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TEMPERATURE CONTROL APPARATUS

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Fig. 1

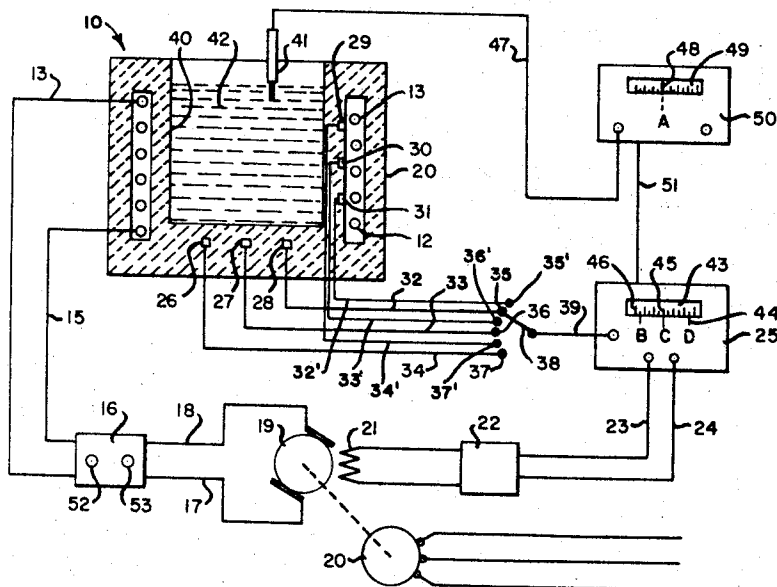
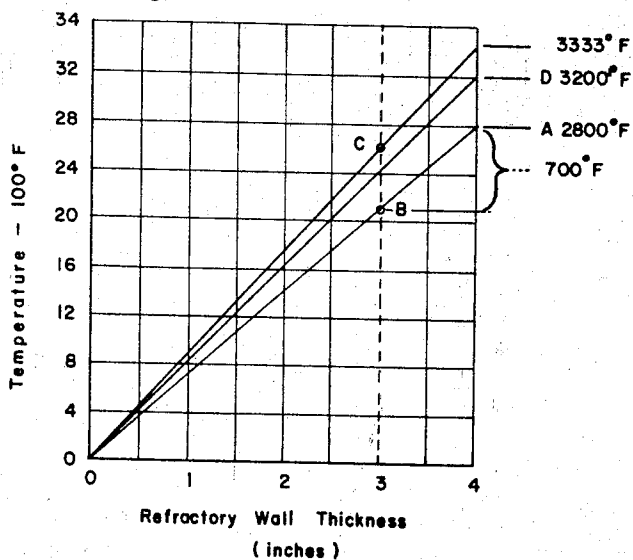


Fig. 2



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TEMPERATURE CONTROL APPARATUS

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4 Claims. (Cl. 13-27)

This invention pertains to the art of temperature-control apparatus and more particularly to a control apparatus usable in furnace applications for treating molten metals and the like.

The invention is particularly applicable to furnaces wherein it is desired to attain melting temperatures of metals and to sustain operating temperatures within very narrow limits in order to control the metallurgical qualities of the metal in the finished article.

While the control apparatus is especially suited for furnaces which reduce metal to molten condition, it is by no means limited to this application and those skilled in the art can be expected to make numerous other applications of the invention wherever it is desired to obtain a close temperature control of a material which does not readily admit of direct temperature sensing over an extended period.

It has been the usual practice over a period of years to control the molten bath temperature of metals and the like within a furnace, by use of either an optical pyrometer or an immersion thermocouple which is located within the steel or other high temperature molten bath metal.

This procedure is subject, however, to substantial error because optical pyrometer readings are adversely affected by slag or gases and therefore erroneous temperature readings are produced. The immersion thermocouple is quickly deteriorated if it is held continuously within the metal bath and therefore develops error. If the thermocouple should be used for intermittent readings, i.e. is discontinuous in operation, there is lacking a closeness of control over the metal bath. Consequently, both the pyrometer method and immersion thermocouple are unsatisfactory because of these noted deficiencies.

Since the previously followed means for detecting temperature are subject to gross error, it has been difficult to control with reasonable exactness the temperature of the molten metal and it is therefore difficult to impose reasonable standards of manufacture which will produce a consistent quality product.

Another shortcoming which has been found with the conventionally used method of controlling and sensing the temperature of molten metals is that the thermocouples tend to deteriorate so rapidly that it is practically impossible to realize any extensive use life of the thermocouples.

