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1. Forwarded herewith is Watertown Arsenal Laboratory Report 671/61, "A Vacuum Heating, Melting and Sintering Furnace; Its Construction, Operation and Maintenance", by W. H. Titorchock and L. S. Foster.

Comments on this report will be appreciated.

FOR THE COMMANDING OFFICER:

W. O. Moberg
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For D. G. LUDLAM
Col., Ord. Dept.
Assistant

Incl. 1 Rept.
WAL 671/61

FOR VICTORY BUY UNITED STATES WAR BONDS AND STAMPS

15 April 1947

Watertown Arsenal Laboratory
Report Number WAL 671/61
Problem Number Q-1.1

POWDER METALLURGY

A Vacuum Heating, Melting and Sintering Furnace; Its Construction, Operation and Maintenance

OBJECT

To describe the construction, operation and maintenance of the vacuum heating, melting and sintering apparatus and its components.

SUMMARY

The vacuum equipment of the Powder Metallurgy Branch of the Watertown Arsenal Laboratory was manufactured with the incorporation of design features recommended by the Watertown Arsenal Laboratory. It can be used for melting small charges of metals as well as for sintering powdered metal products under high vacuum.

This report includes detailed descriptions of operating procedures of all components of the equipment.

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INTRODUCTION

The vacuum heating, sintering and melting apparatus may be considered under four major subdivisions: 1. The vacuum chamber and its inductor coil, 2. The pumping unit, 3. The pressure measuring equipment, and 4. The high frequency power source.

These units were assembled and in part manufactured by the National Research Corporation, Brookline Ave., Boston, Mass., with design features as specified by the Watertown Arsenal Laboratory. The design was based to a large extent on a similar unit developed by Professor I. Amdur of the Massachusetts Institute of Technology in connection with work for the Manhattan Project during the period 1943-1945.

A Tocco Junior motor generator high frequency source was procured from War Surplus and modified for this application by a representative of the Ohio Crankshaft Company's Tocco Division.

CONSTRUCTION AND GENERAL CONSIDERATIONS

The construction of the vacuum heating, melting and sintering equipment is presented in the following sequence: Power Source, Inductor Coil, Vacuum Chamber, Vacuum Manifold, Vacuum (Butterfly) Valve, Forepressure Manifold, Mechanical Forepump, Vacuum Measuring Instrumentation and Vacuum Manifold Extension.

POWER SOURCE

The power source for the inductor coil is a modified Tocco Junior, 20 kilowatt motor generator set, type 20STMC10B (Fig. 2). The capacitators originally located in the Tocco housing were removed and remounted as close to the inductor coil as possible (Fig. 3). This was done to reduce power losses sustained in lengthy coil leads. These capacitators are water cooled, Pyranol filled and mounted so as to facilitate capacitator adjustment for power factor.

The sequence program timers, originally used in a mass production heat treatment process have been by-passed and instrumentation, consisting of a voltmeter, ammeter and a kilovar meter with its reactive component compensator, was transferred with the generator field auto transformer to a movable panel unit (Fig. 1). This arrangement facilitates coil input control and allows control from the temperature and pressure observation station.

INDUCTOR COIL

The water-cooled inductor coil (Fig. 11), was fabricated by the National Research Corporation and consists of approximately 20 feet of 1/4 inch standard weight copper pipe wound into a

5-1/2 turn coil, 6 inches inside diameter and 8 inches long with leads about 26 inches long. The coil leads enter the chamber through gasketed seals in a Tur-x plate (International Products Corp., 2554 Greenmount Ave., Baltimore 18, Md.) which in turn is gasketed to the vacuum chamber (Fig. 3).

The original stainless steel lead seals for this coil were replaced with copper parts at the recommendation of a representative of the National Research Corp. to reduce eddy current heating at the entrance port and deterioration of the neoprene gaskets.

VACUUM SYSTEM

The vacuum system consists of a cylindrical vacuum chamber that is exhausted by means of an oil-diffusion pump, supported by a mechanical pump. By means of a butterfly valve and other vacuum tight valves, it is possible to isolate the diffusion pump from the system and to use the mechanical pump for "roughing". When the pressure has been reduced to a sufficiently low value (200 microns) the diffusion pump is cut into the system by proper adjustment of the valves. It is thus possible to isolate the diffusion pump without shutting it off, open the chamber to insert or remove specimens and re-evacuate. With the use of the new silicone vacuum pump oils, that do not oxidize in air, this procedure is not so essential, but the less expensive conventional diffusion pump oils are rapidly darkened and thickened by short contact with air.

VACUUM CHAMBER (Fig. 1, 3, 4)

The vacuum chamber is constructed of stainless steel. It consists of a double walled, water-cooled cylinder and bottom and is closed on the top by a large, removable, 7/8" thick, stainless steel plate which carries a similar smaller plate. (Figs, 1, 3, 4). The inside dimensions of the chamber are: diameter, approximately 22", and length, approximately 20". The chamber is fitted with two diametrically opposed ports of 6 inch diameter. One port is used to introduce the inductor coil leads and the other carries a flange for the attachment of the vacuum manifold (Fig. 1).

Mountings are of a design that permits reorientation of the chamber about its axis so that the chamber may be used vertically or horizontally.

The large front cover of the chamber is equipped with a smaller, removable cover for convenience in loading operations (Fig. 1). The small cover is equipped with a window port and window shield.

VACUUM MANIFOLD (Fig. 1)

The vacuum manifold is short and leads through a stainless steel elbow to the diffusion pump through the vacuum (butterfly) valve. There are three ports for the connection of vacuum measuring gauges (Fig. 1, 4). A vacuum manifold extension is available that permits the attachment of a vertical quartz vacuum chamber for work at higher temperatures.

VACUUM (BUTTERFLY) VALVE (Fig. 1)

The vacuum valve, designated by the National Research Corporation as, "valve, 6K, type #1119, stainless steel," consists of a manually operated, gasketed disc that may be seated on an annular opening thereby sealing the diffusion pump from the vacuum manifold. The open or shut valve position is controlled by a geared lever (Fig. 1, 4) that actuates the valve disc through a vacuum tight gland.

The vacuum manifold side of the valve housing is connected to the forepump manifold. The vacuum (butterfly) valve is used with another, Sylphon type, vacuum valve to isolate the diffusion pump when the vacuum manifold and chamber are being brought back to atmospheric pressure. The vacuum (butterfly) valve is used to isolate the diffusion pump when forepump pressures rise above 200 microns. Valve manipulations for the isolation of the diffusion pump are schematically shown in Fig. 8.

DIFFUSION PUMP (Fig. 1)

This pump, used as a vacuum booster pump, is the National Research Corporation H6 diffusion pump, type 104 with a rated capacity of 1250 cu. ft. per min. at 2 to 0.5 microns pressure (Fig. 1). The body is constructed of stainless steel and the vapor duct and jets are of aluminum. The H6 diffusion pump uses National Research Corp. "Narcoil 10".

The diffusion pump outlet is connected to the forepressure manifold which is valved to allow the isolation of the diffusion pump.

FOREPRESSURE MANIFOLD (Fig. 8)

The forepressure manifold is a system of valved pipes connecting the butterfly valve housing, diffusion pump and forepump (Fig. 8). This manifold is valved to allow the selection of the following gas flow circuits: 1. forepump evacuation of vacuum manifold and chamber, 2. forepump evacuation of the diffusion pump, 3. introduction of gas or atmosphere to vacuum manifold and chamber.

