straight such that the hollow cores 55 are also
25 straight. Any curvature in the internal material flow path of the central tube 50 may result in increased localized wear on a portion of one or more of core tubes 54a, 54b, 54c. Again, such wear will substantially reduce the service life of the central tube 50.

30

To facilitate assembly of the central tube 50 joiners 64 are provided to join adjacent core tubes 54. In this embodiment, the joiners 64 are in the form of

strips that extend across the abutting ends of adjacent core tubes 54a, 54b, 54c and parallel to the elongate direction of the central tube 50. The joiners 64 also assist in maintaining an approximately concentric annular clearance between the core tube assembly 54 and the outer sheath 56 during assembly of the central tube 50. A person skilled in the art will appreciate that a minimum of two joiners 64 of this type can be used to maintain an annular clearance that is substantially concentric.

10 However, the number of joiners provided will be at least partly influenced by the assembly procedure for the central tube 50.

The thickness of the joiners 64, in the radial direction of the core tube assembly 54 is less than or equal to the radial thickness of the annular clearance.

The grout 58 creates a mechanical bond with core tubes 54a, 54b, 54c by engaging surface imperfections on the outer surface of the core tubes 54a, 54b, 54c. Such surface imperfections may be formed by way of example, on the core tubes 54a, 54b, 54c by the manufacturing process. Accordingly, a strong and reliable bond between the grout 58 and the core tubes 54a, 54b, 54c is formed once the grout 58 has set. By forming a mechanical bond with substantially the whole of the external surface of the core tube and the internal surface of sheath 56, the grouting is better able to withstand shear forces arising from pneumatic conveying of material through the core tube assembly 54 and into the molten bath of the vessel. This has proven more reliable than previous methods of welding high chromium white cast iron tubes to steel sleeves and straps.

In order to minimize the chance of the grout 58 disbonding from the outer sheath 56 and releasing the core tube assembly 54 from the central tube 50, each of the forward and rearward ends of the outer sheath 56 is provided with a set 66, 68 of ribs 69 that extend at least partly circumferentially about the internal surface of the outer sheath 56 (see figures 8A, 8B and 9). Each of the ribs 69 provides an interference, or physical barrier, with the grout 58 that prevents the core tubes 54 and grout 58 from moving longitudinally with respect to the outer sheath 56, even if the grout 58 should disbond from the outer sheath 56.

As shown in Figure 4B, one set 66 of ribs 92 at the forward end F of the outer sheath 56 is believed to be sufficient. However, and as shown in Figures 8A, 8B and 9, the set of ribs 66 at the forward end F of the outer sheath 56 may be provided in three longitudinally spaced apart subsets. Each rib 69 within a subset is circumferentially spaced from the other ribs 69 within the same subset. Similarly, the set 68 of ribs 69 at the rear end of the outer sheath 56 is provided in three longitudinally spaced apart subsets. Each rib 69 within a subset is circumferentially spaced from the other ribs 69 within the same subset. The longitudinal spacing between subsets of ribs 69 within each set 66, 68, and the circumferential spacing of ribs 69 within each subset, facilitates the flow of grout 58 between the ribs 69 during assembly of the central tube 50 as grout 58 is introduced into the annular clearance.

The ribs 66 at the forward end of the outer sheath 56 are arranged such that two passages 70 extend longitudinally through the ribs 66. The two passages 70 allow the joiners 64 to slide through the ribs 66 during
5 assembly of the central tube 50. In addition, the height of the ribs 66, 68 (in the radial direction) is less than, or equal to, the annular clearance between core tubes 54a, 54b, 54c and the outer sheath 56. In one embodiment, each rib 69 can be in the form of a weld bead.

10

A person skilled in the art will appreciate that the thickness of the annular clearance should be minimized to reduce the overall mass of the core tube assembly. In practice, the thickness of the annular clearance is at
15 least equal to the height of each rib 69; that is, at least 2mm.

As previously noted, the lance can be exposed to temperatures in excess of 1400°C. Accordingly, the
20 central tube 50 will also be exposed to very high temperatures. It will be appreciated that liquid entrained in the grout 58 could be disastrous in such conditions, as such liquid could expand as it undergoes a phase change to vapour. It is therefore desirable for the
25 grout 58 to be free of any moisture prior to use of the lance. To facilitate the drying of the grout 58, a number of breather holes 72 are formed in the outer sheath 56. The breather holes 72 can be formed at any time after the grout 58 is sufficiently hard. In this embodiment,
30 breather holes 72 are spaced longitudinally by approximately 100mm to 250mm. In addition, the breather holes 72 are sequentially rotated by 120° relative to one another along the length of the outer sheath 56.

One example of a process for assembling a central tube 50 according to the embodiment described in connection with Figures 3 to 9 is set out below.

5

The core tube assembly 54 is formed by aligning core tubes 54a, 54b, 54c such that the ends of adjacent core tubes 54a, 54b, 54c are abutting and the hollow cores 55 are in alignment. Where the core tubes are made of material such as high chromium white cast iron, the joiners 64 may be adhered to the outer surfaces of the core tubes 54 using an adhesive, such as an epoxy resin, as shown in figures 6 and 7.

