

Aug. 11, 1959

W. J. SIEMONS
PURIFICATION MELTING PROCESS FOR METALLIC
CONSUMABLE ELECTRODES
Filed June 10, 1958

2,899,294

Fig. 1

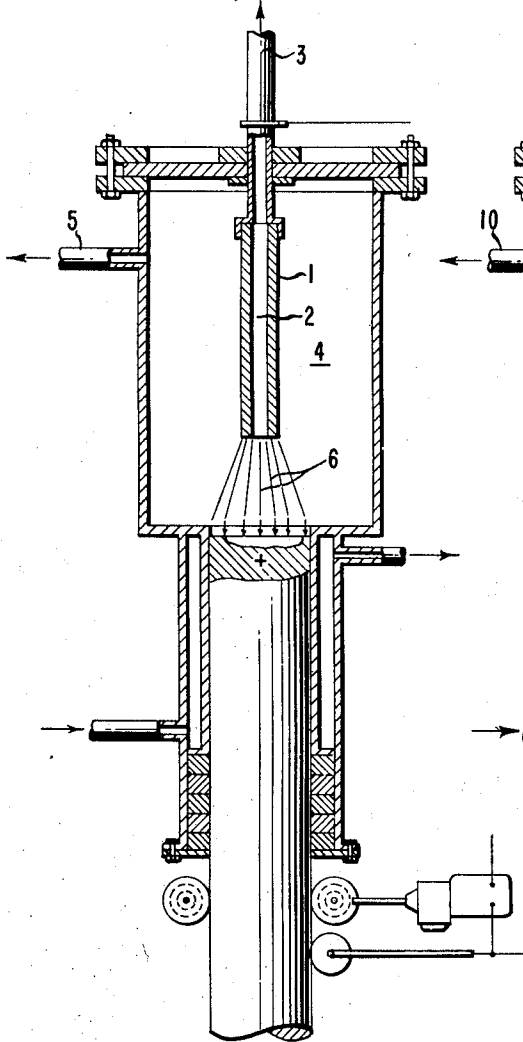


Fig. 2

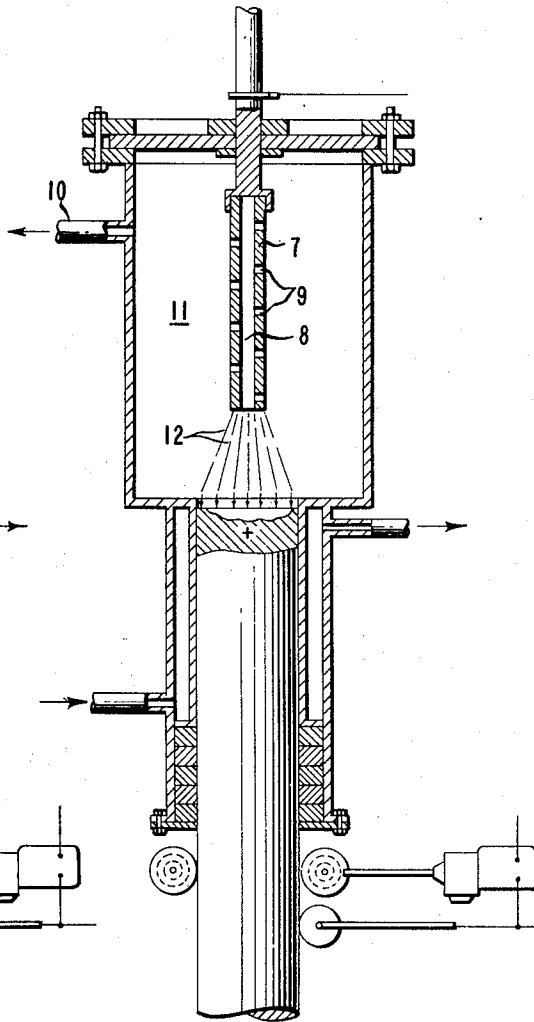
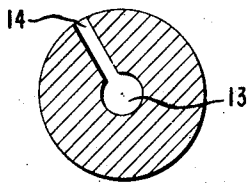


Fig. 3



INVENTOR
WILLEM J. SIEMONS

BY *James R. Morrison*

ATTORNEY

1

2,899,294

PURIFICATION MELTING PROCESS FOR METALLIC CONSUMABLE ELECTRODES

Willem Jan Siemons, Landenburg, Pa., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

Application June 10, 1958, Serial No. 741,048

6 Claims. (Cl. 75—10)

This invention relates to the process of consumable-electrode arc melting, and more particularly to an improvement in the process of arc melting for the consolidation or purification, or both, of high-melting point metals or alloys.