MECHANICAL FOREPUMP (Fig. 5)

This pump is a 25 cubic feet per minute, size 778, type VSD Kinney pump and is used in series with the diffusion pump. The purpose of this pump is to reduce the exhaust pressure for the satisfactory operation of the diffusion pump. The pumping time required to obtain the necessary reduction of pressure to 200 microns is about 10 minutes.

ATMOSPHERE DRYER

Gases such as helium, which are used to "crack" the vacuum are dried in a Pittsburgh Lectrodryer before being introduced through the forepressure manifold (Fig. 8). The dryer is an activated alumina, dual chamber type equipped with a reactivating system. It is designated as the Pittsburgh Lectrodryer Type BAC, Size 0, Serial #1787, manufactured by the Pittsburgh Lectrodryer Corp., Pittsburgh, Pa.

VACUUM MEASURING INSTRUMENTATION (Fig. 1, 9)

The National Research Corporation, type 706, Thermocouple and Ion Gage Control Unit is used to measure vacuum system pressures. (Fig. 1). The vacuum manifold dry air pressures are measured by means of a thermocouple gage and an ion gage (Fig. 9); the forepressure manifold dry air pressures are measured by means of a single thermocouple gage (Fig. 8). The thermocouple gages are used in the range 2 to 500 microns of mercury and the ion gage is used in the range 0.001 to 1.0 microns of mercury. A Bourdon type vacuum gage is used to indicate approximate pressures when gases such as helium are used to "crack" the vacuum (Fig. 8).

ADDITIONAL COMPONENTS

VACUUM MANIFOLD EXTENSION (Fig. 2)

The stainless steel vacuum chamber may be disconnected from the vacuum manifold adapter and a stainless steel manifold extension elbow may be attached in its place. This elbow is designed for use with a quartz tube vacuum chamber. The elbow is equipped with a window port and a window shield (Fig. 2).

OPERATION AND MAINTENANCE - SEQUENCE OF OPERATIONS

FOREPUMP (KINNEY VACUUM PUMP, VSD) (Fig. 5, 8)

1. Before starting pump.

   a. It is necessary that the oil in the Kinney pump be at the proper level in the oil separator tank, as indicated by the marker on the tank.

b. The pump is turned by hand, in the direction shown by the arrow on the head (clockwise, facing the large pulley), before the power is turned on. This should be done to insure free rotation of the pump. (If the pump does not rotate freely, it is dismantled and inspected as in "5" below.)

c. Valve #1 should be closed and must remain closed until the pump is running at full speed, then valve #1 is opened fully. Valves #3 are then opened from 1 to 1-1/2 turns. No further adjustment of these (#3) valves should be necessary unless the operating condition of the pump changes because of wear. (Valve locations Fig. 5).

d. The power for the forepump is controlled by switch d (Fig. 1).

2. Before shutting down pump.

   a. Before the power is turned off, valve #1 is closed and the pump is allowed to run about 30 seconds to free itself of oil. Valves #3 should be left opened (See "1c").

3. Changing the oil.

   a. The oil should be changed when it appears dirty and discolored.

   b. The oil may be drawn off at valve #5 and replaced through the filling plug.

4. Grade of oil.

   a. For vacuums of approximately 0.5 mm Kinney Special Dry Vacuum Oil is recommended. For vacuums of approximately 1 mm, a good grade of turbine lubricating oil may be used, having a viscosity of 300 SUV (Saybolt Universal Viscosity) at 100°F.

5. Overhaul of pump.

   a. Shut down procedure as in "2a" above, is followed.

   b. Working parts are then removed, observing assembly and location, and cleaned in a suitable solvent.

   c. In reassembling, shellac is used to make tight joints; no gaskets are inserted.

DIFFUSION PUMP, H6, TYPE 104 (Fig. 1, 6, 6a)

1. Starting the pump.

   a. When the forepressure has fallen below 200 microns as indicated by the forepressure manifold thermocouple gage, the diffusion pump can be started.

   b. The cooling water is turned on and the flow is checked at the jacket outlet. (Approximately 1 gallon per minute at 70°F).

   c. The heater circuit is now energized. (Switch e) (Fig. 1).

   d. In the H6 diffusion pump, oil vapor is produced at a pressure of several millimeters in the boiler at the bottom of the pump by an electric heater. This vapor travels up the jet tube on the inlet side of the pump and is emitted downward at a very high velocity by means of three umbrella type jets. Air or gas molecules diffusing into the pump are entrained by these vapor jets. The vapor is condensed on the water cooled wall of the pump and returned to the boiler. A water jacket on the pump outlet provides additional surface for the condensation of the oil vapor and prevents excess oil from diffusing into the forepressure manifold.

      Since the diffusion pump is useful only when pumping against a low pressure an adequate forepump is necessary.

2. Shutting down the pump.

   a. The heater coil is turned off (Switch "e")(Fig. 1). To prevent its oxidation the pump oil should not be exposed to the atmosphere until the pump has cooled sufficiently to allow the hand to be held on the boiler without discomfort. The system may be opened earlier if an inert gas such as helium is used to "crack" the vacuum. These precautions are not necessary if silicone oils are employed.

   b. If it is desired to leave the diffusion pump in operation during operation, while opening other parts of the system, the vacuum (butterfly) valve and valve #3 (Fig. 8), are closed. The chamber and vacuum manifold pressures may now be brought to atmospheric by suitable means without damage to the hot pump oil (Fig. 8).

3. **Special Precautions.**

a. **Exposure of more than a FEW SECONDS to the atmosphere will cause the pump oil to break down.**

b. The heater must be turned off (Switch e)(Fig. 1) and the diffusion pump isolated immediately if a large leak becomes apparent. Operation at a forepressure higher than 300 microns, as indicated by the forepressure thermocouple gage, causes the jet action to break down and allows the oil vapors to contaminate the system and possibly reach the forepump.

NOTE: Instructions for valve manipulations for isolating the diffusion pump are presented in tabular and schematic form in Fig. 8.

CONTACT WITH THE HOT FUMES FROM THE OIL IS TO BE AVOIDED AS THEY ARE EYE AND SKIN IRRITANTS.

4. Maintenance (Fig. 6, 6a)

a. The pump should be inspected after 100 hours of normal operations for:

1. carbonization and pyrolysis of diffusion pump oil from overheating or exposure to the atmosphere while hot.

2. contamination of oil with condensable vapors, such as water, from the system.

3. contamination of oil with dirt, filings, grease, etc., from the system.

b. To clean the pump the jet assembly is removed and the oil drained while still warm. Warm oil may be removed by suction after removing the elbow (vacuum manifold) and the vacuum (butterfly) valve. The pump body and the jet assembly should be cleaned with carbon tetrachloride or some other suitable solvent.

c. In the event that a heater element should burn out, the wiring is disconnected, the heater cover removed, the heater holding clamp removed and the heater unit replaced.

d. When the pump has been cleaned, 250 ml of National Research Corporation, NR, Narcoil-10, diffusion pump oil is introduced before replacing the jet assembly. Pouring will be facilitated by heating the oil to 65°C (150°F).

e. In replacing the jet assembly, the assembly is pressed down firmly to insure proper seating.

THERMOCOUPLE-IONIZATION GAGE UNIT (Fig. 1, 7, 9)

The gage unit (National Research Corporation, type 706) is designed to operate on 115 v 50/60 cycle A.C. The thermocouple gage controls are located at the left and the ionization gage controls at the right of the panel.

Table I (page 16) lists the operating characteristics of both gages.