15

The sets 66, 68 of ribs 69 are formed on the internal surface of the outer sheath 56. A flange 52 is attached to the rear end of the outer sheath 56. The rear surface of the flange 52 is to be flush with the rear end of the outer sheath 56.

20

To facilitate alignment of the rear end of the core tube assembly 54 with the rear surface of the flange 52 and the rear end of the outer sheath, a blank (not shown) may be applied over the flange 52. The blank provides an abutment surface that is flush with the rear surface of the flange 52. The blank also assist in containing grout within the annular clearance as the annular clearance is being filled.

30

A hole (not shown) is provided in the outer sheath adjacent the flange such that grout can be delivered from a delivery system (not shown) through the outer sheath 56 into the annular clearance. To facilitate

connection of the delivery system with the hole in the outer sheath, an attachment point (also not shown) can be secured to the outer sheath 56 about the hole.

5 The partially assembled central tube 50 is stored to allow the grout to harden to a sufficient level. Subsequently, the extension piece 60 is fitted over the forward end of core tube 54c and secured in position on the forward end of the outer sheath 56.

10

 Once the grout 58 has hardened sufficiently, breather holes 72 can be drilled in the outer sheath 56 to allow any moisture in the grout 58 to escape.

15 The attachment point for injection of grout 58 may be cut from the outer sheath 56 to enable the central tube 50 to fit within an annular cooling jacket.

 Pockets of air that become entrapped in the
20 annular clearance could result in failure of the central tube 50 when heated. The grout 58 should completely fill the annular clearance. During the grout filling step the forward end of the central tube 50 is raised such that it is at least above the rear end of the central tube 50.
25 Elevating the forward end of the central tube 50 minimizes the chance of air pockets remaining in the annular clearance after the annular clearance has been filled with grout. In addition, grout can be provided to the annular clearance until such time as excess grout overflows from
30 the forward end of the central tube 50.

 To avoid the grout 58 cracking during hardening, the partially assembled central tube 50 can be stored in a

cradle or the like. Accordingly, there is minimal stress on the partially assembled central tube 50 while the grout 58 hardens to a sufficient level.

5 Many modifications may be made to the embodiments described above without departing from the spirit and scope of the present invention.

10 The ribs on the internal surface of the outer sheath can extend at least partly in the longitudinal direction of the central tube.

15 It will be appreciated that alternative processes for assembling the central tube 50 may be employed.

20 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, i.e. 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.

25

30 It is to be understood that, any prior art publication referred to herein 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 injecting solid material into a vessel, such as a direct smelting vessel, the apparatus
5 having a central tube comprising:
a core tube assembly that defines a passageway for solid material, the core tube assembly having at least one core tube and having an inlet for receiving solid material at a rear end and an outlet at a forward end;
10 an outer sheath that extends over at least a portion of the core tube assembly, the outer sheath having an internal diameter that is greater than the outer diameter of the core tube assembly such that a substantially annular clearance is provided between the
15 core tube assembly and the outer sheath; and
a cementing agent that fills the annular clearance and forms a bond that secures the core tube assembly within the outer sheath.
- 20 2. The apparatus as claimed in claim 1, wherein the apparatus is a solids injection lance.
3. The apparatus as claimed in either claim 1 or 2, wherein the core tube assembly comprises at least two core
25 tubes formed of wear resistant material that are arranged such that the ends of adjacent core tubes abut one another, and such that the hollows of the core tubes are in alignment.
- 30 4. The apparatus as claimed in any one of claims 1 to 3, wherein the internal surface of the outer sheath is provided with a plurality of ribs that provide an interference with the cementing agent.

5. The apparatus as claimed in claim 4, wherein the ribs extend circumferentially about the internal surface of the outer sheath.

5

6. The apparatus as claimed in either claim 4 or 5, wherein each rib of said plurality of ribs extends over a partial circumference of the internal surface of the outer sheath.

10

7. The apparatus as claimed in any one of claims 4 to 6, wherein said plurality of ribs are spaced circumferentially about a common diameter of said inner surface of said outer sheath, with clearance between at least two adjacent ribs.

15

8. The apparatus as claimed in any one of claims 4 to 7, wherein the plurality of ribs extend partly longitudinally with respect to the elongate direction of the core tube assembly.

20

9. The apparatus as claimed in any one of claims 4 to 8, wherein the ribs include one or more sets of ribs.

25 10. The apparatus as claimed in claim 9, wherein the ribs of a respective set of ribs are arranged in longitudinally spaced apart subsets of ribs.

11. The apparatus as claimed in either claim 9 or 30 10, wherein a first set of ribs is located adjacent the forward end of the outer sheath and a second set of ribs is located adjacent the rear end of the outer sheath.

12. The apparatus as claimed in any one of claims 1 to 11, in which the core tube assembly comprises at least two core tubes, and the central tube further comprises one or more joiners on an outer surface of the core tube
5 assembly that extend across the abutting ends of adjacent core tubes and join together the adjacent core tubes.

