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 **54 Linings for crucible furnaces and transfer vessels and method of applying same.**

 A crucible furnace or molten metal transfer vessel is provided with a composite lining having an outer insulating liner (12) and an inner cast working liner (14). The insulation liner (12) has a high insulating characteristic and the working liner has a high heat-retention characteristic. The working liner (14) may be cast in position against the insulating liner (12) and a removable form (18).

Description

LININGS FOR CRUCIBLE FURNACES AND TRANSFER VESSELS AND METHOD OF APPLYING SAME

The present invention relates to linings for crucible furnaces, holding vessels and transfer vessels used to repetitively handle molten metal and provides an improved composite lining therefor. It also relates to a method for applying a lining to such furnaces and vessels. Linings of the invention also have more general application in for example, the petrochemical and gas transfer industries. In a particular application they can be used as internal linings for ducts adapted to carry media at high temperatures.

In the use of a typical crucible furnace, the metal to be heated is placed in a silicon carbide crucible supported on a pedestal within a furnace which is commonly heated by gas-fired or oil-fired burners acting on the crucible. The furnace has a steel shell with an internal lining. The working inner face (hotface) of the shell lining is subjected to the maximum temperature in the furnace and is spaced from the crucible a predetermined distance. Hence, since the maximum size of crucible for a given furnace is limited by the thickness of the lining, it is desirable to minimize the lining thickness.

In the handling of molten metal, it is advantageous to have a durable lining with the physical ability to withstand the conditions at the hotface for long life while also insulating against heat loss from the vessel. Unfortunately, strong refractory materials generally do not have the heat resistivity required to meet efficient thermal requirements.

In the past, it has been common in the crucible furnace art to use ceramic fibre liner material offering relatively fast installation with no cure-out and good insulation quality. The disadvantages are relatively poor heat retention and resistance to burner erosion, and short life due to poor resistance to metal spills. Various castable refractories have been used having the advantage of being inexpensive but having as disadvantages poor resistance to erosion and metal attack if formulated for a good insulation characteristic, and poor heat retention if formulated for strength. Also, castable refractories have been criticized as being messy and unduly time-consuming to apply and as requiring long cure-outs. Various plastics have also been used to give strong mechanical strength to resist erosion and good resistance to metal wetting, but these too have had relatively poor heat retention and insulation characteristics, have been time-consuming to install, and have involved extensive cure-out schedules.

The present invention is directed at the provision of a lining for furnaces and vessels for holding or handling molten materials which is relatively thin overall to maximize capacity, and which has improved thermal efficiency to the extent of substantially decreasing fuel consumption and shortening the melting period in a crucible furnace. The invention also seeks to provide a lining which is easy and quick to apply, has a long life, and is suitable for lining transfer vessels, such as ladles, crucible furnaces, and ducts adapted to carry media at high temperatures.

The lining of the present invention comprises a first, outer insulating liner selected for its good insulating ability, and a second, dense inner working liner with a durable hotface. The working liner has a high heat-retention characteristic and low insulation value as compared to the insulation liner, and is preferably cast in position. The insulating liner is usually supplied and fitted in board-like form and can have adequate structural strength to support the working liner at high temperatures. Where the second liner is cast in position, the first liner can serve as an outer form complementing a portable removable inner form when the working liner is cast.

The present invention permits the working liner to be selected in terms of density, volume (thickness), K-factor (thermal conductivity), and specific heat to define a heat-retention capability maximizing thermal efficiency. It has been found that, ideally, the heat-retention capability should approximate the heat required to melt the metal being heated in the crucible and raise its temperature to casting temperature after taking into account exterior heat losses via the furnace shell. The composite lining of this invention, by providing a relatively thin, outer insulating liner or layer with a high insulating characteristic between the furnace shell and an inner working liner or layer of high heat-retention ability, makes it possible to obtain the desired heat-retention capability for the working liner without increasing the overall lining thickness. The working liner will normally be substantially thicker, usually several times thicker than the insulating liner, but nevertheless we have found it has been possible in some crucible furnace operations to decrease the overall lining thickness, and therefore increase the furnace capacity, while at the same time decreasing fuel consumption and decreasing the heating period for each cycle of bringing a charge (aluminium, for example) from room temperature to a casting state.

In carrying out the present invention, it is preferred to use a readily castable, water-free refractory material for the working liner, such as the "DRI-VIBE" refractories made by Allied Mineral Products, Inc., Columbus, Ohio. Such includes "DV6-A", which has been used in the practice of this invention for aluminium melting crucible furnaces. This liner material is 60% Al_2O_3 , 38% SiO_2 and 2% TiO_2 , in addition to containing heat-setting sintering mechanisms, and has a density of about 145 pounds per cubic foot (2320 kg/ms). It develops adequate strength after one hour at 800°F (427°C) to initiate use.