1. Thermocouple gage (TC gage) operation and maintenance.

   a. "TC GAGE" switch is snapped to the on position.

   b. "TC INPUT" current is adjusted to 0.6 amperes plus the correction (the number in hundredths of an ampere) stamped on the hexagonal stem of the TC gage; i.e., if the number "4" is found stamped on the stem, the TC INPUT gage should be adjusted to 0.64 amperes.

   c. The TC GAGE heater circuit will operate at 1 ampere at atmospheric pressure without damage to the heater element.

   d. The vacuum manifold TC GAGE is designated as T.C. #1; the forepressure TC GAGE is designated as T.C. #2. The control unit panel is equipped with a TC GAGE selector switch.

2. Maintenance.

   a. The heater of the TC gage operates in series with the TC INPUT meter and the TC ADJUST control. Therefore, if the TC gage circuit is turned on and the input meter shows no indication of current, an open circuit exists. In this event the fuses X are checked, the TC gage cord and the TC gage are checked with an ohmmeter (prongs 1 and 5, Fig. 7) to determine whether the heater element is burned out or the cord circuit is open. Since the heater elements of both the gages used in the vacuum system are in series, failure of one gage will indicate both gages as being inoperative.

3. Ionization Gage (Ion Gage) Operation and Maintenance.

a. If the vacuum manifold pressure is below 5 microns the ion gage may be operated. Before applying power to the ion gage the three position switch marked "NORMAL" and "OUTGAS" is set to the "OUTGAS" position. (Fig. 9). (The center position is "OFF")

b. The "ION POWER" switch is now turned on and the "ION GRID CURRENT" control is rotated counter-clockwise to its limiting stop. This will energize the control relay which applies the current to the filament circuit. When the relay is closed the pilot light will be on.

c. Current should now be applied to outgas the gage for five minutes. This is done by rotating the "ION GRID CURRENT" control clockwise until the grid of the ion gage shows a dull red glow. While the gage is outgassing the amplifier will warm up and become stable.

d. In switching from "OUTGAS" to "NORMAL" or vice versa, the filament circuit relay drops out. This is a safety feature to prevent damaging of meters, ion gage filament or both. In order to re-energize the filament circuit, it is always necessary to turn the "GRID CURRENT" control back to the start position (as in "b" above).

e. Next, the "ION GRID CURRENT" control is turned towards "INCREASE" until "ION GRID" meter shows a current of 5 milliamperes. At this input full deflection of the "ION PLATE" meter indicates a pressure of 0.50 microns of mercury at the ion gage. Should the pressure be in excess of 0.50 microns, the "ION GRID CURRENT" control may be turned back until the "ION GRID" meter indicates 2.5 milliamperes. At this input full scale deflection of the "ION PLATE" meter indicates a pressure of 1 micron at the ion gage.

f. For the measurement of pressures below 0.1 microns it is recommended that the input be doubled from 5 ma to 10 ma so that the sensitivity of the gage circuit will be approximately doubled.

g. Fuses and gage cord receptacles are located at the rear of the case and are easily accessible. If a difficulty arises that is more serious than the replacement of tubes or cords, the National Research Corporation recommends that the unit be returned to them for servicing and readjustment.

4. **Leak Hunting.**

a. Leaks may be located with either the TC gage or the ion gage. The TC gage may be used when the pressures are below 200 microns, but above one micron. The procedure is outlined as follows:

1. The "TC INPUT" is adjusted so that "TC OUTPUT" meter indicates as near full scale as possible.

2. Acetone or ether is sprayed over the suspected area of the vacuum system and the output meter watched closely. A sudden apparent rise in pressure indicates that the organic vapor has entered the system and that the leak has been found.

3. At pressures below 1 micron the ion gage may be used in a similar manner after adjustment of the "ION GRID CURRENT" control has been made so that the "ION PLATE" meter is at the low pressure end of the scale.

POWER SOURCE (Fig. 2, 4)

The motor circuit of the Tocco motor generator set is controlled by a 600 volt switch on the right side of the lower portion of the Tocco housing. None of the other controls on this side is being used in the present installation. (Fig. 4).

1. To energize the inductor coil:

a. The cooling water for the coil, condensers and vacuum chamber is turned on. Flow should be adjusted so that outlet water is always cool.

b. The Tocco motor is now started (Switch b, Fig. 4). When the motor circuit is closed a white light will appear on the upper right front panel. The generator field is energized (Switch a, Fig. 2). Excitation of the generator field in the Tocco Junior is obtained from an assembly of copper oxide or selenium rectifiers arranged for full wave rectification. This rectifier assembly is located within the lower housing of the machine. Control of the generator field and thus the control of the generator line voltage, is obtained by supplying current to the rectifiers from a single phase variable voltage transformer. The variable transformer is mounted on the instrument panel table (Fig. 1). In the event of failure during operation the field control system fuses located on the control fuse panel in the lower housing should be inspected before looking further.

e. The jumper or foot pedal control plug is inserted in the "HEAT MANUAL" receptacle. (The program timers used to actuate the auxiliary relay in mass production processes have been disconnected, hence it is necessary to use the manual control system to actuate this relay in order to energize the high frequency line contactor.) For continuous heating operations the manual heat control receptacle is "jumped" by inserting a copper loop. (Fig. 2). For intermittent applications of high frequency current to the coil for the purpose of changing coil spacing and/or capacitator taps, a foot pedal control may be placed in the circuit. When the high frequency circuit is closed, a red light will appear on the upper left front panel of the machine.

Failure of operation of this circuit may be traced to the housing door safety switches or the overload relay contacts. Beyond these, any further difficulty might arise from loose connections.

ADJUSTMENT OF POWER FACTOR

1. All jumpers on the terminals of the capacitators should be removed.

2. The furnace assembly is placed in coil.

3. Water flow in the chamber, coil and condenser is checked.

4. The motor generator is started following instructions given above.

5. The main line contactor is closed by use of foot pedal control.

6. With foot pedal control closed meters (voltage and amperage) are read and the variable transformer is adjusted for a low but readable value.

7. The kilovar meter should now show a "lag".

8. The foot pedal control is released and field switch disconnected before adding jumpers to capacitator terminals.

9. Starting with the lowest values of capacitance, subsequent steps are added until approximately unity power factor is reached as indicated by the kilovar meter reaching the zero mark (Capacitator step values are shown in Fig. 12). Further adjustments may be necessary as the electrical resistance load changes with temperature.

POWER OUTPUT

Calculations of power output should be made only when the kilovar meter indicates unity power factor (or as near as possible).

Where: E is given in Volts (panel voltmeter reading)

I is expressed in Amperes (panel ammeter reading)

Then: Power $= \frac{EI}{1000}$, expressed in kilowatts (KW)

INDUCTOR COIL

1. The inductor coil spacing should be maintained to give a space factor as near to unity as is possible. A space factor of 0.85 is considered satisfactory. The term "space factor" is defined as follows:

   Where: N = number of turns

   W = width of a single turn

   L = length of coil

   Then: $\frac{NW}{L}$ = space factor

2. Coil dimensions and characteristics are calculated in accordance with "Design of Induction-Heating Coils for Non-Magnetic Loads" (AIEE paper #45-107) by J. T. Vaughan and J. W. Williamson.

VACUUM CHAMBER (Fig. 1, 3, 4)

1. The following notations refer to the vacuum chamber.

   a. The water flow through the chamber jacket should be such that outlet water temperature is less than 85°F.

   b. The large cover need not be removed except to replace the inductor coil.

   c. The small hatch may be removed for furnace loading and adjustment of the coil position and spacing, and replacing gasket.

   d. Extra calibrated windows are stocked as replacements for the sight hole window in the small hatch. These windows are of "Vycor" (Corning Glass Co.), 0.21 inches thick. Each window has been polished and calibrated for radiation losses and corrections, as determined with an optical pyrometer, and have been recorded for the range 1000 C - 2000 C (Table III, p. 18).

