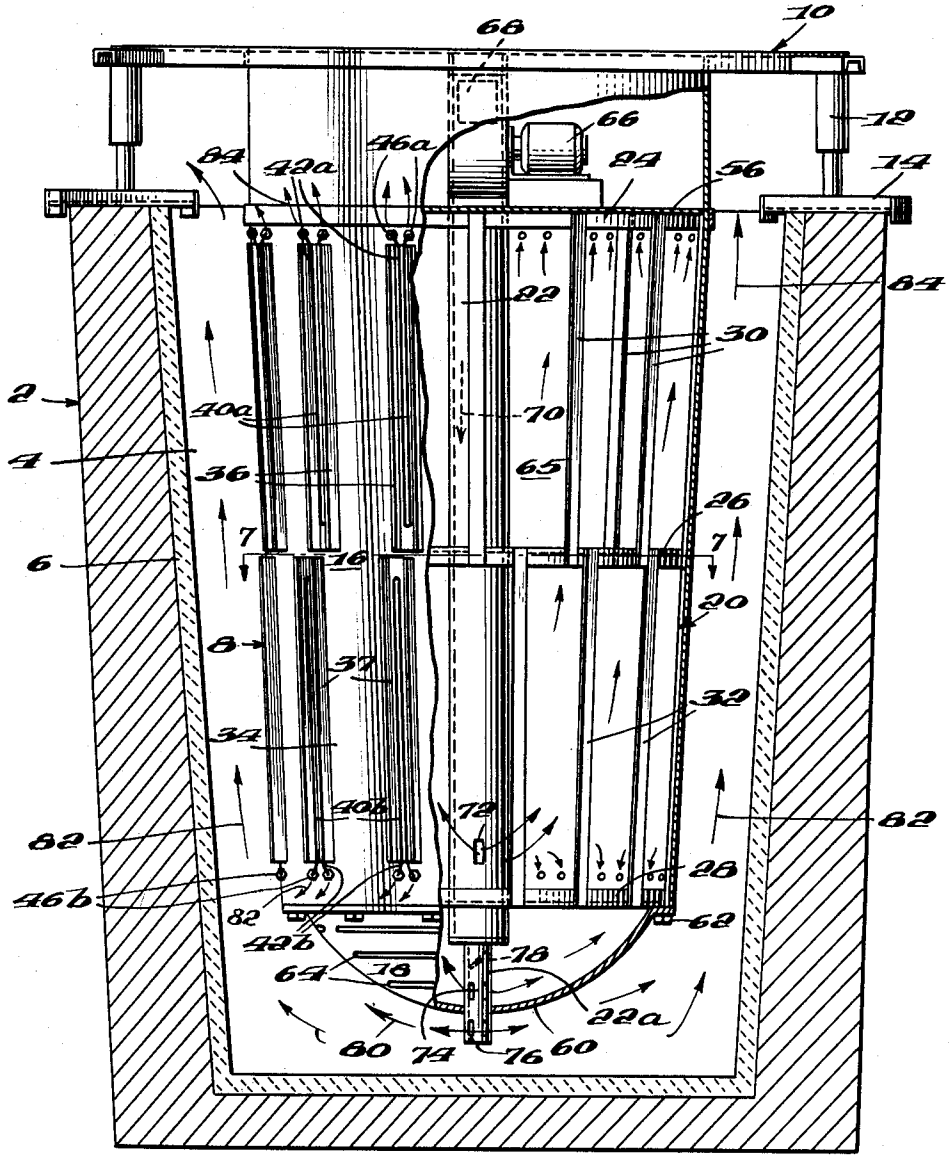
Sept. 8, 1964 D. A. AITKEN ET AL 3,148,272

APPLICATOR FOR HEAT TREATING REFRACTORY LININGS OF LADLES

Filed Oct. 23, 1962 4 Sheets-Sheet 1

Fig. 1.



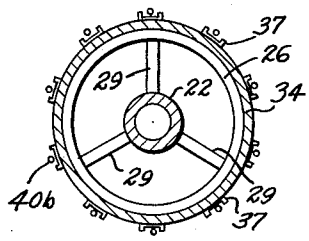


Fig. 7.

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APPLICATOR FOR HEAT TREATING REFRACTORY LININGS OF LADLES

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4 Sheets-Sheet 2

Fig. 2.

