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A LABORATORY ARC MELTING FURNACE FOR THE PRODUCTION OF ALLOY SAMPLES FROM REACTIVE METALS

JOHN C. OLSON

MATERIALS CENTRAL

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A LABORATORY ARC MELTING FURNACE FOR THE PRODUCTION OF ALLOY SAMPLES FROM REACTIVE METALS

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Materials Central

MAY 1961

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FOREWORD

This report was prepared by the Electronic and Magnetic Materials Section, Thermophysics Branch, and initiated under Project No. 7371, "Applied Research in Electrical Electronic and Magnetic Materials," Task Nos. 73711, "Applied Research on Conductors and Semi-conductor Materials," and 73712, "Applied Research on Magnetic Materials." This project was administered under the direction of the Physics Laboratory, Materials Central, Deputy for Advanced Systems Technology, Aeronautical Systems Division.

This report covers work conducted from February 1960 to February 1961.

The author wishes to thank Mr. Robert Patton for assisting in th construction and instrumentation of the apparatus. Special acknowledgement is made to Dr. Karl Strnat who initiated this project and continually supplied advice and constructive criticism.

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ABSTRACT

An arc melting furnace for the production of small samples of alloys and intermetallic compounds has been designed and built. It is used in phase diagram investigations involving reactive materials such as rare earth metals. It has also been used for the laboratory scale preparation of nickel-copper alloys being studied for magnetic thermometry.

In this report, the design, capabilities and operation of the furnace are described.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

JULES I. WITTEBORT
Chief, Thermophysics Branch
Physic Laboratory
Materials Central

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I. INTRODUCTION

In the production of alloys and intermetallic compounds by melting, difficulties are encountered with a great many materials because of the reaction of these materials with their containers. Sometimes it is possible to find by lengthy experimentation, a crucible material which will not contaminate the melt. Such materials can, for instance, be the oxides of the metals to be melted; however, more often the best solution is a method which involves no hot crucible at all. Arc melting (i.e., heating by means of an electrical arc discharge between a water cooled electrode and the material to be melted) constitutes such a method.

This report describes the development of an arc melting furnace for the production of alloy samples from reactive metals. This furnace can be operated under vacuum or with a protective gas at pressures up to at least 5 atmospheres. Arc current and arc length can be adjusted separately. A port permits visual observation during operation. Auxiliary lighting is provided for observation when the arc power is off.

This furnace represents a basic tool for metallurgical work aimed at the construction of phase diagrams.

II. APPARATUS

1. GENERAL DESIGN

The complete furnace is seen in figures 1 & 2. The basic shell of the furnace consists of a brass tube with end flanges, cast as one integral piece. The inside diameter of the tube is 8 inches and the outside diameters of the flanges are 12 inches. The cast assembly is 3/8-inch thick throughout and stands 6 inches tall. A copper plate 1/4-inch thick forms the bottom of the furnace. An O-ring groove is provided in the copper plate and the bottom flange of the casting to effect the required vacuum and pressure seals. A phenolic plastic insulating ring of 3/4-inch thickness with 8-inch I.D. and 12-inch O.D. mates to the top flange and a 12-inch circular disk of brass, 3/8-inch thick which forms the top of the furnace body. The top disk, plastic ring, and the top flange are bolted together with 12 bolts using rubber gaskets at the brass-plastic interfaces, and insulators between the bolts and the top disk. Six tie-down studs in the copper bottom plate secure the bottom flange of the casting to the copper plate. This assures the pressure capability of the furnace. Copper tubing of 1/4-inch diameter is soft-soldered to the foregoing assembly to produce good cooling, especially of the bottom plate. The cooling coils are shown in figure 3.

The top disk has 5 ports which are utilized as follows:

1. a centrally located opening is provided for the cathode mechanism which will be described later;
2. a vacuum port;

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3. a gas inlet;
4. a vacuum/pressure window which permits visual observation of the furnace interior.
5. a port for leads to internal instrumentation.

These items are all soft-soldered to the top disk.

Another major item of the furnace is a rotatable water cooled cathode which is shown in figure 4. It is equipped with an interchangeable thoriated tungsten tip mounted offset so that, as the unit is rotated, the tip describes a 5-inch circle. This is illustrated in figure 5. A disk of copper slightly less than 8-inches in diameter, 1/2-inch thick with holes bored completely through it on a concentric 5-inch circle is placed on the bottom plate forming 8 receptacles which confine the materials to be melted. (See figure 9) Figure 6 shows two disks which may be used alternately for rod or button shaped samples. The disk is fastened to the bottom plate, which is the anode, by 4 studs. The cathode may be moved vertically, up or down, allowing the arc to be "struck" by touching the cathode tip to the copper disk insert. The cathode assembly is spring loaded upward with 6 stacked O-rings separated by washers forming the vacuum/pressure seal. It is equipped with an adjustable retaining cap so that the operating arc length may be predetermined.

During operation, the arc itself produces ample light for observation of the melts. However, when the arc power is off, light is supplied by 3 six-volt light bulbs mounted on the inner periphery of the plastic ring. (See figure 5).

2. SUPPLEMENTARY COMPONENTS

(a) The power requirements of the furnace are up to 300 amps of direct current at approximately 20 volts (i.e. 6 kilowatts). The power is supplied by a 25 kilowatt motor-generator set. Control of the arc current permits its adaptation to the amount and the type of material to be melted. The inherent electrical and thermal conductivity and the boiling point of the melt constituents can greatly influence the melting behavior. When large currents are used on a low conductivity melt, a high degree of vaporization can result, fogging the interior of the furnace chamber and making it difficult or even impossible to observe the melting in progress.

