SIXTY-INCH CYCLOTRON

CATALOG NUMBER 9674980

INSTRUCTIONS

GENERAL ENGINEERING LABORATORY

GENERAL ELECTRIC

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GENERAL ELECTRIC

SCHENECTADY, NEW YORK

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RADIATION PROTECTION

The responsibility for the safe operation of this cyclotron is necessarily the responsibility of the operator, and the General Electric Company assumes no responsibility for the safe operation on and after October 23, 1957.

It is necessary that all persons authorized to use or service this cyclotron or to enter any of the areas associated with it, be aware of the danger of excessive exposure to radiation. All such persons should be adequately indoctrinated by a qualified radiation protection expert with regard to the various potential radiation hazards and procedures for preventing excessive exposures.

Although this cyclotron incorporates a high degree of protection against accidental exposure of personnel to the primary beam, no practical design of equipment can provide complete protection. Nor can any practical design compel the operator or his associates to take adequate precautions, or prevent the possibility of authorized or unauthorized persons carelessly, unwisely, or unknowingly exposing themselves or others to direct or secondary radiation.

In addition to the main beam, particle accelerators of this type produce stray radiation fields composed of several components, e.g., thermal and fast neutrons, X- and gamma rays and proton recoils. In order to evaluate these potential hazards, measurements are necessary of both the intensity and energy of the various components. Then, by referring to radiation protection standards concerning the relative effectiveness of different radiations in producing deleterious effects, the biological hazard may be estimated.

It is also important to consider the radiations encountered when work must be done on or around the machine with the primary beam off. The high voltage alone can produce X-rays in vacuum which may cause certain areas to be potentially hazardous. Running the beam for as little as a few microampere-minutes can produce substantial residual radioactivity in many materials; both inside the tank and also at considerable distances from the cyclotron. This activity is induced both by the beam directly and by neutrons throughout the cyclotron and target rooms. Some of this activity may present a hazard for months after the beam is turned off.

One must also consider the possibility of personnel contamination by removable or airborne radioactive material. Neutron-induced radioactivity of vaporized metals, dry chemicals, dust particles, etc., which can be rubbed off or stirred up by workers may be spread to uncontrolled areas, inhaled, ingested, or otherwise become hazardous. Here again, the identity and quantity of the loose radioactive material must be determined in order to properly appraise and control the hazard.

Various Federal and state agencies have promulgated regulations and standards for radiation protection. These are for the most part based on the recommendations of the National Committee on Radiation Protection, which are published as National Bureau of Standards Handbooks. As new discoveries are made in the study of radiation, these recommendations are revised from time to time. It is essential that the person or persons responsible for the safe operation of this installation and the safety of the personnel associated with it keep themselves informed of the current standards and recommendations in the field of radiation protection.

The following is a partial list of references commonly used by radiation safety experts.

References:

Recommendations of the National Committee on Radiation Protection:

"Safe Handling of Radioactive Isotopes", Handbook 42.

"Control and Removal of Radioactive Contamination in Laboratories", Handbook 48.

"Radiological Monitoring Methods and Instruments", Handbook 51.

"Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water", Handbook 52.

"Protection against Betatron-Synchrotron Radiations up to 100 Million Electron Volts", Handbook 55.

"Permissible Dose from External Sources of Ionizing Radiation", Handbook 59.

"X-Ray Protection", Handbook 60 (Addendum to Handbook 60, February 1957)

"Regulation of Radiation Exposure by Legislative Means", Handbook 61.

USAEC Regulations, Part 20 - "Standards for Protection Against Radiation", U.S. Federal Register, Vol. 22, pg. 548. January 29, 1957 (amended May 10, 1957).

"Radiological Health Handbook", compiled and edited by Simon Kinsman, U.S. Department of Health, Education and Welfare, January 1957 (available Office of Technical Services, PB-121784).

"Recommendations of the International Commission on Radiological Protection", British Journal of Radiology, Supp. No. 6, revised December 1, 1954, British Institute of Radiology, London, 1955.

"Report of the International Commission on Radiological Units and Measurements (ICRU)", Handbook 62, National Bureau of Standards, 1956.

"General Handbook for Radiation Monitoring", compiled and edited by Robert F. Barker, second edition, Los Alamos Scientific Laboratory, Sept. 1954, LA-1835.

"Stray Radiation Measurements at Particle Accelerator Sites", Leonard R. Solon, James E. McLaughlin, Jr., and Hansen Blatz, New York Operations Office, U.S. Atomic Energy Commission, June 1, 1956, NYO-4699.

"Fast Neutron Dosimetry at the Argonne National Laboratory Cyclotron", R. B. Rhody, Radiation Research, Vol. 5, 1956.

"Decontamination", R. L. Curtis, Oak Ridge National Laboratory, 1953.

"Neutron Scattering" - J. W. Cure, III, ORNL-2013, 1956.

"Contamination of Surfaces by Radioactive Materials: The Derivation of Maximum Permissible Levels", H. J. Dunster, Atomic Energy Research Establishment, Harwell, Atomics, August 1950.

"An Anthology of Health Physics Data", second edition, H. J. Dunster United Kingdom Atomic Energy Authority, October 1954.

"Shielding of the High Current Cyclotron and a Van de Graaff Machine", M. Clark, Brookhaven National Laboratory, BNL-227, November 1952.

"Recent Developments in Film Monitoring of Fast Neutrons", J. S. Cheka, Nucleonics, June 1954.

"Fifth Conference on Radiation Cataracts", Abstracts and Proceedings, AECU-3018, March 1954.

"A Fast Neutron Detector", W. F. Hornyak, Brookhaven National Laboratory, BNL-1029, 1951.

"Introductory Manual on the Control of Health Hazards from Radioactive Materials", Medical Research Council, UKAEA, January 1949.

"Radiation Hazard Evaluation and Control in Hospitals", G. Ferlazzo, et al, Symposium on Radiation Protection, American Journal of Radiology, December 1954.

"Fast Neutron Monitoring with NTA Film Packets", R. S. Hart, and J. P. Hale, Jr., Atomics Internationale, July 1956.

INTRODUCTION

The cyclotron is an apparatus that produces a beam of high energy nuclear particles (protons, deuterons, or alpha particles). The particles are generated in an ion source located between the dees, two semi-circular segments of a hollow flat cylinder (like a pillbox cut along the diameter, with the two halves pulled apart slightly). A high frequency alternating potential difference applied to the dees produces a rapidly oscillating electric field across the space between them (the "dee gap"). The velocity imparted to the particles is proportional to the magnitude of the electric field. A strong uniform magnetic field is applied perpendicular to the plane of the dees. The result is that a particle enters the dee, follows a semicircular path whose radius depends upon the velocity of the particles, and reappears in the gap on the other side of the center. The time between appearances at the dee gap is constant and depends only upon the strength of the magnetic field; increased velocity of the particle is reflected in increased path radius, not in the time necessary to traverse the path. In order for a particle to gain velocity each time it appears in the dee gap, the strength of the magnetic field must be adjusted so that the time for the particle to travel a semicircle is equal to one-half the electric oscillation period, i.e., the polarity of the electric field between the dees must change just before the particle appears in the dee gap. Under these conditions the particle is accelerated twice in each revolution, and its path continues to spiral outward until the particle reaches the outer radius of the chamber, where it is either captured or allowed to escape.

The cyclotron assembly includes the following major parts:

1. An outdoor sub-station, consisting of a complete sub-station assembly which receives power from the customer's incoming power line. High voltage circuit breakers supply power to the magnet motor generator set, the oscillator rectifier, an auxiliary power transformer, which supplies through a secondary circuit breaker, and a low voltage bus.

2. Indoor switchgear, consisting of a low-voltage bus which feeds the low-voltage circuit breakers, and motor starters which supply all building lighting and building and cyclotron auxiliaries.

3. A magnetic system, which is made up of the following components: the magnet core, the magnet coils, a motor generator set, an amplidyne and magnet current regulator, contactor, and control equipment for the magnetic system.

4. The vacuum system, which is made up of the following components: a vacuum chamber, a rough pump, diffusion pumps, and a fore pump, vacuum valves, and refrigeration systems, vacuum instrumentation, and vacuum control.

5. A power oscillator and dee system, consisting of an oscillator and coupling loops, a power supply, an auxiliary oscillator, oscillator instrumentation and control, dees and liners, tuning bar, positioning mechanisms and controls, instrumentation and controls for the dees.

6. An ion injection system consisting of an ion source, an ion source filament and filament stem, an ion source positioning mechanism, an ion source drive mechanism, an ion source anode supply, an ion source filament supply, an ion source gas supply, controls, and instrumentation.

7. A beam extraction system, consisting of a septum, a deflector, a deflector power supply, deflector and septum positioning mechanisms, an exit beam chamber, and a beam window assembly, controls and instrumentation.

8. An internal rotary target.

9. A cooling system, consisting of a water pump, a heat exchanger, a treated water makeup tank, a still, and protective devices and controls.

TABLE OF ITEMS INCLUDED

Item No.	Quantity	Item
1	1	Magnet core
2	1 pr.	Exciting coils
3	1	Motor Generator set
3a	1	Field rheostat and mechanism
4	1	Amplidyne
5	1	Magnet current regulator, consisting of: a magnet current regulator shunt, a regulator circuit, a drive for amplidyne excitor, and a regulated d-c power supply.
6	1	Magnet control panel
7	1	Dee system, consisting of the following:
7a	2	Lids
7b	1	Dee housing
7c	1	Dee stem housing
7d	1	Dee positioning mechanism housing
7e	1	Left dee assembly
7f	1	Right dee assembly
7g	1	Rotary target
7h	1	Ion source
7i	1	Beam exit chamber
7j	1	Compressor for tuning bar
7k	1	Track
7l	1	Dee current probe
8	1	Vacuum system, consisting of:
8a	2	Diffusion pumps
8b	1	Fore pump and fore vacuum pump
8c	1	Rough vacuum pump
8d	1	Exhaust manifold
8e	1	Refrigeration equipment
9	1	Vacuum instrumentation, consisting of: ionization gages, thermocouple gages, and relays
10	1	Oscillator, consisting of the following:
10a	1	Oscillator cubicle
10b	1	Anode loop and cathode loop
10c	1	Blower assembly
10d	1	Surge Reactor
10e	1	Disconnecting switch
10f	1	Test Oscillator
10g	4	Tubes
10h	1	Filament unbalance relay
10i	2	Filament current limiting reactors
10j	1	Compensating capacitor assembly
10k	1	Auxiliary oscillator

Item No.	Quantity	Item
11	1	Oscillator rectifier system, consisting of:
11a	1	Rectifier
11b	1	Induction voltage regulator
11c	1	Monocyclic network
11d	1	Rectifier transformer
11e	1	Rectifier cubicle
12	1	Deflector supply, consisting of:
12a	1	Rectifier
12b	1	Discharge switch
12c	1	Control panel
12d	1	Protective resistor
12e	1	Voltmeter multiplier
12f	1	Voltage stabilizer
13	1	Ion source supply, consisting of:
13a	1	Filament supply
13b	1	Anode supply
13c	1	Gas supply
13d	1	McLeod gage
14	1	Leak detector
15	1	Cooling system, consisting of:
15a	1	Heat exchanger
15b	1	Heat exchanger regulating valve
15c	1	Flow-temperature indicator panel
16	1	Control console, consisting of
16a	1	Left section
16b	1	Center section
16c	1	Right section
16d	2	Filler compartments
16e	2	Junction boxes
17	1	Relay rack, consisting of:
17a	1	Vacuum cabinet
17b	1	General cabinet
17c	1	Auxiliary cabinet
17d	1	Spare cabinet
17e	1	Vacuum instrumentation cabinet
18	1	Outdoor sub-station, consisting of:
18a	1	High voltage switchgear
18b	1	Transformer
18c	1	Low voltage switchgear
18d	1	Station battery and charger
18e	1	Field application panel
18f	3	Surge capacitors
18g	1	Test cabinet
18h	1	Kirk transfer station
19	1	Cabinetrol, consisting of:
19a	1	Main bank
19b	1	Addition section containing ion source anode supply
19c	1	Additional section containing external beam auxiliary equipment

I. Magnetic System

Magnetic System

I. DESCRIPTION

Magnet

The function of the magnet is to provide the guiding magnetic field for the particles being accelerated. The magnet assembly consists of a core and two coils.

Core

The magnet core is composed of two pole pieces and the rectangular frame that supports them. The frame is made of forged low-carbon steel slabs, rectangular in cross-section. The upper and lower horizontal sections of the frame, called the "yokes", are 204" long, 72" wide, and 32" deep. The vertical sections, of the same cross-section, are 84" high, 72" wide and 32" deep; the assembled frame is 204" wide, 72" deep and 148" high. The pole pieces (also of low-carbon steel) are cylinders, 72" in diameter and 30½" high, with one end beveled at 45° to give a diameter of 60"; they are mounted on the upper and lower horizontal sections of the frame, projecting vertically, with the beveled ends opposed. The upper pole piece is made in two parts (straight cylinder and beveled portion) to facilitate installation of the coils after the frame has been assembled. Dowels are provided to locate the parts in their correct relative positions. The upper pole pieces are held to the upper yoke by studs which pass through the yoke and are supported with nuts on the upper ends. The studs are long enough to allow the upper pole piece parts to be lowered to rest on the bottom pole piece before the nuts are disengaged. There is no dowel between the upper pole piece and yoke; this permits slight adjustments of position at the time of assembly in order to obtain exact concentricity of the pole pieces. The other joints of the frame are fastened only by dowels, the weight being sufficient to keep the parts in place.

The attached print, Bethlehem Steel Company Drawing 180558, shows the core structure, and the photograph C323849-NACA, shows the assembled core during installation.

In addition to the pole pieces mentioned above, there are two pole tips of forged low-carbon steel, 6" thick and 62" in diameter. They are part of the magnetic circuit, but are structurally a part of the upper and lower surfaces of the vacuum chamber. Each pole tip is composed of two disks, one 5" thick, having a shoulder and gasket grooves fitted to the vacuum chamber, and one 1" thick, forming the outer face of the pole tip. These disks are bolted together with countersunk cap screws. The 1" disk may be removed and rings or disks of other thicknesses substituted, if it is desired to change the characteristics of the magnetic field. The inner faces of the 5" thick disks are machined to a concave step contour to produce the desired magnetic field distribution. The outer edges of the inner faces are 10" apart. There is a gap of ½" between the outer face of each disk and its pole piece, and the disks are concentric with the poles. Spacer blocks of brass are bolted to the outer faces of the disks at the edge to maintain the ½" separation when the magnet is energized. The attached photograph, ENV2C1932651-NACA shows the vacuum tank with the disks in place before the tank was placed between the magnet poles. Small corrections in the magnetic field distribution are made by inserting steel plates of various shapes and dimensions in the one-half inch gaps. The particular distribution of iron in the shim gaps, shown in the two attached diagrams, has been found to produce the desired field distribution.

<u>Coils</u>

The coils are concentric with the magnetic poles, the lower one resting on the lower magnet yoke and the upper one held up to the upper yoke. Photograph EN2C-18549 shows the lower coil before it was placed on the magnet. Photograph 60" Cyclotron C682649 shows the magnet with both coils assembled on the core. Each coil consists of six vertically-stacked sections of spirally-wound copper strip. Each section consists of two flat spirals of copper, and the sections are separated by a spiral of rectangular copper tubing used for cooling. Paper coated with zinc oxide paste is used as insulation between the turns of the spiral, and varnished pressboard is used as insulation between the copper strip spirals and the cooling coils, between sections and on the inside of the end plates. The entire winding and cooling coil assembly is clamped between the two end plates, one of aluminum and one of steel, by means of vertical brass rods equally spaced around the inner and outer circumferences. Aluminum cylinders are also clamped between the plates around the inner and outer circumferences, completely enclosing the winding assembly. All joints are gasketed to be watertight. The coils are 29-3/16" high, 73" inside diameter, and 109½" outside diameter. The coils are placed on the poles with the steel plates next to the yokes and the aluminum plates facing each other. The upper coil is held to the upper yoke by bronze studs from the yoke through the coil to its lower plate. The lower coil merely rests on the lower yoke with four 3/4" steel screws through the lower plate to the yoke to locate it. Each coil weighs approximately 28,000 lbs. Each winding section has 225 complete turns of copper strip, making a total of 2700 turns for the two coils. A terminal board is mounted on each coil with the terminals of each section mounted on it. To provide the best match between the coil resistance and the current and voltage rating of the generator which supplies the magnetizing current, the 12 sections are divided into four groups of three sections each. The three sections in each group are in parallel;

the groups are connected in series. So connected, the total resistance is approximately 0.382 ohms at operating temperature. The rating is 660 amperes, giving a total magnetomotive force of 594,000 ampere-turns. In order to provide the desired magnetic field distribution, it was found necessary to connect a shunt resistor across the lower coil. This resistor consists of a number of ceramic-coated resistors connected in parallel, with switches provided to vary the number in use. Normal operation requires a shunt current of about 10.5 amperes. The cooling coils are connected in parallel, and they require a total of about 64 gallons of water per minute at a pressure of 7 lbs. per square inch to maintain a temperature rise of 10°C. in the water when the magnet coils are operating at rated current. They are supplied with treated cooling water from the closed circuit cooling system described elsewhere in these instructions. Indicating dial thermometers are located in the outlet water connections, and electrical contacts are provided on them to open the magnet circuit breaker if the outlet water reaches an abnormally high temperature. Flow operating switches are also located in the cooling water circuit to open the magnet circuit breaker if the flow of cooling water stops.

II. MAGNET OPERATION

Caution: Before energizing the magnet be sure that there are no loose tools or magnetic objects lying in or near the magnet. Such objects may be drawn into the magnet with great force from a considerable distance when the magnet is energized. For example, an iron pipe standard, such as might be used to support mirrors, lights, or other apparatus near the cyclotron, might be drawn into it from a distance of several feet. Any magnetic tool or other object lying in or on the lower coil or the vacuum chamber would be drawn forcibly into one of the shim gaps.

All control of the magnet is accomplished from the control console and the motor generator starting panel in the generator room.

The first step in energizing the magnet is to turn on the master switch on the console. This starts the water pump, establishes the cooling water flow, and makes it possible to start the motor generator set. Next the main and amplidyne motor generator sets are started from the control panel in the generator room. The magnet excitation switch on the control console is turned momentarily to START; the magnet circuit breaker will close and the magnet current will begin to build up. The magnitude of the magnet current is indicated by the d-c ammeter on the control console, labeled MAGNET, and it is adjusted to the desired value by means of three knobs below the ammeter, labeled COARSE, MEDIUM, and FINE MAGNET CURRENT ADJUST. These knobs are part of the magnet current regulator which is described elsewhere in these instructions. The regulator is continuously energized as long as the control power is on and is always in readiness to function whenever the magnet current is turned on. The magnet may be de-energized by turning the magnet excitation switch momentarily to

STOP. This opens the magnet circuit breaker and reduces the generator excitation very nearly to zero. However, opening the circuit breaker does not open the magnetic circuit, but merely inserts the resistor in it, and residual flux in either the amplidyne or main generator fields may be sufficient to cause a small amount of current to flow. This current may maintain sufficient flux in the magnet to prevent working near the poles or shim gaps with magnetic tools. In order to reduce the magnet current to zero, it is necessary to stop the main motor generator set, either by means of the switch on the starting panel in the generator room, or by turning the master switch to OFF. Turning the master switch to OFF will also stop the water pump after a time lapse of about two minutes. There are several emergency push-button stations located in the cyclotron and generator rooms, labeled POWER. Pushing the STOP button of any one of these will have the same result as turning the master switch to OFF, i.e., stopping both motor generator sets and opening the magnet circuit breaker. Before the magnet can be energized again, the push-button station which was pushed to STOP must be returned to RUN and all the other stations must also be in the RUN position. The above starting sequence may then be repeated. It is not desirable, particularly in warm, humid weather, to permit the water pump to run for any extended period without having the magnet turned on. Continued flow of the cooling water may cool the unenergized coils enough to cause condensation of moisture upon them.

Because of the large inductance of the magnet, the current builds up or dies down slowly. Changing the magnetic flux in the magnet produces eddy currents in the solid iron core and in the coil flanges, inner and outer cases, and cooling tubes, so that flux changes occur considerably more slowly than current changes, and it takes several minutes for the magnetic field to reach its final value after the magnet is turned on. There is noticeable lag even in very small changes; therefore, when adjusting the magnet current to obtain maximum beam current, the operator must make only very small adjustments of current and wait to see their effect on the beam before making further changes. Otherwise, he may overshoot the optimum adjustment before he realizes it. There is a small amount of hysteresis in the magnetic field, with the result that the current necessary to maintain the optimum field will depend on whether it has been reached by decreasing from higher current values or increasing from lower current values. This effect is small, however, because of the large air gap in the magnetic circuit and the low carbon content of the iron.

III. MAINTENANCE

Magnet Core

The magnet core assembled in proper alignment may be expected to remain in alignment without attention, barring seismic disturbance or settling of the building's foundation. Keep the exposed surfaces painted to prevent rust. Any good paint commonly used for this purpose may be used except for the flat inner surfaces of the poles and the beveled surface two inches down from the edge. These surfaces have been sprayed with a single coat of aluminum paint consisting of G.E. 1557 clear lacquer mixed in equal parts with G. E. D5B19 thinner and having 8 ounces of aluminum paste or powder added per gallon of mixture. A similar mixture may be used to touch up these surfaces. Avoid, as far as possible, overcooling the coils, to prevent condensation of moisture. If room temperature and humidity changes are severe enough to cause condensation during shut-down, it would be well to energize the magnet for a time in order to warm it and dry it off. Keep the magnet free from loose magnetic objects. Occasional inspection should be made of the shim gaps to make certain that all shims are tightly wedged in place.

Magnet Coils

The above paragraphs regarding overcooling of the core and condensation of moisture on it are equally applicable to the coils. The coils, once in place, may be expected to remain in position without attention. The exposed edges and surfaces of the steel coil plates should be kept protected with paint. The aluminum surfaces need no protection. It is well to test the protective devices periodically by energizing the magnet and closing the valves in the cooling water circuits, to make sure that the flow switches operate to open the magnet circuit breaker. Then, by restricting the water flow so that the outlet temperature rises, make sure that the contact-making thermometers also operate to open the magnet circuit breaker. The ends of the cooling tubes coming to the outlet header should be checked occasionally during operation to make certain that there is no clogging which would cause the temperature to rise above the normal. Maintenance of the cooling system, such as maintaining the correct level of treated water in the make-up tank, periodically cleaning the strainer, and maintaining the proper chemical composition of the water, is treated in detail elsewhere in these instructions. The electrical connections should be inspected periodically to make sure that there are no loose connections which might cause severe arcing, accompanied by dangerously high voltages across the coil. Freezing of the cooling water in the coils should, of course, be guarded against.

IV. SERVICE

Magnet Core

No trouble may be expected with the magnet core if the simple precautions described under Maintenance are observed. If erratic behavior of the cyclotron output seems to indicate that the magnetic field distribution has changed, the distribution of shims in the shim gaps should be compared with the shim diagram. If the shims are found to be loose or have shifted, they should be readjusted according to the diagram and wedged securely in place. Check also to see that no large masses of iron have been placed near the magnet in such a way as to change the field distribution inside the gap. If it should ever become necessary to disassemble the magnet core because of settling of the foundation, because of a break in some underground water main, or for any other reason, the parts can be lifted apart if suitable lifting equipment is provided. The crane in the room (10 tons) is not adequate. The approximate weights of the different parts of the magnet core are as follows: upper yoke, 132,850 lbs; each side leg, 54,770 lbs; lower yoke, 133,000 lbs; upper section of upper poles, 22,400 lbs; lower section of upper pole, 11,590 lbs; lower pole, 334,050 lbs; each coil, 28,000 lbs. Each part should be lifted straight up until the dowels are cleared before attempting to move the part to the side. Lifting eyes are provided at the top yoke. After this has been removed, the eyes can be used for the side legs and then for the lower yoke. As the dowels are exposed they can be removed by unscrewing the threaded plug in the center and screwing in the lifting eye provided for that purpose. Underneath each dowel, except the pole dowels, is a threaded hole filled by a plug with a screw slot in the top. These plugs can be removed and the yoke-lifting eyes put in their place. The upper pole parts can be handled by replacing the supporting studs with screw-in lifting eyes provided with the cyclotron. The lower pole can be handled by removing the two diametrically opposite plugs from the side of the pole and screwing in the two collar bolts provided for the purpose of receiving the lifting cable slings. Care should be exercised in handling so that the mating surfaces are not injured, since the iron is soft and quite easily deformed. The mating surfaces should also be protected with a thin film of grease at this time to prevent them from rusting. Upon reassembly the grease should be removed.

Magnet Coils

Experience with coils of this type has not revealed any particular trouble to be anticipated. Should failure of the insulation occur, because of a leak in the cooling tubes or by overheating caused by a clogged cooling tube, or should there be a break in the electrical circuit, the coil will have to be removed for repair.

It is necessary to remove the upper coil before the lower one can be removed. Before this can be done, it is necessary to remove the lower part of the upper pole piece to provide room between poles through which the coil can be removed. The attached photograph, ENV-2-C-58349 NACA was taken when the upper coil was not yet in place and shows how the pole piece is assembled. The vacuum tank will, of course, have to be withdrawn first. It will be necessary to provide heavy timbers extending from the top of the lower pole to a substantial support several feet from the side of the magnet, on which to slide the lower part of the upper pole piece to a place where it can be removed with a crane. This part weighs about 11,590 lbs. The timbers must not extend more than 12" above the lower pole piece to allow clearance of the upper coil. Lower the lower part of the upper pole piece onto the timbers by unscrewing the nuts on the two center studs on the top of the magnet. Unscrew the two nuts simultaneously so that the pole piece remains level as it descends. Be sure that the studs do not turn in the pole piece, because they might screw out, allowing the pole piece to drop. To prevent the nuts from binding, put a small amount of heavy grease on the studs and work some into the nuts at the start of the operation. When the pole piece is resting on the timbers, and there is obviously enough room under the upper coil to slide it out, the studs can be unscrewed and pulled out. The pole piece can then be removed and taken out of the way.

Suitable jacks and cribbing must be supplied to lower and remove the upper coil. The coil weighs about 28,000 lbs. Means must be provided to slide it out between the poles when it is lowered. After the jacks are in place, the studs holding the coil to the upper yoke can be removed. These studs must be distinguished from the ones which hold the coil plates together. The studs holding the coil plates together have simple counter-sunk hex socket heads and are uniformly spaced around both the inner and outer circumferences of the plates. The ones holding the coil to the yoke are located between the others and have a counter-sunk round nut with spanner slots threaded onto them. By using a spanner wrench, these can be removed, and the studs can be unscrewed from the yoke and removed. The coil can then be carefully lowered and removed from between the poles. The lower coil may now be removed. Photograph EN-2-C-2-8-8-49-NACA shows the lower coil being jacked down into place during installation. The four bolts locating the lower flange on the lower yoke must be removed. Then the coil may be jacked up and slid out over the lower pole. The coils are heavy composite structures of many heavy parts. Care must be exercised in handling to keep them supported uniformly; dropping will result in distortion and damage. Reassembly may be made by following the above procedures in the reverse order.

In replacing the studs in the lower part of the upper pole piece, be sure they are screwed firmly to the bottom of the holes, leaving no magnetic void there. Be sure the upper surface of the lower part and the lower surface of the upper part are clean, and that no burrs or other irregularities have been raised on them, so that they will fit together well and the pole face surface will be parallel with that of the lower pole. Care must be taken that the dowel at the center enters its hole without being burred or deformed.

V. ILLUSTRATIONS

The following illustrations are provided for reference to the text covering the magnet:

Bethlehem Steel Company drawing 180558 with part numbers omitted

Photograph C-32-3-8-49-NACA - Assembled core during installation

Photograph ENV-2-C-19-3-26-51 - Vacuum tank with disks in place

Photograph EN-2-C-1-8-5-49 - Lower coil before placement on magnet

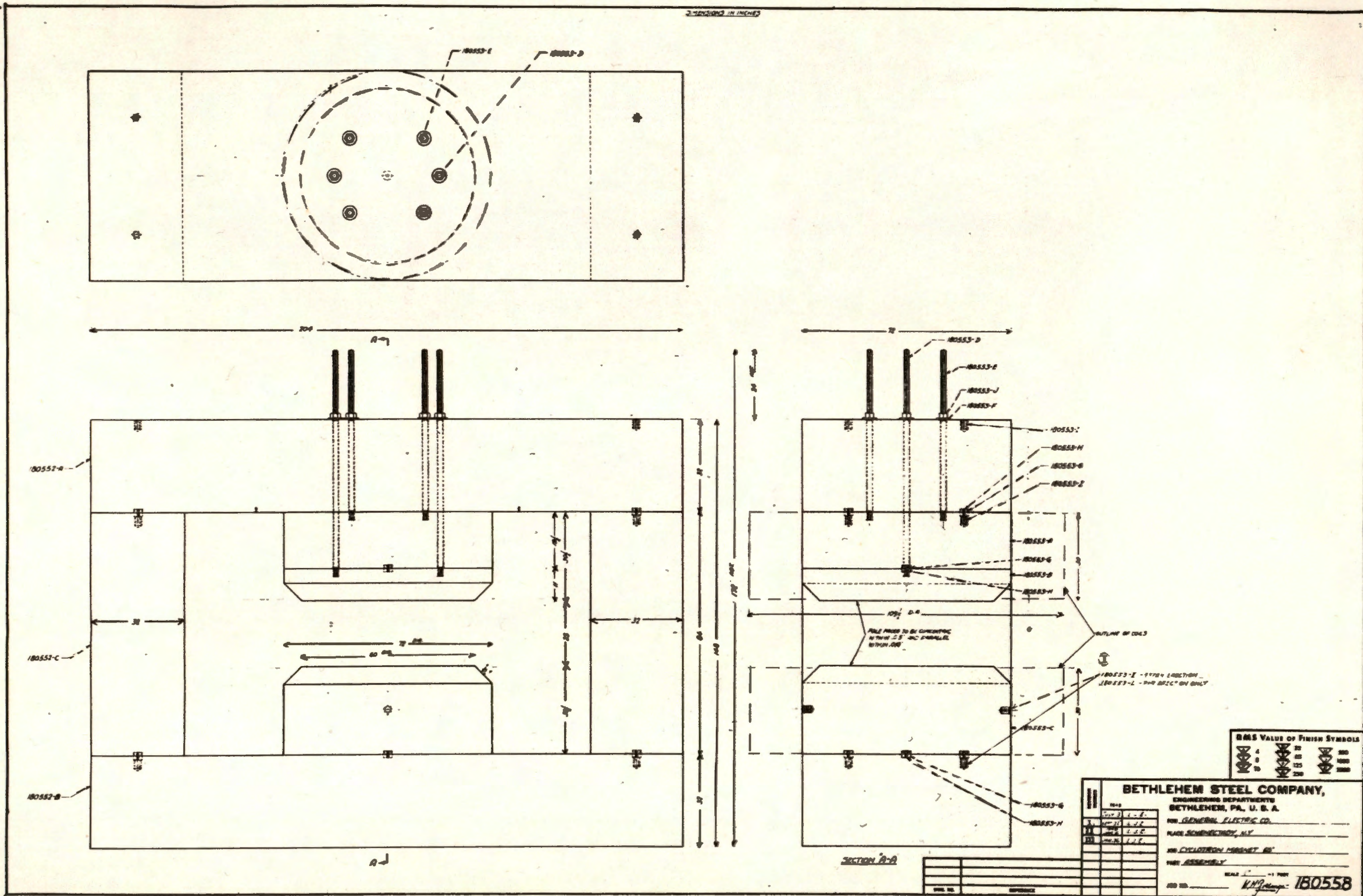
Photograph 60" Cyclotron C68-26-49 - Magnet with both coils assembled

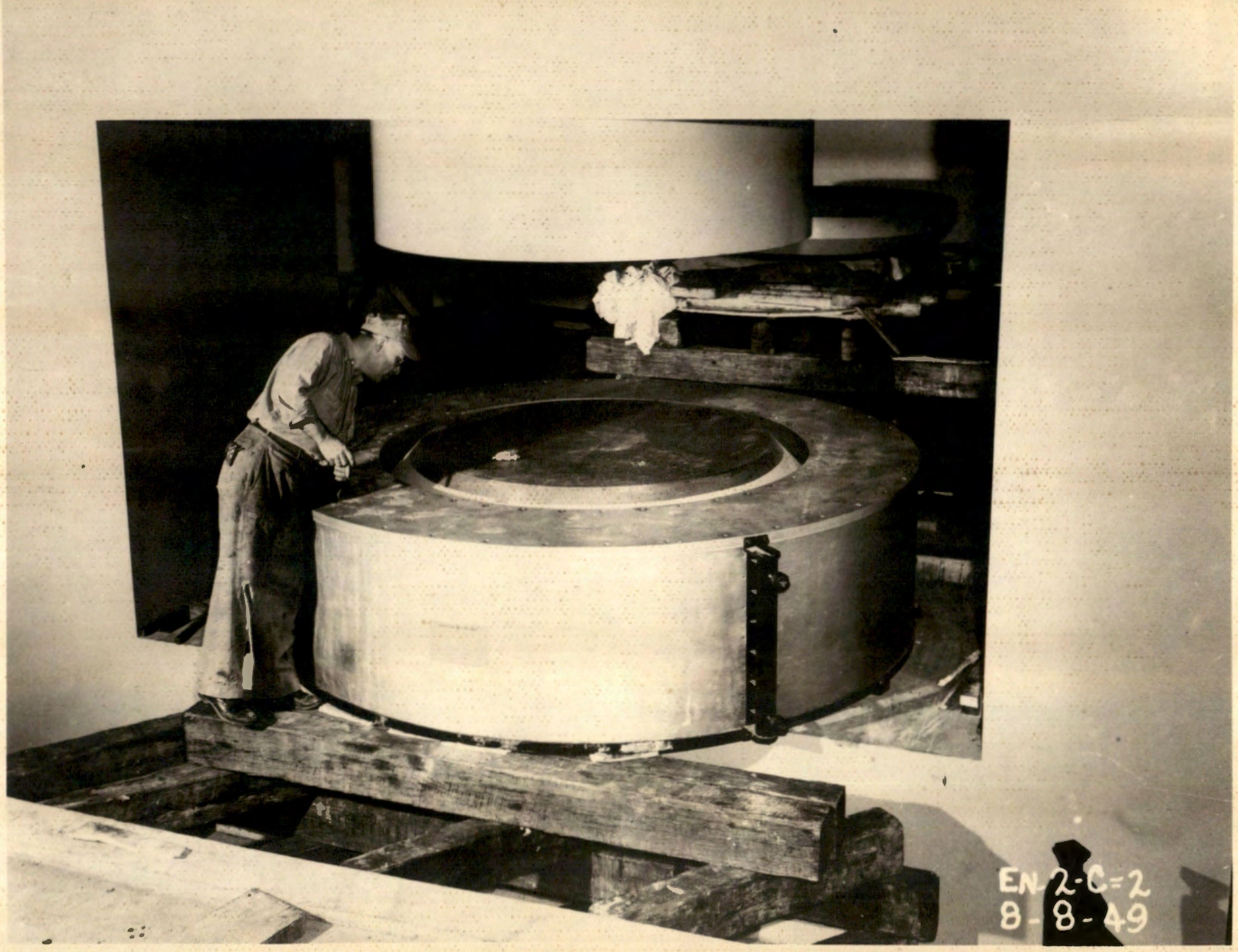
Photograph ENV-2C58-3-49-NACA - Upper coil not yet in place, showing how the pole piece separates