For the insulating liner of the composite lining, it is preferred to use a product such as "BARNESBOARD," sold by R A Barnes Inc, Seattle, Washington, which is a fiberboard-type product containing silica (73%-91%), mineral wool or other suitable inorganic fibres (1%-6%), organic fibres (1%-3%), calcium silicate (3%-5%), diatomaceous earth (2%-5%), and binder (2%-8%), such as a suitable phenolic resin (all percentages by

weight). This product has a density in the range of about 40 pounds per cubic foot (640 Kg/ms) and a K-factor of about 0.25 at room temperature, compared to a K-factor of about 10.0 for the "DV60A" refractory material. Typically, the insulation liner is one inch thick and is in sheet or board form, and may have parallel V-grooves extending at regular intervals along its length so that a sheet or board may be readily bent into circular cross-section with the sections between grooves forming chords of the circle. In any event, the insulating liner should preferably have sufficient crushing resistance to support the working liner in all working conditions. 5

The above-identified fiberboard product, preferred for the insulating liner, has an unusually low K-factor through a wide temperature range and also maintains adequate crushing strength through a wide temperature range to support the working liner. For example, a thermal conductivity test, ASTM C-201, indicates that when the hotface of the insulating liner board is 1993°F (1090°C), the coldface is only 202°F (94°C); and a hot crushing test on two-inch cubes of the liner board indicates an average crushing pressure of 27 psi (130 N/m²) at 1000°F (538°C) and 11 psi (53 N/m²) at 2000°F (1093°C) to reach 20% deformation. The cold crushing strength is 225 psi (1077 N/m²). 10

The invention will now be described by way of example and with reference to the accompanying schematic drawings, wherein: 15

Figure 1 is a vertical cross section through the centre of a crucible furnace according to the invention at completion of casting the working liner and before removal of the inner casting form and burner plug; and

Figure 2 is a vertical cross section through the centre of the lined furnace before installation of the burner and crucible.

A typical crucible furnace has a cylindrical shell 10 with a flat closed bottom 10a. The burner(s) extends through a side port 10b in the shell and lining. After the used lining to be replaced is removed and the burner(s) is shifted out of the way, in the practice of the present invention, sections of insulating board are fitted around the inside of the cylindrical side wall and over the round bottom wall of the furnace shell to provide an insulating liner 12. Dry refractory material 14 for the working liner is then poured into the shell to a desired height from the bottom circular insulation liner portion and hand-tamped and de-aired to get a smooth, compact, level surface. Preferably, a vent hold is provided in the bottom by using a ceramic tube, wooden dowel or other suitable core. A plug 16 is also provided for each burner port. Then a cylindrical steel form 18 is lowered into the shell, onto the bottom layer of refractory material, and its outer face engages the end of the burner port plug(s) 16, which is correspondingly shaped. Refractory material 14 is then poured between the steel form and the surrounding insulating liner 12, which then also functions as a form, 20 25 30

The next step is to vibrate the steel form 18 as by mounting a portable vibrating machine 20 on a rod 22 extending diametrically across the top of the form. Following this step, the refractory 14 is heated for at least one hour at 800°F (427°C) as by an heating torch set in the steel form, whereupon the form is cooled and lifted out of the furnace. Removal of the burner plug 16 completes the lining operation.

The theoretical heat requirements for a well-designed 450-lb (200 Kgs) , gas-fired, aluminium-melt crucible furnace having a crucible and pedestal weight of 250 lbs (114 Kgs) and a steel shell weight of 500 lbs (225 Kgs) is as follows using the composite liner materials previously discussed and assuming a one-inch (2.54 cms) thick insulating layer and a five-inch (12.7 cms) thick working layer in a furnace having an inside diameter of 42 inches (107 cms) and an inside height of 39 inches (100 cms): 35 40

K-factor for insulating liner 0.33

K-factor for working liner 9.80

$$R = \frac{\text{thickness}}{K}$$

$$R = \frac{1}{0.33} + \frac{5}{9.8} = 3.5$$

Heat loss at 220°F = 377 BTUH/ft³ (1.4x10⁶ J/m³)

Coldface area = 45.4 ft² (4.21m²)

Heat loss through lining = 17,124 BTUH (18x10⁶J)

Volume of working liner = 14.14 ft³ (0.4m³)

Density of DV60A = 145 lb/ft³ (2320 kg/m³)

Weight of working liner = 2050 lbs (930 kg)

Mean temperature of working liner at casting temperature of Al = 1020°F (549°C)