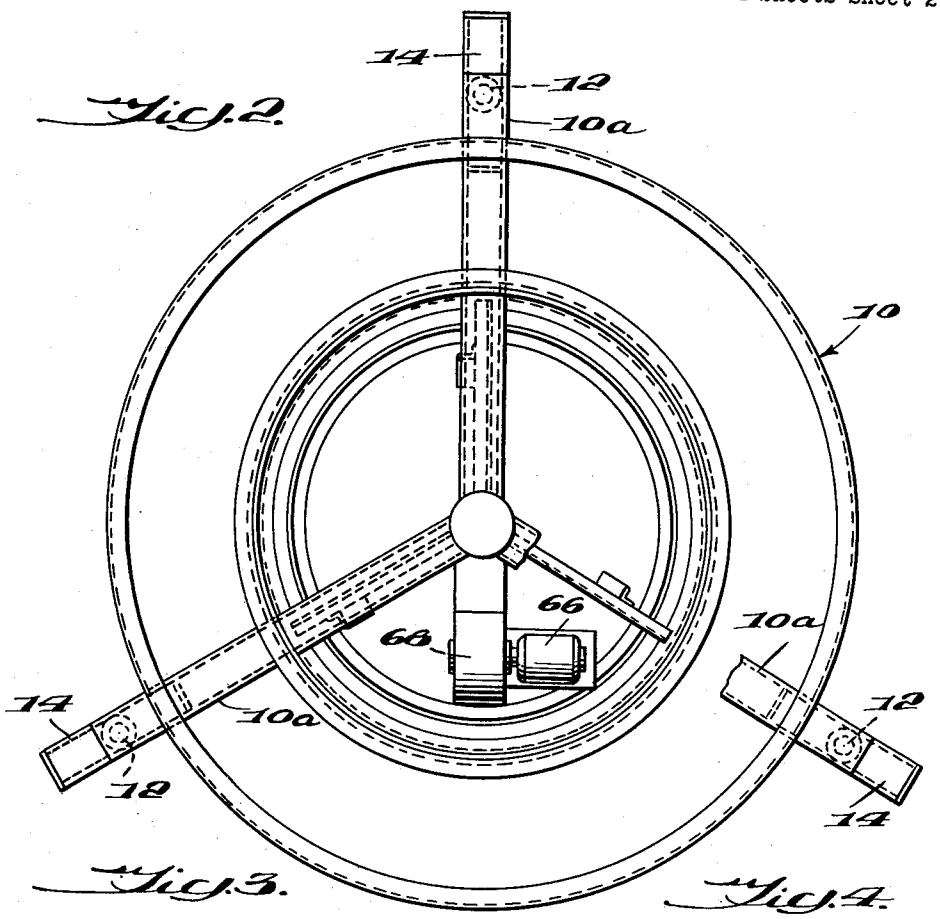


Fig. 3.

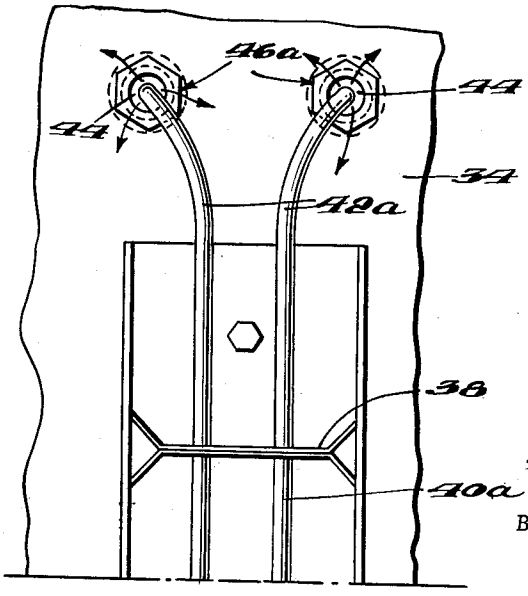
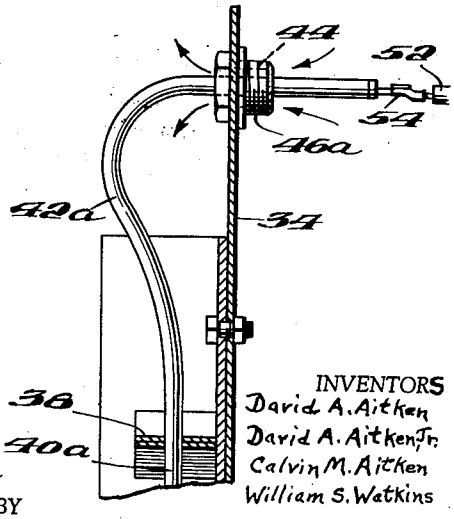


Fig. 4.



