Nov. 21, 1972 T. A. CLISHEM ET AL 3,703,391

ELECTRIC MELTING FURNACE AND PROCESS OF USING IT

Filed July 29, 1970

3 Sheets-Sheet 1

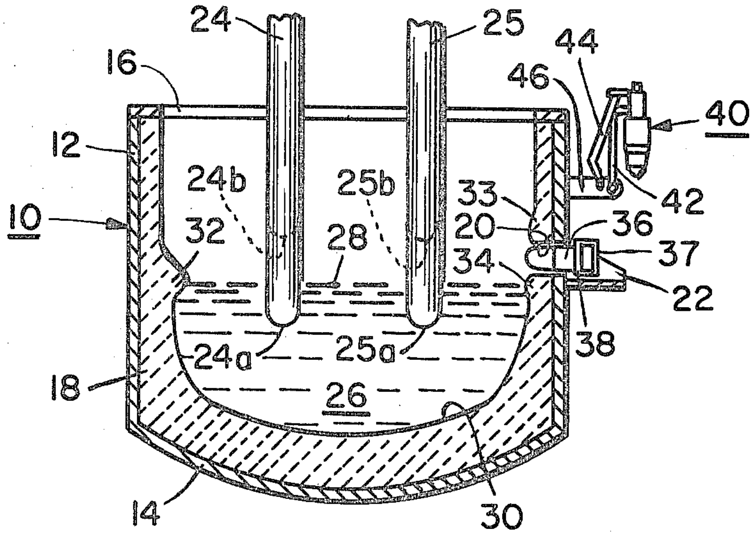

Fig. 1

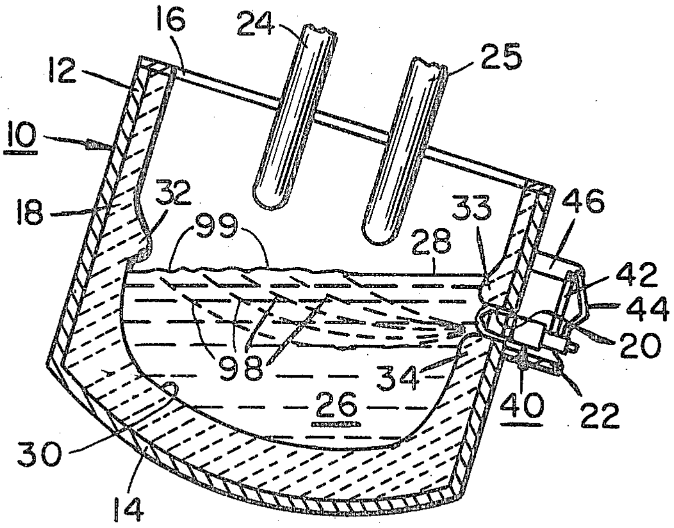

Fig. 2

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ELECTRIC MELTING FURNACE AND PROCESS OF USING IT

Filed July 29, 1970 3 Sheets-Sheet 2

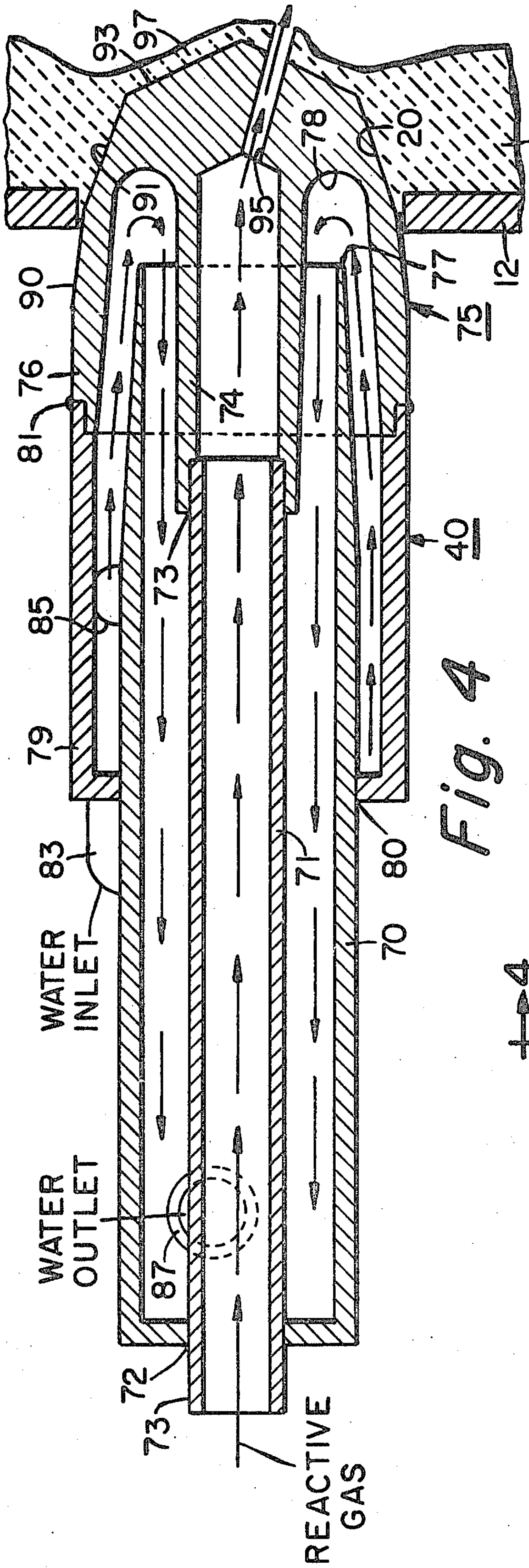

Fig. 4

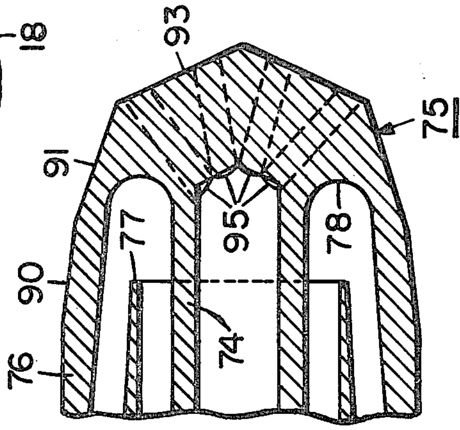

Fig. 5

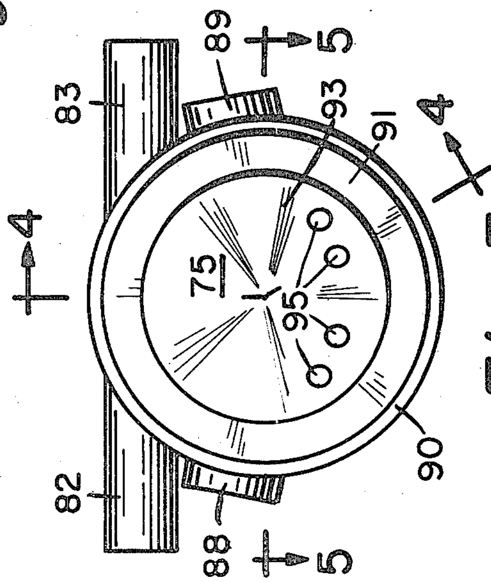

Fig. 3

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ELECTRIC MELTING FURNACE AND PROCESS OF USING IT

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3 Sheets-Sheet 3

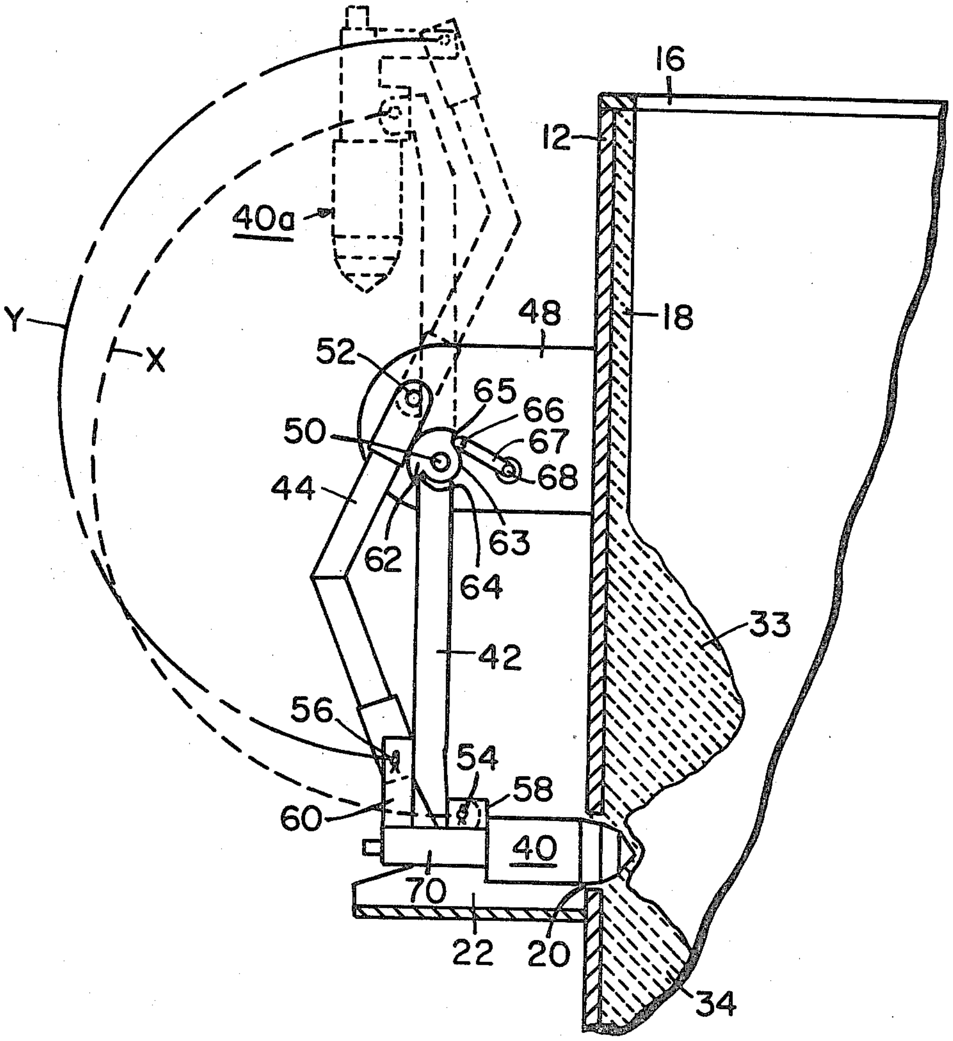

Fig. 6

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ELECTRIC MELTING FURNACE AND PROCESS OF USING IT

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Int. Cl. C04b *35/48*
U.S. Cl. 106—57 5 Claims

ABSTRACT OF THE DISCLOSURE

Furnace has carbon electrodes suspended in a refractory-lined melting pot with a tap hole in the middle of a front wall portion thereof. A water-cooled copper lance sealably and removably engages the tap hole for injecting reactive gas into a molten charge in the pot. The lance has a tapered portion for sealably engaging the walls of the tap hole and has a stubby end as the only part thereof protruding inside of and facing into the pot. The stubby end has a plurality of jet orifices for discharging reactive gas, which orifices have axes disposed at an acute downward angle from the horizontal and in a divergent fan-like pattern in the direction of gas flow in the lance. Furnace is operated to produce molten oxidic refractory material by providing a shallow pool of that molten material in the pot, electrically melting further oxidic refractory material by means of the electrodes to enlarge the pool, engaging the water-cooled lance in the tap hole and causing reactive gas, e.g. oxygen, to flow from the lance into the pot, tilting the