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AN ELECTRICALLY HEATED, RETORT-TYPE, PIT FURNACE

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ABSTRACT

A specially designed, electrically heated pit-type furnace capable of continuous operation at temperatures up to 1100°C is described together with the thin-wall, Inconel* retorts used in the furnace. The furnace, which is used for annealing and brazing pure copper parts in a 100% pure, dry hydrogen atmosphere, has been cycled over 1,250 times with highly successful results. The parts include four-inch diameter copper cylinders and disks which are brazed together to form 10-foot sections of disk-loaded waveguide that make up the accelerator structure. They also include sections of rectangular waveguide up to 12-feet in length together with stainless steel end flanges and copper water temperature control tubes that are brazed to all waveguide sections. The retorts, each of which has a 750-pound capacity, have been used up to 260 times each and, with over half of these runs being under the most severe operating temperatures, no leaks have occurred. The furnace is housed in an 18-foot deep pit, is four feet in inside diameter, and has 30 Chromel* heating elements. The 1/16-inch thick retorts are 16 feet long and two feet around. Retort cooling occurs outside of the furnace to permit greater utilization.

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INTRODUCTION

Large amounts of high-purity, oxygen-free copper (OFHC*) have to be annealed and brazed during the fabrication of parts for Stanford's Two-Mile Linear Electron Accelerator being built under contract to the U.S. Atomic Energy Commission. (Two million pounds of copper in ingot form were purchased.) Annealing was required to stabilize the copper parts so that extremely close tolerances could be achieved and maintained when the parts were finished machined, and to relieve part stresses for machining purposes. It was also necessary to bring parts to the highest temperature they would undergo during subsequent brazing cycles to determine if that temperature (1030°C) would cause impurities to surface on the copper.

Because of the large number of parts and tight production schedules, a special, continuous-operation pit furnace was designed together with specially built, thin-wall retorts that provided for mobility, fast, uniform heating and rapid cooling. Some parts are brazed in the furnace as assemblies that include stainless steel flanges. Therefore, to protect and bright-braze the flanges and to keep the copper from oxidizing, brazing had to be performed in a pure hydrogen atmosphere.

Presently, the furnace has been cycled over 1,250 times with the total weight of parts involved estimated at over 600,000 pounds. Nine retorts are in use, and, with cooling taking place outside of the furnace, nine loads are processed in a 16-hour period. The original retort has had over 260 runs with approximately half of these being made under the most severe operating temperatures. No leaks have occurred in this or the other retorts. When the furnace stabilizes at the annealing temperature, only 10°C difference exists between the parts in the retort and the furnace wall.

DESCRIPTION

The furnace (Fig. 1) has 30 Chromel XX heating elements which are ribbon-type and secured to the inner wall with ceramic holders. Its other main components include the 2300°F insulating fire brick which forms its inner wall, 1900°F block insulation which backs up the fire brick, and a 3/16-inch thick welded steel case which encloses the furnace. The bottom

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of the 18-foot pit in which the furnace is located also has a second layer of insulating fire brick rated at 2000°F. Expansion joints are provided to take care of brickwork expansion and contraction during temperature changes and alloy shelf supports are attached to the outer steel casing to carry the weight of the brickwork. Rolling doors with a retort support ring are located at the top of the furnace. They form a heat shield and a safety barrier when a retort is installed and, with a plug, can seal off the furnace to hold in heat when a retort is not installed.

The outside diameter of the furnace is 69 inches plus the thickness of the steel case. The inside diameter is 51 inches or 48-inches clear space from heater element to heater element. The heater elements are controlled in groups of ten or in three zones and each zone has a heating capacity of 100 kW. The elements are powered by a 208V, three-phase transformer of 300 kVA capacity.

The retort, which is also shown in Fig. 1 and in Fig. 2, is made from 16-gauge or 1/16-inch thick Inconel. This weight was chosen for a number of reasons. Past experience with the standard 1/4-inch thick retorts had shown that there was a problem of cracks appearing at the welded seams. With the 16-gauge retorts, the thickest part of the assembly is the weld and the rest of the retort acts as a bellows to compensate for expansion and contraction, reducing the strain on the welded areas. Also, the thinner walls provide for more rapid and uniform heating and cooling of the parts within the retort. This also means that retort weight is reduced, providing for ease of movement which is important when up to 6,750 pounds of parts are to be handled during the nine furnace runs each day.

