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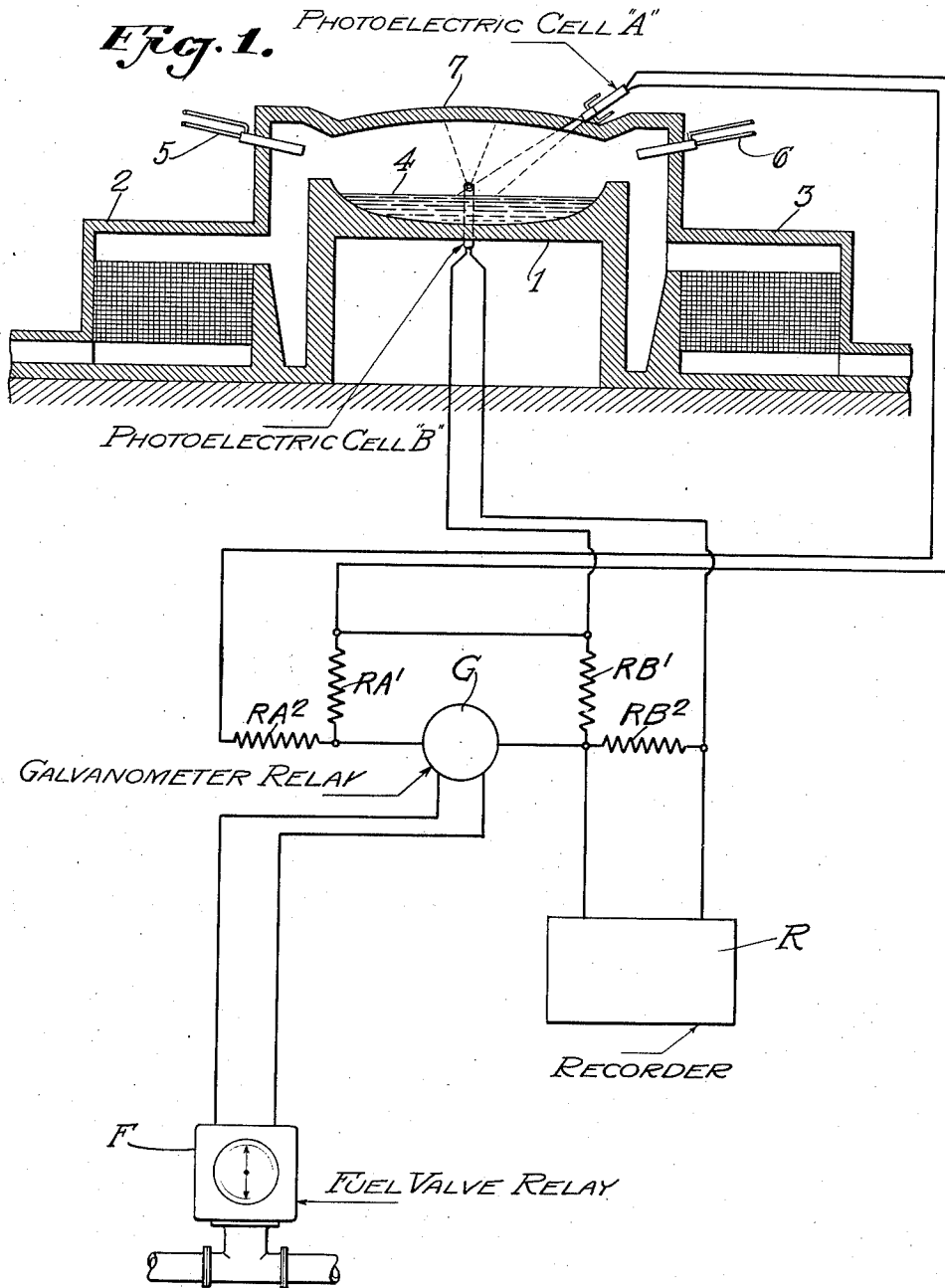
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METHOD AND APPARATUS FOR DETERMINING THE TEMPERATURES OF MOLTEN BATHS