The current control is achieved in the following ways;

1. the generator voltage can be varied between the limits of 0-150 volts.
2. The circuit shown in figure 7 permits high initial amperage for melting and later its reduction by means of the push-button switch S, to a level predetermined to keep the melted charge liquid or to slow-cool melts which tend to shatter if "quenched" by suddenly turning off the arc.

(b) Normally inert atmospheres of argon or a mixture of argon and helium are used in the furnace. A mechanical pump with a quick-disconnect fitting allows the furnace to be evacuated. Gases may be introduced while the furnace is evacuated thus providing a flushing action. Figure 8 shows the vacuum pump and the connected gas cylinder. The furnace will hold pressures over 5 atmospheres and can be operated under both pressurized and evacuated conditions. Operation under vacuum is normally reserved for the outgassing of scavenger materials such as zirconium or titanium. Buttons of these

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metals are ordinarily melted first to gather the remaining traces of oxygen after flushing but prior to the actual production of reactive samples.

IV. SAMPLE PRODUCTION

Since its completion, the furnace has been used to produce samples of several materials. A series of nickel-copper alloys with compositions around 70% Ni have been produced very successfully. Other materials which have been melted include zirconium, titanium, yttrium and manganese. The first three produced good button samples with no difficulty. Manganese requires more attention, however, because of its tendency to vaporize. Lowering the arc current reduces vaporization as does melting at inert gas pressures of several atmospheres.

The sample size which can be produced by this furnace is 7 cc by volume or about 60 grams, for materials like copper or nickel. Figure 9 shows samples before and after melting.

