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H. GRUBER ETAL

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APPARATUS FOR VIEWING THE INTERIOR OF FURNACES

Original Filed Nov. 10, 1958

3 Sheets-Sheet 1

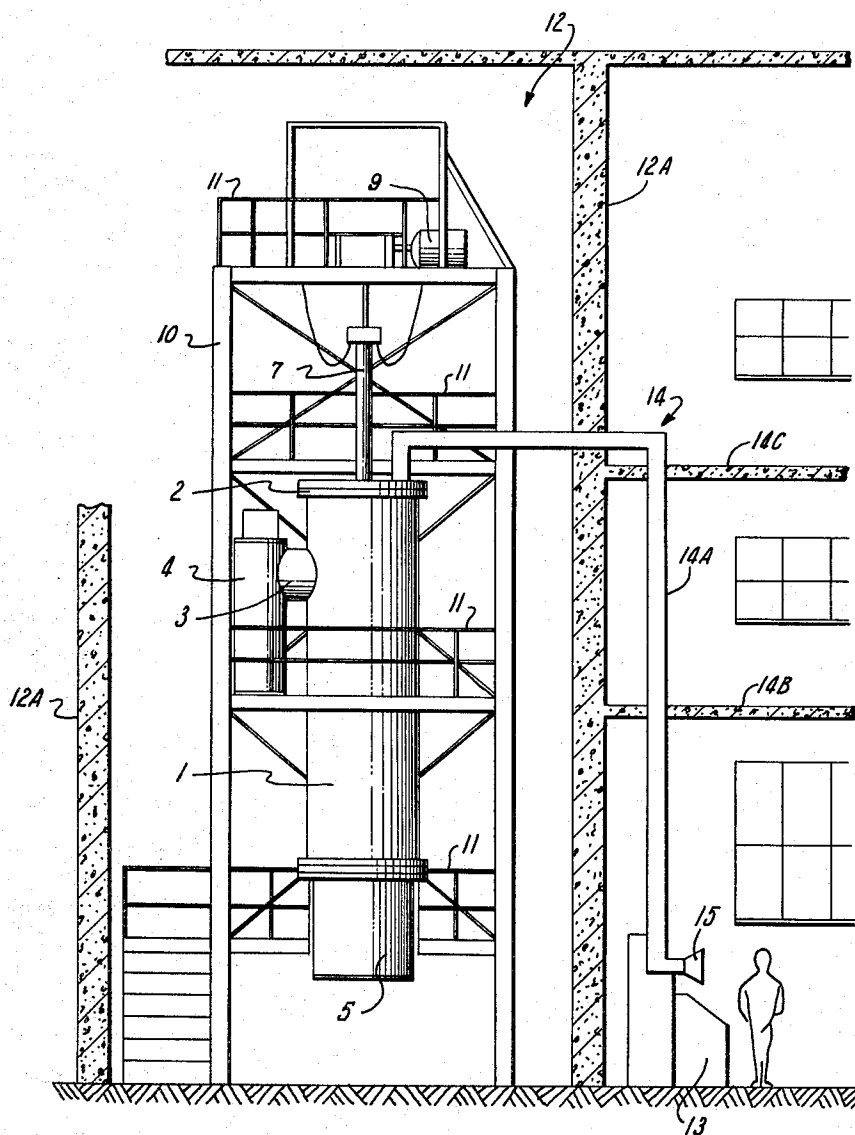


Fig. 1.

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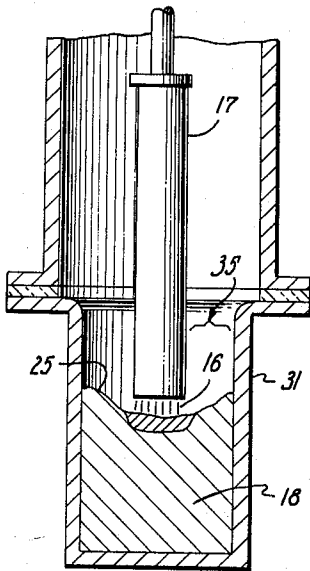


Fig. 5A.

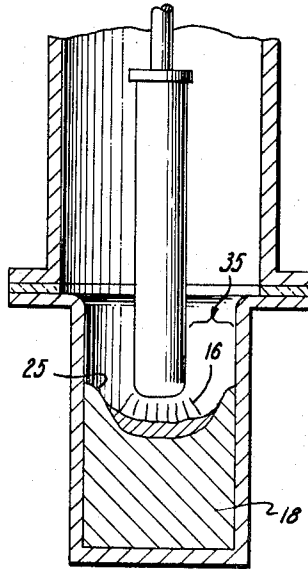


Fig. 5B.