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APPLICATOR FOR HEAT TREATING REFRACTORY LININGS OF LADLES

Filed Oct. 23, 1962 4 Sheets-Sheet 3

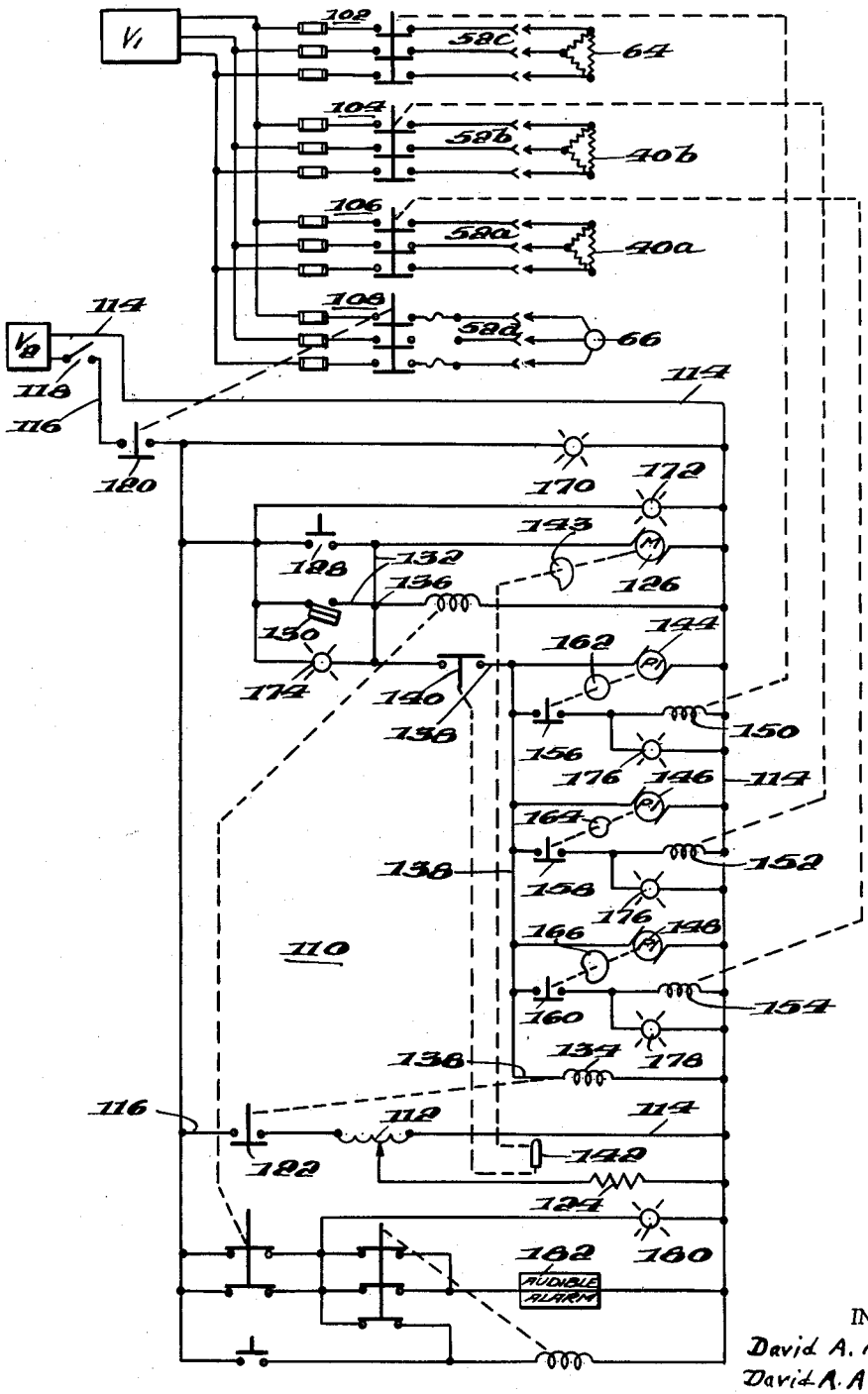


Fig. 5.