Consumable-electrode arc melting has found wide application in the metallurgical industry. It has proved to be of special value where the metals or alloys to be fabricated are highly refractory. Not only is consumable-electrode arc melting a convenient method for producing solid ingots from sponge, or from sintered or compressed material having voids or an undesirable shape, but this method of melting also provides a means for the removal of impurities which have a substantial volatility at the melting point of the feed material. In order to increase the rate of removal of such impurities, the arc melting operation is often performed under reduced pressure.

Certain phenomena associated with the operation of arc furnaces, however, tend to impair the efficiency of this method for the removal of impurities. One such phenomenon is the pressure which is built up in the arc during the operation of the furnace. This is the so-called arc plasma pressure which is believed to be caused, predominantly, by the magnetostriction of the arc. Each charge carrier in the arc produces a magnetic field, which field exerts a force on the other carriers, and this force is directed toward the axis of the arc. Although this force is exerted only on charge carriers, it will be transferred by collisions to the non-ionized entities in the arc plasma as well. One effect of this inwardly directed force is to inhibit the escape of the volatile impurities in the arc plasma, with the result that they are carried down with the melt from the consumable electrode.

It is an object of this invention to overcome this disadvantage of prior methods of consumable-electrode arc melting. A specific object is to provide a process for the purification of metals, including alloys, by consumable-electrode arc melting by which volatile impurities contained therein can be more efficiently and completely removed. Other objects and advantages of the invention will appear from the ensuing description.

According to this invention these objects can be realized by arc melting a consumable electrode of the metal, including alloys, to be purified while maintaining the internal section of the consumable electrode at a pressure lower than that prevailing at the center of the arc, and removing the volatile impurities through this area of lower pressure. This can be done by providing the consumable electrode with an axial bore, and connecting this bore to a vacuum pumping system. If the melting process is being carried out under vacuum, as is often the case, the axial bore of the electrode may be connected to a pumping system separate from that used to evacuate the main chamber of the furnace. It is essential that the pressure of the chamber connecting to the bore of the electrode be less than the pressure prevailing at the center of the arc. Alternatively, the electrode may be provided with one or more lateral bores in addition to

2

the axial bore, these lateral bores being either at right angles to, or slanting from the central bore, thus permitting the volatile impurities to flow via the axial bore through these lateral bores into the main chamber and to be removed from there.

To illustrate the operation of this invention, reference is made to the attached drawings showing a general form of apparatus which may be used. In Figure 1 the electrode 1 is supplied with an axial bore 2 which is connected to a vacuum pumping system (not shown) at 3. The main body of the chamber 4 may be supplied with an inert gas atmosphere or may be evacuated through 5. Whichever method of operation is preferred, the essential point of operation illustrating this invention is that the pressure within the axial bore 2 of the consumable electrode must be less than the pressure prevailing in the arc plasma at 6. An alternative form of electrode and method of operation is illustrated by Figure 2, where the electrode 7 having both axial 8 and lateral bores 9 is connected to a pumping system through 10 which is also used to evacuate the main chamber 11. The arc plasma pressure at 12 will provide the driving force for removal of the volatile impurities from the plasma via the central bore and lateral bores into the melting chamber where they will be removed by the pumping system.

It is possible to prepare the electrode itself by drilling a hole through a solid stock which has previously been melted, compressed, or sintered. Several such pieces may be connected to form one long electrode. If short portions be pressed from the material to be melted, each of these provided with an axial bore, and these short sections connected by spot welding, sintering, or other techniques, the desired electrode may be formed. A preferred technique for the formation of the electrode is illustrated by Figure 3. This figure illustrates a pressed or machined disc having not only an axial bore 13, but also an opening 14 extending from the axial bore to the periphery of the disc. When several such discs are connected co-axially by welding, sintering, or other techniques, these openings from the axial bore to peripheral surface will provide the electrode with the lateral bores described previously. It is also possible to lengthen an existing electrode by pressing additional sections onto it. This may be done in such a manner that an axial bore is obtained and, if desired, one or more lateral bores also.

To illustrate the operation of my invention further, the following Example is given. This is for purposes of illustration only and should not be construed as a limitation of the invention.