13. The apparatus as claimed in claim 12, wherein the joiners are secured to the core tubes by an adhesive.
10

14. The apparatus as claimed in either claim 12 or 13, wherein the joiners have a thickness that is substantially equal to the radial thickness of the annular clearance.
15

15. The apparatus as claimed in any one of claims 12 to 14, wherein the joiners are in the form of an elongate strip that extends in the elongate direction of the core tube assembly across the abutting ends of adjacent core
20 tubes.

16. The apparatus as claimed in claims 9 and 15, wherein one of the sets of ribs has a passage that allows the joiners to slide through the respective set of ribs
25 during assembly of the central tube.

17. The apparatus as claimed in any one of claims 1 to 16, wherein the central tube further comprises an extension piece that extends over a portion of the forward
30 end of the core tube assembly.

18. The apparatus as claimed in any one of claims 1 to 3, wherein the extension piece is secured to the forward end of the outer sheath.

5 19. The apparatus as claimed in claim 1 to 18, wherein the central tube further comprises a flange that extends about the rear end of the outer sheath.

20. The apparatus as claimed in claim 19, wherein a rear surface of the flange is flush with the rear end of the outer sheath and/or the core tube assembly.

21. The apparatus as claimed in any one of claims 1 to 20, wherein the cementing agent is a grout.

15

22. A solids injection lance comprising the apparatus of any one of claims 1 to 21.

23. A direct smelting plant comprising at least one apparatus as claimed in any one of claims 1 to 21.

24. A direct smelting method for producing a molten metal from a metalliferous feed material that comprises injecting a solid feed material, such as the metalliferous feed material, into a direct smelting vessel via at least one apparatus according to any one of claims 1 to 21.

25. A method of assembling the apparatus of claims 1 to 21, comprising the steps of:

30 (a) inserting a core tube assembly into the outer sheath such that the annular clearance is established between the outer sheath and the core tube assembly;

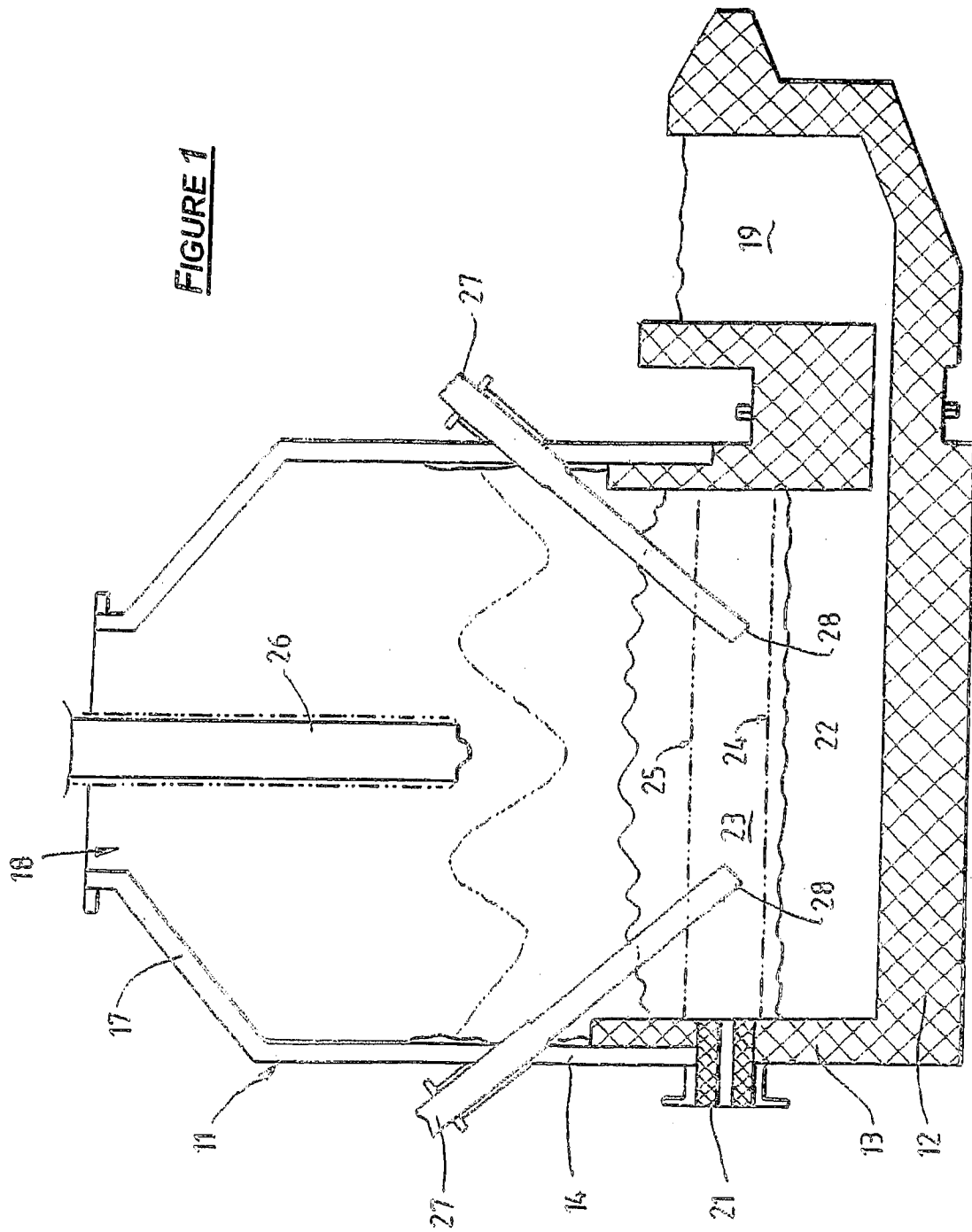
- (b) filling the annular clearance with the cementing agent; and
- (c) allowing the cementing agent to harden to form a bond that secures the core tube assembly within the outer sheath.