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2 Sheets-Sheet 1



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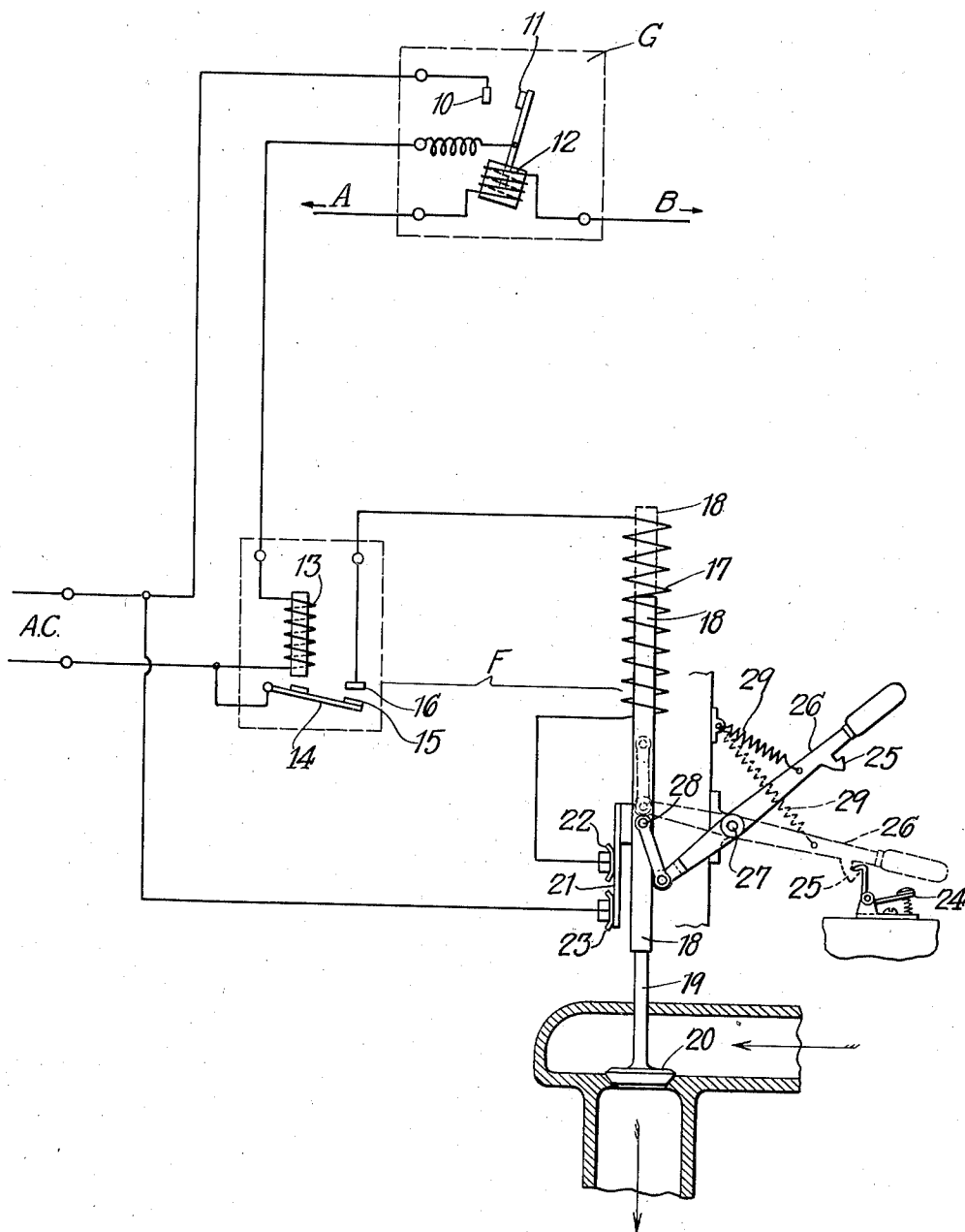
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Fig. 2.



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METHOD AND APPARATUS FOR DETERMINING THE TEMPERATURES OF MOLTEN BATHS

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8 Claims. (Cl. 73-343)

This invention relates to metallurgy and more particularly to a method and means for accurately determining the temperatures of molten metal baths.

Heretofore in the art the determination of the temperatures of molten metal baths has been rather difficult due to the fact that the molten metal bath and the fluxing materials over the surface of the bath have a definite solvent action on pyrometric devices that may be inserted therein. Many attempts have been heretofore made to obtain a measurement of the temperature of the bath through the use of photo-electric devices sensitive to the radiant heat energy of the bath or by devices known in the art as optical pyrometers.

The present invention has for its object the provision of a method and means for more accurately determining the temperatures of molten metal baths.

Another object of the present invention is to provide a method and means for determining the temperatures of molten steel baths.

Other objects and advantages will be apparent as the invention is more fully disclosed.

In accordance with the above objects we have found that when a molten metal bath is contained in a crucible, or on a hearth, or similar container and the space above the bath is enclosed from the atmosphere by any suitable refractory cover, the comparative temperatures of the bath surface and refractory lining of the said cover may be utilized in determining the bath temperature.