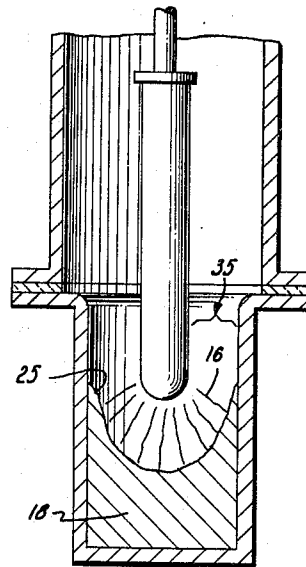


Fig. 5C.

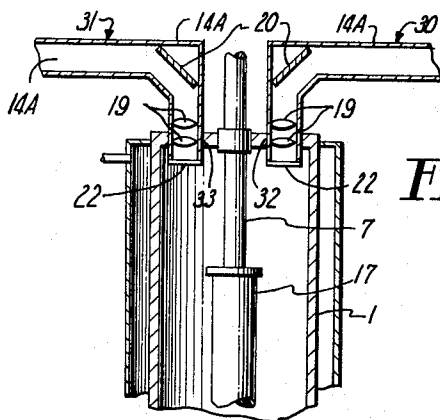


Fig. 4.

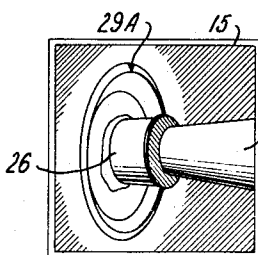


Fig. 4A.

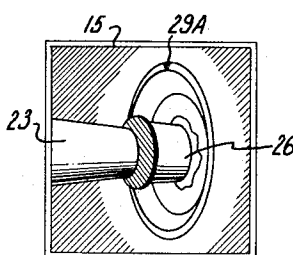


Fig. 4B.

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APPARATUS FOR VIEWING THE INTERIOR OF FURNACES

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Continuation of application Ser. No. 772,795, Nov. 10, 1958. This application Mar. 7, 1962, Ser. No. 179,508
Claims priority, application Germany, May 29, 1958, H 33,420

2 Claims. (Cl. 13—31)

This application is a continuation of our application Serial No. 772,795, filed November 10, 1958, and now abandoned.

The present invention relates to furnaces and more particularly to furnaces including means for viewing the interior of the furnaces.

In the past many furnaces for melting metals have been provided with windows located in the sides of the furnaces through which observation of the melting process is possible. The use of such windows is generally very inconvenient because of the high temperatures to which the observer is exposed. Furthermore, the vision through such windows is impaired by metal splashing and condensing onto the windows. While devices for cleaning the windows can be employed, such devices are expensive and difficult to maintain in an operating condition. Furthermore, observation through such prior art windows is possible only for relatively short times even when cleaning devices are employed.

The prior art observation windows have many other disadvantages, especially when employed in arc furnaces. For example, in arc furnaces the arc starts at the bottom of a water cooled crucible and moves gradually upward toward the top of the crucible during the melting process. Since the crucibles employed in many arc furnaces are more than eight feet long, observation of the arc during the entire melting process from the side of the furnace is impractical, if not impossible. The use of the observation windows in sides of vacuum arc furnaces is even more impractical because of the protective walls which generally enclose such furnaces.

To overcome some of the above disadvantages television systems have been employed in arc furnaces. Television cameras have been placed outside of the furnaces adjacent a window located close to the arc. This window is frequently covered with splattered metal and vapor which makes continuous viewing impossible. Furthermore, television cameras are sensitive to the magnetic and electric fields which exist in arc melting furnaces. Also, the television systems that have been employed do not reproduce a picture of the melting process in color since color television has not been considered practical for this purpose at the present time. Since the color of the arc and the molten metal within the crucible are very important in determining whether the arc is of the correct length and whether any parasitic arcs exist between the electrode and the side of the crucible, a black and white picture of the interior of an arc furnace is of little value.

The disadvantages of the prior art system for observing the interior of furnaces such as arc furnaces are overcome by the present invention in which an optical system is employed for permitting remote observation of the entire melting process in an arc furnace in true color

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without requiring continuous cleaning of a window in the furnace. The apparatus in accordance with this invention is arranged to project an image of a selected portion of the interior of the furnace onto an image-receiving screen or ground glass plate located at a remote operating panel for the furnace.

