A lance nozzle tip for a refractory lance for feeding an additive wire into a quantity of molten metal below the surface of the molten metal surface has a refractory casing and a conduit located within the refractory casing. The refractory casing has a nozzle portion which has a lance nozzle insert. The conduit has a first portion in the nozzle portion and a main portion having a second portion of the conduit. The first portion of the conduit has a passage extending from an inlet end of the first portion of the conduit to an outlet end of the first portion of the conduit. The passage has a diameter for a substantial portion of the length of the first portion of the conduit and a funnel-shaped portion at the inlet end of the first portion of the conduit for guiding the additive wire conveyed through the passage and second portion of the conduit.
FIELD OF THE INVENTION

The present invention relates to methods and apparatus for metal production.

BACKGROUND

In the production of steel, a ferrous melt is typically produced in a suitable furnace and then tapped into a ladle where it is treated with one or more ingredients for refining or alloying purposes. It is well known to add calcium to the molten ferrous material at this point as a refining agent for oxide inclusion flotation, oxide inclusion morphology modification, desulfurization, etc. Unfortunately, the low density (relative to steel), volatility and reactivity of calcium severely complicate the task of providing a satisfactory process for its addition to the molten material in the ladle.

A variety of techniques have been employed for the addition of calcium to the molten material in a steelmaking ladle. Bulk addition of calcium-containing particulate materials is unsatisfactory because these materials rapidly rise to the surface of the melt without spending a sufficient residence time therein. Efforts to increase residence time by pouring the particulate material directly into the tapping stream from the furnace give rise to excessive reaction of the calcium with atmospheric oxygen. Introductions of calcium-containing materials by plunging or the injection of clad projectiles into the melt generally provide adequate residence times but are complicated, expensive and time-consuming procedures. It has also been proposed to inject calcium-containing powders into a melt by inert gas injection through a refractory lance. Since sizable flows of gas are required to propel the powder into the molten ferrous material, a high level of turbulence is generated at the surface of the melt as the gas is released, thereby causing an excessive exposure of the molten ferrous material to oxygen and nitrogen in the atmosphere. Furthermore, after leaving the lance, the calcium tends to rise rapidly through the melt in the inert gas plume surrounding the lance or in upwelling molten material adjacent the plume. Thus, calcium residence time in the bath is unacceptably low.

In an attempt to overcome the above-mentioned problems, calcium has also been added to melts in steelmaking ladles in the form of a calcium metal-containing wire (clad or unclad) continuously fed through the upper surface of the melt. A major advantage of wire feeding is that large flows of gas are not needed, as in powder injection, to propel the calcium-containing material into the molten ferrous material. However, the high volatility of calcium hinders the attainment of an efficient utilization of the calcium added in wire feeding. If the wire does not penetrate to a sufficient depth below the surface before the calcium in the wire desolidifies, a low residence time and poor utilization of the calcium results along with a non-uniform treatment of the melt. It is particularly important that most or all of the input calcium remain unreacted until just after the melt. It is well known to add calcium to the molten ferrous material at this point as a refining agent for oxide inclusion flotation, oxide inclusion morphology modification, desulfurization, etc. Unfortunately, the low density (relative to steel), volatility and reactivity of calcium severely complicate the task of providing a satisfactory process for its addition to the molten material in the ladle.

uniform treatment of the molten ferrous material and the generation of a large amount of turbulence at the surface of the melt.

SUMMARY

According to an embodiment, a nozzle tip for a refractory lance for feeding an additive wire into a quantity of molten metal below the surface of the molten metal comprises an inlet and an outlet, a passage provided therebetween for the additive wire being fed through the lance, a refractory casing, and a conduit and a nozzle insert provided within the refractory casing.

The conduit provided within the refractory casing comprises an inlet end and an outlet end and a second passage extending from the inlet end to the outlet end of the conduit. The inlet end of the conduit is configured to mate with a conduit in the main portion of the refractory lance.

The nozzle insert provided within the refractory casing comprises an inlet end and an outlet end and a second passage extending from the inlet end to the outlet end of the nozzle insert. The inlet end of the nozzle insert is configured to mate with the outlet end of the conduit connecting the second passage to the first passage for conveying the additive wire.