Components of the retort, which is 24 inches in inside diameter and 16-1/2 feet in total length, include a thermocouple junction box and 24 chromel-alumel thermocouples equally spaced within the retort. An 11-gauge Inconel plug weldment forms the lid of the retort and a neoprene O-ring seal is located under the lid to preserve the gas-tight atmosphere of the retort. A water connection and water cooling jacket provide the cooling for the O-ring seal when the retort is in the furnace. A load hanger assembly is also a part of the retort and provides the connection point for the tree-type supports to which parts are attached.

FURNACE CONTROL

The control panel for the pit furnace is shown in Fig. 3. There are a master and two slave controllers in the circuitry of the furnace and they, in effect, provide three independent temperature control zones. Each zone has its separate over-temperature indicating device and meter and this provides both for shunt tripping and a visible alarm in the event of over-temperature. Each zone also has a spare thermocouple well for test purposes. Control of temperature between the center zone of 10 heaters, which are controlled by the master controller, and the upper and lower end zones can range between ±100°C.

A 24-point strip-chart recorder is also provided and connected, through the thermocouple junction box, to the thermocouples in the retort. It records part temperatures from all 24 thermocouples with one being recorded each two seconds.

FURNACE OPERATION

Figure 4 shows in simplified form the sequence of operations performed when the pit furnace is used for an annealing operation. In Fig. 4a, accelerator cylinders have been placed on a tree-type hanger fastened to the load hanger assembly of the retort lid. Figure 4B shows the loaded retort being transferred to the furnace building. Prior to insertion into the pit furnace, the retort is placed in another pit in the furnace building and is purged of air with a 99% nitrogen-1% hydrogen mixture. This mixture is introduced into the lid of the retort through the same pipe through which the thermocouple leads pass. A second pipe extends through the lid of the retort to its bottom and air escapes to the atmosphere through this pipe as the purge gas is pumped in.

Through a series of quick-disconnect couplings and flow meters mounted on the wall of the furnace building, the nitrogen-hydrogen mixture is replaced, following purging, with a 100% pure, dry hydrogen purge gas. A combustible gas analyzer probe is connected to the atmosphere exhaust pipe during both purging cycles. It provides for continuous analysis and indication of hydrogen-nitrogen content in the retort during the first purge and for hydrogen-oxygen content during the second. Pure hydrogen is not introduced into the retort until the analyzer indicates the escaping gas is the 99-1 mixture. Following this, the furnace operator waits until the analyzer indicates 70% hydrogen content in the escaping gas. At this point he removes the analyzer probe and ignites the escaping gas at the pipe (Fig. 4c). The analyzer is a fail-safe unit so that a false indication will not be provided in the event of a failure of one of its components or a power failure.

An added safety feature for the furnace are low pressure regulators in the purge gas lines to the retort. In the event that the hydrogen gas flow into the retort isn't maintaining the proper pressure, nitrogen immediately and automatically begins to flow into the retort to compensate for the pressure drop.

After the hydrogen is ignited, the retort is lowered into the pit furnace (Fig. 4d) which has already been brought to the annealing temperature. This temperature is 1030°C within the retort and approximately 1040°C at the furnace wall. The hydrogen continues to burn throughout the annealing cycle which takes approximately 40 minutes. Following this, the retort is removed from the furnace with the hydrogen still burning and is placed in a cooling pit in the furnace building. When it has cooled to 650°C, the flame is extinguished by switching from hydrogen to nitrogen gas flow into the retort. With this arrangement, while one or more retorts are cooling, the furnace can still be in use for another retort.