Optical systems per se for reproducing an image of the interior of an arc furnace at the control panel for the furnace have been considered impractical heretofore because of the distances between the window in the furnace and the control panel. Such distances may vary from sixty feet for small furnaces to one hundred feet for large furnaces. Because of the long optical path that is required there is a great loss of light energy. Furthermore, the amount of light energy that may be transmitted by such an optical system must be relatively small to prevent the sizes of the necessary lenses, mirrors and shutters, etc., and consequently their cost, from becoming impractical. For the above reasons, television systems have been used despite their great cost and other disadvantages.

It has been discovered that a purely optical system is feasible despite the loss of light energy occurring along the optical path of the system because of the high level of light intensity within the furnace. In accordance with the present invention, there is provided in combination with a furnace having a housing including at least one opening and a crucible for holding a molten metal secured to a bottom portion of the housing, an apparatus for permitting remote observation of the interior of the furnace including a light-transparent window secured to the housing and disposed over the opening therein, an image-receiving screen remotely located from the housing of the furnace and an optical system coupled between the window and the screen for projecting an image of a selected portion of the interior of the furnace onto the screen.

The invention will be described in greater detail in connection with the accompanying drawings in which:

FIG. 1 is an elevation, partially in section, of one embodiment of the present invention;

FIG. 2 is a sectional view of a furnace and optical system for use in the apparatus of FIG. 1;

FIG. 3 is a view taken along the line 3—3 of FIG. 2 showing schematically the field of observation;

FIG. 4 is a sectional view of a portion of a furnace and optical system in accordance with another embodiment of the present invention;

FIG. 4A is a schematic view of the field of observation through one of the optical systems of FIG. 4;

FIG. 4B is a schematic view of the field of observation through the other optical system of FIG. 4;

FIG. 5A is a sectional view of a portion of an arc furnace illustrating a relatively short arc length;

FIG. 5B is a sectional view of a portion of an arc furnace of FIG. 2 illustrating a normal arc length;

FIG. 5C is a sectional view of a portion of an arc furnace of FIG. 2 illustrating a relatively long arc length.

Referring now to the drawing and more particularly to FIG. 1 thereof, a vacuum arc melting system is illustrated as including a furnace housing 1 and a cover 2 secured to the top of the housing by suitable means. A vacuum conduit 3 is connected between the housing 1 and a vacuum pump 4. A crucible 5 is suitably secured to the housing 1 in a conventional manner to hold the molten metal and form an ingot. An electrode holder 7 is

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disposed through an opening in the top of the cover 2 and is secured at the lower end to an electrode to be described. The electrode holder is moved up and down by means of a motor 9 in a conventional manner. The motor 9 is secured to the top part of a supporting frame 10 which also supports the furnace housing 1 and the vacuum pump 4. Protective rails 11 are also carried by the support 10 to protect the operators when inspecting the apparatus.

The complete furnace and support 10 therefor is enclosed in a vault, indicated generally at 12, which includes protective walls 12A. An operating panel 13 is located outside of the vault 12 and controls all parts of the furnace in a conventional manner. To permit observation of the arc and the melting process from the location of the control panel 13, an optical system 14 is provided which projects a picture or image of a portion of the interior of the furnace onto an image-receiving screen to be described. The optical system 14 includes a cylindrical housing 14A which extends through floor members 14B, 14C and the wall 12A, as shown in FIG. 1.

