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3,080,755

METALLURGICAL PROCESS CONTROL

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2 Sheets-Sheet 1

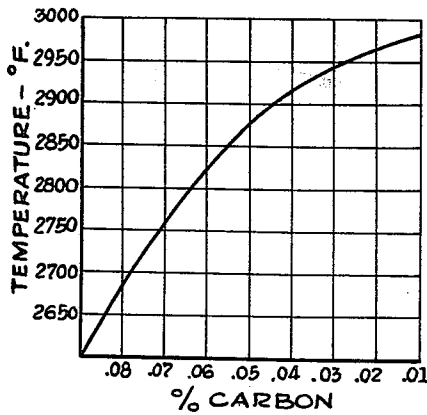
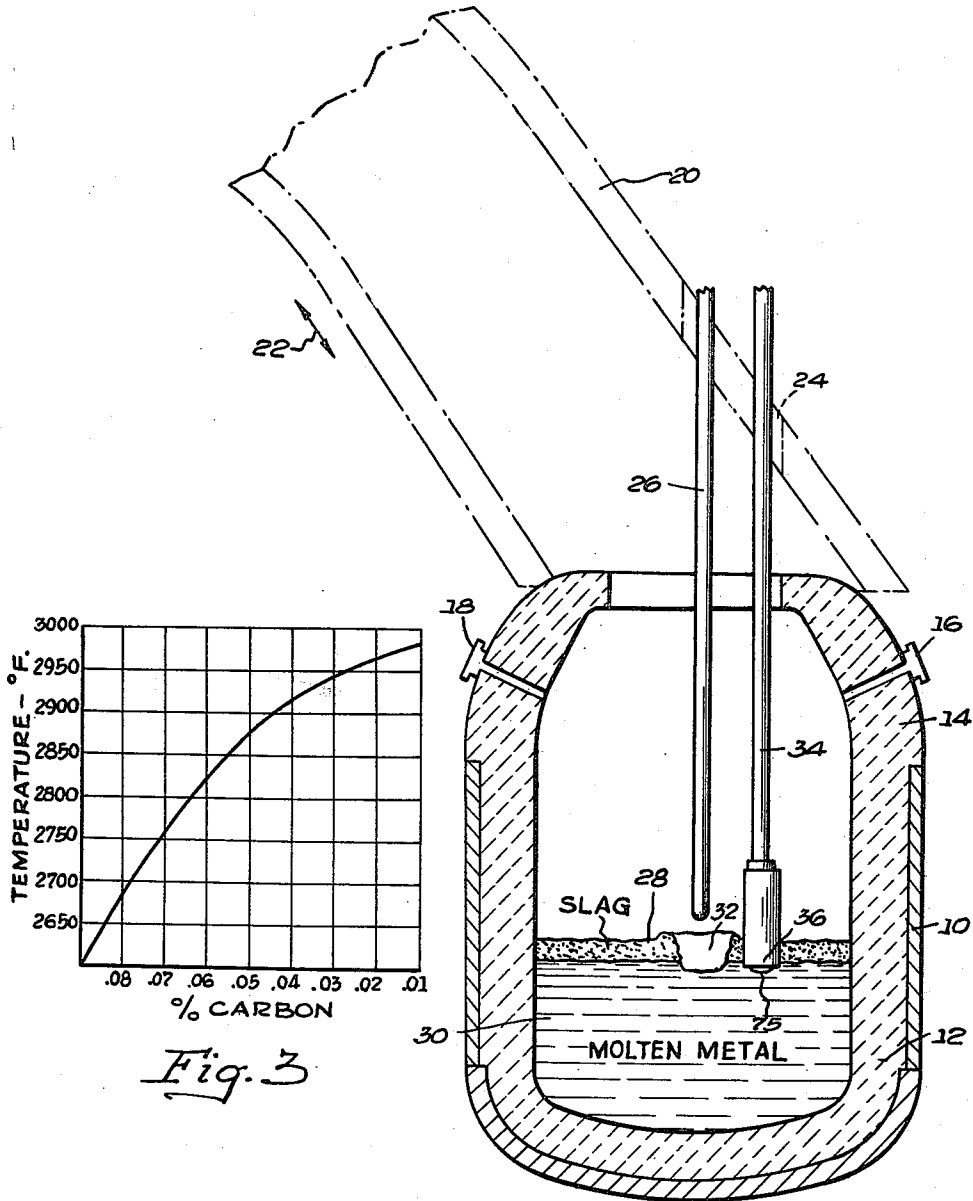