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Filed Oct. 23, 1962

4 Sheets-Sheet 4

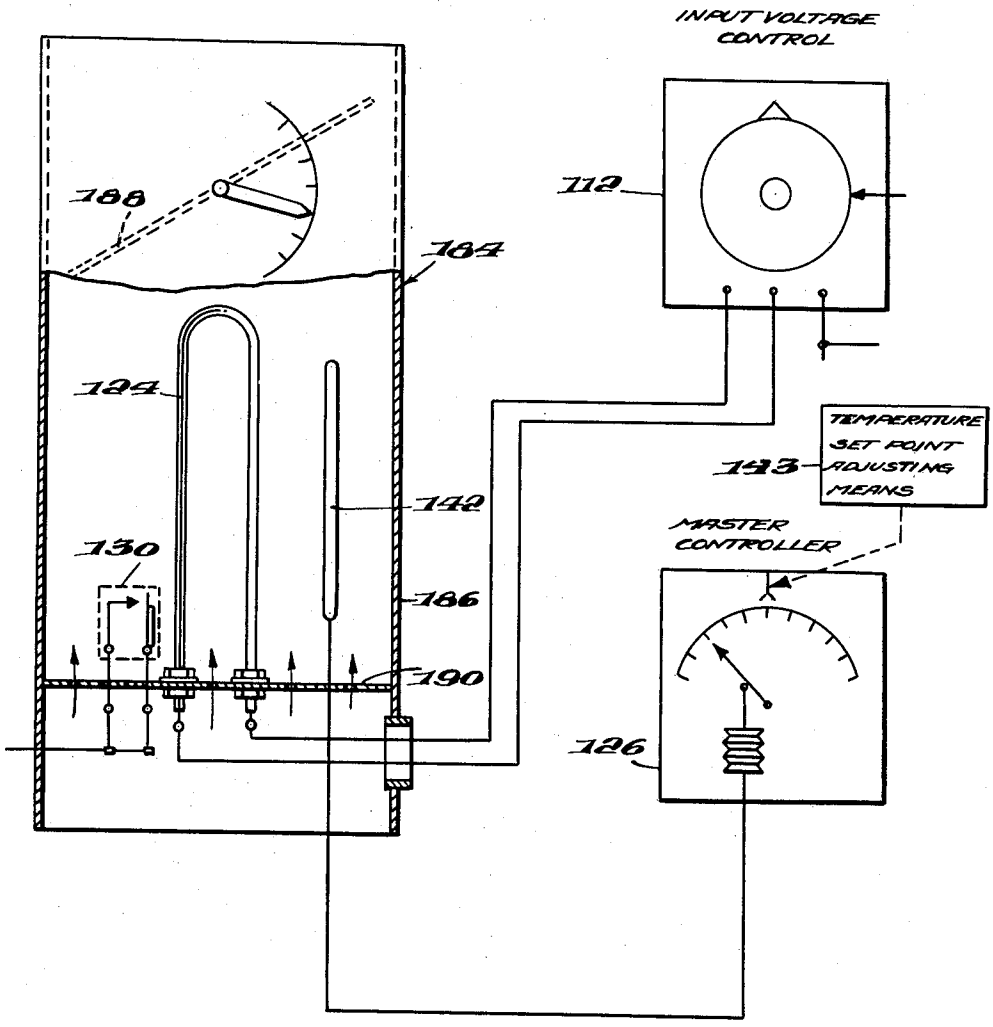


Fig. 6.

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3,148,272

APPLICATOR FOR HEAT TREATING REFRACTORY LININGS OF LADLES

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Filed Oct. 23, 1962, Ser. No. 232,479
14 Claims. (Cl. 219—537)

This invention relates to an improved apparatus for heat treating the refractory linings of large capacity hot-metal ladles.

In steel mills and other industries, it is conventional to use hot-metal ladles for handling molten metal. These ladles include a steel and cast iron shell containing a cavity that is lined with a layer of refractory material, such as firebrick, that is capable of withstanding the heat of the molten metal. At frequent intervals this lining must be renewed, and it is necessary to dry or "cure" the new lining by the uniform application of heat thereto. The various methods and apparatus proposed in the past for heat treating the refractory lining have proved to be dangerous and difficult to control and have not afforded sufficiently uniform curing, particularly when the ladles are of the size of 55 ton blast-furnace ladles. Furthermore, fuel burning heat applicators are inherently dangerous to operating personnel and often cause damage to the refractory linings. The present invention was developed to avoid the drawbacks of the devices of the prior art and to provide a heat treating apparatus of the electrically-energized radiant heat type which is easily controlled to afford uniform heating, is clean in operation, and which eliminates the danger of fire, burning of the lining, smoke inhalation and explosions.

One object of the present invention is to provide a radiant heat applicator that is adapted to be supported in—and spaced from the refractory lining surfaces of—the ladle cavity. The applicator includes a housing that generally conforms with the cavity configuration and supports, on its peripheral surfaces, a plurality of electrical heating elements adjacent the side wall and bottom surfaces of the cavity. The housing includes a chamber that contains a harness of electrical conductors which supply energy to the heating elements. The heating elements have non-heating end portions that extend into the chamber through openings in the housing wall and are connected with the harness conductors by means of conventional terminal connectors.

In the heat treatment of refractory linings it is desirable to provide pressure fluid means for expelling from the ladle cavity the moisture-laden air that is evaporated from the lining during the drying process. Furthermore, the heating temperatures adjacent the external surfaces of the applicator often rise to such high values as to cause physical damage to the heating element leads, the terminal connectors, and the adjacent portions of the harness conductors connected thereto.

Accordingly, a more specific object of the invention is to provide an applicator including a generally imperforate housing containing a chamber and including oversized openings through which the non-heating end portions of at least some of the heating elements extend for connection with the harness conductors by terminal connectors

within the housing chamber, said applicator further including means for introducing a gaseous cooling fluid under pressure into said chamber whereby said fluid flows outwardly through said oversized openings to cool the terminal connectors and the non-heating portions of the heating elements connected thereto. This pressure fluid then expels the moisture-laden heated air from the ladle cavity.

In order to permit simple external replacement of a defective heating element, in accordance with another feature of the invention the cross-sectional dimensions of the terminal connectors and the portion of the harness conductors connected thereto are smaller than the corresponding opening dimensions. Consequently, assuming that appropriate slack is provided in the harness conductors, when the heating element end portions, the terminal connectors and the adjacent portions of the harness conductors are withdrawn from the housing chamber via the oversized openings, the defective heating element may be mechanically and electrically disconnected from the applicator and replaced by another, whereupon the heating element ends, the terminal connectors and the conductors connected thereto are again inserted into the chamber via the oversized openings.

The applicator housing includes a tubular body section and a dish-shaped end section removably connected with said body section, said end section being adapted to be positioned adjacent the bottom of the ladle cavity. The means for introducing cooling fluid into the housing chamber include a pipe or conduit that extends axially through the chamber and extends at one end axially outwardly through a corresponding opening in said end section. Blower means introduce atmospheric air into the other end of the pipe and into the housing chamber via apertures in the pipe. In order to purge moisture-laden air from the bottom of the ladle cavity, the free end of the pipe that extends through the end section also is provided with apertures through which air is expelled from the pipe. Heating elements supported upon the outer surface of the end section are electrically connected with harness conductors in the housing chamber. The harness conductors are provided with sufficient slack to permit disconnection and removal of the end section from the tubular section.