As a general rule in high temperature furnaces, there is a rapid heat interchange by radiation between bath surface and the inner surface of the refractory cover. During the heating of the bath the temperatures of the bath and inner surface of the cover are not necessarily identical but when the application of heat energy to the bath is terminated, then the temperatures of the bath and inner lining of the cover will tend to equalize, the particular time interval to obtain equalization of temperatures, naturally, varying with the specific conditions.

However, we have found that by sighting one radiation sensitive pyrometer device upon the inner surface of the cover and a second such device upon the surface of the molten bath, and continuously recording the temperature of the said inner surface of the cover, the temperature at which the two reach equilibrium may be recorded on the said record. Since the cover has a relatively low heat capacity and the molten

bath has a very large one and since the insulation of the cover is in general inferior to the bath, the temperature at which the two come to equilibrium is substantially the temperature of the molten bath prior to the turning off of the fuel.

As a specific embodiment of the present invention but not as a limitation thereof we will describe the same as it has been developed for the determination of molten steel baths on a regenerative furnace hearth. Modern steel manufacture demands that the actual temperatures of the molten steel bath during the manufacturing process be known and controlled. This is particularly true in so-called "open hearth" steel or steel made in the regenerative furnace. The elimination of certain impurities and the chemical processes in the bath during the refining process each demand the maintenance of certain temperatures or ranges of temperatures which in the past have been exceedingly difficult to obtain. By the practice of the present invention, however, an accurate record of the bath temperature at each stage of the refining process may be obtained and recorded.

Before further disclosing the present invention reference should be made to the accompanying drawings wherein Fig. 1 illustrates diagrammatically the temperature measuring means of the present invention and indicates its mode of combination in a regenerative furnace; and Fig. 2 illustrates diagrammatically the electrical and mechanical means forming a part of the present invention.

Referring to the drawings, we have illustrated in section a typical regenerative furnace 1 with associated checker chambers 2 and 3. The particular structure of the furnace 1 and chambers 2 and 3 form no part of the present invention.

In such a furnace the molten metal bath 4 is retained on a hearth substantially as indicated and burners 5, and 6 are alternately ignited, the burning gases passing over the surface of bath 4 and heating the same to the desired temperatures. In passing over the bath surface these burning gases also heat up the inner surfaces of the roof 7 and side walls (not shown) which enclose the bath surface from the atmosphere. Due to a more rapid heat absorption by convection stirring in the molten bath 4, the inner surface of roof 7 is usually somewhat hotter than the bath surface.

In alternately igniting burners 5 and 6 which is commonly spoken of in the art as furnace reversing, there is a time interval between the turning off of the fuel to one burner and the turning

on of the fuel to the other burner. During this time interval the radiant heat energy emitted by bath and incandescent inner wall surfaces tend to rapidly equalize the temperatures of the bath and surfaces so that within a relatively short, time interval each are at the same temperature. It is evident that if either burner is turned off at any time the said equalization of temperatures will also occur and in the practice of our invention we intend to make use of this equalization phenomenon whether it occurs at the furnace reversal or at any other period.

We therefore propose to sight a radiation sensitive device A through the roof 7 (or any other wall of the furnace 1) upon the surface of molten metal bath 4 and to sight a second radiation sensitive device B through a side wall upon the inner surface of said roof, preferably upon the surface most directly subjected to radiant heat emitted by the said bath 4. We then propose to electrically connect the devices A and B to a galvanometer relay G which is able to detect the attainment of equality by the outputs of said devices and to actuate fuel valve F when said equilibrium has been attained. We further propose to connect a continuous recorder device R to the circuit of device B so as to record its output without regard to the output of device A. Whenever fuel valve relay F is operated manually to shut off the flow of fuel to burner 5 or 6, galvanometer relay G becomes operative and is able to turn on the fuel through relay F when the inner surface of the roof and the top surface of the bath closely approach the same temperature as reflected in equality of outputs of devices A and B. The temperature recorded on R just prior to the turning on of the fuel at either 5 or 6 is therefore the temperature of the bath as well as of the inside surface of the roof.

In operation after the burner is turned off the roof temperature immediately begins to fall off and the temperature of the bath and slag composition superposed thereon rapidly equalizes and as the temperature of the roof surface approaches that of the equalized bath and slag temperature it cools more and more slowly. By having a continuous record of the roof temperature and by providing a sensitive galvanometer relay device "G" electrically connected to be energized when the "match point" is reached, the turning on of the same burner or of the other burner in case the operation is being carried out at the time of furnace reversal may readily be accomplished through fuel valve relay F.

The abrupt termination in the fall of temperature on the record will indicate the match point temperature with a sufficient degree of accuracy for the purpose of steel manufacture.