The second passage has a diameter for much of its length and flares out to a funnel-shaped portion at the inlet end of the nozzle insert. The first passage has a diameter that is substantially equal to the diameter of the second passage and flares out to a funnel-shaped portion at the inlet end of the conduit for receiving and guiding the additive wire being conveyed through the first and second passages. The outlet end of the nozzle insert forms the lance’s outlet.
According to another embodiment, a lance nozzle for feeding an additive wire into a quantity of molten metal below the surface of the molten metal comprises an inlet, a lance outlet, a main portion, and a nozzle tip portion. The main portion comprises a first refractory casing and a first conduit located within the first refractory casing providing a first passage for conveying the additive wire to the lance outlet. The nozzle tip portion forms the outlet end of the lance.

The nozzle tip portion comprises a second refractory casing, a second conduit provided within the second refractory casing and a nozzle insert provided within the second refractory casing. The second conduit comprises an inlet end and an outlet end and a second passage extending from the inlet end to the outlet end of the second conduit. The inlet end is configured to mate with the first conduit connecting the second passage to the first passage for conveying the wire to the lance outlet. The nozzle insert has an inlet end and an outlet end and a third passage extending from the inlet end to the outlet end of the nozzle insert. The inlet end of the nozzle insert is configured to mate with the outlet end of the second conduit thus connecting the third passage to the second passage for conveying the additive wire. The outlet end of the nozzle insert forms the lance’s outlet. The third passage has a diameter flaring out to a funnel-shaped portion at the inlet end of the nozzle insert and the second passage has a diameter that is substantially equal to the diameter of the third passage and flares out to a funnel-shaped portion at the inlet end of the second conduit. The funnel-shaped portion of the second passage of the nozzle insert receives and guides the additive wire being conveyed through the second and third passages.

According to another aspect of the present disclosure, the lance nozzle insert comprises an inlet and an outlet, a passage provided between the inlet and the outlet for the additive wire being fed through the lance. The lance nozzle insert may be made of a material comprising stabilized zirconium oxide, graphite and resin. The graphite can be natural graphite or synthetic graphite but natural flake graphite is preferred.

According to another embodiment, a lance nozzle for feeding or injecting an additive wire into a quantity of molten metal below the molten metal surface is disclosed. The lance nozzle comprises a refractory casing having a conduit providing a passage therein for conveying the additive wire to an outlet through which the wire exits the lance. The outlet is provided at the end of the lance that gets immersed below the surface of the molten metal. A lance nozzle insert is provided within the refractory casing in communication with the conduit and forming the outlet. The lance nozzle insert may be made of a material comprising stabilized zirconium oxide, graphite and resin. The graphite can be natural graphite or synthetic graphite but natural flake graphite is preferred.

Because the nozzle tip end of the lance nozzle is immersed in the molten metal for substantial lengths of time while the molten metal is being treated, the lance nozzle insert is exposed to the harsh conditions imposed by the molten metal. The stabilized zirconium oxide and graphite composition provide much better temperature and corrosion resistance than pure carbon that is currently used in lance injection and improves the durability of the lance nozzle insert in this harsh environment. The result is that the lance nozzle insert of the present invention has substantially longer operational life than the conventional lance nozzle inserts.

The refractory casing of the lance nozzle can be formed in two pieces, a main portion and a lance nozzle tip portion. In that configuration, the main portion contains a main portion of the conduit and the lance nozzle tip portion contains a second portion of the conduit and the lance nozzle insert. The main portion and the second portion of the conduit are configured and adapted to removably engage one another so that the lance nozzle tip portion can be removed from the main portion of the lance nozzle if necessary. This would allow the lance nozzle tip portion to be replaced with a new one should the lance nozzle insert becomes too worn out either from the corrosive effects of the molten metal treatment environment or the mechanical wear from the additive wire passing through the lance nozzle insert.

The various embodiments of the invention will be described with the aid of the following drawings, in which, like reference numbers represent like elements.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective representation of a lance apparatus used for treatment of a quantity of molten metal with additives in the form of a wire.

FIG. 2 is a perspective, partially cut-away, view of the lance of FIG. 1.

FIG. 3 is a cross-sectional view of the lance nozzle according to an embodiment.

FIG. 4 is a side view of a lance nozzle insert and a conduit assembly without the refractory casing.

FIG. 5 is a cross-sectional illustration of the inlet end of the conduit portion of the lance nozzle tip.

