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VACUUM FURNACE

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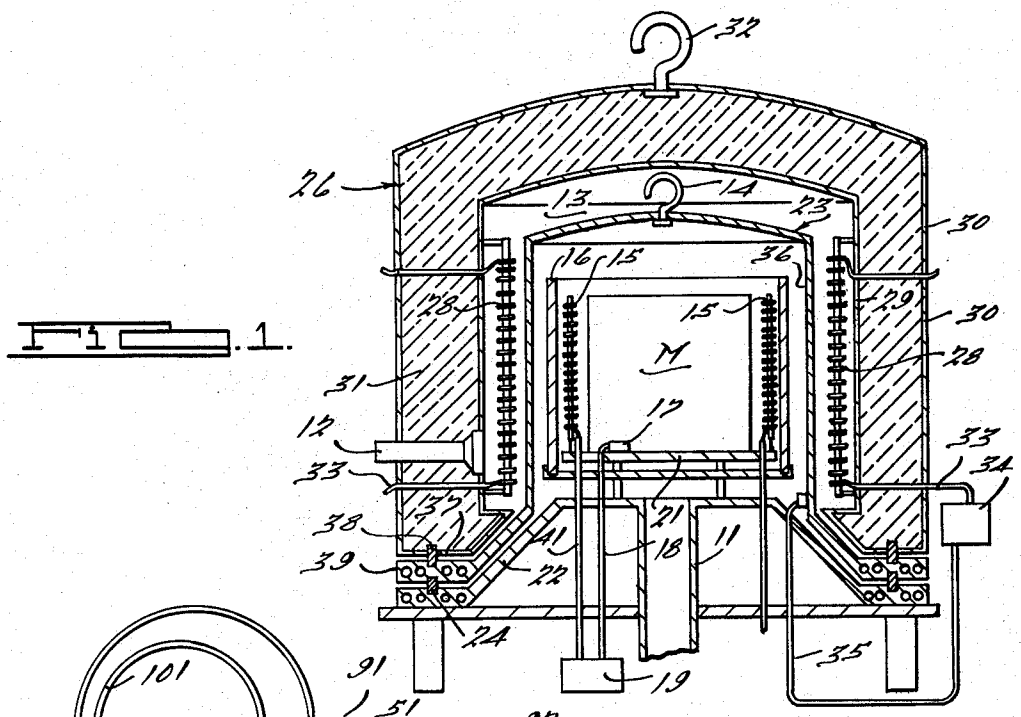


FIG. 1.