Fig. 3

Fig. 1.

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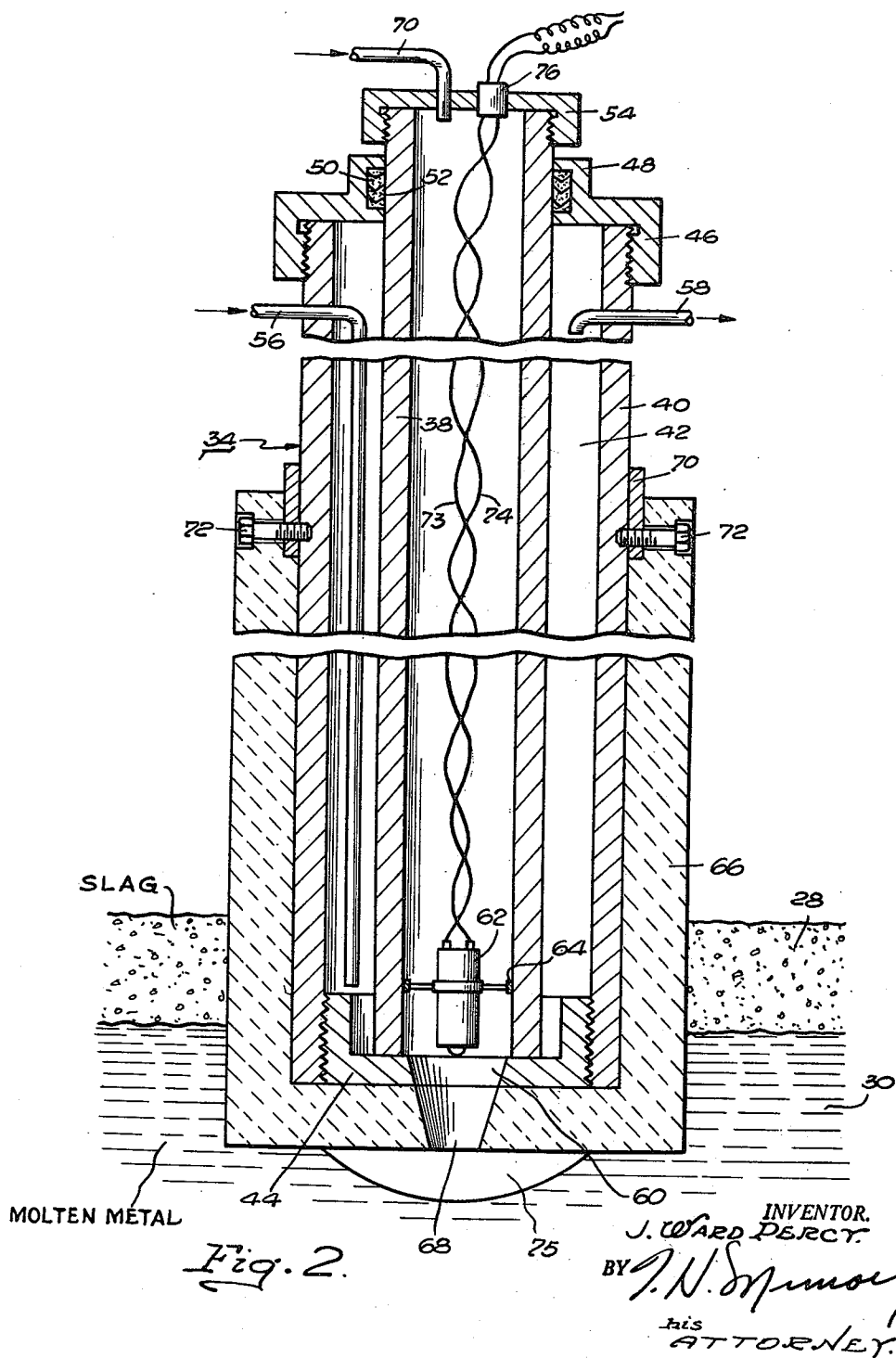
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METALLURGICAL PROCESS CONTROL
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 8 Claims. (Cl. 73—355)