GASKETS

1. Table II (p. 17) shows gasket material and sizes as used between system components.

FURNACE DESIGN AND CONSTRUCTION

1. Furnace design and construction are schematically shown in Fig. 10.

2. Variations of heater material and dimensions will change inductor coil efficiency. Redesign will be facilitated by reference to "Design of Induction Heating Coils for Non-Magnetic Loads" (AIEE paper #45-107) by J. T. Vaughan and J. W. Williamson.

ATMOSPHERE DRYER

The Lectrodryer, size (0), is intended for the drying of gas or air at a maximum of 15 psi pressure, and at a flow rate up to 0.40 standard cubic feet per hour with an input moisture content of not over 5.7 grains per cubic ft. Maintenance and operation of the dryer system is described in detail in the instructions received with the equipment (Ref. Wtn. 400.152/3805).

REPORT ON A TYPICAL RUN

For the purpose of demonstrating a typical operation, the following log is reported.

It is desired that the empty heater ring (graphite) be brought to a temperature of 1400°C in vacuum for outgassing.

The coil was loaded with the furnace assembly shown in Figure 10. The small hatch was bolted down and the water flow commenced in the chamber, coil, capacitator and diffusion pump cooling systems. Forepressure manifold valves were positioned for normal operation (Fig. 4). Capacitator taps had been previously adjusted to unity power factor.

ELAPSED TIME (MIN.)	OBS. TEMP. (°C)	ION GAGE	TC 1	TC 2	POWER (KW)
0	forepump started				
10	---	---	100	100	---
	Diffusion pump heater energized				
30	---	---	off scale	50	---

ELAPSED TIME (MIN.)	OBS. TEMP. (°C)	ION GAGE	TC 1	TC 2	POWER (KW)
Ion gage outgassed and inductor coil energized					
40	---	0.2	off scale	25	4.5
50	750	0.5	---	40	4.5
70	1050	1.0	---	60	4.5
For this last observation it was necessary to reduce the ion gage input to 2.5 ma to read the pressure. Ion gage was then turned off.					
80	1075	---	4	110	4.5
Power increased to 8.7 KW					
90	1150	---	6	150	8.7
110	1350	---	2	70	8.7
120	1385	---	off scale	30	8.7
Ion gage outgassed					
125	1385	0.3	---	30	8.7
It was necessary to make small power adjustments in order to maintain observed temperature at 1385°C					
140	1385	0.5	---	25	8.7 ± .05
180	1385	0.8	---	30	8.7 ± .05
Power off (inductor coil), motor generator off					
240	black	0.09	---	25	---

Diffusion pump off and isolated from vacuum chamber and manifold. Forepressure maintained at low value. Helium admitted to chamber and manifold, small hatch removed.

Helium flow maintained until hatch replaced.

255 Forepump shut down, diffusion pump completely isolated.

TABLE I

OPERATING CHARACTERISTICS

FOR

THERMOCOUPLE AND IONIZATION GAGE CONTROL UNIT
(National Research Corporation, Type 706)

	Thermocouple Gages N.R.C. Type 507 1/8" IPS Nipple	Ionization Gage N.R.C. Type 507 3/4" Nonex Glass Tubulation
INPUT	0.60 to 0.64 amperes	Filament: 5 V, 5 A (approx.) Grid : 150 V, 5 Milliamps Plate : 20 V Max. Emission: 20 Milliamps.
RANGE (dry air calib.)	500 to 2 microns Hg	1 to .001 microns Hg
SENSITIVITY	Non linear response Output at 500 microns, 3. lmv Output at 2 microns 15.1 mv	100 microamps per micron Hg

TABLE II

GASKET LOCATIONS, MATERIALS, THICKNESS, AND CEMENT

Gasket between	Material	Thickness in.	Cementing Agent
Coil leads and Tur-x plate*	Neoprene	1/8 (grommet)	Silicone grease
Tur-x plate and chamber flange	"	1/8	"
Large hatch and chamber*	"	"	"
Small hatch and large hatch	Silicone rubber Grade 12600 (G.E.)	"	"
Shield valve and small hatch*	Neoprene	"	"
Window assembly and small hatch	"	"	Castor oil
Chamber and adapter*	"	"	Silicone grease
Adapter and vacuum manifold*	"	"	"
Manifold and vacuum valve	"	"	Castor oil
Vacuum valve and diffusion pump	"	"	"
All forepressure manifold gaskets	"	"	"

*Semi-permanent installations that have been painted with Glyptol.

<u>TABLE III</u>

WINDOW CORRECTION VALVES
(Determined by Testing Methods Section, Watertown Arsenal)

Window #	Reading Without Window °C	Reading Through Window °C	Correction (°C)(Additive)
1	1004	994	10
	1555	1538	17
	2335	2300	35
2	1003	989	14
	1570	1548	22
	2345	2310	35
3	1003	994	9
	1568	1545	23
	2330	2295	35
4	1037	1025	12
	1450	1431	19
	2000	1971	29
5	1035	1025	10
	1450	1435	15
	2000	1972	29
6	1033	1024	9
	1450	1430	20
	2000	1970	30

FIGURE I

FRONT VIEW

A — PANEL MOUNTED TOCCO INSTRUMENTS

B — VACUUM "BUTTERFLY" VALVE HOUSING

C — DIFFUSION PUMP

D — MECHANICAL (KINNEY) PUMP SWITCH

E — DIFFUSION PUMP SWITCH

FIGURE 2

TOCCO MOTOR GENERATOR

A – GENERATOR FIELD SWITCH

B – "JUMPER" IN PLACE

C – VACUUM MANIFOLD EXTENSION AND
QUARTZ TUBE MOUNTING RINGS

FIGURE 3

CAPACITATOR MOUNTING

A – "TUR-X" PLATE

WTN.681-207

21

FIGURE 4

REAR VIEW

A – VACUUM "BUTTERFLY" VALVE MECHANISM

B – TOCCO STARTING SWITCH

WTN.681-208

WTN.639-8950

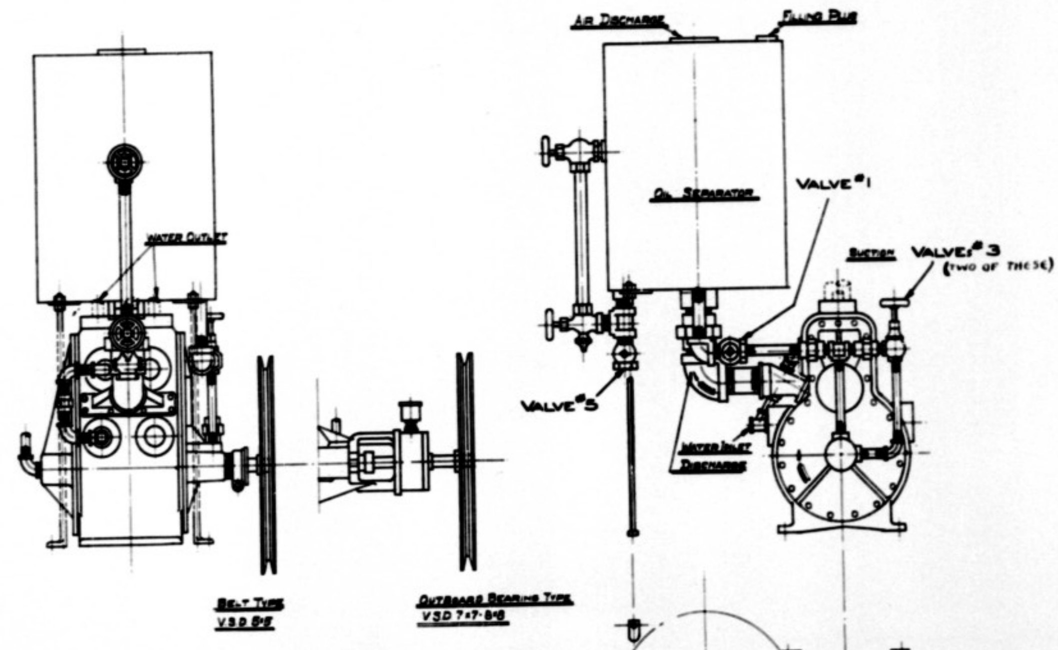


FIGURE 5

KINNEY VACUUM PUMP

TYPE V. S. D.