The refractory linings generally have a thickness of approximately 8 to 12 inches. While it is always desirable to heat treat the lining as quickly as possible to get the ladle back into operation, it is necessary to control the rate of heat application so that drying is not too rapid. For example, the application of too much heat early in the drying cycle may form a skin on the surface of the lining which will interfere with the release of moisture from deeper areas. Accordingly, another object of the invention is to provide a heat applicator including programmed control means for automatically controlling the rate at which heat is supplied by the heating elements in accordance with changes in the ladle conditions. Use is made of analog computer means remote from the ladle cavity to simulate the drying conditions in the ladle and to control the heating rates of the various heating elements. In order to obtain differential heat treatment of various zones of the refractory lining, a plurality of preselected groups of the heating elements may be operated in different programmed manners. The heating element groups

may be axially spaced relative to the applicator housing for zoned heat treatment, or, under certain circumstances, the heating elements of one group may be circumferentially arranged on the housing in interspersed relationship with the heating elements of another group.

Other objects and advantages of the invention will become apparent from a study of the following specification when considered in conjunction with the accompanying drawing, in which:

FIG. 1 is a side elevation view, with certain parts broken away, of the applicator mounted within a ladle cavity having a refractory lining that is to be heat treated;

FIG. 2 is a plan view of the applicator with certain parts removed;

FIGS. 3 and 4 are detailed views of the means by which the non-heating end portions of the heater elements extend through oversize openings in the applicator shell;

FIG. 5 is a schematic diagram of an electrical analog computer system affording multizone control over groups of the heater elements of FIG. 1;

FIG. 6 is a generally diagrammatic representation of the miniature oven of the analog computer control; and

FIG. 7 is a sectional view taken on line 7—7 of FIG. 1.

Referring more particularly to FIG. 1, the steel and cast iron ladle 2 contains a cavity 4 lined with a layer 6 of refractory material (for example, fire brick) that is to be heat treated. Heat applicator 8, having a generally inverted truncated conical configuration, is adapted to be supported within ladle cavity 4 by means of top ring assemblage 10 which includes a plurality of legs 12 the lower ends of which are connected with saddles 14 that rest upon the upper edge of the ladle. Preferably, legs 12 are adjustable in length to permit positioning of the applicator at a desired depth in the ladle and spaced from the cavity walls thereof.

Applicator 8 consists of detachable upper and lower sections 16 and 18, respectively. Upper section 16 includes a rigid frame 20 of generally squirrel cage configuration that consists of a vertical pipe 22 secured at its upper end to radial elements 10*a* of top ring assemblage 10, axially spaced annular rings 24, 26 and 28 that are secured to pipe 22 by radial angle iron elements 29 (FIG. 7), and peripherally-arranged longitudinal angle iron elements 30 and 32 the ends of which are secured to rings 24 and 26 and rings 26 and 28, respectively. In the illustrated embodiment, the frame tapers inwardly in the direction of its lower end to conform with the cavity configuration. Secured to the outer periphery of frame 20 is a light gauge covering sheet or "skin" 34 of a heat reflecting material, such as aluminum.

Connected with the outer surface sheet 34 are two groups of longitudinally arranged, circumferentially spaced U-shaped reflectors 36 and 37 each having flanges which extend radially outward from the applicator. The reflectors are formed of a reflecting material such as aluminum. Mounted between the flanges of each reflector by transverse support means 38 (FIG. 3) are U-shaped infra-red heating elements 40 having non-heating end portions 42. As shown in FIGS. 3 and 4, the non-heating ends 42*a* of the heating elements 40*a* associated with reflectors 36 extend upwardly from the reflectors and pass through oversize bores 44 in upper sleeve fittings 46*a* which extend through—and are rigidly mounted in—openings in sheet 34. The free ends of end portions 42*a* are connected with wiring harness conductors 52 in the applicator by terminal connectors 54. It is important to note that the diameter of each bore 44 is considerably larger than the outer diameters of element end 42*a* and conductor 52 and the transverse dimension of terminal 54. With appropriate slack in the harness conductors, each element end 42*a*, terminal 54 and the adjacent end of conductor 52 may be withdrawn from the applicator through the corresponding fitting bore 44 for ready replacement of a defective heating element. As will be described below, the oversize bores also permit the flow of cooling air radially outward from the applicator across terminals 54 and the portions of the conductors connected thereto.

Similarly, non-heating end portions 42*b* of the heating elements 40*b* associated with the lower group of reflectors 37 extend downwardly from the reflectors and pass through oversize bores in lower fittings 46*b* mounted in openings in applicator sheet 34. Sheet 56 mounted on the upper end of ring 24 extends transversely across the applicator and contains a central opening receiving pipe 22.