All drawings are schematic illustrations and the structures rendered therein are not intended to be in scale. It should be understood that the invention is not limited to the precise arrangements and instrumentality shown, but is limited only by the scope of the claims.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows a general view of a wire injection lance apparatus for treating a molten metal product using one or more processing elements provided in the form of a wire 20. A typical application for such apparatus is treating ferrous molten metal in a ladle with calcium wire. The wire 20 is conveyed from a reel 22 to the quantity of molten metal 56 in a receptacle 52 (e.g. a ladle of ferrous molten metal). In order to accomplish such feeding, a feeding mechanism 24 draws the wire from the reel 22 and conveys the wire along a feed path. Adjacent the output portion, especially in the vicinity of a refractory lance nozzle 60, the wire 20 is carried in a gas-tight conduit 44. An inert gas is supplied to the gas-tight conduit, and a seal mechanism 30 located immediately upstream of the inert gas input prevents loss of inert gas around wire 20 in a direction backwards along the feed path. The conduit 44 extends into the lance nozzle 60 providing a passageway for the wire 20 through the lance nozzle 60. The lance nozzle 60 comprises a replaceable lance nozzle tip 68.

A detailed description of a suitable wire feed mechanism 24 can be obtained from U.S. Pat. No. 4,235,362, the disclosure of which is incorporated herein by reference. A wide range of wire sizes and compositions are possible, including both sheathed and unsheathed wires. The wires, such as calcium wires, used for treating molten metals are generally of dimension and composition that results in fairly stiff wire. Accordingly, the feed mechanism as well as the
wire-carrying members must be capable of withstanding rough wear. Moreover, it should be expected that during feeding the relatively stiff wire will be prone to a certain amount of vibration and transverse displacement because of various discontinuities along the wire feed path and also because of bumps and bends that may be present in the wire.

The lance nozzle tip 68 shown in detail in FIG. 2, according to an embodiment comprises a refractory casing 62 surrounding a conduit 78a and nozzle insert 70 assembly. The refractory casing portion 62 may be made of alumina silica refractory or any other suitable refractory material such as those used to line kilns and the like. The conduit 78a comprises a passage 86 and the nozzle insert 70 comprises a passage 80. The passages 86 and 80 are aligned longitudinally allowing the additive wire 20 to be conveyed therethrough and exit through a lance outlet 84 formed by the lance nozzle insert 70.

FIG. 3, is a detailed cross-sectional view of an embodiment of the lance nozzle 60. The lance nozzle 60 comprises a main portion 66 and a lance nozzle tip portion 68 that is removable from the main portion 66. The main portion 66 comprises a refractory casing 62 and a main conduit 78b provided within the refractory casing 62. The additive wire 20 is received and conveyed through the main conduit 78b in the direction A as shown.

The lance nozzle tip 68 comprises a lance nozzle insert 70 and a conduit 78a provided therein encased in a refractory casing 62. The lance nozzle insert 70 and the conduit 78a are configured and adapted to engage one another in a suitable manner. For example, in the illustrated embodiment, the lance nozzle insert 70 has a neck portion 74 that engages the conduit 78a by fitting into the recess 77 provided at the end of the conduit 78a. The lance nozzle insert 70 and the conduit 78 may be assembled together before they are encased in the refractory casing 62. The lance nozzle insert 70 forms the lance outlet 84 at the terminal end of the nozzle tip portion 68 while the conduit portion 78a forms an inlet end of the nozzle tip portion 68 that removably engages the main portion 66.

The conduit 78a has an inlet end 170 and an outlet end 172 and is configured and adapted to engage the lance nozzle insert 70 at the conduit’s outlet end 172 and configured and adapted to removably engage the main conduit 78b at the inlet end 170. For example, the conduit portion 78a may be provided with an extending threaded neck 79a and the main conduit 78b may be provided with a recessed portion 79b that is threaded to mate with the threaded neck 79a. Thus, the nozzle tip portion 68 and the main portion 66 of the lance nozzle 60 are assembled together by threading the conduit 78a and the main conduit 78b together. The conduit portions 78a and 78b are preferably axially centered within the lance nozzle tip 68 and the main portion 66, respectively, as shown in FIG. 3 so that when the lance nozzle tip 68 and the main portion 66 are assembled together, they form a unitary lance nozzle 60.

The conduit 78a is provided with a passage 86 extending from the inlet end 170 to the outlet end 172. The lance nozzle insert 70 is provided with a passage 80 extending therethrough and ending at the lance outlet 84. Thus, the passages 86 and 80 provide a continuous passage way for the wire 20 through the lance nozzle tip 68. The wire 20 advances in the direction of the arrow A shown. The passage 86 of the conduit 78a has a diameter D2 that is substantially the same as the diameter D1 of the passage 80 of the lance nozzle insert 70. The diameters D1 and D2 of the passages 86 and 80 are configured to be close to the diameter of the wire 20 to maintain the pressure of the inert gas being pumped therethrough without interfering with the movement of the additive wire 20 therethrough.