ACKNOWLEDGEMENTS

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FIGURE CAPTIONS

1. Phantom view of pit furnace.

2. Sixteen-foot retort.

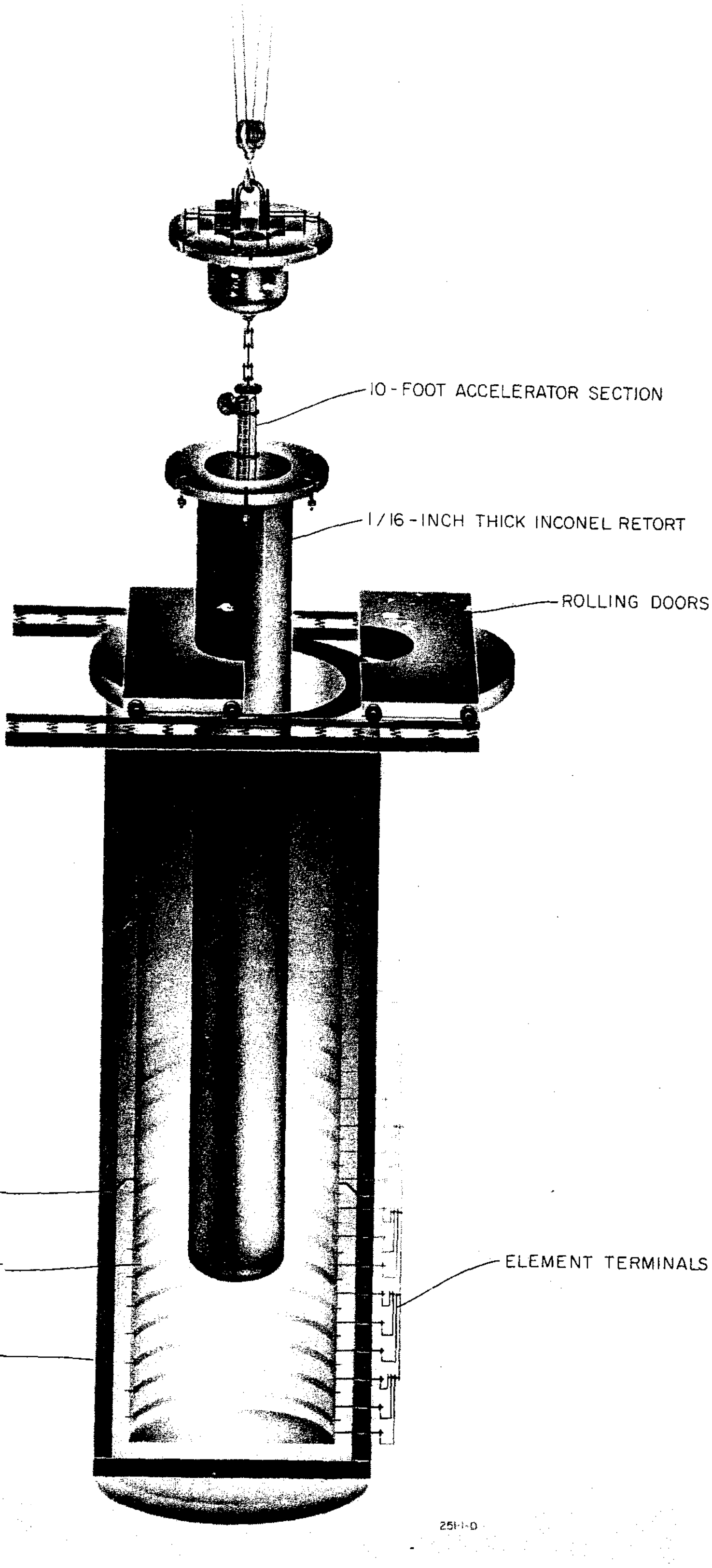
3. Pit furnace control panel.

4a. Accelerator cylinders and disks on tree hanger of retort.

4b. Moving loaded retort to furnace building.

4c. Retort with hydrogen flame ignited.

4d. Interior of furnace showing heated elements.