Photograph EN-2-C-28849-NACA - Showing lower coil being jacked into place

Shim Gap Diagram No. 1 - Distribution of shims in upper gap

Shim Gap Diagram No. 2 - Distribution of shims in lower gap


DIMENSIONS IN INCHES
180553-E
180553-D
204
72
180553-J
180553-F
180552-A
180552-C
180552-B
31
32
SECTION "A-A"
OUTLINE OF COILS
RMS Value of Finish Symbols
BETHLEHEM STEEL COMPANY,
ENGINEERING DEPARTMENTS
BETHLEHEM, PA., U. S. A.
FOR GENERAL ELECTRIC CO.
PLACE SCHENECTADY, N.Y
CYCLOTRON MAGNET 60"
ASSEMBLY
180558



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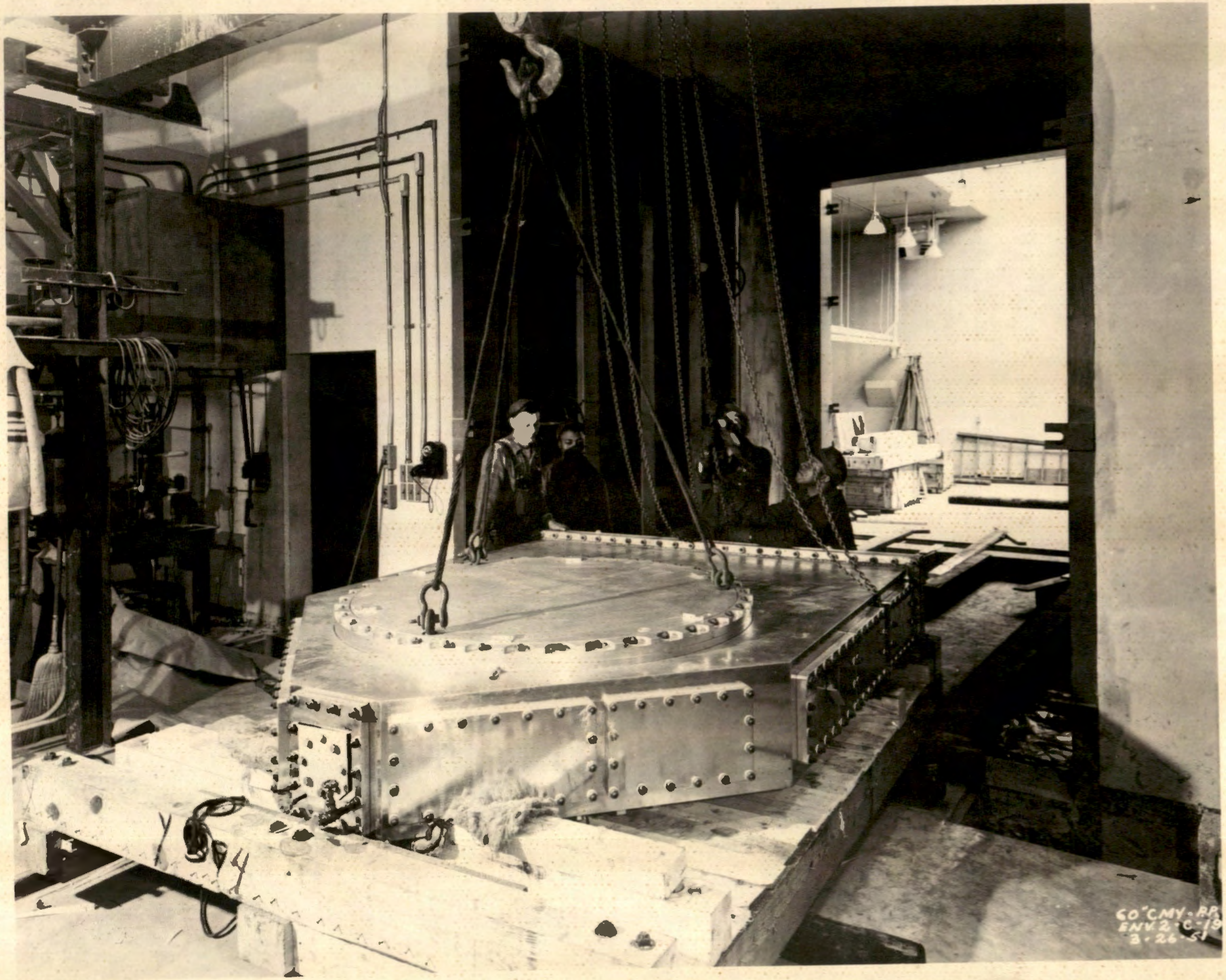

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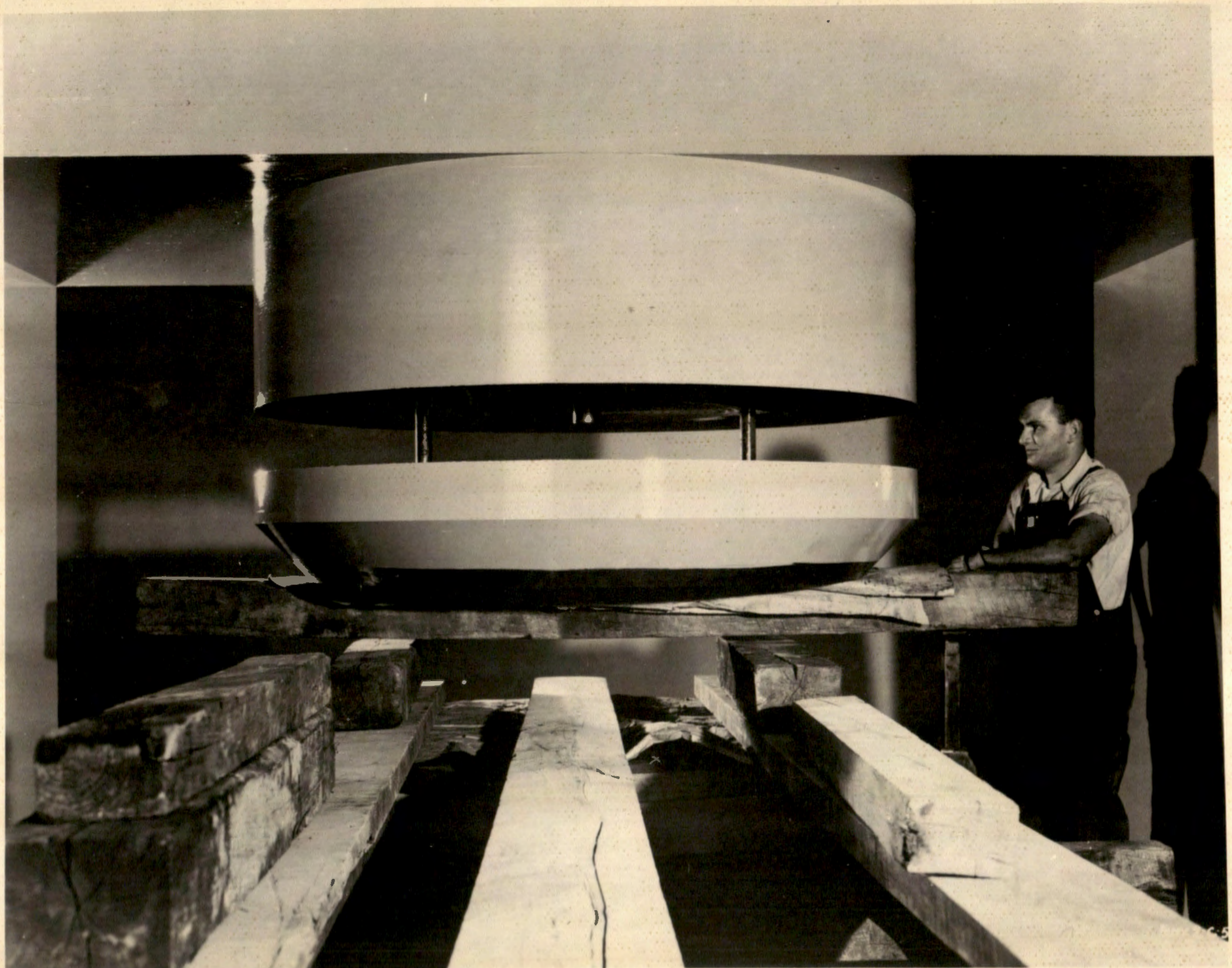

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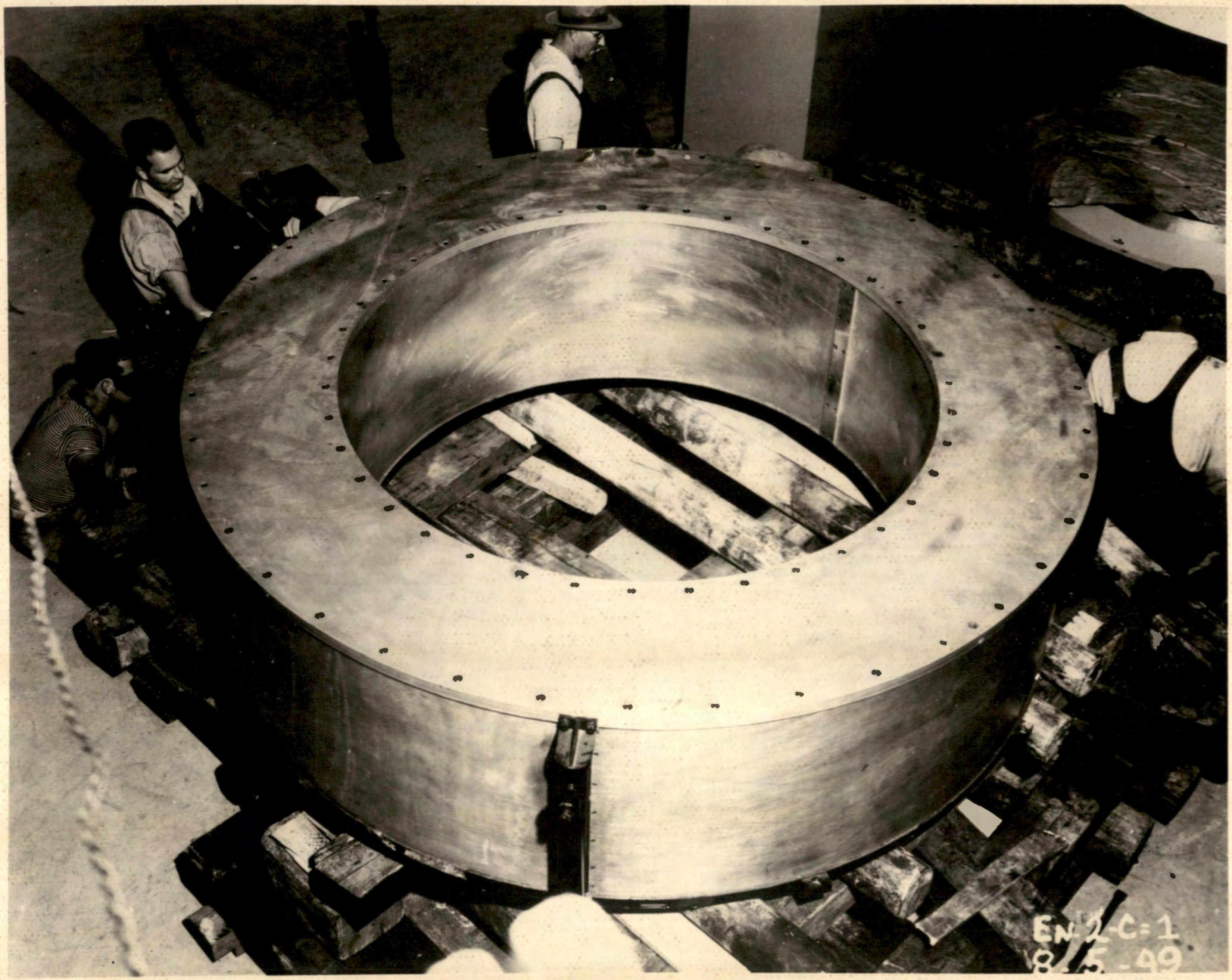

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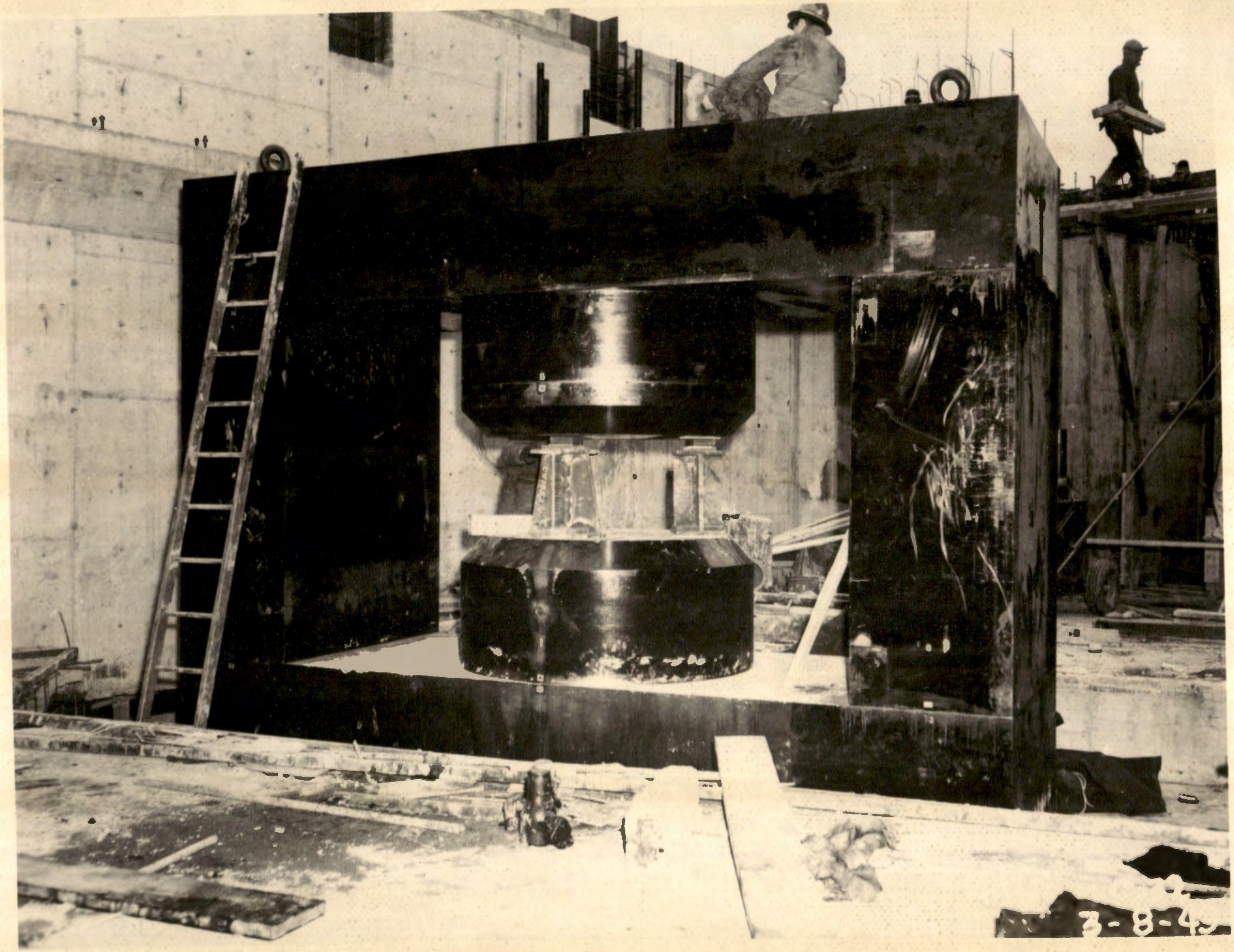

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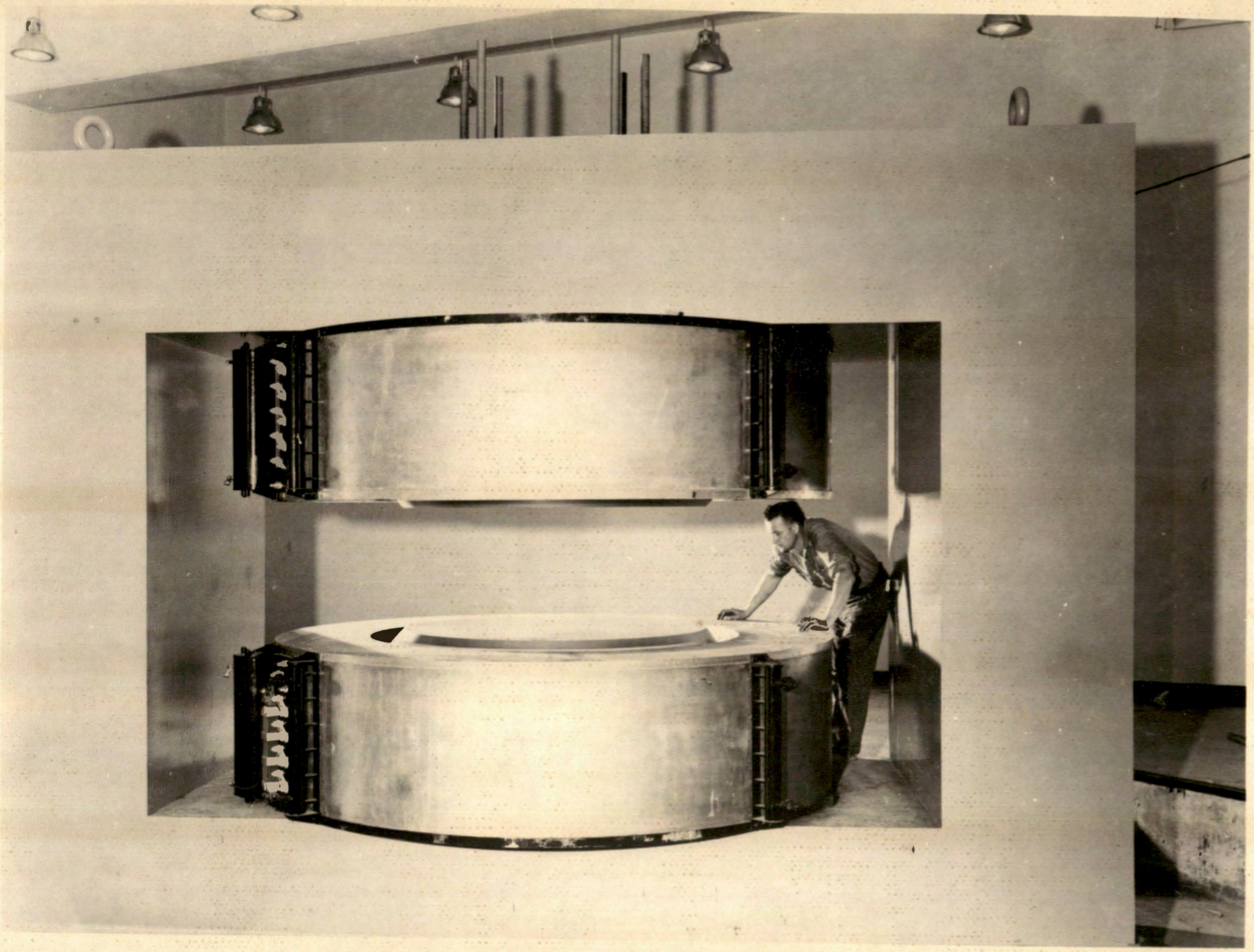

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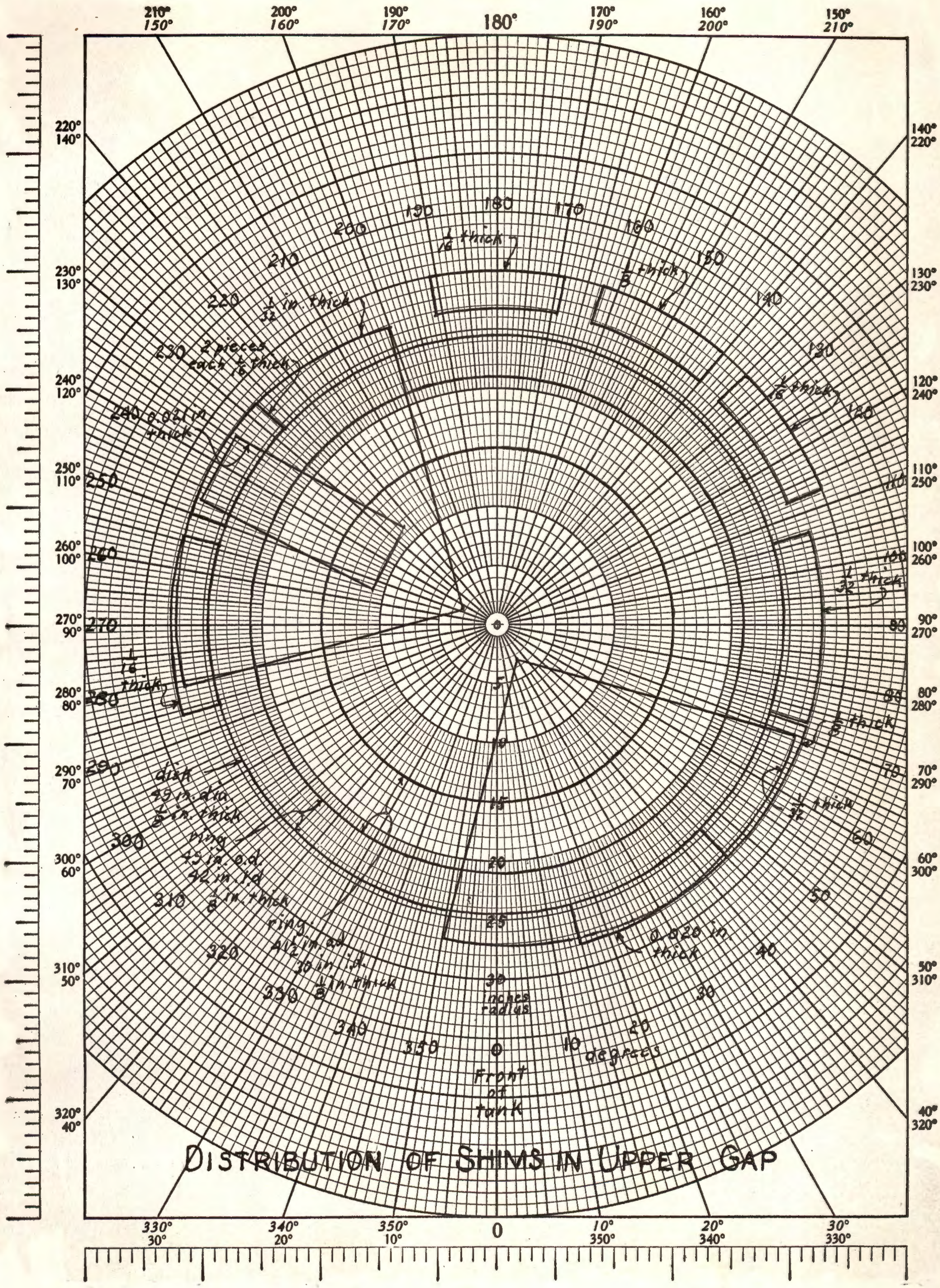
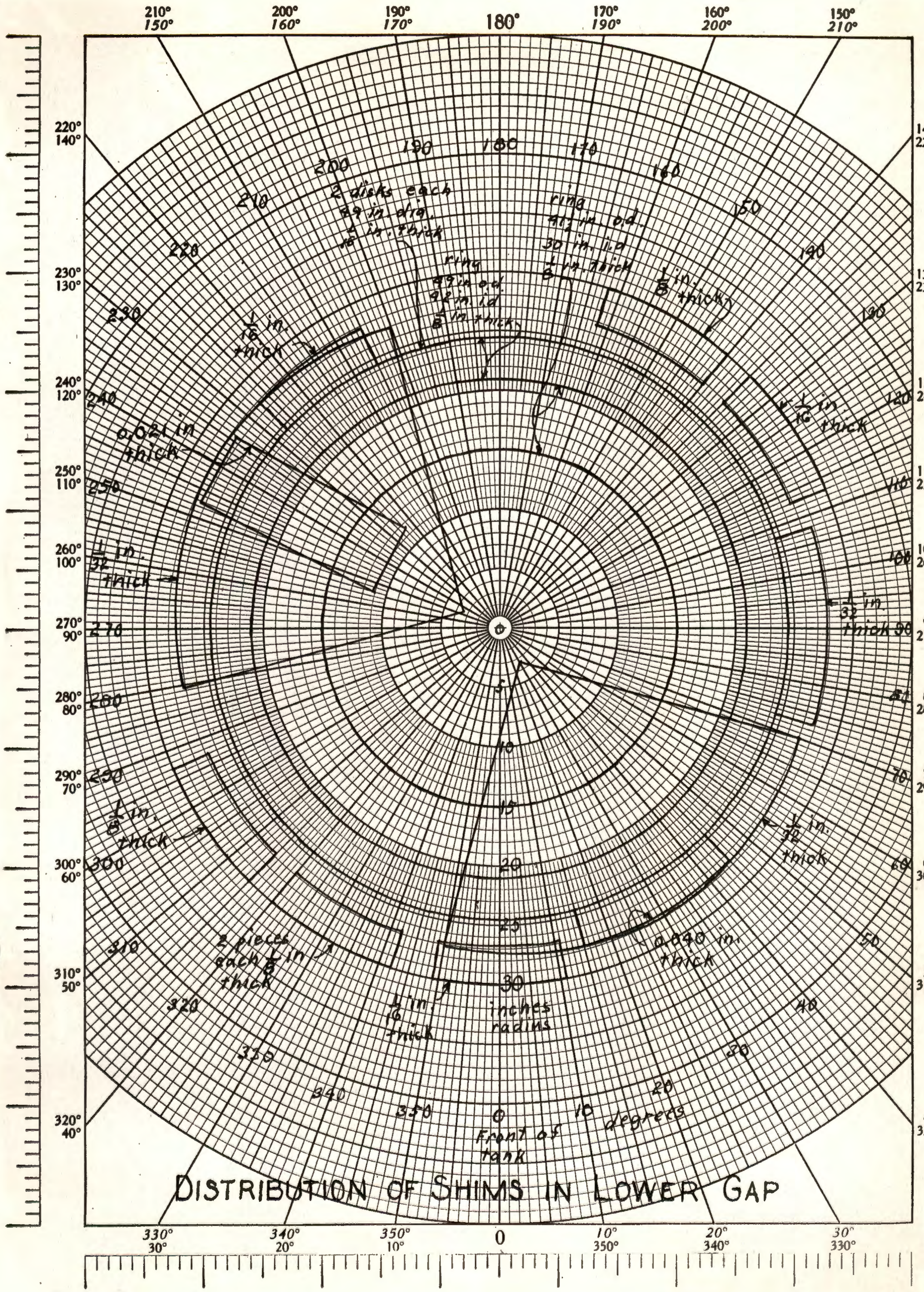


DISTRIBUTION OF SHIMS IN UPPER GAP



DISTRIBUTION OF SHIMS IN LOWER GAP

Magnet Power Supply

I. DESCRIPTION

The magnet power supply furnishes direct current power to the magnet coils. It is composed of the following equipments:

Motor Generator Set

Generator Rating: 200 kilowatts, 1200 rpm, 250 volts, shunt wound, separately excited at 125 volts. Two-wire direct current.

Motor Rating: 300 horsepower, 1200 rpm, 2300 volt, 3-phase, 60-cycle, 0.8 power factor (leading) synchronous motor.

Generator Field Exciter

Amplidyne Generator Rating: 5 kilowatts, 1800 rpm, 125 volts, center-tapped control field, winding impedance of 1298 ohms each leg. Maximum control field current, 150 ma each leg. G.E. Catalog No. 5AM614B34.

Amplidyne Motor Rating: 7½ horsepower, 1800 rpm, 208 volts, 3-phase, 60-cycle induction motor. G.E. Catalog No. 5K284D2658.

II. OPERATION

The operation of this equipment is best explained by consulting the overall elementary diagram TT9674980 while reading the following description of the operations:

Main and Amplidyne Motor Generator Sets (Elementary Key 17-20)

With the 125 volt d-c control power available from the control power battery and control power switch 8 (18-A3) in the on switch, the main synchronous motor starting breaker can be closed. This can be done by turning the breaker contact switch 1/CS (18-E), mounted on the field panel, to the closed position, provided:

a. The permissive control switch 69 (18-A3) is in the normal position;
b. The phase sequence or undervoltage relay 47 (18-A3) is energized (this device appears on key #2); and
c. The master control relay 4-3 (17-2) is energized.

At the same time, provided the above conditions have been met and the breaker has been closed, the following operations occur in the field application circuit:

a. Auxiliary relay 52 CL (18-A3) is energized, opening a normally-closed contact which turns on green lights in the cubicle 18-A3 and the field application panel (18E) and closing a contact in the motor field circuit;
b. An incomplete sequence relay 48 (18-E) starts timing the starting sequence;
c. The yellow indicating lamp circuit (18-E) is completed through the normally-closed contacts of the field contactor 4-41 (18-E), the contacts of the relay 40 (18-E) and the breaker auxiliary contacts;
d. The synchronous speed relay 13 (18-E) in the metering circuit is energized by motor starting current. This opens contacts of the relay in the field application control circuit to prevent closing of the field contactor until the motor has reached approximately synchronous speed. When exciter voltage reaches set value, the exciter 53 (18-E) is connected. Normally-open contacts close and seal the relay in through the 200-ohm variable resistor. At the same time, the normally-closed contacts used in the field portion of the circuit open, placing the exciter field rheostat back in the circuit. The exciter shunt field can now be regulated by the field rheostat. Upon reaching approximately synchronous speed, the synchronous motor speed relay 13 (18-E) is de-energized. This closes the contact which places power on the field contactor 41 (18-E). When the field contactor 41 (18-E) is energized, the following operations occur simultaneously:

    (1) The two contacts close to complete the motor field excitation;
    (2) A contact opens to remove the discharge resistor from the circuit;
    (3) A contact closes to short out the synchronous speed relay 13 (18-E) coil and places the remote instrument M 103 (17-3) back in operation;
    (4) A contact in the breaker trip circuit opens to prevent tripping of the motor breaker 52 (18-EA3), when the incomplete sequence relay 48 (18-E) reaches the end of its timing cycle;
    (5) A contact opens and the field contactor holds itself in through the 250-ohm resistor. Field relay 49 (18-E) is now energized by the motor field current. This causes a contact to short out the yellow indicating lamp (18-E) and open a contact to complete the circuit through the red indicating lamp. The incomplete sequence relay

should now time out, closing a contact in the breaker trip circuit and opening a contact to remove its motor from the circuit. The main m-g set breaker will trip if any of the following faults occur in the motor field circuit:

(a) Motor overload - This will energize the overcurrent relays 49 (18-E), closing a contact which will then energize the trip circuit.

(b) Loss of field current - This will de-energize the field relay 40 (18-E), closing a contact to complete and energize the trip circuit through the contact of the incomplete sequence relay 49 (18-E).

(c) Incomplete starting sequence - If for any reason either of the field contactors 41 (18-E) or the field relay 40 (18-E) does not close within a predetermined time, the incomplete sequence relay will cause the trip circuit to be energized. This may be due to failure of the motors to reach synchronous speed or failure of the exciter relay 53 (18-E) to energize within that time.

(d) Operation of the short circuit selective relays 50 (18-A3) - This will close a contact, completing the trip circuit.

(e) The trip circuit of the main m-g set may also be energized by any of the following methods:

1. De-energizing the master control relay 4-3 (17-2).
2. Turning the breaker control switch 1/CS (18-E) to trip position.
3. Turning the permissive control switch 69 (18-A3) to the trip position.

Amplidyne Motor Generator Set (Key 21)

The amplidyne motor breaker 42E (19-K) is operated from the field application panel (18-E) by the amplidyne motor starter switch 42 E/CS (18-E). The 120-volt, 60-cycle control power for energizing the breaker is obtained between the 60-amp fuse and the breaker contact for phase 1 of the amplidyne motor. The following permissive conditions must exist before the breaker can be operated:

a. Master control relay 4-1 (17-2) must be energized;

b. The auxiliary relay for the auxiliary filament supply contactor must be energized.

The above conditions having been satisfied, the amplidyne motor may be started by turning the amplidyne motor starting switch to ON position. This energizes the amplidyne motor breaker and the following operations occur simultaneously:

a. The breaker closes, applying power to the amplidyne motor.
b. The breaker seals itself in through a normally-open contact.
c. The normally-closed contact of the breaker in the green indicating lamp circuit opens and extinguishes the green lamp.
d. The normally-open contact of the breaker in the red indicating lamp circuit closes, lighting the red lamp.
e. Auxiliary relay 42-EX (17-2) is energized, closing the contact in the magnet excitation control circuit.

The amplidyne motor breaker can be de-energized by any of the following methods:

a. Turning the amplidyne control switch 42E/CS to OFF position.
b. De-energizing the master control relay 4-1 (17-2).
c. De-energizing the auxiliary relay 48 FX (17-2) for the auxiliary filament supply contactor.
d. Energizing the overload relays in the phase 1 and phase 3 of the motor supply circuit.
e. Blowing of 60-amp fuses in the motor supply circuit.
f. Disconnecting the supply contactor from the 208-120 volt, 60-cycle, 3-phase bus by use of the disconnect switch.

III. MAINTENANCE

The equipment as installed requires only occasional service. The bearing lubrication reservoirs must be kept filled with the grease supplied with the machines. The only other common service required is the replacement of the exciter brushes on the main generator and the amplidyne generator. It is necessary to replace these when they are worn sufficiently to cause erratic behavior of the magnet field current. The brushes for the main generator exciter can be obtained from the National Carbon Company (Catalog Number SA3538) or the General Electric Company. The brushes for the amplidyne generator can be obtained from the General Electric Company in carbon grade GE377 by referring to the amplidyne catalog number.

Magnet Current Regulator

I. DESCRIPTION

General Description - Schematic Diagram #P-5122841

The magnet current regulator is an electronic regulator capable of holding to very close tolerances any set direct current within its range. The high degree of regulation is attained by using a shunt reference voltage held constant to the accuracy of a standard cell voltage. The regulating loop consists of a shunt, the magnet current regulator, an amplidyne generator, and a large d-c generator with the aforementioned shunt in series with the load.

Specifications

Power Requirements: 115 volts, 60 cycles, approximately 300 watts.

Output: Push-pull to two balanced windings of the amplidyne generator. (Field specifications - 2 control fields of 2050 turns per pole and 1300 ohms per control field.)

Current Range: 250 amperes to 700 amperes d-c with complete coverage.

Regulation: Current variation is less than 0.01% at any set value over a four-hour period.

Reference Voltage: Standard cell.

Controls

Current Selector Switches

This selector also consists of three controls--COARSE (50 ampere steps), MEDIUM (5 ampere steps), and FINE. They adjust the shunt reference voltage by adjusting the tap on a constant current divider controlled by the standard cell and its associated galvanometer and phototube arrangement.

Power Switch

A main power switch is provided on the power supply for the magnet current regulator when system operation or test does not require its use.

Indicator Light

This light on the control console when energized indicates that the regulator is not functioning.

II. INSTALLATION

Special Precautions and Instructions

The only ground permitted in the regulating loop is at the negative end of the 0.240 volt shunt.