The passage 86 flares out to a funnel-shaped inlet at the inlet end 170 of the conduit 78a. The flared inlet 89 of the passage 86 enables the additive wire 20 to advance smoothly without kinks or jamming as the wire is transitioned from the main conduit 78b to the conduit 78a. The inlet 83 of the passage 80 flares out providing a funnel-shaped inlet. This enlarged opening enables the wire 20 to advance smoothly without kinks or jamming as the wire is transitioned from the conduit 78a portion to the lance nozzle insert 70. These features are especially helpful at the initial feed of the wire 20 through the lance nozzle 60.

Furthermore, according to an embodiment, the conduit 78a is made from material that is less prone to mechanical wear and abrasion than the lance nozzle insert 70. For example the conduit 78a may be made from steel alloy while the lance nozzle insert 70 is made from stabilized zirconium oxide (ZrO2) and graphite (see discussion below). Because the conduit 78a is made of material that is less prone to mechanical wear and abrasion than the lance nozzle insert 70, the passage 86 is resistant to wear from mechanical abrasion of the additive wire 20 moving through the passage 86. This maintains the dimension of the diameter D2 for extended periods of use. Thus, even if the passage 80 of the nozzle insert 70 widens from mechanical abrasion of the additive wire 20, the passage 86 maintains its diameter dimension. This feature helps maintain the positive pressure of the inert gas pumped into the conduit 44 (see FIG. 1) and through the passages within the lance nozzle 60. The positive pressure of the inert gas prevents any of the molten metal from entering the passage 80 which could clog the lance. In conventional lance nozzle tips currently being used in the industry, the conduit 78a has a diameter that is substantially larger than the diameter D1 of the passage 80 and the positive pressure of the inert gas is maintained by the nozzle insert 70 only. As the passage 80 widens through mechanical wear, the gas pressure drops and allows molten steel to penetrate into the passage 80 which causes wire jamming and failure of the lance nozzle.

FIG. 5 shows a cross-sectional view of the inlet end 170 of the conduit 78a. In one embodiment, the diameter D2 of the passage 86 is 0.375 inches to accommodate additive wire 20 having a diameter in the range of 0.3 to 0.36 inches. The diameter D2 of the passage 86 can be changed appropriately to accommodate additive wires having different diameters. The flared portion 89 of the passage 86 is inclined at an angle 0 of 20°. The diameter D3 of the opening at the inlet end 170 is about 1.0 inches.

The outer surface of the lance nozzle insert 70 may be provided with some contouring surface structure to promote mechanical locking of the nozzle insert with the refractory casing 62 surrounding the nozzle insert. In this embodiment, the lance nozzle insert 70 is provided with recessed channels 72 on the outer surface. The conduit 78a may also be provided with one or more anchoring members 75 (see FIG. 4) on its outer surface to promote mechanical locking of the conduit 78a with the refractory casing 62. The lance nozzle 60 is formed by casting or molding the refractory material around the assembly of the conduit 78a and the lance nozzle insert 70 and the contoured surface of the lance nozzle insert.
70 ensures that the nozzle tip is held securely within the refractory casing 62 by mechanical locking.

[0036] The removable lance nozzle tip 68 is useful where the lance nozzle insert 70 is exposed to a very corrosive environment and/or a lot of mechanical abrasion from the wire 20 which requires replacement of the lance nozzle insert 70 and/or thermal shock of the refractory casing 62 due to subsequent steel dipping. In such situations, only the nozzle tip portion 68 of the lance nozzle 60 needs to be replaced rather than replacing the entire lance nozzle. This provides the user with much more economical technology.

[0037] The overall lance nozzle 60 is made long enough to extend to a preselected depth in the reservoir of molten metal. It is usually preferred that the wire additive be discharged from the nozzle about 2-8 feet below the slag/metal interface. Accordingly, with due regard to the high temperature and corrosive nature of the slag and metal, the refractory casing 62 are generally on the order of about 10-15 feet long.

[0038] FIG. 4 shows a plan view of the lance nozzle insert 70 and conduit 78a assembly according to an embodiment. The conduit 78a has the passage 86 that has substantially the same diameter as the passage 80 of the lance nozzle insert 70. The conduit 78a may be provided with one or more outer anchor members 75 that extend outward and anchor the conduit 78a within the refractory casing 62.

