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HIGH TEMPERATURE FURNACE FOR TREATING REFRACTORY MATERIALS WITH METALS AND INTERMETALLIC COMPOUNDS

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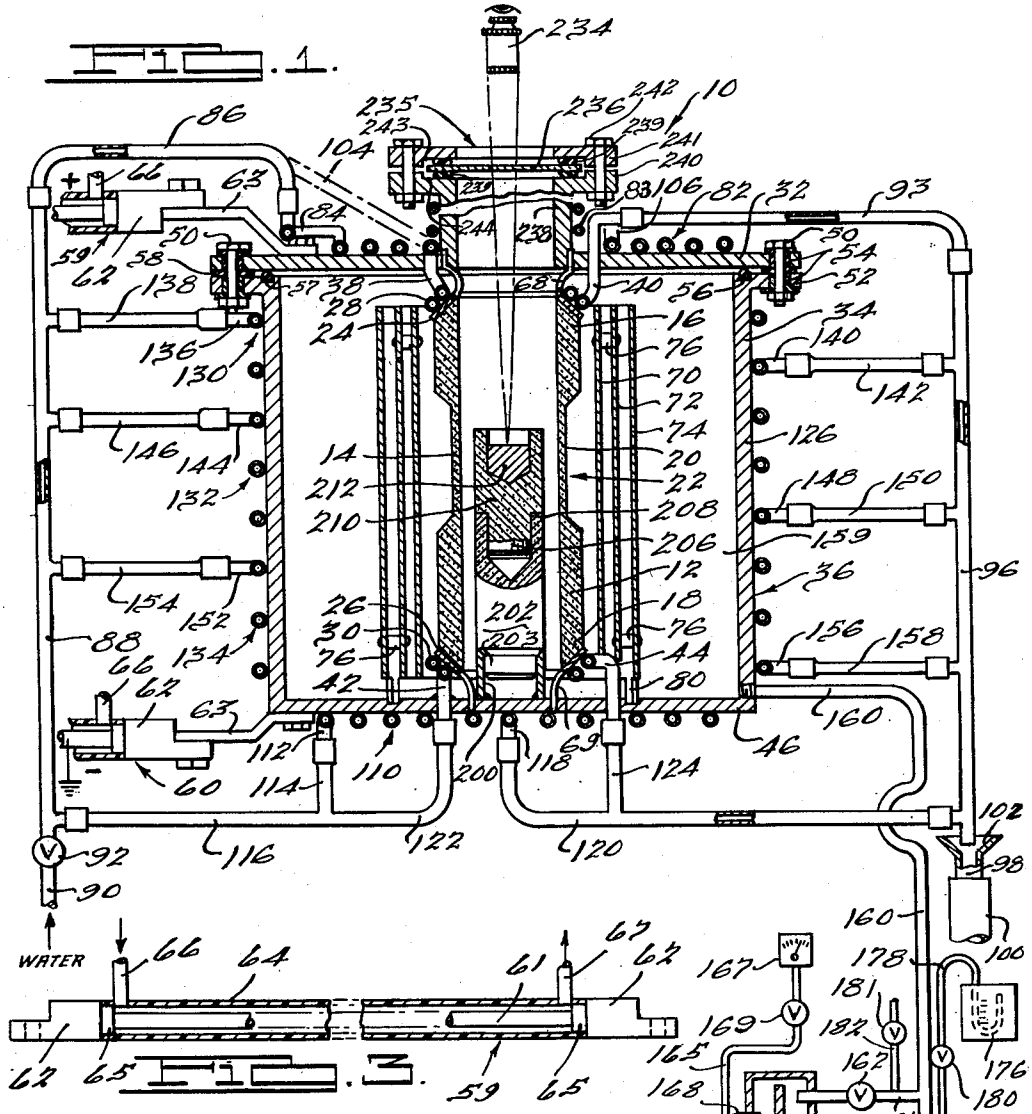


FIG. 1.

FIG. 3.

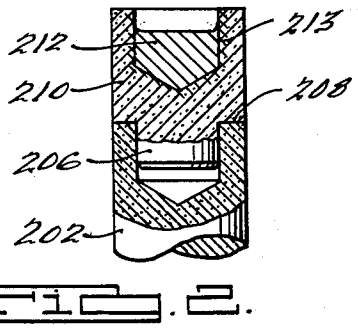


FIG. 2.