Before putting in service, the galvanometers must be unblocked. Remove back of temperature-lagged box and then remove the paper movement supports, being careful not to move the compensating ring at the bottom of the galvanometer.

After all interconnections have been made and tubes inserted, the unit is ready for initial operation.

Preparation for Use

Amplidyne generator and main generator not running.

Do not replace back of temperature-lagged box.

Plug in or turn on 115-volt, 60-cycle supply voltage to magnet current regulator. After approximately 25 to 30 seconds, K2 will pick up and energize K4 in the temperature-lagged box. Galvanometer G1 will move the light beam completely off its associated phototube V12. In another few seconds either G1 will move the light beam on the phototube where it will remain, or K4 will drop out and the light beam from G1 will gradually drift back to the vicinity of V12. Relay K4 should then pick up and cause the light beam to center itself on V12. If K4 does not pick up, depress the push-button (PB1) on the power supply chassis for a second or two. K4 will then be energized and the light beam from G1 should fall partially on V12 and remain when the push-button is released.

Approximately half the light beam should impinge on the phototube (V12). If its position is off center in either direction, potentiometer R-74 (in the temperature-lagged box) should be adjusted with an insulated screwdriver.

The regulator should now be ready to function properly.

III. OPERATION

A. Principles of Operation

The electronic circuit consists of: (1) a regulated 300-volt power supply with a voltage regulator tube reference; (2) the shunt reference voltage supply with a standard cell reference; (3) the current variation detector; (4) the divider for the magnet voltage; and (5) the amplidyne field control amplifier.

The regulated 300-volt power supply is a standard series regulated power supply using 815's (V3 and V4) as the series tubes with a 6SH7 (V5) serving as control amplifier tube and a 5651 (V6) tube for a voltage reference. Compensation for line voltage variations is furnished by R13 from the unregulated d-c to the screen of the 6SH7 (V5). The voltage of the 300-volt supply is adjustable by potentiometer R18.

The shunt-reference voltage supply is another series regulated power supply fed by the 300-volt supply. The 6V6 (V8) is the series tube with a 6SH7 (V9) serving as a control amplifier. The control amplifier (V9) receives its signal from the 917 phototube (V12) through one section of the 6F8G (V13) cathode-follower. The 917 phototube (V12) receives a beam of light from galvanometer G1. The position of the light beam is determined by the difference voltage across resistor R76 and the standard cell. The galvanometer G1 is a compensated flux-meter type galvanometer and deflects through a wide angle for a small applied terminal voltage. The feed-back loop is then completed through resistor R76, galvanometer G1, phototube V12, control amplifier V9, and the series regulating tube V8. In this way the voltage drop across R76 is held equal to the voltage of the standard cell. The current flowing through R76, a precision aged resistor, also flows through R73, R74, R75, the current selector dividers (R77, R78, R79 and R81) and R80. The current selector dividers, made up of precision aged resistors, provide a very stable reference voltage for the current variation detector. To protect the standard cell from excessive current drains if the circuit refuses to function, the standard cell relay K4 is energized through relays K2 and K1. Relay K2 does not pick up until the 300-volt supply has reached its approximate operating voltage. Relay K1 picks up and drops out K4 if the shunt reference supply varies more than ±2 volts from its proper value. Tube V11 (6SN7) performs this function.

The current variation detector is another galvanometer phototube arrangement consisting of galvanometer G2 and 919 phototube (V23). The galvanometer detects the difference between the current selector voltage and the shunt voltage. The shunt output voltage is fed by cable K to galvanometer G2 through a compensating network R71 and C18. The output of phototube V23 is fed to the amplidyne field control amplifier through one section of the 6F8G cathode-follower (V13). This section of the 6F8G also furnishes a compensating voltage to galvanometer G2 to limit its excursions during transient current conditions.

The magnet voltage divider is also fed through cable K with the reference point of the magnet voltage divider located at the ground end of the shunt. The voltage divider selector is ganged with the COARSE current selector. The divider output goes to 6SN7 (V15) through time-constant compensation resistor R40 and capacitor C15.

The amplidyne field control amplifier receives voltage and current signals and applies corresponding field excitation to the amplidyne. The 6SN7 (V15) sets up a cathode reference voltage for the 6SK7 (V17) corresponding to the magnet voltage divider output. The 6SK7 (V17) receives the current signal on its control grid through the limiting circuit consisting of R42, R43, R44, and crystal diodes X1 and X2. The 6SF5 (V18) which receives its signal from the plate output of V17 serves as a d-c voltage adjustment to feed the signal to the phase inverter tube 6SN7 (V20). The output of the phase inverter V20 is applied directly to the amplidyne field series control tubes V21 and V22.

To limit the speed of response of the amplidyne and to stabilize the regulating loop, a signal is fed through capacitor C13 from the amplidyne output to the grid of the 6SN7 (V15) which receives the magnet voltage signal.

Because the magnet exciting current lags the applied magnet voltage by an appreciable time, relay K5 is not permitted to pick up and apply the shunt voltage to galvanometer G2 until the magnet exciting current has risen to a reasonable value. This is done by relay K3, which is controlled by V14 (6J5). V14 receives its signal from the magnet voltage divider and permits relay K3 to be energized after the magnet voltage has reached the approximate value called for by the COARSE current selector.

B. Operating Instructions

(1) Turn on the magnet current regulator and allow approximately one-half hour warm-up period.

(2) Select the desired current on the "Automatic" current selector.

(3) Start the amplidyne and main generator.

(4) Close magnet contactor.

(5) In approximately one minute the magnet current regulator should be holding the current within the specified regulation limits.

(6) To change current it is only necessary to move the automatic current selector to the new desired value as follows:

a. Move the MEDIUM current selector slowly by single steps to allow the current in the magnet to follow and keep up with the selector settings.

b. The COARSE current selector should be advanced when the MEDIUM selector is at maximum. Simultaneously, the MEDIUM selector should be brought back to minimum or near minimum setting.

c. The reverse of the above should be followed in lowering the COARSE setting for each step.

IV. MAINTENANCE

At approximately monthly intervals, the following checks should be performed:

A. The ~~#82~~ #1709 lamps in the two light sources should be inspected. If a lamp shows excessive darkening of the glass bulb, replace the lamp and readjust the associated light source to center the light beam on the galvanometer mirror.

B. Observe the position of the light beam on the 917 phototube (V12) with power on the magnet current regulator. If the light beam is not properly balanced on the phototube (V12), adjust R74 with a well-insulated screwdriver. (R74 is in the upper left-hand corner of the temperature-lagged box, looking in with the back cover removed.) If reasonable centering of the light beam cannot be achieved, the 6F8G (V13), the 6SH7 (V9) and 6V6 (V8) tubes should be checked. If these are all good, the 917 phototube (V12) should be replaced.

V. SERVICE

CAUTION: DO NOT ADJUST R46, R52, OR R56 EXCEPT AS INSTRUCTED!

A. When the response of the magnet current regulator is slow, it is usually necessary to replace the 919 phototube (V23).

B. If the operation of the regulator is normal, except that it does not cover the entire range for each 50-ampere setting of the COARSE current selector, the magnet current regulator is in need of adjustment as follows:

(1) Remove back of temperature-lagged box.

(2) Place a 0 to 300 volt d-c voltmeter (vacuum tube voltmeter required) across the generator voltage signal leads (terminals K3 and K4 in temperature-lagged box.)

(3) Adjust R52 and R56 to approximately mid-position with a small screwdriver.

(4) Energize the magnet with the COARSE current selector set at 250 amperes and MEDIUM current selector at 45 amperes.

(5) While observing the light beam falling on the 919 phototube (V23), reduce the MEDIUM current selector slowly to the lowest value of current possible with the equipment still regulating. (When the light beam falls off V23 and stays off, the regulator is no longer regulating current.)

(6) Adjust R46 to bring the light spot over a larger area of the phototube.

(7) Check each position of the COARSE current selector to see that the regulator works for the maximum setting of the MEDIUM and FINE selectors.

(8) Repeat 6 and 7 until regulator is set for optimum operation, adjusting R52 and R56 if necessary.

(9) Tighten the shaft locks.

C. If relay K1 operation does not coincide with the operation of the standard cell reference power supply, its range may be corrected by adjusting R33, which is located on the rear right-hand corner of the power supply chassis. Further adjustment may be obtained with R28 (on the top of the power supply chassis near the right rear corner).

II. Dee System

Dee System

DESCRIPTION

Dees

The dees, the electrodes which induce the r-f power to the ion beam, are shown on Dwg. TT9671920. In more detail, the left dee is shown on Dwg. TT9671945 and the right dee on Dwg. TT7384D17.

Each dee has an internal supporting framework which extends into the transition section of the dee stem. A clamp, Dwg. 451C825, on the tip of each dee, adjusts the tension in the top member of the frame to compensate for sag in the dee.

Each dee is cooled by the flow of treated water through the copper tubes brazed to the inner surfaces of the dee shells.

Carbon blocks have been positioned inside the dees to protect the dee frames and clamps from the ion beam.

Dee Stems

The dee stems support the dees, and with the dees and tuning bar, form a one-quarter wave length resonant system. The resonance of the system is in the range of 11 to 13 megacycles.

The dee stems are constructed of 18"-diameter steel pipe which is metallized on the outside with copper. This coating extends from seven inches in front of the pivots to the transition section.

Each stem is made of two concentric steel pipes with a one-half inch space between them, in which cooling water flows. The return flow path is through piping from a header, at the forward end of the dee stem, back through the inside of the dee stem.

Piping for the cooling of the dees and the transition sections passes through the inside of the dee stems. This piping is connected to feed-through connectors, in the rear wall of the tank, by flexible metal hose.

The right dee contains the deflector stem which houses cooling tubes and the linkage from the deflector positioning drive mechanism to the deflector. The deflector stem is supported along the axis of the dee stem on Micalex spider insulators.

The dee stems are pivoted approximately three feet from their rear end in trunnions so that each dee may be moved either vertically or horizontally.

Dee Positioning Mechanism

The dee-positioning drive motors are shown as Items 25, 26, 27, 28 on Dwg. TT9671920.

Upward motion of the dee is accomplished by exerting a force downward in the back of the pivot, while downward motion of the dee is obtained by backing off on the vertical drive and allowing the dee to lower by its own weight. Horizontal motion of the dees is accomplished in the same way as the vertical motion, except that heavy coil springs provide the restoring force.

The control switches, the control circuitry and the dee positioning drive motors for vertical and horizontal positioning of each dee are similar in operation and construction.

The control switches are mounted and connected so as to simulate the motion of the dees; that is, when it is desired to move the dee to the left, the horizontal dee switch is moved to the left, and when it is desired to move the dee to the right, the horizontal dee switch is moved to the right. The vertical operation is similar; the switches are moved either up or down to obtain the desired position.

Remote indication of the dee positions is given on instruments mounted above their respective control switches on the right-hand panel of the control console. Limit switches are provided to stop the motors at the end of travel.

Transition Sections

The transition sections (Dwg. T9740333) connect the cylindrical dee stems and the flat dee surfaces. These sections are made of sheet copper. Cooling tubes have been brazed to their inner surfaces.

Each section is made in two halves split horizontally at the sides so that piping connections can be made to the dees. Knife-edge clamps (Dwg. 916A270 and 663B262) make the high current r-f connection between the transition section and the dee stems and dees.

These clamps go completely around the dee assembly at both joints. They are fastened by ¼"-20 Trodalloy screws. The clamps are tightened so that the knife edges bite into the surfaces slightly. The clamps bridging the transition section and the dees are fastened with spring-loaded screws, because the slight movement of the dee, caused by temperature cycling, tends to loosen the clamps.

Liners

The liners are provided to furnish the r-f current a low resistance return path in the dee chamber.

The liners consist of bottom and top assemblies. Each assembly consists of two sections and the sections are fastened to each other and to the dee chamber by countersunk ¼" Trodalloy flathead screws.

The sections are made of 1/8" sheet copper polished on the exposed surfaces. Cooling tubes are brazed to the unexposed surfaces and are connected to the feed-through ports after assembly. The rear ends of the liners are fastened to the inner surface dee stem housing by knife-edge clamps similar to those used on the transition section. These clamps are provided to carry r-f current from the liners to the metallized (copper) inner surfaces of the dee stem housing.

Tuning Bar

The tuning bar, Dwg. T9740395, is a movable vertical plane of copper, forming the back surface of the dee housing chamber. It is connected electrically to the inner surfaces of the dee stem housing and around the dee stems by means of bellows-actuated knife edges.

The bellows are expanded with dry nitrogen furnished them by a header and flexible copper tubing from a tank and pressure regulator located outside of the housing.

The tuning bar is supported by rollers that ride on metallized rails attached to the top of the dee positioning chamber.

Clamps are provided for the purpose of making r-f connection between the tuning bar and the rails, so that the support rollers behind the tuning bar do not heat excessively.

Cooling tubes are brazed to the back side of the tuning bar, and cooling tubes are soldered to the edges of the supporting frame near the bellows. Inlet and outlet water connections to these cooling tubes are made by O-ring connectors and copper tubing to the inlet and outlet headers furnished for cooling the dees.

Trimmer Capacitors

The trimmer capacitors are movable side portions of the copper liners. They are provided for the purpose of balancing the left and right dee voltages. They are moved in and out by a shaft extending through an O-ring seal in side ports of the dee housing chamber. The drive mechanisms are operated from the control console by two switches labeled "left and right trimmer". Indication of the positions of the two capacitors is given on instruments located above the control switches on the left panel of the control console.

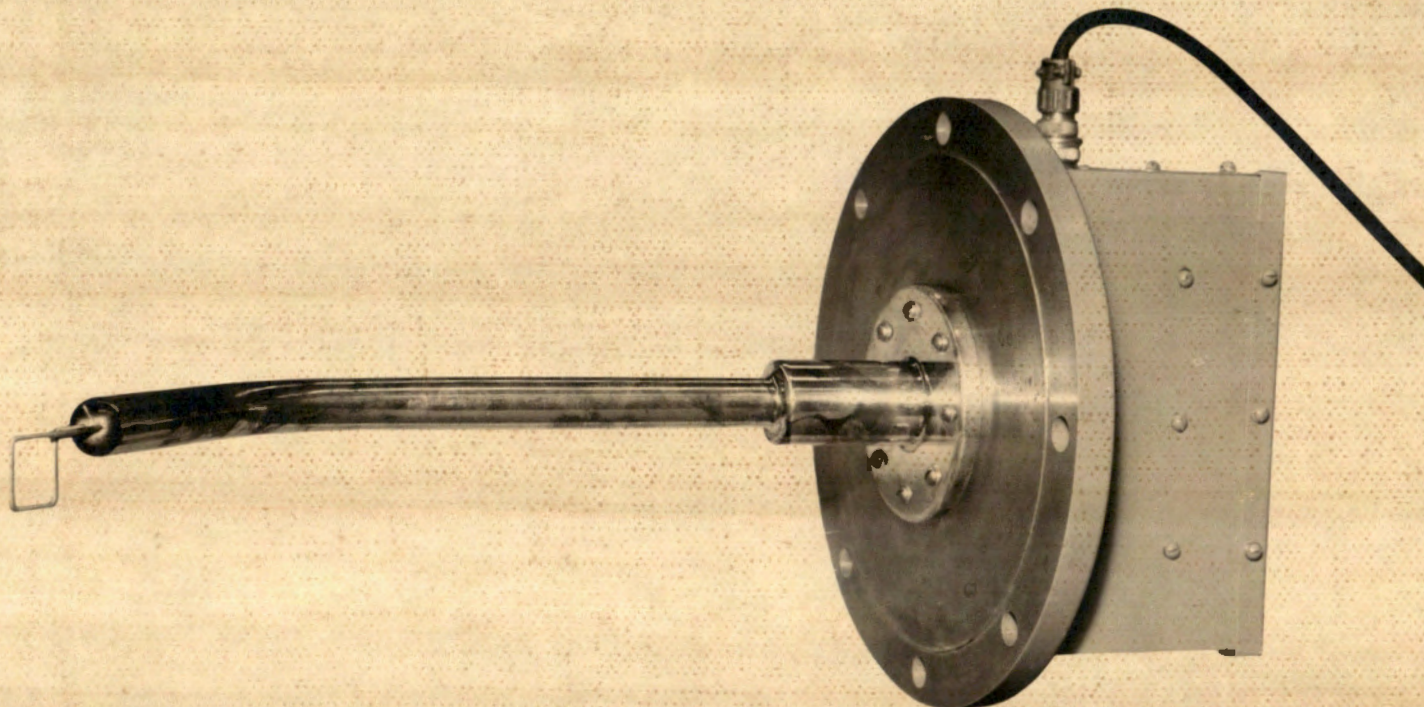
Dee Current Probe

The dee current probe is a device used to monitor the r-f current flowing in the right dee stem.

The probe unit (Photograph #1087898) consists of a one-inch square pickup loop in which a voltage is induced. This voltage is proportional to the current in the dee.

A capacitive voltage divider is connected across the loop, and a germanium rectifier and a choke input filter convert the r-f voltage to direct current which is read at the control console.

3a



1087 898 D-LINE CURRENT PROBE, CAT. 30896, FOR 60-IN. CYCLOTRON. SIDE VIEW.

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Dee Voltmeters

The dee voltmeter system consists of a capacitive coupling from the dees to r-f type instrument thermocouples. The d-c output of these thermocouples is fed through cables to self-balancing potentiometers associated with instruments on the control console.

The capacitive coupling to the voltmeter circuits is effected by means of rectangular electrodes (Dwg. 451C838) attached perpendicularly to the outer edges of the dees. The receiving electrodes are 1"-diameter disks located in the dee chamber walls.

OPERATION

Dees

Normal operation of the cyclotron requires that only small adjustments of the dee positions be made. This is accomplished by moving the dees in small increments with the dee positioning mechanism controls.

These adjustments should be made with the cyclotron producing a low current beam. Observations of the inside of the accelerating chamber should be made during these adjustments to avoid melting the septum notch and other exposed portions of the dees.

It is necessary to exercise extreme caution when adjustments are made.

It is considered advisable to have one person observe the inside of the accelerating chamber through a telescope and mirror system to note any change in intensity or location of hot spots. Since these incandescent spots locate the areas of intense beam impingement, the use of this information is helpful in obtaining optimum dee adjustment, as well as avoiding burnout of sensitive components.

Another person should observe the temperature rise in the septum and deflector coolants during dee adjustments. Since there is some time lag in the reaction of the thermistor circuits, the operator should wait until equilibrium temperature is reached before making further adjustments to the dee positions.

The trimmer capacitors are used to compensate for small imbalances in dee voltage, due to differences in dee positions. Therefore, when adjustments are made in dee positions, compensating changes should be made in the trimmer capacitors.

Observation of the dee voltages and dee current should be made while adjusting the dees. Sparkover of the dees can be observed by a sudden downward deflection of the dee voltmeter. Excessive sparkover should be avoided as it is damaging to the dee and liner surfaces.

MAINTENANCE

Dees and Liners

The dees require that periodic inspections and replacements of the carbon scraper blocks be made. Since these blocks are eroded by the beam, it is necessary, before long runs are made, to ascertain by visual inspection that sufficient carbon remains to protect the dee beams and clamps.

The surfaces of the dees and liners, with ordinary use, should require no regular maintenance. However, if the dees are allowed to spark too vigorously, erosion of the surfaces of the dees and liners will result in extremely low sparkover voltages. When this occurs, it is necessary to remove the dees from the tank and polish the dee and liner surfaces.

Tuning Bar

If it is necessary to change the position of the tuning bar (to change the frequency of the dee system), the procedure is as follows:

1. Close the vacuum chamber to the pumping system and bleed with air to atmospheric pressure.

2. Remove the rear manhole cover.

3. Make a survey of the radiation hazards inside the tank to ascertain what safeguards must be taken.

4. Loosen tuning bar rail clamps. Use a 3/8" Allen wrench and rotate the screws one half turn.

5. Bleed the dry nitrogen supply to the tuning bar bellows. The tuning bar is now free to slide on the rails and the dees.

6. After the tuning bar has been positioned, hold it in place until the bellows are energized.

7. Tighten the inner rail clamps.

8. Tighten the outer rail clamps.

9. Remove any debris or tools.

10. Replace the manhole cover after cleaning the O-ring.

Transition Section

Whenever the vacuum chamber is open, it is well to check the knife-edge clamps around the transition section and liners for tightness. A loose clamp tends to overload the other clamps.

Trimmer Capacitors

No maintenance required.

Dee Current Probe

No regular maintenance is required. Whenever personnel enter the vacuum chamber through the entrance manhole in the oscillator floor, care should be taken to avoid bending or breaking the loop.

Dee Voltmeters

No regular maintenance is required other than occasional calibration. This circuit may be calibrated by applying measured d-c current from a battery from the bushing to ground, and comparing this current and the console reading with the calculated current normally expected to flow through the thermocouple at the various dee voltages.

The spacing between the dee electrodes and the pickup disk should be 1-3/32". Whenever the electrodes are removed, they should be checked for spacing.

III. Oscillator System

Sixty-Inch Cyclotron Auxiliary Oscillator

The auxiliary oscillator, or "tickler", has the function of driving the main cyclotron oscillator into oscillation. The main oscillator will not start oscillating (except at a low level) when the plate voltage is applied, but once oscillation is initiated by means of the tickler, it continues in stable oscillation, even with the tickler off, until either the plate power is interrupted or a spark-over occurs.

When plate power is applied to the main oscillator, the tickler will emit pulses of oscillator frequency of about 20 milliseconds duration and at intervals of about 600 milliseconds. These pulses continue until the main oscillator starts, and a relay actuated by the main oscillator grid current cuts off the tickler. Should the main oscillator spark off, the tickler immediately starts pulsing and continues until the main oscillator restarts.

I. DESCRIPTION

The tickler consists of an oscillator, a frequency doubling amplifier (the "doubler") which is capacitively coupled to the grid plane of the main oscillator, a pulser, and power supplies.

Oscillator

The oscillator located in Section "B", Dwg. 338D143, employs a 4-400A tube. It is tuned by a motor-driven variable vacuum capacitor operated by the auxiliary oscillator tuning switch on the control console. The tuning range adjustment is adequate for normal changes of main oscillator frequency. To extend the tuning range, remove panel "B", loosen the three thumb screws at the front of the capacitor and one at the back, and rotate the capacitor by means of the micrometer knob at the front. <u>These adjustments must be made with the power off. High voltages are present.</u>

Doubler

The doubler is located in Sections "A" and "E", Dwg. 338D143. It employs four 4-1000A tubes operating in two pairs. The grids of each pair are coupled to opposite ends of the oscillator coil; thus the pair in Section "A" is driven when one end of the oscillator coil is positive, and the pair in Section "E" is driven when the opposite end is positive. The frequency is therefore doubled with each pair furnishing alternate cycles.

The oscillator is normally tuned to one-half the cyclotron frequency, so that the frequency output of the doubler corresponds to the main oscillator frequency. Both the oscillator and doubler are biased beyond cutoff, so that the oscillator will oscillate only when driven by the pulser and the doubler only when driven by the oscillator.

Timing Generator

The pulser or timing pulse generator is shown in elementary diagram #451C519. The amplitude of pulse may be adjusted in approximately 25-volt steps with the switch S2. Ordinarily it is run at maximum voltage. Potentiometer R19 adjusts the bias on V-1, (3E29), and potentiometer R15 controls the pulse shape. Both have screw-driver slot controls accessible from the back and should need no further adjustment once the equipment has been put in operation. The positive pulse output of this unit is delivered from connector J4 through a coaxial cable to pulse transformer T2 in the oscillator, which delivers the pulse to the grid of the oscillator tube. Plate voltage for V2 (6AG7) is applied through the normally-open contacts of relay $\frac{K1}{F}$. Relay $\frac{K1}{F}$ is actuated through a normally-closed set of contacts of relay 37-OG (17-4) and a normally-open set of contacts on relay $\frac{K1}{D}$ (Elementary Diagram 451C514).

Power Supplies

Oscillator and Doubler Plate Supplies

The plate power supply for the oscillator and doubler is located in Section "D" (Elementary Diagram #451C520) which is behind panel "C". It employs a bridge rectifier using four 866A mercury vapor rectifier tubes. The high voltage transformer T-1 is fed through variable transformer T-4 which normally never has to be adjusted. T-4 is fed through T-3, a power-driven variable transformer which is so arranged that it automatically runs up to full voltage when the plate power is switched on and returns to zero when the plate power is switched off.

Doubler Bias and Timing Generator Supplies

The doubler bias and timing generator power supplies are located in Section "G" (Elementary Diagram #451C517). Both employ full-wave rectifiers using 5R4GY tubes. Relay $\frac{K1}{G}$ operates just below doubler bias operating voltage. Bias voltage is adjusted by the knob on the right side of the front panel, and relay $\frac{K1}{G}$ operating voltage is adjusted by the knob in the center of the panel.

Oscillator Bias and Screen Supplies

The oscillator bias and screen supplies are located in Section "H" (Elementary Diagram #451C516). Oscillator bias supply is the same as the doubler bias supply above except for the transformer and bleeder resistance ratings. The screen supply has the same type of full-wave rectifier and bleeder resistor.

Doubler Screen Supply

The doubler screen supply is located in Section "J" (Elementary Diagram #451C518). It uses 3B28 rectifier tubes, but, except for ratings, is the same as the oscillator screen supply above.

II. INSTRUMENTATION

Except for the plate supply, which has meters on the metering panel for reading current and voltage, all power supplies have jacks for reading current and voltage on the test meters provided on the metering panel.

Table I gives the normal readings at the various jacks. In most cases the current readings are so low that they do not indicate on the test meter, but an indication is given when the capacitor rectifier unit is used in series. The peak voltages, as observed on an oscilloscope, are also given in Table I.

Metering Panel

The metering panel occupies the top six inches across the front of the cabinet. The four indicator lamps and their functions are taken up in the control sequence below.

Meter M-1 indicates the doubler filament voltage in Section "E" which is presumably the same as in Section "A". This voltage is adjusted by the switch and the variable transformer beside the meter. Variable transformer $\frac{T2}{M}$ and transformer $\frac{T1}{M}$ are used for varying the doubler filament primary voltage 0-5 volts from line voltage. Switch $\frac{S1}{M}$ in the upper position adds this voltage and in the lower position subtracts this voltage. In the center position the filament voltage is off. Normal filament voltage is 7.5 v.

Meter M-2 reads the doubler plate voltage, normally 2.8 kv.

Meter M-3 reads doubler grid current. This is ordinarily zero, but kicks slightly with the pulses.

Meter M-4 reads doubler plate current. A normal value is 15 ma, and it kicks slightly with the pulses.

Test meters M5 and M6 are 100 microampere meters. These are equipped with multipliers which are so adjusted that the meters read full scale with 10 volts on the jack plugs. They may be plugged into any of the jacks on panels F, G, H, or J, or may be used with the capacitor rectifier unit in any of these jacks.

The fuse panel "C" contains, in addition to the fuses indicated on Elementary Diagram 801A788, switches for controlling the tickler plate voltage. Switch $\frac{S1}{C}$ in the manual position allows the operator to turn the tickler on with momentary contact switch $\frac{S2}{C}$ and turn it off with momentary break switch $\frac{S3}{C}$.

Switch $\frac{S1}{C}$ is normally left in the automatic position, so that the functions of the latter two switches are taken over by the oscillator switch in the control room and its associated relays.

III. CONTROL SEQUENCE

The control sequence may be followed through on Dwg. 451C514. The tickler is normally left with 115 v a-c power on D47 through switch #1 (panel 17-C) in the generator room. In such conditions only green indicator lamp I-1 is on. When the master switch is turned on in the control room, the blowers supplying the main oscillator cooling air start. Part of this air is diverted through a 3½" pipe into the back of the tickler cabinet to cool the oscillator and doubler tubes. When the main oscillator filament is turned on in the control room, relay 42FOX (17-3) closes. This energizes K4 and K1 (K1 is a five-minute time-delay relay). A normally-open contact of relay K4 controls the operation of the instrument dial lamps, the doubler filaments, the oscillator filament, the doubler plate-supply filaments, the doubler screen-power-supply filaments, the oscillator screen-power-supply filament, the doubler bias-power-supply filament, and the pulser filaments.

After a five-minute delay, the operation of relay K1 causes the green indicator lamp I-1 to go out, red indicator lamp I-2 to come on, and the power supplies for the pulser plate, doubler bias and oscillator bias to come on.

When the doubler bias voltage approaches the operating level (800 v), relay $\frac{K1}{G}$ operates. When the oscillator bias approaches the operating voltage (400 v), relay $\frac{K1}{H}$ operates. When both of these relays are energized, green indicator lamp I-3 comes on.

When switch $\frac{S1}{C}$ is in automatic (upper) position and the oscillator switch on the control console is turned on, relay 52CL(18A4) is energized, allowing power to flow from D39 to D40, de-energizing indicator lamp I-3 and energizing relays K2 and K3. When K3 is energized, power flows to the variable transformer T-3 drive motor $\frac{B1}{P}$, driving it in the raise direction. Another set of contacts energizes variable transformer windings. When relay K2 is energized, the variable-transformer drive motor lower connection is interrupted, so that current will not flow in this circuit when the lower limit switch is released. Another set of contacts of K2 bypasses momentary contact switch $\frac{S2}{C}$ when operating $\frac{S1}{C}$ in the manual position. When the doubler and oscillator plate voltage approach operating voltage, relay $\frac{K1}{D}$ operates to energize the oscillator screen and doubler screen power supplies and relay $\frac{K1}{F}$. When relay $\frac{K1}{F}$ is energized, the pulser emits pulses, thereby causing the oscillator and doubler to emit pulses. When the main cyclotron oscillator starts oscillation, grid current causes relay 37-OG (17-4) to operate, de-energizing relay $\frac{K1}{F}$ and cutting off the tickler. Should the main oscillator spark off, relay 37-OG (17-4) is de-energized, relay $\frac{K1}{F}$ is energized, and the tickler comes on again.

Note: Limit switches are shown in their normal (unoperated) position, Switch LSL is in operated position when motor $\frac{B1}{P}$ is at its lower limit, and switch LSR is in operated position when the upper limit of motor $\frac{B1}{P}$ is reached.

When switch LSR operates, the raise power to motor $\frac{B1}{P}$ is interrupted and indicator light I-4 comes on.

IV. SERVICE

Voltages may be read on the test meters. The pulse signal may be traced around the pulser circuit with a cathode ray oscilloscope. The voltage at all jacks is influenced to some extent by the pulse. The last column in Table I gives the pulse height in volts as calibrated by a Dumont 304H oscilloscope.

TABLE I - AUXILIARY OSCILLATOR TEST DATA

Component	Jack Title	Readings Mult. by*	Meter Readings Osc. off	Meter Readings Osc. on	Cap. Rect. Reading	Oscilloscope Peak Readings
Timing Generator Section F	Pulser Plate J1	50	0	0	.4	7.1 volts
	Pulser B+ J2	50	5.2	5.2	5.2	15.0 volts
	Pulser Grid J3	5	4.8	4.8	4.7	7.9 volts
Timing Generator Power Supply Section G	Bias Volts	9	7.0	7.0	7.2	4.0 volts
	Plate Volts	50	5.2	5.2	5.2	3.5 volts
	Plate Amps	20	7.2	7.2	9.6	5.7 M.A.
Doubler Bias Power Supply Section G	Bias Volts	100	7.9	7.9	7.9	5.5 volts
	Bias Amps	1	0	0	1.0	8.5 M.A.
Oscillator Bias Power Supply Section H	Bias Volts	50	7.1	7.1	7.0	6.5 volts
	Bias Amps	20	0	0	0.9	7.0 M.A.
Oscillator Screen Power Supply Section H	Screen Volts	100	0	7.5	7.5	8.7 volts
	Screen Amps	20	0	0	6.0	7.2 M.A.
Doubler Screen Power Supply Section J	Screen Volts	200	0	6.0	6.0	8.2 volts
	Screen Amps	40	0	0	6.0	1.6 M.A.

NOTE: Test meters read full scale with 10 volts on the plug. Meter readings are in volts except where noted as current.

*To obtain actual voltages or currents all readings must be multiplied by the factors in this column.

Main Oscillator

I. DESCRIPTION

The main oscillator furnishes radio frequency power to the dee system. The oscillator consists of two pairs of 9C21 power triodes operating "push-pull". See elementary diagram P-9784622. The oscillator plates and the dee system are coupled by a plate coupling loop which is grounded at its midpoint. The drive for the main oscillator is obtained from an inductively-coupled cathode loop.

The frequency of the main oscillator is primarily determined by the resonant frequency of the quarter wave length dee system. Since the main oscillator will not normally start by itself, a radio frequency pulse is supplied by the auxiliary oscillator to drive one-half of the cathode loop. The main oscillator frequency is adjusted by changing the position of the tuning bar in the dee system. This operation has been described elsewhere in this instruction book (under Dee System - Maintenance).

The various components of this oscillator are cooled either by treated water from the main cooling system or by air from the blower mounted on the outside wall of the oscillator cubicle. The treated water enters the oscillator cubicle through two headers. One header furnishes water to the center stem of the anode loop. The water flow then divides and supplies both legs of the loop. The water leaves the ends of the anode loops in Saran tubing and goes to the anode water jackets of the center 9C21 tubes. The anode water jackets are connected in pairs with copper piping. The outlets of the outer cooling jackets are then connected with Saran piping to the main outlet header. The second header furnishes treated cooling water to the cooling coils of one filament transformer, the associated bifilar choke, the cathode loop, the other bifilar choke, and then the other filament transformer.

There are magnetrol flow alarms and thermal switches in each of the two water outlets.

The grid resistors, grid seals and filament seals on the 9C21's are cooled by a filtered blower system. Saran piping directs a stream of air on the glass seals of each tube. The grid resistors are mounted in the exhaust duct of the oscillator cubicle. Herkolite tubes direct cooling air to the grid seal headers.

The blower system is furnished with flow and pressure sensing switches which prevent operation of the oscillator when the air flow is insufficient.

The main oscillator cooling system, like that of the dee system, is interlocked so that the cooling system continues to remove heat from the oscillator components for about two minutes after shut down of the oscillator.

II. OPERATION

The operation of the main oscillator is accomplished from the control console. The normal starting sequence can be followed if the following conditions are met: (See control sequence diagram W-9748285)

a. The tank vacuum is adequate to prevent glow discharge.

b. The magnet is energized.

c. The safety interlocks are closed (oscillator cubicle, discharge switch, main rectifier cubicle)

d. Permissive relays are energized.

The normal main oscillator starting sequence is:

1. Energize the oscillator filaments and main rectifier filaments.

2. Wait for time-out of filament circuits (approximately 2 min.)

3. Energize the main rectifier anode (this also starts the auxiliary oscillator)

4. Apply voltage to the oscillator by operating oscillator excitation switch.

5. The anode voltage and current instruments should now indicate.

6. Adjust the anode voltage to the desired value by operation of the switch labeled Anode Reg.

7. Adjust the frequency of the auxiliary oscillator to the main oscillator frequency. This is best done by listening to a short wave radio receiver tuned to the main oscillator frequency and adjusting the auxiliary oscillator until the maximum response is heard.

8. The oscillator should now oscillate. The control console instruments indicate grid current and dee voltage current.

   When spark-over of the dees occurs, the restarting of the oscillators is automatic. A suppression circuit in the oscillator which is mounted on the B-plane prevents the oscillator from continuing to put power into the dee system. The resultant lack of grid current causes the grid relay to drop out. A normally-closed contact on this relay then applies the pulse from the pulse generator to the grid of the oscillator tube in the auxiliary oscillator. The subsequent doubler stage then furnishes the drive pulse to the cathode loop.