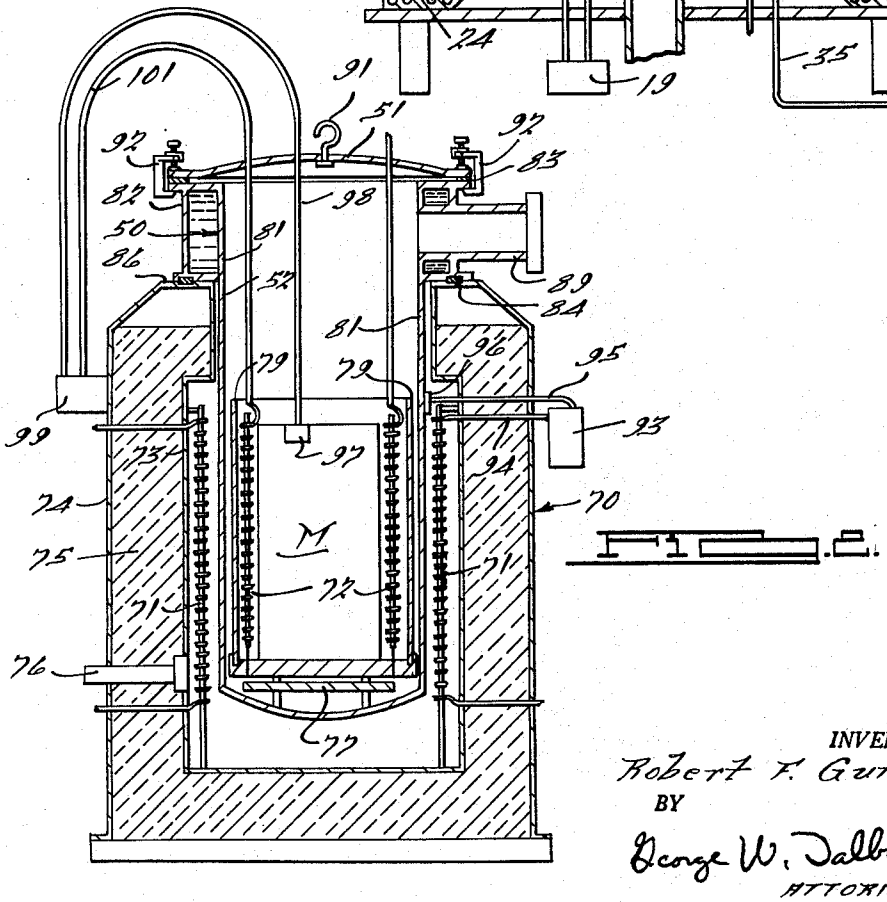


FIG. 2.

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VACUUM FURNACE

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This invention relates to vacuum furnaces and particularly to the heater arrangements therefor.

It is a primary object of this invention to provide a vacuum furnace design utilizing primary and secondary heating means arranged and controlled in a novel manner such that improved efficiency and output as well as improved range may be achieved.

It is still another object of this invention to provide an improved heater arrangement for vacuum furnaces, or the like, in combination with burner baffle means such that maximum efficiency and output is obtainable.

It is a further object of this invention to provide a furnace of the disclosed type having primary heaters within the retort or chamber, and secondary heaters outside the retort or chamber with suitable control means for the secondary heaters to control the temperature of the retort walls and other control means for the primary heaters to control the temperature of the load material.

It is still another object of this invention to provide an improved type of vacuum furnace that is of a simplified, economical construction having an improved efficiency and operating range.

Other objects and advantages of this invention will be apparent from a reading of the following description and a consideration of the related drawings wherein:

FIG. 1 is a sectional elevational view of a bell-type electrically heated furnace embodying this invention; and

FIG. 2 is a sectional elevational view of a pit-type electrically heated furnace embodying this invention.

The demand for high performance materials, particularly in the aircraft and guided missile industries, has placed an emphasis on new processing techniques. The use of vacuum furnaces in metallurgy has evolved from the search to develop methods of processing these materials. Few metallurgical techniques have grown in popularity as rapidly as the use of vacuum operations.

It might be well to review two principles of physics and physical chemistry that have an important bearing on vacuum operations. First all metals have a definite vapor pressure even at room temperature. Second, compounds have definite dissociation pressures at a given temperature.

Vapor pressures of pure metals are higher than that of solid solutions. This fact permits at elevated temperatures and high vacuums the processing of alloys containing relatively high vapor pressure elements without loss of alloying constituents. Manganese and chromium are two widely used alloying elements. In the pure state and at temperatures of 1590° F., manganese has a partial pressure of .76 micron of mercury. Chromium has a partial pressure of .76 micron of mercury at 1970° F. However, even at pressures as low as .1 micron of mercury and at these temperatures, there have been no reports of a serious loss of these elements from commercial alloys.

The fact that compounds have definite dissociation pressures at a given temperature may be used to advantage. Most nitrides and hydrides have relatively high dissociation pressures at moderate temperatures. The vacuum pressures and temperatures are within the range of commercial furnaces. Consequently degassing in the solid state is a practical method of purifying contaminated materials.

Most oxides have rather high dissociation pressures.

An example is iron oxide, which has a dissociation pressure of 10^{-8} microns of mercury at 1700° F. Where the dissociation pressure of oxides is relatively low, vacuum operations may be used to dissociate the oxides and purify materials in the solid state.

Although most commercial furnaces are not operated at the extremely low pressures required to dissociate oxides, the deoxidizing of surfaces may take place by vaporization of oxide films. Many metallic oxides are vaporized at temperatures and pressures within the limits of commercial operations. The end result is quite similar to the cleaning action of reducing atmospheres. Oxidized 302 stainless steels, for example, can be cleaned in a vacuum. 302 stainless sheet stock, dark in appearance before treatment, will be bright after processing in a 2100° F. and one-half micron of mercury furnace cycle.

