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THE DESIGN AND SOME CONSTRUCTION DETAILS OF TWO LABORATORY VACUUM FURNACES FOR CASTING METALS

By Eugene D. Selmanoff

ABSTRACT

The designs of two laboratory furnaces for vacuum casting metals are described in detail. The first furnace employs a tungsten or molybdenum resistance winding. The furnace is constructed in two parts, an upper brass cylindrical "can" containing the heating coil, resting on a similar lower can in which the mold is placed. Bottom pouring technique is employed in both furnaces. The second furnace uses high frequency induction heating, but may be adapted for resistance heating. It consists of an open-end silica tube resting on a brass cylindrical can. The induction coil fits around the silica tube and the crucible stands inside the tube. The mold is accommodated by the brass can. In both furnaces temperatures in the neighborhood of 1500 degrees C at pressures of 10^{-3} to 10^{-5} mm Hg have been obtained. The design of a vacuum gate valve, compression gland are also given.

* * * * *

Techniques for vacuum casting metals, both in the laboratory and in industry, have been greatly improved and developed during the war period. New furnace designs and methods of construction should be of considerable interest to the metallurgist and others concerned with the problem of casting metals in vacuum. This is especially true in view of the scarcity of metallurgical or other scientific literature in this field.

Furnaces for melting or casting metals may be divided into two groups, (1) glass systems, and (2) metal systems. The former similar in construction to the glass systems commonly used in chemical and physical laboratories for carrying out reactions or experiments in vacuum. The majority of the parts and connections are usually made by the fusion of the glass or by the use of ground glass joints of one type or another. Such a system, as far as melting of metals is concerned, is usually limited to small melts, from less than 1 g to several hundred grams. A strict upper limit cannot be set. For melts of greater size and especially where casting is required it is desirable to go to metal systems primarily because of their greater mechanical strength and ease of construction when dealing with large parts. In these systems the majority of the parts are metal, usually brass, copper or steel, and the various components of the system are connected by soft or hard-soldering, welding, or bolting. The furnaces discussed in this paper are parts of metal systems.

LITERATURE ON VACUUM CASTING

The writer could find no literature on furnaces designed for vacuum casting. However some literature is available on the design of vacuum melting furnaces. The Arsem[7] vacuum furnace is probably the most widely known of this type. It employs a helical graphite coil as an electrical resistance unit and the vacuum is produced within a cylindrical gun-metal casting. Temperatures of 3100 degrees C were obtained in the original furnaces constructed by Arsem.

List of Parts for Figure 1.

Number	Material	Part (nonimal dimensions in inches)
1	Brass or steel	3/8-16 x 1-1/4 Hex head screw
2	Rubber	1/8 x 1/8 Gasket
3	Brass	8 Diam x 1/2 Top plate
4	Brass	8-32 x 1/2 Filister head screw
5	Brass	Window cover plate
6	Glass	1 Diam x 1/8 Pyrex window
7	Rubber	1/8 x 1/8 Gasket
8	Brass	1/4 Diam Pouring rod extension
9	Brass	1/4 Wilson seal
10	Copper	1/4 OD Cooling water coil
11	Steel	6-13/16 OD x 6-11/16 ID x 1/4 Split ring
12	Brass	8 OD x 6-3/4 ID x 1/2 Ring
13	Brass	3/8 x 3/8 x 1-3/4 Bar
14	Stainless steel	Pouring rod extension, 1/4 Diam
15	Stainless steel	Pouring rod coupling
16	Brass or copper	6-3/4 OD x 6-1/2 ID x 10 Furnace can
17	Copper	1/4 OD Cooling water coil
18	Suitable refactory	3/8 Diam Pouring rod
19	Steel	6-1/2 OD Furnace support
20	Brass	8 OD x 6-3/4 ID x 1/2 Ring
21	Rubber	1/4 x 1/4 Gasket
22	Brass	8 OD x 6-3/4 ID x 1/2 Ring
23	Brass	1/4 Compression gland
24	Brass or copper	6-3/4 x 6-1/2 x 6 Mold can
25	Brass	8 Diam x 1/2 Bottom plate
26	Brass	Flange, See Figure 2-11
27	Copper	Water-cooled lead
28	Suitable refractory	1/4 Coverplate
29	Suitable refractory	1/4 Crucible cover
30	Steel	5 OD x 4-15/16 ID x 5-1/4 Coil can
31	Alundum	Insulating tube
32	Alundum-60 mesh	Insulation
33	Alundum	3-3/4 OD x 3-1/4 ID x 4-1/4 Coil tube
34	Tungsten or molybdenum	30 mil wire
35	Suitable refractory	Crucible
36	Sil-o-Cell	Insulation
37	Suitable material	Mold
38	Steel	5 Diam x 1-1/4 Mold stool
39	Copper	1/4 OD Cooling water coil