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HIGH TEMPERATURE FURNACE FOR TREATING REFRACTORY MATERIALS WITH METALS AND INTERMETALLIC COMPOUNDS

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This invention relates to apparatus for and a method of treating base materials especially of refractory character with metals, intermetallic compounds or alloys of metallic elements. It especially concerns an electric resistance furnace in which said treatment may be practiced.

In my copending application Serial No. 747,497 filed July 9, 1958, I have described a method and apparatus whereby structures made of forms of allotropic carbon such as graphite, may be treated with a metal chloride vapor which will react with the carbon to form a metallic carbide layer or diffusion barrier that will protect the underlying carbon from corrosion and other attack by metals of high melting point character which may be handled or carried by the carbon structure. The present invention provides a furnace equipment and procedure for determining the diffusion resistance and barrier capabilities of the carbide coatings of refractory structures for instance of graphite treated in accordance with the invention of my copending application. Moreover, it provides a method for obtaining a metallic carbide interface on carbon base objects by treating the same with a molten metal which is to form the carbide, i.e. the vapor of said metal.

A feature of the invention is the provision of a high temperature electric resistance furnace having a current conducting, carbon resistance member shaped to provide a high resistance zone wherein heat treatment will be at its optimum.

Another object is to provide a high temperature resistance furnace employing a current conducting carbon resistance structure resiliently mounted between opposite current conducting members of opposite polarity.

A further object is to provide a high temperature resistance furnace as in the preceding object wherein the resilient mountings are provided by helical current conducting tubular coils which may also serve to conduct a cooling medium for cooling the region of contact between the current conducting members and the resistance structure.

An additional feature is the provision of a high temperature resistance furnace in which a plurality of shielding elements are provided surrounding the resistance element for cutting down heat losses in the heating zone.

Still another object is to provide a high temperature resistance furnace that includes a casing and cover wherein each is provided with fluid conducting heat exchange elements secured to each thereof.

A further object is to provide a method for treating an allotropic carbon structure with a high temperature metal forming a carbide of the metal at the interface between the metal and the carbon.

Still another object is to provide a method and high temperature furnace for checking the surface penetration of allotropic carbon receptacles having a metallic carbide facing, with a high temperature refractory metallic compound or alloy.

Other objects and advantages of my invention will be evident from the following description and from the drawing illustrating without restriction my invention as applied to a graphite crucible.

In the drawings:

FIGURE 1 is a schematic arrangement of a preferred

form of the apparatus of my invention, certain elements being shown in section and certain elements for purposes of clarity being shown of greater dimensional size than others;

FIGURE 2 is an enlarged view of a form of allotropic carbon structure to be treated and showing the manner of supporting the same; and

FIGURE 3 is a view partly in section of the liquid cooled cable.

In the drawing, similar numerals have reference to corresponding parts of the structure.

Referring especially to FIGURE 1, the numeral **10** generally refers to an electrical resistance furnace comprising a central current conducting and heating structure preferably of graphite for instance a tubular current conducting resistance element **12**, such as a cylindrical graphite pipe to which current is supplied at its opposite ends in any suitable manner preferably as hereinafter described. This element **12** preferably has a central longitudinal portion **14** between its ends **16**, **18** formed, as by turning, with a wall **20** of reduced thickness to provide a preferred electrical resistance heating zone or path generally designated by the numeral **22** which is preferably of high resistance so as to provide a zone of high heat concentration. The element **12** is moreover preferably made of allotropic graphite having a density between about 1.6 to 1.9, the higher the density the greater the current and temperature produced for a given applied voltage.

The ends **16** and **18** of the resistance element **12** are preferably tapered to fit into contact with opposite current conducting resilient mounts in electrical connection with the source. These mounts comprise metallic conducting collars **24**, **26** for instance of brass, which in turn nest in and are welded, silver soldered or brazed to the largest turn of the conically spirally wound spring coils **28**, **30** which are constituted of tubular metal elements, the opposite ends of which extend through the cover **32** and casing **34** respectively of the metal housing **36**, as shown, and are secured as by welding, silver soldering or brazing thereto in a manner to provide a rigid support for the coils and gas tight joint without effecting the resilience of the latter and to make good electrical connections. Thus the ends **38**, **40** of the coil **28** extend through and are secured to the cover **32** and the ends **42**, **44** of the coil **30** extend through and are secured to the wall **46** of the casing **34**.