This invention relates to a method and apparatus for measuring the temperature of a molten metal bath, and also to a method for controlling the composition of a molten metal bath by measurement of its temperature.

While not limited thereto, the present invention is particularly adapted for use with a rapid oxygen steel-making process. In such a process, oxygen of high purity is blown onto the surface of a molten steel bath to produce a product comparable to, or better than, that obtained in an open-hearth furnace. However, aside from the quality of the steel, the rapid oxygen process has a distinct advantage over the open-hearth in that the time required to refine the melt is as little as twenty or thirty minutes as contrasted with about ten hours in the open-hearth.

Although the rapid oxygen process has the foregoing and other advantages over the open-hearth, it also has certain inherent disadvantages. One such disadvantage resides in the difficulty sometimes encountered in attempting to accurately control the carbon content of the melt. In any steelmaking process, pig iron or the like containing various impurities and a high carbon content is charged into a furnace or vessel, as the case may be, where the impurities and excess carbon are burned out in an oxidizing process. Since the open-hearth method is relatively slow, samples of the heat may be taken from time to time and chemically analyzed to determine the carbon content. In the rapid oxygen process, however, there is insufficient time available for taking such samples so that the carbon content is usually determined by a trial and error method which is analogous to Bessemer converter practice in that it consists of observing the flame at the mouth of the vessel. When the carbon content of the steel in the vessel decreases below a certain level, the flame at the mouth of the vessel drops. However, since the oxygen-steelmaking process produces a great quantity of fume and smoke, it is almost always necessary to provide a flue or hood over the mouth of the vessel to carry away the products of combustion, meaning that it is difficult to observe the flame. In any event, even if the flame can be seen, controlling the carbon content by observing the flame is not at all accurate and often results in a fully-blown steel requiring that it be recarburized in one way or another.

Aside from the difficulties encountered in controlling the carbon content, it has heretofore been a problem in the rapid oxygen process to control the tapping temperature of the bath. As is known, too high a tapping temperature will produce certain undesirable effects including damage to the furnace or ladle linings; while if the temperature is too low, ladle skilling and pouring nozzle difficulties may result which are undesirable from the standpoint of steel quality. In the open-hearth furnace, because of the relatively long time involved, various devices including optical or radiation pyrometers may be employed to measure and control the temperature of the bath. In the oxygen process, on the other hand, similar techniques have not been successful so that the time at which the proper tapping temperature is reached must be determined empirically, a procedure which is altogether unsatisfactory.

As an overall object, the present invention seeks to provide a method and apparatus for controlling the temperature and composition of a molten metal bath which overcomes all of the foregoing difficulties and others.

More specifically, an object of the invention is to pro-

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vide a method for controlling the carbon content of steel produced by the rapid oxygen process.

Another object of the invention is to provide a method, particularly adaptable in refining steel, for continuously controlling the temperature of the molten bath during the entirety of the refining process.

Still another object of the invention is to provide a temperature measuring device which may be immersed in a molten metal bath for relatively long periods of time to continuously measure the temperature of that bath.