The present invention contemplates a more accurate detection of temperatures of high melting point molten metal charges within furnaces and which is less susceptible to erroneous temperature readings because of presence of slag, gases or other foreign materials which produce error in the temperature-sensing operation.

In accordance with the present invention there is provided a furnace wherein thermocouples are disposed within refractory heat-resistant walls of the furnace at locations which are in proximity with the molten bath to be at temperatures which are proportionate to the temperature of the molten metal bath, but considerably lower in magnitude.

In accordance with the present invention there is provided an apparatus for controlling the temperature of a molten metal within a furnace having refractory walls. The apparatus comprises an induction heating coil surrounding the furnace, an electric generator for energizing the coil, temperature sensing means within the refractory

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walls and spaced from the molten metal, means for measuring the temperature sensed by the sensing means, calibrating means for establishing a temperature sensed by the sensing means which corresponds to the desired temperature for the molten metal in the furnace, a control device for comparing the temperature measured by the measuring means and the established temperature, a signal generating device to control the generator in accordance with the difference between the measured temperature and the established temperature.

One of the objects of the present invention is to provide a control mechanism comprised of a plurality of thermocouples which are disposed protectively within the heat resistant refractory walls of a furnace so as not to be subjected to the deteriorating effect which could result from direct exposure to high temperature molten metal; while at the same time, providing a temperature reading which is calibrated to be an exact measurement of the actual molten metal temperature.

Another object of the invention is to provide a control system in which calibration can be readily obtained and which is accurate in value, regardless of the temperature of the molten bath which is to be obtained. The protection which is to be given the calibrated thermocouple, once it is properly calibrated, is well suited to maintain accuracy of calibration owing to the protection which is given the thermocouple device.

Another object of the invention is to provide a control system which will operate fully automatically and accurately, to provide a self-compensating control of metal temperatures.

Other objects, and a fuller understanding of the invention, will become apparent from the following description of a specific embodiment of the invention included herein for purposes of description and not of limitation, and is taken in conjunction with the accompanying drawings, in which:

FIGURE 1 illustrates the control system in combination with a molten metal furnace which is illustrated in section, and

FIG. 2 is a graph of Temperature versus Refractory Wall Thickness, the graph being useful to show the temperature gradient which occurs through the cross-section of the furnace.

Referring now to the drawings which illustrate a specific embodiment of the invention for purposes permitting others to better understand the invention and not for the purpose of limiting the invention, there is illustrated a furnace designated generally by reference numeral 10 comprised of heat resistant refractory material of any suitable construction and composition such as well known to those skilled in this art. Within the walls of the furnace is a circular cavity 12 wherein are disposed induction heating coils having conductors 13 and 15 connecting with a control station 16. Conductors 17, 18 from station 16 connect with a generator 19 driven at constant speed by a motor 20 which may be a three-phase alternating current squirrel-cage induction motor.

The field coil windings 21 of the generator 19 are subject to variable voltage by means of a voltage regulator 22 so that the output of the generator 19 is a function of the voltage obtained from regulator 22, this voltage in turn being regulated by a signal obtained from conductors 23 and 24 which connect the voltage regulator 22 with a control 25. The control 25 receives information as to the temperature of thermocouples 26, 27, 28 and their companion thermocouples 29, 30 and 31 which are connected through their associated conductors 32, 32', 33, 33', 34 and 34' with a respective one of contacts 35, 35', 36, 36', 37 and 37'. Switch arm 38 is then movable into engagement with one of the contacts 35-37 to com-

communicate the temperature obtained from a respective one of the thermocouples through conductor 39 to control panel 25.

Referring to FIG. 2, which plots Temperature versus Refractory Wall Thickness, there is a known temperature gradient through the wall thickness of the furnace which is generally linear so that thermocouples 26-31 which are located, for example, three inches within the wall thickness bear a definite proportion to the temperature at the inner surface 40 of the furnace which is the temperature value at "4" inches refractory wall thickness. Thus, a thermocouple reading at 2100° F. is obtained when the internal furnace temperature and its molten metal charge reaches 2800° F. There is, in other words, a temperature gradient of 700° F. between the point of location of the thermocouple and the molten metal charge when the molten metal charge is at a temperature of 2800° F.

The temperature differential can be obtained by means of a thermocouple 41 which is momentarily immersed within the molten metal charge 42, from time to time, in order to calibrate the readings obtained from thermocouples 26-31. For example, assuming that an end temperature of 3200° F. is required of the bath, heating is developed by induction heating coils 12 until the thermocouple 41 registers the end temperature of 3200° F. and the temperature of thermocouples is then noted to be approximately 2425° F. at said temperature of 3200° F. for the molten metal bath. The temperature differential is then 775° F. What is required is a calibrated temperature of the thermocouples 26-31 for each set temperature to which the metal is intended to be raised so that the temperature of the thermocouples can be read in terms of the bath temperature and will register accurately the set temperature when the set temperature is attained by the molten bath.