furnace forward to cause the pool surface to rise above the tap hole and to effect injection of gas into the pool with stirring thereof, then back-tilting the furnace after a predetermined time of lancing, discontinuing flow of the gas and removing the lance from the tap hole in preparation for fusion-casting the pool.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to an electric furnace with carbon (graphite) electrodes and a water-cooled metal lance for blowing reactive gas into material melted in the furnace, and to a method of employing such furnace in producing a melt of refractory oxide material for fusion casting into desired shaped bodies.

Description of the prior art

It has long been recognized that, for almost any given refractory oxide composition, the fusion-cast (or fused cast) product thereof vis-a-vis a burned or sintered product tends to possess the optimum resistance to corrosion and erosion by an environment to which it is most suitably matched as heretofore known. However, oftentimes the fusion casting process has produced conditions that adversely affected certain aspects of the product chemistry and other properties controlled thereby. Within about the last decade, it has been discovered that many such adverse conditions and effects can be substantially overcome by contacting the molten oxidic refractory material with a suitable reactive gas for the purpose.

As noted in French Pat. No. 1,208,577 and the four additions thereto, a number of detrimental effects are produced in a great variety of refractory oxide compositions by the chemically reducing action of the electrodes on the molten material during either immersed-electrode melting (of material having relatively low electrical conductivity in the molten state) or short-arc melting (of material having relatively high electrical conductivity in the molten state). The procedure (referred to as the "long arc process") described in that patent for substantially overcoming such detrimental effects is the use of a longer arc combined with agitation of the bath of melt and constantly renewed oxidizing atmosphere above the bath in the arc path. However, that procedure involves greater heat loss and concomitantly greater furnacing costs.

