METHOD OF MELTING METALS BY USE OF AN ELECTRIC FURNACE

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The present invention relates to methods of melting metals by use of electric furnaces, especially those metals having extremely high melting temperatures, such as tungsten. A specific application of our new method resides in the manufacture of tungsten carbide compounds and, although the invention will be described with that aspect in mind, it is to be understood that it is in no manner limited thereto.

In order to accomplish the melt successfully in the production of a commercial tungsten carbide alloy (referred to herein as simply tungsten carbide, since that is the predominant ingredient) it is necessary to carry out the final stages of heating very rapidly, which requires the use of equipment capable of a very high rate of energy or heat input to the furnace and charge. The rapidity with which tungsten absorbs carbon, and the large extent of radiation of heat from the crucible occasions the use of this high rate of heat input to reach the required melting temperature. It is further essential that this heat input be applied within exact time limits, since excess carbon makes the alloy too brittle.

An opposite condition is required during the preliminary stages of melting. If the heat were applied initially at the same rate as best suited for final heating, the material would be heated too rapidly, and much or all of the powdered charge would be blown out the vent holes of the crucible by the gases evolved by heating. By heating the charge at a lower rate, blowing can be prevented, because the gases would be generated over a longer period of time so that their escape would be less rapid and violent. In addition, blowing is materially reduced apparently by a preliminary sintering or alloying of the elements having lower melting points that binds the charge together into a more or less unitary mass. It is further believed that heating at a slow initial rate lowers the final melting point of the charge, this phenomenon resulting apparently from either an alloying of the solid tungsten, having a melting point of 3370° C., with the molten elements; or a pre-carburizing of the tungsten that forms a carbide of lower melting point than the tungsten alone, being about 2700° C.

The rates of initial and final heating must be made variable, being dependent upon several factors, including the weight of the charge, the elements contained therein, the proportions used, and the character of the resulting product.

To satisfy the above noted conflicting conditions of low initial heating rate, higher final heating rate, and variability in those rates, it has been necessary heretofore to provide expensive and complicated equipment capable of furnishing a current varying as the heat input requirements change from a low initial rate to a much higher final rate. These complications of equipment are normally attended by large power losses and poor electrical efficiency, conditions which are obviously undesirable. Additionally, if it is desired to permit flexible operation covering wide ranges in the rates of heating, the undesirable conditions are amplified by the necessity for additional expensive equipment.

Accordingly, it is an object of our invention to be able to utilize simple equipment in the process of heating the charge.

It is a further object of our invention to devise a method of using simple heating equipment in such manner as to heat the charge at different rates.

It is a further object of our invention to devise a method of using simple heating equipment, having a constant rate of heat input in such manner as to heat the charge at different rates.

It is a further object of our invention to devise a method of using simple heating equipment in such manner as to provide flexibility in the heating rates of the charge.

It is a further object of our invention to devise a method of operating an electric furnace in such manner as to provide variability at will in the heating rates of the charge.

It is a further object of our invention to form a tungsten carbide alloy by the use of simple heating equipment.

The manner of attaining the above and other objects of our invention can be understood from a consideration of the following description and annexed drawing, wherein:

The single figure is a side view of an electric furnace with the crucible shown between the electrodes.

The device illustrated on the drawing includes a supporting structure from which extends an upright. Mounted on the supporting structure is a lower electrode and pivotally supported by the upright is an upper movable electrode. This latter electrode is fixed to a plate parallel to the upright and pivoted at the point to a manually operable lever. The lever is pivoted to the upright by a pin, and the plate is connected to the upright by means of a link connected to the upright by the pin and to the plate by the pin. The above described lever and linkage arrangement constitutes a parallel motion device, with which the upper electrode...
can be moved parallelly in order to cause or break contact with the carbon crucible 12 placed on the lower electrode 3. The crucible includes a container for the charge 12a, a lid 12b engageable with the upper electrode, and one or more vents 12c through which gases may escape during heating.