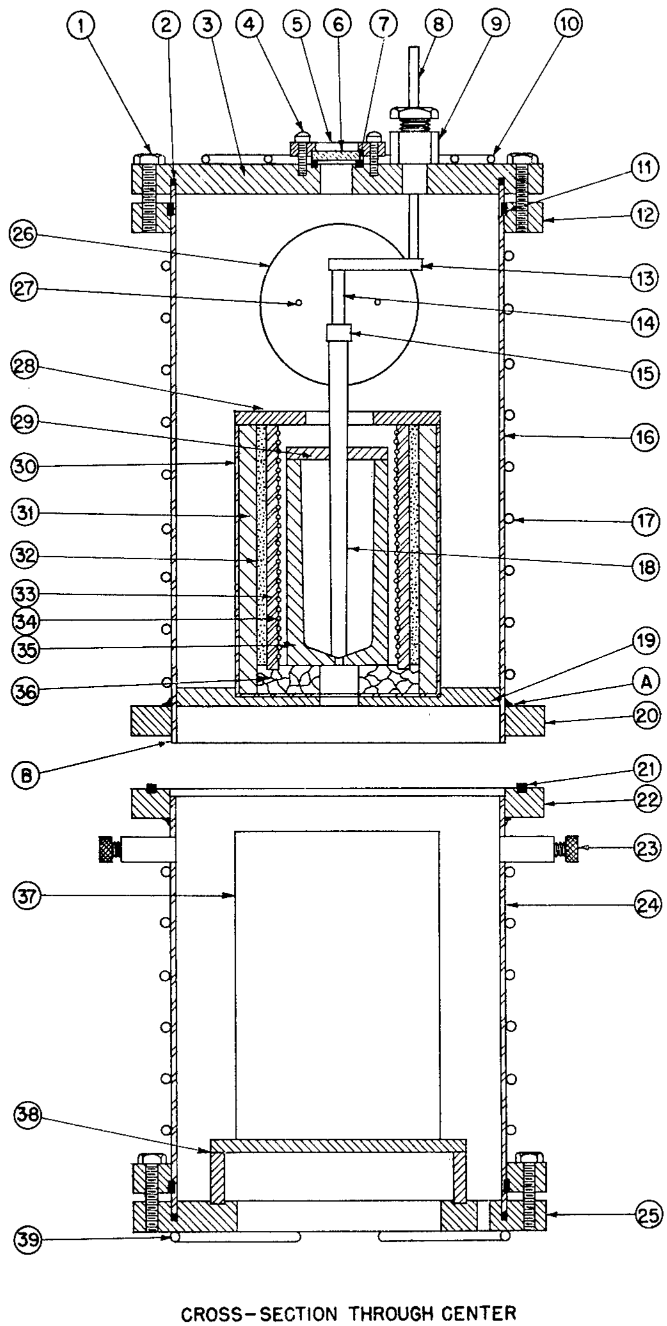

Figure 1. Resistance heated vacuum casting furnace.

W. F. Ehret and David Gurinsky[8] have described a carbon tube resistance furnace which they claim has the advantages of low cost, compactness, and rapid heating. The metal vacuum can is roughly 7 inches in diameter by 7 inches in height and operates in the pressure range 10^{-3} to 10^{-5} mm Hg or with a special atmosphere. Twenty-five g melts have been made at 1550 degrees C in 6 minutes, and charges up to 100 g can be used.

Two vacuum distillation furnaces which are suitable for melting and employing high-frequency induction heating have been described by J. B. Friauf.[9] In these furnaces, the vacuum is produced within a fused quartz tube around which the induction coil fits. In one furnace, the silica tube is 4 inches inside diameter and 2 feet long; and in the other, it is 6 inches inside diameter and 30 inches long. The furnaces differ principally only in size. The upper end of the silica tube is sealed to a brass ring which has a side tube leading to the vacuum pumps. The vacuum connection at the top of the quartz tube has some advantage over one at the bottom of the furnace, because it allows the entire furnace to be placed at a lower, more convenient location.

