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LOW FREQUENCY INDUCTION FURNACE

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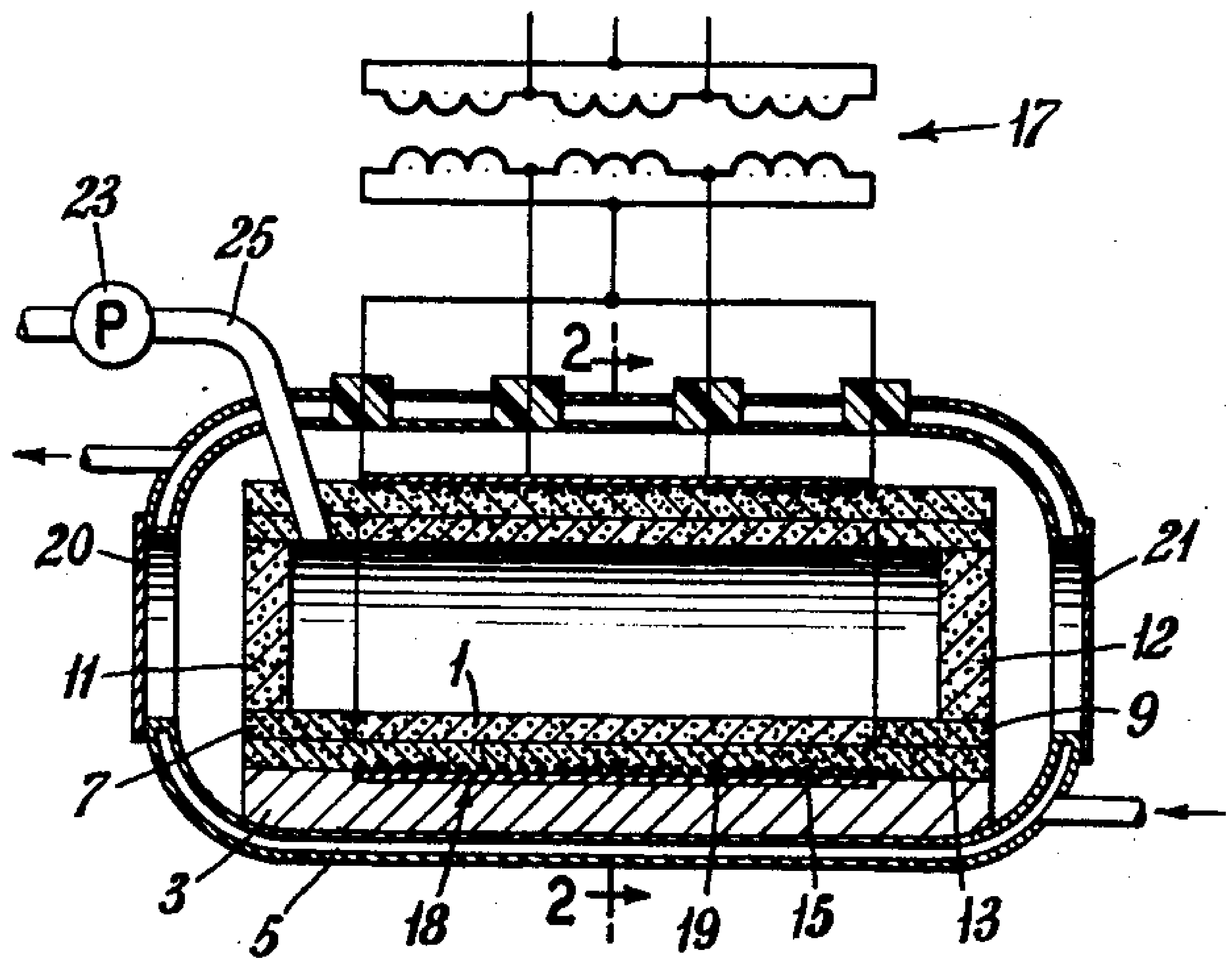