23

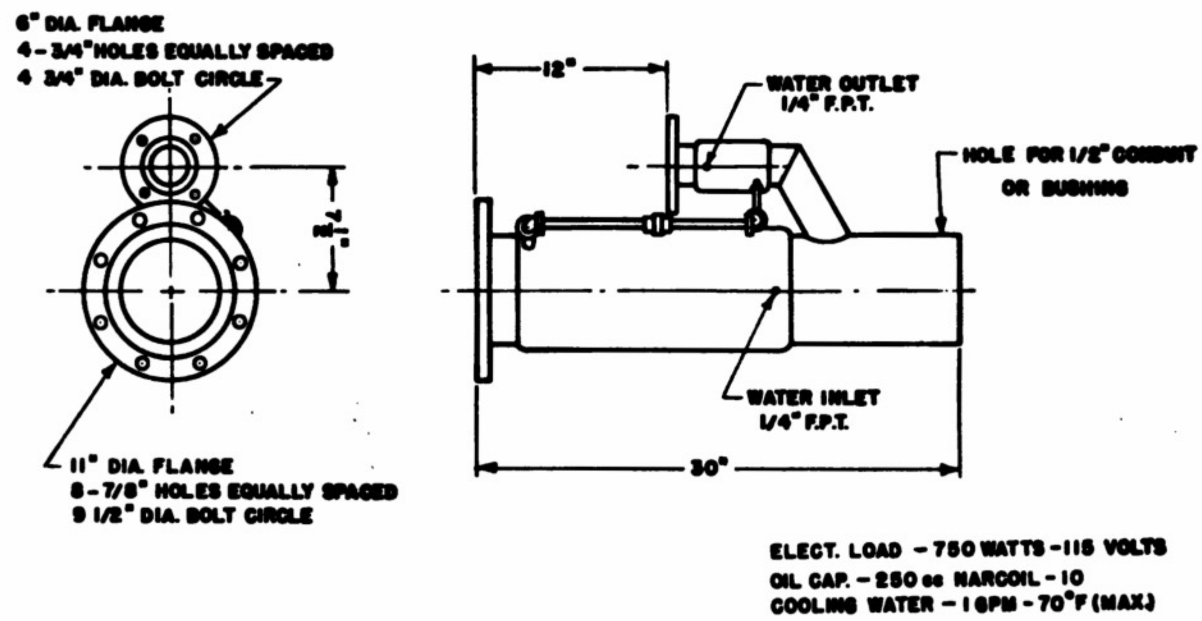


FIGURE 6

VACUUM DIFFUSION PUMP

MODEL H$_S$ TYPE 104

NATIONAL RESEARCH CORPORATION

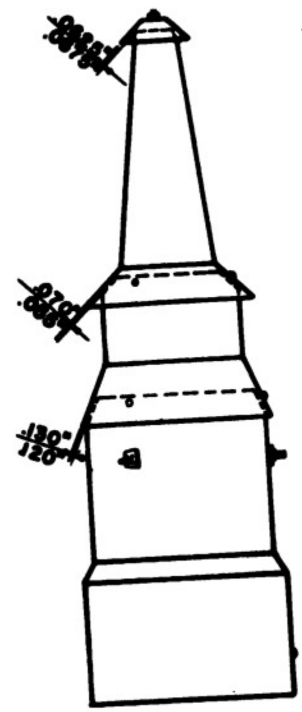


FIGURE 6A

UMBRELLA JET
H6 DIFFUSION PUMP

WTN.630-0052

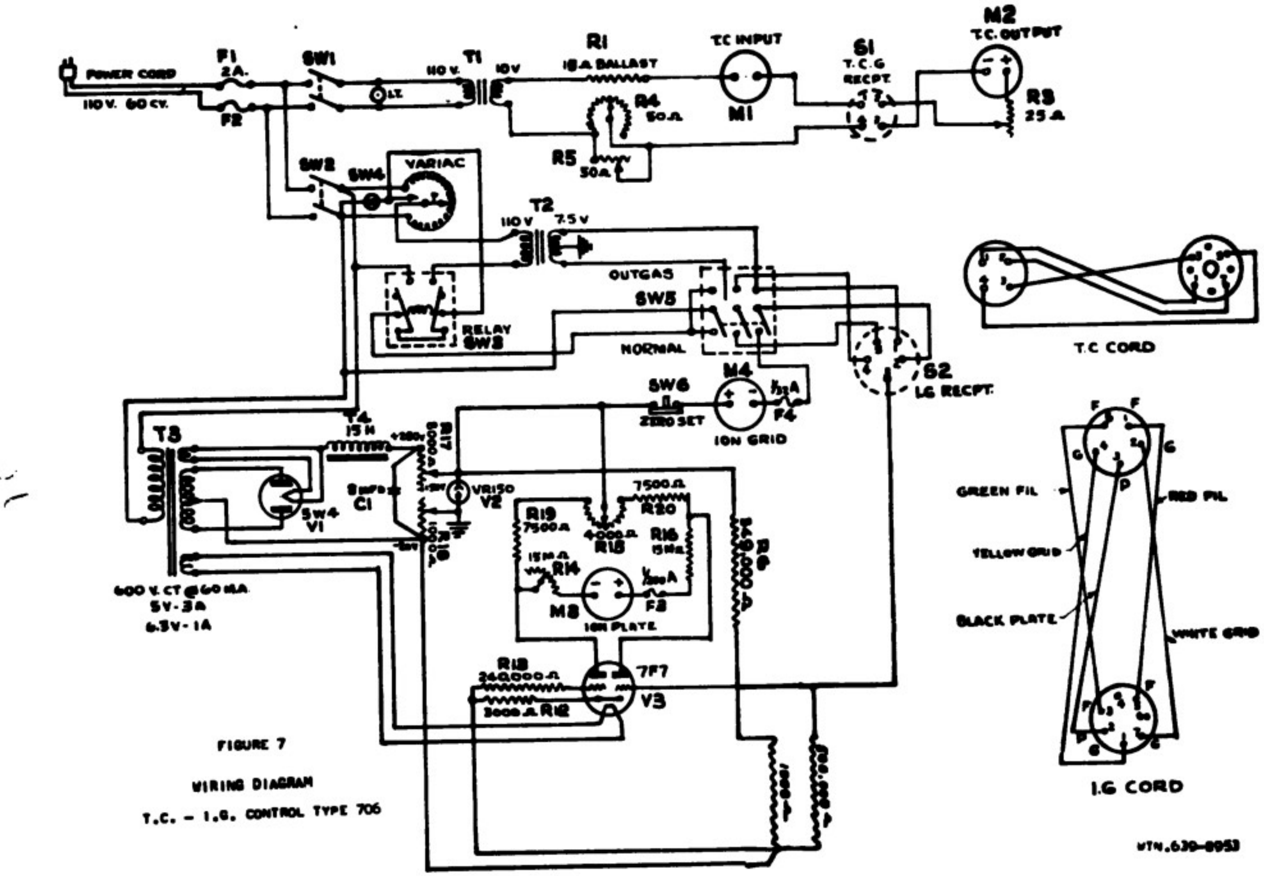
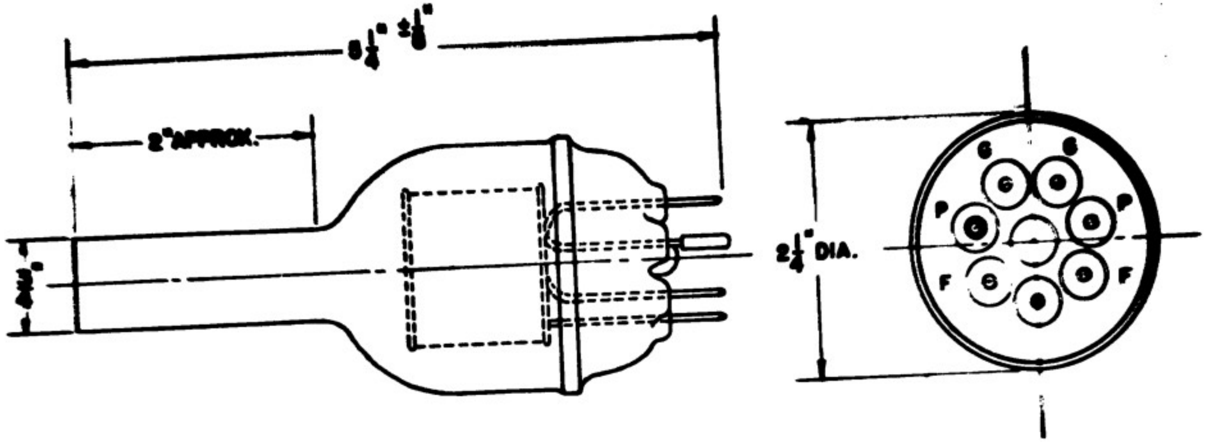