F. M. Walters[12] has described a high-frequency induction furnace used for melting under a controlled atmosphere (argon). It consists of a fused quartz tube 10 inches in diameter and 24 inches long, closed at the bottom by a water cooled brass casting, and at the top by a brass ring and water cooled cover. The high-frequency coil is placed inside the quartz tube, three leads passing through one inch holes drilled in the quartz tube. Melts of 2-5 lbs. were made in this furnace.

Methods and applications of melting and evaporating metals in vacuum have been discussed by Kroll.[10] The paper mentions several more unusual methods of vacuum melting, such as an arc furnace, and the Hultgren[10] electron-bombardment furnace.

This article will describe the design and some details of construction of two laboratory furnaces designed for vacuum casting, one employing resistance heating and the other employing induction or resistance heating. The reader desiring merely a melting furnace can easily simplify the designs given to meet this single function. In addition some accessory metal vacuum system equipment will be described.

A RESISTANCE-HEATED FURNACE

A furnace designed for resistance heating is shown in Figure 1. The furnace is composed of two parts, the upper "can"* (16) which contains the heating coil, and the lower can (24) which contains the mold. The advantage of this type of construction is that the heating coil, which tends to become quite fragile with use, is not disturbed (as would probably be the case if the entire furnace were in one part) when the mold is placed in, or removed from the furnace.

The design and method of construction can be seen by an examination of Figure 1 and Figure 1-List of Parts. In the List of Parts, some of the dimensions are given only nominally, and some were omitted if they were of little importance.

Upper Can

The upper furnace can, which may be made of either brass or copper, is 6 3/4 inches in diameter and 10 inches high. It is cooled by water flowing through several turns of 1/4 inch diameter copper refrigerator tubing (17). The turns are spaced 1 inch or slightly more apart and are soft-soldered to the can. The can is closed at its upper end by a brass plate (3) bolted to the can by six machine screws (1) and a ring arrangement (11, 12).

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* The figures in parentheses in this section refer to parts shown in Figure 1, unless otherwise indicated.

The plate has a Pyrex window (6), a sliding (or Wilson) seal (9) for introduction of translatory motion into the vacuum, and is water cooled (10). The window shown is 1 inch in diameter, but in general a larger window facilitates visual and pyrometric observations of the melts. Suitable Pyrex windows of various dimensions may be obtained from the Corning Glass Works. A window shutter (not shown) has been found effective in preventing or decreasing fogging of the window due to condensation of volatile constituents from the melts. Such a shutter may be fashioned from a 20 gauge piece of sheet steel, roughly teardrop in shape and pivoted at the narrow end by a screw threaded to the underside of the top plate. The shutter can be opened and closed by sliding an Alnico magnet in the desired direction along the topside of the plate. The construction and dimension of the Wilson seal have been thoroughly described by Wilson.[17] It is probably desirable, where possible, to interchange the position of the Wilson seal and the window as shown in Figure 1, because an off-center window usually provides a better view of the melt.

It is necessary to have some play in the pouring rod connections to compensate for the small misalignments of the crucible or the whole heating coil assembly that usually occur. A sloppy fit where extension (14) is threaded into coupling (15) has usually been sufficient. The pouring rod (18) fits into a hole in the coupling and is secured by an Allen head screw. When the crucible is loaded the pouring rod together with the coupling (15) and extension (14) is placed in position. After the crucible is lowered into the furnace, extension (14) fits into a hole in arm (13) and is fastened with a thumbscrew. This operation is performed as the top plate is held in a horizontal position several inches above the can.

The rubber gaskets (2, 7, 21) can be obtained, in various cross sections, by the foot. Circular cross section gaskets can also be used.

The heating coil consists of 30 mil tungsten or molybdenum wire inside wound on a 3 1/4 inch inside diameter alundum tube. It was not possible to purchase inside-threaded tubes so the threads were ground by an abrasive wheel; six threads per inch, approximately 1/8 inch deep. Tungsten wire is easier to wind than molybdenum, due to the greater stiffness of the tungsten. The two ends of the coil winding are fastened to 50-60 mil molybdenum wire which is run to the water-cooled leads (27). Several methods of fastening two pieces of resistance wire together have been used successfully. The two pieces may be placed alongside and running parallel to each other and be tied together with 1-2 mil molybdenum wire. Another method is to run a single loop of 20-30 mil molybdenum wire around the two pieces, placed in any position, and tightening the loop by twisting its ends together. The heating coil unit rests on a steel ring (19) which in turn rests on three pins (not shown) fastened to the wall of the can. Heat loss by radiation may be reduced by introducing one or more metal shields between the heating coil assembly and the can.