9. The dee voltage may now be adjusted to the desired operating value by operating the switch labeled Anode Reg.

10. The balance of the two dee voltages may be adjusted by changing the positions of the trimmer capacitors. The switches labeled Left and Right Trimmer are operated and positions of the capacitors noted from calibrations of their respective position indicators.

III. MAINTENANCE

Periodic failures of various vacuum capacitors (due to leakage) may be expected. This is usually indicated first by difficulty in starting the oscillator (when, for example, very fine adjustment of the auxiliary oscillator frequency is necessary before the oscillator will start). Inspection of the suspect capacitors is usually in order at any time difficulty in starting is experienced. A hi-pot test of the capacitors will determine those at fault.

Failure of the 9C21 tubes is to be expected because they have limited life and deteriorate even in storage. A visual difference in color while operating seems to be the first indication that failure is imminent. Replacement of these tubes necessitates the removal of the various air ducts and the removal of the B-plane from the oscillator cubicle. The grid and cathode connections must be removed, as well as various components attached to the B⁻ and grid planes. The anode water jacket seals must be loosened with the handles provided and the tubes removed. The reverse of this procedure is followed when inserting replacements.

Replacement tubes should be operated for 5 minutes before application of plate power. (See RCA 9C21-10-43 sheet included with each tube.) Occasional replacement of Saran tubing in the cooling circuit is necessary.

The filters in the blower inlet ducts must be cleaned at regular intervals. Care must be exercised in the cleaning and disposal of these filters, as the dust which is collected may be radioactive.

The calibration of the grid current circuit may be accomplished by passing a known DC current through the primary winding of the reactor and noting the indication on the control console instrument.

The operation of the temperature and flow alarm system for the oscillator should be checked occasionally by shutting off the inlet throttling valve for an instant to insure that the magnetrol alarms are working. The temperature set contact may be closed, simulating increase in temperature, to ascertain that the protection circuits are in working order.

Oscillator Filament Supply

I. DESCRIPTION

The oscillator filament supply consists of an open delta transformer, two induction voltage regulators, two surge reactors and a capacitor cubicle, and two filament transformers.

The open delta transformer and the induction voltage regulators furnish a stable voltage source for the filament transformers. The surge reactors prevent excessive inrush current to the filaments of the main oscillator tubes. The capacitor cubicle provides taps for adjustment of the filament operating voltage.

II. OPERATION

The operation of the oscillator filament supply is automatic and is shown schematically on the overall elementary diagram TT9674980.

The application of filament power is accomplished by operating the control console switch labeled Oscillator Filament. The current in the filaments is indicated on an instrument, labeled Filament, on the left panel of the control console.

III. MAINTENANCE

A periodic check of tightness of the connections on the filament transformers should be made.

When new tubes are installed in the main oscillator, the voltage and current should be checked at the tube connections, and the voltage adjusted to proper value by changing taps in the capacitor cubicle.

INSTRUCTIONS GEI-28280

HIGH-VOLTAGE D-C POWER SUPPLY UNIT

Rated

17.5 Kv d-c, 30 Amperes

Serial Numbers

8978263 Rectifier Transformer
8978264 Rectifier Unit

FOR

NATIONAL ADVISORY COMMITTEE OF AERONAUTICS

CLEVELAND AIRPORT

CLEVELAND, OHIO

G.E. REQUISITION XCL-193000-2 Item 11

APPARATUS DEPARTMENT

GENERAL ELECTRIC COMPANY

SCHENECTADY, N.Y.

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REFERENCES (Appended)

Photographs

G-E Monocyclic Network, Front View Showing Arrangement of Internal Equipment............ 3012655

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G-E Monocyclic Network, Left Oblique View Showing Detail of Interlock System with Equipment Open.. 3012657

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Instruction Books

Pyranol Transformers.................................. GEH-1093 B
Induction Voltage Regulator........................... GEH-1704

~~Service Sheet for Electronic Tubes~~..................... ~~GES-969~~
GL-857-B, Phanotron Tubes, General Information........ ETI-146 A

GL-857-B, Phanotron Tubes, Technical Information...... ETI-152 A
Instantaneous Overcurrent Relays 12PJC11A4............ GEI-~~12090~~

Time Delay Relay, CR2820-1099R........................ GEH-985 G
Phase-sequence and Undervoltage Relay, 1CR15A......... GEI-~~12093~~

AC Magnetic Switches, CR2811-C30H..................... GEH-1157
AC Magnetic Switches, CR2811-C21BG.................... GEH-1082 A

Pressure Relief Device................................ GEI-28020 C
Thermostats, CR2992-R1................................ GEJ-554 C

Air-insulated Junction Box............................ GEI-27727
Removing and Rewelding Covers on Transformers......... GEI-16090 B

Dry type Instrument Transformers...................... GEH-230 W
Capacitor Equipments.................................. GEH-255 J

INTRODUCTION

Reference must be made to the following instructions for information on the installation, operation, and maintenance of the High-Voltage D-c Power Supply Unit shown on the title page of this book. These instructior are to be used in conjunction with the overall instructions being separately provided by the General Engineering and Consulting Laboratory. This equipment is designed to supply a continuous range in d-c voltage from approximately zero to 17.5 kv d-c at a maximum current of 30 amperes from a three-phase, 2400-volt, 60-cycle source of power supply. Rated voltage and current can be obtained simultaneously. Full power output of the equipment can be obtained continuously without exceeding a 55C rise, when the equipment is operated in a 30 C ambient.

The power supply equipment consists of the following principal parts:

1. Pyranol* Rectifier Transformer Unit for the 17.5 kv, full-wave rectifier;

2. Rectifier Assembly with the GL-857-B rectifier tubes, discharge switch, filament transformers, arc-back indicators, filter capacitors, constant voltage transformers, blower and air duct for the rectifier tubes, and other miscellaneous equipment assembled within a sheet steel cabinet with provision for bolting to the transition compartment on the end of the rectifier transformer;

3. Induction Voltage Regulator, motor operated; and the

4. Monocyclic Network Unit with its capacitor bank, reactor bank, current transformers, and overcurrent relays.

The power supply equipment employs a three-phase transformer with the phases of the primary connected individually into the six load points of the monocyclic network, and with the secondary delta-connected into a six-phase double-way rectifier circuit. A terminal board is provided in the rectifier assembly for reversing the output polarity of the equipment.

Kirk type interlocks are provided on the equipment for keying in with the user's interlock system.

*Registered trade mark for G-E askarel

Insert the GL-857-B tubes in their brackets mounted on insulators on the tube panel, and make the plate (anode) and the filament terminal connections. Before installing the rectifier tubes in their sockets, refer to the appended instructions for the GL-857-B tubes, and follow instructions contained in GES-969.

Note: The mercury may have become spattered on the tube electrode prior to installation of the tubes in the unit. In order to distribute this, when the tubes are first placed in operation, the filaments should be energized for at least one-half hour before plate voltage is applied.

The capacitor units for the monocyclic network are shipped separately and should be installed in the capacitor racks within the network housing as shown on the Capacitor Assembly Drawing T-9524071 after the assembly is permanently located on site. Refer to the Connection Diagram M-9806419 and make the capacitor connections as shown.

Refer to the Interconnection Diagram M-9821700, and make all the interconnections indicated between the units of the power supply equipment furnished and those separately provided. See Elementary Diagram P-9814162 for the elementary circuit diagram of the power supply equipment. Note that the supply voltage phase rotation must be in accordance with the sequence shown on the Elementary Diagram.

Connect the power supply equipment for the desired output voltage polarity. Refer to Elementary Diagram P-9814162 for the polarity link connections to be made on the polarity terminal board (item 10, Outline T-9524596).

Arrange the discharge switch solenoid and the discharge switch interlocks in the 120-volt, 60-cycle control circuit so that the discharge switch will be opened whenever the main transformer is energized and closed when the main transformer is de-energized.

Connect the contacts of the phase-sequence and undervoltage relay into the trip and permissive circuits of the main anode supply circuit breaker so that the circuits will be opened should unbalanced three-phase voltages appear across the filament supply circuit.

The five-minute time delay relay contacts should be connected in the circuit breaker closing circuit so as to prevent the application of plate power before the filaments of the GL-857-B tubes are properly heated.

See that the filament supply contactor solenoid is connected into the 120-volt, 60-cycle filament contactor control circuit.

Rectifier Assembly

The rectifier assembly consists mainly of the rectifier rated 525 kw, 17,500 volts, six-phase, double-way; and the following principal parts:

1. Six GL-857-B phanotron tubes arranged in a six-phase, double-way circuit. Refer to appended instructions on the electron tubes for technical information covering the phanotron tubes. Note that the phanotron tubes are provided with quadrature excitation.

2. Phanotron tube motor blower for phanotron tube forced air flow. Motor rated: 1/20 horsepower, 1725 R.P.M., single-phase, 240 volts, 60 cycles.

3. Filament transformers cat. #87G204, each rated 0.150 kva, 230 to 5/2.5 volts, 50/60 cycles, for stepping down the filament supply voltage to the rated voltage required by the phanotron tube filaments.

4. Constant-voltage transformers cat. #30M829, rated: 500 VA, 60 cycles, primary voltage range of 190 to 250 volts, secondary 230 volts furnished in a special three-phase assembly, product of Sola Electric Company. Used for maintaining a constant filament voltage, and arranged so that filament currents will flow in time quadrature with the anode currents.

5. Air heaters cat. #2A153 G-2 for phanotron tube forced air flow. Heaters each rated 500 watts, 230 volts.

6. Arc-back indicators type 9XY15A1 rated: 5 amperes, 125/250 volts. These indicators are for visual indication of reverse current in any of the anode circuits. This device consists of a U-shaped magnetic circuit in which is inserted a permanent magnet. This U-shaped circuit is closed by a magnetic flag which is pivoted at one leg of the U and is free to flip away from the other side of the U under the influence of a small spring whenever, the permanent magnetic field set up in the circuit is neutralized. A current coil is wound around this magnetic circuit and connected in the anode circuit of the rectifier tube in such a way that the normal plate current increases the flux created by the permanent magnet. The indicator is so designed that if a reverse current of specified value flows through the current coil, the permanent magnetic field is cancelled out, allowing the flag to release, thus changing its position. Micro-Switch contacts attached to the indicators are provided for connecting into the customer's control circuit. These contacts are closed with the releasing of the arc-back indicator flag.

Monocyclic Network Unit

The three-phase monocyclic network cat. #38F695 rated 650 kva, 4600 volts, 60 cycles is designed to be used in conjunction with the other power supply equipment furnished and it functions to deliver an output current which is proportional to its input voltage. This assumes balanced input voltages and balanced load impedances on the three phases.

The monocyclic network consists mainly of the following:

a. Three-phase capacitor bank, each phase matched to give a capacitance of 27.2 muf ± 2 ½ per cent. Each phase consists of (14) cat. #16F85 capacitors each rated 1.72 muf, 4800 volts, 15 kva and (1) cat. #13F73 capacitor rated 1.26 muf, 10 kva, 4800 volts. The capacitors are mounted on steel racks insulated from the housing.

   A grounding stick (part 25, Capacitor Assembly Drawing T-9524071) located behind one of the capacitor compartment doors as shown on drawing is provided to ground and discharge the capacitors before doing any work in the compartment.

b. Three-phase reactor bank consisting of one cat. #87G280 dry-type reactor per phase. Each reactor is rated 126 kva continuous, 3500 volts, single-phase, 60 cycles, 36 amperes, 0.259 henries, for use in 4800-volt circuit.

c. Disconnects consisting of (3) 15-kv, 400-ampere, hook operated disconnecting switches Cat. #6129330 G-40 for disconnecting the capacitor sections if desired. A switch hook stick for operating the disconnects is provided in a holder located on the inside corner of the capacitor equipment on the right-hand side of the end door.

d. Three cat. #407X23 current transformers with a 50 to 5-ampere ratio and three overcurrent relays type PJC, model 12 PJC12A3, hand reset, with a calibration range of 2 to 8 amperes for the protection of the capacitor bank. Each relay is provided with two normally open contacts for connecting into customer's circuit breaker trip circuit.

e. Fused potential transformer cat. #93X876 rated 4800 to 120 volts connected across one phase of the input to the monocyclic network for use with a remote voltmeter to read the output voltage of the induction voltage regulator.

Induction Voltage Regulator

The three-phase, Pyranol-filled induction voltage regulator is a separately installed unit. The regulator is rated type IRT, 340 kva, 60 cycles, 2400 to 2400 volts, 81.5 amperes, 55C rise, form VTA. The regulator is designed for 100% buck or boost of the power supply voltage and it is used for regulating the voltage applied to the monocyclic network and the rectifier transformer low-voltage winding.

The regulator is motor operated by a single-phase, 1/3 horsepower, 220-volt, 60-cycle capacitor type motor. Power for the motor is to be supplied from the customer's control circuit. A motor control relay in the control compartment controlled by means of the customer's raise and lower switch controls the operation of the motor. Limit switches are provided to limit the travel of the regulator rotor at the maximum positions.

The terminals of the regulator windings are brought out to line bushings located in the conduit housing (item 17, Outline P-9535263) on the top of the regulator. Provision is made for bringing in the user's control leads into the control compartment (item 10, Outline P-9535263) by means of a 2-inch hole in the top of the compartment for the user's conduit. Refer to the Diagram of Connections P-9535244 for the internal connections of the regulator. For detailed information on the operation and maintenance of this unit, refer to Instructions GEH-1704 (appended).

OPERATION

Refer to Elementary Diagram P-9814162 for the devices listed below and for the elementary circuit of the power supply equipment.

The power supply equipment is designed for providing a variable voltage at the high-voltage output terminal that can be varied continuously from approximately zero to a maximum voltage of 17.5 kv d-c at 30 amperes from a three-phase 2400-volt 60-cycle source of supply. Both rated current and voltage may be obtained simultaneously.

Provision is made for connecting the power supply equipment for positive or negative output polarity with the opposite end grounded.

The control circuit for complete operation of the power supply equipment is not provided as a part of this equipment. Consequently, the following is a general discussion subject to some variations within the limitations of the power supply equipment.

With the equipment connected as explained in the section under installation, the filament transformer circuit will be energized with the energizing of the filament contactor (6).

A network overcurrent relay (51) is connected in each phase of the monocyclic network through a current transformer in series with the capacitor bank for each phase. In case of an overcurrent condition in the network, the relay coils will be energized to open contacts in the main circuit breaker control circuit, opening the circuit breaker thus interrupting the power supply to the induction voltage regulator and the rectifier transformer.

To discharge the high-voltage lines and the filter capacitors on de-energizing of the equipment, a discharge resistance and an automatically operated discharge switch (29) are connected across the power supply output lines. With the discharge switch solenoid connected into the user's control circuit as recommended in the section on installation, the solenoid coil for the discharge switch will be energized to open the switch and remove the short circuit from the output lines whenever the rectifier transformer is energized. When the rectifier transformer is de-energized, the discharge switch will close to connect the high-voltage output line to ground through the discharge resistance thus discharging the output circuit.

Arc-back indicators (32) in each of the phanotron tube plate circuits are provided for visual indication of reverse current in any of the anode circuits. A reverse current of a specified value will flow through a current coil wound around the magnetic circuit in such a direction as to cancel out the permanent magnetic field thus releasing a flag indicator under the influence of a small spring. A Micro-Switch attached to the indicator is activated by the releasing of the flag. This switch is provided for connection into customer's control circuit.

To reset the arc-back indicator, remove the voltage from the set and manually reset the flag to its original position.

Provision is made for using a leakage type voltmeter across the output lines of the power supply equipment. The meter is to be connected in series with four 5-megohm resistor assemblies so that the meter deflection will be proportional to the current through the meter. Provision is also made for inserting a d-c load ammeter in the output circuit. A 50-ampere shunt is provided with the ammeter for connecting across the meter.

mechanically. Return the capacitor to the factory for inspection or refilling under the special processes employed in manufacture. Do not attempt to add any insulating liquid to a capacitor.

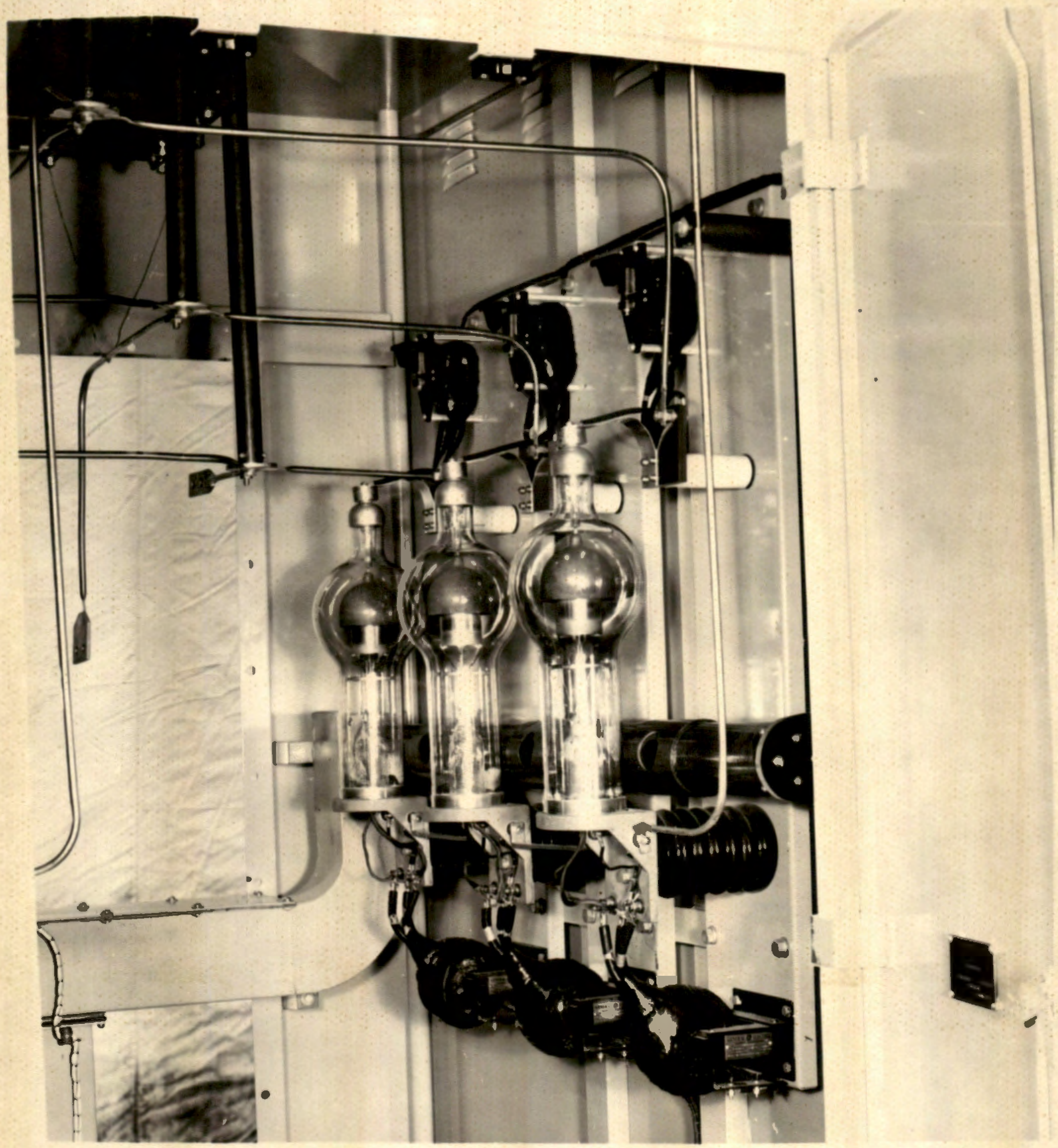
The air filter located in the side of the rectifier housing should be cleaned and serviced periodically. The time interval between filter cleanings is dependent on the condition of the air drawn into the housing and will therefore be determined by operating experience.

The outer surface of the filter, which will tend to collect the larger foreign particles from the cooling air, should be brushed off with a whisk broom. The filter should then be washed in any solvent such as a solution of Tri-Sodium Phosphate and water, Climalene and water or gasoline, after which the filter should then be "charged" as recommended in the following paragraph.

To "charge" the filter with oil, dip it in oil of approximately SAE 30 or 40 viscosity when used in temperature of 20F or higher. Then, drain the filter thoroughly to remove the excess oil. To drain the filter properly, lay it flat with the "approach face" (air entering side) down.

The filters are accessible for cleaning by removing the screws which fasten the filter cover assembly to the outside of the rectifier housing.

Separate instructions, where available, on devices used with this equipment are appended and should be referred to for details not included in the text of these instructions.

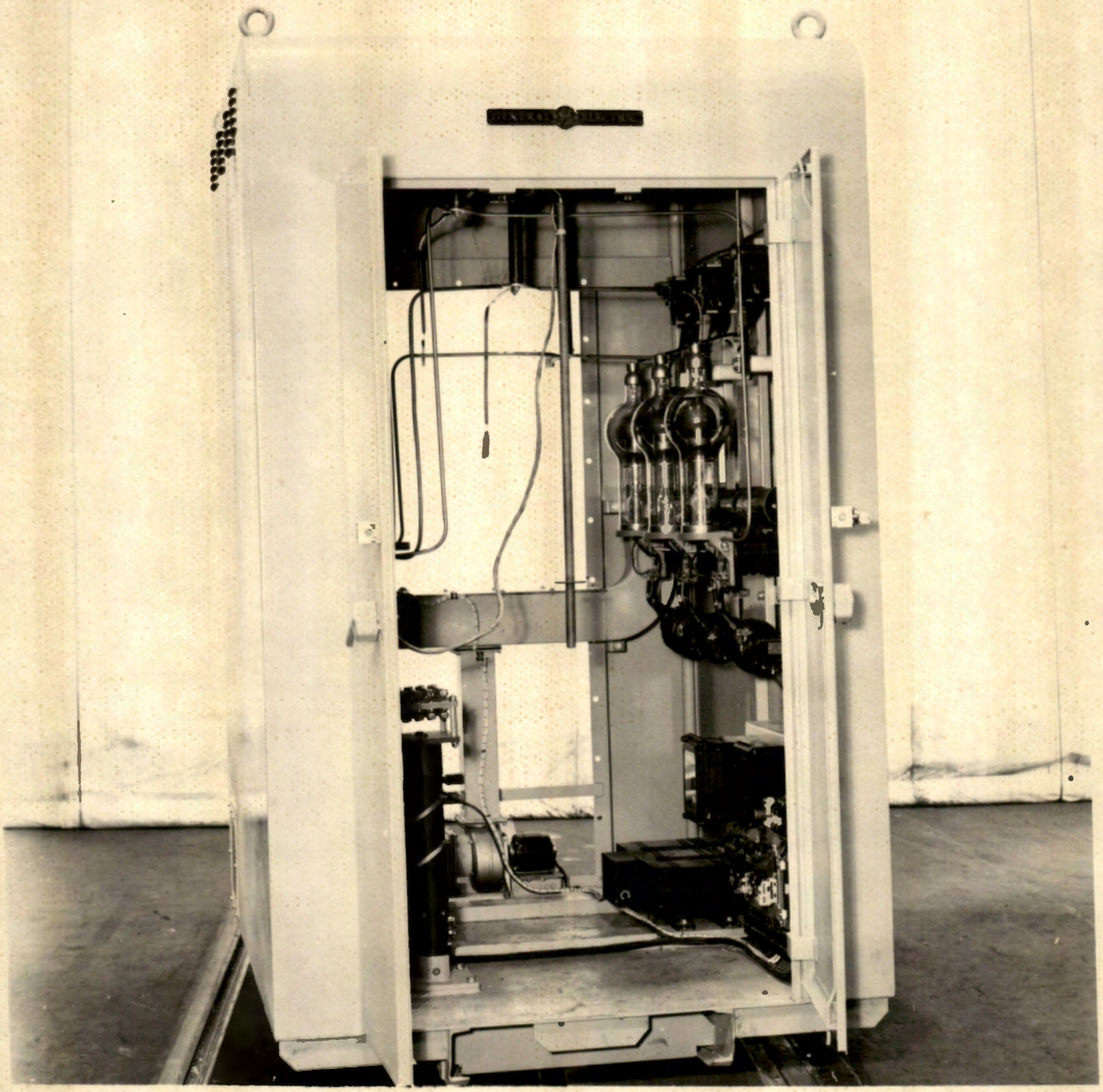


3014571

Transformer
and Allied Product
Divisions

G.E. PHANOTRON RECTIFIER ASSEMBLY FOR 17.5 KV – 30 AMPERE D-C POWER SUPPLY, DL-9512114. FRONT VIEW SHOWING DETAILS OF TUBE MOUNTING AND CONNECTIONS.

REQ. XCL-193000-2 PO-723582



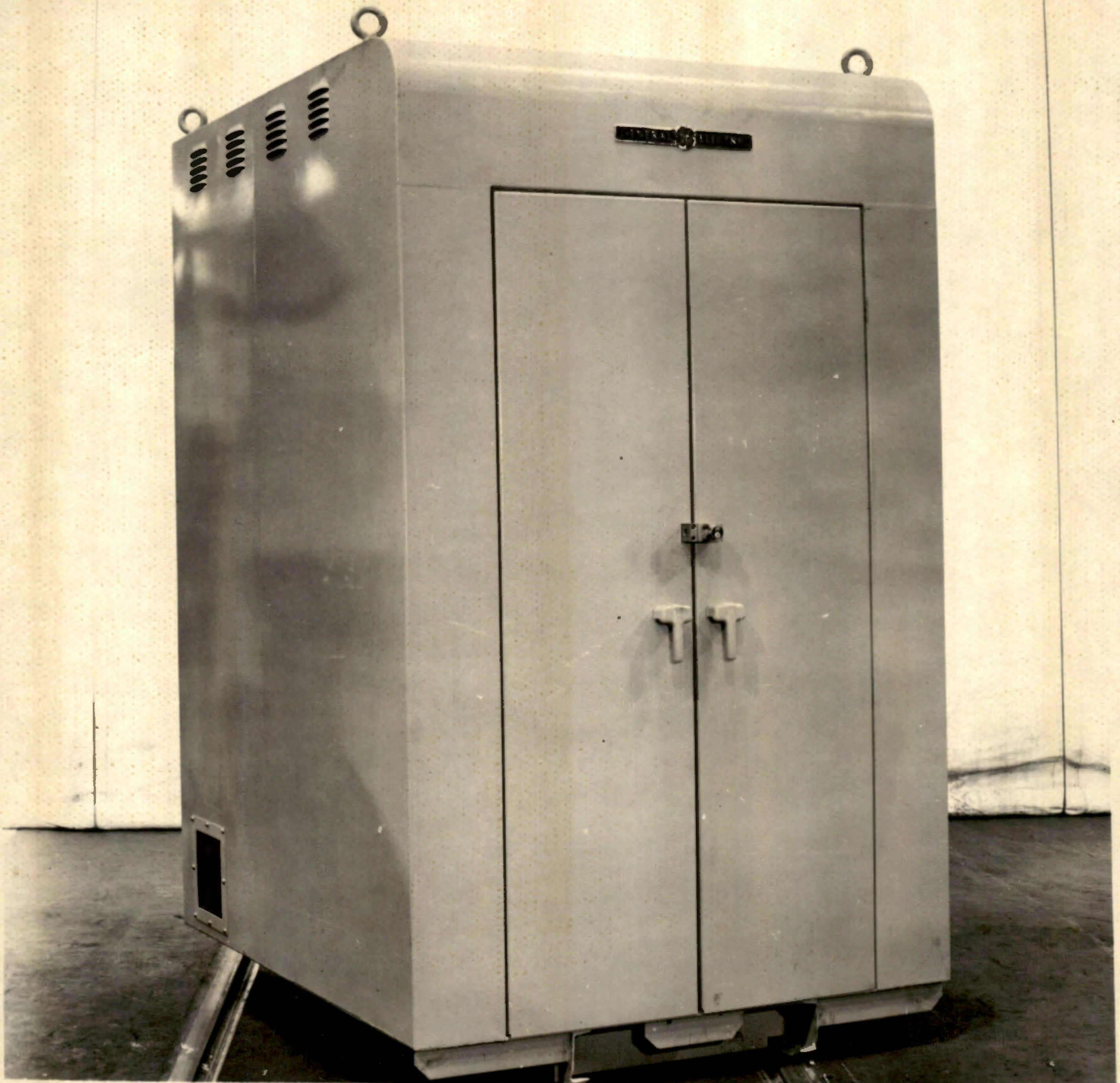
3014570

Transformer and Allied Product Divisions

G.E. PHANOTRON RECTIFIER ASSEMBLY FOR 17.5 KV – 30 AMPERE D-C POWER SUPPLY, DL-9512114. FRONT VIEW WITH DOORS OPEN TO SHOW INTERNAL ARRANGEMENT.

REQ. XCL-193000-2 PO-723582

3/2/50



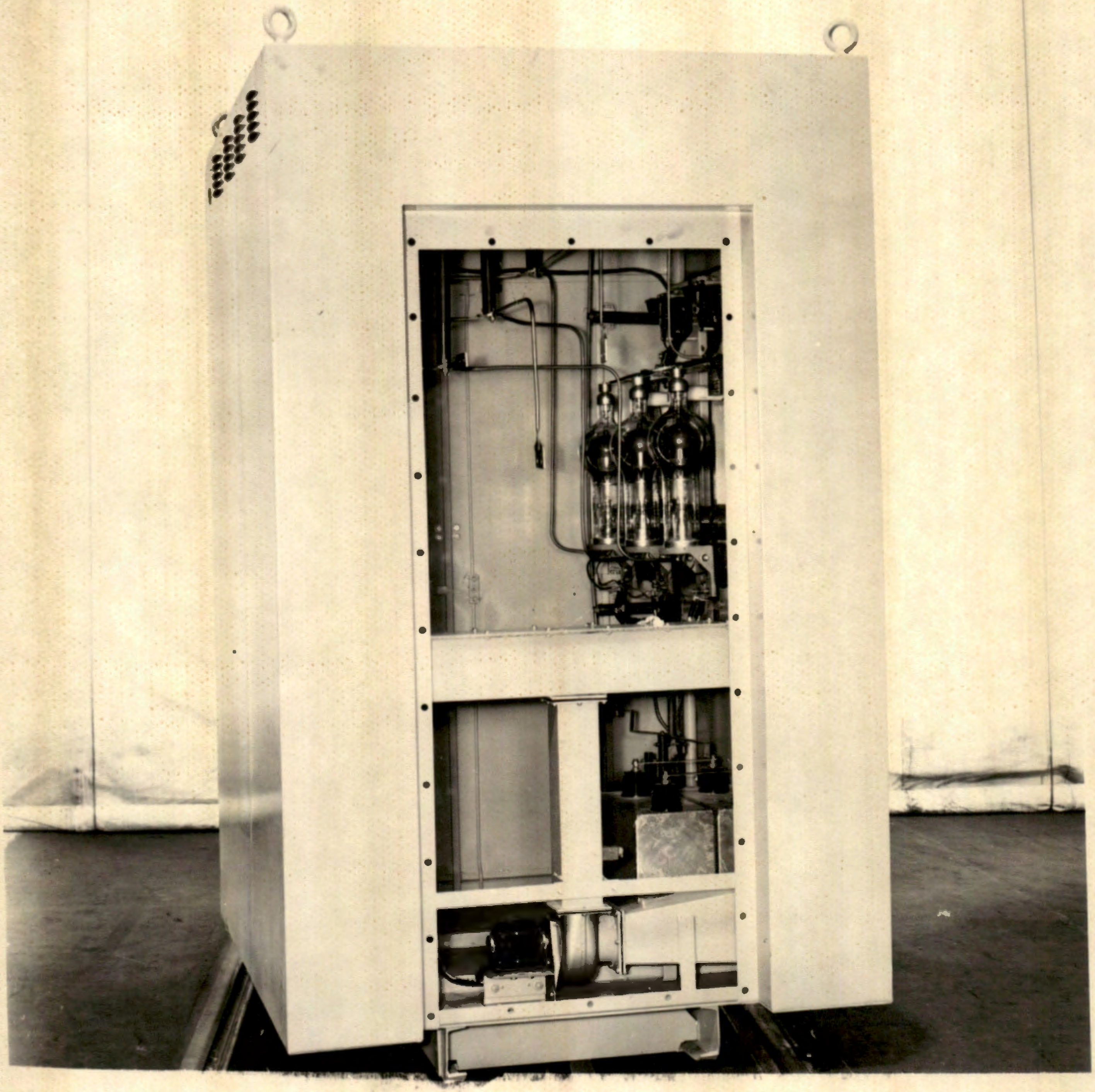
3014569

Transformer
and Allied Product
Divisions

G.E. PHANOTRON RECTIFIER ASSEMBLY FOR 17.5 KV – 30 AMPERE D-C POWER SUPPLY, DL-9512114. FRONT OBLIQUE VIEW OF CABINET SHOWING MOUNTING OF KEY INTERLOCK.

REQ. XCL-193000-2 PO-723582

3/2/50

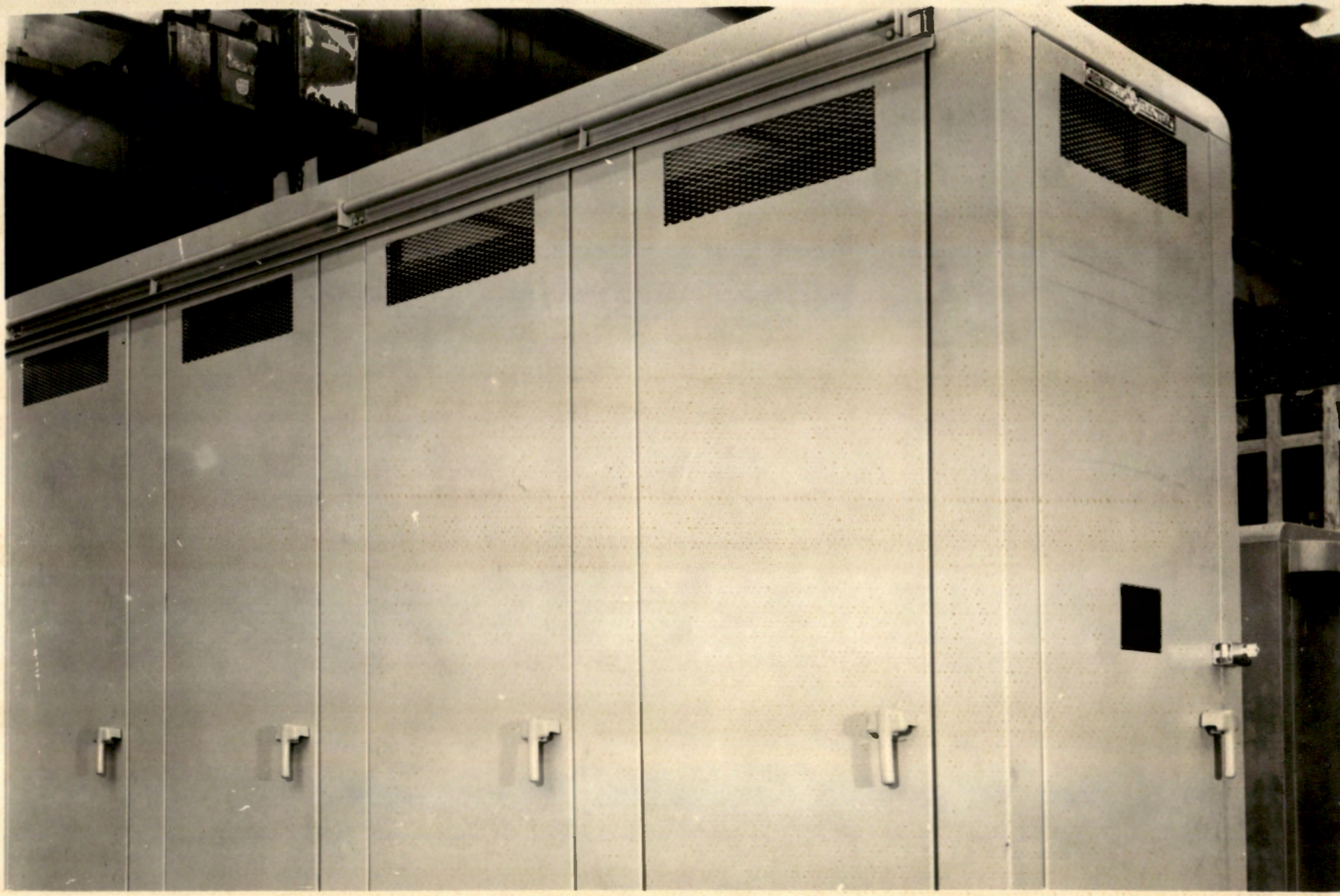


3014568

Transformer and Allied Product Divisions

G.E. PHANOTRON RECTIFIER ASSEMBLY FOR 17.5 KV — 30 AMPERE D-C POWER SUPPLY. DL-9512114. REAR VIEW SHOWING FLANGES FOR BOLTING TO RECTIFIER TRANSFORMER.