Coldface of working liner = 530°F (277°C)

Specific heat of working liner = 0.258 BTU/lb (600J/Kg)

Heat retention (working liner) (205) (1020) (0.258) = 539,478 BTUH (569x10⁶J)

A typical, current, 6-inch (15.25 cms) thick lining system for such a furnace would have the top 20 inches (51 cms) of the 39-inch (100 cms) height as a ceramic fibre working layer to a thickness of 3 inches (7.6 cms), and would have the remaining 3 inches (7.6 cms) outside of the ceramic fibre and the 6 inches (15.25 cms) of lining below the ceramic fibre as a castable, dense refractory having, for example, a specific weight of 130 lb/ft³ (2080 kg/m³) and a K-factor of 4.0 at 1000°F (528°C) mean temperature. Calculation will show a heat loss of 7600 BTUH (8x10⁶J) and heat retention of only 128,466 BTUH (13.5 x 10⁶J) as compared to the 539,478 BTUH (569x10⁶J) heat retention of the composite lining of this invention for the same furnace.

A typical start-up of a crucible furnace with a composite liner of the present invention to achieve a first heat will typically take about twice as long as for subsequent heats. By use of the composite lining of the present invention, the heat-retention ability of the lining can be selected to shorten the melt period. Since there is a maximum rate at which the metal charge being melted in the crucible will absorb heat, there is little advantage in having a surplus of heat-retention ability in the working liner. In fact, too much surplus can result in breakage of the crucible. Accordingly, it has been discovered that it is preferable to make the heat-retention ability of the working lining approximately equal to the heat required to melt the charge and raise to casting temperature. This heat requirement can be readily calculated for a given weight of metal being melted since the specific heat, melting temperature, heat of fusion, and casting temperature will be known. Hence, the composite lining of the present invention can be readily engineered to provide the preferred heat retention to the lining.

Although the foregoing discussion has been directed to crucible furnaces, the composite lining of the invention is of value for holding vessels and molten metal transfer vessels such as ladles. Because of the increased heat retention by the lining, the tap temperature of the molten metal at the melt furnace can be lower at the start of the transfer operation than otherwise, thus saving energy and wear on the furnace, reducing

oxidation of the molten metal, and allowing for more consistent temperatures in the casting operations. Furthermore, the lining in the ladle will last significantly longer than before. In this regard, a thin, third liner layer can be applied to the working liner as a wear surface to be replenished to increase the life of the rest of the liner.

Linings of the invention also have general application where media at high temperatures is to be handled. As noted above, a duct adapted to carry such media can usefully be provided with the lining described.

Claims

1. A lining for surfaces adapted to handle media at high temperatures
CHARACTERISED IN THAT
the lining comprises a first liner (12) covering said internal surface, and a second liner (14), inside the first liner (12), the first liner 12 having an high insulating characteristic and a low heat-retention characteristic relative to the second liner (14), and the second liner (14) comprising a dense refractory material having an high heat-retention characteristic and a low insulating characteristic relative to the first liner (12).
2. A lining according to Claim 1 CHARACTERISED IN THAT the thickness of the second liner (14) is greater than that of the first layer (12).
3. A lining according to Claim 1 or Claim 2 CHARACTERISED IN THAT the first liner (12) comprises sections partially separated from one another by inwardly facing grooves which are substantially parallel to the axis of the shell (10).
4. A lining according to any preceding Claim CHARACTERISED IN THAT the first liner (12) comprises sections of dry insulating board.
5. A lining according to any preceding Claim CHARACTERISED IN THAT the second liner (14) is supported by the first liner (12).
6. A lining according to any preceding Claim CHARACTERISED IN THAT the second liner (14) is a monolithic casting having the first liner (12) as a permanent form therefor.
7. A lining according to any of Claims 1 to 5 CHARACTERISED IN THAT the second liner (14) is a monolithic casting and the first liner (12) is not a casting.
8. A lining according to any preceding Claim CHARACTERISED IN THAT the first liner (12) contains silica and mineral wool, is self-supporting and is not a casting.
9. A lining according to any preceding Claim CHARACTERISED IN THAT the thermal resistivity of the first liner (12) is more than ten times that of the second liner (14).
10. A furnace comprising a shell (10) having a bottom wall (10a) with a burner port (10b) in a side wall and a lining on the internal surface of the side and bottom walls
CHARACTERISED IN THAT
the lining comprises a lining according to any preceding Claim.
11. A furnace according to Claim 10 CHARACTERISED IN THAT a crucible is supported in a space surrounded by the second liner (14) and spaced therefrom.
12. A duct adapted to carry media at high temperatures CHARACTERISED BY having an internal lining according to any of Claims 1 to 7.
13. A vessel for the thermally efficient handling of molten material, comprising a rigid outer shell (10) with an internal lining
CHARACTERISED IN THAT
the lining comprises a lining according to any of Claims 1 to 9.
14. A method of lining a vessel having a substantially tubular shell (10),
CHARACTERISED BY the steps of:
covering the inside of the vessel with a dry first liner (12) having an high insulating characteristic;
inserting a form (18) through the open top of the vessel, which is spaced inwardly from the first liner (12);
filling the space between the first liner (12) and the form (18) with a castable liner material which becomes monolithic and has a high heat-retention characteristic when heated to a predetermined setting temperature for a predetermined time period;
heating the form (18) to said temperature for said time period to form a second liner (14) from the liner material which has an high retention characteristic; and
removing said form (18).
15. A method according to Claim 14 CHARACTERISED IN THAT the first liner (12) has sufficient structural strength to support the second liner (14) through a wide temperature range above said setting temperature.
16. A method according to Claim 14 or Claim 15 CHARACTERISED IN THAT the form (18) is vibrated before being heated to compact the liner material.
17. A method according to any of Claims 12 to 14 wherein the vessel has a closed bottom (10a)
CHARACTERISED IN THAT the closed bottom (10a) of the vessel is covered with a layer of the castable liner material after being covered with the first liner (12) and before the form (18) is inserted so that the form rests on said layer when inserted.
18. A method according to any of Claim 14 to 17 in which the vessel is a furnace and has a side port (10b)