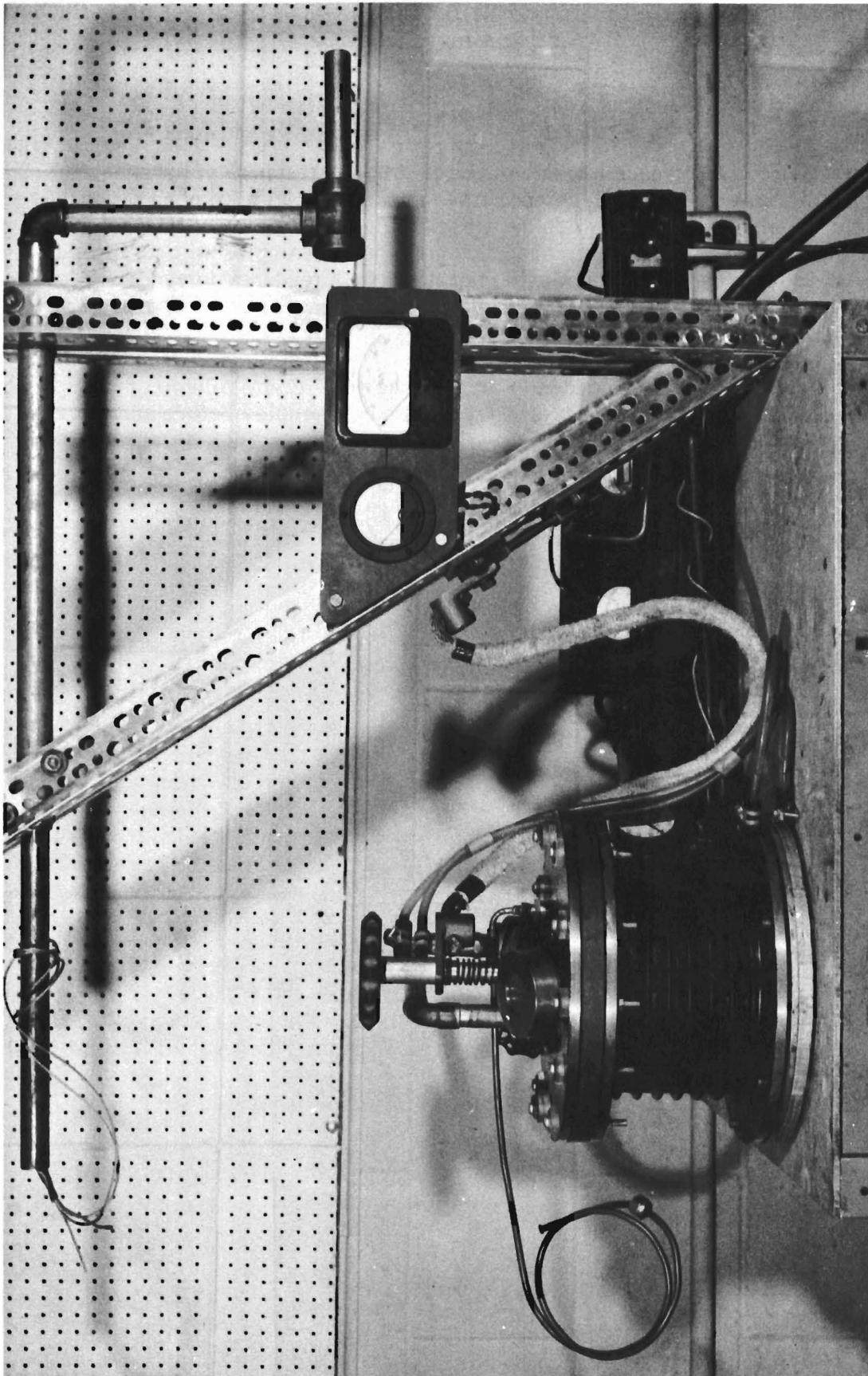


Figure 1. Front view of furnace

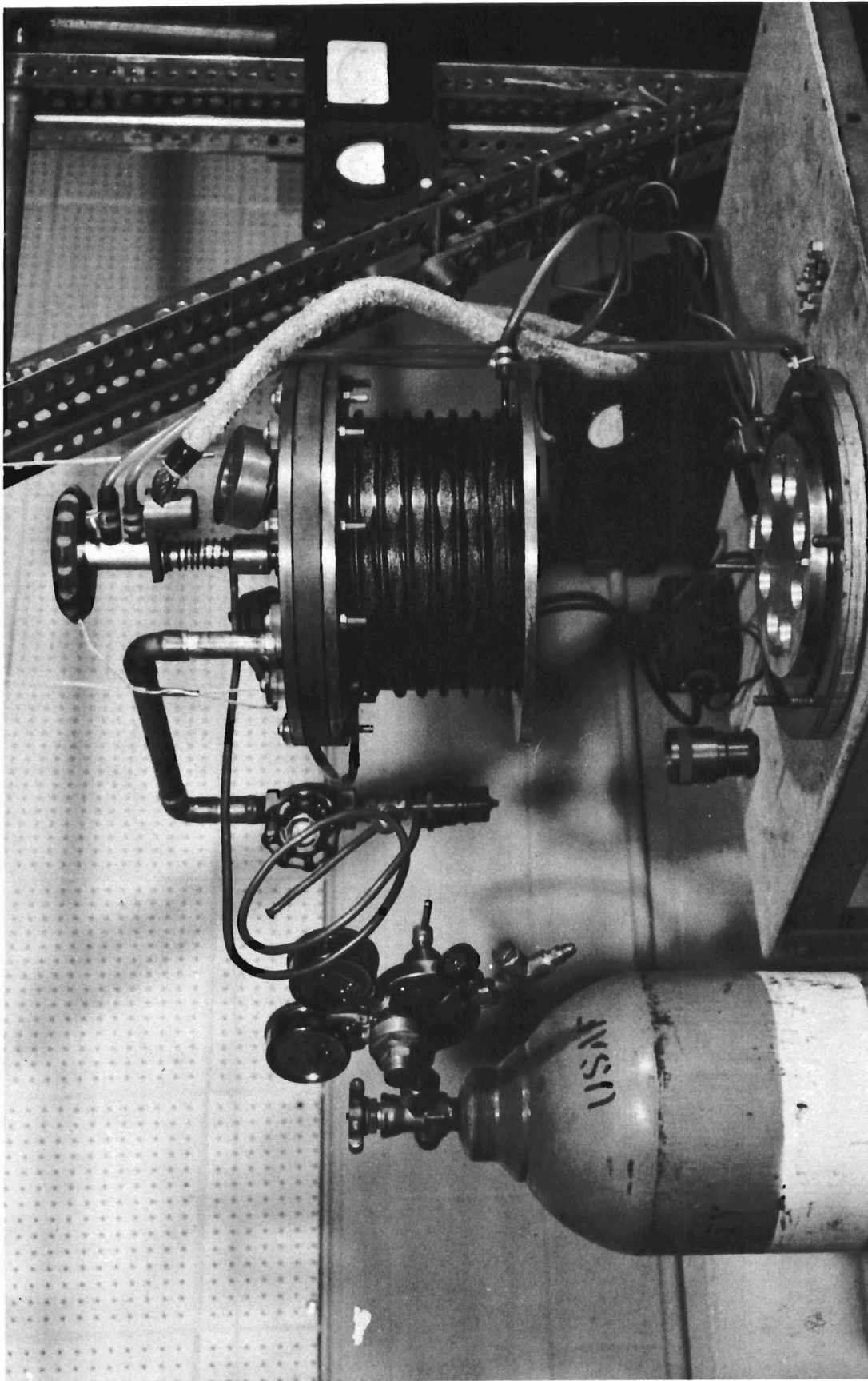