Water-Cooled Leads

The construction of the water cooled leads is shown in Figure 2. The brass flange* (11) is soft-soldered to the back of the upper can (Figure 1-26). An insulating plate (7) is screwed to the flange and the two leads protrude through and are secured to this plate. The drawing does not show the small hole through the extreme right end of (8) through which the furnace lead passes and is held by an Allen head screw. An electrical input wire is fastened to a hose clamp which is clamped on the excess threaded portion of (8) next to nut (4). The water inlet and outlet (1, 2) are soft-soldered to disc (3) which is soft-soldered to (8). Two or three 3 inch diameter sheet metal radiation shields are placed in front of the insulating plate to protect it from direct radiation. Pyrex tubes are slipped over the ends of the leads to prevent contact and subsequent electrical shorting by the shields.

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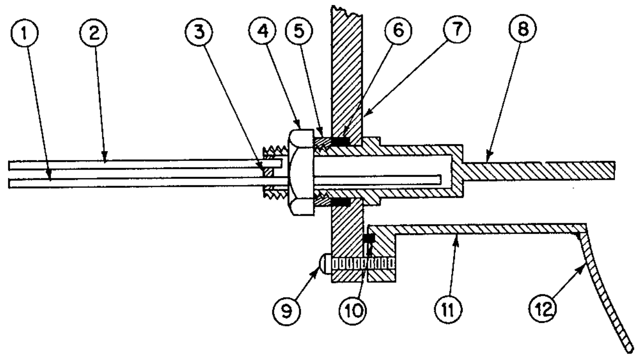
* The figures in parentheses in this section refer to parts shown in Figure 2, unless otherwise indicated.

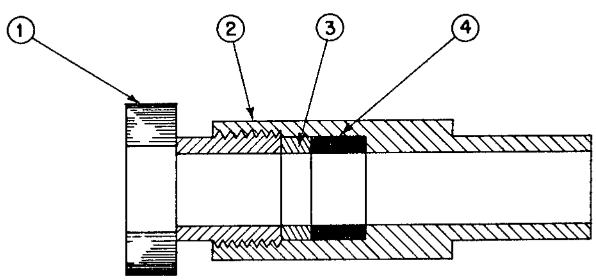


CROSS-SECTION THROUGH CENTER

Figure 2. Construction of water-cooled leads.

Figure 2 – List of Parts

Number	Material	Part (nominal dimensions in inches)
1	Copper tubing	1/8 OD hard drawn, Water inlet
2	Copper tubing	1/8 OD hard drawn, Water outlet
3	Copper	1/2 Diam x 3/16 End piece
4	Brass	3/4 - 16 Hex head nut
5	Brass	1 OD x 3/4 ID x 1/4 Washer
6	Rubber	1 OD x 3/4 ID x 1/4 Gasket
7	Micarta	4-3/4 Diam x 1/2 Insulating Plate
8	Copper	Lead Body
9	Brass	Filister head screw
10	Rubber	1/8 x 1/8 Gasket
11	Brass	4-3/4 OD x 3 ID x 1/8 Wall x 3-1/4 Flange
12	Brass or Copper	Furnace can wall



CROSS SECTION THROUGH CENTER

Figure 3. 1/4 inch compression gland.

Figure 3 – List of Parts

Number	Material	Part (nominal dimensions in inches)
1	Brass	Hex head screw
2	Brass	Body
3	Brass	Washer
4	Rubber	Gasket

Lower Can

The upper can rests on the lower (mold) can. A vacuum tight seal is provided by the gasket (21). It should be noted that this gasket is protected from direct radiation of heat by a slight projection of the upper can (B). It is important that no rubber gaskets in the system be subjected to direct radiation. The rings (20, 22) are hard-soldered to their respective cans (A).

Four 1/4 inch compression glands (23 and Figure 3) are soft-soldered roughly 45 degrees apart around the back side of the can. They are used for the introduction of vacuum gages, thermocouple wires, electrical connections to a mold heating coil, etc., into the system. A convenient method of interchanging vacuum gage tubes in the system is to fuse the female part of a semiball joint to each tube. By means of an L-shaped glass tubing having a stopcock, the male part of a semiball joint on one end, and the other end in the compression gland, tubes may be changed during a run without breaking the vacuum.