for a burner, CHARACTERISED IN THAT a removable plug (16) covering the port and extending inwardly from the port to the location of the from (18) is inserted before the castable liner material is placed in the vessel to the level of the port, the plug being removed after the second liner (14) is formed.

5 19. A method according to any of Claims 14 to 18 CHARACTERISED IN THAT the castable liner material is a dry, granular material when placed in the vessel.

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FIG.1

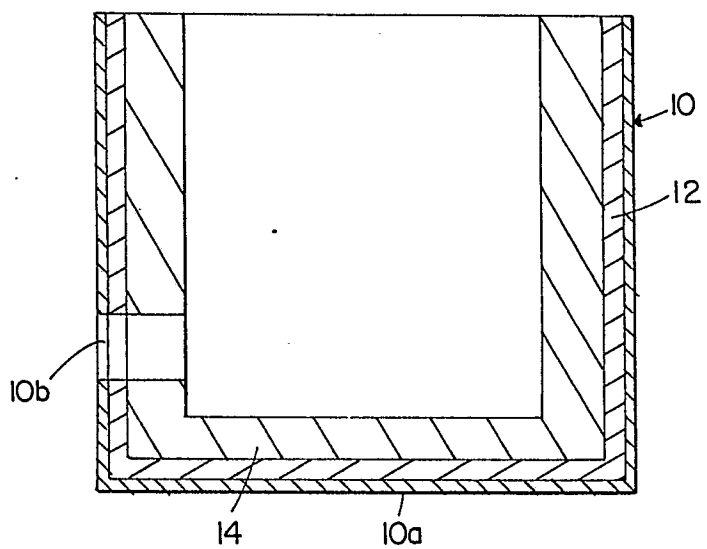
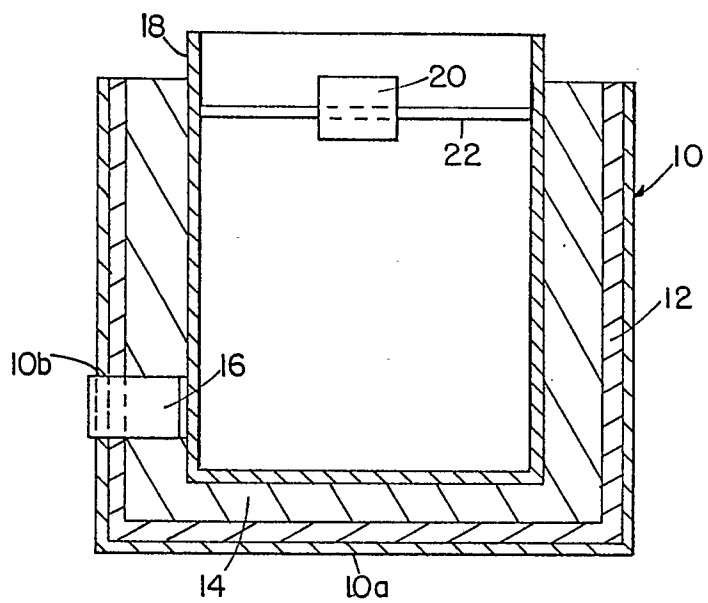


FIG.2