More recently, e.g. as noted in Japanese patent application publication No. 39/24,347, it was discovered that the more economical, older melting procedures (viz. immersed-electrode and short-arc melting) could still be used and their deleterious effects equally substantially overcome by injecting air or oxygen gas into the melted material, by means of an overhead lance projected down into the furnace with its lower jet-end portion substantially immersed in the molten material, prior to pouring it into molds. However, this overhead lancing process is not without serious shortcomings.

Firstly, the construction of a suitable water-cooled metal lance for the overhead lancing process is necessarily of expensive, bulky, complex or intricate design to accommodate the required large volume flow of water therein for cooling as well as to safely contain the water so that it does not leak out into dangerous explosive contact with the molten material. Such construction has unavoidably involved critical weld joints at locations that have to be submerged in the molten bath. Not only is it necessary to make elaborate preliminary tests for soundness of these critical weld joints, but frequent additional elaborate retesting during service is essential to guard against undetected dangerous deterioration. Such retesting requires removal and reinstallation of lances from and in the furnace, with consequent loss of production time and extra labor costs, and use of valuable factory space therefor and any possible reworking of salvable lances. Moreover, efficient operation necessitates an inventory of spare lances and storage space for them. In relation to their average service life, these lances involve costs that are a significant factor in the overall costs of producing fusion-cast products.