The bottom plate is secured to the lower can in the same way that the top plate is secured to the upper can. The bottom plate has a 4 inch diameter vacuum outlet and a 1/2 inch diameter hole for connection to a roughing system. It is also water cooled (39). The mold (37) which rests on a short metal stool (38) can be raised if it is desired to shorten the distance through which the metal drops from crucible to mold.

Furnace Support

A method of supporting the entire furnace has not been shown. Four 3/8 inch diameter steel rods are threaded into the bottom of a steel ring similar in cross section to (19). The rods are then bolted to a table top and the furnace is placed on the ring. Sufficient distance is allowed between the ring and the table top for insertion of a gate valve (Figure 5) which is bolted on to the bottom plate (25).

AN INDUCTION OR RESISTANCE-HEATED FURNACE

A furnace that was originally designed for induction heating, but which may easily be adapted for resistance heating, is shown in Figure 4. The lower can is very similar in design to the lower can shown in Figure 2. The crucible is placed within a fused quartz tube* (13) which rests on the top plate (17) and around which the induction coil (not shown) fits. The tube shown is 3 1/2 inches in outside diameter by 3 inches in inside diameter by 15 inches in height. A tube of this length allows one to place both the crucible and mold within the quartz tube, provided the diameter of the mold is small enough to fit. The crucible may then rest directly on the mold, if desired, thereby eliminating the long metal drop which is unavoidable when the crucible and mold are in the positions shown in Figure 4. It is always desirable to have the outside diameter of the tubes as small as possible because increasingly greater magnetic coupling as obtained as the diameter of the induction coil approaches the diameter of the crucible. On the other hand, the tube should be large enough to permit the use of radiation shields, and to allow free passageway for gases past the crucible to the vacuum outlet. The design shown in Figure 4 is useful because it permits the use of a mold which has too large a diameter to fit inside of the quartz tube.

Fused quartz tubes having either a sand cast surface or a mold surface (both have been used satisfactorily) may be obtained from Thermal Syndicate Ltd., New York, or Amersil Co., Inc., Hillside, New Jersey. Tubes supplied by the former have had less variation in the dimensions of the inner and outer diameter. Vycor (Corning Glass Works) and Pyrex tubes have also been used satisfactorily, although they have thinner walls and are more easily damaged by mechanical shock. It is desirable to have a radiation shield (24, 26) around the crucible (27). Refractory or metal shields may be used. Metal shields must be slotted to prevent heating by induction.

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*The figures in parentheses in this section refer to parts shown in Figure 4, unless otherwise indicated.

List of Parts for Figure 4

Number	Material	Part (nominal dimensions in inches)
1	Brass	4-1/2 Diam x 1/2 Top plate
2	Brass	8-32 x 1/2 Filister head screw
3	Brass	Window cover plate
4	Glass	1 Diam x 1/8 Pyrex window
5	Rubber	1/8 x 1/8 Gasket
6	Brass	1/4 Diam Pouring rod extension
7	Brass	1/4 Wilson seal
8	Copper	1/4 Diam Cooling water coil
9	Brass	3/8 x 3/8 x 1 Bar
10	Stainless Steel	Pouring rod extension, 1/4 Diam
11	Stainless Steel	Pouring rod coupling
12	Suitable refractory	5/16 Diam Pouring rod
13	Fused quartz	3-1/2 OD x 3 ID x 15 Tube
14	Suitable refractory	Crucible support
15	Rubber	3-1/2 OD x 3 ID x 1/8 Gasket
16	Copper	1/4 Diam Cooling water coil
17	Brass	8 OD x 2-1/2 ID x 1/2 Top plate
18	Steel	6-13/16 OD x 6-11/16 ID x 1/4 Split ring
19	Brass	8 OD x 6-3/4 ID x 1/2 Ring
20	Copper	1/4 OD Cooling water coil
21	Brass or Copper	6-3/4 OD x 6-1/2 ID x 6 Mold can
22	Brass	8 OD x 4 ID x 1/2 Bottom plate
23	Rubber	3-1/2 OD x 3ID x 1/8 Gasket
24	Suitable refractory	2-3/4 Diam x 3/16 Radiation shield
25	Suitable refractory	2 Diam x 3/16 Crucible cover
26	Suitable refractory	2-3/4 OD Radiation shield
27	Suitable refractory	2 OD Crucible
28	Suitable refractory	2-3/4 Diam Insulating plate
29	Suitable refractory	2-3/4 Diam Insulating plate
30	Brass	3/8-16 x 1-1/4 Hex head screw
31	Rubber	1/8 x 1/8 Gasket
32	Brass	1/4 Compression gland
33	Suitable material	Mold
34	Steel	5 Diam Mold stool
35	Copper	1/4 Cooling water coil