Vacuum furnaces designed for these services may be either gas heated or electric heated. The three essential requirements are a heating source, a sealed chamber or retort, and a pumping system. Parts to be processed are placed in a chamber or retort. The retort or chamber is evacuated and the heat applied. With gas heated furnaces, the whole chamber is heated with exterior burners. With electric furnaces there is a choice between placing the heating elements inside the retort or placing the heating elements outside the retort or, as disclosed in this improved type of vacuum furnace placing the heating elements both inside and outside of the chamber or retort and controlling the heating elements in a novel manner to improve the operation and efficiency of the furnace as well as the heating process.

Although heating is usually accomplished only by radiation, temperature uniformity in the hot zones of these vacuum furnaces is surprisingly good. It is not difficult to obtain the minimum uniformity required by Government agencies for certification.

Furnaces may be further divided into three categories; vertical furnaces in which the retort is placed into a pit (see FIG. 2); bell-type vertical furnaces in which the furnace is placed over the retort (see FIG. 1); and horizontal furnaces which are not directly concerned with this invention. Horizontal vacuum furnaces generally have a stationary retort. Material to be heated is loaded on trays or fixtures for positioning in the furnace hot zone. The horizontal furnaces are closely patterned after the atmosphere muffle equipment used for many years. The sequence of operations in a horizontal furnace is much the same as that to be outlined for the other furnaces herein described.

Bell furnaces are of the type shown in FIG. 1. Material M to be processed is placed on stand **21** on a base **22**. The retort **23** is lowered over the load M and onto the base **22**. A water-cooled seal **24** between the retort **23** and base **22** prevents atmosphere leakage into the retort **23**. The retort **23** is evacuated and the heating chamber **26** positioned over the retort **23**.

An advantage of bell furnaces is that once the parts to be processed are placed in position, there is little danger of the parts overturning. With vertical pit furnaces (see FIG. 2) there is always the possibility of overturning the parts assemblies in transfer of the retort into and out of the furnace pit. Pit furnaces, on the other hand, are less expensive and more easily installed than bell furnaces.

In bell designs, the furnace **26** is lifted from the retort **23** during cooling cycles, while in pit designs the retort **50** is removed from the furnace **70** during this part of the cycle. Cooling time depends upon the nature of the load. Heat is removed almost entirely by radiation when the load is kept under vacuum during cooling. A three to five hundred pound load will normally cool from 2000°

F. to 300° F. in about four hours. The introduction of an inert atmosphere at a temperature below the efficient radiant range shortens this cooling time by providing convection cooling.

With the pit furnaces (see FIG. 2) the retort **50** is removable and loading may be accomplished with the retort either in or out of the furnace **70**. The material M to be processed is placed in the retort **50** by means of a loading platform (not shown). A cover **51** is placed over the top opening to seal the retort **50** from the atmosphere. To protect the inner walls **52** of the retort **50** from oxidizing, the retort is never placed in a hot furnace heating chamber without first evacuating the retort.

There are, of course, many variations to the three basic designs for vacuum furnaces. Addition of cooling chambers, location of vacuum lines, and multi-retort systems are only a few variations that might be mentioned.

As previously stated, electric furnaces may be subdivided into three categories: those which have the heating elements inside the retort, and those which have the heating elements outside the retort and furnaces of the improved design herein disclosed having heating elements both on the inside and outside of the retort or chamber. Two designs of electric heating vacuum furnaces are shown in FIGURES 1 and 2.

The basic principle underlying the design of each of the two types of furnaces disclosed involves first, the use of a conventional heating source such as electric resistance heaters or gas heaters to heat the exterior of the retort up to about 2000° F.–2200° F. so as to control the heat loss and the temperature of the retort wall with conventional pyrometer techniques. Secondly, to use a second set of heater elements, preferably electric resistance or induction heaters, or the like, placed within the retort adjacent the load material to raise the temperature of the load material from approximately 2000° F. to 4500° F. Thirdly, baffles are positioned within the retort so as to surround the interiorly located heaters and the work load with the baffles being arranged to reflect the heat of the interior heaters back onto the load material and to also cause a temperature gradient between the interior heaters and the retort walls.