A second significant shortcoming of overhead lances is that they have been found to inevitably cause substantial splashing of molten material in and from the furnace. This splashing apparently is the result of the injected gas, in the required volume flow for desired product properties, rapidly expanding and rising in the molten material in a detrimental manner or pattern. This splashing per se is not so much a danger to workmen around the furnace as it is to proper operation of the furnace. In the ordinary course of melting refractory oxide material, substantially unmelted or partially fused batch or charge material remains generally around and partly over the perimeter areas of the surface of the molten material as a partial crown or batch cover, and the pot lining is formed at least in part by solidified oxidic refractory material. The molten material in contact with such crown and solidified lining material of essentially the same composition necessarily exists at temperatures only slightly higher than its own solidification temperature (i.e. contains very modest superheat). When the hot liquid material is splashed upward during lancing, many of the molten droplets or globules then fall back upon the crown and quickly solidify there. By this process, the crown enlarges and grows into a rigidly consolidated mass extending further over the surface of molten material until it closes the open area needed for, and restricts the capability of, removing and reinserting the lance as well as proper, evenly spread feeding of additional bath material for further melting without localized overheating of furnace walls. Moreover, such growth of a rigid crown often has extended to the point where the electrodes rub on it, thereby interfering with the necessary movement of the electrodes to maintain proper electrical conditions for further melting. This crown growth problem is especially critical because of rapid development thereof when melting magnesia-chrome ore compositions or zirconia-alumina-silica compositions with over 60 wt. percent ZrO_2, but it is also seriously detrimental with other known compositions. The occurrence of such an enlarged crown necessitates production delay as well as danger and fatiguing labor for workmen while they chop down the enlarged crown to about its original size.

A third shortcoming of the overhead lancing process is that it is quite sensitive, to and difficult to control to avoid, "overgassing" or excessive lancing when trying to attain optimum correction of the detrimental effects caused by the electrodes during melting. The "overgassing" condition causes the fusion-cast ware to be undesirably porous and cannot be corrected with a reasonable period of maintaining the bath quiescent after lancing and immediately before pouring. This problem is complicated by the fact that bath volume changes in an unpredictable variable manner from melt to melt especially due to splashing losses.

The use of permanently submerged lancing, similar to the bubbler flues in the bottom of a furnace illustrated in the third Addition No. 82,310 to the above-noted French patent, are subject to the same shortcomings as those of the overhead lancing. Moreover, in the case of permanently submerged lancing, the shortcomings of the first type noted above are further magnified due to such positioning of the lance. Also, there are the competing problems of the lance being plugged up by solidified oxidic refractory material or gas wastage in continuously maintaining flow thereof in an attempt to avoid the plugging of the lance.

SUMMARY OF THE INVENTION

We have now discovered a new combination of tiltable electric furnace and fluid-cooled metal lance means, and a new method of providing molten oxidic refractory material for fusion casting by using such apparatus combination, that significantly overcomes the shortcomings described above.

In our invention, we employ a conventional tiltable electric furnace comprising a refractory-lined melting pot having a tap hole in a front wall portion thereof and carbon (usually graphite) electrode means associated with the pot for heating charge material contained therein above the melting point of said material, which heating can be done by either immersed-electrode or short-arc practice as is and/or has been appropriate for economical operation. The improvement provided in our invention is the combination with such conventional furnace of a fluid-cooled metal lance means adapted to be sealably and removably engaged in the tap hole for injecting gas into the molten charge material in the pot when the furnace is tilted forward so that the molten material covers an end of the lance means facing into the pot, and of means for alternately sealably engaging the lance means in the tap hole and for removing it from the tap hole.

A lance means especially effective for substantially overcoming the noted shortcomings of the prior art, according to our invention, has a tapered portion terminating in a stubby end. Such tapered portion is so constructed and arranged to sealably and removably engage the walls of the tap hole with only the stubby end protruding inside of and facing into the pot. The stubby end has gas jet means therein for discharging gas from the lance means at relatively high velocity so that the gas penetrates into, stirs and thoroughly mixes with the molten charge material. While a single gas discharge orifice can be employed, excellent penetration, stirring and mixing is particularly obtained by gas jet means comprising a plurality of jet orifices with axes disposed, when the lance means is engaged in the tap hole, at an acute downward angle from the horizontal in the direction of gas flow in the lance means toward the stubby end. Also advantageously for the same purposes, the jet orifices should be disposed transversely of the lance means in a divergent fan-like pattern in the direction of gas flow toward the stubby end.

To provide a very practical arrangement for substantial forward tilting without spilling the molten contents of the furnace and so as to shift the surface of the molten pool substantially above the top of the tap hole, the tap hole may be located about midway between the upper and lower extremities of the front wall portion.