5

26. The method as claimed in claim 24, wherein step (a) further comprises forming the core tube assembly by aligning a plurality of core tubes such that the ends of adjacent core tubes are in abutment and the hollow cores are in alignment.

10

FIGURE 1



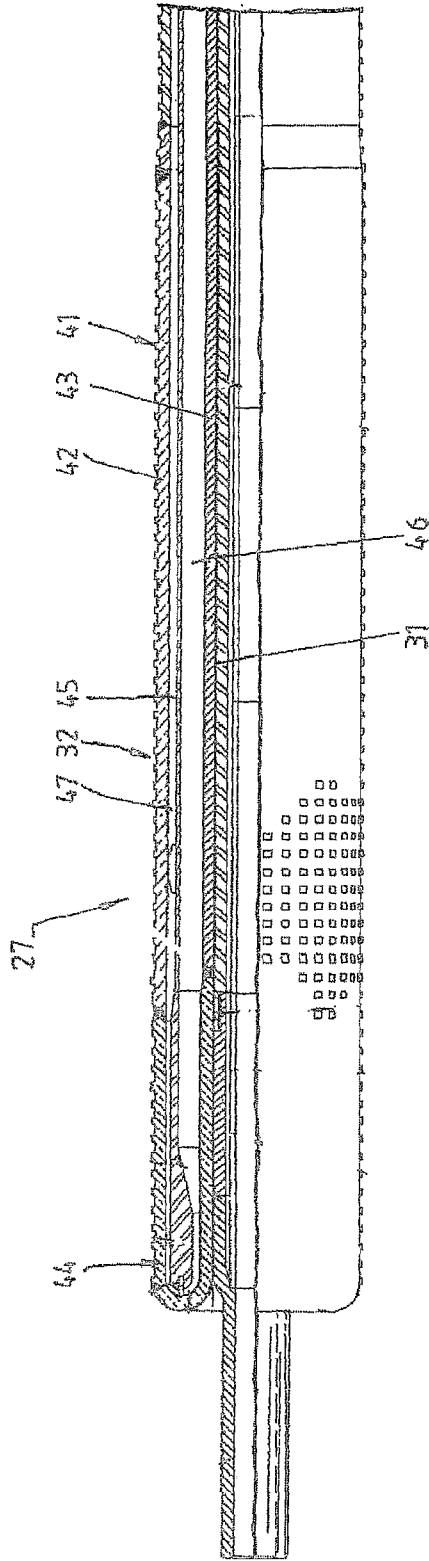
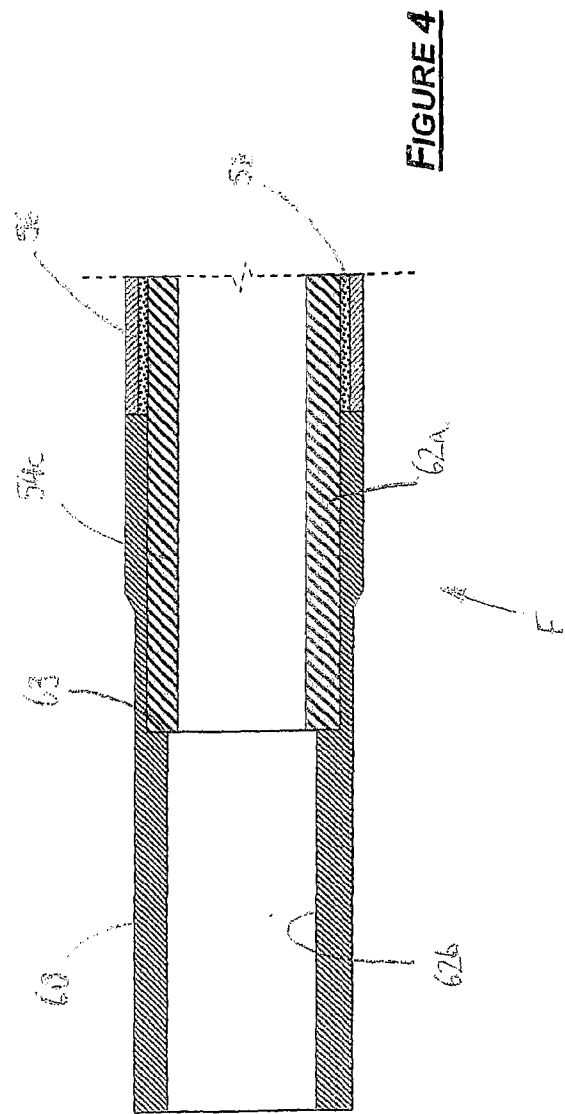
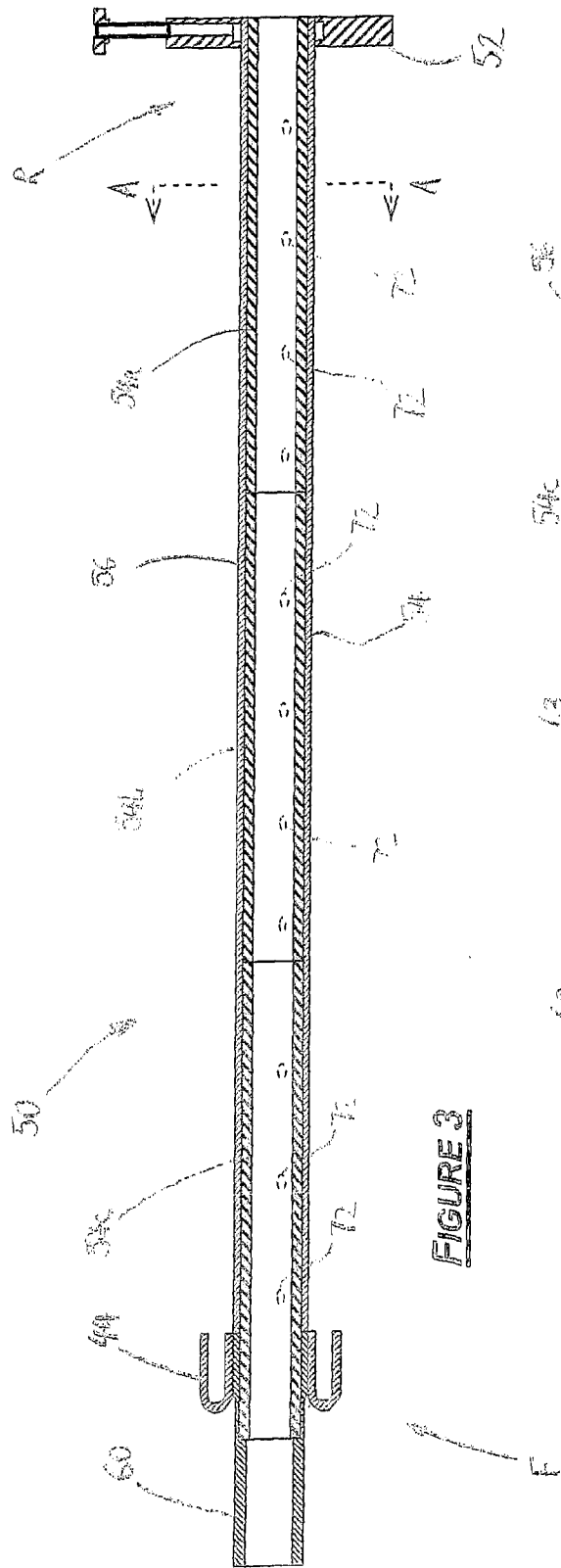


