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METHOD OF GLASS MELTER ELECTRODE LENGTH MEASUREMENT USING TIME DOMAIN REFLECTOMETRY (TDR)

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DISCLAIMER

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METHOD OF GLASS MELTER ELECTRODE LENGTH MEASUREMENT USING TIME DOMAIN REFLECTOMETRY (TDR)

The present invention was conceived and developed under U.S. Government Contract No. DE-AC09-96SR18500 awarded by the U.S. Department of Energy. The Government has rights in this invention.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to measuring a consumable electrode length and, more particularly, the invention relates to measurement of the erosion of a consumable electrode in a joule heated vitrification melter using time domain reflectometry technology.

2. DESCRIPTION OF THE RELATED ART

In recent years, vitrification has become utilized as an approach to disposing of hazardous wastes and recycling glass manufacturing scrap. In this vitrification process molten glass is used as a binding agent for the hazardous wastes and then the mixture cooled for eventual, stable disposal.

Conventional glass-making furnaces are large refractory lined tanks using direct heat from gas burned in the furnace above the upper surface of a pool of molten glass. Electric glass furnaces have also been developed which heat vitrifiable material by application of electrical energy through the material, which is commonly referred to as Joule effect heating. Fluid flow in such a furnace is primarily convective flow. In either gas fired or electrically heated glass-making furnaces, only limited agitation, if any, of the glass bath is permitted so as to minimize formation of bubbles in the glass. Bubbles are generally undesirable in finished glass products.

The operation of a Joule-heated vitrification melter is dependent on the resistivity of the glass and the properties of the electrodes used to pass current through the glass/waste mix. The distance between the electrodes, the contact surface area and the glass affect the resistance. In the case where molybdenum is used as an electrode material, it chemically erodes and wears in time. As the electrodes wear, it is necessary to insert them further into the melter. The melter operator needs a guide or indicator of the electrode length in order to properly control melter operation. As this erosion takes place it affects the resistance of the circuit, and the resistance of this circuit can be measured by ratioing the applied electrode voltage and the electrode pair current.

However, due to the unknown and variable resistivity of the glass/waste mix, it is not possible to isolate the contribution of the physical characteristics of the electrodes to the resistance. If the electrodes become too short and are operated beyond their life, then there is a risk of eroding the refractory of the melter and causing the glass/waste mix to leak out.

The need therefore exists for a measurement apparatus and method to measure and determine the length and condition of the electrodes of a Joule-heated vitrification melter.

SUMMARY OF THE INVENTION

The present invention overcomes the drawbacks inherent in the prior art and solves the problems inherent in conventional Joule-heated vitrification melters, where the melter preferably comprises a vessel having a refractory liner and an opening for receiving material which is converted into molten vitreous material in the vessel. The vessel has an outlet port for removing molten vitreous material from the vessel. A plurality of electrodes is disposed in the vessel and electrical energy is passed between electrode pairs through feed material and molten vitreous material in the vessel. Typically, the electrodes erode and wear in time, and this invention seeks to monitor and evaluate the length and condition of the electrodes.

The present invention uses time domain reflectometry (TDR) methods to accurately measure the length of an electrode that is subject to wear and electrolytic decomposition due to the extreme conditions in which the electrode is required to operate. Specifically, TDR would be used to measure the length and effects of erosion of molybdenum electrodes used in Joule-heated vitrification melter. Of course, the inventive concept should not be limited to this preferred environment.

Time domain reflectometry (TDR) is a science of electromagnetic propagation. The principal of TDR is that the speed of an electromagnetic wave in a medium is a function of the dielectric constant of that medium. As discontinuities in the medium (and thus the dielectric) are seen along its length, the speed of the wave changes and reflections are created in the wave front. By capturing and analyzing the wave reflections, the TDR instrument will indicate the impedance versus time of the medium. Time and distance are directly related in the TDR display. Therefore, the instrument can directly measure the length of a waveguide or conductor. In this invention, an ordinary coaxial cable waveguide is extended to effectively include the melter electrode. The electromagnetic wave is carried along the coax and the electrode and reflects off of the end inside the melter and returns to the instrument. The length of the electrode is determined directly from the display of the TDR instrument.