Lower applicator section 18 includes a dish-shaped support 60 that is removably connected with lower ring 28 of frame 20 by bolts 62. Support 60 contains a central aperture that receives tubular axial extension 22*a* of pipe 22. Heating elements 64 rigidly secured to the outer surface of dish 60 have non-heating end portions (not shown) which extend through conventional openings in the dish for connection with harness conductors, not shown. As distinguished from the oversized bores 44 in fittings 46, the dimensions of the dish openings conform with the dimensions of the sheaths of elements 64. The heavy gauge dish serves both as a support and a reflector for heating elements 64. Dish 60, sheet 56 and cover sheet 34 thus define a chamber 65 within the applicator housing.

Mounted in the upper end of pipe 22 are blower means that are driven by blower motor 66. The blower draws atmospheric air into pipe 22 via opening 68 and forces it downwardly as shown by arrow 70. The air is emitted from pipe 22 through axially-spaced openings 72 and 74 within applicator chamber 65, and openings 76 in the portion of extension 22*a* that extends below dish 60. Adjustable baffle 78 arranged transversely in pipe extension 22*a* intermediate openings 72 and 74 controls the quantity of air emitted through openings 74 and 76. The lower extremity of extension 22*a* is closed by a transverse end wall.

In operation, the applicator is mounted within the ladle as shown in FIG. 1 and electrical power is supplied to heating elements 40*a*, 40*b* and 64 to apply radiant heat to refractory lining 6. Blower motor 66 is energized to force atmospheric air downwardly through pipe 22. A portion of this air is emitted through openings 76 and serves to "purge" (i.e., force out) the moist air that might otherwise be confined in the bottom of the ladle cavity. This purged air is forced upwardly around the applicator and out of the ladle cavity as shown by the flow arrows 80. The quantity and temperature of the bottom purging air may be varied by appropriate adjustment of baffle 78. Furthermore, it should be noted that if baffle 78 should be completely closed, air within the applicator chamber will flow into the bottom of the ladle cavity via openings 74, extension 22*a* and openings 76. A portion of the air introduced into the applicator chamber via pipe openings 72 and 74 flows outwardly through the oversize bores of lower fittings 46*b* as shown by the arrows 82, and the remaining portion of this air within the applicator flows upwardly in a turbulent manner and is emitted through the oversize bores of upper fittings 46*a* as shown by the arrows 84. It is important to note that as the air in the applicator chamber flows outwardly through the oversize bores of fittings 46*a* and 46*b*, it flows across harness wires 52, terminal connectors 54, and element end portions 42*a* and 42*b* and thereby prevents the terminal connectors, and the adjacent portions of the insulated conductors connected thereto, from being heated to harmful, damaging high temperatures. Furthermore, this cooling air in the applicator chamber sweeps across the inner surfaces of peripheral sheet 34 and carries the heat from the wiring harness, terminals and heating element leads out into the ladle cavity. The air streams 82 and 84 entrain or displace the moist air evaporated from refractory lining 6 and force it upwardly out of the ladle.

An important feature of the applicator is the ease of external replacement of a defective heater element without disassembly of the sections **16** and **18**. As indicated above, by gently pulling the exposed portions of heater ends **42**, the terminal connectors **54** and adjacent ends of harness conductors **52** may be withdrawn through fitting oversize bores **44**. The leads **54** are disconnected from the terminal conductors, the defective heater **40** element is replaced, the end portions of the new element are connected to the terminal connectors, and the terminal connectors and the adjacent portions of element ends **42** are again inserted into the applicator chamber via oversize bores **44**.

In accordance with the invention, differential heating of various zones of the ladle cavity may be obtained by appropriate programmed control over preselected groups of the heating elements. Referring now to FIG. 5, voltage source V_1 (which may comprise, for example, a source of 3-phase, 25 cycle, 440 volt energy) is connected with delta-connected groups of heater elements **40***a*, **40***b* and **64**, respectively, and with blower motor **66** by wiring means including conductor groups **52***a*, **52***b*, **52***c* and **52***d*, respectively. Normally-open solenoid-controlled multiple-contact switches **102**, **104** and **106** control the flow of current to loads **64**, **40***b* and **40***a*, respectively. Manual switch **108** serves to start the blower and to energize the control circuit. In accordance with the present invention, an analog computer system **110**, which simulates the actual heating effect produced in the ladle cavity by applicator **8**, controls the operation of switches **102**, **104** and **106** in a predetermined programmed manner. The analog computer system includes a voltage source V_2 (for example, a source of 25 cycle 110 volt energy) one terminal of which is connected with one end of adjustable tap analog input voltage control transformer **112** via conductor **114**. The other terminal of source V_2 is connected with the other end of transformer **112** by means of conductor **116** which includes on-off switch **118**, auxiliary contact **120** of switch **108**, and the normally-open contacts of solenoid-controlled switch **122**. Analog control heater **124** is connected at one end with the adjustable tap of transformer **112** and at the other end with conductor **114**.

One terminal of master program drive motor **126** is connected with conductor **116** via start switch **128** and the other terminal is connected with conductor **114**. Analog thermostat switch **130** is connected in parallel with start switch **128** by conductor **132**. One end of the control relay **134** of switch **122** is connected with conductor **114**, and the other end is connected with conductor **132** at junction **136** by conductor **138** that includes the contacts of master controller switch **140**. Switch **140** is mechanically operated by temperature responsive capillary tube means including a temperature-sensing bulb **142** that is arranged in close proximity to analog control heater **124**. As will be hereinafter described, the temperature set point of capillary tube **142** is continuously adjusted by cam **143** that is driven by master program drive motor **126**.