Figure 2. Furnace in elevated position

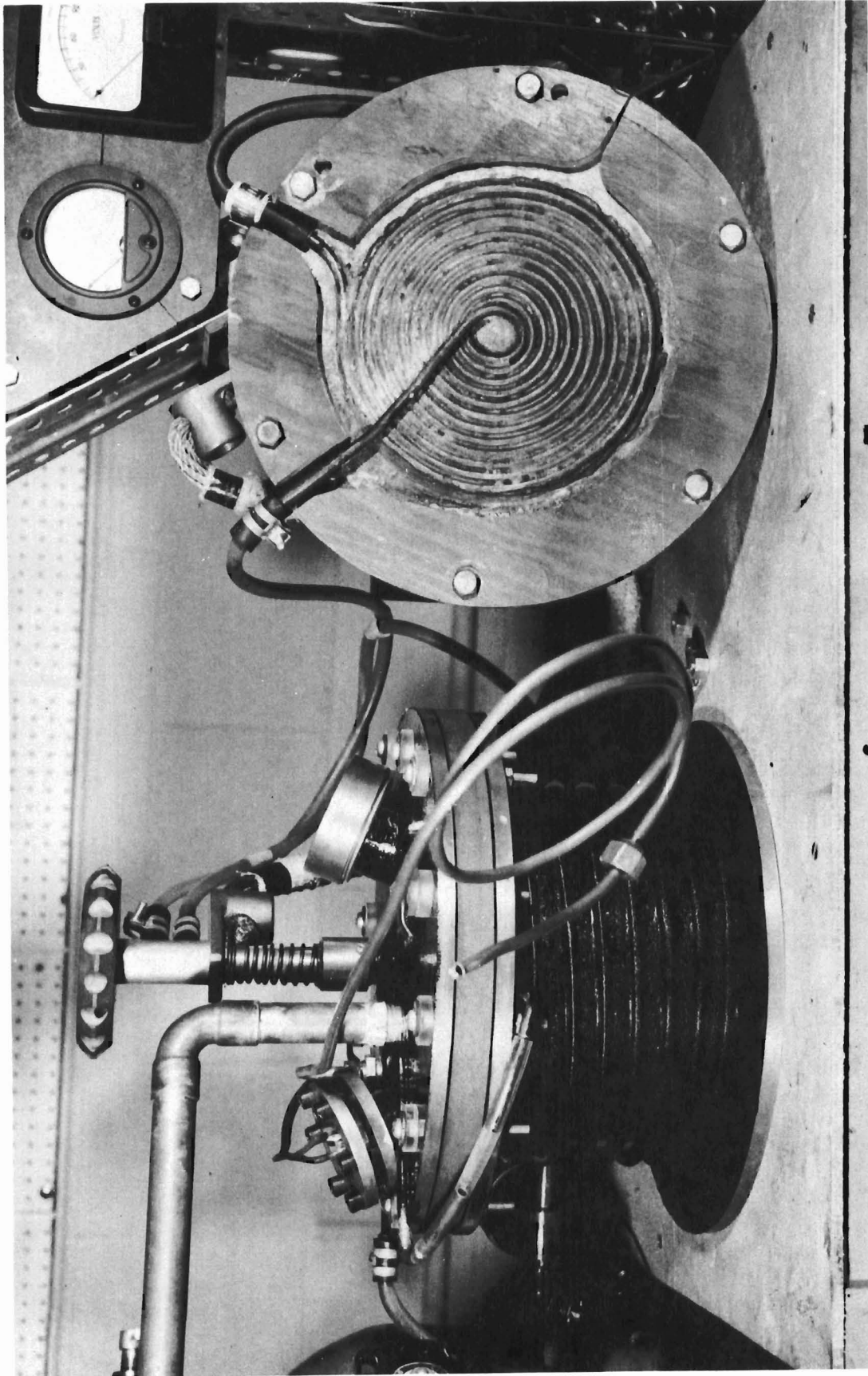


Figure 3. Furnace with cooling coils exposed

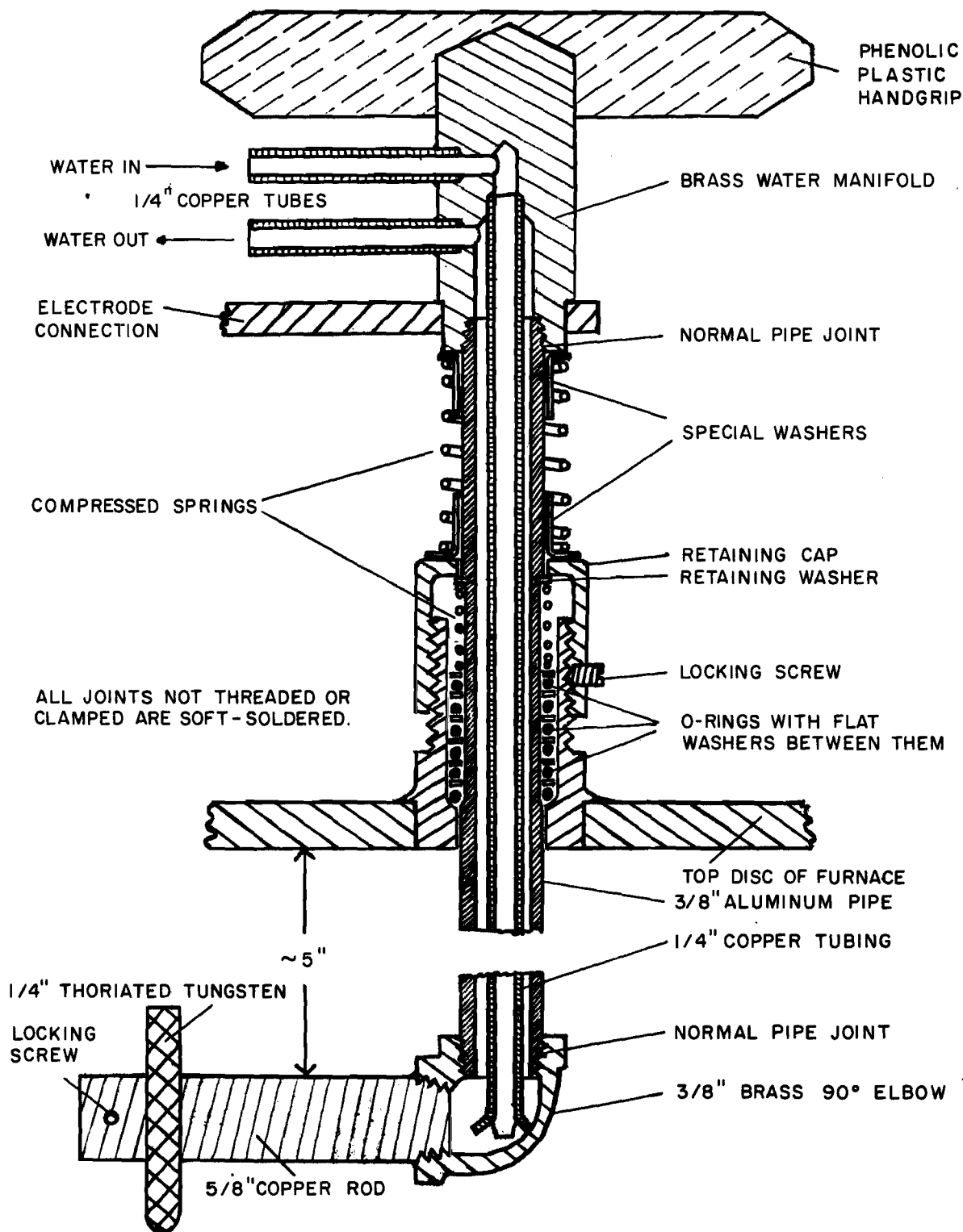