The coils **28** and **30** preferably have sufficient resilience to permit the current conducting structure such as the resistance element **12** to be releasably held between the collars **24**, **26** with good electrical contact being maintained between these parts and between the collars **24**, **26** and the coils **28**, **30**, which in turn have good electrical contact with the cover **32** and casing **36** respectively. It is a feature of the invention that the helical coils **28** and **20** serve as support or spring mountings and electrical conductors for the tubular element **12**. They also serve to accommodate expansion and contraction of the element **12** and preferably act as liquid coolant conductors in heat exchange relationship with the collars **24**, **26** for cooling these collars and the end portions of the element **12** adjacent the zone **22** as hereinafter described.

The cover **32** is suitably secured as by cap screws **50** to a flange portion **52** of the casing **34**. These cap screws **50** are suitably insulated as by plastic tubes **54**, which may be of "Tygon" insulation, from the metal of the cover. A circular rubber O-ring seal **56** is provided between the cover **32** and flange **52** which is preferably provided with an O-ring groove **57** to provide a gas tight seal. Teflon rings **58** may be placed inside or outside of the O-ring seal to minimize possibilities of short circuits between cover and casing.

Suitable electrical connectors generally designated by the numerals **59, 60** preferably made of heavy woven flexible copper cable **61** provided at their ends with solid copper terminals **62** and suitably liquid cooled as shown in FIGURE 2, are secured as by welding, silver soldering or bolting to extension straps or lugs **63** welded to the cover and casing respectively of the housing **36** and bring a high current of low voltage to the element **12**.

As seen in FIGURE 3 showing one of the connectors, **59, 60**, these are provided with flexible tubular sheaths **64** of synthetic plastic insulating material which are suitably cemented or sealed to shoulder portions **65** of the terminals **62**. The sheaths are of a size to provide a space surrounding the cables **61** to which liquid coolant such as water may be circulated; suitable side tubular inlet and outlet connections **66** and **67** being provided for this purpose to be connected to a source of coolant and drain respectively. These connectors **59, 60** are in turn preferably connected to an A.C. single phase saturable reactor and isolation transformer (not shown) the high voltage side of which is connected to a source of power. Using a 2" internal diameter 14-inch long resistance tube **12**, it is found possible to obtain temperatures up to about 4800° F. using the 9-volt output side of a 208 volt transformer at a current density of about 14 kw. By using a transformer with a 25-volt secondary, the temperature can be considerably higher up to 5500° and higher, the sole limitation being the vaporizing property of the carbon tube. In some cases due to the large current being conducted to the element **12**, it may be desirable to provide separate flexible copper conductors **68, 69** between the collar **24** and the cover **32** and between the collar **26** and casing **34** respectively.

Arranged within the casing and suitably surrounding the resistance element **12** in spaced relation thereto is a radiation shield structure for reducing heat losses in the critical area **22**. Such preferably comprises two or more inner tubular shields **70, 72** of a high melting point metal such as molybdenum or tantalum or other suitable refractory material of low emissivity (high reflectivity) arranged concentric with the element **12** and surrounded in turn by a single concentric stainless steel tubular radiation shield **74**. These shields may be connected together by suitable tie bars **76** or wire preferably of molybdenum or tantalum and secured to the base of the housing **36** in any suitable manner as by screws (not shown) secured through foot extensions **80** of the radiation shields. The outer shield may alternatively rest in a groove cut in the base **46** and be positioned and supported radially by the groove.