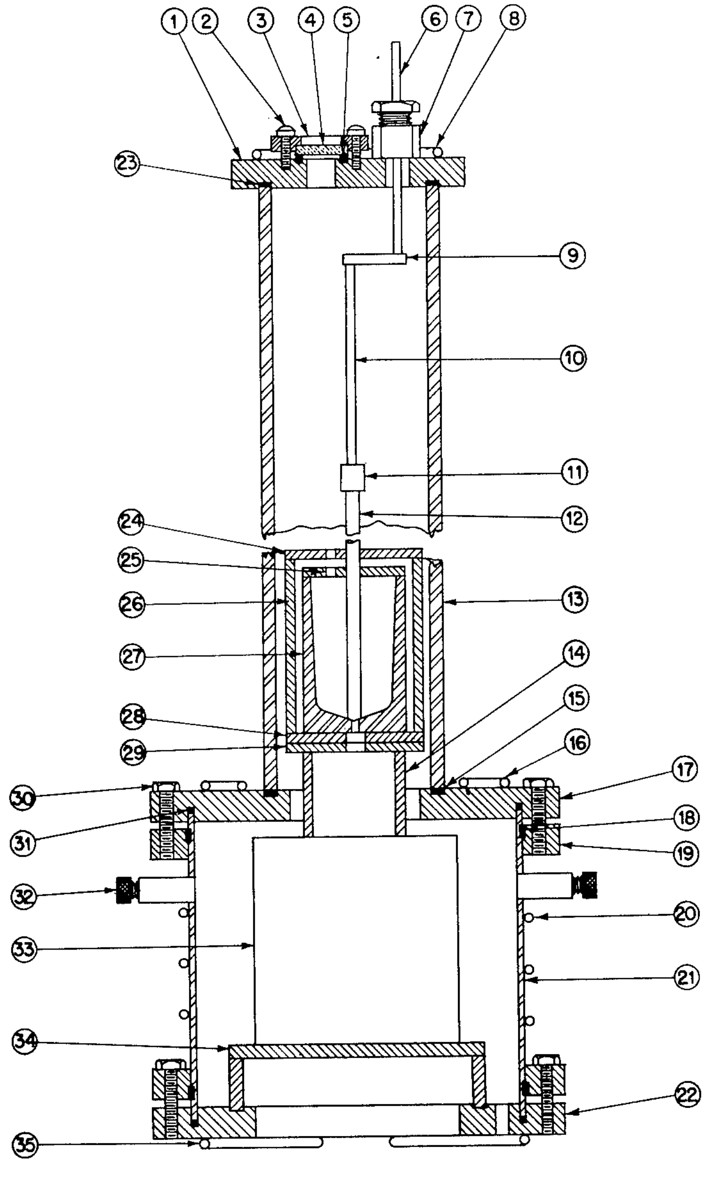

Figure 4. Induction or resistance heated vacuum casting furnace.

It will be noted that the quartz tube is not fastened to the plates at either end. Vacuum tight seals are obtained by the use of atmospheric pressure. Top and bottom plates may be secured to the quartz tube by means of a ring arrangement similar to that used on the brass lower can,* but this arrangement has been found to be unnecessary.

The cooling coil (16) may be eliminated by turning a groove in plate (17) and soft soldering an annular copper ring on top of the groove. This change will permit the induction coil to be lowered slightly without arcing the top plate. Other design features of the lower can may be obtained from the description of Figure 1. The entire furnace is supported in the same way as the resistance-heated furnace.

Adaption for Resistance Heating.

The lower mold can in Figure 4 may be used "as is" to support an upper can containing a resistance heating coil. The upper can is identical in design to that shown in Figure 1 with the exception of the bottom ring (Figure 1-20) which is modified to fit on to the top plate (Figure 4-17).

A VACUUM GATE VALVE

A relatively simple design of a vacuum gate valve is shown in Figure 5. The principal feature of this design is that it allows an unobstructed and unrestricted flow of gas from furnace to pumps when the valve is in the open position. The valve is shown in the closed position.

The principal parts of the valve are a guide plate† (10) which slides in a horizontal direction in the valve housing (3, 8, 9), the upper and lower gates (12), and a cam (11) actuated by the rod (4).