[0039] The lance nozzle insert 70 has a generally elongated shape with the passage 80 extending longitudinally therethrough for conveying the wire 20. The embodiment of the lance nozzle insert 70 as illustrated has a generally cylindrical outer shape but the insert does not need to be limited to such shape. For example, the lance nozzle insert may have a four-sided elongated shape or any other shape that is suitable for manufacture as long as it has the passage 80 therethrough for conveying the wire 20. One end of the passage 80 is the outlet 84 where the wire 20 exits into the molten metal. The opposite end of the lance nozzle insert 70 is configured and adapted to engage with the conduit 78a. For example, in this example, the lance nozzle insert 70 is provided with a neck portion 74 at the inlet end which has a smaller outer diameter than the rest of the nozzle insert 70 for engaging into a recess 77 (shown in FIG. 3) of the conduit 78a.

[0040] The lance nozzle 60 may be raised and lowered with respect to the metal receptacle 52, or vice versa, by means of appropriate mechanical linkages. As shown schematically in FIG. 1, the metal receptacle 52 may be carried by a winch/conveying system, including yoke assembly 48. Alternatively, it may be preferable to raise and lower the entire feed mechanism as a unit. In any event, it is beneficial to avoid flexing the conduit 44.

[0041] In order to add the wire additive to the molten metal 56 at a point well below the surface of molten metal, it is necessary to overcome substantial fluid pressure in the molten metal. The fluid pressure is, of course, a function of the depth below the surface of molten metal. The particular pressure will depend upon the particular metal, but will usually be quite substantial at a depth of one or two meters. The pressure of inert gas supplied must overcome this fluid pressure in order to prevent molten metal 56 from rising in the nozzle. Should any molten metal be permitted to run into the nozzle, the wire 20 can immediately be seized and welded to a conduit wall as the molten metal solidifies.

[0042] According to an embodiment, to improve the useable life, i.e. the durability, of the lance nozzle insert 70, the lance nozzle insert is made from a new material that has higher oxidation resistance and slag corrosion resistance and at the same time still has a low friction surface to help feed the calcium wire through the lance nozzle insert at high speed. Higher resistance to oxidation and slag corrosion provides much longer useable life for the lance nozzle insert and thus necessitating much less frequent replacement of the nozzle insert during the life of the lance or may not even require any replacement.

[0043] The new material for the lance nozzle insert comprises stabilized zirconium oxide (ZrO₂), graphite and resin binder for holding the material together. The material comprises about 60-85 wt. % of ZrO₂, about 10-36 wt. % graphite and about 4-15 wt. % resin binder. The material preferably comprises about 67-77 wt. % of ZrO₂, about 19-29 wt. % graphite and about 4-8 wt. % resin binder. The ZrO₂ grains in the nozzle tip provide high corrosion resistance against the ladle slag in the ferrous molten metal. But ZrO₂ needs to be stabilized to avoid thermal spalling, caused by phase transformations due to subsequent thermal cycling. ZrO₂ can be stabilized with several oxides: CaO, MgO, Y₂O₃, or CeO. Typical ladle slag contains elevated lime concentrations and under these conditions, CaO is the preferred stabilizer because it is the thermodynamically most stable form of stabilized ZrO₂ for such environment.

[0044] The presence of graphite in combination with ZrO₂ in the new material increases the thermal shock resistance of the lance nozzle insert. The graphite component can be natural graphite or synthetic graphite. However, natural flake graphite (amorphous graphite being other common form of natural graphite) is preferred because of natural flake graphite's high oxidation resistance, which increases the nozzle insert's oxidation resistance properties. The corrosion resistance of the ZrO₂/graphite blend is significantly higher compared to the current lance nozzle inserts which are made from pure carbon.

[0045] Because ZrO₂ grains are very hard and have sharp edges, a fine grain size distribution (~325 Mesh, i.e. less than 44 μm particle size) is preferred to minimize mechanical friction and wear properties of ZrO₂. If the grain size distribution is not controlled to such fine size, excessive mechanical wear at the inner bore of the lance nozzle insert 70 may be observed from the wire feeding through the nozzle insert, which would shorten the life of the lance nozzle insert.

[0046] The fabrication process for the lance nozzle insert involves blending ZrO₂ powder and graphite. Then, resin binder in the amount specified above is added to the blend to form a slurry. The resin binder is preferably a thermosetting binder material that is added in a combination of liquid and solid powder form. Both the powder and the liquid resins are phenol-formaldehyde polymer resin. The powder resin can be classified as novolak while the liquid resin can be classified as resole. The powder resin and liquid resin is provided in a powder/liquid wt. % ratio of about 60/40 to about 40/60 and preferably about 50/50. The slurry is continuously mixed until the temperature of the slurry reaches 140° F. The temperature of the slurry rises during the mixing process because of the internal friction of the slurry material from the mechanical mixing action. At this stage, the blended slurry comprises globules of the mixed material bound by the liquid resin. Generally, because the amount of liquid resin added to enable homogeneous blending of the material is more than optimal for the next molding step, the slurry is then dried in a rotating furnace. The drying step is engineered in terms of the temperature and time duration to produce a slurry having the
desired moisture content for the molding step. The dried slurry is then molded into a desired shape for the lance nozzle insert and thermally treated.