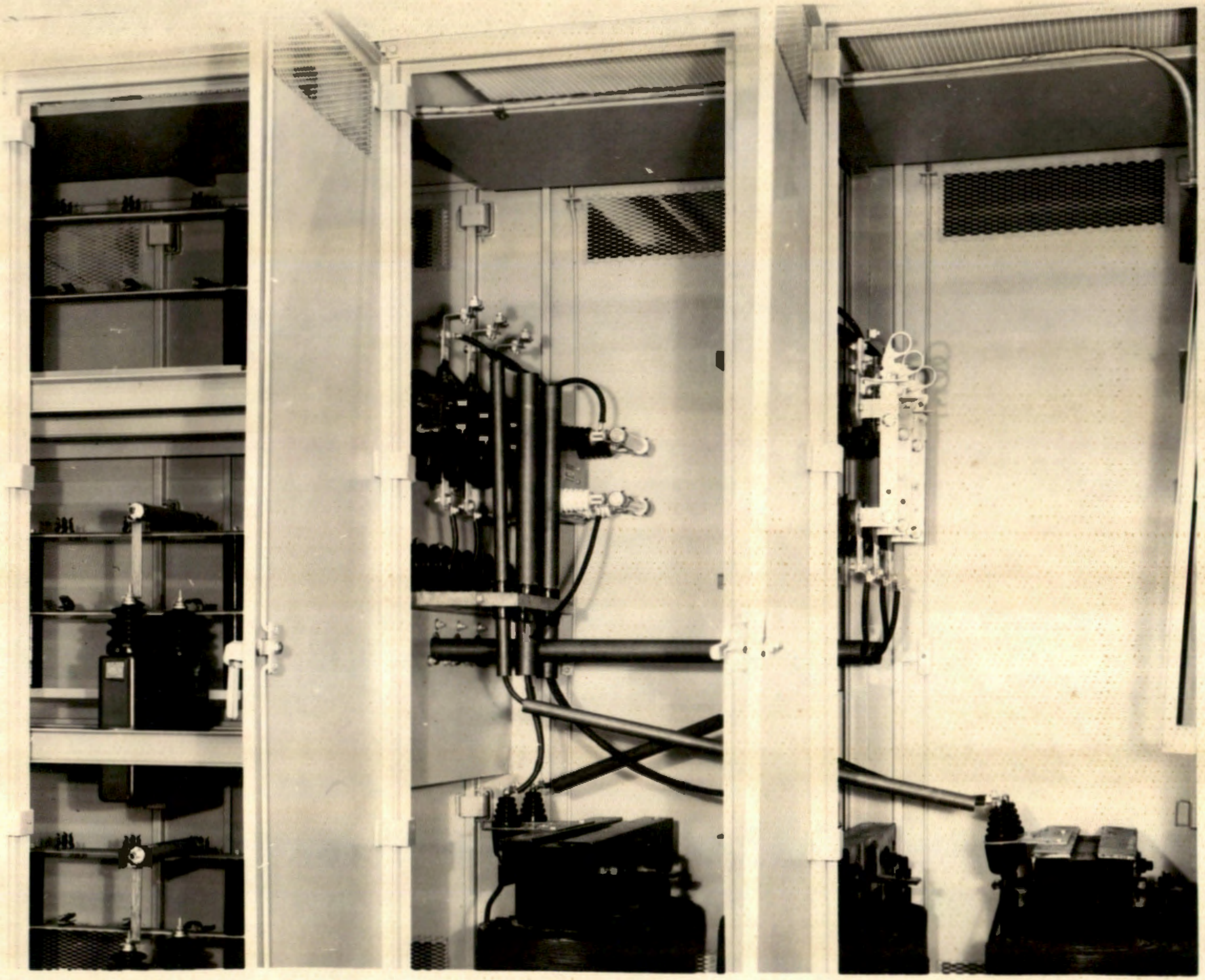
REQ. XCL-193000-2 PO-723582



30I2658

Transformer
and Allied Product
Divisions

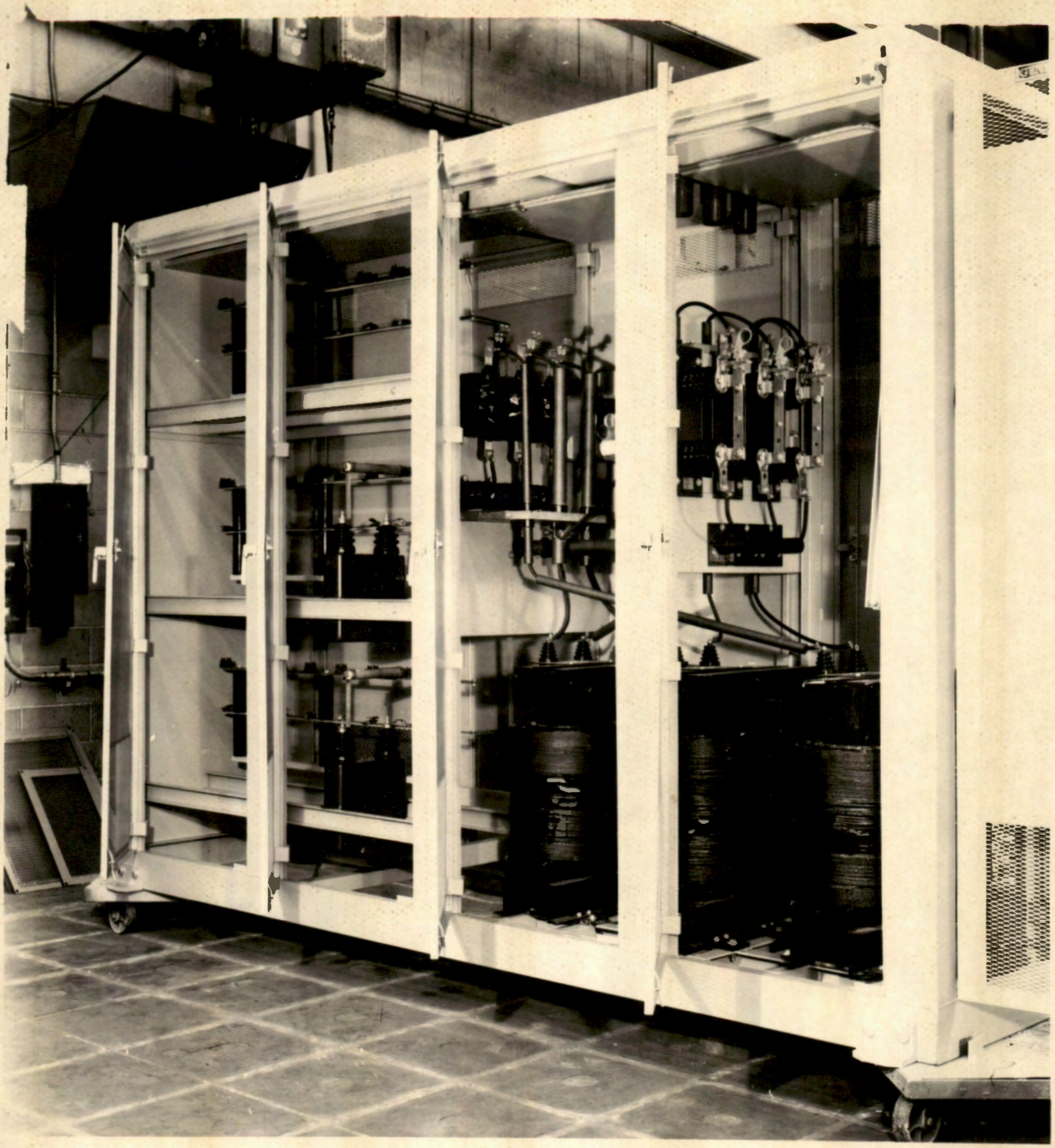
G-E MONOCYCLIC NETWORK CLASS HLI, CAT. 38F695, RATED 650 KVAR, 4600 VOLTS, 3 PHASE, 60 CYCLE. FOR CYCLOTRON APPLICATION. LEFT OBLIQUE VIEW SHOWING DETAIL OF INTERLOCK SYSTEM WITH EQUIPMENT CLOSED.



3012657

Transformer and Allied Product Divisions

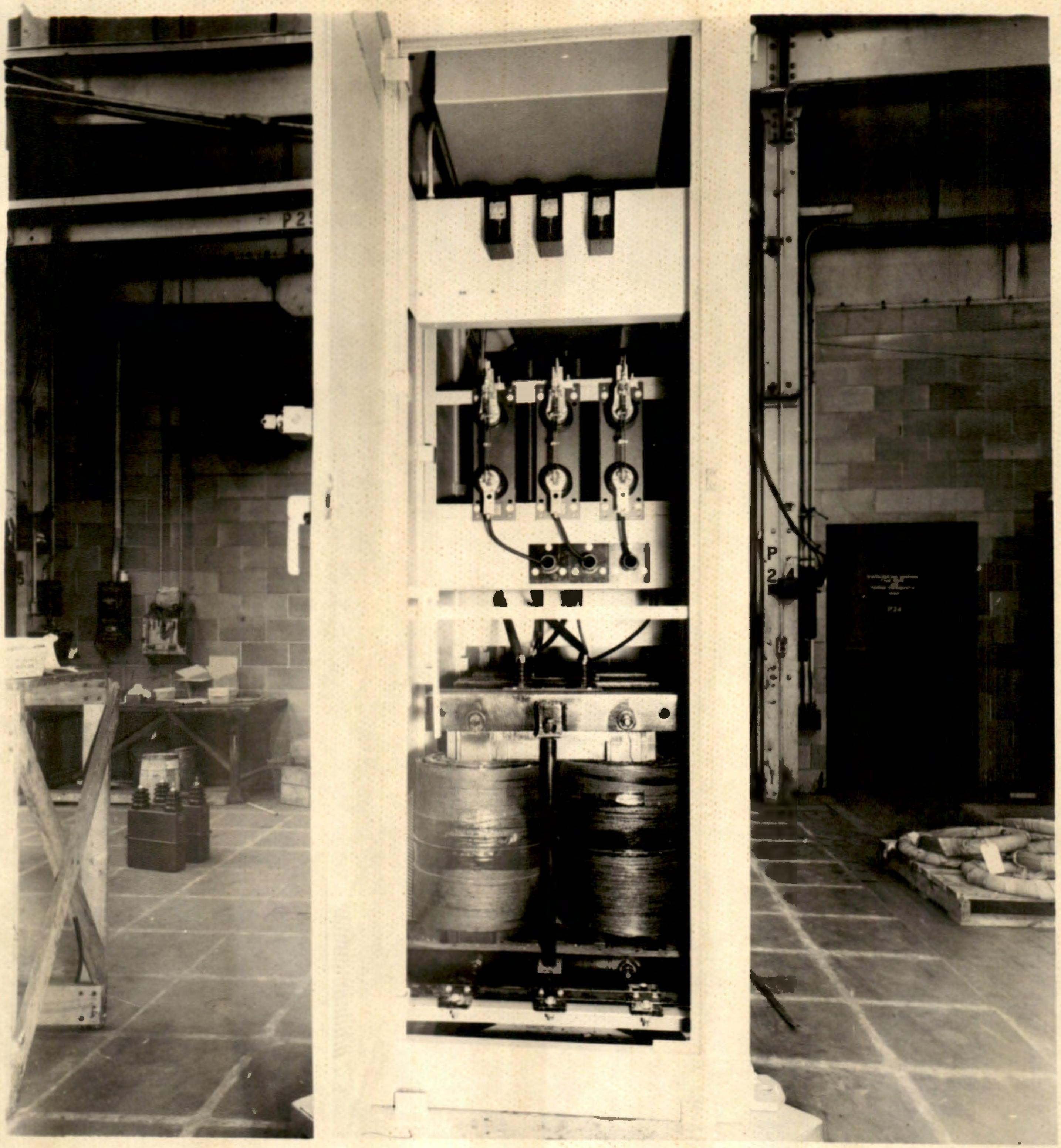
G-E MONOCYCLIC NETWORK CLASS HLI, CAT. 38F695, RATED 650 KVAR, 4600 VOLTS, 3 PHASE, 60 CYCLE. FOR CYCLOTRON APPLICATION. LEFT OBLIQUE VIEW SHOWING DETAIL OF INTERLOCK SYSTEM WITH EQUIPMENT OPEN.



3012656

Transformer and Allied Product Divisions

G-E MONOCYCLIC NETWORK CLASS HLI, CAT. 38F695, RATED 650 KVAR, 4600 VOLTS, 3 PHASE, 60 CYCLE. FOR CYCLOTRON APPLICATION. LEFT OBLIQUE VIEW SHOWING MOUNTING OF REACTORS AND CAPACITOR UNITS.



30 12655

Transformer
and Allied Product
Divisions

G-E MONOCYCLIC NETWORK CLASS HLI, CAT. 38F695, RATED 650 KVAR, 4600 VOLTS, 3 PHASE, 60 CYCLE. FOR CYCLOTRON APPLICATION. FRONT VIEW SHOWING ARRANGEMENT OF INTERNAL EQUIPMENT.

ION SOURCE SYSTEM

The Ion Source System consists of an Ion Source Anode and Filament Assembly, an Ion Source Anode Supply, an Ion Source Filament Supply and an Ion Source Gas Supply.

Ion Source Anode and Filament Assembly

I. DESCRIPTION

The charged particles to be accelerated in the cyclotron are formed in a low pressure electric arc maintained in a gas. The gas is composed of initially uncharged moelcules of the type it is desired to accelerate. The ION SOURCE provides means of producing the arc, introducing the gas at the correct pressure and place, cooling the arc electrodes and chamber, and introducing the charged particles into the cyclotron chamber at the correct place between the dees.

The arc chamber, see Fig. 1, consists of a hollow carbon chimney or hood supported vertically on a hollow copper block, which is in turn supported on the end of a long hollow copper stem extending inward from the front wall of the cyclotron chamber. In the side of the carbon chimney facing the dee feelers there is a vertical slit through which the charged particles emerge. Inside the copper stem are two copper tubes carrying cooling water for the copper portion of the arc chamber and one copper tube carrying gas to the arc chamber. Inside the stem is a smaller stem of stainless steel (filament stem) which supports a tungsten filament at its end in the arc chamber under the carbon hood. Inside the filament stem are two copper tubes which carry cooling water to the filament terminal blocks and also serve as electrical conductors for the filament heating current and arc current. These various tubes are brought out through appropriate vacuum seals, and the entire assembly is supported on two brass plates having an O-ring seal between them, so that one can be moved on the other to change the position of the assembly in the cyclotron chamber.

The stationary plate is bolted to the front of an air-lock chamber which is in turn bolted to the front wall of the cyclotron chamber. The ion source stem extends inward first through the air lock and then into the cyclotron chamber. A vacuum gate is provided at the inner end of the air-lock chamber to close the opening into the cyclotron chamber when the ion source stem is removed. This arrangement makes it possible to remove the entire ion source assembly from the cyclotron without disturbing the vacuum in the cyclotron chamber.

Mechanisms are provided for remotely adjusting the position and inclination of the ion source hood with respect to the cyclotron chamber and dees. Four different motions are provided:

1. Side to side
2. Up and down
3. In and out
4. Inclination of the hood from side to side

In addition an in-and-out adjustment of the filament stem within the arc chamber is provided.

Driving motors and control relays for these different motions are mounted in an assembly on the upper magnet coil above the ion source. Drive rods extend from the motors to couplings at the bottom of the assembly, where flexible shafts are coupled on and extend to the mechanisms on the ion source. Suitable limit switches are provided where necessary, to stop the drive motors at the end of the travel and prevent damage should the operator attempt to run the motion beyond its range. Position indicator units are located on the ion source to provide remote indication at the control console of the position of the different ion source elements. Electrical connection to the limit switches and position indicator units is made by flexible cables from the ion source to easily removable plug-in connectors on the bottom of the motor assembly.

The cooling water connections are made with flexible hoses. Shutoff valves and removable connections at the ion source are provided. The electrical connections to the filament stem for the filament and arc currents are made by wires inside the cooling water hoses, so the electrical connection is made when the hoses are connected.

The gas connection is made by a large loop of small diameter copper tubing which has sufficient flexibility to accommodate the motion of the ion source. Two valves are provided where the tubing is coupled to the ion source, so it can be uncoupled without admitting air to either the ion source or the gas tube.

A supporting jig is provided to assist in removing the ion source from the tank and to prevent bending the stem when it is withdrawn. The jig consists of an aluminum rail supported, at one end, by a pair of adjustable legs, and, at the other, by a bracket extending out underneath the ion source. The legs are provided with wheels, so the jig can be easily moved into place or taken to a storage area. Sliding on the rail is a Textolite block with means for attaching it to the outer end of the ion source stem assembly. At the inner end of the rail is a bracket which can be bolted to the ion source base plate at the air lock.

The ion source is operated remotely from the control console, which is described elsewhere. All the positioning motions can be operated in either direction by suitable switches, and all except the hood inclination are provided with position indicators above the switches.

The filament current can be turned on or off and increased or decreased by means of two switches, located on the control console, and an ammeter is provided to give an indication of the amount of current flowing. The ammeter actually measures the current in the input side of the filament power supply and does not indicate filament current directly. The input current is proportional to the filament current, however, and is adequate as an indication for operating purposes.

The arc voltage can be turned on or off and increased or decreased by means of two switches on the control console. An ammeter and voltmeter are provided which measure arc current and voltage.

The ion source gas can be turned on or off and its rate of flow adjusted by a pneumatically-operated remote control device at the control console.

II. OPERATION

In order to operate the ion source and obtain an emerging stream of ions from the hood, it is necessary that other components of the cyclotron be in operation, as follows:

1. The cyclotron chamber must be under operating vacuum. This is insured by an interlocking circuit which permits the ion source filament to be turned on only when the tank ion gage is on.

2. The magnet must be on, providing an operating magnetic field between the poles. An interlocking circuit prevents the ion source excitation from being turned on until the magnet current regulator has raised the magnet current above a set minimum value.

3. The exit beam gate must be open into the target chamber. An interlocking circuit prevents turning the excitation on until the gate is open.

4. There must be an adequate flow of cooling water of the proper temperature. Flow-controlled and thermostatically-controlled switches prevent turning on the filament or the excitation unless the flow and temperature are correct.

5. The gas supply cabinet must be properly charged, and the valves must be open in the supply line. No interlocks are provided for this, since no harm would be done by inadvertently trying to start the ion source without gas supply.

6. In addition to all these, if the oscillator and deflector are on, the ion source excitation cannot be turned on unless all the safety interlocks at the gate and BEAM SAFE positions are closed. The ion source excitation can be turned on with the safety interlocks open if the oscillator and deflector are not on.

   If the ion gage, magnet regulator, water flow and temperature or safety interlocking circuits are open, appropriately-labeled amber lights will glow on the panel at the left of the control console. If the target gate is closed, the green light will show under the target gate switch.

For normal operation, the position adjustments having previously been made to approximately optimum conditions, the following steps are taken:

1. Turn on the gas, and set the flow control at the previously determined rate for satisfactory operation. This will probably be at approximately 5 on the scale. It is well to turn on the gas several minutes before attempting to start the ion source, in order that a uniform gas flow may be established.

2. Turn on the ion source filament. Raise the filament current to an approximate operating value dependent upon the number of hours the filament has previously been operated. If a new filament has just been put in, the filament primary current as indicated by the ammeter may have to be raised to six amperes or more before an arc can be started. There is an automatic run-back feature incorporated in the filament circuit which runs the filament power supply back to zero each time the filament is turned off.

3. Hold the ion source anode raise-lower switch in the lower position for several seconds to make sure that the initial voltage application will be low, and turn on the ion source excitation. Raise the voltage, observing both the ion source anode voltmeter and ammeter, until the current rises suddenly and the voltage drops, indicating formation of the arc. If no sudden rise of current occurs by the time the voltage has reached 300 volts, increase the filament current somewhat and the arc will start. If the ion source has been in operation and was turned off only momentarily, the excitation may be applied without first reducing the voltage.

4. After the arc has been formed, the current, voltage, and filament can be adjusted for optimum beam current when the cyclotron is in operation. It will be found when operating the ion source anode raise switch to raise the current that the arc voltage may drop slightly, and the opposite effects will occur on lowering. The voltage may be raised by reducing the filament current. Reducing the gas supply will also tend to raise the voltage. Reducing either the filament current or the gas supply too far will make the operation unstable and cause the arc to go out.

If a new filament has been put in just before starting the ion source, it may be necessary to move the ion source filament stem in or out slightly by means of the ion source in-out switch at the control console, in order to obtain stable operation. This adjustment can then be repeated, when the cyclotron is in operation, to obtain the maximum beam current.

If a new hood has been installed, or the entire ion source assembly has been removed from the tank for any other reason and replaced, it will be necessary to adjust the ion source inclination to get good operation. This can best be done with the help of an observer who can look into the tank through the front window and see the hood as the ion source is started. It is helpful to have the cyclotron room darkened for this adjustment, and, of course, the oscillator must not be in operation. With the arc started and turned up to a high current, the top of the hood will become red hot if the inclination is correct. If a red-hot spot appears on the side opposite the slit, the hood must be tilted slightly toward that side. If the hot spot appears on the slit side above the slit, or if the beam of electrons can be seen emerging from the top of the slit, the hood must be tilted slightly toward that side. When correctly adjusted, the top of the hood will be hot, and a blue glow will indicate a cloud of ions emerging from the slit. Slight readjustment may be necessary, after the cyclotron is in operation, to get maximum beam.

The ion source in-out, left-right, and up-down adjustments can be optimized for maximum beam current when the cyclotron is in operation. If any very large changes are to be made, particularly if there seems to be difficulty in obtaining a beam, arrangements should be made to watch the inside of the tank from as many angles as possible while the adjustments are being made. This can be done by means of mirrors and a telescope, or by closed-circuit television, if available. Incorrect positioning of the ion source may possibly cause oscillations of the internal beam to such an extent that the beam may strike some parts of the dees or septum and cause damage. Insofar as possible, all vulnerable parts are protected by carbon plates or blocks so the beam will hit the carbon instead. The carbon will become incandescent where the beam strikes it, illuminating the inside of the dees. Little damage is done to the carbon, however, by repeated heating. Sometimes the location of the heated spot may give useful information for making corrective adjustments.

In normal operation the ion source anode voltage may range from 140 volts to 200 volts, and the current from 1 amp to 3 amps. The filament supply primary current may be as high as 7 amps, for a new filament, and decrease to between 3 amps and 4 amps, when the filament is about to burn out. It is desirable to keep a log of these values, along with all other operating cyclotron data. Time meters are provided in the cabinet at the left in front of the control console, marked VACUUM CABINET. One of these indicates the time that filament current is on, and another indicates the time that anode excitation is on. Both of these may be recorded in the log each time a filament is replaced. The anode-on time is the more significant in its effect on filament life, as there is relatively little deterioration of the filament without anode voltage applied, even though it may be kept at incandescence for considerable periods.

III. Maintenance

The motors in the motor box on the magnet coil are lubricated for long periods, and will require no attention for several years. They are operated only intermittently, and for short periods. The worm and gear assemblies on the ion source operate without lubrication and require no attention.

The most frequent item of maintenance on the ion source is the replacement of filaments. The filament life varies considerably with conditions of operation, but is usually about 10 hours of actual operation with anode excitation on. Somewhat longer life is obtained on continuous runs than for a succession of short runs, particularly if the short runs are made near the end of the filament life. An old filament may break when turned on, or when turned up higher than normal to start the arc, whereas it might have run for a considerably longer time if it hadn't been turned off. Enough filaments are supplied with the cyclotron for 1000 hours of operation.

The filament is a U-shaped length of tungsten wire, shown in drawing #916A377 Pt. 1. The legs of the U are held in a horizontal position, one above the other, in two copper blocks at the end of the filament stem, and are clamped in place by two small socket-head screws. See Drawing #338D417. A tantalum shield is attached to the lower copper block extending out under the filament. The shield is provided to prevent the formation of an arc downward to the bottom of the arc chamber and to catch broken pieces of filament, so that they are removed when the filament is replaced. The carbon hood is offset toward the left dee and feelers and the filament mounting holes are set at an angle in the copper blocks, so that the filament extends out from the blocks at an angle, with the U-shaped part under the hood.

Tantalum wire may be used for the filament instead of tungsten wire, if desired. It has an advantage over tungsten in being sufficiently ductile to be formed cold.

The procedure for replacing the filament may be divided into the following steps. Two men are needed.

1. Shut off the water supply to the filament stem by closing the valve in the supply line just below the ion source. There is a check valve in the return water line, so there is no valve to be manually closed in this line.

2. Remove the two water connections from the filament stem, and drain the small amount of water out of the stem into a bucket, applying light air pressure to the upper water connection, if desired, to insure complete draining.

3. Uncouple the latch at the upper edge of the filament stem flange.

4. Hook the end of the chain which hangs from the ion source into the loop attached to the filament stem flange.

5. Pull the filament stem slowly out from the ion source until the chain becomes taut and prevents further motion. Be sure to pull straight back and avoid bending or binding of the stem.

6. Close the air lock gate by lifting the vertical knob on top of the ion source and turning it 90 degrees to the left. Push the knob down again. Note that the screw slot in the top of the knob was parallel with the filament stem before closing the gate, and is now crosswise to the stem. Pushing the knob down into place locks it there, so that slight spring pressure is applied to the gate to keep it closed.

7. Push the filament stem in slightly, providing a little slack in the chain, and unhook the chain from the filament stem flange.

8. With one man holding the filament end of the stem in a clean cloth, remove the stem completely from the ion source and lay it on a clean table top. The pieces of the old filament and any debris brought out on the shield may be radioactive, and appropriate precaution should be exercised in the handling of them. The entire stem may be radioactive and should be handled accordingly.

9. Loosen the set screws holding the legs of the filament in the copper mounting blocks, and remove the parts of the old filament.

10. Clean the legs of the new filament with emery cloth and insert the filament in the mounting blocks. Adjust its position until it extends a total of 9/16 in. from the copper block, and tighten the set screws firmly. Make sure the shield hasn't been deformed.

11. Inspect the filament stem. Make sure it is clean. There should be a very light film of vacuum grease adhering to it. It may be necessary, after a number of removals, to rub a very small amount of vacuum grease on the stem near the flange end where the O-ring seal rests during operation.

12. Start the rough pump, if it is not already in operation.

13. With one man holding the filament end in a clean cloth, insert the filament end into the ion source far enough to be able to hook the chain again to the loop at the filament stem flange, and pull back slightly until the chain is taut.

14. Open the roughing valve into the filament stem air lock. This valve is in the line which connects to the underside of the ion source by a long length of vacuum hose. Hold the filament stem firmly to prevent its being sucked inward against the gate, with possible damage to either the gate or the filament and end of the stem. Make sure the bleed valve in this line is closed.

15. Close the roughing valve after it has been open for several minutes with the rough pump in operation, and open the air lock gate by lifting the vertical knob on the ion source and turning it 90 degrees to the right.

16. Push the filament stem slowly into the ion source, being careful to avoid bending or binding.

17. Engage the latch coupling the filament stem flange to the ion source and clamp it in place.

18. Put the water hoses in place and open the water supply valve.

19. Engage the position indicator magnet with its armature so that the filament in-out indicator is in operation. Shut down the rough pump.

Carbon hoods, of the design now used in the cyclotron, have not been run to destruction. Measurements made on a hood run about 150 hours indicate that its life may be about 300 hours. Failure of the hood occurs when the upper end is eroded inside by the electron beam until the hole extends through the top. The electron beam will then emerge into the tank and impinge upon the upper copper liner, and it may melt a hole through the liner and even through the magnet lid. It is well, after a hood has been in operation for 250 hours or more, to observe it frequently with the ion source in operation. The electron beam can be seen as a blue glow emerging from the top with occasional sparks if the top of the hood has been burned through. The top of the hood probably will not heat to redness if there is a hole through it, the ion source operation may be erratic, and the cyclotron output beam may be severely reduced.

The slit in the side of the hood will be eroded slowly during the operation of the ion source, and, before failure of the hood, the slit may have become considerably enlarged. It is improbable that replacement of the hood will be necessary for this reason, however.

The dimensions of the hood, except for the slit, are given in Drawing No. 916A250 Pt. 1. Several of these hoods are supplied with the cyclotron, along with a jig for use in cutting the slit. Various sizes of slit have been used. A typical slit is 1/16 in. wide, by 3/4 in. high, the bottom being 2-3/8 in. above the bottom of the base flange. The sides of the slit are filed away on the outside nearly to the inner bore so that the edges are quite thin.

The procedure for removing and replacing the ion source for replacement of the hood, or for other purposes, is as follows:

1. Remove the filament stem, following steps 1-8 as listed above.

2. Be sure the gas supply is turned off at the control console.

3. Close the valve in the water supply line leading to the ion source. This valve is just below the ion source, beside the valve in the filament stem water supply line. There is a check valve in the return water line.

4. Close <u>both</u> valves in the gas supply line at the ion source. One of these valves extends horizontally from the right side of the ion source, the other diagonally upward from the right side.

5. Remove the two water hoses by uncoupling the flare fittings at the ion source.

6. Remove the gas supply line from the ion source by removing the two screws holding the horizontal valve to the side of the ion source and the two screws which hold the connecting block to the side of the diagonal valve. Hang the gas supply line up by the small chain hanging from the bottom of the motor assembly. Note that the horizontal valve is removed with the gas supply line, while the diagonal valve remains on the ion source. Be careful not to lose or damage the small O-ring seal between the connecting block and the diagonal valve. The screws holding this block are held captive in the diagonal valve base and cannot be lost.

7. Remove the roughing connection to the filament stem air lock by removing the four socket-head screws holding the connector flange to the under side of the ion source.

8. By holding the ION SOURCE UP-DOWN switch at the control console in the UP position, run the ion source up until it reaches the upper limit switch. Likewise, using the LEFT-RIGHT switch, run the ion source to the right until it reaches the right limit switch. (This will be to the left of a person standing in front of and facing the cyclotron.) Watch the tank ion gage for signs of leakage when these movements approach the extremes, particularly the horizontal movement. If excessive pressure rise occurs just as the horizontal extreme is reached, the motion may be reversed momentarily until the leak stops. Care must be taken, however, that the motion is within 1/16 in. of the stop, even at the expense of allowing some leakage. Have an observer watching the hood through the front tank window to make sure it does not contact the right dee and get broken. If this becomes imminent, the right dee must be moved to the right before completing the horizontal ion source movement.

9. Using the ION SOURCE IN-OUT switch, run the ion source OUT until the rack on the bottom of the stem disengages the driving pinion.

10. Uncouple the five flexible shafts from the ion source, and unplug the four flexible cables from the bottom of the motor box.

11. Bring the supporting carriage up to the ion source so that the unsupported end of the rail fits over the Textolite bracket projecting outward under the ion source. Carefully line up the rail with the bracket so the screws at the side of the bracket fit in the notches of the rail flanges, limiting the in-and-out motion of the rail. Check that the rail is level, and adjust the supporting legs, if necessary, to make it level.

12. Push the carriage toward the ion source until the verticle bracket at the end of the rail lies against the ion source base plate, and clamp the bracket to the plate by means of the two bolts hanging in the base plate T slots.

13. Bring the sliding block along the rail so it approaches the filament stem opening of the ion source. Loosen the vertical and horizontal adjusting screws. Make sure the round brass rod is clean and free from nicks or scratches, and push it into the filament stem opening until the flange is against the ion source. Clamp the flange to the ion source by the clamp used with the filament stem. With the sliding block fitting securely on the rail, tighten the adjusting screws.

14. Slowly pull the ion source outward, keeping the sliding block firmly seated on the rail. Keep careful watch of the hood through the tank window, holding the ion source so the hood remains vertical, and making sure the hood does not hit the dee as it is withdrawn.

15. When the sliding block is drawn back to the first set of marks on the side of the rail, hold the block between the two marks and turn the ion source 90 degrees to the right (facing the cyclotron), so the hood is now horizontal.

16. Continue withdrawing the ion source, carefully avoiding turning the ion source and keeping the hood horizontal, until the block is between the second set of marks and it can't be pulled any farther. Hold it in place.

17. Close the air-lock gate by lifting the handle at the left side of the air lock (to the right of an observer facing the cyclotron) and hold it firmly closed. Make sure the handle is lifted fully to the vertical position, so the gate is not caught on the end of the ion source stem.

18. Open the bleed valve admitting air to the air lock. The gate will then stay firmly closed of itself.

19. Remove the four screws holding the ion source to the air lock, and pull the entire carriage and ion source outward, the end of the rail sliding on the bracket of Textolite* electrical insulating material, until the screws at the side of the Textolite bracket prevent further motion.

20. With a man at each side grasping the handles on the ion source base plate, the entire assembly can be lifted off the Textolite bracket and wheeled away to a table where the end of therail can be rested on the table top.

21. If the object of the operation is toreplace the hood, turn the ion source back so the hood is vertical. Carefully lift the hood out of the ion source, remembering that it is radioactive, and dispose of it as radioactive material. Remember also that the ion source stem is probably very radioactive, especially in the region between 20 and 30 inches from the end, and handle it accordingly.

*Registered trademark of the General Electric Company

22. Inspect the interior of the arc chamber. Turn the stem over with the opening down and catch on a paper any debris that falls out, so it can be wrapped and disposed of as radioactive material.

23. Inspect the ion source stem, making sure it is clean and free from nicks or scratches and has a very thin film of vacuum grease covering it. If necessary, put a small amount of vacuum grease at the base of the stem where the O-ring seal normally rests.

24. Turn the ion source stem over so the hood opening is up, and place the new hood in position. Observe the index mark on the side of the base flange, and line it up with the index mark on the ion source stem. Observe also that when this is done the hole in the hood will coincide with the gas supply opening in the side of the hood opening of the stem. Make sure that the hood is firmly seated on its flange and does not fit loosely.