Current is supplied to the electric furnace from a suitable source through the control switch 13 to the step down transformer 14, having a primary winding 15 and a secondary winding 16. From the secondary winding of the transformer flexible leads 17, 17' are connected to clamps 18, 18' and around the electrodes 3, 4 respectively.

With the main switch 13 closed, and with the apparatus in a position disclosed on the drawing, current will flow through the carbon crucible 12 and heat will be applied to the crucible and its contents. Upon moving the lever 7 upward, contact between the upper electrode 4 and the crucible 12 can be broken, and, consequently, the heat imparted to the crucible will be discontinued.

By intermittently manipulating the lever 7 so as to make and break contact between the upper electrode 4 and the crucible 12, current will be applied intermittently to the crucible, and the crucible will have heat imparted to it at intervals. If contact between the upper electrode and the crucible were maintained continuously for a fixed period of time, for a substantially constant current value a certain amount of heat would be imparted to the crucible and its contents. During an equal period of time, and with the same current value, if contact were to be broken at intervals, the time during which current would flow through the crucible would be less than the above named period. Therefore, less heat would be imparted to the crucible, and its temperature would not be raised to the same degree as when current was applied continuously during the period.

Accordingly, the rate of temperature rise of crucible 12 and its contents can be controlled with an approximately constant current supplied by the secondary winding of the transformer. All that is required is that the electrode make contact with the crucible for a relatively short period of time, and then such contact be broken for a period of time. Subsequently, contact will again be made, and this cycle of operation would be repeated until the desired temperature in the crucible is obtainable and the desired rate of temperature rise effected.

While the temperature at the outside of the crucible fluctuates because of radiation losses during the non-heating intervals, the temperature at the center of the charge increases at a substantially uniform rate, because the crucible walls become much hotter than the charge at the end of each heating period and heat is transmitted inwardly to the charge during the intervals between heating periods.

By intermittently making and breaking the circuit through the crucible, it is possible to use the simple electric furnace disclosed to control the rate of temperature rise and the final temperature reached. If it is desired to heat the crucible rapidly, contact between the upper electrode and the crucible would be maintained for longer periods and the breaking of the contact would occur for shorter periods. The converse would be true if the rate of heating of the crucible were desired to be less. It will be seen, therefore, that the manner of operating the electric furnace possesses flexibility to a high degree.

The apparatus and method of operation can be used in a variety of processes. For the purpose of illustration, we shall describe in detail a particular process of manufacturing carbide, which is typical of our improved process, though the process is no way limited to the manufacture of that particular product.

The charge of powdered metals includes primarily tungsten and small proportions of one or more of such elements as copper, molybdenum, or nickel, as well as a very minor amount, about 1% to 2% usually, of impurities inherent in commercial grades of those metals. The charge is put in the carbon crucible 12, which is placed between the two electrodes 3, 4.

As the heat is applied, the powdered charge is agitated by the evolution of gas as the impurities vaporize. The initial heating must be at a rate sufficiently low to prevent the gases from blowing the charge out the vents, since it is possible to blow an entire charge from the crucible by applying heat at an excessively high rate. By using the above described simplified apparatus, current is supplied to the electrodes at only one approximately constant rate, the rate of heating being controlled and reduced to any desired low value by applying the current intermittently for predetermined periods.

By way of example, a charge of about three pounds is placed in the crucible and a current of about 18,000 to 20,000 amperes at 20 volts is applied at the beginning of the preliminary heat period. The actual average rate of heating is but a small part of the maximum rate possible, since for a period of two minutes the current is applied for only one second out of each fifteen seconds. In between these one second periods of heating, the circuit is broken so that no heating takes place during the intervals. The circuit could be broken in any suitable manner or place, but for convenience we prefer to break it at the crucible by breaking the contact of one electrode with the crucible. After the first period of two minutes, the rate of heating is increased to one second in each ten seconds for a period of two minutes, and then again increased to one second in each seven and one-half seconds and maintained at this rate for one minute, followed by a further increase to one second in each five seconds for a period of one minute. At the end of the six minutes of preliminary heating a temperature of around 2,000° C. has been reached in the charge, and the impurities nearly all driven off as gases, so that blowing has nearly stopped. However, the vaporization point of the metals to be retained in the final alloy has not been reached, although practically all of the charge except the tungsten has become molten.