[0047] One of the advantages of using organic resin over water to form the slurry is that water will evaporate during subsequent thermal processing steps leaving behind pores and resulting in an unacceptably high porosity in the lance nozzle insert 70. On the other hand, organic resin gets partially burned off during subsequent thermal processing steps and leaves behind carbon residue. This residual carbon material promotes lower porosity and enhances the properties of the nozzle insert. Higher porosity is not desired because pores promote the corrosion mechanism that attacks the nozzle insert when immersed in the molten metal.

[0048] Pure Zirconia, although having better corrosion resistance than pure carbon, currently used for lance nozzle insert, is not suitable because of its poor thermal shock resistance attributable to its monoclinic tetragonal crystal structure. Stabilized ZrO₂, however, having a cubic crystal structure has better thermal shock resistance and, thus, is better suited for lance nozzle insert application. Both the thermal shock resistance and the surface abrasion (i.e. friction) properties are further improved by blending the ZrO₂ with graphite resulting in more durable lance nozzle inserts. Test results show about 2-20 times improvement in the useful life of the ZrO₂-based lance nozzle inserts compared to the lance nozzle inserts made from conventional pure carbon.

[0049] The molding process for forming the pre-dried slurry into the lance nozzle insert can be any one of a variety of molding processes available that would work for this particular blend of material and the final shape of the insert. An example of such molding process is isostatic molding. Isostatic molding is a process where molding pressures are applied evenly in all directions around the part being made, unlike in compression molding which has pressure applied in only one direction. An isostatically molded part is made to near net shape and thus significantly less waste material is generated compared to other molding techniques. Isostatically molded parts generally have highly consistent material properties. Isostatic molding applies the pressure on the mold by placing the mold inside a high pressure vessel filled with hydraulic fluid. The hydraulic pressure of 5,000 to 20,000 psi and even higher may be used. Such high isostatic pressure produces lower porosity and more favorable pore size distribution of the molded part.

[0050] Next, the isostatically molded lance nozzle insert is cured at about 180° C. to volatilize the organic vapors from the polymer resin. Then, the lance nozzle insert is fired preferably about 800-1200° C. in reducing atmosphere. If necessary, the lance nozzle insert may be further machined to print dimensions.

[0051] As the wire 20 is fed, it can be expected to vibrate and rattle around the allowed space within the passages 86 and 80 of the nozzle tip 68. However, the wire generally remains centrally positioned in the discharge passages 86 and 80 even if resting against a side wall of the passages. The space which is left open between the wire 20 and the side wall of the passages 86 and 80 is small enough that the pressure of the gas being pumped through the lance nozzle 60 overcomes the fluid pressure of displaced molten metal, otherwise tending to flow up the nozzle. Interactive movement of the wire and the inert gas enhance the ability of the nozzle to resist clogging.

[0052] The seal mechanism 30 is provided in the wire feeding system to prevent a backwash of inert gas. Seal mechanism 30 comprises a housing having at least one pair of opposed pistons 32 having contoured sealing surfaces for slidably engaging the wire moving therethrough, which clasp the advancing additive wire 20 in a gas-tight fashion. Downstream of the opposed pistons 32, the inert gas is fed from inert gas source 31 via conduit 33 to the area of the wire 20, the wire now being enclosed in a gas-tight conduit 44 leading from seal 30 to the lance nozzle 60. A compressed air source 34 is preferably used to drive opposed pistons 32 against the wire 20. Spring biasing, hydraulic pressure or the like are also possible. A manifold 36 may be used to equally distribute the air pressure of compressor 34 or other source. The particulars of the seal mechanism 30 are disclosed in U.S. Pat. No. 4,512,800, assigned to the applicant, the disclosure of which is incorporated herein by reference.

[0053] A suitable control mechanism may be connected simultaneously to the pinch roller wire feed device 24 and to the inert gas pressure control 42. To avoid waste, the gas control 42 should be left closed until the wire becomes engaged by opposed pistons 32 of seal 30. In any event, no particular gas pressure is required until the wire injector lance nozzle 60 is brought into proximity with the molten metal 56, or the slag 54 thereupon. At this point, the feeder and inert gas pressure control can be simultaneously activated, and the nozzle plunged into the molten metal. Melting additive and inert gas are discharged at the nozzle orifice, well below the slag/metal interface.