25. Turn the ion source stem so that the hood is horizontal, and make sure the stem is pulled back as far as possible. Check the condition of the O-ring seal on the base plate and make sure it is clean and greased.

26. Wheel the carriage back in place in front of the cyclotron with the rail resting on the Textolite bracket. Make sure it is carefully lined up with the bracket. Make sure the face of the air lock flange is clean.

27. Push the carriage toward the cyclotron until the ion source base plate engages the dowels in the air lock flange and comes in contact with the flange. Bolt the flange and base plate together.

28. Start the rough pump. Close the air lock bleed valve, and see that the filament stem air lock gate is closed.

29. Open the roughing valve leading to the air lock. Be sure someone is holding the ion source to prevent its being drawn inward or turned. Hold the air lock gate firmly closed while the air lock is being evacuated.

30. After the roughing valve has been open for several minutes with the rough pump operating, close the valve and open the gate. Be sure the gate handle turns down to a horizontal position and is not caught by the end of the stem.

31. Slowly move the ion source inward, keeping the sliding block firmly on the rail and making sure the ion source does not turn.

32. When the sliding block reaches the first set of marks on the side of the rail, stop and carefully turn the ion source 90 degrees to the left (facing the cyclotron) so that the hood is vertical.

33. Continue to move the ion source carefully inward, watching the hood through the tank windows to make sure it is not broken against the dee. Continue until the driving rack on the bottom of the stem enters its slot and approaches the pinion. With a screwdriver turn the worm and gear and pinion until one or two teeth of the rack are engaged.

34. Unclamp and remove the sliding block fixture from the filament stem opening.

35. Unbolt the rail bracket from the base plate of the ion source, and remove the entire carriage assembly to a storage area for future use. Leave the two clamping bolts, together with their nuts and washers, in the T slot of the base plate.

36. Replace the gas supply line, making sure that the O-ring seal is clean and greased. Replace the water lines and the filament stem roughing line. Open the water valve.

37. Couple the flexible shafts to the ion source, and plug the flexible cables into the bottom of the motor assembly.

38. Slowly open the diagonal gas valve. This will let the air trapped between the two valves be pumped into the tank and will raise the tank pressure momentarily. After this valve has been opened several minutes, open the horizontal gas supply valve.

39. Check the condition of the filament stem and replace it as outlined in Steps 11 - 19. If the filament is partly burned away it should be changed, as outlined in Steps 9 - 10, before putting the filament stem in place.

40. Engage all position indicators, placing the magnets in contact with their armatures, and adjust the ion source to its normal operating positions, using the appropriate switches at the control console.

As mentioned under OPERATION, it may be necessary to readjust the hood inclination after the ion source has been removed and replaced. The hood should be carefully observed when the ion source is first put into operation, and any necessary readjustments made as described there.

It may be necessary after long intervals of operation to replace the O-ring seals in the ion source. There are three which operate as sliding seals and may eventually become worn or damaged; one around the filament stem, one around the main ion source stem, and one between the base plates. Of these, the one around the filament stem receives the greatest wear and is subject to the most hazard, because the full length of the filament stem slides in and out through it each time the filament is changed.

The filament stem O-ring can be replaced while the ion source is in the cyclotron, without disturbing the tank vacuum. Remove the filament stem, as described above, and lay it aside. Uncouple the flexible shaft driving the filament IN-OUT motion, and with a screwdriver turn the worm until the rack on the under side of the damping collar disengages its pinion. Remove the damping collar. The O-ring is in a groove just inside the opening. See Drawing 338D415, Part 58. It may be removed from the groove by carefully prying it out, using a short thin strip of copper or brass. Be careful not to scratch the bottom of the groove. Carefully clean the groove and coat the inside surfaces with vacuum grease. Provide a new O-ring of the correct size (see the parts list of above drawing) and coat it with vacuum grease. Place the new O-ring in the groove, and replace the clamping collar, turning the worm to engage the pinion and rack and return it to about its former position. The filament stem may then be put in, following the procedure described above.

To replace either of the other two sliding O-rings it is necessary to remove the entire ion source from the cyclotron, as described above, and remove the ion source stem from the base plate assembly. It is necessary to disassemble the ion source stem in order to do this. Refer to Drawing 338D415. Note that the outer copper tube, Part 3, is brazed into the block, Part 8, and the copper arc chamber fits over the other end of the tube, being held in place by a smaller tube inside, Part 2, which is threaded into the arc chamber and is held in place at the other end by a spring and collar assembly. The purpose of the spring arrangement is to maintain tension in the tube, holding the arc chamber firmly in place, despite differences in thermal expansion or contraction between the two tubes. It is convenient to do the disassembly while the ion source is held on the supporting carriage which is used to remove the ion source from the tank.

Remove the hood, Part 5, and lay it aside to avoid breaking it. Provide a block to support Part 9 directly on the rail of the supporting carriage, and separate the filament stem air lock assembly from the rest of the assembly by removing the four screws, Part 50. It will be necessary to remove the position indicator and limit switch also. This will expose the end of the inner tube. Remove the three screws, Part 46, from the flange at the end of the tube, Part 2, and temporarily insert longer screws of the same thread, being careful not to turn them in far enough to engage the spring and washer assembly back of the flange. Insert a stick of wood or plastic between the screws and gently turn the tube, Part 2, so as to unscrew it from the arc chamber, Part 4. This tube may then be removed completely and laid aside. The threads on the end of the tube are fine, and the arc chamber into which they fit is made of copper, so care must be exercised not to damage the threads. Make sure the arc chamber, Part 4, does not fall from the end of the large tube, Part 3, and bend or damage the three small tubes, Parts 6 and 7, which are attached to it. Remove the two fittings, Part 14, and the valve, Part 16. The ends of the small tubes to which these were coupled can then be pushed inward until they clear the inner wall of the opening. The arc chamber, Part 4, can then be gently pulled off the tube, Part 3, and withdrawn, care being taken not to bend the three small tubes attached to it. This leaves the end of tube, Part 3, free of any obstruction so that it can be withdrawn from the base plate assembly. Make sure there is no roughness or burr at the end where the arc chamber came off, and draw the tube straight back without binding.

The O-ring which surrounded the ion source stem, Part 3, can then be readily removed, the groove cleaned and regreased, and a new O-ring greased and put in place.

To separate the two base plates, remove the up-and-down position indicator magnet, the down limit switch, and the up limit switch stop. Then, with a screwdriver, turn the up-and-down worm to screw the sub-base assembly upward until the threaded rod is out of the worm gear. Continue pushing the assembly upward, pushing evenly on both sides until the guides at the sides leave the T slots and the sub-base is free. The O-ring between the plates can then be removed, the plates cleaned, inspected, and greased, and a new O-ring put in. If any scratches or nicks appear in the face upon which the O-ring slides, rub them out with crocus cloth. Make sure there are no sharp edges around the opening over which one side of the O-ring must slide when the plates are reassembled. Also make sure the end of the ion source stem is smooth and rounded before inserting it into the opening in the sub-base.

Assembly of the ion source stem is done in the reverse order from that in which it was taken apart. Carefully clean out any scale and debris from the arc chamber before putting it back in place. Treat this debris as radioactive material. Care must be taken to avoid bending the small tubes attached to the arc chamber as they are inserted into the stem and the arc chamber is put on the end of the stem. The arc chamber must be carefully oriented so that the hood will be vertical when the assembly is complete. This may be done as follows. Adjust the tilt cam which lies in the upper part of Parts 8, 9 and 12 (Drawing 338D415) to about the midpoint of its total throw. With the ion source stem horizontal, turn it so the rack, Part 10, is exactly on the bottom. This can be checked by holding a spirit level vertically along first one side and then the other of Part 9, and then measuring horizontally from the level to the rack on each side. Adjust until the two measurements are equal and the rack is exactly on the bottom. Then, holding the stem in this position, lay the level across the top of the arc chamber and turn the chamber on the stem until the top surface is exactly level, and lightly push the chamber onto the stem until its inner shoulder fits squarely against the end of the stem. Make sure there is no dust interfering with the fit at this point, and that the soft copper of either the chamber or the stem has not been deformed. Make sure the arc chamber does not shift on the stem during the subsequent operations before it is clamped in place by the inner tube.

Carefully insert the ends of the three tubes, Parts 6 and 7, into the holes in Part 8, making sure the tubes are not crossed inside the stem. Holding the tubes close to the wall of the stem, put on the O-rings, Part 52, and the fittings and valve, securely clamping the tubes in place. Be sure the O-rings, tube ends, fittings, and O-ring seats are clean and well greased, as these are vacuum seals. Next carefully insert the tube, Part 2, into the bore of the ion source stem until the threads at the end engage the threads in the arc chamber, having first placed the spring and ring, Parts 22 and 23, around the tube in the correct order, and screw the tube into the arc chamber until the outer surface of the flange, Part 24, is within the end surface of Part 8. Remove the temporary screws from the flange and put in the screws, Part 46. Turn in these screws, compressing the spring, until the screws are flush with or slightly within the surface of the flange. Clean and grease the O-ring, Part 57, and the groove in which it lies. Clean and lightly grease the mating surface of Part 20, and bolt Parts 20 and 8 together, completing the assembly.

Procedure for replacing the O-ring, Part 55, or making repairs to the filament air lock gate or its seal, will be evident from a study of the drawing, #338D415.

There are three seals in the filament stem which may need replacement, making it necessary to disassemble the filament stem. Refer to Drawing 338D417. One of these is a vacuum-to-water seal between the two copper blocks, Part 3, at the filament end of the stem. The other two are around the water pipes at the outer end of the stem, Part 6. These seals are cut from sheet silicone rubber, and are not O-rings. The drawing will serve to show most of the procedure necessary to take this filament stem apart and put it together. The Parts 20 - 24 will have remained in the ion source when the filament stem was removed. Loosen the turnbuckle screws, Part 11, and lift them out with their associated clamping blocks, Parts 9 and 10. Slide the blocks, Part 8, along the water tubes as close to Part 7 as possible. Remove the support blocks, Part 17, and their clamps, and the two capacitors. The fittings at the end of the pipes can then be removed by heating them with a torch. They are attached with soft solder. Clean the solder from the ends of the tubes and make them smooth, so the old seals can be removed and new ones put on without injury. For complete disassembly, remove all the parts from the water tubes and withdraw the tube and filament block assembly from the filament end. Be careful not to bend the water tubes or break the sections of glass tube with which they are insulated. Remove the filament from the blocks. Slide the Teflon collar back off the blocks, and remove the screw holding the blocks together. This exposes the seal between the blocks, which can then be replaced with a new one.

In putting the stem together, be sure that the filament blocks are one above the other when the clamping notches in the flange at the other end of the stem are one above the other, so that the filament will be in a vertical plane when the stem is in the ion source. Make certain that the pipes are not twisted within the stem. Put all the parts on the outer end of the pipes and carefully solder the fittings in place, using a wet cloth around the pipes near the seals to prevent overheating them. Clean off any excess solder from the pipes at the joints with the fittings so that the clamping blocks will fit snugly. Assemble the turnbuckle clamps and tighten them carefully, so that the filament blocks at the other end of the stem seat properly in the Teflon collar. Put on the supporting blocks, Part 17, and clamp the fittings securely. Put on the two capacitors.

IV. TROUBLE SHOOTING

In case of faulty operation of some part of the ion source, the following will be helpful in locating the cause and making the necessary correction.

1. The filament will not come on. The signal light at the ion source filament switch remains green. The master switch is on.

   a. The ion gage is off. Check the indicator light panel and the tank ion gage panel. Start the tank ion gage if the tank vacuum permits.

   b. The water flow or water temperature interlocks are open. Check the indicator light panel. Operate the reset switch and see if the water flow light goes out. If it does not, the water flow is low or the water is too hot. Check the filament water supply valve at the ion source to make sure it is open, and check that there are no broken hose connections.

2. The filament current will not rise, although the filament switch signal light is red. A momentary surge of current was indicated when the switch was turned on.

   The filament is broken and must be replaced. The momentary surge of current is exciting current in the primary side of the filament supply transformer.

3. The ion source excitation cannot be turned on.

   a. The filament is not on. See Item 1 above.

   b. The ion source water flow or temperature interlocks are open. Check the indicator light panel and operate the reset switch. If the water flow light does not go out, check the ion source water supply valve to make sure it is open, and check for broken hose connections.

   c. There is an open beam safe switch or the safety interlock at the corridor gate is open. Check the indicator light panel. Find and close the open switch.

   d. The target chamber gate is closed. Check the signal lights at the target chamber gate switch. Check the target chamber thermocouple vacuum gage before opening the gate, and do not open the gate unless the target chamber pressure is below 50 microns. If the pressure is higher than this, the rough pump must be started and the target chamber pumped down.

4. The tank pressure rises when the master switch is turned on, starting the water pump, and falls when the pump stops.

   a. This indicates a probable water leak into the tank at some point. It may not be in the ion source at all, but there are two cooling water circuits in the ion source which could spring leaks at some point in the tank vacuum. Shut off both ion source water supply valves, filament water, and arc chamber water, and again turn the master switch on. If the pressure in the tank rises, the leak is not in the ion source. If, however, the pressure does not rise when the master switch is turned on, open the two valves, one at a time with the pump running, and observe the tank pressure. The pressure will rise when the valve is opened to the circuit having the leak. If the leak appears to be in the filament stem, which is the more likely, remove the filament stem and see if the tank pressure returns to normal with the pump running. If the leak has been shown to be in the filament stem, it is most likely to be at the gasket between the copper filament blocks, and the stem must be disassembled and the gasket replaced as outlined under MAINTENANCE. A yellow chromate deposit can sometimes be found where the leak has been, if the leak has been present for some time.

   b. The checks made under (a) above may show the leak to be in the arc chamber water circuit. This is very unlikely except, possibly, when first turning the water on after the ion source has been out and taken apart. The water pipes may have been damaged either at their junction with the arc chamber or at the elbows where they enter the fittings at the other end. The ion source will have to be removed and taken apart to repair the leak. It is less probable, but possible, that a leak has developed in the arc chamber itself from the drilled water passages, particularly at the plugged end of the cross-over hole, drilled to connect the input and output water passages.

5. Abnormal tank pressure, not affected by starting or stopping the water pump, indicates a leak somewhere in the vacuum system. Because the ion source or the filament has just been out, or for some other reason, the leak is suspected to be in the ion source.

   a. Search for the leak at the various seals, using the best vacuum leak detecting procedures available. Remove the filament stem and see if the pressure returns to normal.

b. Water or some other high-vapor-pressure material may have been inadvertently introduced while the ion source or filament stem was out of the tank, and the high tank pressure is caused by outgassing of this material rather than by a leak. Removing the filament stem will show whether or not the material is in it. If no leak can be found, continued pumping may finally remove the contaminating material and bring the pressure down to normal.

6. The ion source anode voltage is abnormally high and the filament current is abnormally high. The arc may be unstable and erratic.

   a. The gas supply is low or completely shut off. Check the two valves on the ion source to be sure they are open, and check the gas supply cabinet. Recharge if necessary.

   b. If a new hood has just been put on, the slit may have been cut so that the gas opening in the base does not match the opening in the chamber wall, blocking the entrance of gas into the hood.

7. The ion source anode voltage and current are normal, but the cyclotron beam current is low. All conditions seem correct for a beam.

   a. There may be an air leak in the gas line, which seriously dilutes the deuterium entering the arc chamber. With the <u>oscillator off</u>, the room dark, and the anode current <u>low enough so</u> that the top of the hood is not glowing, observe the ion cloud emerging from the slit. If the deuterium supply is not diluted, the cloud will be blue in color. If it is greenish with a suggestion of yellow, the presence of air or water is indicated. The filament life is materially shortened by the presence of air or water in the gas, and the eroded ends of the broken filament will have a frosted, rather than a shiny or polished, appearance.

8. One of the ion source positioning movements does not respond to its operating switch as shown by the position indicator.

   a. The position indicator unit on the ion source has become disengaged from its holding magnet so that the sliding rod does not follow the motion. Check that the rod slides freely, and extend it to contact the magnet.

b. The flexible shaft has failed. Uncouple the shaft and check. See if the lower end turns when the switch at the control console is operated. Attempt to hold the lower end with pliers while it is turning to see if there is slippage. Replace with a new shaft if the old is found to be defective.

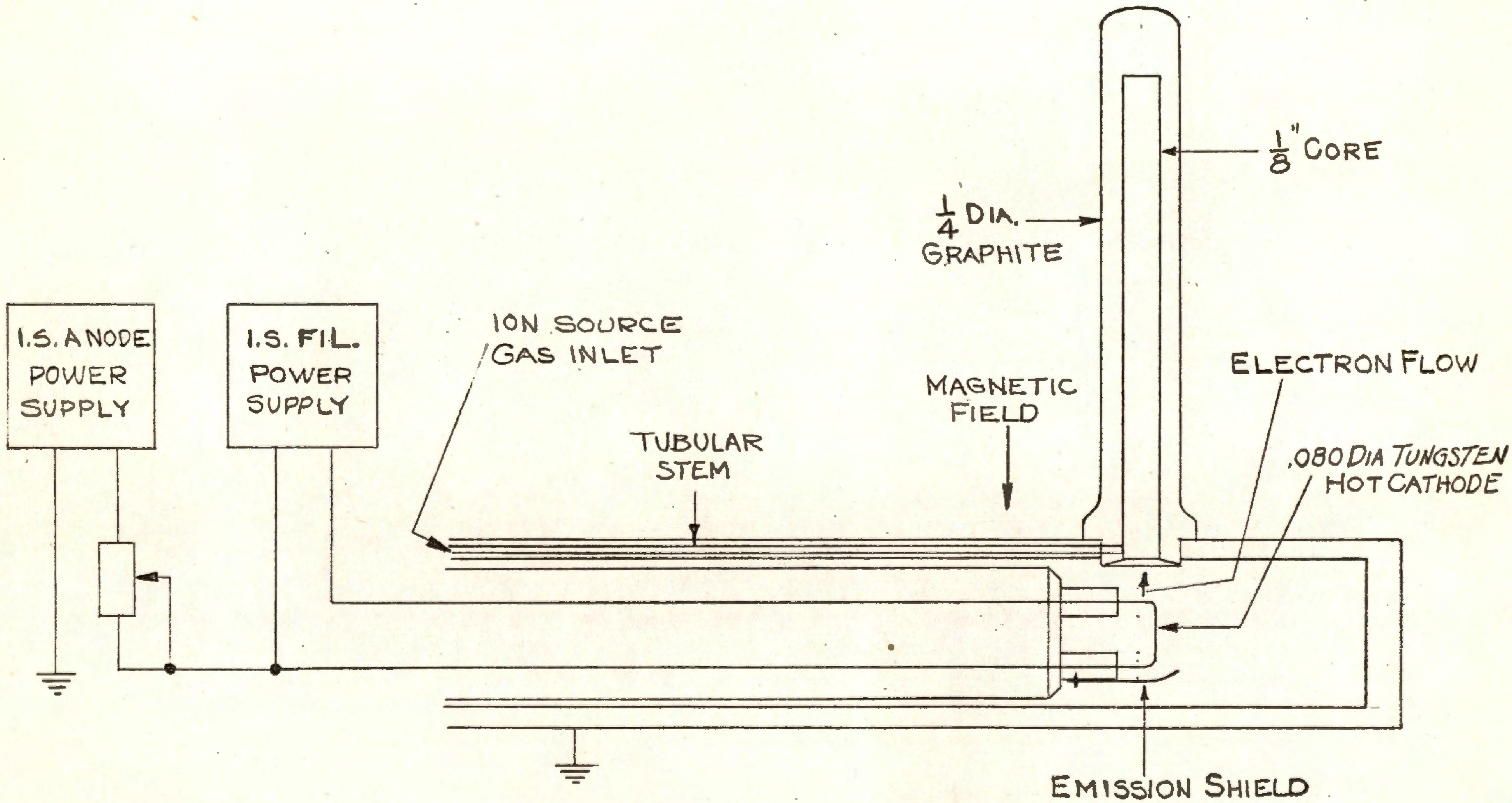


FIG. 1
ION SOURCE SCHEMATIC DIAGRAM.

Ion Source Anode Supply

I. DESCRIPTION AND FUNCTION

This is a five ampere, 450-volt direct current supply. A regulated, variable a-c voltage source feeds a 6-phase, star-connected rectifier bank. The filtered direct current output is available, through a stabilizing resistor, either as a continuous current or as a series of pulses. The pulse rate is 60 per second and the pulse width may be varied from one millisecond to approximately nine milliseconds. A crest voltmeter and crest ammeter are provided so that the operator can monitor the direct current output whether it is continuous or pulsed.

The anode supply provides either continuous or pulsed beam currents by modulating the ion source anode.

II. PRINCIPLES OF OPERATION

Refer to Elementary #T-9747087.

Transformers 68G955, connected Y to Y, are constant voltage transformers whose purpose is to make the direct current output independent of voltage fluctuations in the 3-phase 208-volt input lines. The secondaries supply the Y-connected, motor-driven powerstat MX11263Y.

The motor-driven powerstat controls the magnitude of the direct current output by furnishing voltage to transformers T5 through T11.

T5 through T11 are six 1:2 step-up transformers connected Y on the primary side and star on the secondary side. The six-phase rectifier bank, consisting of tubes V1 through V3, is supplied by the line to neutral star at 416 volts. Power factor correction capacitors C1 through C3 are connected in delta across the primary input to T5 through T11.

Capacitors C4 through C8 are connected in parallel and, together with inductance L1, act as a choke input filter for the rectifier bank.

For operation requiring continuous direct current through the ion source, the rectifier is connected to the load through the normally-closed contact K1.

For operation requiring pulsed direct current through the ion source, the rectifier is connected to the load through the normally-open contact K1 and thyratron V4. This connection is effected by closing switch S1; it allows pulsing the ion source at a 60 cycles-per-second repetition rate with an adjustable pulse width of from one to 8 milliseconds.

This pulsed operation requires the commutation of current from V4 to thyratron V5, and this is done as follows:

The operator sets R20 for the required pulse width.

V4 is fired by a positive pulse on its grid. Capacitors C12-C14 charge up to a potential somewhat less than rectifier voltage. Capacitors C9-C11 charge up to rectifier voltage.

After a time interval which has been selected by the operator when he sets R20, the grid of V5 is pulsed positive and C9-C11 discharges through the inductance L2. A voltage equal to that formerly on C9 through C11 (full rectifier voltage) temporarily appears across L2, driving the cathode of V4 toward full positive rectifier potential. Capacitor C12 holds the plate of V4 at a constant potential; the result is that the cathode of V4 goes positive with respect to its anode, and the tube abruptly stops conducting current. The bias potential for the grids of V4 and V5 is obtained from the plate power supply for tubes V6, V7, and V8. The capacitor C15 fixes the a-c potential, with respect to ground, of the grid of tube V 4 and aids in the current commutation from V4 to V5.

The resistance R8 through R11 allows C9 through C11 to charge up while V4 is conducting and allows V5 to go out after commutation takes place.

The resistance R12 is a damping resistor and prevents capacitors C12-C14 from oscillatory charging. Since the rectifier voltage is constant, there would be an oscillation in the ion source current if there were an oscillation in the capacitor charging current (the two currents are complementary).

The pulses which fire the two thyratrons V4 and V5 are obtained as follows:

Tube V8 is in a multivibrator circuit which is not free-running, but must be synchronized by the peaking transformer T17 at a 60 cycles-per-second repetition rate.

At the two plates of the V8 appear square voltage wave forms, one going up while the other goes down. The length of this square pulse is controlled by the potentiometer R20.

These two square waves are differentiated and the resultant pulses put on the grids of amplifier tubes V6 and V7. V6 and V7 fire V5 and V4 respectively.

There are two circuits for metering peak current and voltage. Both involve charging up a capacitor through a rectifier. The voltage on the capacitor is used to make a meter indicate; the time constant is long enough so that the meter reading is proportional to the peak voltage on the capacitor.

For the voltmeter, the voltage from a potential divider R5, R6 is used to charge the capacitor C19. For the ammeter, the voltage across a resistor R7, which carries the ion source current, is used to charge the capacitor C16.

Operating Instructions

1. Continuous Ion Source Current

   a. Turn switch S1 to the off position.

   b. Raise the voltage supplied by the motor-driven powerstat until the current to the ion source, as monitored by the ammeter M23, is sufficient.

2. Pulsed Ion Source Current

   a. Turn switch S1 to the on position.

b. Set the potentiometer R20 to the position corresponding to the pulse width required.

c. Raise the voltage supplied by the motor-driven powerstat until the crest current to the ion source, as monitored by the ammeter M23, is sufficient.

3. Metering

The ammeter M23 and voltmeter M24 indicate crest current and voltage, respectively. Therefore, for pulsed operation, they indicate the same reading as they would if continuous direct current were flowing.

III. MAINTENANCE

Periodic Checks:

a. Contacts on relay K1 should be cleaned at 6-month intervals.

b. The voltage across the filaments of tubes V1 through V5 should be checked to make sure it is within 2.37 to 2.63 volts.

IV. SERVICE

If the circuit does not function properly, the source of the trouble may be localized by a combination of two methods.

1. Using an oscilloscope, compare the waveshapes of the voltages at various points with those shown in the accompanying illustration. A significant difference in the waveshape will point to the source of trouble.

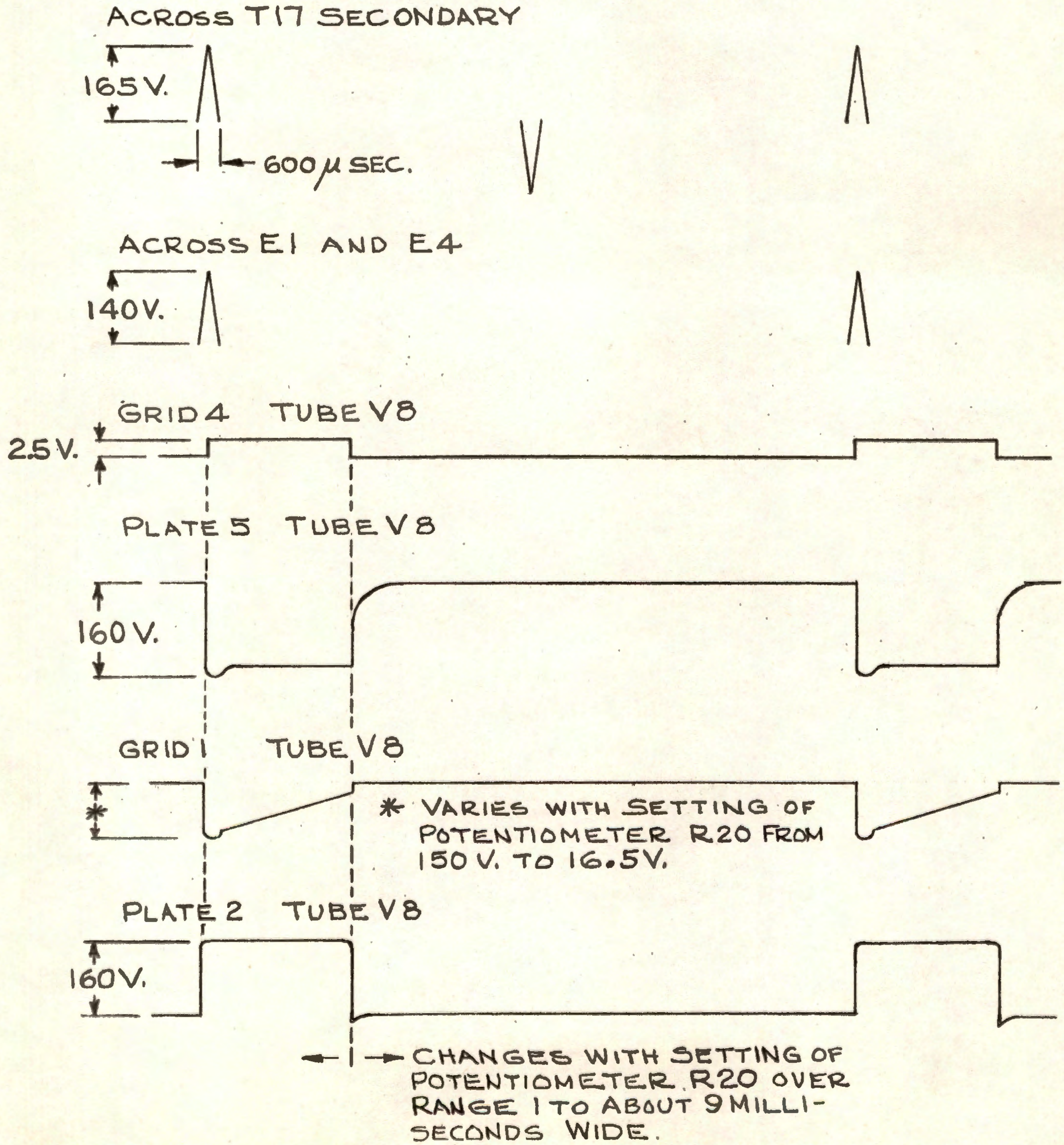
2. Using a voltmeter, measure the following voltages and compare the observed reading with that listed for satisfactory operation.

D.C. Voltages (Measured from B-unless otherwise indicated)

Point of Measurement		D.C. Volts
	B+	212
V6	Pin 3 (Plate)	5
V6	Pin 4 (Screen)	44
V7	Pin 8 (Plate)	29
V7	Pin 6 (Screen)	78
V8	Pin 5 (Plate #1)	166
V8	Pin 6 (Cathode)	39
V8	Pin 2 (Plate #2)	92
V4	Grid to Cathode	149
V5	Grid to Cathode	175

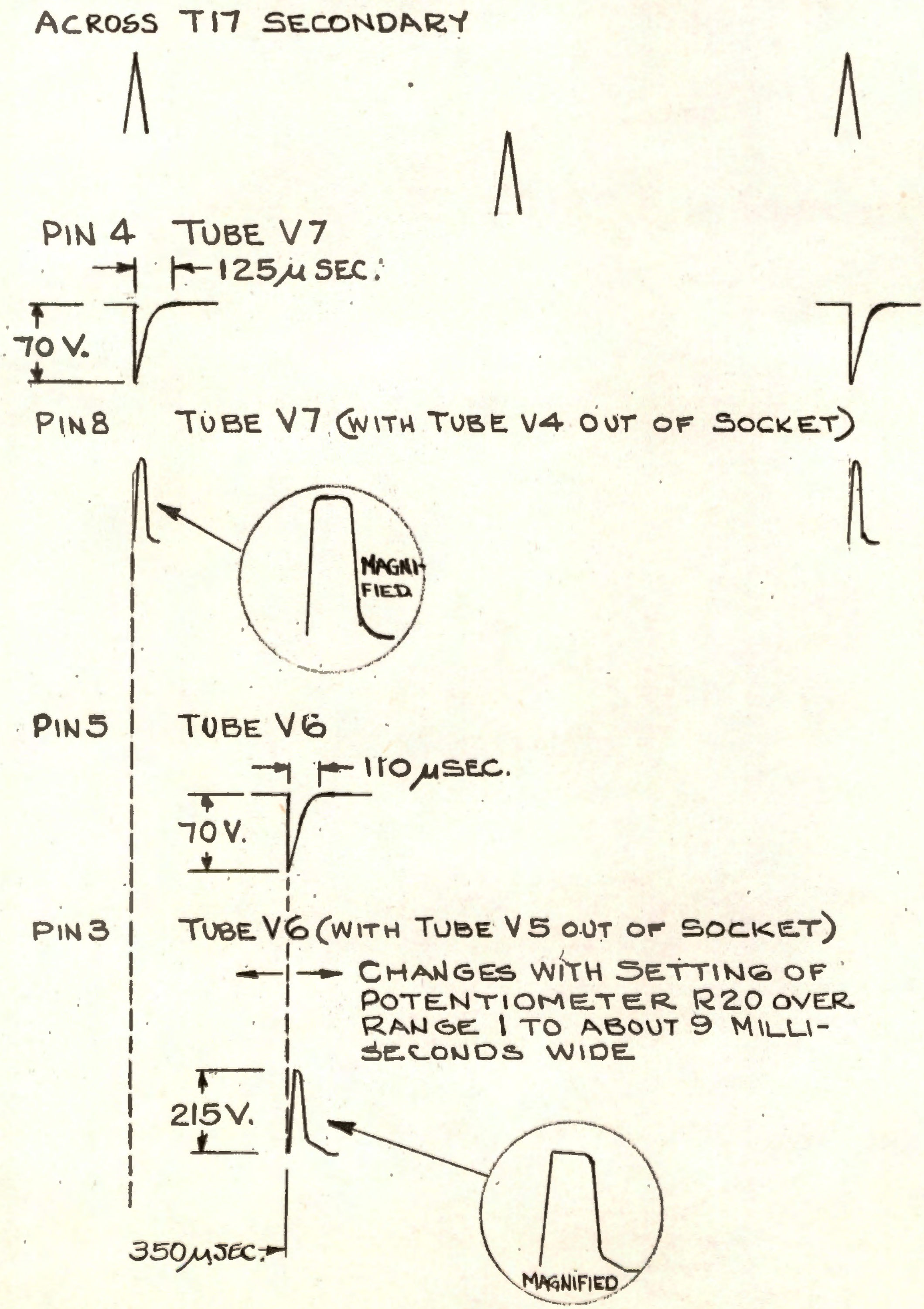
ION SOURCE ANODE SUPPLY
PULSER WAVE SHAPE DIAGRAM

ALL VOLTAGES TO B− UNLESS INDICATED OTHERWISE.

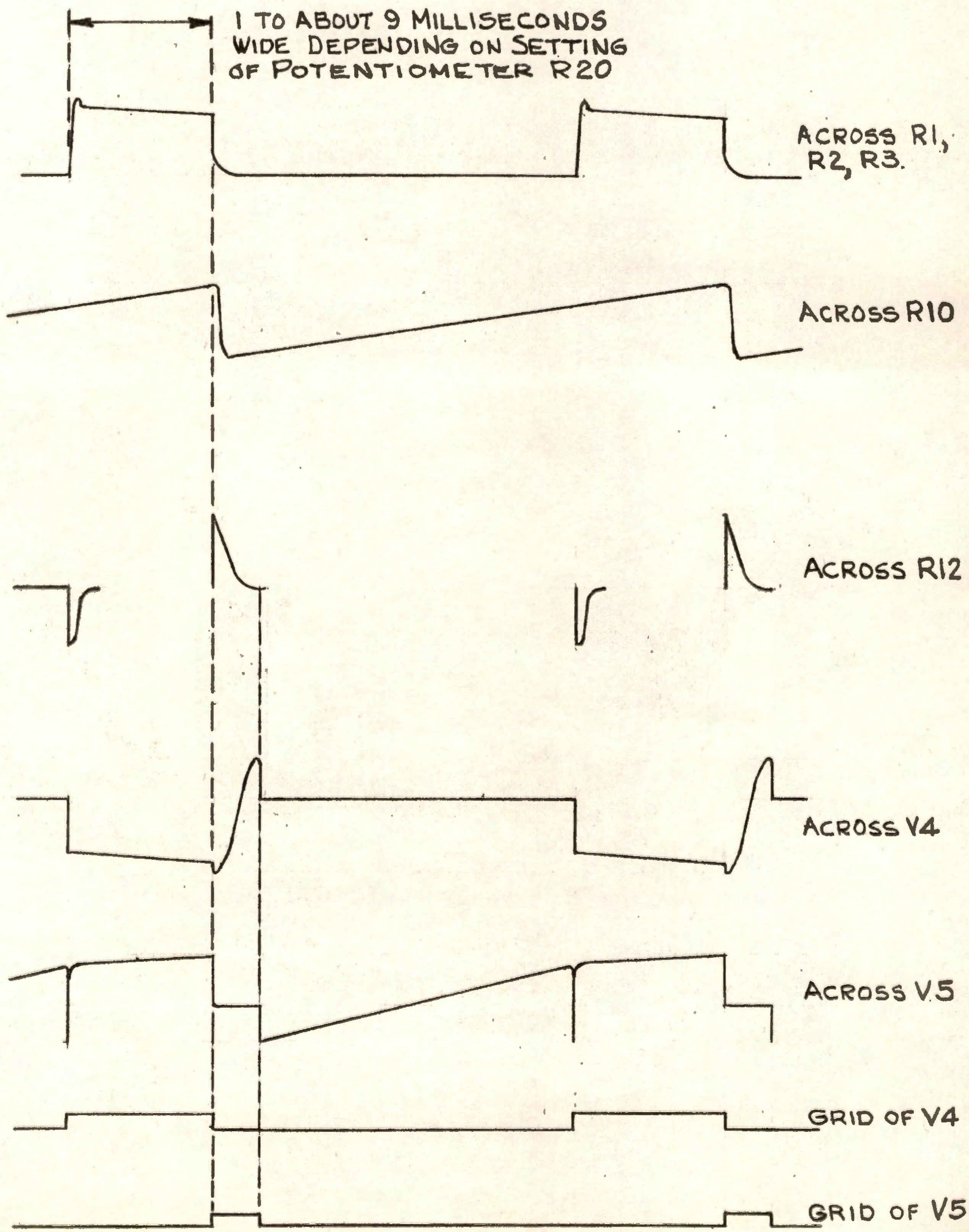


ION SOURCE ANODE SUPPLY
PULSER WAVE SHAPE DIAGRAM

ALL VOLTAGES TO B− UNLESS INDICATED OTHERWISE.