Percent-input control motors **144**, **146** and **148** are connected between conductors **114** and **138** in parallel with solenoid winding **134**. Solenoid windings **150**, **152** and **154**, which control the operation of switches **102**, **104** and **106**, respectively, are also connected between conductors **114** and **138** by conductor means including switches **156**, **158** and **160**, respectively. Switches **156**, **158** and **160** are operable by adjustable cams **162**, **164** and **166** that are driven by motors **144**, **146** and **148**, respectively. These cams rotate at approximately 1 R.P.M. so that the adjustment can be used to vary the "on" time of each zone over a range from 0% to 100% of each minute. The analog computer control includes additional system refinements—such as the indicator and alarm lights **170**, **172**, **174**, **176**, **178** and **180** and the audible alarm **182**—which afford an indication of the state of operation of the various circuits and elements. The operation of the various indicating and alarm systems is obvious and hence will not be described.

Referring now to FIG. 6, the analog computer control includes a miniature "oven" **184** which is physically arranged in a control panel remote from the applicator and ladle. The miniature oven contains the various elements which simulate the heat treating and drying conditions of the ladle lining. The oven includes a tubular wall **186** which is open at each end for the conduction of convection air. The rate of flow of the convection air is adjusted by damper means **188** that are pivotally mounted in the upper end of the oven. Mounted in the oven upon perforated transverse support **190** are the analog heater **124**, analog heater thermostat **130**, and capillary tube temperature sensing element **142**. If desired, protective screen means, not shown, may be placed across the upper and lower ends of the oven wall.

While ultimate control over the applicator heating elements would be obtained with the use of condition-sensing transducer means mounted in the ladle cavity for indicating that a desired temperature and/or moisture condition has been obtained, in actual practice such a control would be impractical. Owing to characteristics of radiant heat, the use of a temperature detector imbedded in the refractory material would be required to give a valid indication, and even then it would be correct only for that precise point. Also, the moisture, heat and rough handling inherent in the operation would be abusive to sensors located in the vicinity of the heat applicator. Therefore, it has proved to be more practical, and sufficiently accurate to make use of the temperature responsive element **142** in the analog computer oven for simulating the ladle heat treating conditions. By appropriate adjustment of the various analog computer parameters, the output of the analog heater will be a function of the output of the applicator-heating elements. Consequently, variations in line voltage and ambient temperature may be compensated for by the analog oven.

Assume that damper **188** and the adjustable tap of transformer **112** have been set to positions which cause the temperature of analog computer heater **124** to simulate the heat treating conditions that occur in the ladle cavity, that cam **143** has been cut to estabilsh the desired heating program and is set to the start of rise for a given cycle, and that cam **143** adjusts the temperature set point of bulb **142** between 150° and 250° F. in a predetermined programmed manner. Assume further that cams **162**, **164** and **166** are so adjusted that for each revolution of the respective cams, switches **156**, **158** and **160** are maintained closed 90, 80 and 70 percent of the time, respectively.

Manual closing of switch **108** effects energization of blower motor **66** and closing of contact **120**. Manual switch **118** is closed to activate the analog computer control. When start switch **128** is closed manually, drive motor **126** is energized to initiate driving of program control cam **143**. Switch **140**, which is initially maintained closed by the temperature responsive capillary tube means **142**, permits energization of precent-input motors **144**, **146** and **148** and driving thereby of cams **162**, **164** and **166**, respectively. These cams cause closing of switches **156**, **158** and **160**, energization of solenoids **150**, **152** and **154**, and closing of switches **102**, **104** and **106**, respectively, for cam rotation periods of 90%, 80% and 70%, respectively. Consequently, assuming that cams **162**, **164** and **166** are driven at the same speed, during a given period of time, heater elements **64**, **40***b* and **40***a* will be energized 90%, 80% and 70 %of the time, respectively, to effect differential heating of distinct zones in the ladle cavity. Relay **134** is energized simultaneously with motors **144**, **146** and **148** and closes switch **122** to energize analog control heater **124** via transformer **112**. Start switch **128** must be held in the closed position until ther-

mostat switch 130 is closed by the heat generated by analog control heater 124 and shorts out switch 128.

If the temperature of analog computer heater 124 should rise to the initial set point temperature of bulb 142 (150° F.), master controller switch 140 is opened to de-energize solenoid windings 134, 150, 152 and 154 whereby switches 122, 102, 104 and 106 are opened to de-energize heaters 124, 64, 40*b* and 40*a*, respectively. However, during the various heat treating phases, the set point temperature of bulb 142 is progressively increased, in accordance with the program configuration of cam 143, to effect the desired heat treatment of the refractory lining. Consequently, the temperature in the ladle being treated and time of opening of main controller switch 140 by capillary tube 142 is dependent upon the configuration and rotational position of cam 143, and upon thermal conditions in the analog oven. Switch 140 will open and close at various times as the heat in the miniature oven reaches the value called for by the cam 143. After the predetermined time required for the full heating cycle has elapsed, the cam will have progressed to the point where its configuration calls for heat shut-off, at which point the process has been completed.