PHANTOM VIEW OF PIT FURNACE

Figure 1

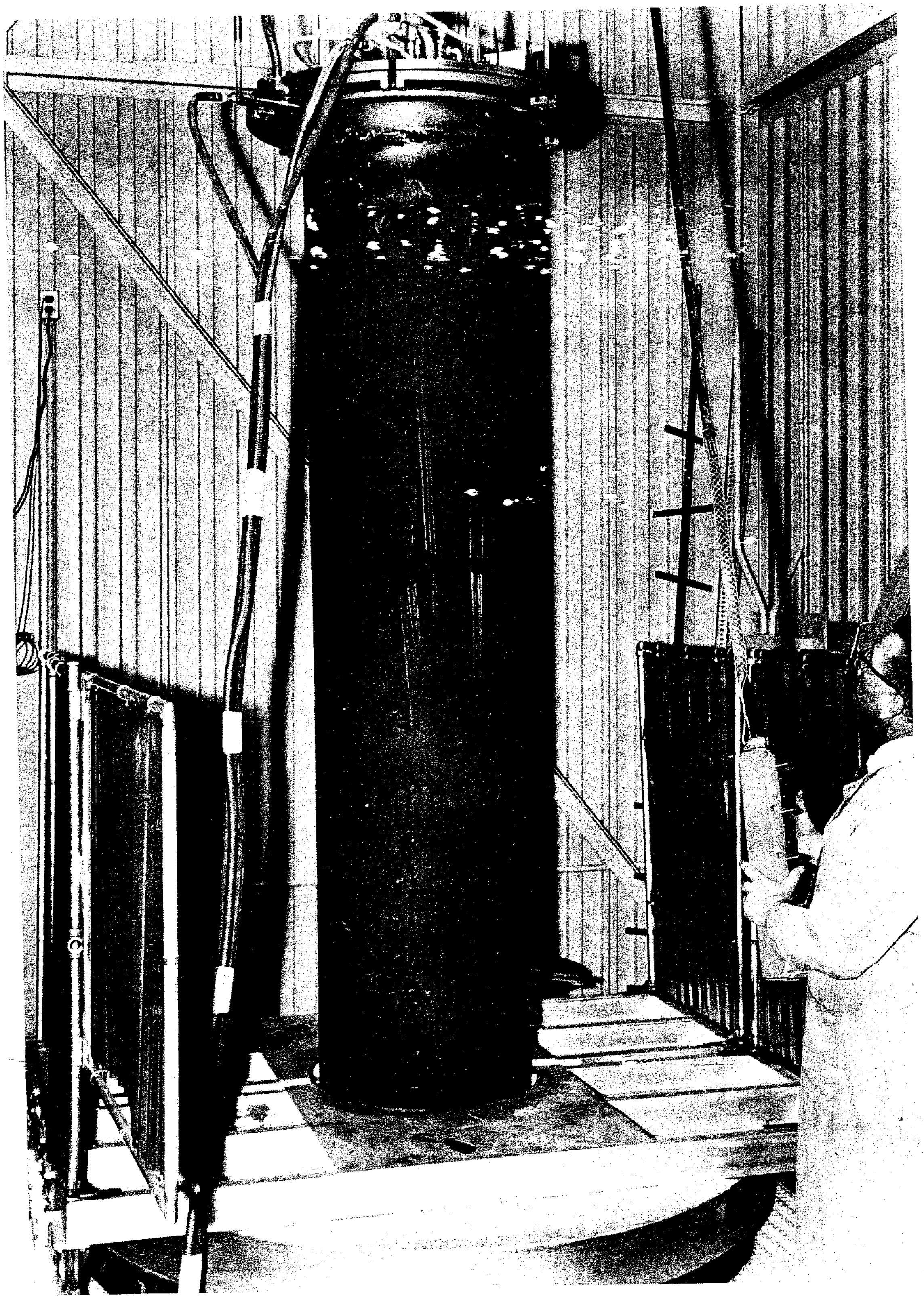