Figure 4. Cross section view of cathode mechanism

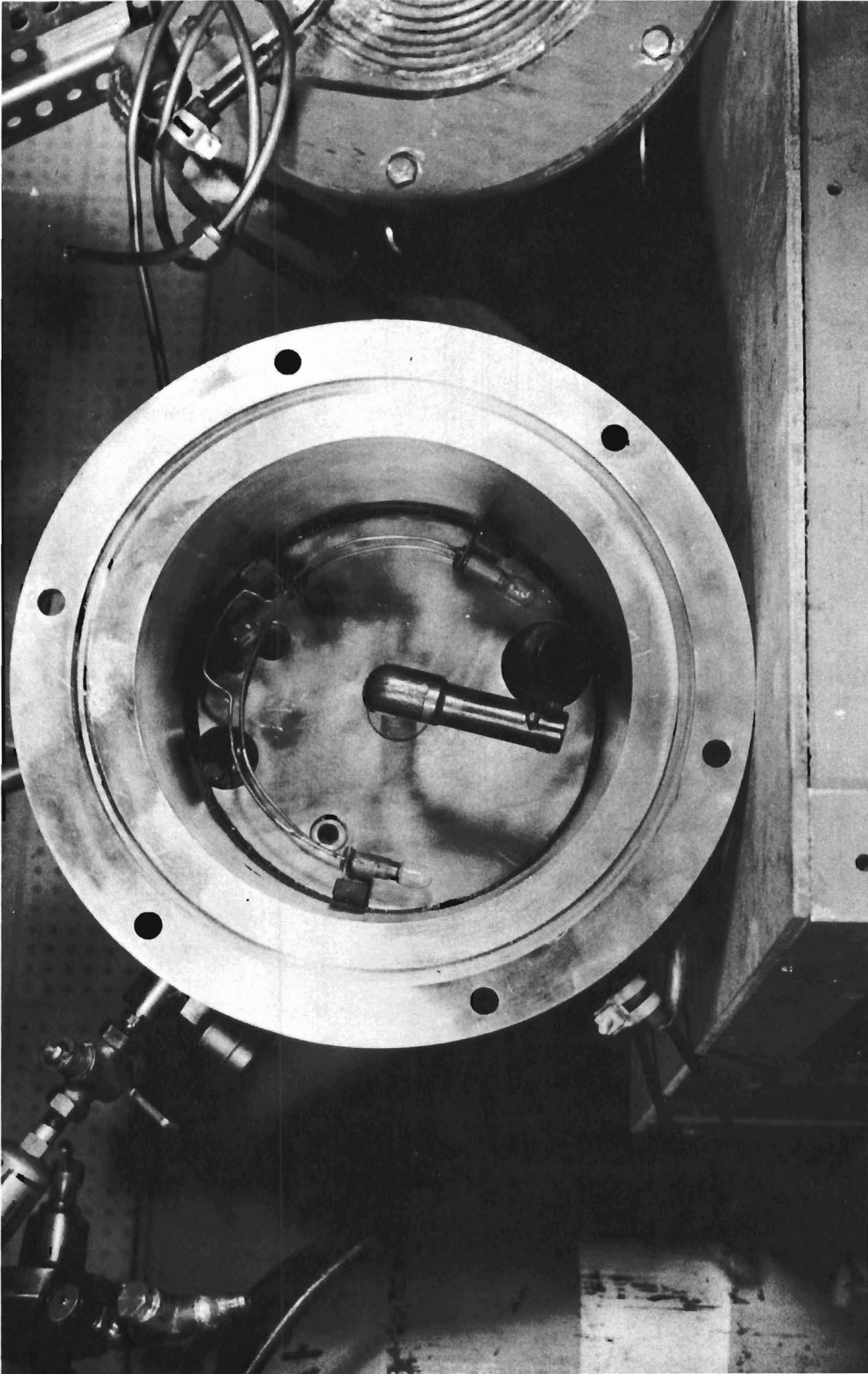