The temperature of analog heater 124 is a function of the rate of flow of convection air through the analog computer oven 184 as determined by the setting of damper 188. Furthermore, the heating temperature of heater 124 is determined by the setting of transformer 112. Consequently, the settings of damper 188 and transformer 112 may be varied as desired to simulate the heat treating conditions in the ladle. Adjustment of cams 162, 164 and 166 controls the duty cycles of heater elements 64, 40*b* and 40*a*, respectively.

If, for any reason, analog heater 124 should fail to heat, thermostat 130 will open to shut off all heat and to actuate an alarm.

The invention makes possible the drying of a succession of ladle linings at a high rate of speed. Experimental use of the invention has produced linings which greatly outlast linings dried by known methods and apparatus.

While in accordance with the provisions of the patent statutes we have illustrated and described the preferred embodiment of the invention, it will be apparent to those skilled in the art that certain modifications in and embodiments of the disclosed apparatus may be made without deviating from the invention set forth in the following claims.

What is claimed is:

1. Apparatus for heat treating the wall surfaces of a cavity, comprising

an applicator housing adapted to be mounted in and spaced from the walls of said cavity, said housing having substantially imperforate walls defining a chamber;

a first group of electrical heating elements mounted externally on said housing and having non-heating end portions extending into said chamber through openings in said housing walls, the dimensions of said openings being greater than the corresponding cross-sectional dimensions of said heating element end portions;

means in said chamber for supplying electrical energy to said heating elements;

and means for introducing a gaseous cooling fluid under pressure into said chamber, whereby said cooling fluid is forced out of said chamber through said openings to cool the end portions of said heating elements and to force the heated fluid surrounding said housing out of said cavity.

2. Apparatus as defined in claim 1 wherein said energy supplying means includes a harness conductor within said chamber, and a terminal connector electrically connecting said harness conductor with the end portion of one of said heating elements, said terminal connector and said harness conductor having smaller cross-sectional dimensions than the corresponding dimensions of said opening and said harness conductor being provided with sufficient slack to permit withdrawal of said terminal connector and the adjacent end of said harness conductor from said chamber through said opening.

3. Apparatus as defined in claim 1 wherein said means for introducing a gaseous cooling fluid consists of a conduit, and said housing comprises a rigid skeletonized frame of generally squirrel cage configuration including a plurality of colinearly-arranged axially-spaced rings, a plurality of peripherally arranged longitudinal elements connected with said rings, and radial elements connecting said rings with said conduit; a sheet of heat reflecting material connected with and surrounding the longitudinal peripheral surface of said frame; and end members connected with opposite ends of said frame and cooperating with said sheet to define said housing chamber, the opposite end portions of said conduit extending axially from said housing through openings in said end members.

4. Apparatus as defined in claim 3 wherein said means for introducing gaseous cooling fluid into said chamber comprises blower means communicating with one end of said conduit external of said housing for introducing atmospheric air into said conduit, said conduit containing first openings within said chamber for the introduction of atmospheric air thereto.

5. Apparatus as defined in claim 4 wherein the portion of the other end of said conduit that extends outside said housing contains second openings for introducing air directly into said cavity.

6. Apparatus as defined in claim 5 wherein said conduit includes third openings in said chamber intermediate said first and second openings, and further including baffle means in said conduit intermediate said first and third openings.

7. Apparatus as defined in claim 5 wherein the end member associated with said other end of said conduit is removably connected with said frame and supports a second group of said heating elements on the external surface thereof, said first group of heating elements being supported on the external surface of said sheet of heat reflecting material.

8. Apparatus as defined in claim 7 wherein said means supplying electrical energy to said heating elements include control means for regulating the energy supplied to the respective groups of heating elements to effect programmed differential heating of predetermined zones of said cavity.

9. Apparatus as defined in claim 1, and further including at least one additional group of said heating elements mounted externally on said housing, said means supplying electrical energy to said heating elements including programming means controlling differentially the operation of said groups of said heating elements, and analog computer means remote from said applicator housing for controlling the operation of said programming means in simulation of the actual heating conditions that occur in the ladle cavity.

10. Apparatus as defined in claim 9 wherein said analog computer means includes an electrically energized analog control heater, and means responsive to the temperature of said analog control heater for interrupting the operation of said programming means and for controlling the electrical energy supplied to said applicator heating elements.

11. Apparatus as defined in claim 10 and further including an oven containing said analog control heater and said temperature-responsive means, and means controlling the temperature of said control heater.

12. Apparatus as defined in claim 11 wherein said means controlling the temperature of said analog control heater includes means for varying the electrical energy supplied to said control heater.

13. Apparatus as defined in claim 12 wherein said oven contains a vertical passage for the flow of convection air across said analog control heater, and further wherein said temperature controlling means includes adjustable damper means in said oven passage.

14. Apparatus as defined in claim 13, wherein said programming means includes means for automatically adjusting the temperature set point of said temperature responsive means to provide predetermined temperature settings in accordance with desired progressive phases of the heating cycle.

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