Figure 2

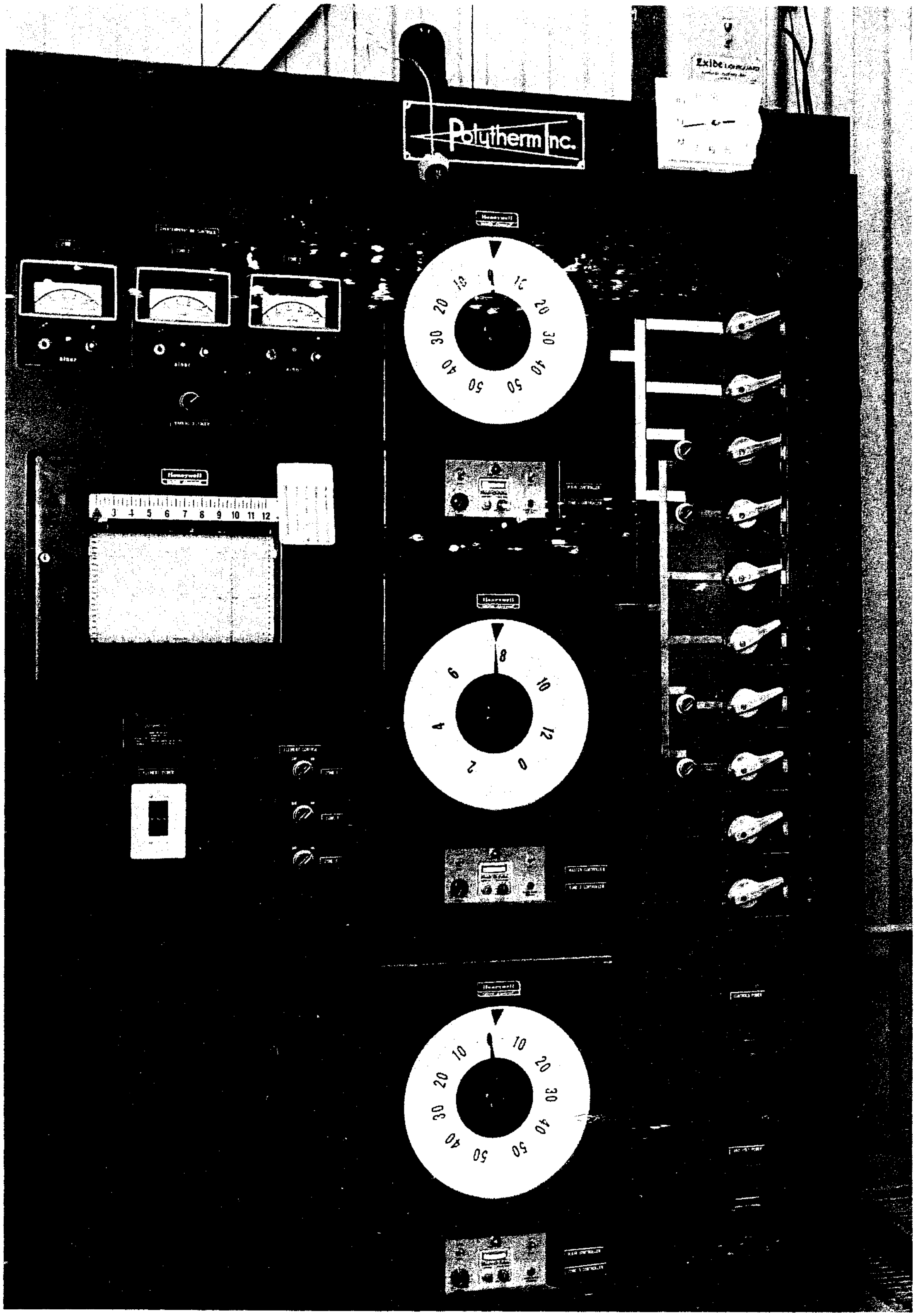


Figure 3