In order to use this type of furnace heater arrangement to the greatest advantage it is preferable to control the heat of the heating elements located on the exterior of the retort by temperature controls that are responsive to the temperature of the retort walls. This type of heater control tends to reduce heat loss through the furnace walls to a minimum and at the same time will keep the retort walls from ever reaching such a critical temperature that they might be damaged. Control of the heating elements located within the retort is arranged so as to be responsive to the temperature of the work load material within the retort. For purposes of description hereafter the heater elements within the retort or furnace chamber will be referred to as the primary heaters whereas the heater element on the exterior side of the retort will be designated the secondary heaters.

FIG. 1 shows an electric heated bell furnace **26** equipped with resistance type secondary heaters **28**. Furnace **26** comprises inner and outer bell-type housings **29** and **30** that are spaced by a wall of heat insulating material **31**. A hook or cleat **32** is fixed to the top of the outer housing **30** to permit the ready lifting of the furnace **26** by a crane or chain hoist. The several sets of secondary heater units **28** mounted on housing **29** are each connected by a lead **33** to a control unit **34**. Control unit **34** is also connected by suitable temperature responsive means **35** to the wall **36** of the retort **23**. Temperature responsive means **35** is arranged such that when the temperature of the walls **36** of retort **23** approach a critically high temperature the control **34** will automatically reduce the heating effect of the secondary housing element **28**. Thereupon there will be a greater heat loss through retort walls **36** and through the walls **29—31** of furnace **26** so that the temperature of retort walls **36** will drop.

The bottom wall **37** of furnace **26** carries a sealing ring **38** that is adapted to engage and seat in a groove in the water cooled base portion **39** of retort **23**. Base portion **39** of retort **23** also sealingly engages the ring seal **24** carried by the furnace base **22**. Retort **23** has a lifting hook **14**.

Furnace base **22** is pierced by a conduit **11** that may be connected to a vacuum producing source or to the atmosphere or to a source of some inert gas or the like. Conduit **11** will normally be used to evacuate the inside of the retort **23**. Another conduit **12** is connected through the walls **29—31** of furnace **26** so that a vacuum can also be developed in the space **13** between the retort **23** and the encircling furnace **26**. It is necessary to evacuate space **13** when the retort interior is evacuated so the retort will not collapse from external pressure in space **13**.

Base **22** of the furnace has a shelf or table **21** mounted thereon that is adapted to support the load material M that is to be heated and/or treated. Mounted on the base table **21** are the primary heater elements **15** that are used to apply heat directly to the load material M and raise the temperatures to the maximum desired. A suitable load temperature recording device **17** may be connected by means **18** to a temperature control unit **19**. Control unit **19** is also connected by means **41** to the primary heater units **15** so that the heaters **15** can be automatically operated to achieve the desired load temperature. Baffle means **16** surrounds the load M and the primary heaters **15** so that the heat from units **15** will be reflected back onto the load material M and thereby use the heater units **15** to maximum advantage and efficiency.

FIG. 2 shows a pit type furnace **70** having electric primary heaters **72** and electric secondary heaters **71**. It is thought to be obvious that gas secondary heaters could be substituted for the electric secondary heaters **71**. The pit furnace **70** comprises a closed bottom cylinder formed from inner and outer walls **73, 74** separated by suitable heat insulation **75**. Piercing the walls **73—75** of the furnace **70** is a conduit **76** that can be connected to an evacuation source or to the atmosphere or to a supply of an inert gas or the like.

The upper open end of the pit furnace **70** is adapted to receive the cup-like retort **50**. Retort **50** has a load supporting shelf or platform **77** at its bottom to support the work load M. Stand **77** mounts the primary heaters **72** and the surrounding baffle means **79** that reflect the heat of the primary heaters **72** back onto the load material M. The upper portion of the retort wall **81** is ringed by a liquid circulating cooling collar **82**. Cooling collar **82** mounts seals **83** and **84** on its upper and lower surfaces to sealingly engage respectively the retort cover **51** and the top surface **86** of the furnace **70**. Piercing the cooling collar **82** and the retort wall **81** is a conduit **89** that is adapted to connect the interior of the retort to a source of vacuum, the atmosphere or some source of inert gas or the like. The retort cover **51** has a hook **91** to facilitate lifting of the retort **50** from the pit furnace **70**. Cover **51** of retort **50** is clamped to the cooling collar **82** by a plurality of screw-type C-clamps **92**.