In proceeding with the invention, there is provided an elongated water-cooled tubular member having an open end adapted to be immersed in a molten metal bath. Positioned within the tubular member, adjacent its open end which projects below the surface of the bath, is a temperature measuring device such as a radiation or optical pyrometer. In this manner, the open end of the tubular member may be projected through the layer of slag on top of the bath and into the bath itself while the interior of the tubular member is pressurized to prevent the metal from rising therein and damaging the temperature measuring device. Surrounding the end of the tubular member which is immersed in the bath is a casing or jacket of refractory material which prevents the slag and hot metal from attacking the walls of the tubular member. Thus, by the combined action of the refractory casing and the cooling water, the device may be made to withstand extremely high temperatures on the order of 3000° F. for long periods of time, facilitating the continuous temperature measurement of the bath.

In the past, temperature measuring devices such as that shown in Mead Patent No. 2,493,078 have been proposed which comprises a pressurized tubular member containing a temperature measuring device, and having an open end which is immersed in a molten metal bath. Such a device, however, is employed only to take a spot-check of the temperature of the bath in an open-hearth furnace, for example, and can remain in the bath for only about thirty seconds. It is, therefore, entirely unsatisfactory for continuous temperature measurements which are achieved by use of the present invention.

In accordance with another aspect of the invention, the composition of a molten metal bath is controlled by continuously measuring its temperature. In the case of steel, it is known that the carbon content of the steel decreases steadily while its temperature increases. Curves can be drawn, based upon experiment, to determine what temperature corresponds to a given carbon content. In the case of the rapid oxygen process, for example, these curves will depend upon the carbon content and initial temperature of the hot metal to be refined as well as the oxygen blowing rate. Thus, by continuously measuring the temperature of the bath and by comparing that measured temperature with the corresponding carbon content determined by experiment, the percentage of carbon can be determined at any point during the blow, and the blow stopped when the carbon content drops to the desired value as indicated by the temperature of the bath.

The above and other objects and features of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings which form a part of this specification and, in which:

FIGURE 1 is a cross-sectional view of a rapid oxygen steelmaking facility, showing the location of the continuous temperature measuring device for the present invention;

FIG. 2 is a cross-sectional view of the temperature measuring device of the invention; and

FIG. 3 is a graph illustrating the relationship between the carbon content and temperature of a molten steel bath.

Referring now to the drawings which are for the purpose of illustrating an embodiment of the invention and not for the purpose of limiting the same, in FIG. 1 a rapid oxygen steelmaking vessel is shown which comprises an outer steel shell 10 having a basic refractory lining 12 provided on its inner surface. Above the furnace proper is a refractory open-ended nose cone 14 having a pair of tap holes 16 and 18 in either side thereof. Pig iron, scrap and other materials are charged into the vessel through the opening in the nose cone 14; while the molten metal, after refining, is poured from the vessel through one of the tap holes 16 or 18.

Surrounding the mouth of the vessel is a water-cooled flue or hood, schematically indicated at 20, which serves to convey fumes and smoke to a stack, not shown. The hood 20 may be moved upwardly or downwardly as indicated by the arrow 22 whereby it may be removed from the mouth of the vessel to facilitate charging or pouring. Provided in hood 20 is an elongated opening 24 which receives a water-cooled oxygen lance 26. The lance depends downwardly into the vessel as shown and terminates above the surface of a layer of slag 28 which overlies the molten metal bath 30.

In the operation of the device, oxygen of high purity is projected under pressure onto the surface of the slag 23 and molten metal 30 to produce a cup-shaped cavity as at 32. In this process, a turbulent action is produced in the bath 30 while the oxygen reacts with the various impurities in the steel to form oxides which pass off as gases or accumulate in the slag layer 28.