FIGURE 7

WIRING DIAGRAM

T.C. – I.G. CONTROL TYPE 706



ST'D OPERATING VALUES
FILAMENT 5 V. @ 5 A., A.C.
GRID +150 V. @ 5 MA.
PLATE −20 V.

FIGURE 7A
IONIZATION GAUGE
TYPE 507

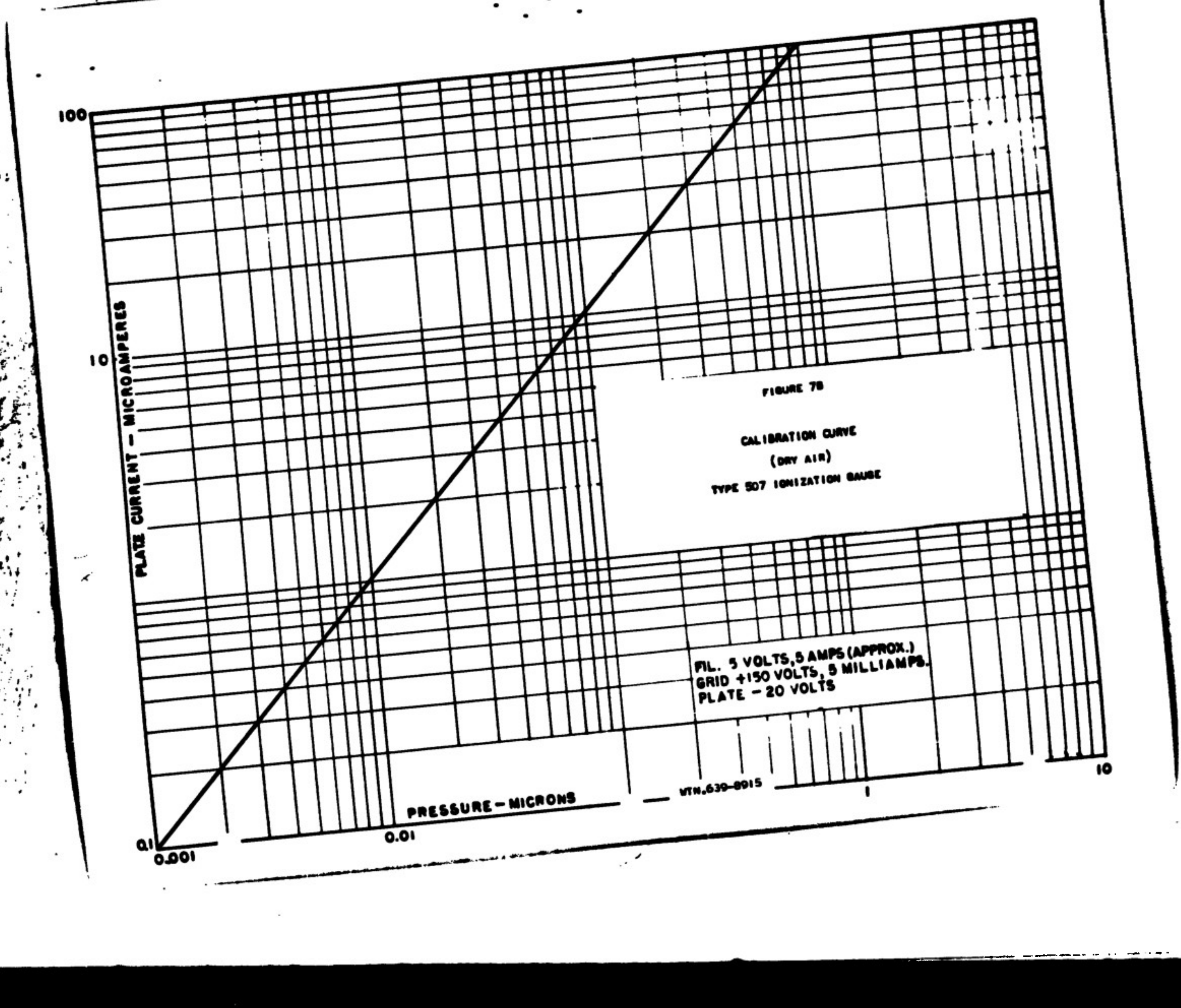


FIGURE 7B

CALIBRATION CURVE

(DRY AIR)