In addition to the coils **28, 30** for cooling the ends of the element **12** there is preferably provided a plurality of independent copper coils in heat exchange relationship with the cover **32** and casing **34** of the housing and which are secured to the respective parts of the housing preferably by welding or silver soldering. FIGURE 1 shows a spirally wound copper tube section generally designated by the numeral **82** mounted on the cover **32** of the housing and which has an outer end or coil **84** connected through a plastic tube **86** with a source of liquid coolant such as water from a copper pipe line **88, 90**, a suitable control valve **92** being located between the pipe sections **88** and **90** for controlling flow of the liquid coolant. The inner end of the section **82** is preferably connected to the end **38** of the copper coil **28** surrounding the upper end of the element **12**, the opposite end **40** of this coil being connected by suitable plastic piping **93**, and copper tubing **96, 98** with a drain **100**. A funnel **102** is provided below the lower end of the copper tube sections **96** to give visual indication of the outflow of liquid coolant. Thus it will be seen that liquid coolant entering at **84** will flow through the coils of the section **82** leaving at the inner end thereof and entering the coil **28** at the inlet **38** and flowing through the coil

28 leaving at the outlet **40** thereof and entering the drain section **92**. In certain cases it may be desirable to have the liquid coolant directly conducted from the input line **86** to the coil **28** inlet **38**. In that event a branch line **104** is provided between the plastic section **86** and the inlet **38** and a discharge outlet section **106** is provided between the inner coil of the section **82** and discharge outlet pipe **40**. Moreover, in order to inhibit deterioration of the sight glass gaskets **239**, the cooling coil section **82** will preferably be extended up or down the sight glass tube **238** as at **83** in which case the free end of this extension will connect with the end **38** of the coil **28** or with the outlet **106** as the case may be.

A similar heat exchange section generally designated by the numeral **110** may be provided against the base wall **46** of the housing. This section has its outer coil inlet **112** connected by copper or synthetic plastic tubing **114, 116** with the pipe line **88** to bring liquid coolant to this section. The innermost coil has an outlet **118** which in turn connects by a copper or synthetic plastic tube conductor **120** with the pipe line **96** and thereby to the drain **100**. An extension **122** of the inlet line **116** connects with the end **42** of the lower coil **30** supporting the element **12** to bring liquid coolant to such coil and the outlet extension **44** of the coil **30** is connected by a copper or synthetic plastic tubular section **124** with the discharge line **120** aforesaid. It will be understood that the section **110** and coil **30** may be interconnected as in the case of the upper coil **28** and section **82** to cause the liquid coolant to first traverse the section **110** and then the coil **30** and pass to the drain **100**. A coolant fed heat exchange section is also provided surrounding the body **126** of the housing **36**. This section preferably comprises two or more copper coil sections (three being shown) generally designated by the numerals **130, 132**, and **134** each mounted as by welding or silver soldering to the body **126** of the housing for the purpose of cooling the body of the furnace when required which is desired prior to opening the furnace to remove a specimen. This cooling also prevents deterioration of the cover gasket. The uppermost section has its inlet **136** connected by a copper or synthetic plastic connector tube section **138** with the pipe line **88** of the source of liquid coolant and has its discharge end **140** connected by a copper or synthetic plastic section **142** with the discharge line **96** of the drain. Similarly, the inlet **144** of the section **132** is connected by a tube **146** with the liquid coolant feed line **88** and its discharge outlet **148** is connected by a connector tube **150** with the drain line **96**. Similarly, the section **134** has its inlet **152** connected by a connector tube **154** with the liquid coolant feed line **88** and has its discharge outlet **156** connected by a connector tube **158** with the drain line **96**. It will thus be apparent that each section of the housing as well as the current conducting end supports of the element **12** are provided with heat exchange devices for conducting heat away from the furnace.

The interior chamber **159** of the housing **36** is connected by a pipe line **160** with a series arranged vacuum pump **164** and a diffusion pump **166** through a shutoff valve **162**, cold trap **163** and pipe **168**. A suitable vacuum gauge **167**, which may be of the "Phillips" ionization type is connected to the section **168** of the pipe line between the valve **162** and the diffusion pump **166** by a conductor **165** and is controlled by a valve **169**. When the shutoff valve **162** is open it is possible to exhaust the air from within the chamber **159** and to operate the diffusion pump **166** for conveying the gases out of the furnace to establish a lower relative pressure than the vacuum pump **164** alone could attain. The pipe line **160** is also connected by a section **170** through a valve **172** with a source **174** of inert gas such as helium or argon. To indicate the pressure in the line **170** a manometer or pressure gauge **176** is provided which is connected by a pipe **178** through a valve **180** with the pipe section **170**. Means for venting

the chamber **159** to atmosphere is provided by a valve **181** connected by a pipe **182** to the pipe line **161** between the chamber **159** and the valve **162**.