In accordance with the present invention, temperature measuring apparatus generally indicated at 34, projects through the opening 24 in hood 20 and has an open end as at 36 which is pushed through the layer of slag 28 and immersed in the molten metal bath 30 at a point removed from the cavity 32. With reference to FIG. 2, it will be seen that the apparatus 34 comprises concentric inner and outer tubular members 38 and 40 which together define an annular cooling chamber 42. Preferably, the members 38 and 40 are formed from copper or other material of high heat conductivity. As shown, the lower end of the inner tubular member 38 is welded to an annular member 44, this latter member being threaded into the outer tubular member 40. Threadedly received on the upper end of the outer tubular member 40 is an annular nut 46 having an upwardly extending flange 48 thereon which surrounds the inner tubular member 38. This flange is provided with an annular cavity 50 which receives a water-tight seal 52. The assembly is completed by a cap 54 which is threaded onto the top of the inner tubular member 38.

With this arrangement, the annular cooling chamber 42 is completely enclosed and water-tight so that a cooling fluid under high pressure may be conveyed into the cavity through conduit 56 and removed therefrom through conduit 58. Positioned within the inner tubular member 38 adjacent the opening 60 in annular member 44 is a temperature measuring device 62 which may, for example, comprise a radiation or optical pyrometer. The device 62 is securely held in position by means of a spider 64 securely fastened to the inner periphery of tubular member 38.

Around the lower portion of the outer tubular member 40 is a generally cup-shaped or cylindrical member 66 of refractory material having a centrally disposed opening 68 in its bottom portion which coincides with the opening 60 in annular member 44. Surrounding the tubular member 40 is an annular collar 70 which receives bolts 72 inserted through openings in the cup-shaped refractory member 66 and threaded into the collar 70 to hold the refractory member in place.

Projecting through the cap 54 is a conduit 70 which serves to convey a gas into the interior of the inner tubular member 38. Preferably, this gas is non-oxidizing for a purpose which will hereinafter be explained. The tem-

perature device 62 has a pair of electrical leads 73 and 74 which pass through a plug 76 in the cap 54 to a temperature recording device, not shown.

In the operation of the device, the assembly 34 is lowered through the opening 24 and hood 20 to a point where its lower end passes through the slag 28 and is immersed within the molten metal bath 30. By virtue of the fact that the interior of the inner tubular member 38 is pressurized, however, a small cavity will be formed as at 75 and the molten metal will be prevented from rising through the openings 68 and 60. Nevertheless, the temperature measuring device 62 may view the molten metal through these openings. As was mentioned above, the inner tubular member 38 is pressurized with a non-oxidizing gas to prevent oxidation of the metal immediately adjacent the opening 68. Otherwise, the oxidation of the metal in this region might lead to erroneous temperature measurements. For this reason it is important to place the lower end of apparatus 34 in the bath at a point removed from the cavity 32 so that the oxidation taking place in this region will not give erroneous temperature readings. With the lower end of the assembly 34 immersed in the bath 30, oxygen is blown onto the surface of the bath through lance 26 for a period of about twenty or thirty minutes while the impurities and excess carbon are burned out of the metal. During this entire time, the temperature of the bath is recorded by means of the temperature measuring device 62. Refractory member 66, which may be formed from graphite or other highly heat-resistant material, protects the lower end of the outer tubular member 40; while the cooling fluid passing through the cooling chamber 42 serves to carry away heat and prevent melting or other damage to the assembly. If desired or necessary, the refractory member 66 may be increased in length or may even cover the entire length of the apparatus.

Referring now to FIG. 3, it can be seen that there is a definite relationship between the carbon content of a steel bath and its temperature. Specifically, as the carbon content falls, the temperature rises; or, as the temperature is increased, the carbon content is lowered. Thus, if it is assumed that about 0.04% carbon is in the bath at a temperature of 2910° F., the blow will continue until the temperature measured by the device 62 rises to 2910° F., at which time it will be known that the carbon content is at the desired level. At this point, the blow will be stopped and the metal poured from the vessel, assuming that a carbon content of 0.04% is required.