Example

A niobium electrode 22 inches in length by 1 3/4 inches in diameter was provided with an axial bore 1/2 inch in diameter, and with four 1/4 inch lateral bores per inch of ingot. The electrode was obtained by screwing together five individually machined arc-melted pieces of niobium. A furnace chamber similar to that disclosed in Figure 2 was evacuated to a pressure of 10⁻³ mm. Hg and the electrode was arc-melted into a 3 inch diameter ingot using a current of 2100 amps. The furnace chamber was maintained at substantially this reduced pressure level and the volatile impurities removed through the central bore and lateral bores to the main chamber where they were collected and removed. The hardness of the metal before melting ranged, at various places on the electrode, from 240 to 500 points on the Brinell hardness scale. The hardness of the 3 inch ingot produced was found to range from 180 to 380 points on the Brinell hardness scale, the measurements being taken at various places on the surface of the ingot. When melted under similar conditions, an ingot of

comparable hardness, but not provided with axial or lateral bores, produced an ingot of hardness ranging between 220 and 430 points on the Brinell hardness scale. It has been recognized by metallurgists that the hardness of niobium metal is dependent upon the presence of interstitial impurities therein. A discussion of the effect of oxygen in this respect is given in *Journal of Metals*, 1954, p. 774 (A. U. Seybolt).

By the practice of this invention advantage can be taken of a phenomenon of arc melting which previously had hindered the efficient operation of such a process. The force resulting from the magnetic field produced by the charge carriers in the arc, which force is directed towards the axis of the arc, creates a pressure which increases when going from the outside towards the center of the arc. This pressure will be highest at the axis approximate to the electrode of highest current density. The arc thus acts like a pump in producing in its center a pressure higher than that of the surrounding area. By maintaining the internal section of the electrode at a pressure lower than that prevailing in the arc, this pumping effect may be used to enhance the removal of volatile impurities through the internal section.

The values of the arc plasma pressure due to the magnetostriction phenomenon depend upon the dimensions of the electrode and upon the current being fed to the system. These values may be calculated by methods discussed by L. Tonks, "High Current Densities in Low Pressure Arcs," *Trans. Electrochem. Soc.* 72, 167 (1937), and by H. Maecker, *Z. Physik*, 141, 198 (1955). By providing one electrode with a bore, actual values for the plasma pressure can be determined which are in good agreement with theoretically calculated values.

While niobium metal has been used to illustrate a specific embodiment of the process, it is understood that the invention is equally applicable to consumable-electrode arc melting of metals and alloys in general in order to overcome the deleterious effects of the magnetostriction phenomenon. The invention is particularly suitable for the purification of refractory metals such as niobium, molybdenum, titanium, zirconium and the like as well as high-melting nickel and cobalt base alloys.

I claim as my invention:

1. The process for the purification of a metal, including alloys, which comprises arc melting a consumable electrode of said metal, said electrode having an axial bore through its length, maintaining the pressure within

said bore lower than that prevailing in the axis of the arc plasma during the melting operation, removing volatile impurities through said bore, and recovering the purified melt product.

2. A process for the purification of a refractory metal, including alloys, which comprises arc melting a consumable electrode of said refractory metal, said electrode having an axial bore through its length, connecting said axial bore to a space having a pressure lower than the pressure at the axis of the arc plasma, removing volatile impurities through said bore to said space, and recovering the purified melt product.

3. A process for the purification of a refractory metal, including alloys, which comprises arc melting a consumable electrode of said refractory metal, said electrode having an axial bore through its length and at least one communicating lateral bore, connecting said lateral bore to a space having a pressure lower than the pressure at the axis of the arc plasma during the melting operation, removing volatile impurities through said axial bore and connecting lateral bore to said space, and recovering the purified melt product.

4. A process for the purification of niobium which comprises arc melting a consumable electrode of said niobium, said electrode having an axial bore through its length, connecting said axial bore to a space having a pressure lower than the pressure at the axis of the arc plasma during the melting operation, removing the volatile impurities through said bore to said space, and recovering the purified niobium.

5. A process for the purification of molybdenum which comprises arc melting a consumable electrode of said molybdenum, said electrode having an axial bore through its length, connecting said axial bore to a space having a pressure lower than the pressure at the axis of the arc plasma during the melting operation, removing the volatile impurities through said bore to said space, and recovering the purified molybdenum.

6. A process for the purification of tantalum which comprises arc melting a consumable electrode of said tantalum, said electrode having an axial bore through its length, connecting said axial bore to a space having a pressure lower than the pressure at the axis of the arc plasma during the melting operation, removing the volatile impurities through said bore to said space, and recovering the purified tantalum.

No references cited.