Figure 5. Interior of furnace viewing it from the bottom

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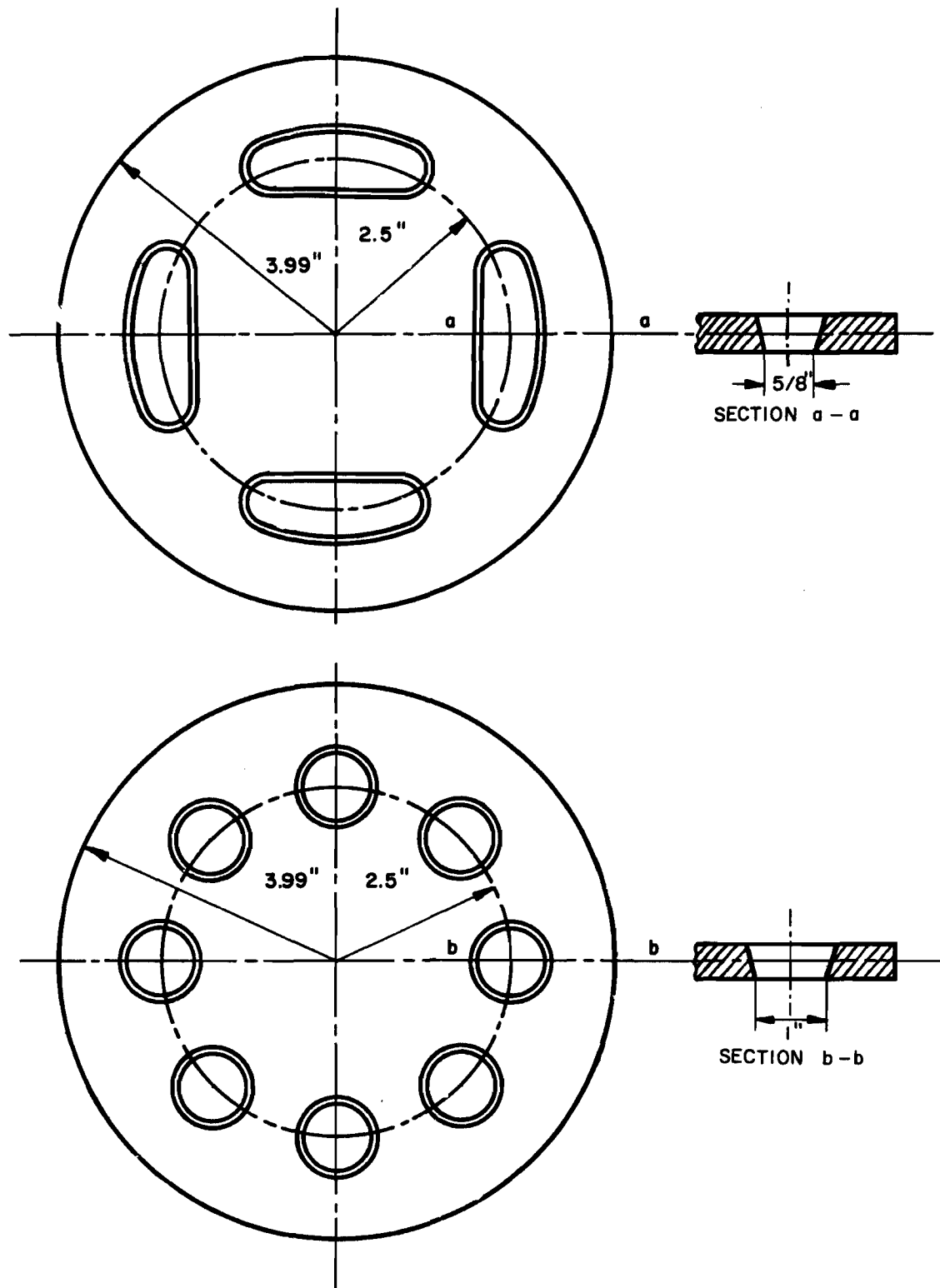