TDR instruments are commercially available which are suitable for this application. The instrument and operator can be located in a control room environment away from exposure to the melter. Little or no modification is required for the melter to accommodate the method of measurement.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic cross-sectional view of a Joule-heated vitrification system including a consumable electrode as set forth in the present invention.

FIGS. 2a-2c present a schematic view showing the features of the present invention including a vitrification system and a TDR measurement apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to Figure 1, the vessel 10 is shown wherein electrodes 20 extend through sidewalls 11 of the vessel 10. The impeller 40 mixes the glass melt 15 to circulate the glass melt in the vessel 10 and thereby distribute the heated portion of the glass melt 15. The vessel 10 preferably has a metal shell 12 and a refractory liner 13. The metal shell 12 is often constructed as a liquid-cooled heat exchanger in order to regulate the temperature of the refractory liner 13.

According to the invention, the apparatus for vitrifying feed material includes a refractory vessel 30 having a plurality of electrodes 20 disposed in pairs in the vessel. The refractory lining or walls 13 preferably have alumina/zirconia/silica refractory bricks or chrome oxide refractory bricks having known electrical resistance. Other refractory material may be selected, dependent upon the composition of the glass being melted. The electrodes are spaced from the bricks sufficiently to minimize current flowing through the bricks. The electrodes are also positioned to minimize current flowing through the impeller 40, if an impeller is present. Refractory vessels are also advantageously used in vitrification of feed streams containing constituents which are highly oxidizing. Sodium nitrate is an example of such an oxidizing constituent.

If molybdenum electrodes 20 are used, exposure to oxidizers as well as the flow of the glass itself would result in unacceptable erosion of the electrodes 20. Commonly, water-cooled electrode holders 24 are used to shield the molybdenum electrodes 20 from erosion and reduce heat conduction.

Other vessel constructions may be used to incorporate the novel measurement apparatus and method set forth by this invention without departing from the spirit and scope of the invention set for herein. For example, the inclusion of an impeller is not necessary to the present invention. While certain vitrification melter have impellers, others do not. The present invention will work equally well whether the melter has an impeller or not.

The invention is shown in schematic form in Figures 2a through 2c, where a vessel 110 comprises flux brick walls 112 and refractory lining 113. The vessel is filled with a vitrification glass/waste mix (shown generally as 101). Electrodes 120 (preferably formed of molybdenum) are extended through the sidewalls of the vessel 110. As shown in Figure 2a, the electrodes 120 extend into the vessel 110 by a length of 'x' for the purpose of heating the mixture 101, whereas in Figure 2b the electrodes extend into the vessel by a length 'y' that is shorter than 'x'. Thus, the difference between the distance 'x' and the distance 'y' reflects the erosion of the electrode 120. Figure 2c schematically shows erosion of the electrode through the refractory lining 113 at point 114, in which case the glass/waste mix 101 may leak out of the containment vessel 110.

Figure 2c also schematically shows the TDR measurement system 210 applied to the Joule-heated vitrification melter of the invention. The erosion of the electrodes 120 is measured using any known and reliable TDR technique to ascertain the length of the electrode 120, and thereby determine the amount of electrode erosion.

There are many time domain reflectometry (TDR) devices available, and for illustrative purposes U.S. Patent No. 4,734,637 is hereby incorporated by reference to provide merely one type of system capable of performing the instant invention. However, those of skill in the art may provide any known TDR device with the system and method of the present invention to precise and quickly measure the amount of electrode erosion.

While the foregoing description provides a preferred embodiment and best mode of the invention, it will be understood by those of skill in the art that various changes in form and detail may be made without departing from the spirit and scope of the present invention. As set forth in the appended claims, the present invention uses time domain reflectometry (TDR) methods to accurately measure the length of an electrode pair that is subject to wear and electrolytic decomposition due to the extreme conditions in which the electrode is required to operate in Joule-heated vitrification melter.