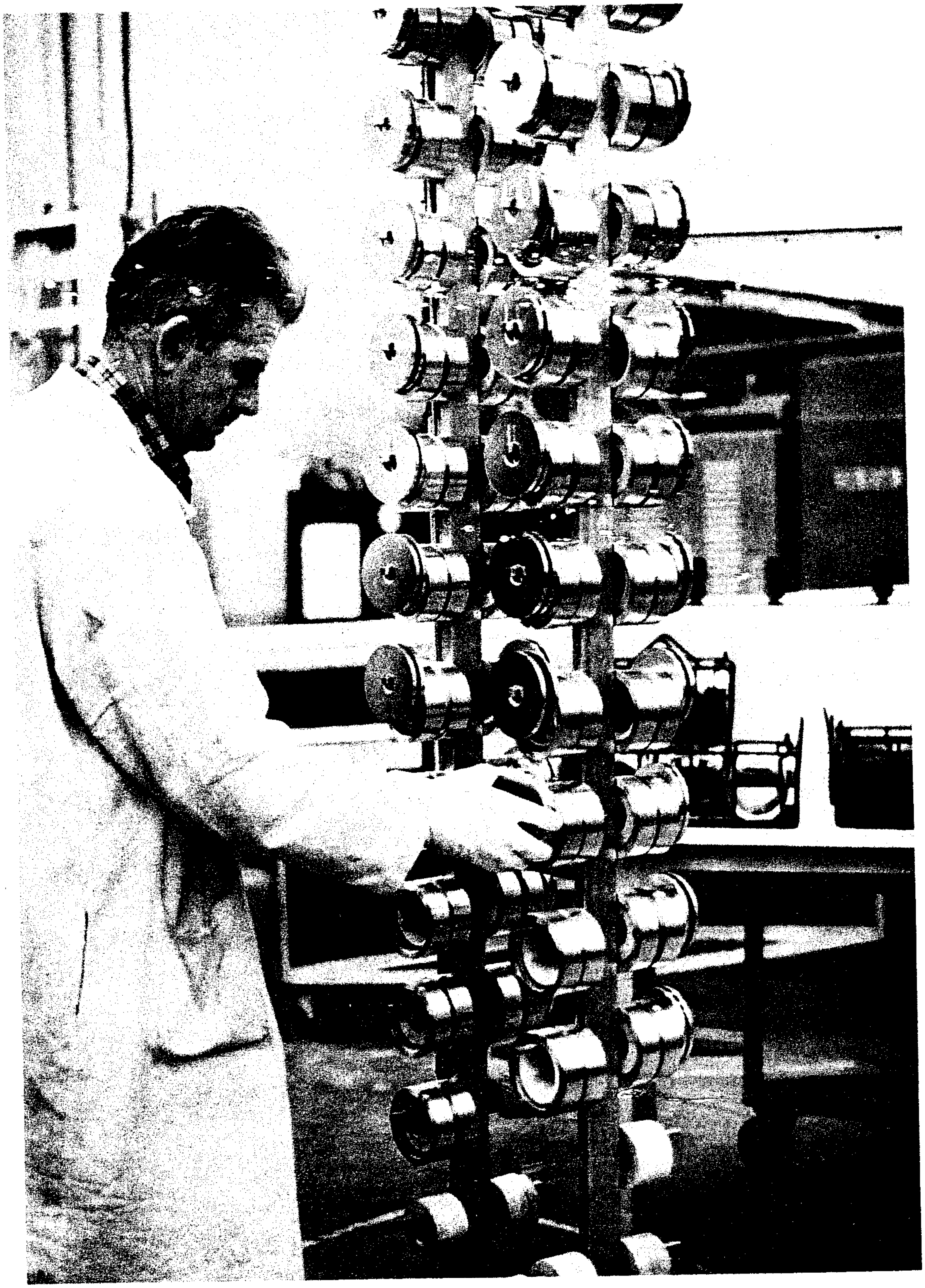


Figure 4a