Interiorly of the element **12** there is preferably provided a tubular metal base or coupling **200** secured as by welding to the base **46** of the housing and on which may be supported a graphite pedestal **202** having an end portion **203** of reduced section which fits within the metallic support **200**. The upper end of the pedestal **202** preferably has a bore **206** forming a rim seat **208** for supporting an object or article to be treated with a high temperature boiling point metal. As seen in FIGURES 1 and 2, the object to be treated may for example be a graphite crucible **210** in which has been placed a quantity of a high boiling point metal **212** to effect such treatment. By preference a pedestal **202** of suitable length will be provided so as to position the crucible **210** and/or its contents preferably centrally, longitudinally of the wall **20**, so as to place the same in the maximum temperature zone **22** provided thereby. The crucible in FIGURE 2 is shown to have a metal carbide surface strata **213** previously produced in accordance with the teachings of my copending application Serial No. 747,497 aforesaid. It will be understood that the treating metal **212** may be placed directly into a carbon crucible that does not have the previously formed metallic carbide surfacing.

The conditions prevailing in the furnace may be visibly determined as seen in FIGURE 1 by sighting an optical pyrometer generally designated by the numeral **234** through a clear viewing piece generally designated by the numeral **235** secured to the upper end of the furnace. The viewing piece may be an elongated tubular member **238** which may be an extension of the cover **32** or may be a separate tubular structure attached to the latter and of minimum size at the cover **32** and maximum size at the viewing end. The viewing piece **235** has a heat resisting clear window **236** suitably mounted and sealed therein by suitable heat resisting gaskets **239** as of synthetic rubber, between a flanged portion **240** of member **238** and a bezel **241** through bolts and nuts **242**. As seen, the bezel **241** and flange portion **240** may be recessed as at **243**, **244** to receive the window and gaskets, the lower one of which is preferably an O-ring. By means of the window visible observations of the temperature existing in the working area of the element **12** will be determinable.

In operation of the furnace **10**, the article to be tested or treated, for example a crucible **210** made of carbon material such as graphite which is preferably pure and free of volatile materials such as hydrocarbons, is placed in the vacuum furnace as shown in FIGURE 1 and seated on the pedestal **202**. This crucible may have previously been treated in accordance with the invention in my copending application aforesaid to obtain a suitable carbide layer, for example a titanium carbide surface layer **213** or strata within the hollow of the crucible, in which case the crucible is to be treated by placing a quantity of pure uranium within the crucible. If the crucible **210** is of an untreated character, its cup portion may for example be provided with a mixture of zirconium and bismuth for the purpose of obtaining a zirconium carbide layer at the interface.

Whatever the treatment to be accorded the article, the furnace **10** is then sealed so that it will hold a vacuum. Valve **92** is opened to permit flow of coolant water to the coils covering the casing and head of the furnace and to flow to the drain **100**. Water also may be supplied to the cable sheathing inlets **66** to flow within the sheathing of the cables connecting the furnace terminals **63** with the transformer. The mechanical vacuum force pump **164** is then actuated and permitted to operate for several minutes or until the pressure at the inlet of the diffusion pump **166** reads between 100 to 500 microns of mercury absolute depending upon the type of diffusion pump employed or less if a McCleod or thermocouple gauge (not shown) on the same line as the ion gauge **167**. Heat is then turned on the boiler of the diffusion pump and the vacuum system allowed to pump the furnace down to an absolute pressure preferably in the range of 1–10 microns readable on the ion gauge **167**. It is generally found that a lower pressure than one micron is not required and it is preferred to get down to 10 microns or less in order to remove most of the air from the furnace so that the air will not react with the material to be treated.

As soon as the system is pumped down to 1–10 microns, the power supply is connected to the local power distribution feeder, for example, a 208 volt, single phase system. About 30 volts of direct current is then applied to the saturable core reactor (not shown) in the power supply system, thus allowing current to flow through the reactor and through the isolation transformer (also not shown) which is in series with the reactor. The secondary of the isolation transformer is preferably connected through the water cooled large wires or cables **59** to the furnace at **63** so that large currents depending upon the characteristics of the transformer can be carried at voltages to be selected, for example 2500 amperes at a voltage of about 9 volts. The characteristics of the transformer will determine the temperature obtainable in the furnace within the capabilities of the current conducting.