TYPE 507 IONIZATION GAUGE

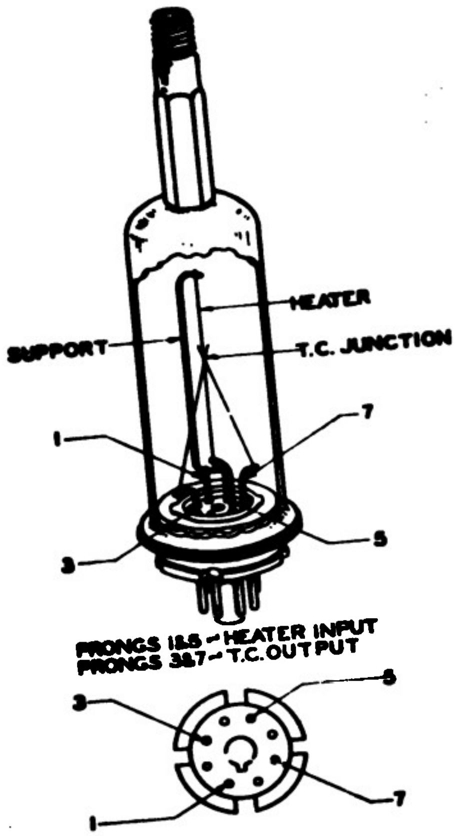


FIGURE 7C

THERMOCOUPLE GAUGE
SECTIONAL VIEW
TYPE E

WTN.630-0005

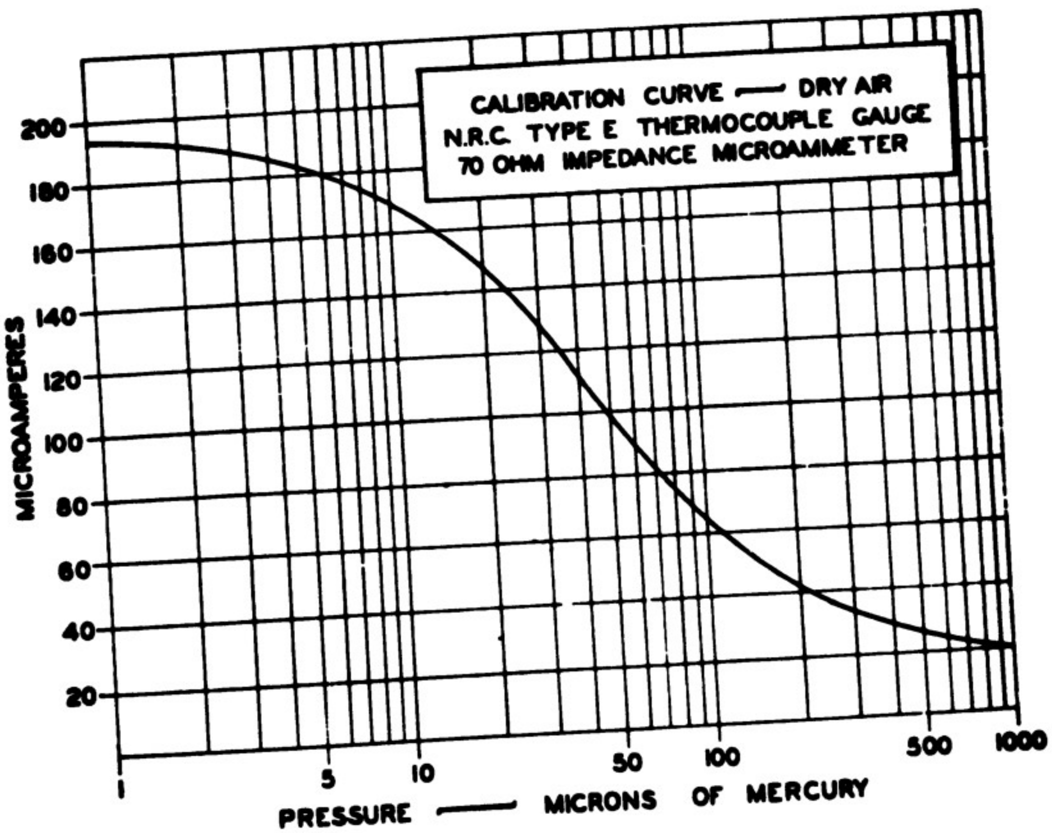


FIGURE 70

WN.630-6867

	VALVE #	1	2	3	4
TO START		OPEN	OPEN	CLOSED	CLOSED
TO ISOLATE DIFFUSION PUMP AND CONTINUE PUMPING WITH FOREPUMP		CLOSED	CLOSED	OPEN	CLOSED
TO ADMIT GAS TO CHAMBER ONLY		CLOSED	~~OPEN~~ CLOSED	CLOSED	~~CLOSED~~ OPEN