Fig. 1

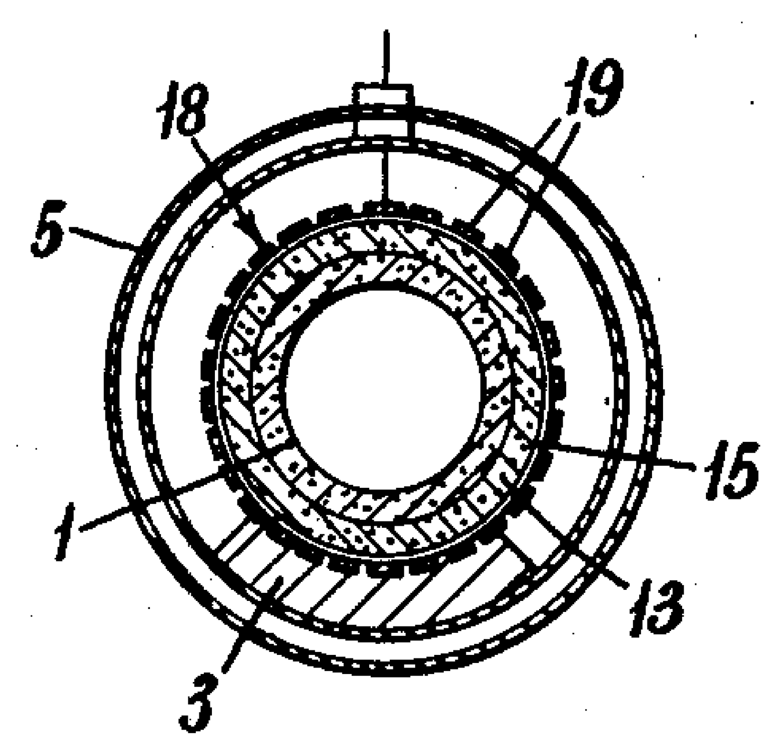

Fig. 2

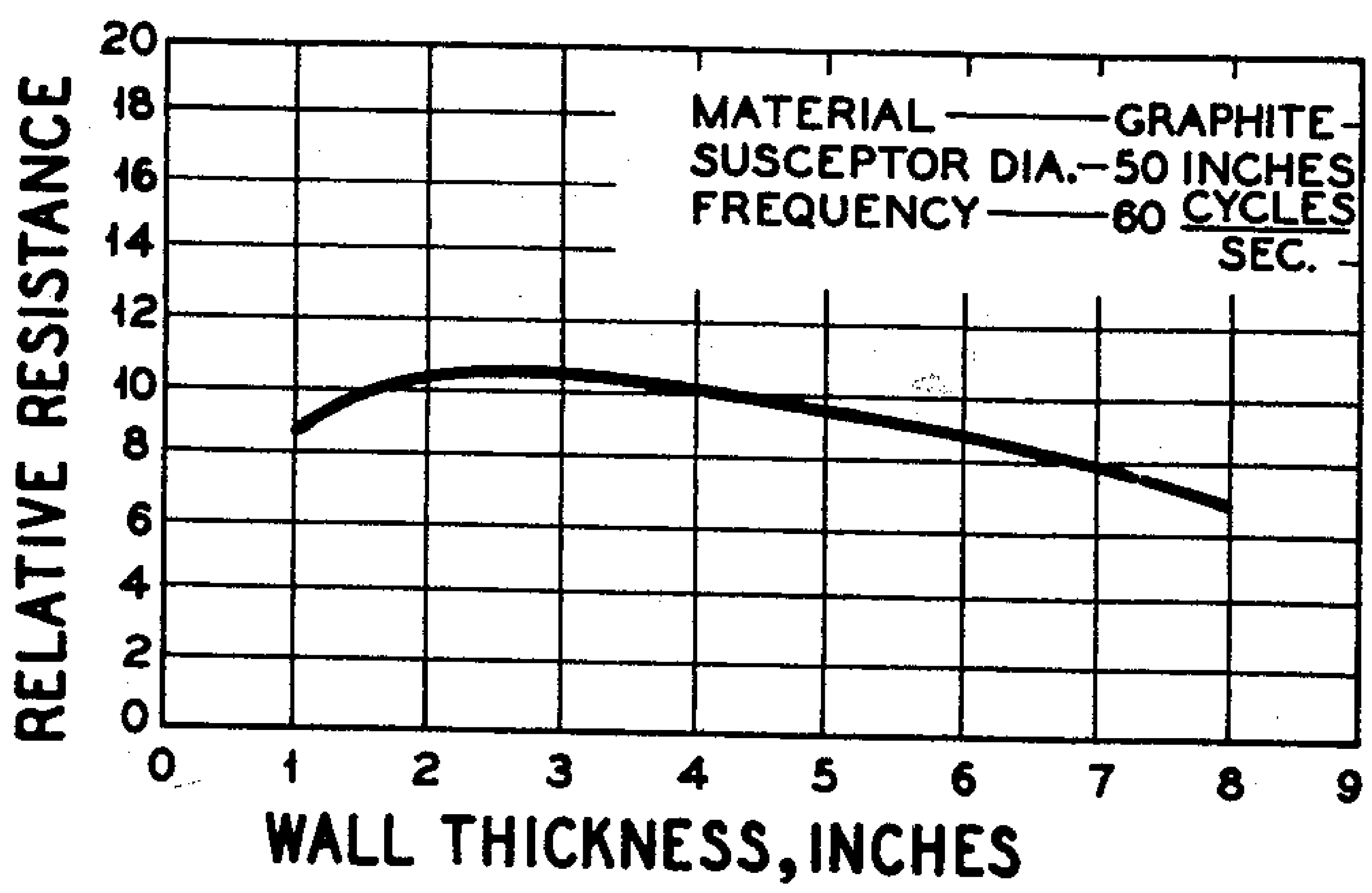

Fig. 3

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LOW FREQUENCY INDUCTION FURNACE