In operating this improved furnace apparatus for providing molten oxidic refractory material in substantial volume suitable to be fusion cast, the process initially comprises providing a shallow pool of the molten oxidic material in the pot with the furnace in a substantially upright position. This is conventionally done by either retaining part of the pool of a previous melt or forming a completely new pool by customary procedures in the central upper portion of a fresh batch material charge. The next step is to cause electrical current, with sufficient energy to melt further oxidic refractory material, to pass from one part of the electrode means through the pool to another part of the electrode means. Then oxidic refractory batch material is charged into the pot and into contact with the pool while continuing the passage of current until the volume of the pool is enlarged so that the surface of it remains at least slightly below the bottom of said tap hole at least when the furnace is tilted backward, without spilling any of the contents of the pot. After forming the enlarged pool, the lance means is engaged in the tap hole with the one end thereof facing into the pot while the surface of the enlarged pool remains below the bottom of the tap hole. Then reactive gas is caused to flow from the lance means into the pot above the enlarged pool surface. Thereafter, that surface is caused to rise substantially above the top of the tap hole so as to also cause the pool to cover the one end of the lance means facing into the pot. The latter step is accomplished by tilting the furnace forward. Such step effects the solidification of a small portion of the pool liquid as a thin layer covering over the juncture and forming a temporary seal between the tap hole and the lance means, and also effects injection of the gas into the pool with stirring thereof. The enlarged pool surface is maintained in the risen position for a predetermined time to effect a predetermined reaction between the gas and the entire contents of the enlarged pool. Thereafter, the enlarged pool surface is caused to fall at least slightly below the bottom of the tap hole by tilting the furnace backward and gas flow is then discontinued. Finally, the lance means is removed from the tap hole and the pool is ready for conventional fusion casting.

The amount of rise of the enlarged pool surface above the top of the tap hole is not particularly critical to attainment of adequate lancing effects while substantially avoiding the prior art shortcomings. However, it is to be noted that efficiency of gas usage increases as pool volume above the jet orifices increases. Therefore, the greatest amount of rise without danger of spilling any of the contents is most desirable.

Likewise, there is nothing particularly critical about the volume and rate of gas injection for attaining similarly adequate effects. These factors are basically governed by the obvious competing practical consideration of the speed of accomplishing adequate lancing and the avoidance of undesirable turbulence at the surface and heat loss from the molten pool.

When the molten oxidic refractory material is melted in a manner to be subjected to a reducing action, such molten material has an oxygen deficiency imparted to it. Such oxygen deficiency can be eliminated via an oxidation reaction by injecting a reactive gas that is oxidizing with respect to the molten pool of oxidic material. Satisfactory reactive gas can be selected from oxygen, air, nitrous oxide, carbon dioxide and mixtures thereof.

The process and apparatus of this invention employing an oxidizing reactive gas has been found to be especially effective in producing molten oxidic refractory material for fusion casting of the following two types of compositions:

(1) Oxidic refractory material for lining glass melting tanks and the like, which consists essentially, analytically by weight, of 25 to 90% ZrO_2, up to 20% SiO_2, up to 4% Na_2O and the balance Al_2O_3 with incidental impurities; and

(2) Oxidic refractory material for lining molten metal-producing furnaces (e.g. steel, copper, etc.) and the like, which consists essentially of a mixture of magnesia and chrome ore and the mixture contains, analytically by weight, at least 40% MgO and at least 4% Cr_2O_3.

The furnace and method employing the tap hole mini-lance according to this invention represents a very substantial improvement over the prior overhead lancing. Since it can be made less bulky and of simpler design, the cost of a commercial tap hole mini-lance is less than half that of a commercial overhead lance. The mini-lance has been found to have an average service life of over four times that of an overhead lance. The average water comsumption of a mini-lance is about 0.5% of that needed for an overhead lance. The cost of labor to change or replace the mini-lance on the furnace is about one third that of an overhead lance. Unlike the overhead lance, the tap hole mini-lance can be inspected or changed in its "removed" position without any loss of furnace production time. Since only an end area of the mini-lance is in contact with molten oxidic refractory material, cooling requirements are less critical so as to facilitate lancing of very high melting temperature compositions such as those with over 60 wt. percent ZrO_2 and those of magnesia-chrome ore mixtures. For reasons not yet fully understood, the mini-lance is readily operated without detrimental splashing, which fact also facilitates lancing the above-noted high melting temperature compositions. Critical weld joints are located along the sides of the lances. In the case of the mini-lance, such joints never contact molten ceramic and are easily located outside the tap hole when the mini-lance is positioned in the tap hole. Hence, there is much less danger of a water or alternative fluid leaking from such joint. The smaller, simpler mini-lance requires much less time and space for storage, inspection and repair. The longer service life also means that a smaller inventory of spare mini-lances is practical. Lastly, a very significant factor is that lancing with a mini-lance is much less sensitive and is easy to control to avoid "overgassing" or excessive lancing. This result is also not fully understood; nevertheless, it does consistently occur thereby requiring less precision in the control of the amount of reactive gas lancing to successfully condition the molten oxidic refractory material to the desired state.

A surprising factor contributing to the successful operation of the furnace and method of this invention is the lack of difficulty in maintaining reproducible suitable sealing of the tap hole lance without necessitating substantial loss of operating time for redressing or reforming the tap hole after removal of the lance so as to again properly receive the lance with complete annular sealing therebetween. It is known that any molten oxidic refractory material with modest superheat will deposit a freshly frozen layer in the tap hole during pouring therethrough for fusion casting. Such frozen material layer in the past has often been difficult to remove in a manner that will leave the pre-existing smooth tap hole contour, which is important for the sucess of the present invention. Unexpectedly, it has been found that any fresh frozen layer formed in the circular tapered tap hole, as formed with the lance in place, could again be easily and quickly broken out completely, without damage to the pre-existing tap hole contour. Although it is not fully understood why this is the consistent result, it is suspected that possibly the tapered and smooth tunnel surface character provided in the tap hole by the lance is repsonsible for it.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a view in vertical cross-section of a preferred embodiment of a furnace according to the present invention after completion of melting charge material to form the enlarged pool and prior to inserting the lance in the tap hole.