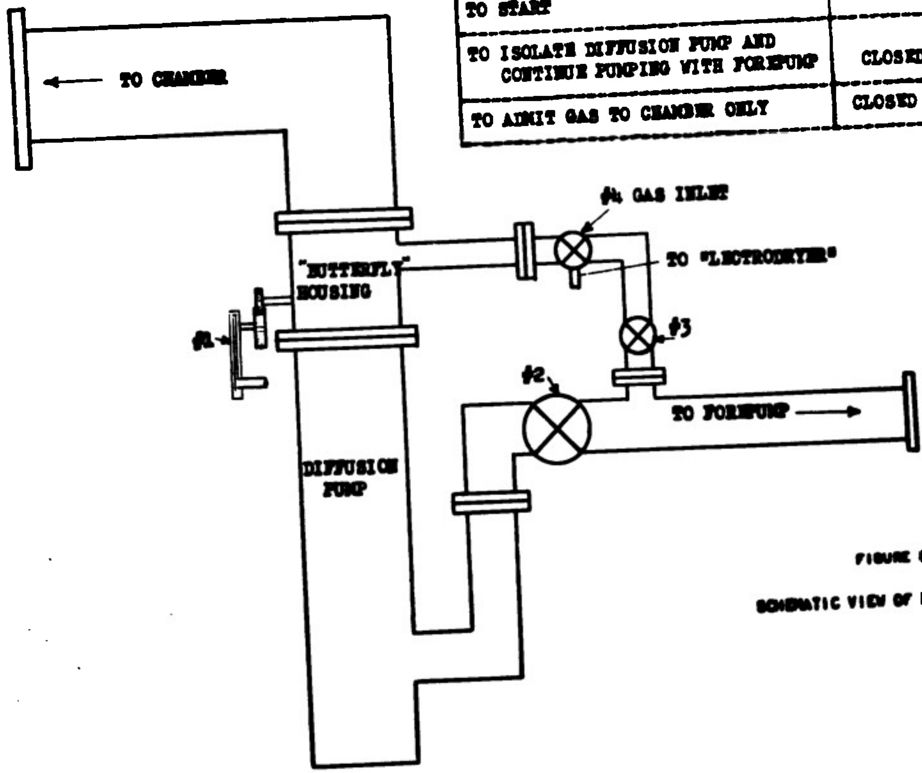


FIGURE 8

SCHEMATIC VIEW OF MANIFOLD VALVING

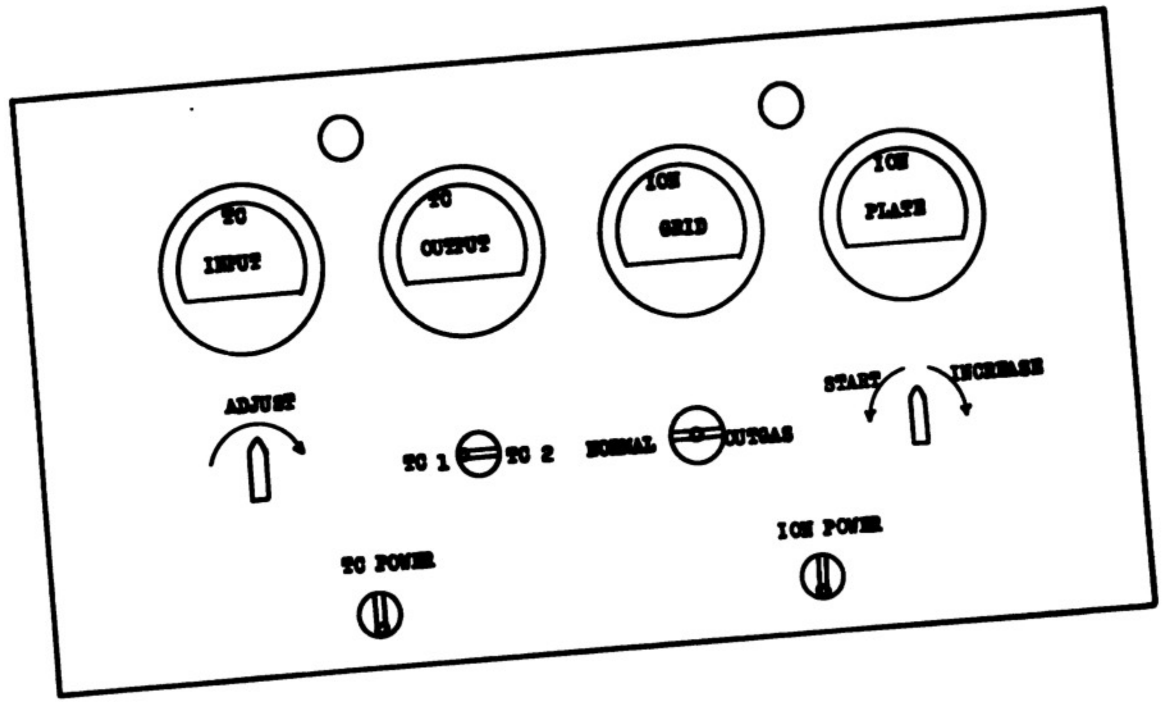


FIGURE 9

VACUUM MEASURING INSTRUMENT CONTROL

WTN.630-[illegible]

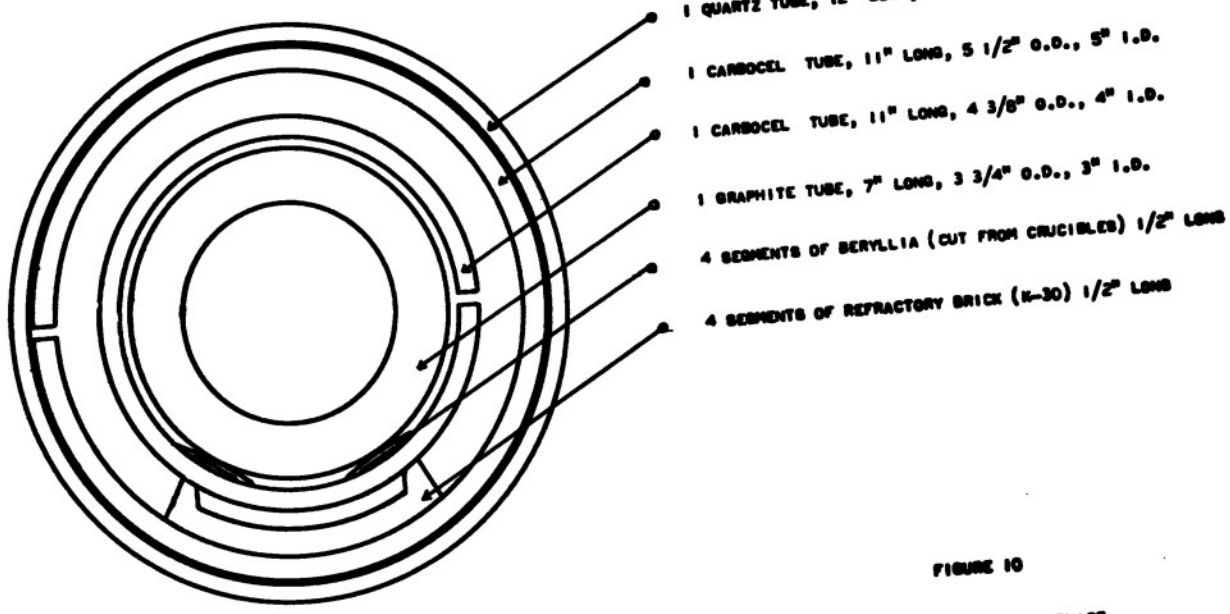


FIGURE 10

INDUCTION HEATING FURNACE

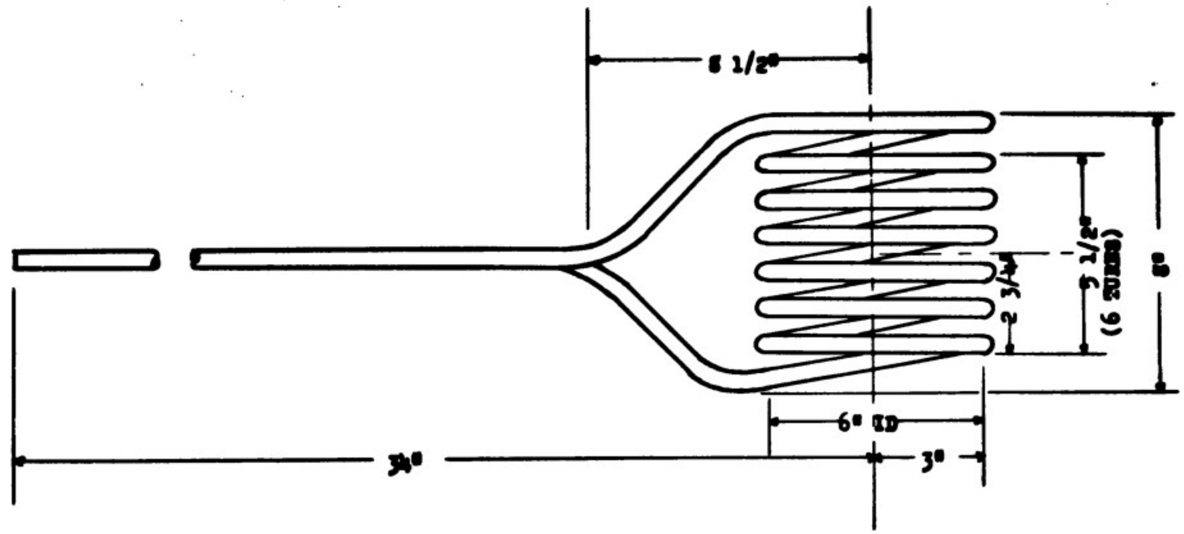


FIGURE 11
COIL FOR INDUCTION FURNACE

WTN.630-0061

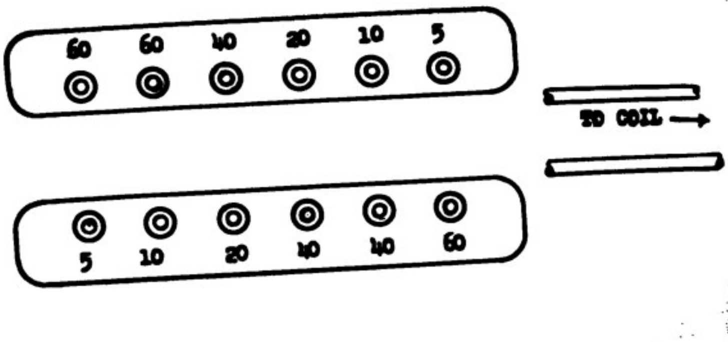


FIGURE 12

SCHEMATIC (TOP) VIEW OF CAPACITATORS
CAPACITATOR TAP VALUES GIVEN IN KVA

WTN.630-8062

REEL – C

344

A.T.I.

9505

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ABSTRACT:

Furnace for melting small charges of metals, as well as for sintering powdered metal products under high vacuum, is described. Main components of equipment are power source with 20-kw motor generator set, inductor coil consisting of 20 ft 1/4 in. standard weight copper pipe wound into 5-1/2 turn coil, vacuum chamber and manifold of stainless steel, diffusion pump used as vacuum booster pump of 1250 cu ft per min capacity at 2 microns pressure, and dual chamber type dryer with a reactivating system.

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