ION SOURCE ANODE SUPPLY
PULSER WAVE SHAPE DIAGRAM



V. Beam Deflecting System

D.C. deflector power supply equipment: GEI 29325

Pothead installation instructions: GEI 32351

Beam Deflecting System

I. DESCRIPTION

The deflector and septum provide means of extracting the circulating ion beam from its orbit within the dees and deflecting it into a path leading out of the dees and out of the guiding magnetic field to the exit window. They are arc shaped members lying inside the right-hand dee, approximately parallel to one another, forming a channel through which the beam passes. The septum is the inner member. It is attached to the dee structure and is at dee potential. The deflector is the outer member and is supported on insulators. Both are adjustable in position and angle; the septum is adjusted by means of a key which extends through a seal in the chamber wall. The deflector is adjusted remotely from the control console. Drawing TT-9671945 shows the septum and the deflector located in the right dee.

Deflector Power Supply, Cable, and Insulators

Power is supplied to the deflector from a Kenotron rectifier power supply which is described in instruction book GEI29325. Complete instructions for installation, operation, and maintenance of the power supply are given therein. Not included in GEI29325 are modifications covered in drawings 451C885, 451C888, and 663B381. These provide for the addition of a voltage stabilizer ahead of the induction voltage regulator, and a relay which automatically returns the regulator to the zero voltage position when the main contactor is opened. The power supply is located in the machine room remote from the cyclotron room. It is within a lead shield enclosure which protects personnel from low-energy x-rays produced by the rectifier tubes.

The power is conveyed from the power supply into the cyclotron room by a single-conductor lead-covered high-voltage cable. Copper braid is substituted for the lead sheath for a length of several feet back from the cyclotron to permit greater flexibility. The cable terminates in an entrance pothead on top of the cyclotron chamber over the back of the right dee stem. Complete instructions for installing the pothead are given in GEI32351.

Connection is made from the inner terminal of the pothead to the deflector control-rod assembly at the center of the right dee stem through a Globar resistor of 2 megohms. The resistor is mounted in clips at each end which hold it in place and permit movement of the dee stem during adjustment of dee position. Several spare resistors are supplied with the cyclotron.

The control rod assembly is supported in the center of the right dee stem by a series of Mycalex-insulated spiders. The control rod couples to the actuating rod at the back of the chamber by means of a Mycalex rod. The control rod assembly is supported just back of the deflector by a Mycalex insulator, Drawing #916A256.

Deflector Cooling System

The deflector is provided with internal passages for circulation of a liquid coolant to carry away heat liberated by stray portions of the ion beam. The coolant used is Toluene. The elements of the cooling system within the cyclotron chamber are shown in TT-~~9761965.~~ 9671965. At the back of the dee stem the toluene is carried through two glass tubes to provide electrical insulation. These tubes with their mounting seals are shown in Drawing #451C827.

Outside the cyclotron chamber the toluene is circulated through a heat exchanger by an Eastern Industries bronze centrifugal pump Model 3J, Type 211. It is fitted with a stuffing box type of gland seal and driven by a 3/4 h.p., 3450 rpm ball-bearing motor.

A flow switch and a contact-making thermometer are included in the coolant return line. These prevent application of voltage to the deflector if the coolant is not flowing or is at too high a temperature.

The heat exchanger is a Ross, Type BCF, size 502, as indicated on Drawing W9179209, supplied with cooling water from the city water system through a throttling valve and solenoid-operated shut-off valve.

Deflector Positioning Mechanism

The deflector position and angle relative to the septum and the right dee are varied by a mechanism attached to the rear of the cyclotron chamber just back of the right dee stem. It is shown by Drawing TT9671968. It is controlled by switches at the control console, and both position and angle adjustments are remotely indicated there.

Septum Tips

The septum lies in the right dee just inside the deflector, forming an inner wall to the deflected beam channel. A portion of the septum at the entrance end, called the "septum tip", is subject to possible damage by the beam, and is replaceable. See drawing 451C606 for the replaceable tip, and drawing 451C607 for the entire septum.

Septum Cooling

The septum is water-cooled from the main closed-circuit cooling system. It has copper tubes fastened to the inside of the upper and lower edges extending the full length of the septum, including the replaceable tip. Easily disengaged O-ring sealed connectors join the replaceable tip cooling tubes to the others. The septum cooling-water tubes are connected to supply and drain tubes in the right dee by O-ring sealed connectors and flexible metal hose which permit removal and adjustment of the septum. The drain line extends back through the right dee stem and out of the cyclotron chamber before being connected to the system drain manifold. Thermistors located in this drain line and in the supply water line are connected to an indicating circuit at the control console to monitor the temperature rise in the septum cooling water. A water-flow switch and a contact-making thermometer are also in the drain line.

Septum Positioning Mechanism

The septum is not attached rigidly to the dee, but can be moved about on the lower dee surface. The entrance end is restricted by pins at the top and bottom which slide in slots in the dee structure, so that the entrance end can move only in and out radially. A worm-and-gear, rack-and-pinion mechanism is attached to the exit end of the septum and engages with a rack on the dee structure in such a way that the entire septum can be moved along the slots at the entrance end, or the exit end of the septum can be moved in and out, pivoting about the pins at the entrance end. The mechanism is actuated by a key which extends through a flexible bellows seal in the chamber wall beside a viewing window. The key is withdrawn from the mechanism except when adjustments are being made, so that the dee is not grounded. See drawings 338D406, 663B263, and 451C823.

II. OPERATION

Deflector Power Supply

The deflector power supply is operated remotely from the control console. One switch energizes the rectifier filaments, another energizes the induction regulator and high-voltage transformer, and a third operates the induction regulator up or down. The second switch will not close the contactor energizing the transformer until the filaments have been on for a predetermined length of time and the time-delay relay has closed. The third will not operate the induction regulator until the contactor has been closed. The regulator automatically returns to the zero-voltage position each time the contactor is opened, so that high voltage cannot be suddenly impressed on the deflector.

Two voltmeters at the control console indicate voltage of the d-c output, one on the power-supply side of the series resistor and the other on the deflector side of the resistor. The difference between the indications represents the voltage drop in the resistor and is a measure of the load current.

The door to the power supply enclosure must be closed, and its safety interlock closed, before the circuit breaker can be closed.

There must be an adequate flow of deflector coolant, which must be within the operating temperature range.

The chamber vacuum must be within the operating range, permitting the ion gage to be on, before the voltage can be applied to the deflector by the contactors.

Deflector Cooling System

Operation of the deflector cooling system is entirely automatic. Cooling water flows in the heat exchanger, and the toluene pump runs, whenever the deflector power supply and the ion source anode are both on, and they continue for a short period after either is turned off, in order to remove stored heat from the deflector. The flow switch and contact-making thermometer in the toluene line automatically protect the deflector from overheating by opening the ion source anode supply if the toluene flow stops or if the temperature becomes abnormally high. The ion source anode supply is interlocked with the deflector power supply so that the ion source anode supply voltage is cut off when the deflector power supply circuit breaker opens.

Deflector Positioning Mechanism

Deflector spacing and angle are remotely adjustable from the control console. Position indicators are mounted over the operating switches. They have linear numerical scales which can be referred to simple charts to obtain scales of inches and degrees. These do not indicate spacing and angle with respect to the septum, however, since the septum is also movable.

Care must be exercised when moving the deflector in, or changing the angle in large increments, that the deflector does not contact the septum and cause excessive stress in the mechanism. When preliminary adjustments are being made an observer should be stationed at one of the chamber ports where he can see the deflector, report its movement over the communications system, and caution the operator if it approaches the septum too closely. During operation of the cyclotron, adjustments are normally made only in small increments and it is sufficient to observe the effect on the beam. If there is no beam, the deflector voltmeter should be watched carefully, and further movement towards the septum stopped at the first signs of excessive sparking.

The deflector thermistor indicator should be watched during deflector adjustments (both position and voltage adjustments), if there is a beam circulating, to note any signs of excessive bombardment of the deflector by the beam.

Septum Tips

CAUTION When adjustments of dee and ion source positions are being made to optimize the beam, it is necessary to provide a telescope and mirror system, or closed-circuit television, so that an observer can watch the entrance notch in the septum tip. It is possible to melt away a portion of the notch without any indication at the control console if a maladjusted beam strikes one spot for more than a few seconds.

Septum Cooling System

Operation of the septum cooling system is entirely automatic. Cooling water circulates at all times when the cyclotron master switch is closed and the main water pump is operating. The flow switch and the contact-making thermometer in the septum return line will shut down the ion source anode if the flow ceases or if the temperature of the outlet water becomes abnormally high.

Septum Positioning Mechanism

The septum position can be adjusted by means of the mechanism linking the exit end of the septum to the right dee structure. The operating key is normally retracted from the dee and hangs from a hook outside the chamber with only its inner end in the flexible vacuum seal. There is a clamp around it next to the seal which prevents it from being drawn into the chamber by the vacuum.

Septum position adjustments are made as follows. Provide a light at the window beside the operating key so the adjusting mechanism in the dee can be clearly seen. Make sure the key is clean and free from nicks or scratches that might damage the O-ring. Apply a very light film of vacuum grease to the surface. Be sure the oscillator is not operating. Lift the outer end from the supporting hook and loosen the clamp, allowing the key to move inward toward the dee. Engage the inner end with one of the sockets on the mechanism, depending on the adjustment desired. The upper socket will move the entire septum in or out as viewed from the entrance end, changing the radius at which the beam enters the septum, but keeping the angle constant between the septum and the beam. Turning the key clockwise will move the septum inward. The lower socket will move the exit end of the septum in or out, changing the angle, but not changing the radius of the entrance end. Turning the key clockwise will move the exit end of the septum inward. When adjustments are being made it is well to keep a record of the number of turns and fractions of turns of the key which have been made, beginning the count after having taken up the slack in the worm and gear teeth. After the adjustment is completed, be sure to retract the key, place the retaining clamp firmly in position, and hang the outer end in its hook. During the adjustment it is well to have some one watching the chamber vacuum indication, and, if any rise in pressure occurs, to check the key seal and be sure it has sufficient vacuum grease in it.

III. MAINTENANCE

Deflector Power Supply

The attached instructions, GEI 29325, describe all maintenance procedures likely to be required by this equipment.

Deflector Cable, Pothead and Insulators

No maintenance attention is required by the cable. If it should be necessary at some time to replace the cable, the normal handling procedures for high voltage cable should be used. GEI 32351 gives instructions for installing the entrance pothead on the cable.

No maintenance attention is required by the entrance pothead. If it should be broken at some time during work on the cyclotron the above instructions will cover replacement. If the dees are to be removed from the vacuum chamber, it is necessary first to remove the entrance pothead from the back section of the chamber and set it on a temporary cradle just ahead of the back section. The cradle and lifting brackets are provided with the cyclotron. There is sufficient flexibility in the cable to accommodate this movement without disturbing the cable mounting in the pothead. Before lifting out the pothead, see that the resistor between it and the deflector control rod assembly has been removed. Care must be exercised to avoid damage to either of the mating surfaces or to the O-ring gasket between the pothead flange and the chamber. When replacing, be sure the surfaces and O-ring are clean and covered with a film of vacuum grease.

The 2-megohm resistor between the inner terminal of the pothead and the deflector control rod assembly will have an indefinitely long life during normal operation of the cyclotron. If the deflector is allowed to spark frequently for extended periods the resistor may heat and eventually be destroyed. To replace it the vacuum chamber must be opened to air and the port at the back removed. One can then enter the chamber, remove the defective resistor and install a new one. Be careful to restore the electrostatic shield to its original position when installing the new resistor. When entering the chamber, a clean smock and a protective cap should be worn. Suitable precautions should be taken to check the radioactivity level in the chamber before entering.

The insulating spiders which support the deflector control rod assembly at the center of the right dee stem will not deteriorate and will not need replacement unless they suffer accidental breakage during some other maintenance operation.

The pedestal insulator which supports the deflector and the inner end of the control rod assembly will have an indefinitely long life under normal operating conditions. If, however, some abnormal condition causes it to fail, it can be replaced from within the cyclotron chamber. Remove the chamber entrance manhole in the oscillator house and the right side port opposite the deflector. Observe all necessary precautions for radiation safety. Raise the deflector off the insulator as high as possible without stressing the control rod assembly abnormally, and temporarily block it there. Be sure the blocking and the bars used to raise the deflector are scrupulously clean and leave no grease film on the deflector parts. Enter the chamber through the oscillator house, wearing clean coveralls, head covering, clean socks but no shoes, and clean cotton gloves. Remove the clamps on the upper cover of the right dee transition section and raise the cover at the forward end as high as the flexible tubing permits and block it in the raised position. Be sure all tools and blocking materials are clean. Then with a length of stiff wire having a large hook on one end, carefully fish the damaged insulator back through the opening under the transition section cover. The insulator rests in a slight recess in the dee and must be raised or tilted slightly to remove it. The damaged insulator may be very radioactive and must be handled with adequate safety precautions. The new insulator must be clean and completely free of any grease film or other surface contamination that might induce surface flash-over. It can be pushed in place by means of the hooked wire and a light rigid bar. Be sure it is correctly oriented and seated. Lower the deflector carefully onto the insulator, making sure the control rod assembly seats properly in the saddle on top of the insulator. Lower the transition section cover and replace the clamps. Leave the chamber, making sure all tools and materials are removed, and replace the oscillator house manhole. Replace the right side chamber port. Make sure the O-rings are clean and greased and the sealing surfaces are clean and greased when replacing ports.

Deflector Cooling System

The toluene pump shaft seal requires periodic attention maintenance. The pump should be observed occasionally for toluene leakage, and when any leakage occurs, the packing nut may be tightened with the fingers a maximum of one-half turn or a small amount of Garlock lubricating paste (Compound No. 3) added through the alemite fitting. When the packing nut has finally been taken up to its limit and the gland requires repacking, drain the system, remove the packing nut, and carefully clean out all the old packing. Provide a 16-inch length of #908 Garlock Packing (string), 3/16 inch in diameter. Inspect the shaft to be sure it is not scored or worn and does not require replacement. Carefully wind in the new packing, working in a little of the lubricating paste with it. Screw up the packing nut until finger tight, remove the plug directly opposite the alemite fitting, and fill the cavity about the packing with Garlock lubricating paste (Compound No. 3) through the alemite fitting until the paste begins to flow from the unplugged hole. To insure filling of the cavity, build up a slight pressure within the cavity by holding a finger lightly over the hole. Replace the plug and refill the system with toluene. Start the pump and run it for about four hours to "run in" the packing. During this period the packing nut may be tightened gradually to seal any leaks that may occur. However, it is important that the packing nut never be fully tightened. During the "run in" period the maximum number of turns should be limited to two full turns. If this is not sufficient to seal leakage, refill the packing housing with the lubricating paste. In any event, the packing housing should be refilled with lubricating paste at the end of the "run in" period. Satisfactory packing operation may be obtained thereafter by occasional maintenance. The extent of the maintenance involved in an addition of lubricating paste or a maximum of one-half turn on the packing nut, or both.

The Buna N rings which seal around the glass insulating tubes in the toluene lines are slowly dissolved by the toluene. It is desirable to replace them at about yearly intervals if the cyclotron is open for other maintenance. See drawing 451C827. If the cyclotron tank is not open for other reasons, these seals may be continued in use until a leak develops. When high chamber pressure indicates a vacuum leak, the presence of the leak in the deflector circuit may usually be confirmed by turning the toluene pump on and off and noting that the pressure varies. The seals are easily changed by draining the toluene from the system and entering the chamber through the round port at the back. The glass tubes should be thoroughly cleaned of any deposit on the inside walls at the same time.

The joints in the toluene passages between the deflector and its supporting bracket are sealed by Buna N "O"-rings. See Drawing 451C834. These also are slowly dissolved by the toluene. Replacement is a difficult task, so, when the deflector is made accessible by other work, the opportunity should be taken to replace these O-rings if they have been in use for a year. To replace these O-rings, it is necessary first to remove the septum, as will be described later. Then, after draining the toluene from the system, the deflector can be disconnected from its supporting bracket by removing the single attaching screw, and then removed from the dee with the special handling tool provided. It will undoubtedly be highly radioactive and must be handled with extreme caution.

Deflector Positioning Mechanism

This mechanism, Drawing TT9671968, is completely enclosed and packed with lubricant for long life without attention.

Septum Tip

With normal operation and care the septum tip will have an indefinitely long life. It is possible to damage the entrance notch, however, if the operator fails to raise the deflector voltage before starting to accelerate a large beam, or if the deflector voltage fails through sparking or other cause while circulating a large beam. Maladjustment of the ion source or dee positions may also cause damage.

It is necessary to remove the septum from the chamber in order to change the tip. This may be done as follows, bearing in mind that the parts are very radioactive and all radiation safety precautions must be observed.

Drain the water from the right dee system. Apply light air pressure to make sure nearly all the water is out.

Bleed the chamber up to atmosphere and remove the right diagonal chamber ports and the left diagonal port.

It may be desirable for convenience to remove the first section of the beam pipe between the cyclotron and the focus magnets.

Remove the ion source filament stem and retract the ion source on the temporary carriage used for ion source removal until the hood end is within the recess at the front of the chamber.

Lower the right dee to the floor of the chamber and raise the left dee to the ceiling.

Disconnect the septum cooling tubes, taking care not to damage the flexible metal tubes or the connectors, and provide clean rags to absorb any water which may drip from the open ends.

With a long screw driver turn the upper septum positioning shaft clockwise to its limit, pulling the septum entrance end inward. Similarly, turn the lower shaft clockwise, moving the exit end inward until the pinion runs off the rack.

Push the exit end a little farther inward and then slide the entire septum forward, disengaging it from the notches at the entrance end.

Carefully work the septum out of the right dee onto the floor of the chamber under the left dee, and from there out the left diagonal port.

The septum tip may be taken off by removing two screws which hold it to the septum rails and sliding it out of engagement.

The new tip as furnished may not have an entrance notch. If so, cut the notch to the desired shape and depth before putting the tip on the septum.

Inspect the water connectors of the new tip, provide new O-rings and apply vacuum grease.

Carefully put the new tip in place, making sure the connectors are fully engaged and are not wedged, and put in the retaining screws.

Replace the septum in the right dee, reversing the procedure described for removing it.

Inspect the water connectors and their O-rings. Supply new O-rings if necessary, and apply vacuum grease. Engage the connectors.

Adjust the septum to its original position in the dee, and return the dees to their operating positions as shown by the position indicators.

Return the ion source to its original position. Put in the filament stem (first putting on a new filament if necessary) and make all connections to the ion source.

Close up the vacuum chamber and begin pumping it down.

Replace the beam tube.

Septum Cooling System

The septum cooling system requires no periodic maintenance. The water connectors at the septum and septum tip will not deteriorate for indefinitely long periods if not disturbed. They should be carefully inspected at any time they may be disconnected. The flexible bellows-type tubes leading to the septum must be treated with care whenever it is necessary to handle them, as they are easily damaged.

Septum Positioning Mechanism

This mechanism is designed to operate without lubrication. It should be used as sparingly as possible, however, as there is a tendency for the bearings to bind when operated in the vacuum.

INSTRUCTIONS GEI-29325

DC DEFLECTOR POWER SUPPLY EQUIPMENT

- Rated -

Input

Single-Phase, 120 Volts, 60 Cycles

DC Output

140,000 Volts, 15 Milliamperes

Serial Numbers

8978266 Rectifier Unit
9595857 Relay and Contactor Panel
9596245 Voltmeter Multiplier Unit

FOR

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CLEVELAND AIRPORT

CLEVELAND, OHIO

G-E REQUISITION XCL-193000-2

APPARATUS DEPARTMENT

GENERAL ELECTRIC COMPANY

SCHENECTADY, N.Y.

January 1950 Printed in U.S.A.

REFERENCES

Photographs

Instruction Books

Drawings

INTRODUCTION

Reference must be made to the following instructions for installation, operation and maintenance of the DC Deflector Power Supply Equipment shown on the title page of this book.

This equipment is for indoor operation in power supply service. The equipment is designed to supply a negative polarity d-c voltage output with a continuous range in voltage from approximately zero to 140,000 volts from a 120-volt, 60-cycle source of supply. Full power output of the equipment can be obtained continuously without exceeding a 55C rise when the starting temperature of the equipment does not exceed an average room temperature of 30C maximum.

The power supply equipment consists of the following principal parts:

1. Rectifier Unit with the main transformer, two filament transformers, voltage doubler capacitors, and voltmeter multiplier resistors mounted in a common oil-filled tank and the KC-4 kenotron tubes installed in sockets on insulated bushings on the tank cover;
2. Relay and Contactor Panel with the motor-operated induction voltage regulator for controlling the voltage applied to the low-voltage winding of the main rectifier transformer, voltage stabilizer, overload relays, contactors, and other miscellaneous power supply control devices;
3. Discharge Switch and Resistance for automatically grounding and discharging the high-voltage d-c circuit when the equipment is de-energized; and the
4. Series Resistor for limiting the d-c load current.

RECEIVING HANDLING AND STORAGE

Upon receipt of this equipment, make a thorough inspection for any damage which may have occurred during shipment. Check all wiring connections, mechanical parts, and bolted connections. Make any necessary adjustment of parts and tighten any loose connections. Evidence of damage or rough handling enroute may require reference to the nearest District Office or to the Pittsfield Works of the General Electric Company for advice before proceeding with the installation.

To facilitate handling of the equipment, eyebolts are provided on the rectifier transformer and on the contactor and relay panel for lifting these units.

If for any reason the equipment cannot be installed upon arrival, store all parts in a clean, dry place to avoid rusting or damage.

The rectifier transformer was shipped oil-filled. Before placing the equipment in operation, refer to GEI-23200, "Oil Insulated Testing Transformers", for information on the inspection and the testing of oil samples. Samples may be obtained by removing the air vent in the cover of the rectifier transformer tank, inserting a thief tube, and drawing oil from the top and bottom oil levels. Check the oil level in the tank and note that the oil level should be approximately 1-1/2 inches below the cover at 25C. If the oil in the unit shows evidence of moisture or tests less than 22 kv, the unit must be dried and the oil filtered to bring it up to the recommended dielectric strength.

The accuracy of results obtained when testing the oil samples will be seriously affected if the samples are not obtained in the right manner and properly cared for until tested. Therefore, the following important points, which experience has indicated as essential in obtaining reliable results, should be strictly adhered to:

a. Thoroughly clean with non-leaded gasoline all containers and accessories used for sampling to remove all traces of acid, alkali, and moisture. Then dry them thoroughly.

b. Use glass container, so that if any water is present it may be readily observed. If metal containers are used, be sure that they are free from rust and solder.

c. Use no rubber or composition of rubber for gaskets or stoppers.

d. Before pouring the sample into the containers, rinse out the containers two or three times with the oil from which the sample is taken in order to remove any moisture which may have collected. Do not mix these rinsings with the oil samples.

e. Carefully seal the containers to prevent leakage and exposure of the oil to the atmosphere.

f. Each container should be tagged, showing the rating and serial number of the transformer and whether the oil was taken from the top or bottom of the tank.

g. When pouring the oil sample into the testing receptacle, pour it slowly so that no air bubbles form, and fill the receptacle to overflowing. After filling, gently jar the receptacle before each shot to dislodge air bubbles or carbon particles from the electrodes.

h. Agitate the sample gently before each filling to prevent variations in results due to the oil settling in the container.

c. KC-4 Kenotron Tubes. Refer to appended instructions for technical information.

d. Voltage Doubler Capacitors cat. #14F31, 0.1 microfarad.

e. Voltmeter Multiplier Resistance rated 150 megohms, 1.0 milliampere d-c and consisting of (10) resistor racks of 15 megohms each. Each resistor rack made up of (8) type BT-2, 560,000-ohm I.R.C. resistors and (17) type BT-2, 620,000-ohm I.R.C. resistors.

f. Charging Resistance rated 15,000 ohms, product of Ward Leonard Electric Company.

3. Induction Voltage Regulator

Type AIRS, form M, 1.57 kva, 60 cycles, 120 volts, 13.1 amperes, 100% buck or boost, motor operated by 120-volt, 60-cycle motor.

4. Contactor and Relay Panel Components

a. Filament Supply Contactor type CR-2810-B11AC1A-2 rated for 120-volt, 60-cycle control.

b. Main Contactor type CR-2810-D11AA1B-2 rated for 120-volt, 60-cycle control.

c. Auxiliary Relay for Discharge Switch type CR2790-E100B2 rated for 115-volt, 60-cycle control.

d. A-c Time Delay Overload Relay type 12 PAC12A10, hand-reset, calibration range 10 to 30 amperes, set to trip at 15 amperes after three seconds.

e. A-c Instantaneous Overload Relay type 12 PAC11A12, hand reset, calibration range 20 to 60 amperes, set to trip at 25 amperes.

f. Time Delay Relay for Resistor Shorting Relay, Cat. #TC-60S-SPST product of RW Cramer Co., rated 115 volts, 60 cycles, set for 60 second time delay.

g. Resistor Shorting Relay type CR-2790-E100 B2, rated for 115-volt, 60-cycle control.

h. Resistor type CR-9033-C rated 2.7 ohms, 12.6 amperes with an adjustable tap terminal.

i. Resistor type CR-9033-6 rated 9.9 ohms, 6.56 amperes.

j. Voltage Stabilizer cat. #69G100, rated for 95 to 130 volts input, output 115/120/125 volts depending upon terminal board link connections.

A 1/4-20 steel screw and hex nut located on the side of the kenotron socket is provided for tightening the socket about the kenotron tube socket terminals.

The transformer is of the cover suspended type of construction. The core and coils can be removed by removing the bolts holding the cover to the tank and using the eyebolts on the cover for lifting the transformer from the tank. Do not remove or loosen the nuts located within the outer bolt rectangle of the cover or the (2) eyebolts on the cover while the transformer is assembled in the tank as serious damage may result to the transformer.

Induction Voltage Regulator

The induction voltage regulator, for regulating the voltage applied to the main rectifier transformer low-voltage winding, is mounted on the contactor and relay panel unit. It is designed for 100% buck or boost of the power supply voltage. By this means, the supply voltage can be reduced to approximately zero and gradually increased from zero to approximately twice the supply voltage of 120 volts applied to the equipment to give the rated output voltage of 140,000 volts.

The regulator is operated by a 1/40 horsepower, 1000 R.P.M., 120-volt, single-phase, 60-cycle, capacitor-type motor. Power for the motor is supplied from the user's 120-volt control circuit. A "Raise and Lower Switch" provided in this circuit controls the operation of the motor. Limit switches operated by a cam on the regulator rotor open the power supply lines to the motor when the regulator has reached its maximum or minimum voltage position.

Refer to the Diagram of Connections K-5239574 and to the Elementary Diagram P-9814147 for the regulator connections. For further details of the induction voltage regulator, see appended Instructions GEH-1085.

Relay and Contactor Panel

The relay and contactor panel is provided as a separate unit for mounting the various control devices and miscellaneous components of the power supply equipment.

Refer to the Outline Drawing M-9806941 for the devices mounted on the panel. The wiring of the contactor and relay panel is shown on Wiring Diagram P-9814153. Interconnection Diagram M-9806985 shows the interconnections of the panel with the other components of the equipment.

OPERATION

Principles of Operation

Refer to Elementary Diagram P-9814147 for the devices listed below and for the elementary circuit of the power supply equipment.

The power supply equipment is designed to provide a negative polarity, d-c high-voltage output that can be varied continuously from approximately zero to the rated voltage of 140,000 volts from a single-phase, 120-volt, 60-cycle source of supply.

The range in voltage variation is accomplished by means of an induction voltage regulator shich is used to control the voltage applied to the main transformer low-voltage winding. The regulator unit is designed for 100 per-cent buck or boost of the source of power supply and is motor-operated. Control power for the regulator motor is to be provided from the user's 120-volt, 60-cycle source of supply.

The filament supply for the KC-4 rectifier tubes is obtained from a 2 kva constant voltage transformer connected through a filament contactor across the 120-volt, 60-cycle source of supply. The filament supply contactor (42DF) is controlled by means of a remote filament supply contactor control switch (42DFCS). A variable resistor in the filament circuit is provided for adjusting the filament voltage. This resistor has been adjusted at the factory and should require no further adjustment. The 9.9-ohm resistor in the filament circuit is provided to reduce the filament voltage to approximately half rated voltage during starting. A resistor shorting relay is provided for shorting this resistor after starting. Energizing of the resistor shorting relay is controlled by a remote time delay relay. The control circuit for the tube filaments is so arranged that the filament circuit will remain energized in case the d-c high-voltage output circuit is tripped by operation of the main transformer contactor control switch (42DACS), functioning of either of the overload relays, or by opening of any other contacts in the main contactor interlock circuit. In case the power supply equipment is to be shut down and then operated again within a two hour period, it is recommended that the filament circuit be left energized during such a stand-by condition.

Leakage type kilovoltmeters are provided to read the d-c voltage output of the equipment. The meters are to be connected in series with the 150-megohm voltmeter multiplier resistors across the high-voltage d-c output so that the meter deflections will be proportional to the current through the meters.

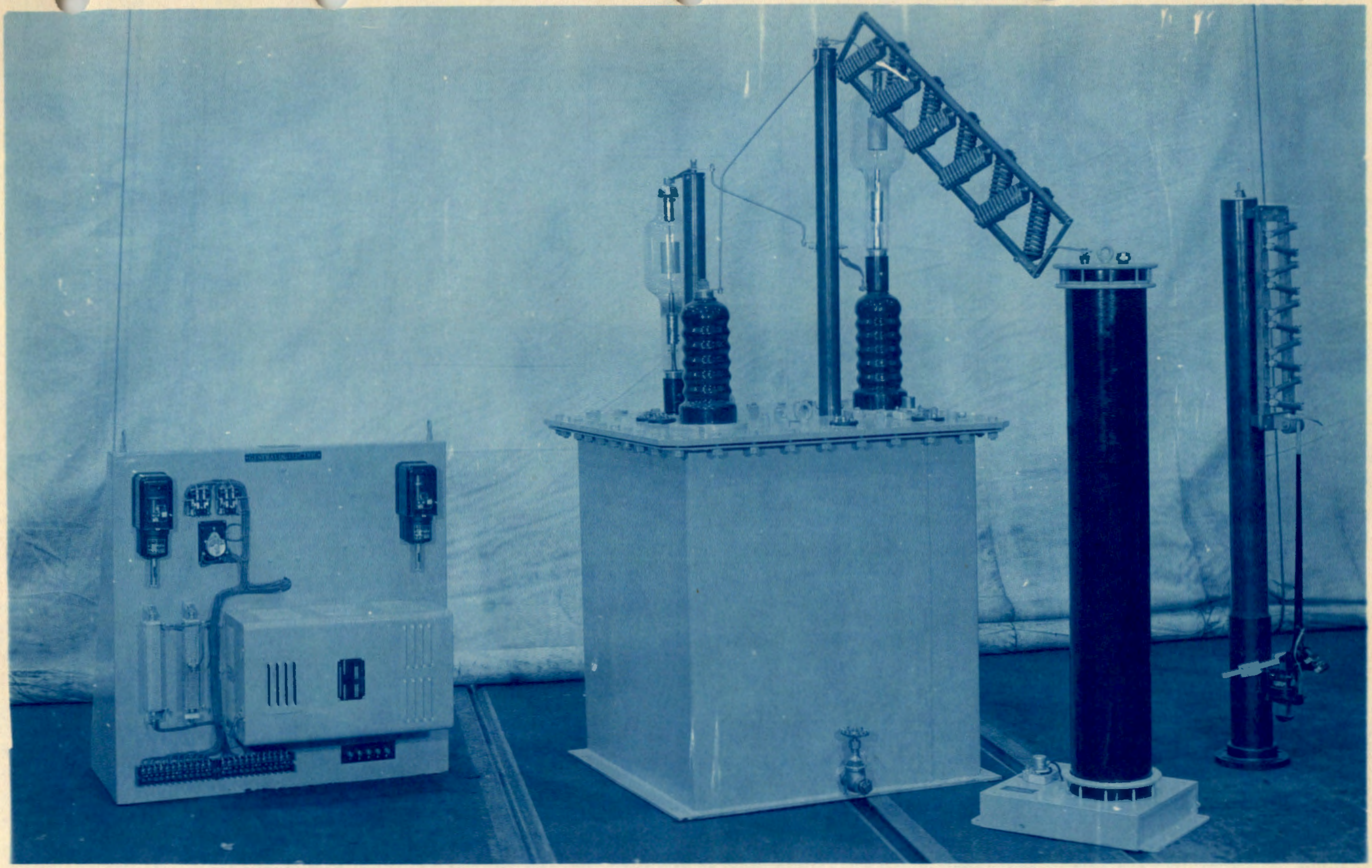
When time delay relay (48D) is energized, it begins its timing out action after which it closes its contacts in the resistor shorting relay circuit to energize relay 48DX.

Energizing of the constant voltage transformer supplies a constant voltage to the filament transformer circuit for the KC-4 rectifier tubes. Relay contacts 48DX close to short out the 9.9-ohm resistor, which is used to reduce the filament voltage to half value during starting, when the resistor shorting relay (48DX) is energized.

Momentarily closing the remote main transformer contactor control switch (42DACS) will energize the auxiliary contactor (29DX) through the normally closed contacts of the a-c overload relays ($51DA_1$ and $51DA_2$), the closed contacts of the filament supply contactor (42DF), and the closed contacts of the resistor shorting relay (48DX). The energizing of the auxiliary contactor (29DX) will close its contacts to complete the circuit to the discharge switch solenoid, which when energized will close contacts in the main transformer contactor interlock circuit to energize the main transformer contactor (42DA) and also open the discharge switch normally closed contacts in the output circuit to remove the short circuit and ground from the line. The main transformer contactor (42DA) when energized closes its contacts in the interlock circuit to lock itself in and in the supply lines to the induction voltage regulator and the main transformer to energize the regulator and the transformer.