FIG. 2 is a view in vertical cross-section of the same furnace as in FIG. 1 but after lancing with reactive gas has begun with the furnace tilted forward.

FIG. 3 is a view of the tap hole mini-lance shown in FIGS. 1 and 2 as seen when looking at the end thereof that faces into the furnace when the lance is positioned in the tap hole.

FIG. 4 is a cross-sectional view of the lance in FIG. 3 taken along lines **4—4** and of a fragmentary portion of the furnace of FIG. 1 containing the tap hole with the lance sealably engaged therein.

FIG. 5 is a fragmentary cross-sectional view of the tapered portion of the lance in FIG. 3 taken along lines **5—5**.

FIG. 6 is an enlarged reversed view of the furnace in vertical cross section and the lance apparatus shown in FIG. 1 with the lance apparatus shown in both the fully engaged and fully removed positions.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the present invention, we employ a conventional basic furnace structure shown in FIG. 1. The metal furnace shell **10** comprises a cylindrical side wall **12**, a dished bottom **14** in the shape of a segment of a sphere, and a top annular rim **16**. Typically, the shell **10** is water-cooled externally, but the apparatus for such conventional water-cooling is not shown to facilitate understanding the furnace components more directly pertinent to the present invention. The shell **10** contains a refractory lining **18**. A tape hole **20** comprises a cylindrical passage through the wall **12** and lining **18** at the front of the furnace about midway between the bottom **14** and rim **16**. A spout **22** is attached to and extends outwardly from the wall **12** generally around the bottom and sides of the tap hole **20**.

Three graphite electrodes, arranged in a customary spaced, triangular, three-phase power configuration, extend downwardly into the furnace. Electrodes **24** and **25** are seen in FIGS. 1 and 2, but the third electrode is behind and hidden by electrode **24**. For immersion-melting, the electrodes are lowered into an initially formed or retained pool and continuously adjustably maintained therein (by conventional apparatus not shown) at a customarily suitable depth for melting charge material to enlarge the pool to the volume desired. In FIG. 1, the enlarged pool **26** is shown with its upper surface **28** slightly below the bottom of the tap hole **20**. The electrodes are immersed in pool **26** to an appropriate depth as indicated at **24*a*** and **26*a***. However, in the case of short-arc melting, the electrodes are lowered to and continuously adjustably maintained at a position where their lower tips are just above the melt surface **28** a conventional amount suitable for melting. During melting operations the lower part of lining **18** continues to maintain a generally dished contour **30** and is made up of charge material, some of which has solidified after being melted and the rest being unmelted charge material. Also formed as part of lining **18** during melting operations is an annular crown **32** in the vicinity of where it joins the enlarged pool surface **28**, which crown is somewhat distorted around the tap hole area as shown at **33** and **34**.

During melting, the tap hole **20** is customarily closed by a conventional graphite plug **36** of shape similar to that of the lance **40**. The plug **36** is fitted with a handle **37**, which is held on the plug **36** by a circular band **38** that is integral with the handle **37**. Handle **37** facilitates removal of plug **36** when it is desired to insert the lance **40** into the tap hole **20**.

Lance **40** is supported by movable arms **42** and **44** (best seen by reference to FIG. 6), which are rigidly connected to separate shafts **50** and **52**, respectively. Shafts **50** and **52** extend between and are journaled in furnace brackets **46** and **48**, which brackets are rigidly attached to wall **12**. Arms **42** and **44** are pivotally connected by pins **54** and **56**, respectively, to brackets **58** and **60**, respectively, which are in turn rigidly attached to water jacket **70** of lance **40**. Also rigidly mounted on shaft **50** is a cam **62** having surfaces **64** and **65** alternately engaged by bar **66** mounted between two supports with its longitudinal axis parallel to shaft **50**. Only one support **67** for bar **66** is shown in the sectional view of FIG. 6. Those supports are rigidly mounted on a shaft **68** extending between and journaled in brackets **46** and **48**. When the lance **40** is swung down and into tap hole **20** by movement of arms **42** and **44**, lance **40** is locked into sealably engaging position by bar **66** engaging surface **65** on cam **62**. After lancing is completed, bar **66** is raised by means of its supports (one being **67**) to allow cam **62** to freely rotate. Then lance **40** is swung out of the tap hole **20** and up into storage position **40*a*** generally along arc paths X and Y traced by pins **54** and **56**, respectively. The lance and its support mechanisms are shown in the storage position **40*a*** by dotted outlines. It is to be noted that the longitudinal axes of arms **42** and **44** lie in different planes parallel to the sheet of FIG. 6 so as not to interfere with the motion of each other. The storage position **40*a*** is maintained by bar **66** engaging surface **64** of cam **62** after cam **62** has rotated clockwise far enough for bar **66** to drop down onto the lower annular cam surface **63** of smaller diameter. Lance **40** is released from storage position **40*a*** by raising bar **66** out of engagement with cam surface **64** so as to allow cam **62** freely rotate counterclockwise.