[0054] According to one embodiment, a nozzle tip for a refractory lance for feeding an additive wire into a quantity of molten metal below the surface of the molten metal is disclosed. The nozzle tip comprising an inlet and an outlet, a passage provided between the inlet and the outlet for the additive wire being fed through the refractory lance, a refractory casing, a conduit provided within the refractory casing, wherein the conduit comprising an inlet end and an outlet end and a first passage extending from the inlet end to the outlet end of the conduit, the inlet end configured to mate with a main conduit in the main portion of the refractory lance. The nozzle tip also includes a nozzle insert provided within the refractory casing, the nozzle insert having an inlet end and an outlet end and a second passage extending from the inlet end to the outlet end of the nozzle tip, the inlet end of the nozzle insert is configured to mate with the outlet end of the conduit connecting the second passage to the first passage for conveying the additive wire. The second passage has a diameter flaring out to a funnel-shaped portion at the inlet end of the nozzle insert and the first passage has a diameter that is substantially equal to the diameter of the second passage and flares out to a funnel-shaped portion at the inlet end of the conduit for receiving and guiding the additive wire being conveyed through the first and second passages. The outlet end of the nozzle tip forms the lance's outlet.

[0055] The lance nozzle insert may be made of a material comprising stabilized zirconium oxide and graphite. The graphite may be natural graphite, natural flake graphite or synthetic graphite. The material for the lance nozzle insert may further comprise a thermosetting resin binder. The material for the lance nozzle insert may comprise about 60-85 wt. % stabilized zirconium oxide and about 10-36 wt. % graphite. The material for the lance nozzle insert may comprise about 65-80 wt. % stabilized zirconium oxide, about 10-36 wt. % graphite and about 4-15 wt. % thermosetting resin binder. The
material for the lance nozzle insert may comprise about 67-77 wt. % stabilized zirconium oxide, about 19-29 wt. % graphite and about 4-8 wt. % thermosetting resin binder. The zirconium oxide may be stabilized with an oxide selected from the group consisting of CaO, MgO, Y2O3, and CeO.

According to another embodiment, a lance nozzle for feeding an additive wire into a quantity of molten metal below the surface of the molten metal may comprise an inlet, a lance outlet and a main portion. The main portion may comprise a first refractory casing, a first conduit located within the first refractory casing providing a first passage for conveying the additive wire to the lance outlet. The lance nozzle also includes a nozzle tip portion forming the outlet end of the lance nozzle. The nozzle tip portion comprises a second refractory casing and a second conduit provided within the second refractory casing. The second conduit comprises an inlet end and an outlet end and a second passage extending from the inlet end to the outlet end of the second conduit. The inlet end is configured to mate with the first conduit connecting the second passage to the first passage for conveying the wire to the lance outlet. The nozzle tip portion also includes a nozzle insert provided within the second refractory casing. The nozzle insert has an inlet end and an outlet end and a third passage extending from the inlet end to the outlet end of the nozzle insert. The inlet end of the nozzle insert is configured to mate with the outlet end of the second conduit connecting the third passage to the second passage for conveying the additive wire. The outlet end of the nozzle insert forms the lance's outlet, wherein the third passage having a diameter flaring out to a funnel-shaped portion at the inlet end of the nozzle insert and the second passage having a diameter that is substantially equal to the diameter of the third passage and flaring out to a funnel-shaped portion at the inlet end of the second conduit for receiving and guiding the additive wire being conveyed through the second and third passages.

The main portion and the nozzle tip portion of the lance nozzle are adapted and configured to removably engage each other allowing the nozzle tip portion to be replaced when necessary.

The essential features of the invention having been disclosed, further variations will now become apparent to persons skilled in the art. All such variations are considered to be within the scope of the appended claims. Reference should be made to the appended claims, rather than the foregoing specification, as indicating the true scope of the subject invention.

What is claimed is:
1. A lance nozzle tip for a refractory lance for feeding an additive wire into a quantity of molten metal below the surface of the molten metal, the lance nozzle tip comprising:
   a refractory casing having an outlet;
   a conduit located within the refractory casing providing a passage for conveying the wire to the outlet, the refractory casing having:
   a nozzle portion having a lance nozzle insert provided within the refractory casing forming the outlet;
   a first portion of the conduit provided in the nozzle portion;
   a main portion having a second portion of the conduit provided therein, wherein the first and second portions of the conduit engage to form the passage for conveying the wire to the outlet;
   wherein the first portion of the conduit has a first passage extending from an inlet end of the first portion of the conduit to an outlet end of the first portion of the conduit, the first passage having a diameter for a substantial portion of the length of the first portion of the conduit and a funnel-shaped portion at the inlet end of the first portion of the conduit for guiding the additive wire conveyed through the first passage and second portion of the conduit.