As indicated in the drawings A and B are "Photronic" cells sighted at bath and roof respectively in an open hearth furnace. If A and B are alike in their characteristics, $RA_1 = RB_1$ and $RA_2 = RB_2$. If this is not the case and K_A and K_B are constants of A and B respectively, $K_A RA_1 = K_B RB_1$ and $K_A RA_2 = K_B RB_2$. If this condition is satisfied, the potential drops across RA_1 and RB_1 will be equal when A and B are equally illuminated. The galvanometer relay G is connected in the circuit in such a manner that the voltage applied to its terminals is the difference between the above two potential drops and it therefore stands on zero when they are equal. Relay G is arranged to close a circuit controlling the fuel valves when the above voltage difference is zero. Since the internal re-

sistance of A and of B is very high compared to RA_1 , RA_2 , RB_1 and RB_2 , the condition of balance or unbalance of the potential drops will have only a negligible effect on the current flowing through RB_2 and therefore on the potential drop across RB_2 as measured by the potentiometric recorder R. Likewise the recorder R will not affect the operation of galvanometer G in determining the balance or unbalance of the potential drops across RA_1 and RB_2 respectively.

There are many ways in which this invention may be applied in the determination of the temperatures of molten metal baths and there is no reason why it need be restricted to the determination of metal baths as it is equally as operative with other molten baths which are being melted within a container and the surface thereof enclosed from the atmosphere. The essential novelty involved is the provision of radiation sensitive means to determine the temperatures of the bath and inner surface of the cover and means to determine the match point or equalized temperature attained by the bath and inner surface of the cover when the means to heat the bath is not operating. This "match point" temperature reading may be utilized to turn on the heating means. One mode of accomplishing this result is indicated in Fig. 2.

In Fig. 2 the operating elements of galvanometer relay G are shown enclosed by dash box lines, and the operating elements of fuel valve relay F are indicated in diagrammatic co-operative relation with a fuel valve. Galvanometer relay G is provided with a fixed contact 10 and a movable contact 11, the moving element 12 of contact 11 being operated by the voltage difference between radiation sensitive devices A and B as hereinabove described. The adjustment in galvanometer relay device G is such that at zero difference in potential the moving element 12 operates to move contact 11 in closed position against contact 10.

With contacts 10 and 11 in closed position electric current from source A. C. passes through solenoid coil 13, moving switch arm 14 upwardly thereby closing contacts 15 and 16 and completing an electrical circuit passing current from source A. C. through solenoid coil 17 which operates to magnetically attract its core 18 upwardly, bringing therewith valve stem 19 and thereby opening valve 20 permitting fluid fuel to pass through the valve to the furnace in the direction indicated by arrows. The upward movement of core 18 is such that contact 21 making wiping engagement with contacts 22 and 23 just clears the contact 23 as it approaches its full upward movement thereby breaking the electrical circuit energizing solenoid coil 17.

We have provided means to mechanically hold or retain valve 20 in its fully open position as indicated in Fig. 2. This means is essentially a latch means 24 adapted to engage a hook extension 25 on lever 26 pivoted at 27, one arm of said lever arm being attached as at 28 to the moving core 18 in such manner as to provide for the pivoting of the lever 26 upon movement of the core 18 upwardly or downwardly. The position attained by lever 26 in valve open position is indicated in dotted lines. The position of lever 26 in valve closed position is indicated in solid lines to conform with the above description. To position valve 20 in closed position after having been opened as above described, latch means 24 is manually operated to release lever 26 which thereby is moved upwardly by spring means 29. 75

This operates to permit core 18, stem 19 and valve 20 to fall vertically locating valve 20 in closed position, in which position contacts 22 and 23 are bridged by sliding contact 21 and the electrical system is in condition to respond as above described to the closing of contacts 10 and 11 of galvanometer relay G upon the attaining of zero difference in potential between the electric currents originated in radiation sensitive devices A and B denoting the match point of temperatures being recorded on recorder R.

Having broadly and specifically described the present invention, it is apparent that many modifications and departures may be made therein without departing essentially from the nature and scope as it may be encompassed in the following claims.

What we claim is:

1. The method of determining the temperature of a molten bath disposed upon a furnace hearth and enclosed from the atmosphere which comprises converting the radiant energy emitted by the bath and the inner surface of the enclosure respectively and separately into electrical energy, applying one of said energies to the forming of a continuous record of the same in terms of degrees temperature, inducing a falling temperature condition in the said furnace, measuring the voltage differences between the two said electrical energies under such falling temperature condition and at the point of zero difference in voltage between the two said energies inducing a rising temperature condition in the said furnace thereby to positively indicate upon the said continuous record the point of temperature equalization between the bath and inner surface of the said enclosure representing this said point of zero difference.