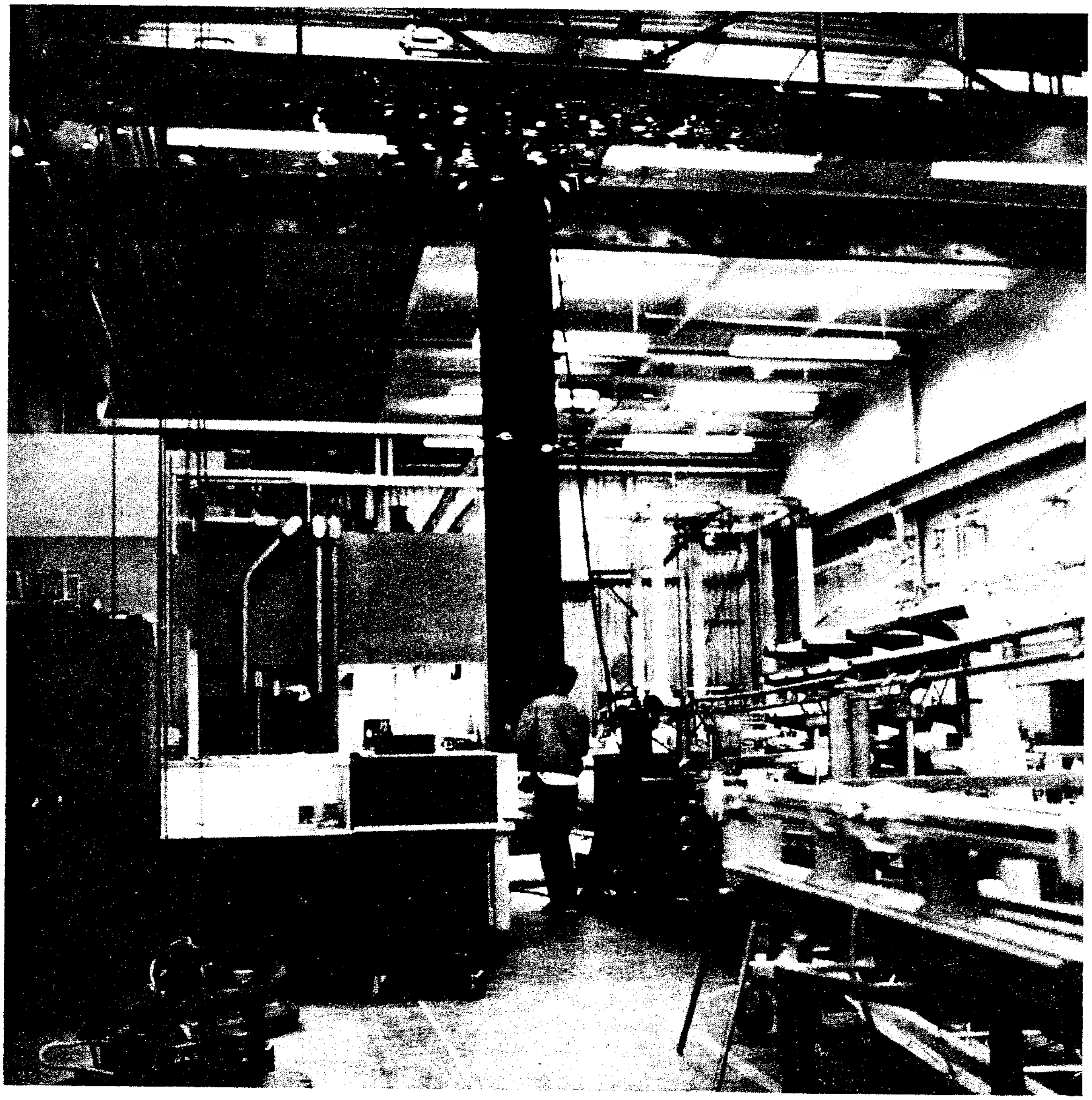


Figure 4b

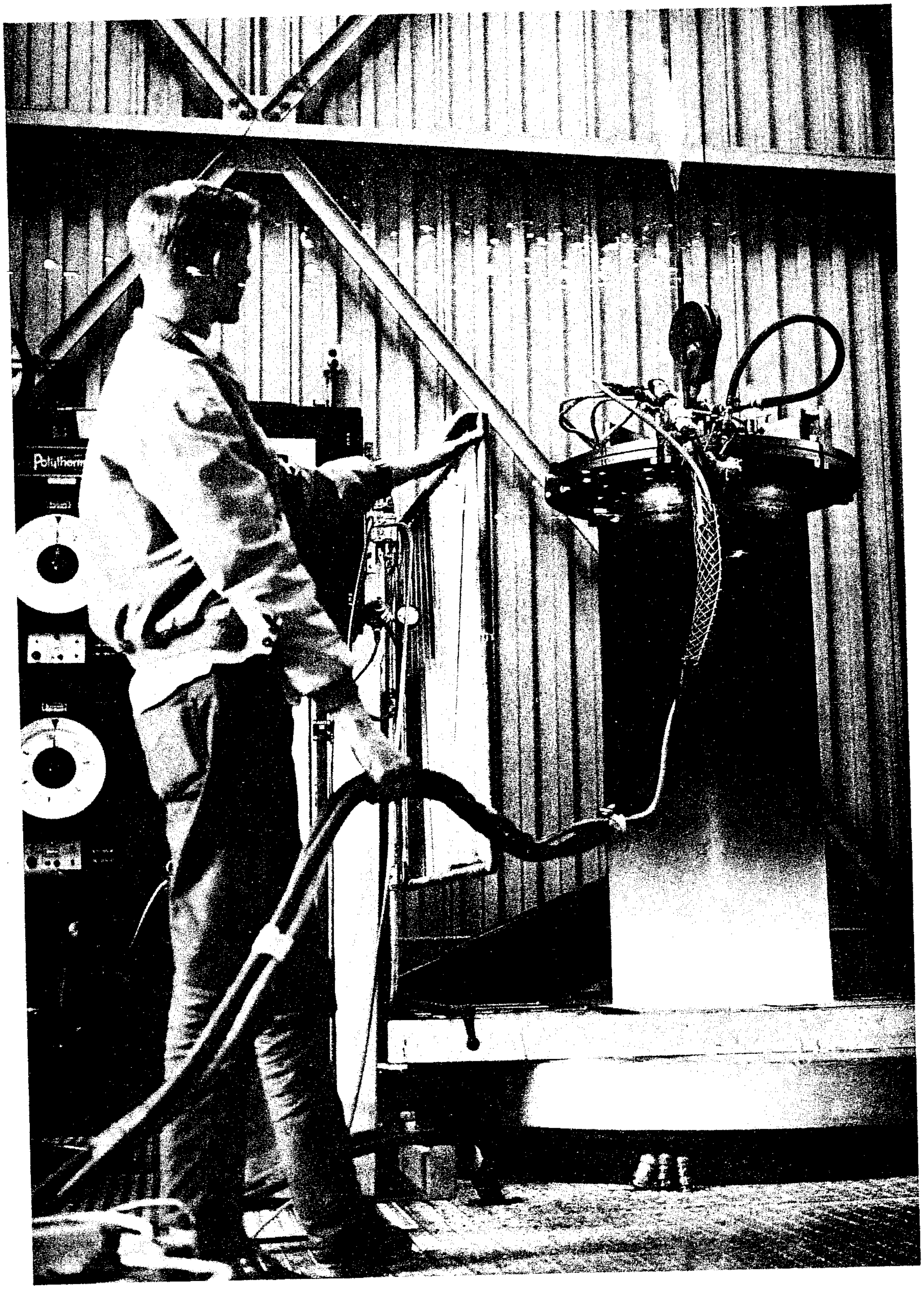