2. The lance nozzle tip of claim 1, wherein the main portion and the nozzle portion are adapted and configured to removably engage each other allowing the nozzle portion to be replaced.

3. The lance nozzle tip of claim 2, wherein the first and second conduit portions are provided with mating threads and the main portion and the nozzle portion of the refractory casing threadably engage each other by operation of the mating threads.

4. The lance nozzle tip of claim 1, wherein the lance nozzle insert has a second passage extending from an inlet end of the lance nozzle insert to an outlet end of the lance nozzle insert, the second passage having a diameter for a substantial portion of the length of the lance nozzle insert and a funnel-shaped portion at the inlet end of the lance nozzle insert for guiding the additive wire conveyed through the second passage and the first portion of the conduit.

5. The lance nozzle tip of claim 4 wherein the diameter of the first passage is substantially the same as the diameter of the second passage.

6. The lance nozzle tip of claim 1 wherein the diameter of the first passage is from about 0.3 to 0.36 inches.

7. The lance nozzle tip of claim 6 wherein the diameter of the inlet end of the funnel shaped portion of the first portion of the conduit is about one inch.

8. The lance nozzle tip of claim 1 wherein the funnel-shaped portion of the first portion of conduit has a flared portion inclined at an angle of about 20 degrees.

9. The lance nozzle tip of claim 1 wherein the lance nozzle insert is made by molding.

10. The lance nozzle tip of claim 1 wherein the lance nozzle insert is made by isostatic molding.

11. The lance nozzle tip of claim 1 wherein the first portion of the conduit is provided with one or more anchoring members on an outer surface of the first portion of the conduit for mechanical locking of the first portion of the conduit with the refractory casing.

12. A lance for feeding an additive wire into a quantity of molten metal below the surface of the molten metal, the lance comprising a nozzle tip comprising:
   a refractory casing having an outlet;
   a conduit located within the refractory casing providing a passage for conveying the wire to the outlet, the refractory casing having:
   a nozzle portion having a lance nozzle insert provided within the refractory casing forming the outlet;
   a first portion of the conduit provided in the nozzle portion;
   a main portion having a second portion of the conduit provided therein, wherein the first and second portions of the conduit engage to form the passage for conveying the wire to the outlet;
   wherein the first portion of the conduit has a first passage extending from an inlet end of the first portion of the conduit to an outlet end of the first portion of the conduit.
conduit, the first passage having a diameter for a substantial portion of the length of the first portion of the conduit and a funnel-shaped portion at the inlet end of the first portion of the conduit for guiding the additive wire conveyed through the first passage and second portion of the conduit.

13. The lance of claim 12, wherein the main portion and the nozzle portion are adapted and configured to removably engage each other allowing the nozzle portion to be replaced.

14. The lance of claim 13, wherein the first and second conduit portions are provided with mating threads and the main portion and the nozzle portion of the refractory casing threadably engage each other by operation of the mating threads.

15. The lance of claim 12, wherein the lance nozzle insert has a second passage extending from an inlet end of the lance nozzle insert to an outlet end of the lance nozzle insert, the second passage having a diameter for a substantial portion of the length of the lance nozzle insert and a funnel-shaped portion at the inlet end of the lance nozzle insert for guiding the additive wire conveyed through the second passage and the first portion of the conduit.

16. The lance of claim 15 wherein the diameter of the first passage is substantially the same as the diameter of the second passage.

17. The lance of claim 12 wherein the diameter of the first passage is from about 0.3 to 0.36 inches.

18. The lance of claim 17 wherein the diameter of the inlet end of the funnel shaped portion of the first portion of the conduit is about one inch.

19. The lance of claim 12 wherein the funnel-shaped portion of the first portion of conduit has a flared portion inclined at an angle of about 20 degrees.

20. The lance of claim 12 wherein the lance nozzle insert is made by molding.

21. The lance of claim 12 wherein the lance nozzle insert is made by isostatic molding.

22. The lance of claim 12 wherein the first portion of the conduit is provided with one or more anchoring members on an outer surface of the first portion of the conduit for mechanical locking of the first portion of the conduit with the refractory casing.