Figure 6. Two inserts for rod or button shaped samples

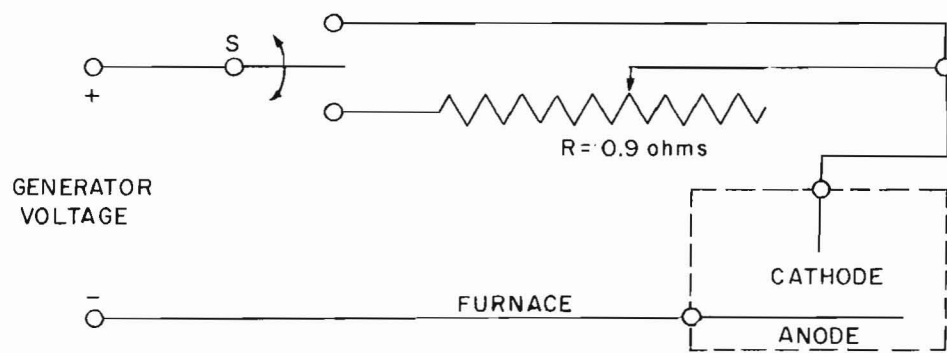
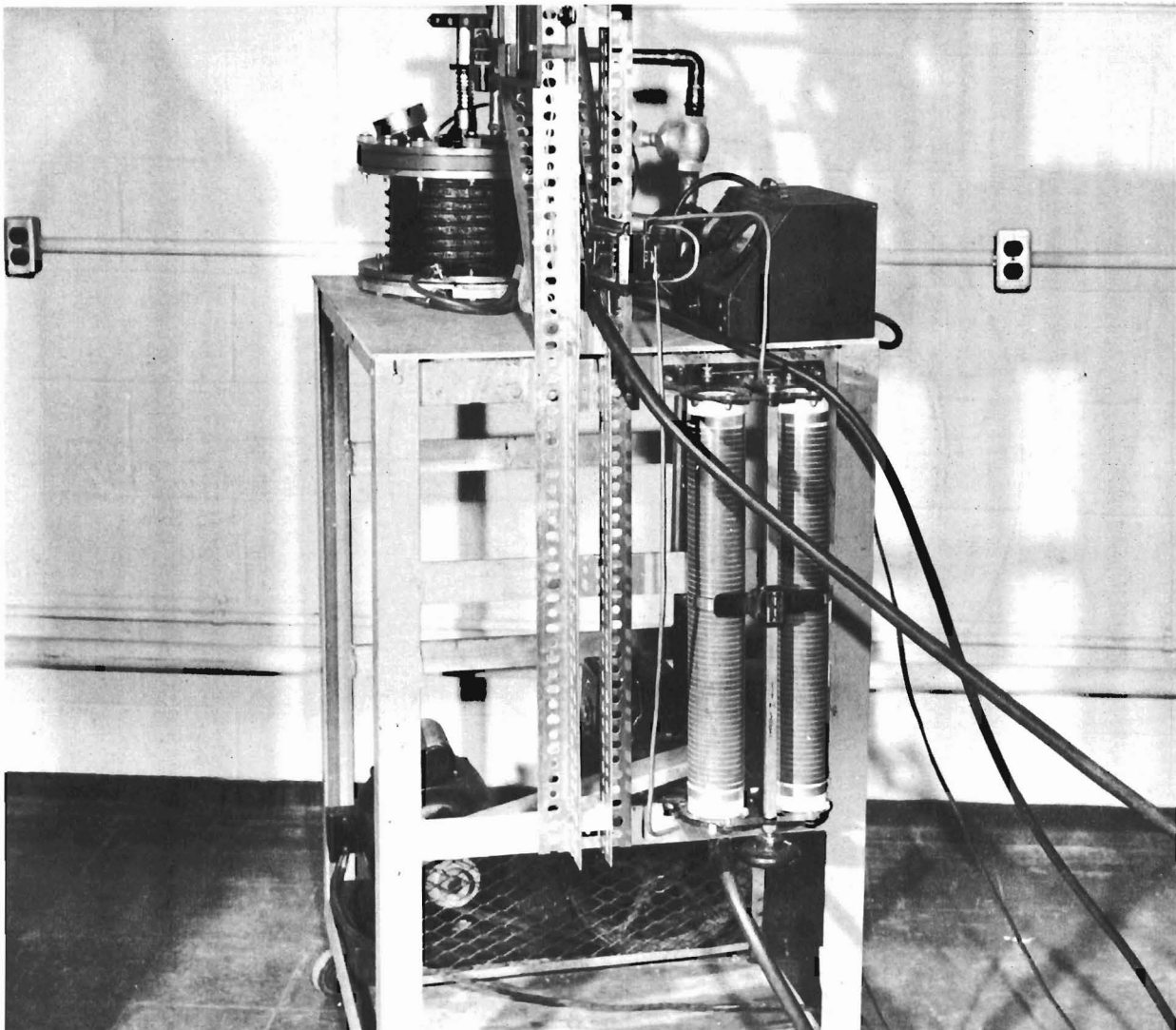