As was the case with the bell-type furnace in FIG. 1, the pit furnace in FIG. 2 also includes control means **93** for the secondary heaters **71** that is responsive to the temperature of the retort walls **81**. Control means **93** has a lead line **94** connected to the secondary heaters **71** and another connection **95** connected to a temperature recording means **96** that measures the temperature of the retort walls **81**. Control means **93** will automatically reduce the heat output of the secondary heaters **71** when the temperature of the retort walls **81** approaches a critical temperature.

A temperature control **97** is connected by means **98** to

a control unit 99 that is adapted to control the heat output of the primary heaters 72. Control 99 is connected to the primary heaters 72 by a lead line 101. As the temperature of the retort 50 is raised by the primary heaters 72 near to its critical temperature the control 93 will reduce the heat output of the secondary heaters 71 so that the heat loss through the retort 50 and the furnace walls 73—75 will keep the temperature of the retort walls 52 from reaching its critical temperature.

In the several forms of the invention disclosed, it is thought to be obvious that the several heaters can be of any conventional types. Also, the retorts can be made from known materials such as type 330 stainless steel Inconel or other high temperature resistant materials. The baffles can be formed from tantalum, tungsten, molybdenum, or other ultra high temperature material. The heating elements, if of the electric type, can be formed from tantalum, tungsten, molybdenum or other ultra high temperature metals.

I claim:

1. In a furnace for subjecting a work piece to heat in a controlled atmosphere, the furnace having outer insulating wall means spaced from and enclosing a heat-conductive retort, the wall means and the retort defining therebetween an outer heating chamber, and the retort enclosing an inner heating chamber surrounding a central work-supporting means for receiving the work piece; the improvements of means for maintaining a controlled atmosphere in said inner chamber, a primary heating means in said inner chamber, a secondary heating means in said outer chamber, thermostatic means responsive to the temperature of said retort to control said secondary heating means, additional thermostatic means responsive to the temperature of the work piece to control said primary heating means, and heat-reflective baffle means disposed about said work-supporting means and interposed between said retort and said primary heating means (1) to reflect heat from the primary heating means onto the work piece and (2) to cause a temperature gradient between the primary heating means and said retort.

2. A furnace as defined in claim 1, said furnace being of the bell-type and the wall means and the retort being mounted on a base which supports the work piece, the primary heating means and the baffle means independently of both said wall means and said retort.

3. A furnace as defined in claim 1, said furnace being of the pit-type and the retort being suspended within the wall means to support the work piece, the primary heating means and the baffle means therein.

4. In a furnace for subjecting a work piece to heat in a controlled atmosphere, the furnace having outer insulating wall means spaced from and enclosing a heat-conductive retort, the wall means and the retort defining therebetween an outer heating chamber, and the retort enclosing an inner chamber surrounding a central work-supporting station for receiving thereon the work piece; the improvement of means for controlling the temperatures of said retort and said work piece to maintain a substantially constant temperature at the work piece while subjecting said retort to a substantially lower temperature, said means comprising (1) primary heating means disposed interiorly of said retort, (2) secondary heating means interposed between said wall means and said retort, (3) baffle means disposed about said work-supporting station to be interposed between said primary heating means and said retort to reflect heat onto said work piece and to inhibit heating of said retort by said primary heating means, (4) means responsive to the temperature of said retort to limit the heat output of said secondary heating means, and (5) means responsive to the temperature of the work piece to control operation of said primary heating means.

5. In a vacuum heating furnace having outer insulating wall means spaced from and enclosing a heat-conductive retort, the wall means and the retort defining therebetween an outer heating chamber, and the retort enclosing an inner chamber for receiving the work piece; the improvements of means accommodating the subjection of a work piece disposed interiorly of the retort to temperatures in excess of those to which the retort is subjected and to vacuum, comprising primary heating means disposed interiorly of said retort adapted to be in juxtaposition to the work piece, secondary heating means interposed between said wall means and said retort, heat reflective baffle means interposed between said primary heating means and said retort to shield the retort, means responsive to the temperature of said retort to limit the heat output of the secondary heating means so that the retort is subjected to a temperature less than that to which the work piece is subjected, means for evacuating the interior of the retort to a predetermined pressure, and separate means for evacuating the space between the wall means and the retort to a second predetermined pressure, the retort thus being subjected only to a differential pressure between the interior and exterior surfaces thereof.

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