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The present invention relates to a novel induction furnace. More particularly the present invention relates to a high temperature, induction furnace which is operable at low frequencies.

While various types of induction furnaces are known to the art, most of these are energized by high frequency electrical current and for this reason are characterized by certain inherent disadvantages. A particular disadvantage is the necessity of providing accessory equipment which is capable of supplying the required high frequency electrical energy.

While low frequency induction furnaces avoid many of the disadvantages of high frequency operation, those low frequency induction furnaces which are presently known do not permit efficient operation at relatively high temperatures, i.e. up to about 2000° C.

Accordingly, it is an object of the present invention to provide a high temperature induction furnace which is efficiently operable at low frequencies.

It is another object to provide a high temperature induction furnace operable at low frequencies having a graphite susceptor with a relatively small wall thickness-diameter ratio and increased electrical efficiency.

These and other objects will be apparent from the following description and claims taken in conjunction with the drawing in which:

FIGURE 1 shows a sectional elevational view of a furnace in accordance with the present invention.

FIGURE 2 shows a sectional view along 2—2 of FIGURE 1 and,

FIGURE 3 shows a graphical illustration of the relationship of relative susceptor resistance to susceptor wall thickness at 60 cycles.

In accordance with the present invention an induction furnace is provided which is adapted to be heated by low frequency electrical currents and which comprises a closed hollow graphite tube for containing the furnace charge.

With reference to FIGURES 1 and 2 of the drawing, a hollow cylindrical graphite susceptor 1 is shown mounted on support 3 within an enclosing steel shell 5. The wall thickness of the graphite susceptor of the present invention is relatively thin, e.g. between about 2 inches and 4 inches. This reduced wall thickness, in addition to other benefits, provides increased furnace efficiency. The design of the susceptor of the present invention is described in more detail hereinbelow.

In the apparatus of the present invention the susceptor 1 is of any suitable length, usually about 6 to 10 feet, and is provided with adjoining carbon sleeves 7 and 9 and removable carbon plugs 11 and 12 which provide a means for the introduction and removal of the furnace charge. The mean diameter of the susceptor is greater than about 20 inches in order to obtain the increased efficiency and other benefits of the present invention.

A layer of thermal insulation 13, preferably carbon black, surrounds the susceptor 1 to prevent over-heating of the furnace elements exterior the susceptor. When the preferred carbon black is used, a layer of between about 1 and 6 inches is employed, with a 6 inch layer being provided for high temperature furnace operation on the order of 2000° C. Other suitable heat-insulating materials can be used, however thermatomic carbon is preferred due to its high bulk resistivity and non-reactivity with graphite. Inductor coil 15 concentrically surrounds the susceptor 1 and heat insulating layer 13 and when connected to a suitable low frequency source of electrical energy, such as transformers 17, inductor 15 causes thermal energy to be developed in the susceptor. Additionally a hollow cylindrically shaped magnetic shunt 18 is arranged concentrically surrounding inductor 15 and is arranged to be at least co-extensive therewith. In a preferred form, the cylindrical magnetic shunt is comprised of closely adjacent electrically insulated steel strips 19 arranged in close proximity to the inductor and parallel to the longitudinal axis thereof.

Steel shell 5, which is shown to be water-cooled, encloses the furnace and is provided with suitable fittings 20 and 21 through which the charge can be introduced and withdrawn from the furnace. Other materials such as copper and aluminum can be used in place of steel construction for shell 5. A suitable pump 23, connected through conduit 25 to the susceptor 1, is provided for controlling the atmosphere within the furnace, i.e. to evacuate the furnace to high vacuum conditions or, if desired, to provide an inert or reducing atmosphere within the furnace.