In preparing for lancing, the three electrodes (of which **24** and **25** are shown in FIGS. 1 and 2) are raised and withdrawn from the pool **26** to a position where their tips are located as indicated at **24*b*** and **25*b*** in FIG. 1 (which is the same position of these electrodes as shown in FIG. 2). The plug **36** is removed from the tap hole **20** and lance **40** is swung down and locked in place thereof.

Lance **40** (see FIGS. 3–5) comprises a central gas conduit **71** surrounded by water jacket **70** except for the short protruding end portion **73** that is connected to a reactive gas supply conduit (not shown). Conduit **71** is water-tightly sealed (e.g. by brazing) at **72** to jacket **70** and at **73** to a central tubular portion **74** in the tapered nose or end member **75**. The outer tubular portion **76** of member **75** forms an annular space with portion **74**. Jacket **70** is positioned into that annular space such that the annular tip **77** of the tapered end of jacket **70** is spaced from the closed end **78** of the annular space to provide a water flow passage. An outer water jacket **79** surrounds a portion of jacket **70** adjacent member **75** and is water-tightly sealed thereto at **80**. Jacket **79** is also water-tightly joined (e.g. by welding) to end member **75** at **81**. Two water inlet tubes **82** and **83** are water-tightly joined to jacket **79** in communication with inlet orifices therein (such as **85**). The water flow follows the path indicated by arrows in FIG. 4 from inlet orifices (such as **85**) through jacket **79** to the annular space in member **75**, around tip **77** and back through jacket **70** to water outlet orifices, one of which is shown at **87**. Two water outlet tubes **88** and **89** are water-tightly joined to jacket **70** in communication with the outlet orifices (such as **87**). Water is customarily supplied to the inlet orifices at tap temperature.

Preferably and advantageously, the parts of lance **40** are constructed of copper or copper alloy because of its high thermal conductivity.

End member **75** desirably has annular tapered surfaces **90** and **91** that provide good sealable engagement with tape hole **20**, which is formed in part by solidified refractory lining **18**. End member **75** also has a stubby end surface **93** facing into the furnace pot essentially defined by lining **18**, and member **75** is so designed that only surface **93** protrudes into the furnace pot and for a very short distance. Such design keeps critical fabrication joints of lance **40** (e.g. weld **81**) out of contact with the molten refractory pool. A plurality of gas jet orifices **95** are provided in the stubby end of member **75** providing communication between the hollow space in tubular portion **74** and the furnace pot at surface **93**. The disposition of the jet orifices with respect to being acutely angled downward is best seen in FIG. 4 and with respect to being in a divergent fan-like pattern is best seen in FIG. 5. The advantages of downwardly angled orifices are suitably obtained with included angles from the horizontal axial plane ranging between about 15° to 45° (e.g. 25°). Similarly, the included angles from the vertical axial plane for the fan-like arrangement desirably lie within the range of about 10° to 75° (e.g. about 15° for the inner two orifices and about 40° for the outer two orifices).

After lance **40**, with the water-cooling flow on, is locked into sealed engagement with tap hole **20**, the flow of reactive gas is turned on. The gas passes through conduit **71**, tubular member **74** and thence through jet orifice **95** to issue therefrom at surface **93** as gas jets. Next, the furnace is tilted forward, as shown in FIG. 2, to a position where the surface **28** of the pool **26** has risen substantially over the top of the tape hole **20** and has covered surface **93** of lance **40**. Except for where the gas jets issue from orifices **95**, a thin solidified layer **97** of refractory material forms onto cooled surface **93** to further assist in sealing the end member **75** to the tap hole **20** and in reducing the amount of heat and wear imparted to end member **75**. The jets of gas generally pass through pool **26** in a manner diagrammatically indicated by dotted lines **98** in FIG. 2 and emerge at surface **28** with formation of modest turbulence or ripples **99**.

Upon completion of the needed gas lancing of pool **26**, the furnace is tilted backward to lower surface **28** below tap hole **20**. The gas flowing through lance **40** is shut off, lance **40** is removed from tap hole **20** and locked in storage position **40*a***, thin-refractory layer **97** is readily punched out, and then the furnace is again tilted forward for pouring most of pool **26** through tap hole **20**, along spout **22**, and into conventional molds (not shown).