Referring now to FIG. 2, the arc furnace of FIG. 1 is illustrated in section without the support 10 to more clearly illustrate the operation of the apparatus for permitting remote observation of the interior of the furnace. As shown, an electrode 17 is slidably disposed within the housing 1 by means of the electrode holder 7 which is secured to the electrode by welding or other suitable means. An arc 16 is formed by conventional means between the lower end of the electrode 17 and the metal or ingot 18 within the crucible 5 which includes a water cooling coil 5A. This melting process is observed in a direction approximately parallel to the longitudinal axis of the electrode 17 through the optical system 14. The cover 2 is provided with an opening 2A therein through which the optical system 14 enters. As shown, a vertical cylindrical housing 14A extends through the opening 2A and is sealed thereto by means of suitable vacuum seals. The optical system 14 includes a horizontal cylindrical housing connected to the housing 14A which extends through the wall of vault 12, and a depending vertical cylindrical housing exterior of the vault terminating in a short viewing tube at eye level adjacent the control panel 13. The optical system 14 also includes a plurality of lenses 19, mirrors 20, shutters 21 and a light-transparent window 22 for projecting an image of a selected portion of the interior of the furnace onto an image-receiving screen such as ground glass plate 15 at the end of the viewing tube. Such mirrors, lenses, shutters, etc., are well known in the art and a detailed consideration thereof is not deemed necessary here. The window 22 is secured in a vacuum tight manner to the end of the housing 14A that extends through the opening 2A in the cover 2. The window 22 is thus positioned a long distance from the arc and the molten metal within the crucible which substantially prevents metal from splashing and otherwise collecting on the window to impair the vision through the window. The direction of vision of the optical system 14 through the window 22 is parallel to the longitudinal axis of the electrode 17. This direction of vision has been found to be very advantageous in that it produces a picture of the interior of the crucible and of the melt that is forming. A control rod 19A is secured at one end to a cylindrical sleeve 19B which is slidably disposed within the housing 14A and secured to one of the lenses 19 as shown. The control rod 19A extends parallel to the optical system to a point adjacent control panel 13 and permits the focus of the optical system 14 to be changed by moving the rod 19A up or down as illustrated. Thus the optical system may be focused at different points within the interior of the furnace by merely adjusting the position of the control rod 19A.

Referring now to FIG. 3, there is shown a simplified view of the picture or image projected onto the ground glass plate 15. The shaded area of the picture represents

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the viewed area within the furnace that is not directly illuminated by the arc. As shown, the image 23 of the electrode rod 7 and the image 26 of the electrode 17 are oblique. The bottom portion of the image of the electrode 17 is surrounded by the image 24 of the inside wall of the crucible 5 and by the image 25 of the melt forming the top portion of the ingot 18. The image 27 of the arc 16 is shown only partially. It is simple to recognize parasitic arcs between the electrode 17 and the crucible 5 even if such arcs occur behind the visible portion of the electrode, since the reflection of the light created by the arcs is visible. The height of the space in a crucible which has not been fitted with metal is also easily recognized in the picture or image projected onto the plate 15.

It is particularly important that the edge of the crucible, which is a critical area, be accurately observed. Therefore, if the optical system 14 is arranged with a fixed focus, the system should be focused sharply on the upper edge of the inside wall of the crucible 5. The quality of the image of the arc burning lower in the crucible is impaired by such a focusing arrangement, but since the distance between the window 22 and the arc 16 is relatively great compared to the length of the crucible the blurring is tolerable. With the system as shown in FIG. 2, however, the focal length and focusing of the system may be changed mechanically by sliding the sleeve 19B and the single lens 19 secured thereto relative to the window 22. This has the advantage of always providing a clear image of the arc and the melt.

Referring now to FIG. 4, there is shown another embodiment of the present invention in which two optical systems, 30 and 31 are coupled to the cover 2 of the furnace 1 to provide two views of the electrode, the melt and the inside of the crucible. As shown, the cover in the furnace of FIG. 4 is provided with two diametrically opposed openings 32 and 33 for receiving the housings 14A of the optical systems 30 and 31 respectively. The optical systems 30 and 31 are similar to the one disclosed in FIG. 2 and include the same arrangements of window 22, lenses 19, mirrors 20, shutters 21 and ground glass plate 15. The images observed in each of the optical systems 30 and 31 are shown in FIGS. 4A and 4B respectively. The two optical systems permit observation of both sides of the interior of the furnace and thus permit the entire electrode and the portion of the arc extending laterally outwardly of the electrode to be seen in their entirety. A mark 29A indicating one point on the crucible is illustrated in each of the FIGS. 4A and 4B to show that the crucible electrode and the arc are viewed from both sides. It is very convenient, to unite the images FIGS. 4A and 4B in such a manner, that the looking person has the impression, to see the whole room around the electrode end.

Even though it may be impossible to observe the arc itself directly, the colors appearing in the furnace and projected clearly on the ground glass plate 15 allow very good evaluation of the arc length and the melting process. Molten, highly heated metals have usually a red, reddish-yellow or even light yellow color, whereas the arc in a high vacuum is usually blue.