The guide plate slides in 1/8 inch deep grooves cut in the two side walls (not shown) of the housing. When in the closed position, the guide plate is at the extreme right hand end of the housing. Four guide pins (15) are fastened (force fit) in the guide plate to direct the vertical motion of the upper and lower gates. The pressure exerted by the cam on the gates (the position shown in Figure 5) is released when the handle (14) is turned 90 degrees. Both gates are then pulled toward the guide plate by the action of coil springs (16) which fit over the guide pins and are fastened to the gates and to the guide plate (the upper gate is assisted by the force of gravity). The handle is then pulled to the right and the entire internal assembly is removed from the position shown leaving a straight unobstructed passageway for the gas molecules.

The upper flange (1) is bolted to the furnace bottom plate and the lower flange is bolted to the desired part of the vacuum system.

The parts of the valve housing are screwed together (using flat head screws) and all seams and screw holes are soft soldered. It is usually advisable to paint over the soldered seams with colorless Glyptal (General Electric Co.).

If the valve is in the closed position for several hours, say 8 to 10, and the system above or below is evacuated, some difficulty may be experienced in opening the valve. This difficulty is due to leakage of air into the valve housing. The air has sufficient pressure to prevent the gate from unseating when the cam pressure is released. A roughing pump connection to the valve housing makes it possible to evacuate that volume and overcome this difficulty.

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* The ring (18) can be cemented to the quartz tube with Saureisen or Insalute cement (Central Scientific Co.)

† The figures in parentheses in this section refer to parts shown in Figure 5, unless otherwise indicated.

SOME ACCESSORY EQUIPMENT

The adaptation of standard plumbing valves for vacuum systems has been described by Du Mond[13] and Rose.[16] Both methods employ a sylphon bellows to prevent leakage along the valve stem. A simpler method which the writer has found to be satisfactory is substitution of a Wilson seal for the valve stem packing. The Kerotest valve commonly used in refrigeration installations and the Hoke valve are needle-type valves which are suitable "as is" for use in vacuum systems.

In the same articles mentioned above, Du Mond has described a flexible, noncollapsible sylphon coupling and Rose has described a method of bolting together metal tubing. Garner[14] has also described other methods of performing this operation.

OPERATION

The furnaces described in this report were connected to identical pumping systems. The systems consisted of the following parts, connected in the order given: a metal baffle, a metal diffusion pump, MC-275,* a metal booster pump, MB-15,† and a Megovac forepump running at double the normal speed.

About 1/2 hour before making a run, the pumping system is started, with the gate valve closed. After loading and closing the furnace it is "roughed out" to about 200 microns by a Megovac roughing pump. The gate valve is then opened and the furnace pumped out to the desired pressure before beginning the melt. Pressures of 10^{-3} to 10^{-4} mm Hg have been obtained with about 1/2 hours of pumping depending on the amount, nature, and condition of the materials in the furnace. When the systems were first constructed and before any melts were made, pressures of between 10^{-5} and 10^{-6} mm Hg were obtained. If it is desired to run the pumping system continuously, or when no operator is in attendance, it is advisable to install a safety device that will cut off the heaters in the oil pumps in case of cooling water failure. Detroit pressure switches are used for this purpose.

The power input for the resistance furnace is controlled by a 28 amp Variac which is connected to a 110 volt line. A maximum power input of only 2 kw, was sufficient to reach temperatures of 1400-1500 degrees C. The maximum temperature of operation would probably be determined by the initiation of a reaction between the tungsten or molybdenum winding and the alundum core (Figure 1-33). Although no determination was ever made of the maximum rate of heating, charges of 500 to 1000 g were heated to around 1400 degrees C in less than 30 minutes. Due to the fact that both tungsten and molybdenum wire are easily oxidized at elevated temperatures the furnace must be cooled to about 200 degrees C before opening to the atmosphere. The cooling period is greatly shortened by admitting an inert gas into the system.

The crucible shown in Figure 1 has a volume of about 275 cc. Although this volume will hold about 2400 g of molten copper, for example, the capacity of the crucible is determined by the amount of metal that can be initially charged into the crucible.

The power supply for the induction furnace was provided by a 10 kw. Thermonic high-frequency converter. Very rapid heating is possible with this unit. Melts of 200-400 g can be heated to 1400-1500 degrees C in less than 10 minutes. The refractory properties of the crucible would determine the maximum temperature of operation rather than any feature of the furnace design.