In the operation of the furnace of the present invention, a solid charge or melt is placed within the susceptor 1; inductor coil 15 is energized from the source of low frequency electrical energy, e.g. 60 c.p.s., and the desired atmosphere is established and maintained within the furnace. The magnetic field developed by the low frequency current flowing through inductor coil 15 is substantially contained in the space enclosed by magnetic shunt 18 and is intercepted by susceptor 1 to thereby provide a heat source for the furnace. The magnetic shunt 18, by substantially containing the magnetic flux developed by inductor 15, reduces heat losses and other adverse effects in the furnace structure and thereby improves the operating efficiency of the furnace. In the practice of the present invention it has been found that between 80 and 93 percent of the electrical energy supplied to the furnace is converted to thermal energy in the susceptor.

As mentioned above, the graphite susceptor of the present invention is designed to have a particular wall thicnkess. The graphite susceptor of the present invention is greater than about 20 inches in mean diameter having a wall thickness of between 2 inches and 4 inches. To provide optimum furnace efficiency the susceptor wall thickness is varied from about 4 inches for a diameter of about 20 inches to about 2 inches for a diameter of about 10 feet. Susceptor wall thickness is maintained at about 2 inches for diameter greater than 10 feet. A susceptor of 50 inch mean diameter constructed in accordance with the present invention has a wall thickness of about 2.5 inches.

The susceptor of the present invention, in addition to providing increased furnace operating capacity, also provides substantially increased furnace efficiency at high temperatures. The graph of FIGURE 3 illustrates the improved efficiency of a furnace in accordance with the present invention by showing the variation of relative susceptor resistance with susceptor thickness for a 50 inch diameter susceptor at 60 cycles. The efficiency of an induction furnace increases with increasing susceptor resistance. With reference to FIGURE 3, it can be seen that a 50 inch diameter graphite susceptor in accordance with the present invention, having a thickness of 2.5 inches, has a relative resistance of about 10.8; susceptors of 50 inch diameter having different wall thicknesses, have lower values of relative resistance. That is, maximum furnace efficiency is obtained by providing a susceptor in accordance with the present invention while a susceptor wall thickness other than in accordance with the present invention will result in reduced furnace efficiency.

Although the graph of FIGURE 3 relates to graphite susceptor having a 50 inch diameter, similar plots can be established for various susceptor diameters, from a minimum of about 20 inches up to almost any conceivable upper limit. Susceptors below about 20 inches in diameter do not provide the increased furnace efficiency and improved furnace operations which are obtained with larger susceptors.

Although the furnace of the present invention has been designed particularly for use with 60 cycle alternating current in view of the ready availability of the electrical power in this form, it has been found that other relatively low frequency power sources can be employed. For example, with graphite susceptors in accordance with the present invention having diameters of about thirty inches or more, the electrical efficiency is practically constant for frequencies between 30 and 180 cycles per second; with graphite susceptors having lesser diameters, a higher frequency (180 cycles) provides a somewhat greater efficiency than lower frequencies (30 cycles).

While the furnace of the present invention can be effectively employed in various metallurgical operation it is particularly suitable for the production of columbium, tantalum, vanadium, calcium metals, carbides and nitrides of the reactive metals, and boron carbide. A specific furnace of the present invention provided an operating temperature of 2000° C. at a pressure of below about 50 to 200 microns. The efficiency of the furnace was about 93 percent. In general, furnaces of the present invention having efficiencies greater than 90 percent can be readily provided.

What is claimed is:

1. A high temperature induction furnace comprising a tubular graphite susceptor greater than 20 inches in diameter and having a wall thickness of from 2 inches to 4 inches; coil means concentrically surrounding said susceptor being substantially coextensive therewith and being adapted for connection to a low frequency source of electrical energy; a cylindrical magnetic shunt closely adjacent to and concentrically surrounding said coil means and being at least substantially coextensive therewith; a thermally insulating layer of carbon black disposed between said magnetic shunt and said susceptor; a metal shell enclosing said coil, susceptor and shunt means and being adapted to permit introduction of charge material into said susceptor, said shell being formed of a material selected from the group consisting of copper, aluminum and steel; means for controlling the atmosphere within the furnace; and a low frequency source of electrical energy connected to said coil means.

2. A high temperature induction furnace comprising a tubular graphite susceptor greater than 20 inches in diameter and having a wall thickness of from 2 inches to 4 inches; coil means concentrically surrounding said susceptor being substantially coextensive therewith and being adapted for connection to a low frequency source of electrical energy; a cylindrical magnetic shunt closely adjacent to and concentrically surrounding said coil means and being at least substantially coextensive therewith; a thermally insulating layer of carbon black disposed between said magnetic shunt and said susceptor; a steel shell enclosing said coil, susceptor and shunt means and being adapted to permit introduction of charge material into said susceptor; means for reducing the pressure within said susceptor to below about 50 to 200 microns and for regulating the atmosphere within said susceptor; and a low frequency source of electrical energy connected to said coil means.

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