At the end of the preliminary heating period, the circuit is held closed continuously so that heat is applied to the crucible uninterruptedly until the tungsten has been melted and sufficient carbon absorbed from the crucible. This period of final heating will depend on many factors, but it is very critical as too much or too little carbon in the final alloy renders it incapable of practical use. As a rule, a charge of three pounds will require a final heating of between 40 and 60 seconds, with the final temperature being in excess of 3,000° C., and possibly reaching 3,500° C.

As the temperature of the crucible increases,
and as the charge melts, their decreased resistance increases the final current from the initial value of 18,000 to 20,000 amperes to a final figure of 20,000 to 22,000 amperes. Although some change in current during the melting process is inherent in any furnace, no variation in current is made in our process, except that necessarily accompanying the resistance change of the crucible and charge, which is caused by their temperature change. In view of this circumstance, the current used may be described as being of generally constant value.

By our method of operation, a very simple electric furnace can be used having no means of direct control of the current, and in which a charge of materials having different melting points can be fused, regardless of whether their melting points are high or low. The charge can be heated at a suitably slow initial speed with a current which is sufficient for the very rapid rise to extremely high temperatures necessary in making alloys of tungsten carbide. The average rate of heating is reduced by limiting the length of the heating periods, and any rate desired can be easily and immediately obtained by varying the time of the heating periods, or the length of the intervals between heating periods, or both. Thus, without expensive and complicated equipment, the method of operating the furnace is made flexible, adaptable to any needs, and fully under the control of the operator at all times.

Various changes may be made and still fall within the scope of our invention. Thus, the preliminary heating may involve any other number and combination of heating rates than the four described. Also, the current may be broken at any place, either in the primary or secondary circuits of the transformer, and the break may be accomplished manually or by automatic controls.

We claim as our invention:

1. The method of melting a charge comprising applying heat to the charge at a substantially constant rate by means of an electric current of substantially constant value, and intermittently interrupting the current to produce predetermined intervals of non-heat application by said current, said intervals being chosen to permit the temperature of the charge to increase progressively and being dependent upon the value of the current and the weight of the charge.

2. The method of melting a charge containing elements having different vaporizing and melting points, comprising applying heat to the charge by means of current of a substantially constant value, intermittently discontinuing said current, the temperature of the charge progressively increasing until it reaches a temperature at which the impurities are substantially all vaporized, but which is below the vaporizing point of any elements to be retained, and then applying said current continuously until all of the remaining elements of the charge are melted, the intermittent intervals being predetermined dependent upon the value of current used and weight of charge to be melted.

3. The method of forming a tungsten carbide alloy comprising placing a charge of tungsten and other substances in a carbon crucible, applying heat to the crucible by means of an electric current of substantially constant value, and intermittently discontinuing said current at intervals permitting the temperature of the charge to increase progressively, the intermittent intervals being predetermined dependent upon the value of current used and weight of charge to be melted.

4. The method of forming a tungsten carbide alloy comprising placing a charge of tungsten and other substances having different vaporizing and melting points in a carbon crucible, applying heat to said crucible by means of an electric current of a substantially constant value, intermittently discontinuing said current, until the charge reaches a temperature at which the impurities are substantially all vaporized, but which is below the vaporizing point of any elements to be retained, and then applying said current continuously until the remaining elements are melted and the tungsten has been alloyed with sufficient carbon absorbed from the crucible, the intermittent intervals being predetermined dependent upon the value of current used and weight of charge to be melted.

5. The method of melting high melting point substances together with vaporizable constituents which comprises charging the same in a crucible and passing a current of substantially constant value through the charge intermittently at first to permit venting of gases and continuously thereafter in order to obtain an initial slow progressive heating increase followed by a final desired high temperature heating to melt the charge; the intermittent intervals being predetermined dependent upon the value of current used and weight of charge to be melted.

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