Figure 7. Photo and schematic of current control resistor arrangement

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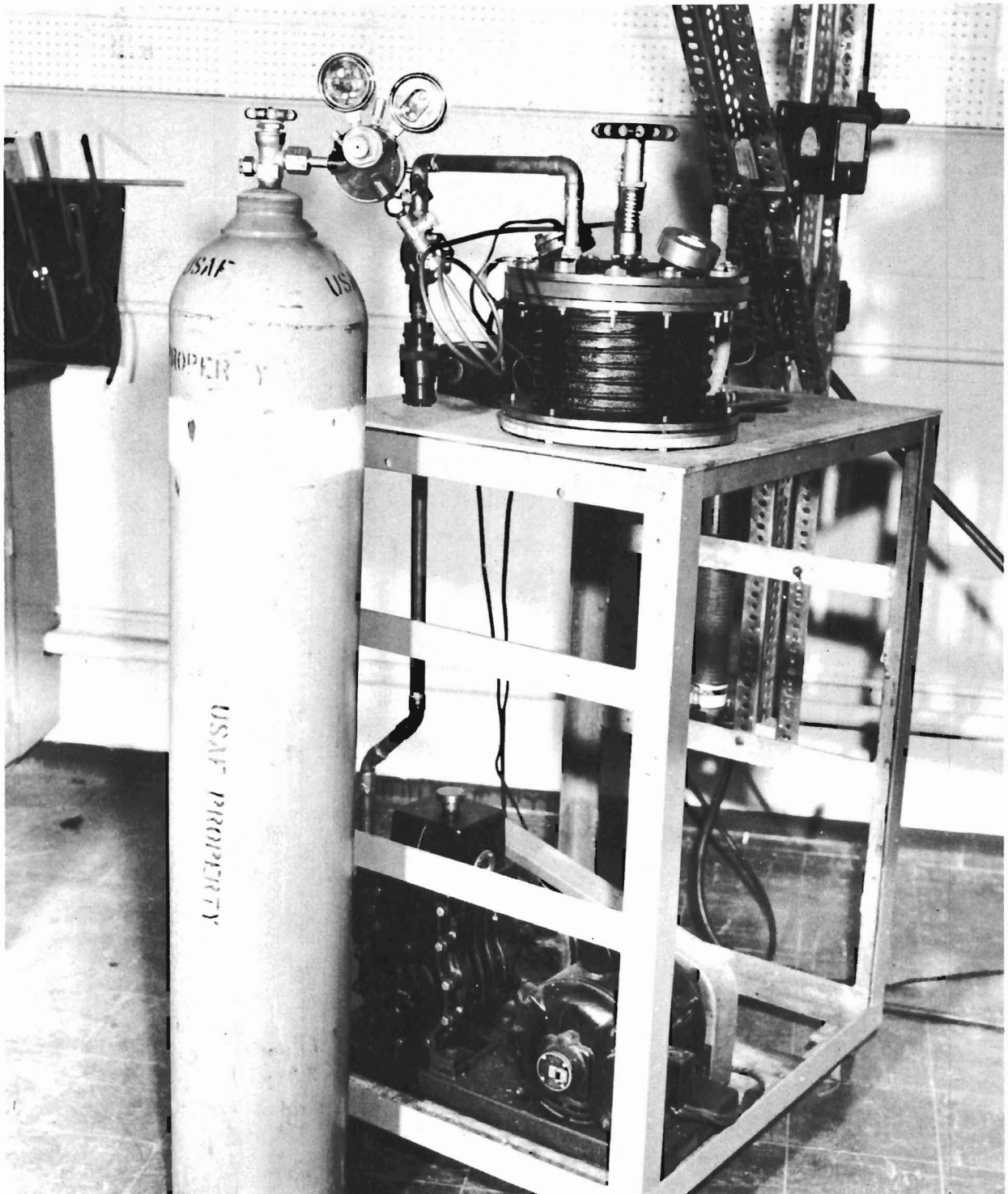
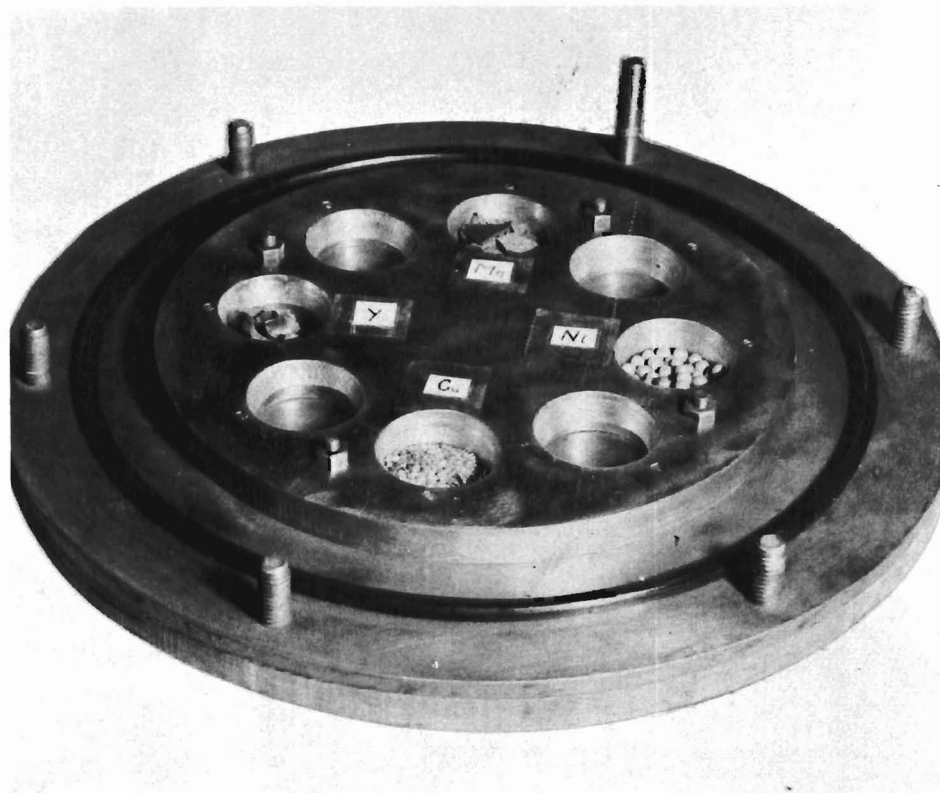
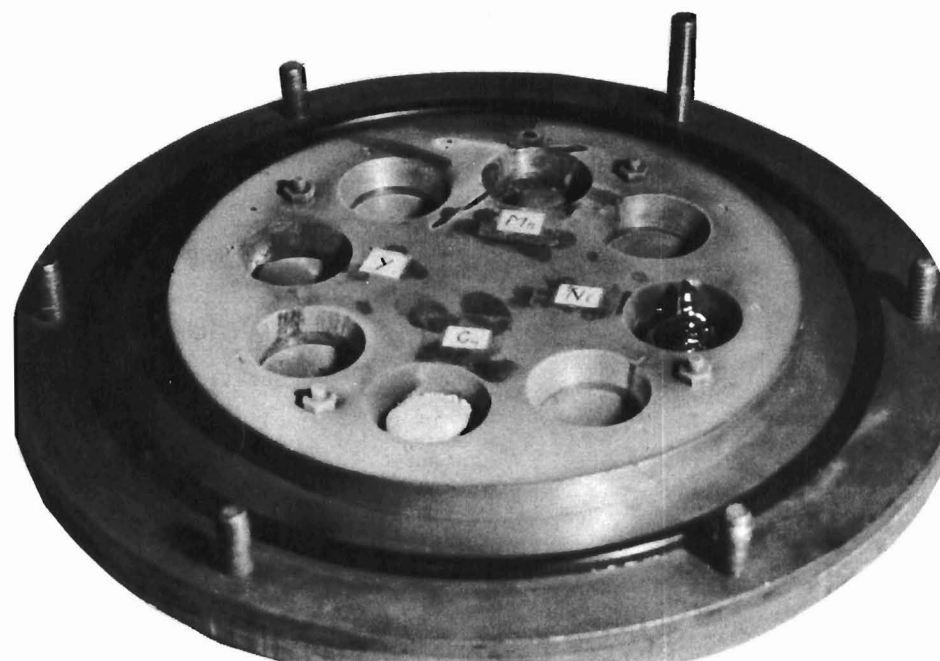


Figure 8. Supplementary equipment in place



Before melting



After melting

Figure 9. Furnace bottom with melts