In order that the thermocouples 26-31 register temperatures in terms of actual molten metal temperature, the thermocouple 41 is used to effect calibration and is then withdrawn from the bath and there is no further requirement for its usage except for periodic testing to see whether the thermocouples 26-31 are holding their accuracy. If however a series of molten bath temperatures are required to be held at, for example 2800° F., the induction coils 12 are heated until 2800° F. is registered by thermocouple 41 and the temperature of 2100° F. obtainable by thermocouples 26-31 is calibrated to read directly 2800° F. In practice, the dial 43 has a setting 44 which registers the desired temperature, and a "set" temperature reading 45 which, after heating, will correspond with the "desired" temperature.

A continuous temperature value from a selected pair of the embedded thermocouples is obtainable by needle 46, this needle reading being calibrated to be the temperature of the molten metal when the molten metal temperature reaches the "set" temperature. When thermocouple 41, which takes a direct reading, indicates the molten metal is at the desired temperature corresponding to the "set" temperature, the pointer 46 from the thermocouple pair is caused to slide across the face of dial 43 to register with the set temperature 45 and the control will then function to maintain said set temperature.

From time to time, the thermocouple 41 can be automatically immersed in the bath and conductor 47 will communicate the "actual" metal temperature through a needle 48 reading on dial 49 of control 50. The control 50 is in turn connected with control 25 through a conductor 51 to check whether the thermocouples are "holding" the set temperature. Normally, once calibration is effected the thermocouples 26-31 will function to maintain a molten metal temperature within a few degrees of the desired temperature.

To safeguard against any erroneous readings of the thermocouples, the thermocouples are provided in pairs so that there is a fair sampling of the temperature gradient around the walls of the furnace 10 and also there are three

pairs of thermocouples which can be individually used as a cross check one against the other.

Because of the fact that different temperature differentials occur between a thermocouple temperature and molten metal temperature, the thermocouple temperatures must be calibrated for each temperature of the molten metal, i.e. its set temperature. For example, if the calibrated thermocouple temperature of 2100° F. were relied upon to achieve an additional 400° of set temperature from 2800° F. to 3200° F. by simply increasing the thermocouple setting of 2100° F. to 2500° F. then the bath temperature would be raised to 3333° F. rather than 3200° F. (see FIG. 2) an error of approximately 133°. Therefore, what is required is that the molten metal temperature at the "set" temperature be accurately determined and a reading then obtained of the thermocouple temperature. The dial 46 of the thermocouple temperature is then adjusted to correspond with the setting 45 which is the "set" temperature.

One of the pairs of thermocouples 26-31, depending upon location of arm 38, will determine through its conductors 23, 24 the operation of voltage regulator 22 which in turn controls the voltage of field windings 21 of generator 19. The generator 19 will, in turn, develop sufficient electrical energy to operate the induction coils in cavity 12 so as to maintain the calibrated temperature sensed by the thermocouples at the "set" temperature. Assuming that a molten temperature of 2800° F. is required, the thermocouple temperature of 2100° F. is calibrated to read 2800° F. and the control 25 will sense any temperature less than 2100° F. to produce a suitable voltage through regulator 22 on the field windings 21 of generator 19 which is driven at a constant speed by the motor 20. When the temperature of the thermocouples is quite low, the voltage will correspondingly be higher and the generator 19 will develop substantial heat to raise the furnace to a suitable level and after the thermocouples register a temperature of 2100° F. the voltage 22 is substantially reduced and is maintained at a value sufficient only to maintain a balance with the heat loss of the system.

The operation of the device can of course be terminated at any time through a control station having suitable start and stop pushbutton controls 52 and 53. In operation, the system can be made to run either automatically or semiautomatically and is of course self-compensating to provide a highly accurate control of the temperature of the molten metal 42.

At the outset, metal is charged to a desired level within the interior 40 of the furnace 10 and a desired temperature noted by setting of indicator 44 on the face 43 of control 25. When the temperature of the molten metal 42 approaches the desired temperature the thermocouple 41 can then be temporarily immersed and actual temperature noted from indicator 48 on dial 49. When the indicator 48 indicates the desired temperature the indicator 46 which registers the actual refractory temperature is then moved across the face of dial 43 to register with the set temperature 45, the set temperature corresponding to the desired temperature. The switch arm 38 is then moved into engagement with one of the contacts 35, 36, 37 connecting a preselected one of the pairs of thermocouples 26-29, 27-30, or 28-31 with control 25 at which time the thermocouple reading is calibrated to be at a temperature reached when metal is at the "set" temperature.