FIGURE 2



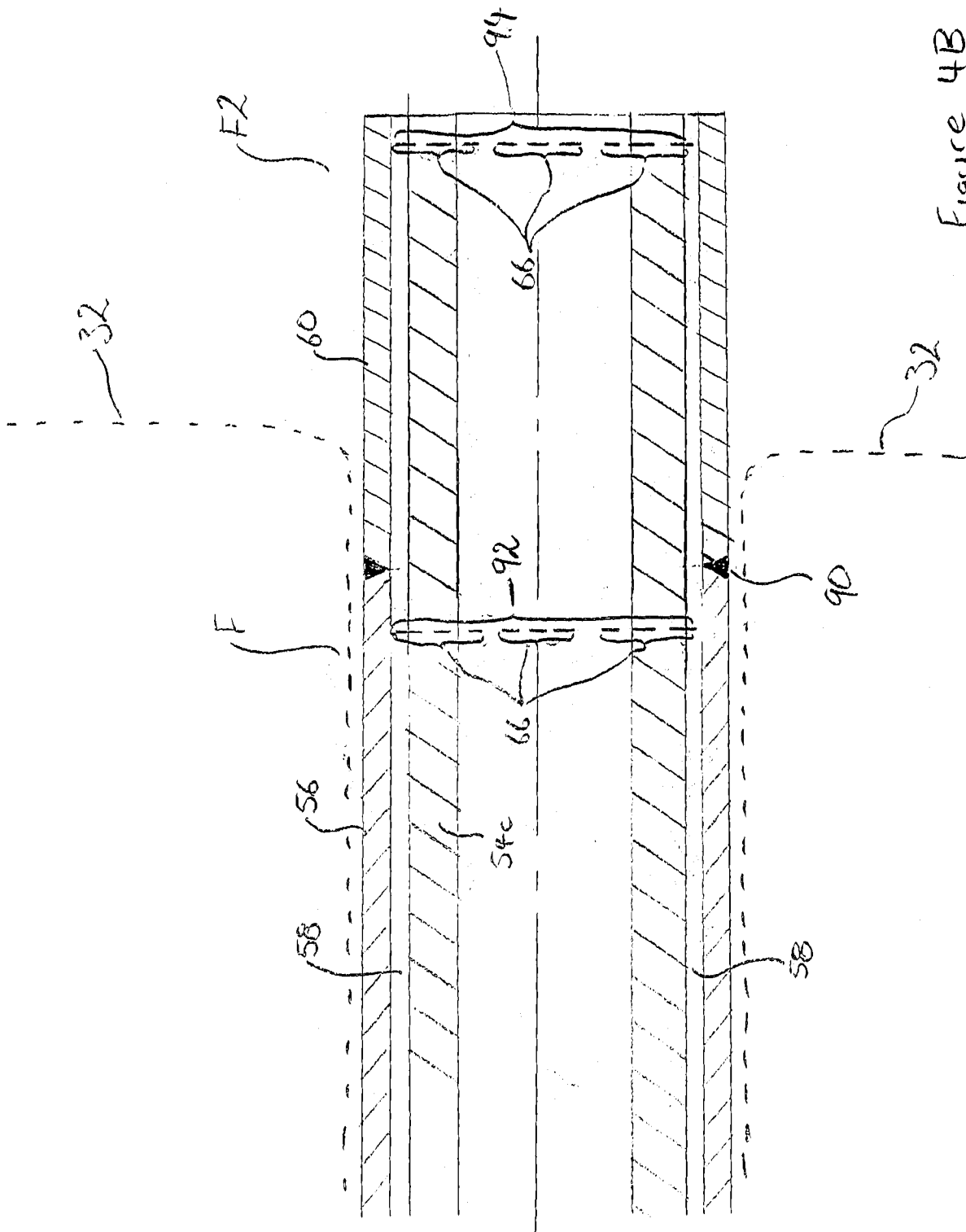


Figure 4B

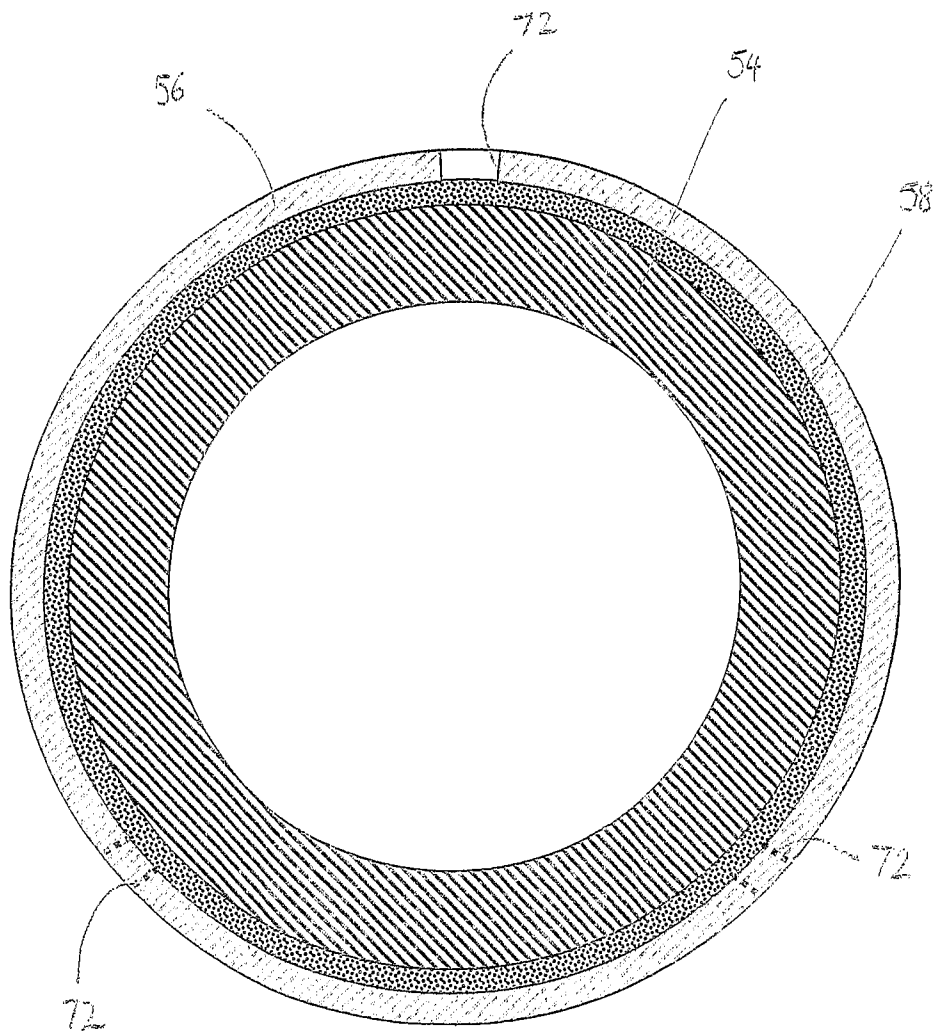


FIGURE 5

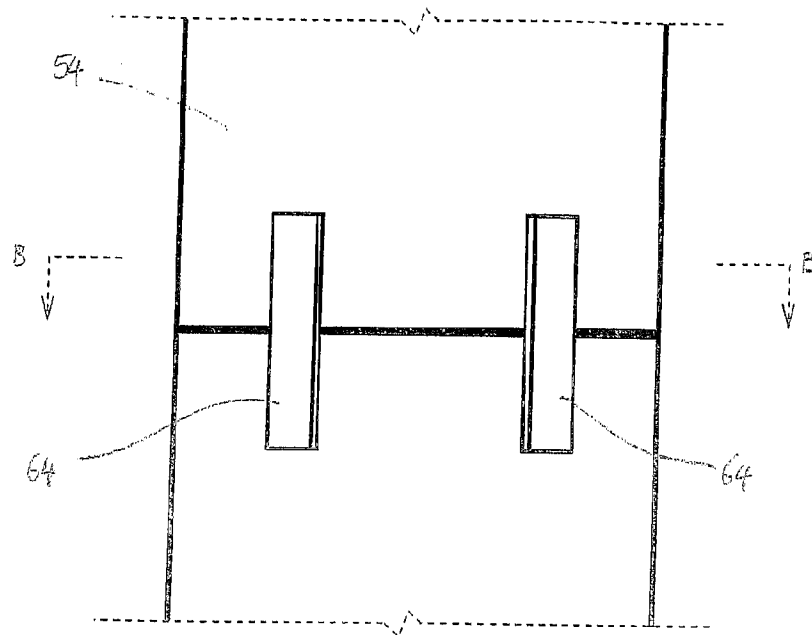


FIGURE 6

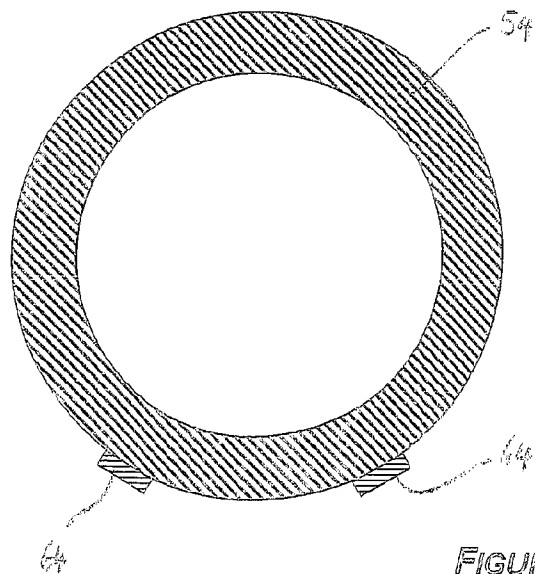


FIGURE 7

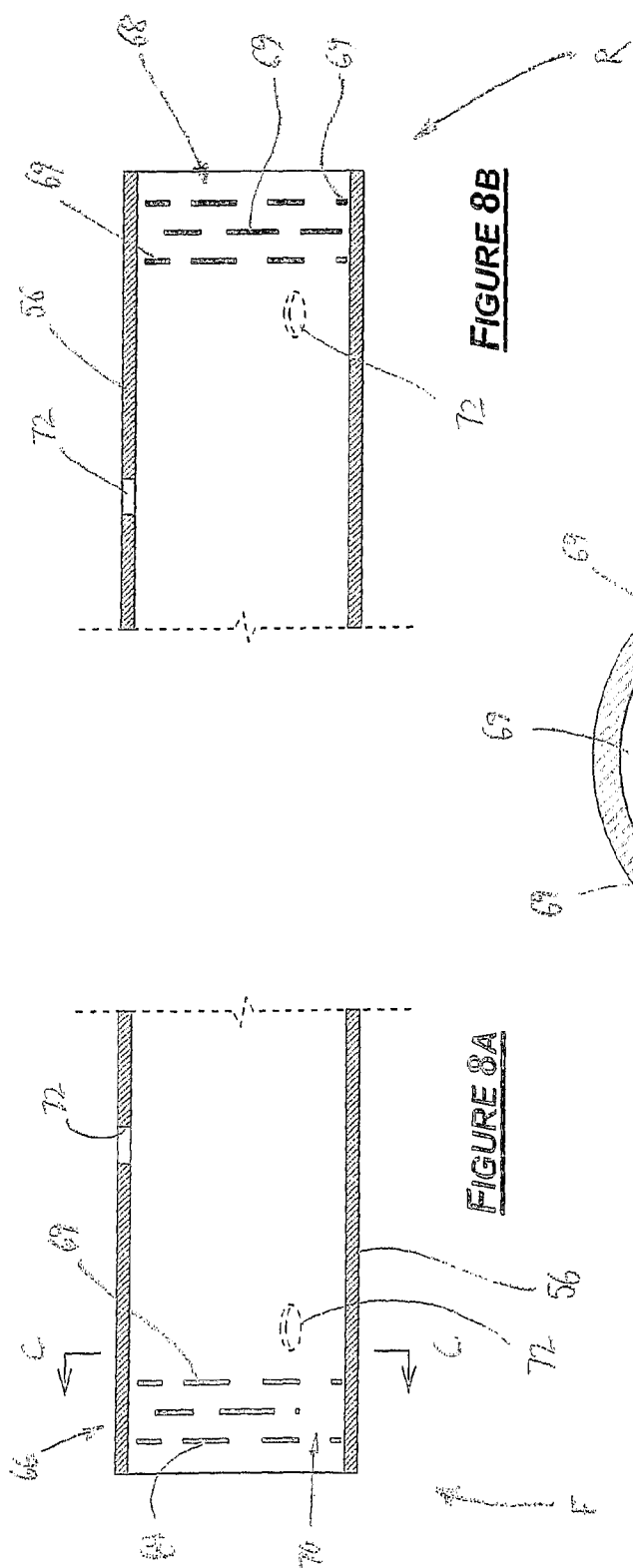


FIGURE 8A

FIGURE 8B

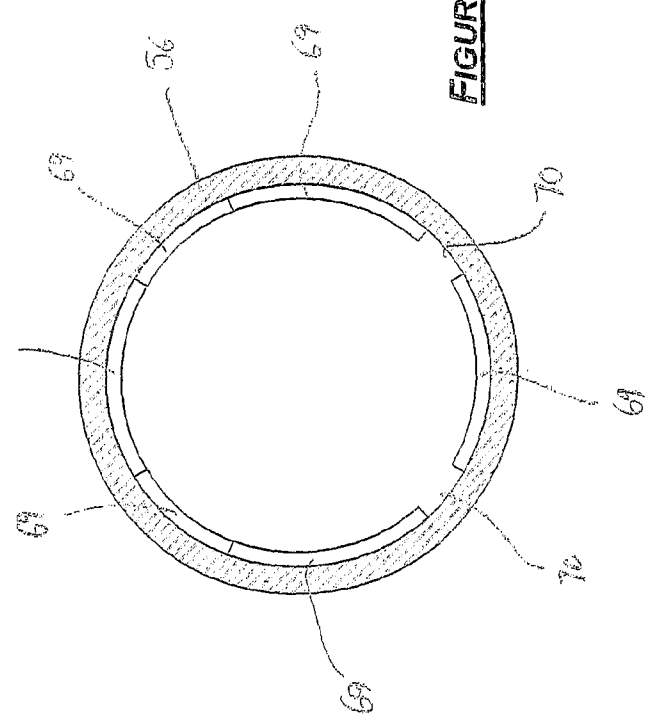


FIGURE 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2008/000887

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

F27B 3/18 (2006.01)*F27B 1/16* (2006.01)*F27D 3/16* (2006.01)*C21B 7/16* (2006.01)*F27B 1/20* (2006.01)*F27D 3/18* (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)

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)

WPI, EPODOC: IPC – F27B 3/18, 1/16, 1/20, F27D 3/16, 3/18, C21C 5/IC, C22B/IC, C21B13/IC, C21B7/16 & Keywords - lance, tuyere, solid, particle, fine, powder, core, passage, tube, pipe, hollow, layer, concentric, coaxial, annular, bond, sheath, adhe+, cement, attach, join, connect, clearance, space, gap

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	AU 777079 B2 (TECHNOLOGICAL RESOURCES PTY LTD) 30 September 2004 Whole document	1-26
A	US 4462824 A (NAUMAN) 31 July 1984 Whole document	1-26
A	US 4239194 A (DEBAISE) 16 December 1980 Whole document	1-26

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

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"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
"E"	earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
09 September 2008

Date of mailing of the international search report

17 SEP 2008

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2008/000887

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Derwent Abstract Accession No. 1981-22710D SU 735640 A (CHERP METALLURG WKS) 28 May 1980 Abstract	1-26
A	Derwent Abstract Accession No. 1975-30739W DE 111524 A (KLIPSTEIN E) 20 February 1975 Abstract	1-26
A	Derwent Abstract Accession No. 1972-28026T FR 2094521 A (IRSID INST RECH SIDERURGIE) 4 February 1972 Abstract	1-26

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2008/000887

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			
AU 777079		AU 11106/01	CA 2332724	CN 1315649	
		DE 10103605	GB 2360082	JP 2001226708	
		KR 2001007813	US 6398842	US 2001015516	
US 4462824		CA 1217336	EP 0128987	GR 79434	
		MX 161196	US 4477279	YU 245183	
US 4239194		BE 868431	DE 2924747	FR 2429259	
		JP 55006494	LU 81417		
SU 735640		NONE			
DD 111524		NONE			
FR 2094521		NONE			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.					
END OF ANNEX					