A short arc is limited to a small area which is less than the area of the lower end of the electrode 17. This short arc is not visible on the plate 15 because of the image of the electrode 17. (See FIG. 5A.) A normal arc is larger or encompasses a larger area than the lower part of the electrode, so that it can be partially seen on the plate 15, whereas a very long arc produces a very intense blue light, filling most of the inside of the crucible that is observed on the plate 15. This characteristic of the arc is shown schematically in FIGS. 5A, 5B and 5C wherein FIG. 5A illustrates a short melting arc; FIG. 5B illustrates a normal melting arc and FIG. 5C illustrates a melting arc that is too long. The arc 16 produces, as mentioned above, a blue light, while the image 25 of the surface of the ingot 18 is generally yellow-red in color.

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The space between the electrode 17 and the inside surface of the crucible 5 is observed in the direction shown by the arrow 35.

In the three cases illustrated by FIGS. 5A, 5B and 5C, the picture on display on the plate 15 shows the following:

Fig. No.	Display on Plate 15	Comment
5A-----	The surface 25 of glowing ingot 18 only may be observed within the crucible. The color of the surface 25 is yellow.	The arc in this instance is too short and the ingot is not well melted on the outside.
5B-----	The outside surface 25 of the ingot 18 is solid and is observed as yellow in color. The inside surface of the ingot 18 is molten and also observed as yellow in color. A portion of the arc 16 is displayed in a blue color.	The length of the arc in this instance is adequate and the ingot 18 is well melted.
5C-----	Only the edge of the ingot 18 which is solid is visible and is displayed in a yellow color. Most of the inside of the crucible is displayed in a blue color indicative of the arc 16.	The arc in this instance is too long and the ingot 18 is not melted sufficiently to produce a sound ingot.

The evaluation is relatively easy to make and gives indications immediately as to what measures of adjustment have to be carried out, if any.

In FIGS. 3, 4 and 5, the surface 25 of the ingot is clearly visible and therefore it is easy to distinguish the molten part of the ingot from the solidified part. It can thus be easily observed if the ingot is molten through to the rim, if it is molten only in the center, if it is melted at all or if the melt is boiling too much. The apparatus of this invention thus permits a very accurate supervision of the melting process for the most advantageous melting conditions in order to obtain an ingot of the quality desired.

What is claimed is:

1. In combination with a vacuum arc furnace, including a frame supported on a floor, a vertical furnace housing of a height substantially in excess of that of a man carried by said frame including a top wall having a central opening and a laterally offset opening therein, an upwardly opening crucible in the base of said housing, an elongated consumable electrode disposed over said crucible with the longitudinal axis passing through the center of the crucible opening, means extending through said central opening in the top wall for lowering the electrode

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axially during the melting thereof, means forming an arc between said electrode and metal in the crucible, a protective wall surrounding said frame, and a furnace control panel outside said wall, an optical viewing system comprised of a vertical cylindrical housing extending through said laterally offset opening and vacuum sealed thereto, a light transparent window closing the end of said cylindrical housing within said furnace housing, a horizontal cylindrical housing extending from the top of said vertical cylindrical housing through said protective wall, a second vertical cylindrical housing depending from the end of said horizontal cylindrical housing exteriorly of said protective wall to a point substantially at the eye level of a man standing on said floor, a horizontally offset viewing tube extending outwardly from the lower end of said last mentioned vertical cylindrical housing adjacent said control panel, an image receiving screen closing the outer end of said viewing tube, and an optical system in said cylindrical housings and viewing tube comprising lenses and mirrors projecting an image of the interior of the crucible and the melt as it forms as seen from a direction parallel to the axis of the electrode on the image receiving screen at eye level adjacent said control panel, whereby an operator may view the melt and arc and control the furnace accordingly.

2. The structure of claim 1 wherein said first mentioned vertical cylindrical housing includes an internally positioned sleeve, one of said lenses being positioned in said sleeve, a control rod connected to said sleeve and extending parallel to said first mentioned vertical cylindrical housing, said horizontal cylindrical housing, said second vertical housing and said viewing tube to a point adjacent said image receiving screen whereby an operator viewing said screen may simultaneously focus said optical system.

References Cited in the file of this patent

UNITED STATES PATENTS

1,479,036	Fosdick	Jan. 1, 1924
1,614,466	Gearon	Jan. 18, 1927
1,952,927	Langmuir	Mar. 27, 1934
1,971,195	McKibben	Aug. 21, 1934
2,743,307	Johnson	Apr. 24, 1956
2,800,519	Garmy	July 23, 1957

FOREIGN PATENTS

343,960	Germany	Nov. 11, 1921
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