Although the invention has been shown in connection with a certain specific embodiment, it will be readily apparent to those skilled in the art that various changes in form and arrangement of parts may be made to suit requirements without departing from the spirit and scope of the invention. In this respect, it will be apparent that instead of continuously measuring the temperature of the metal bath, the apparatus shown herein may be used for short periods of time to determine if the metal is at the proper tapping temperature. In addition, the device may be used to advantage in open-hearth furnaces as well as other steelmaking and metallurgical applications.

I claim as my invention:

1. Apparatus for measuring the temperature of molten material comprising an elongated tubular member having an open lower end adapted to be immersed in the molten material, means for pressurizing the interior of said tubular member to prevent molten material from rising therein when the open lower end is immersed in the molten material, a temperature measuring device positioned within the tubular member adjacent its open lower end and adapted to produce a signal indicative of the temperature of said molten material, and means for cooling the walls of the tubular member adjacent the open end thereof which extends into said molten material, said means comprising a water jacket surrounding said

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tubular member and secured thereto such that the lower end of the water jacket will be immersed in the molten material with the lower end of said tubular member during the taking of a temperature measurement.

2. In apparatus for continuously measuring the temperature of molten material, a temperature measuring device, an elongated metallic tubular member surrounding the temperature measuring device and having a lower end adapted to be immersed in the molten material, and a water jacket for cooling said elongated metallic tubular member, said water jacket surrounding substantially the entire length of said tubular member including said lower end and being secured to the tubular member such that the lower end of the water jacket will be immersed in the molten material with said lower end of the tubular member during the taking of a temperature measurement.

3. Apparatus for continuously measuring the temperature of molten material comprising an elongated assembly having a lower end adapted to be immersed in the molten material, said assembly including an outer tubular member and a concentric inner tubular member which together define an annular cooling chamber between the tubular members which extends upwardly from said lower end and encircles said lower end at all times such that the cooling chamber is immersed in the molten material during a temperature measurement operation, the end of the inner tubular member which is immersed in the molten material being open, means for conveying a cooling fluid through the annular cooling chamber, a temperature measuring device positioned within the inner tubular member adjacent its open end and adapted to produce a signal indicative of the temperature of said molten material, and means for pressurizing the inner tubular member to prevent molten material from rising within said inner member when the assembly is immersed in the molten material.

4. Apparatus for continuously measuring the temperature of a molten metal bath having a layer of molten slag thereon comprising an elongated assembly having an end adapted to be immersed in the molten metal bath, said assembly including an outer tubular member and a concentric inner tubular member of length substantially equal to that of the outer member to define an annular cooling chamber between the members, the forward end of said cooling chamber extending into said layer of slag during a temperature measurement operation, means for

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sealing the annular chamber at its opposite ends, means for sealing the end of the inner tubular member opposite the end of the assembly adapted to be immersed in the molten metal bath while leaving the end of the inner tubular member which is immersed in the metal bath open, conduit means for conveying a cooling fluid through the annular cooling chamber, a temperature measuring device positioned within the inner tubular member adjacent its open end, and conduit means projecting through the sealed end of said inner tubular member for pressurizing the same to prevent molten metal from rising within said member when immersed in the molten bath.

5. The combination claimed in claim 4 wherein the inner tubular member is pressurized with a non-oxidizing gas to prevent oxidation of the metal bath in the area adjacent said open end of the inner tubular member.

6. The combination claimed in claim 4 wherein the temperature measuring device comprises a pyrometer.

7. In apparatus for continuously measuring the temperature of a molten metal bath having a layer of molten slag thereon, a temperature measuring device, an elongated metallic tubular member surrounding the temperature measuring device and having an end adapted to be projected through said layer of slag and immersed in the molten metal bath, a cooling jacket surrounding said elongated metallic tubular member, the cooling jacket having at least a portion which projects through said layer of slag during a temperature measuring operation, and means for continuously conducting a cooling liquid through said cooling jacket during the time that the temperature of said molten bath is being continuously measured.

8. The apparatus of claim 7 and including a generally cylindrical member of refractory material surrounding the lower end of the cooling jacket which projects through said layer of slag.

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