The current is now allowed to flow from the cover **32** through coil **28**, collar **24**, tube **12**, collar **26**, coil **30** and casing **46** of the furnace at a relatively low rate until outgassing of the crucible, metal and furnace parts subside to low rates. The outgassing is usually substantially complete by the time the furnace has reached a temperature between 2000 to 2500° F. If the grades of graphite used aforesaid are such as to contain considerable volatile matter, it can take as long as an hour to heat a 30 or 40 gram graphite crucible of such material to a temperature of between 2000 to 2500° F. without exceeding a pressure of 25 to 50 microns at the diffusion pump inlet. On the other hand, if certain kinds of graphite, for example a spectroscopic electrode grade of low volatile content, is used a whole furnace top weighing about 400 grams can be subjected to full power in one step without releasing enough gas to raise the pressure at the diffusion pump by more than a few microns, for example, 5 to 10 microns for a few seconds, for example 30 seconds.

It is preferred to complete the outgassing step at low temperatures to minimize reaction of the gases with the metal to be heated. Once outgassing has been completed as evidence by a steady pressure of about 1 to 5 microns, power is applied to the furnace by decreasing the direct current voltage on the saturable reactor until the metal and article are heated to a temperature at which the metal **212** will melt and vaporize. This will occur when the vapor pressure of the melt exceeds the residual pressure in the chamber. At a voltage of 9 volts on the transformer secondary and a current flow of about 3000 amperes the temperature in the furnace at the zone **22**, was about 4700 to 4800° F. At this temperature it was noted that the vapor pressure of the melt **212** exceeded the residual pressure in the chamber and there was some vaporization of the metal causing it to coat the inside of the resistance tube **12** with a carbide layer.

The furnace is allowed to run under desired power and predetermined temperature for about thirty minutes during which time the metal reacts with the hot object to produce a carbide interface if there has been no previous carbide layer on the inner surface of the crucible. Otherwise the metal should merely melt and/or vaporize. When the metal has been in molten condition for a sufficient length of time to carry out the desired coating at the interface or test on a previously coated crucible, the power is shut off and the power supply disconnected from the line. The furnace is then allowed to cool. Cooling may require from twenty to ninety minutes depending upon how vigorously cooling is supplied and how cool the treated part must be before withdrawal. After the furnace is cool, the valve **162** between the furnace and

the diffusion pump is shut, the vent valve 181 opened and air admitted to the furnace. The furnace is then unsealed by removing the top sight glass 236. The treated crucible 210 is then pulled out through the top sight opening.

The following examples will illustrate applications made of the furnace in connection with carbon crucibles.

Example I

A crucible previously provided with a smooth even and adherent coating of titanium carbide by the process of my copending application Serial No. 747,497 was placed in the furnace as shown in FIGURE 1. The furnace was first purged of air and other gases and a helium atmosphere admitted thereto at a pressure of 20 p.s.i. The crucible and coating were then subjected to repeated alternate cooling and heating cycles at temperatures of 700° F. to 2300° F. Cooling rates of 500° F. per minute were employed when lowering the temperature. The crucible and coating were subjected to 31 cycles of alternate heating and cooling after which the test was discontinued, there being no discernible change in the titanium carbide coating. This test established that thermal shock had no effect on the adherence of the titanium carbide coating to the carbon crucible and that it did not produce any change in the character of the coating.

Example II

A graphite crucible of the character of Example I having a titanium carbide coating on the interior face thereof was placed in the furnace conditioned with a helium atmosphere as described above in Example I after placing a quantity of uranium metal in the crucible. The crucible with its titanium carbide coating and uranium metal was heated to a temperature of 2300° F. and held at this temperature for four hours after which it was removed from the furnace. There was no evidence of any titanium carbide having been dissolved in the uranium. A number of tests of this character indicated that when the titanium carbide coating was thin some of the molten uranium penetrated the crucible wall to coat the exposed carbon and form uranium carbide therewith. Moreover that when the titanium carbide coating layer was of sufficient thickness it would serve as a complete barrier for preventing penetration of the molten uranium to the underlying graphite of the crucible.