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* Distillation Products Industries, Rochester, N. Y.

† Central Scientific Co.

ACKNOWLEDGMENT

The designs and methods of construction which have been presented in this report were originated or developed by members of an entire group, of which the writer was a part, engaged in vacuum melting and casting. It would be difficult if not impossible to trace each idea back to its originator, but the following list includes those who made the most significant contributions in this work: G. L. Butler, Noble Hamilton, Leonard Levinson, Shadburn Marshall, J. G. McChesney, A. U. Seybolt, Leston Stark, and J. H. Wernick.

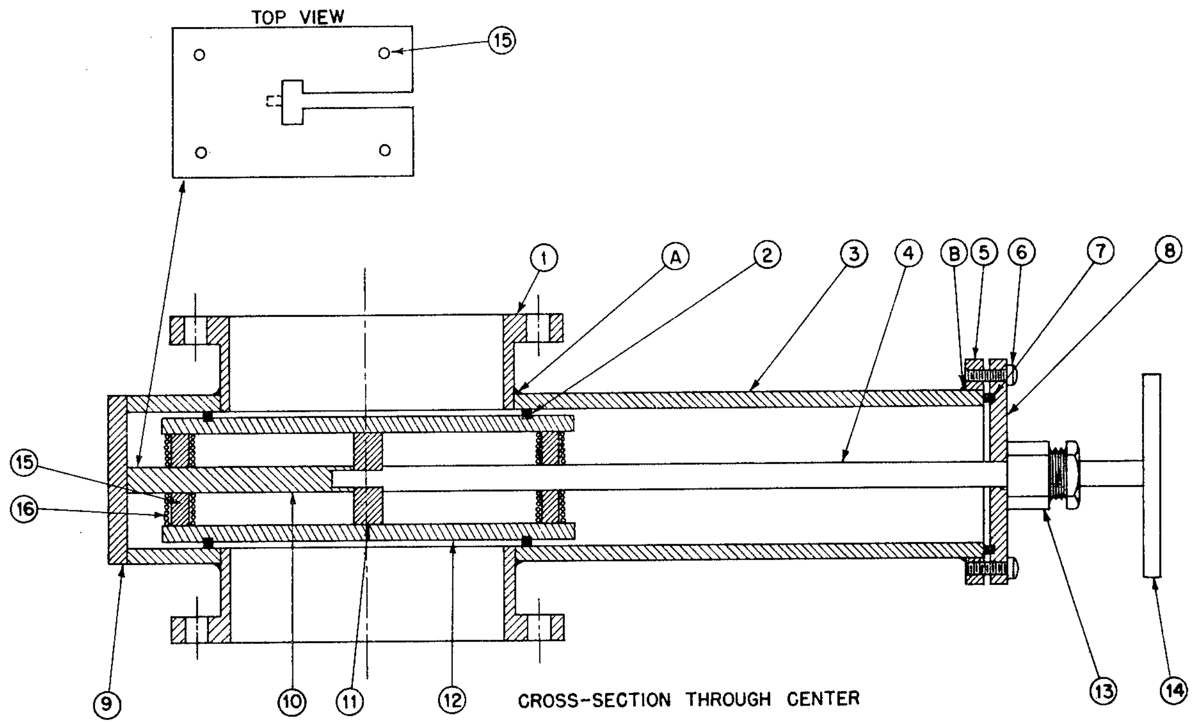

Figure 5. Vacuum gate valve.

List of Parts for Figure 5

Number	Material	Part (nominal dimensions in inches)
1	Brass	5- 3/4 OD x 4 ID Upper flange
2	Rubber	1/8 x 1/8 Gasket
3	Brass	1/4 x 5-1/2 x 12-1/2 Upper plate of housing
4	Brass	3/8 Diam x 11 Rod
5	Brass	Collar
6	Brass	10-32 x 5/8 Filister head screw
7	Rubber	1/8 x 1/8 Gasket
8	Brass	1/4 x 3-3/8 x 6-3/8 End plate of housing
9	Brass	1/4 x 2-1/2 x 5-1/2 End plate of housing
10	Brass	3/8 x 5-1/4 x 7 Guide plate
11	Brass	3/8 Cam
12	Brass	1/4 x 5 x 6 Lower gate.
13	Brass	3/8 Wilson seal
14	Brass	1/4 x 1/2 x 3 Handle
15	Steel	1/4 Diam x 1-7/8 Guide pin
16	Steel	Spring

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Leak-Hunting

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