Any deviation of the thermocouple from its calibrated temperature is sensed by the control 25 which in turn regulates voltage regulator 22 to increase or decrease the voltage in the windings 21 of the constant r.p.m. generator 19 driven by motor 20. Thus, if the thermocouple calibrated setting registers a decrease of temperature then the voltage in winding 21 is increased to increase the heating effect of the induction coils within cavity 12; and correspondingly, if the calibrated temperature should over-

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register then the voltage 21 is reduced so that heat loss will exceed the heating effect of induction coils to lower the temperature of the bath to its set temperature. Either automatically, or by operator control, the immersion thermocouple 41 can be lowered into the molten metal to recalibrate the thermocouples 26-31 from time to time.

Since the thermocouples are located within the refractory lining they are protected against the corrosive effect of the molten metal and are free of the error-producing factors of slag, gases, etc. and, being subjected to a lower temperature, are more sensitive and have a more useful wear life.

It is not necessary, of course, to dispose the thermocouples at any set displacement from the interior wall of the furnace but I have found it advisable to locate the thermocouples closely enough to the interior temperature of the furnace so that there is not a substantial temperature gradient which would preclude rapid response of control to the interior conditions of the furnace. These are factors well known to those skilled in the art and they can be presumed to be changed to meet the individual design of a particular application.

When it is desired to change the set temperature it is necessary to recalibrate the thermocouple temperatures, this being accomplished by either raising or lowering the temperature of the furnace to the point that the actual metal temperature obtained from thermocouple 41 corresponds with the desired temperature at which time the "refractory" temperature obtained from the thermocouple is "set" i.e. the dial pointer 46 is moved across the face 43 so that it registers with the set temperature value 45 at which time the control 25 will then regulate voltage in winding 21 to maintain the furnace-heating induction coils within cavity 12 such that the metal temperature stays at the "set" temperature.

This calibration can be made automatic, by suitably connecting the "desired" temperature with the "actual" temperature of control 50 whereby any change in the "desired" temperature will produce through conductor 51 a signal to control 50 which effects immersion of thermocouple 41 and a calibration of the thermocouple at the new "set" temperature.

Obviously, other equivalent constructions and arrangements will occur to others upon a reading and understanding of the specification and it is my intention to include all such modifications and alterations insofar as they come within the scope of the appended claims or are the equivalent thereof. Having thus described my invention, I claim:

1. Apparatus for controlling the temperature of a molten metal charge within a furnace having heat resistant refractory members defining the walls of said furnace, a plurality of heat-responsive temperature-indicating devices disposed within said refractory walls, means for calibrating the temperature values received from said

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heat-responsive members in relation to actual temperature of the molten charge contained within said furnace, means for communicating heat to said furnace, and control means for said heat-communicating means responsive to the calibrated value of said temperature-indicating means to produce a heating value of said furnace adapted to obtain a set temperature of said charge for which said temperature-indicating device is calibrated, said means for communicating heat is comprised of an induction heating coil, a motor-generator for developing electrical energy transmitted to said induction heating coil, and means for transmitting calibrated temperature values of said temperature-responsive means to said motor-generator to effect an output thereof in accordance with a pre-set temperature established for the molten charge contained within said furnace.

2. An apparatus for controlling the temperature of a molten metal within a furnace having refractory walls, said apparatus comprising an induction heating coil surrounding said furnace, an electric generator for energizing said coil, temperature sensing means within said refractory walls and spaced from said molten metal, means for measuring the temperature sensed by said sensing means, calibrating means for establishing a temperature sensed by said sensing means which corresponds to the desired temperature for the molten metal in said furnace, a control device for comparing said temperature measured by said measuring means and said established temperature, a signal generating device to control said generator in accordance with the difference between said measured temperature and said established temperature.

3. An apparatus as defined in claim 2 wherein said generator is a motor-generator set with a control field winding and said signal generating device changes the voltage across said field winding in accordance with the deviation of said measured temperature from said established temperature.

4. An apparatus as defined in claim 2 wherein said calibrating means is a thermocouple adapted to be immersed into said molten metal, a means for sensing the temperature of said thermocouple, means for correlating said thermocouple temperature to the temperature of said sensing means, and means for establishing the temperature of said sensing means when said thermocouple reads the desired temperature of said molten metal.

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