Example III

A graphite crucible such as shown in FIGURE 1 and containing stoichiometric quantities of pure titanium sponge and carbon was placed in the furnace. The furnace was then purged of air and other gases and its temperature raised while being subjected to vacuum to a temperature of about 2900° F. sufficient to react the titanium and carbide to form titanium carbide. Test of the material indicated that it contained 99.7% pure titanium carbide.

Example IV

A three-gram sample of titanium carbide as prepared in Example III was placed in a crucible such as shown in FIGURE 1 containing uranium. The furnace was purged and then heated to 2400° F. and maintained at this temperature for four hours. During the heating, the uranium melted and the titanium carbide floated on the surface of the uranium. The furnace was thereafter cooled and a small fraction of the parent uranium removed for analysis. Analysis showed a maximum titanium content of 0.02%. This test demonstrated that the titanium carbide would not be broken down by heating in the presence of uranium.

From the foregoing description and examples, it will be evident that a novel furnace structure and method of treating refractory and other base materials with metals, intermetallic compounds and alloys of metallic elements has been disclosed according to which various resulting products may be obtained. It will be understood that numerous changes may be made in the details of construction, in the process steps and in the ingredients employed without departing from the spirit and scope of the invention as set forth above and in the appended claims. For example, the processes described are not limited to the metals disclosed but may be applied to other refractory metals such as tungsten, tantalum or chromium.

I claim:

1. A furnace comprising a housing defining a gas tight chamber having opposite wall portions electrically insulated from each other, passage means connecting with said chamber through which a gaseous medium may be moved to or from said chamber, electric current conducting resistance heating means within said chamber having an interior chamber for receiving means to be acted upon by said furnace and having opposite generally tapering ends, a pair of coaxial mounts for said heating means within said chamber and free of fixed connection with said heating means, said mounts being arranged and constructed to provide a seating member axially adjacent each of said ends of said heating means having a face substantially complementary in shape to said tapering ends of said heating means and coil spring means acting axially of said heating means to resiliently and releasably clamp the said ends of said heating means between said faces in electrical contact therewith, one of said mounts being structurally connected with one of said wall portions and including means providing an electric current conducting path between said heating means and this one wall portion, and the other of said mounts being structurally connected with the other of said wall portions and including means providing an electric current conducting path between said heating means and said other wall portion.

2. A furnace as claimed in claim 1 wherein both of mounts includes said resilient supporting means for said heating means.

3. A furnace as claimed in claim 2 wherein each of said resilient supporting means is in the electric current conducting path between said heating means and said wall portions.

4. A furnace as claimed in claim 1 wherein said heating means is a tubular graphite element.

5. A furnace as claimed in claim 1 wherein said heating means is a tubular graphite element having a layer of metal carbide over its interior surface in the region of said element in which said means to be acted upon by said furnace is to be positioned.

6. A furnace as claimed in claim 1 wherein said heating means is a tubular graphite element and wherein there is a pedestal supported on one of said wall portions interiorly of said tubular element.

7. A furnace as claimed in claim 1 wherein each of said mounts comprises an annular collar having the said seating face and interengaged with said heating means, and a cooling coil interengaged with said collar.

8. A furnace as claimed in claim 7 where the means providing the electrical current conducting path between the heating means and the chamber wall portions comprises said collars and cooling coils of said mounts.

9. A furnace as claimed in claim 7 wherein the means providing the electrical current conducting path between the heating means and chamber wall portions comprises said collars and electrical conductors extending between said collar and wall portions around said cooling coils.

10. A furnace comprising a housing defining a gas tight chamber having opposite wall portions electrically insulated from each other, passage means connecting with said chamber through which a gaseous medium may be moved to or from said chamber, electric current conducting resistance heating means within said chamber having an interior chamber for receiving means to be acted upon by said furnace, a pair of supporting mounts for said heating means and between which said heating means is nested, each of said supporting mounts comprising a frustro conical support member for receiving an end portion of said heating means and a helical cooling coil mounted on and

in electrical contact with one of said wall portions and in electrical contact with and in a resilient supporting relation with said support member, and a pair of electrical conductor means for electrically connecting said wall portions of said housing with a source of electrical power for passing electric current through said wall portions, supporting mounts and heating means for heating the interior chamber of said heating means.

11. A furnace as claimed in claim 10 including at least one heat radiation shielding structure surrounding said heating means.