2. The method of determining the temperature of a molten bath disposed in a furnace upon a hearth enclosed from the atmosphere which comprises converting the radiant energy emitted by the said bath into a current of electrical energy, converting the radiant energy emitted by the inner surface of the bath enclosure into a second current of electrical energy, utilizing one of said energies to actuate a recording means adapted to produce a continuous record of the said measured energy in terms translatable into degrees temperature, utilizing the two said energies to actuate a galvanometer device to indicate thereon the voltage differences between said energies, inducing in the said furnace a falling temperature condition until the voltage difference indicated on the said galvanometer shows a zero difference, and then inducing a rising temperature condition in the said furnace to thereby induce upon the said continuous record of said one energy a positive recording of the temperature representative of that attained at zero difference in voltage between said two energies.

3. Means for determining the temperature of a molten bath disposed on a hearth enclosed from the atmosphere which comprises means energized by the heat energy of the bath to produce electric energy bearing a known relation to the temperature producing said heat energy, means energized by the heat energy of the inner portion of the bath enclosure to produce a second electric energy of similar characteristics to the first said energy, means to apply one of said electric energies to the forming of a continuous record translatable in degrees temperature, means to continuously indicate the voltage difference between said energies, and means to ascertain the

point of zero difference in potential between said electrical energies and the temperature corresponding therewith on the said record.

4. Means for determining the temperature of a molten bath disposed on a hearth enclosed from the atmosphere which comprises means energized by the heat energy of the bath to produce electric energy bearing a known relation to the temperature producing said heat energy, means energized by the heat energy of the inner portion of the bath enclosure to produce a second electric energy of similar characteristics to the first said energy, means to apply one of said electric energies to the forming of a continuous record translatable in degrees temperature, means to continuously indicate the voltage difference between said energies, means to induce a falling temperature gradient in the bath and said bath enclosure, and means to induce a rising temperature gradient in said bath and said bath enclosure when the voltage difference between said electric energies approximate zero.

5. Means for determining the temperature of a molten bath disposed on a hearth enclosed from the atmosphere which comprises means to continuously convert the radiant heat energy emitted by the bath and inner enclosure surface respectively and separately into electrical energies each having a known relation to the temperatures inducing said radiant energy, means to apply one of said electrical energies to the forming of a continuous record translatable into degrees temperature, means to continuously indicate the voltage difference between the two said electrical energies, and means to positively indicate on the said record the point of zero voltage difference between said electrical energies when it occurs.

6. In the combination of claim 5, said means to continuously indicate the voltage difference between said electrical energies comprising a galvanometer and means to electrically connect said electrical energies in series opposition to said galvanometer, and said means to positively indicate the point of zero difference in voltage comprising adjustable contacts adapted to be closed by said galvanometer at the said point of zero difference and an electrical circuit including said contacts adapted to actuate means to increase the heat energy input to the said bath and enclosure upon the closing of said contacts by the said galvanometer, to thereby induce a rising temperature gradient upon the said continuous record.

7. In the combination of claim 5, said last two mentioned means comprising a galvanometer relay device and a fuel valve relay device, the two said electrical energies being electrically connected in series opposition to said galvanometer relay, and the fuel valve relay device being electrically connected to adjustable contacts on said galvanometer relay device, the said contacts being disposed in a position to be closed by said galvanometer device at zero difference in potential and the closing of said contacts operating to energize said fuel valve relay device to open a fuel valve supplying heat energy to the bath and enclosure, thereby increasing the heat energy input to the said bath and enclosure with consequent rise in the temperature of the bath and enclosure and a recording of such rise upon the said record.

8. In a furnace having a hearth enclosed from the atmosphere and fluid fuel means to heat said hearth, means to determine the temperature of a molten bath on said hearth, said means including means to convert the radiant energy emitted by at least a part of the bath and the radiant energy

emitted by at least a part of the inner surface of the enclosure of the hearth separately into electrical energies bearing a known relation to the temperatures producing said radiation, means to
5 apply one of said energies to the forming of a continuous record translatable into degrees temperature, means to continuously indicate the voltage differences between the two said electrical energies, a manually operative valve controlling
10 the supply of fuel to said furnace, an electrically

operative means to open said valve, means energized by the manual closing of said valve to electrically connect said electrically operative means to an open electrical circuit adapted on being closed to energize said means, and means actuated by said voltage difference indicating means to close said open circuit when the said voltage difference indicated thereby approximates zero.

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