Figure 4c

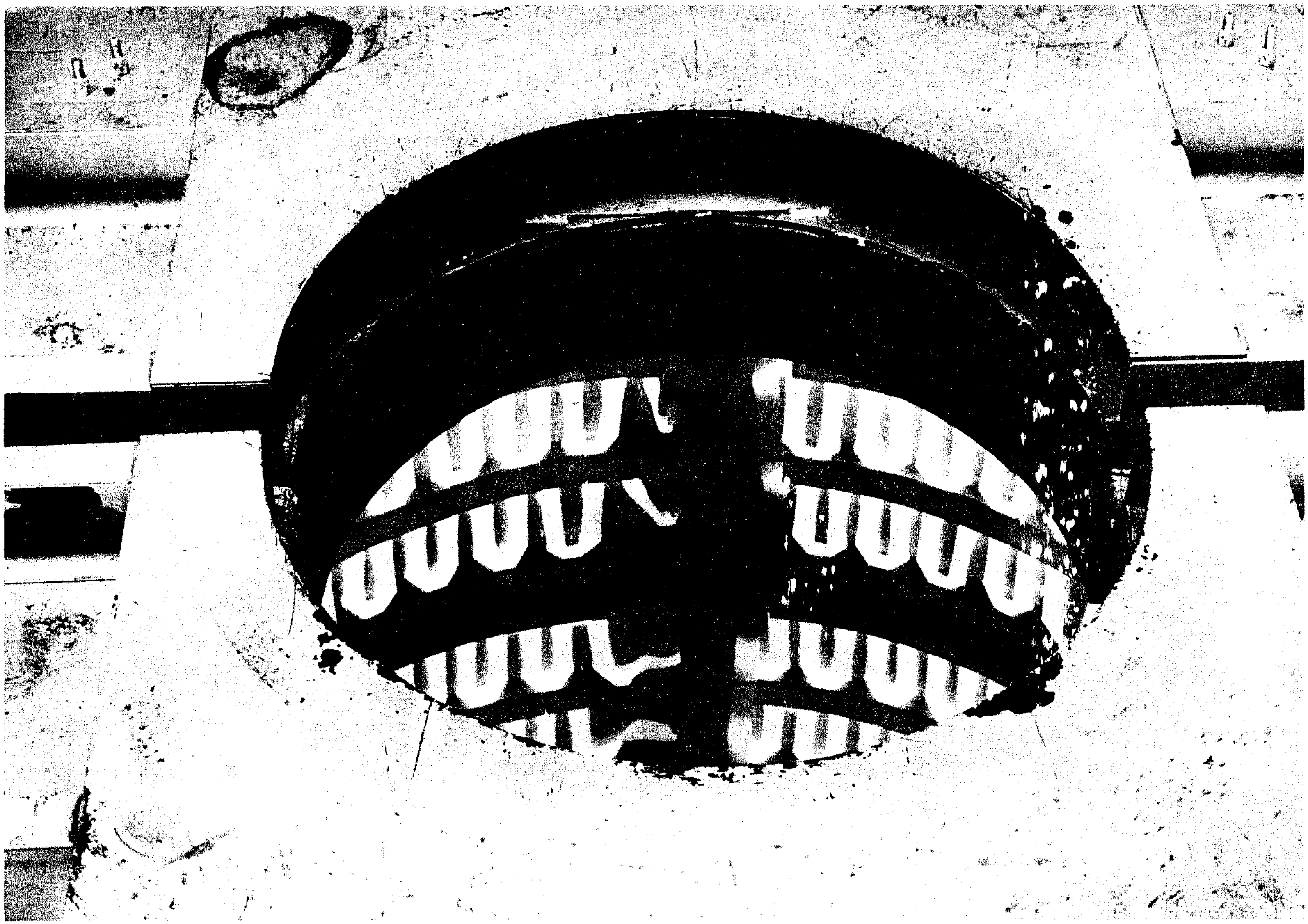


Figure 4d