12. A furnace as claimed in claim 11 including means for establishing and maintaining a vacuum in said furnace.

13. A furnace as claimed in claim 10 wherein said electrical conductor means includes a fluid tight sheathing in non-electrical conducting relationship with said conductor means and providing a fluid containing space for receiving coolant fluid for cooling said conductor means.

14. A furnace comprising a housing defining a gas tight chamber having opposite wall portions electrically insulated from each other, passage means connecting with said chamber through which a gaseous medium may be moved to or from said chamber, electric current conducting resistance heating means within said chamber having an interior chamber for receiving means to be acted upon by said furnace, and a pair of mounts for said heating means and between which said heating means is nested, one of said mounts being structurally connected with one of said wall portions and providing an electric current conducting path between said heating means and this one wall portion, and the other of said mounts being structurally connected with the other of said wall portions and providing an electric current conducting path between said heating means and said other wall portion, each of said mounts including means providing a resilient support for said heating means relative to the wall portion with which such mount connects, said resilient supports being in the electric current conducting path between said heating means and the wall portion with which the mount connects and said resilient supports each comprising a cooling coil.

15. A furnace comprising a housing defining a gas tight chamber having two wall portions electrically insulated from each other, passage means connecting with said chamber through which a gaseous medium may be moved to or from said chamber, electric current conducting resistance heating means within said chamber having an interior chamber for receiving means to be acted upon by said furnace, a pair of generally coaxial electric current conducting support elements engaged with opposite ends of said heating means so to clamp said heating means between them, a cooling coil secured to and in electrical conducting relationship with one of said wall portions, said cooling coil also being an electrical conducting engagement and resilient supporting relationship with one of said pair of support elements, another cooling coil secured to and in electrical conducting relationship with the other of said two wall portions, said other cooling coil also

being in electrical conducting engagement and resilient supporting relationship with the other of said pair of support elements, and current conducting means connecting with said wall portions for conducting electrical current through said wall portions, cooling coils, and support elements to said heating means.

16. A furnace as claimed in claim 15 wherein each of said ends of said heating means has a straight tapered portion which interfits with a complementary tapered face on its associated support element, and wherein the cooling coils are helically wound to a conical shape and the support elements have outer tapered surfaces which interfit with a plurality of turns of the cooling coil.

17. A furnace comprising a housing defining a gas tight chamber having opposite wall portions electrically insulated from each other, passage means connecting with said chamber through which a gaseous medium may be moved to or from said chamber, electric current conducting tubular resistance heating means within said chamber providing an interior chamber for receiving means to be acted upon by said furnace, and a pair of mounts one at each end of said heating means and between which said heating means is releasably and resiliently clamped, one of said mounts being structurally connected with one of said wall portions and providing an electric current conducting path between said heating means and this one wall portion, and the other of said mounts being structurally connected with the other of said wall portions and providing an electric current conducting path between said heating means and said other wall portion, each of said mounts comprising a cooling coil and at least one of said cooling coils comprising resilient means providing a resilient connection for said heating means relative to the wall portion with which such mount connects.

References Cited in the file of this patent

UNITED STATES PATENTS

1,279,146	Peacock	Sept. 17, 1918
1,338,624	Heppes et al.	Apr. 27, 1920
1,513,890	Bryan et al.	Nov. 4, 1924
1,620,940	Bleeker	Mar. 15, 1927
1,700,942	Lederer	Feb. 5, 1929
1,858,062	Ruckstahl	May 10, 1932
1,981,015	Williams	Nov. 20, 1934
2,265,821	Siegel	Dec. 9, 1941
2,355,343	Von Zeerleder	Aug. 8, 1944
2,394,479	Priessman	Feb. 5, 1946
2,404,060	Hall et al.	July 16, 1946
2,756,166	Alexander et al.	July 24, 1956
2,768,277	Buck et al.	Oct. 23, 1956
2,778,866	Sanz et al.	Jan. 22, 1957
2,790,840	Simmad et al.	Apr. 30, 1957
2,798,108	Poland	July 2, 1957
2,969,448	Alexander	Jan. 24, 1961
2,971,039	Westeren	Feb. 7, 1961
3,009,974	Sekkelsten et al.	Nov. 21, 1961