By way of further illustrating a preferred mode of utilizing and carrying out the invention, the furnace apparatus 7 feet in diameter with tap hole mini-lance as described above, was employed to melt a zircon-alumina batch mixture with added soda ash that yielded a fusion analyzing, by weight, approximately 32.9% ZrO_2, 49.3% Al_2O_3, 15.1% SiO_2, 1.56% Na_2O, 0.07% TiO_2 and 0.04% Fe_2O_3. Via submerged electrode melting, 1800 pounds of such batch mixture were converted into an oxygen-deficient molten pool in 29 minutes with the application of 1115 kwh. of electrical power. After locking lance **40** in the tap hole, oxygen gas was supplied at 25–30 cu. ft./min. to the lance **40** with $\frac{7}{64}''$ diameter orifices. The furnace was tilted forward to an axial position 17° from the vertical axial position thereof for a period of 3.5 minutes. Then the furnace was back-tilted for removal of the lance and preparation for pouring the lanced pool material into molds. The resultant fusion-cast product exhibited low porosity, excellently low blistering in contact with molten glass and excellently low exudation of glassy phase at temperatures encountered in glass melting furnaces, which characteristics were quantitatively as well as qualitatively essentially comparable to those of fusion-cast products of substantially the same composition but made by the long arc process and by the overhead lancing process. In contrast, fusion-cast products of similar composition made merely by the old short arc or submerged electrode melting procedures have notably inferior porosity, blistering and exudation characteristics.

As another example of practical utilization of the invention, a smaller 1 foot diameter furnace with only two graphite electrodes employing 120 kw. two-phase power and with a similar but about proportionately scaled down tap hole mini-lance was operated to melt magnesia-chrome ore batch mixtures yielding fusions analyzing, by weight, approximately 56–57% MgO, 20–21% Cr_2O_3, 10–11% FeO, 8–9% Al_2O_3, 0.5–0.7% CaO, 1.0–1.2% SiO_2, and 1.5–1.7% TiO_2. Via short arc melting with an arc length of about 0.30 inch, a batch of about 125 pounds was converted into oxygen-deficient molten pools by application of 1.3 kwh./pound of batch. After the furnace was tilted forward with the lance operating, power was turned back on while a total volume of 3.0 cu. ft. of oxygen at a rate of 90 cu. ft./hr. was injected via the lance jets orifices into the pool. The fusion-cast product resulting from this lanced pool was found to gain only 0.32% in weight upon heating it in air at 1000° C. to full reoxidation. Under the same heating process, a fusion-cast product made the same way, except for omission of the oxygen lancing, gained 0.806% in weight, which is indicative of a substantially greater oxygen deficiency in contrast to the lanced product.

Other tests have shown that nitrous oxide, carbon dioxide and/or air can replace oxygen, in whole or in part, as the oxidizing reactive gas in the foregoing examples with approximately equivalent results with some suitable adjustment, usually an increase, in the volume thereof per unit weight of molten material to be treated.

We claim:

1. The process of operating a furnace for providing molten oxidic refractory material to be fusion cast comprising

providing a tiltable electric furnace comprising
    a refractory-lined melting pot means having a tap hole in a front wall portion thereof,
    carbon electrode means associated with said pot means for heating charge material contained therein above the melting point of said material,
    a fluid-cooled metal lance means adapted to be sealably and removably engaged in said tap hole for injecting gas into the molten charge material in said pot means when said furnace is tilted forward so that said molten material covers an end of said lance means facing into said pot means, and
    means for alternately sealably engaging said lance means in said tap hole and for removing said lance means from said tap hole,
providing a shallow pool of said molten material in said pot means with said furnace in a substantially upright position,
causing electrical current, with sufficient energy to melt additional oxidic material, to pass from one part of said electrode means through said pool to another part of said electrode means,
charging batch material of said oxidic material into said pot means and into contact with said pool while continuing said passage of current until the volume of said pool is enlarged so that the surface of said pool remains below the bottom of said tap hole at least when said furnace is tilted backward,
engaging said lance means in said tap hole with said end thereof facing into said pot means while said surface of said enlarged pool remains below the bottom of said tap hole,
causing reactive gas to flow from said lance means into said pot means above said enlarged pool surface,
causing said enlarged pool surface to rise substantially over the top of said tap hole and said pool to cover said end of said lance means by tilting said furnace forward to effect the solidification of a small portion of said pool as a thin layer covering over the juncture and forming a temporary seal between said tap hole and said lance means and to effect injection of said gas into said pool with stirring thereof,
maintaining said enlarged pool surface in said risen position for a predetermined time to effect a predetermined reaction between said gas and the contents of said enlarged pool,
causing said enlarged pool surface to fall below the bottom of said tap hole by tilting said furnace backward,
discontinuing said flow of gas, and
removing said lance means from said tap hole.

2. The process of claim 1 including the steps of
imparting an oxygen deficiency to said enlarged pool by a reducing action thereon by said carbon electrode means during said melting and pool enlargement, and
providing a reactive gas that is oxidizing with respect to said enlarged pool and that causes said predetermined reaction to be oxidation of said enlarged pool to the point of elimination of said oxygen deficiency.

3. The process of claim 2 wherein said reactive gas is selected from oxygen, air, nitrous oxide, carbon dioxide and mixtures thereof.

4. The process of claim 2 wherein said oxide refractory material consists essentially, analytically by weight, of 25 to 90% ZrO_2, up to 20% SiO_2, up to 4% Na_2O and the balance Al_2O_3 with incidental impurities.

5. The process of claim 2 wherein said oxidic refractory material consists essentially of a mixture of magnesia and chrome ore, said mixture containing, analytically by weight, at least 40% MgO and at least 4% Cr_2O_3.

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