Operating of the remote regulator control switch to the RAISE or LOWER position will complete the circuit through the corresponding limit switch to the regulator motor. The regulator will be operated in a direction to raise or lower the voltage applied to the main transformer. Limit switches on the regulator prevent the regulator overrunning its end positions.

Momentarily moving the remote main transformer contactor control switch (42DACS)or the remote filament supply contactor control switch (42DFCS) to the TRIP position, functioning of either of the a-c overload relays, or opening of any of the user's contacts in the main contactor interlock circuit will open the main contactor contacts, discharge, and ground the d-c output circuit.



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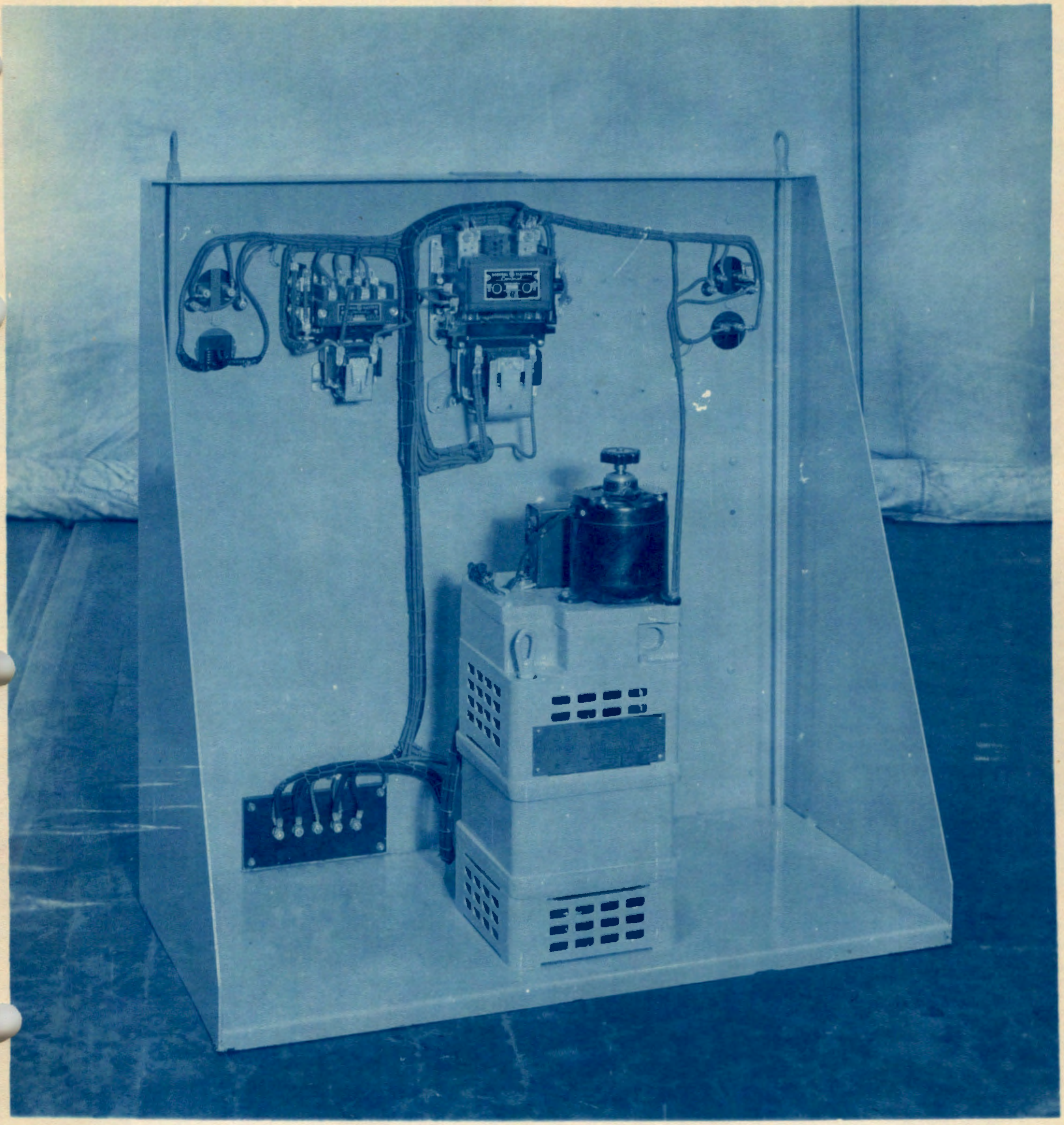
Transformer and Allied Product Divisions

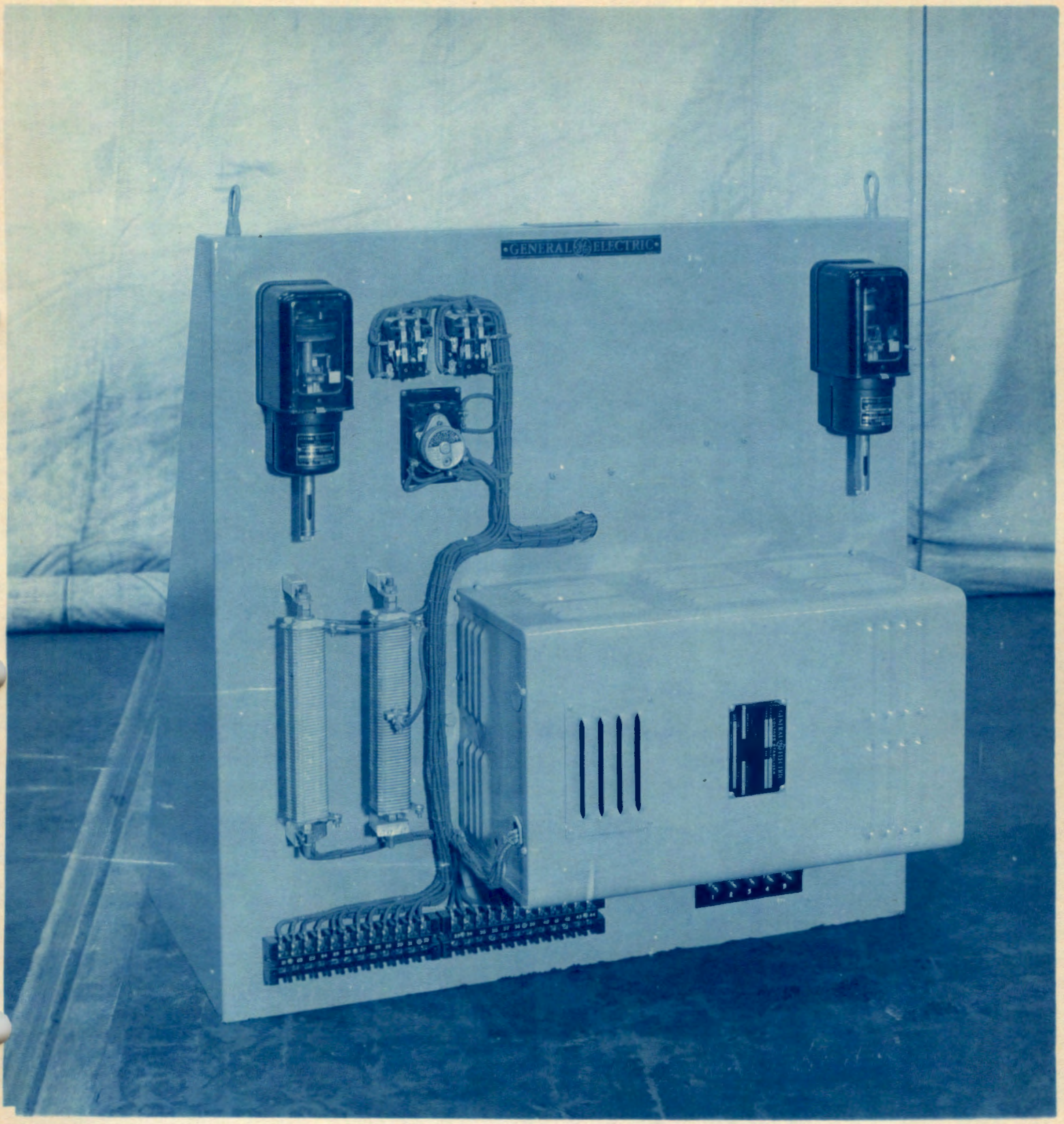
G-E RECTIFIER EQUIPMENT DL-9512169 RATED 140 KV - .015 AMPERES D.C. GROUP PHOTOGRAPH SHOWING COMPLETED EQUIPMENT.
PO-723584 1-30-50



30I4240 G-E RELAY AND CONTACTOR PANEL FOR DL-95I2I69. REAR VIEW SHOWING INDUCTION VOLTAGE REGULATOR.

PO-723584 I-30-50

Transformer and Allied Product Divisions



30 14241 G-E RELAY AND CONTACTOR PANEL FOR DL-9512169. FRONT VIEW.
PO-723584 1-30-50

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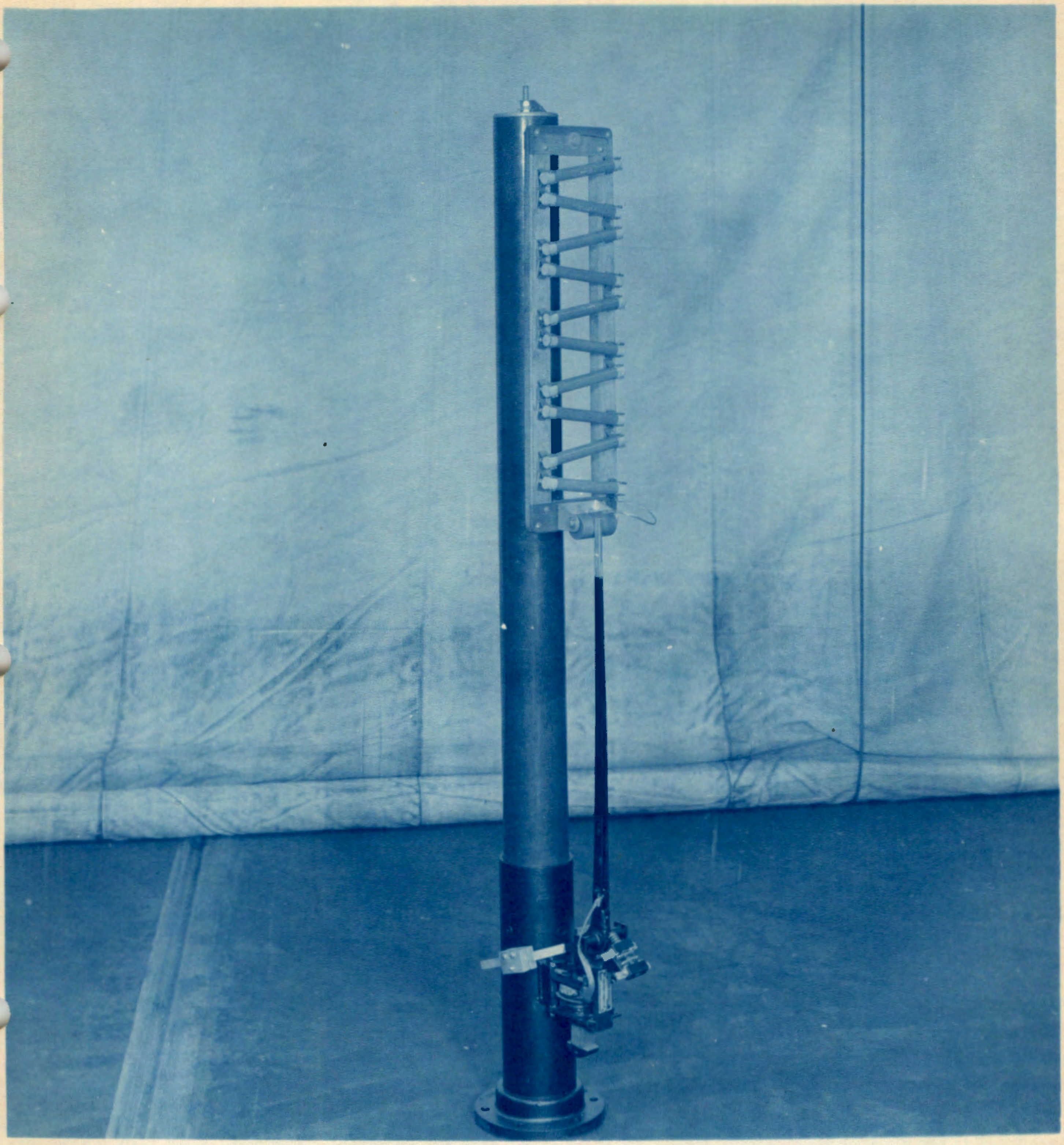
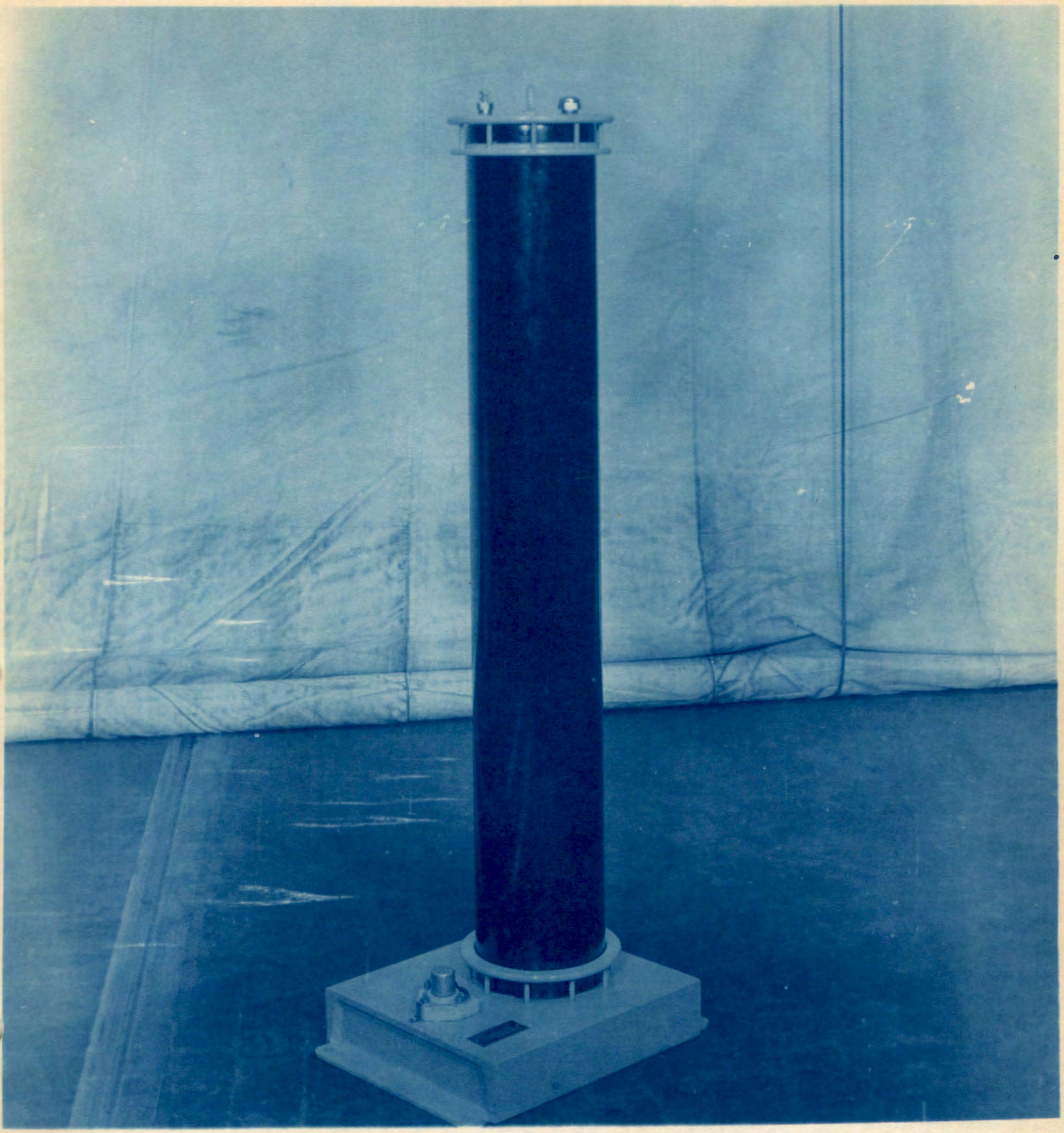


3014242 G-E DISCHARGE SWITCH FOR DL-9512169, RATED 140 K.C.

PO-723584 1-30-50

Transformer
and Allied Product
Divisions



Transformer
and Allied Product
Divisions

30 14243

G-E VOLTMETER MULTIPLIER RESISTANCE P-9535697 G1.
RATED 150 MEGOHMS ONE MILLIAMPERE D.C. USED WITH
140 KV D.C. POWER SUPPLY DL-9512169.
PO-723584

1-30-50

External Beam Equipment

I. DESCRIPTION

The equipment consists of four major components, as follows:

A. A shield tube, which extends into the target chamber to receive the beam from the cyclotron. It provides a region free from fringing field between the target chamber and the focusing magnets.

B. A pair of quadripole focusing magnets which receive the diverging beam and converge it toward a spot farther down the path. These magnets can control the direction of the beam path center only over a small angle.

C. An adjustable slit-diaphragm, which limits the boundaries of the beam passing through it, thus providing a beam of definite size and shape for the deflector magnet.

D. A deflector magnet through which the beam passes after it has come from the slit diaphragm. The deflector magnet bends the beam path in a horizontal plane through an angle of 44 degrees and focuses it to a small spot in another room.

Associated with these components are a system of pipes and couplings and a vacuum chamber for the deflector magnet, with a vacuum pump.

Shield Tube

The part of the shield tube inside the target chamber is a rectangular box structure of low-carbon steel with thick sides. A water-cooled aluminum shield placed just ahead of the box prevents bombardment of the iron parts and permits entrance of the beam only into the opening. The entrance end of the box is cut at a sharp angle, which tends to reduce the horizontal divergence of the entering beam and concentrate more of it into the restricted opening of the quadripoles. This piece is connected, outside the target chamber plate, to a thick-walled iron tube by means of a bellows and a telescoping tubular iron shield, to provide flexibility, vacuum tightness, and complete shielding. This tube extends about four feet along the beam path to a point where further shielding is not required.

At the end of the iron tube, there is a chamber containing a carbon disk with a round opening, which limits the beam to a cross section which will pass through the quadripoles.

Beyond this, there is a diaphragm divided into four insulated quadrants with electrical connections brought out, so that the portion of the beam falling on each can be measured. The position of the quadrants should be adjusted so that opposite quadrants receive about equal beam currents and so that the opening in the diaphragm is centrally located in the beam. A vacuum valve is connected between the diaphragm chamber and the tube through the quadripoles, in order that vacuum may be maintained in this section of the system while the rest of the system is open for target changing.

Quadripoles

The quadripole magnets rest on a steel plate near the end of the shield tube and one leg of the cyclotron magnet. They are provided with adjustable sub-bases so that each can be moved vertically, horizontally, and axially. Each quadripole consists of a circular yoke with four inwardly projecting poles, each pole carrying a magnetizing coil. The inner ends of the poles are given a hyperbolic contour and are spaced apart so as to admit a tube, two inches in diameter, between them. Opposite coils are connected so that one pair magnetizes toward the center while the other pair magnetizes away from the center. The pole axes are 45 degrees to the vertical and horizontal. The resultant field is zero at the center of the opening. The horizontal field component increases from zero in one direction with distance above center and increases from zero in the other direction with distance below center. Likewise the vertical field component increases from zero in one direction with distance to the left of center, and increases from zero in the other direction with distance to the right of center. The effect of this field on the beam is to converge it in one plane and diverge it in the perpendicular plane, while the center path of the beam is undiverted.

The quadripoles are connected so that the first one converges the beam in the horizontal plane and diverges it in the vertical plane, while the second one does the opposite. The net result is to converge the beam in both planes. A thin-walled aluminum tube is coupled to the vacuum valve by a slip coupling and passes through both quadripoles, after which it is bolted to the larger tubing of the rest of the system.

The four coils of each quadripole are connected in series and are energized by a d-c power supply, labeled "focus magnet power supply", located at the left of the control console. The power supply output is readily adjustable from zero to the maximum the coils can carry continuously, and is indicated by an ammeter located on the panel. The two power supplies are interlocked with the cyclotron magnet so that they can be turned on only when the magnet is on.

In order to provide a slight control of the beam direction, an adjustable shunt is provided for either the left or right pair of coils on the first quadripole and another for either the upper or lower pair of coils on the second quadripole. By shunting the left pair of coils, their field is weakened and the beam is deflected slightly to the left; by shunting the right pair of coils, the beam can be deflected to the right. In like manner, by shunting either the upper or lower pair of coils of the second quadripole, the beam can be deflected upwards or downwards. The shunt resistors are located behind a panel at the left of the control console with a series of switches labeled UP, DOWN, LEFT, RIGHT, and two adjustable rheostats for fine control. It was attempted to locate the equipment accurately in the beam path without any shunts being used, so it is not likely that they will be required in many instances.

Diaphragm

The adjustable slit-diaphragm is housed in a vacuum-tight chamber coupled into the beam piping system. It is located between the quadripoles and the deflector magnet, at a point where the beam can be focused upon it by the quadripoles and at the proper distance from the deflector magnet to permit an image of the slit to be focused at the target. It consists of four carbon plates, two of which open and close vertically to form the top and bottom of the slit, and two of which open and close horizontally to form the sides of the slit. The mechanism supporting the plates is on the exit side of the slit and shielded from the beam by the plates themselves. Both vertical plates are adjustable from outside the chamber by knobs which are marked in millimeters. The right horizontal plate is also adjustable from outside the chamber and is marked in millimeters. The entire slit assembly may be moved horizontally by a motor-driven cam outside the chamber; it may also be operated remotely from the control console. A millimeter scale on the chamber provides indication of position, but does not indicate remotely at the control console. The maximum slit opening is 2 cm high by 2 cm wide. Any size opening within these limits can be obtained.

Deflector Magnet

The deflector magnet is a double-yoke electromagnet similar to the main cyclotron magnet, but on a much smaller scale, in which the poles, instead of being circular, are sector-shaped. The sector covers an arc of 41 degrees at the inner radius of 24 inches. This deflects the center of the beam 44 degrees horizontally (to include the fringing field beyond the ends of the sector). The ends of the sector are cut at an angle to the radius such that both vertical and horizontal focusing is provided, and an image of the slit is focused on the target plate. Since the beam contains components of slightly differing energies, they will not all be focused into the same image on the target, but will be dispersed horizontally depending on the difference in energies.

The magnetizing coil on each pole is wound to conform to the shape of the pole. The coils are wound of rectangular hollow conductor in several sections. The sections are all connected in series electrically, but in parallel, through plastic tubing, to water manifolds for cooling by treated water from the main magnet cooling system.

The power supply for the deflector is located in the machine room. It consists of a 30-hp synchronous motor and a generator rated at 340 amperes at 50 volts d-c. Excitation for the generator is supplied by an electronic regulator located in the control room wall at the left of the control console. The regulator serves to maintain the deflector magnet current at the desired level.

An aluminum vacuum chamber is supported between the poles. At the entrance end it is bolted to the beam pipe system coming from the slit diaphragm. At the exit end it is bolted to two pipes. One extends straight through the shield wall in the direction of the undeflected beam. The other extends through the shield wall at an angle of about 44 degrees from the direction of the undeflected beam. An observation port is provided on the side opposite the deflected beam pipe.

II. OPERATION

Shield Tube

Once the shield tube system is adjusted to the correct position, no further attention need be paid to it during operation. The vacuum valve at the end of the system may be closed to maintain tank vacuum in the shield tube while the rest of the beam tube system is open to the atmosphere. CARE MUST BE EXERCISED THAT THE SYSTEM IS PUMPED DOWN AND THIS VALVE IS OPEN BEFORE ATTEMPTING TO PASS A BEAM THROUGH. There is no automatic interlock to prevent turning on the beam with this valve closed. Prolonged bombardment of the closed valve would cause damage to the gate and to the O-ring against which it seats.

Total beam current falling on the four sectors of the round carbon diaphragm can be read on one of the galvanometers, labeled "aperture current", in the metering panel above and to the left of the control console. The differential current between either the vertical or the horizontal pair of sectors can also be read.

Quadripole Magnets

Current for the two quadripole magnets is controlled at the control console by the two power supplies labeled "focus magnet power supplies", and the shunt panel. The power supplies can be turned on only when the main cyclotron magnet is on. The optimum current for each quadripole depends upon the size of the adjustable slit opening, and whether the beam is being deflected down the 44-degree pipe or is going down the straight-through pipe with the deflector magnet un-energized; the two quadripoles interact with each other, so both currents must be adjusted together.

The optimum current adjustment is usually that for which the total beam current falling on the diaphragm quadrants is a minimum and the differential currents between the two quadrants of the horizontal pair and the two quadrants of the vertical pair are minimum. The horizontal differential current should be adjusted at the beginning of a run by moving the slit assembly to one side or the other. After a run is in progress and it is not desired to move the slit, a balance can be maintained by adjusting the horizontal shunt current. The vertical balance can be maintained by adjusting the vertical shunt current. These adjustments will be found to be quite stable. The horizontal balance will require readjustment if dee voltage is changed.

The quadripole currents may gradually decrease and require readjustment for a time after starting until steady operating temperature is reached.

Adjustable Slit Diaphragm

The two knobs placed one above the other at the end of the slit chamber vary the vertical slit opening. The numbers marked on the knobs indicate the distance in millimeters that the quadrants are moved up or down from the center. The total opening is equal to the sum of the readings of the two knobs. The third knob, which moves a small rack in or out, adjusts the position of one horizontal quadrant. The other horizontal quadrant is fixed. The horizontal opening in millimeters is equal to the reading of the knob. Since only one horizontal quadrant moves, it is necessary to move the entire slit assembly in the opposite direction, in order to keep the slit horizontally centered when its width is changed. Horizontal motion of the slit assembly must be accomplished from the control console, where the slit horizontal motion switch is located. The adjustment is usually made from this point by using this switch and watching the differential horizontal slit current. The position of the slit assembly can be ascertained by reference to the scale at the side of the slit chamber. Zero on the scale corresponds to the extreme left position of the assembly. Both inches and millimeters are marked on this scale. The motion of the slit assembly has no limit switches, but simply goes back and forth over the entire range if the switch is held closed.

Deflector Magnet

The master switch on the control console must be on before the deflector magnet m-g set can be started. The set stops when the master switch is turned off. It must be started from the panel in the machine room after the master switch is on. Turning the master switch on also starts the main water pump and establishes cooling water flow in the deflector magnet coils.

The power switch of the current regulator (for operation of current regulated power supply, see the included Alfred Electronics instruction manual) must be turned on a few minutes before current is desired in the deflector magnet. Then, with the m-g set running, the magnet current can be brought to the desired value by operating the current control on the regulator panel. The current necessary to deflect the beam into the 44-degree pipe is about 310 amperes. This should be determined quite accurately as soon as possible after final installation of the magnet and kept on record so that it can always be set at the correct value before turning the beam on. This will minimize the amount of bombardment received by the wall of the deflected beam tube and the vacuum chamber, keeping the induced radioactivity of those parts at as low a level as possible. While adjusting the current to determine its optimum value, a small beam current should be used.

III. MAINTENANCE

In all maintenance and service to the equipments which are in close proximity to the beam of the cyclotron, extremely dangerous radiation hazards exist. These are from induced radioactivity in the equipment itself. Proper radiation safety precautions must be observed and adequate monitoring and handling safeguards must be employed in order that contamination and/or overexposure of personnel is avoided.

Shield Tube Assembly

No maintenance is required for the shield tube parts. They are stationary and not subject to deteriorating conditions.

The light plastic hose carrying cooling water to the shield may have to be replaced after long intervals. It should occasionally be checked to see that it has not been hardened by the radiation field. The O-ring seals around the cooling water pipes will last for long periods unless they are disturbed.

The electrical connections to the four quadrants of the carbon diaphragm should be kept tight.

The vacuum valve may require replacement after a long interval, depending on the frequency with which it is opened and closed.

If the assembly is dismantled in order to put other target equipment directly in the beam at this point, care should be taken to mark the position of the plate carrying the entrance end of the assembly, so that it can be replaced in the same position. All O-rings and seal surfaces should be kept clean and free from damage.

Quadripoles

The quadripole magnets will require no maintenance. Keep the electrical connections tight.

It may be necessary occasionally to replace a fuse in the power supplies.

After long intervals it will be necessary to replace the brushes on the variable ratio transformers in the power supplies.

Adjustable Slit Diaphragm

The driving motor and other external moving parts are permanently lubricated and will require no attention for long periods.

The polished surface of the part which moves in and out of the chamber should be kept clean and free of nicks or scratches. A very light film of vacuum grease may be applied to this surface with the part fully extended to the right; at long intervals, depending on the amount of operation, the surface should be cleaned and regreased.

Keep the electrical connections tight.

Deflector Magnet

Only routine maintenance is required for the m-g set, as outlined in the instructions furnished with it.

Keep the electrical and the water connections tight at the magnet.

Regulator maintenance is outlined in the current regulated power supply instruction manual.

IV. SERVICE

Shield Tube

If a water flow light goes on when the operator attempts to turn the cyclotron beam on, check the connections to the aluminum shield in front of the shield tube.

If no beam appears on the slit diaphragm or target when the beam is turned on, but does appear on the round quadrant diaphragm, check the vacuum valve to be sure it is open.

Quadripoles

If current drops to zero on one or the other of the quadripoles, check the fuse in the power supply.

Adjustable Slit Diaphragm

Any trouble which may develop in this device is apt to be quite evident. None need be anticipated over long periods.

Deflector Magnet

If the deflector magnet goes off and a water flow indicator light comes on, check the valves in the cooling water circuit to make sure they are wide open.

Discussion of the regulator is found in the current regulated power supply instruction manual.

Beam Shutter Target

I. DESCRIPTION

The beam shutter target is provided to permit the alignment of the emergent beam. The alignment of the beam is achieved by maximizing the beam current to the beam shutter target. Once alignment is achieved, the beam shutter target is lifted and the beam permitted to enter the external beam equipment. It consists of a water-cooled copper flag or target attached to a copper tube which extends into the tank from the front, just above the path of the deflected beam. When the tube is turned so that the flag extends downward, it intercepts the deflected beam just before it would enter the target chamber. By turning the tube through 90 degrees, the flag is raised to a horizontal position above the beam path.

The copper tube is supported in a brass bearing equipped with an O-ring seal. The bearing is supported in a Lucite plate which covers the end of the air lock chamber, just above the ion source. Since the plate is transparent, it permits observation of the ion source and dees through this opening, even though the shutter assembly is in place. Two small copper tubes inside the supporting tube carry cooling water to and from the flag target. An easily removed coupling is provided at the outer end to permit quick removal of the water connections when it is desired to remove the shutter from the tank. A light, flexible hose connects the coupling to the supply-and-return pipes mounted on the upper magnet coil. Two thermistors are located in the pipes at this point and connected to an instrument circuit at the control console, so that an indication is provided there of beam current falling on the target.

The target is actuated by a pneumatic cylinder which is pivoted to the bottom of the ion source motor box. The piston rod extends downward and is coupled to a crank arm which is clamped around the target support tube, just outside its bearing. Full travel of the piston, from one end of its stroke to the other, turns the target flag 90 degrees. Air is admitted to the cylinder by two solenoid valves mounted inside the motor box and connected to the cylinder by flexible hose, through two openings in the bottom of the box. The building supply of compressed air is piped into the box and connected to the two solenoid valves. The valves are actuated by a switch at the right of the control console. The valves are so arranged that both ends of the cylinder are open when neither valve is actuated, and the shutter can be manually operated for removal or adjustment. When either valve is actuated, it admits air to the end of the cylinder to which it is connected, driving the piston to the other end, and then releases the pressure as soon as the actuating switch is opened. Each valve has an adjustable flow control device between it and the cylinder, which controls the rate at which air is admitted to the cylinder, but permits full exhaust without restriction. The cylinder is provided with cushioning chambers which reduce the shock at each end of the stroke.

II. OPERATION

The shutter is operated by a switch (labeled "shutter") at the right of the control console. It is not interlocked with any other control and may be raised or lowered independently of any other cyclotron control or condition of operation. There is no position indicator associated with it; the desired position can be obtained at will by appropriate operation of the switch, regardless of the previous position. There are water flow and temperature switches in the cooling water circuit which have the function of protecting the beam shutter target from being subjected to bombardment when the flow is shut off or the temperature is too high. These switches are used as permissive contacts in the control circuit for the ion source.

The shutter is employed as a target with which to tune up the cyclotron and get it adjusted for the desired beam. The amount of beam falling on the target is indicated by the thermistor instrument on the control console. Allowance must be made for a short time lag in the response of this instrument because of the heat capacity of the target itself and the time required for the cooling water to flow from the target flag to the thermistor. Changes in cyclotron adjustments such as deflector voltage, or dee voltage, or magnet current, should be made in small increments, with time allowed after each change to permit the effect to register.

After the optimum adjustments seem to have been reached for the beam on the target and the target has been raised to let the beam out into the external beam system, slight readjustment may be necessary to obtain the optimum for the system. All of the beam striking the target will not get into the beam system, and the best adjustment for the portion that does get in may be slightly different from the optimum for the beam shutter target.

The shutter target can be readily removed from the cyclotron if it is desired to use the airlock for some other purpose.

1. Close the valves in the supply and return water lines, closing the supply valve first.

2. Remove the pin holding the water connector in place, and remove the connector. Be prepared for a small amount of water to run from the open ends of the tubes.

3. Remove the pin that couples the piston rod to the crank, and swing the cylinder aside. Screw the pin back in its clevis for safekeeping.

4. Turn the crank to the left until the target flag is upward, and withdraw the flag into the air lock.

5. CLOSE THE GATE, loosen the bolts holding the Lucite plate in place, and bleed the air lock up to atmospheric pressure. Close the bleed valve.

6. Remove the bolts holding the Lucite plate to the airlock flange, and remove the assembly from the air lock. The target flag will, in all probability, be highly radioactive and should be handled with due caution and speed and stored in a hot-storage area.

To replace the assembly, reverse the procedure.

1. Make sure that the airlock flange O-ring is clean and greased, and that the Lucite plate is clean.

2. Place the assembly in the air lock, and put in the bolts holding the Lucite plate in place. Tighten them only gently.

3. Inspect the copper tube extending from the Lucite plate to see that it is clean, free from nicks or scratches, and has a light film of vacuum grease on it.

4. Pump the air lock down with the rough pump, holding the tube to prevent its being drawn in against the gate.

5. Close the roughing valve and open the gate into the tank. Let the target move into the tank until the crank is in place against its bearing. Tighten the bolts holding the Lucite plate in place.

6. Couple the air cylinder to the crank.

7. Put on the water coupling, making sure the water tubes fit correctly into their O-ring seals without binding, and put the pin in place.

8. Open the return and supply water valves, opening the return valve first.

III. MAINTENANCE

Every few months, depending on the frequency of operation, uncouple the crank and piston rod, and withdraw the tube, exposing the surface in the bearing and seal. If necessary clean and regrease.

Occasionally check the condition of the water hoses.

At long intervals it may be necessary to replace the plungers in the solenoid valves, if continual air leakage is evident.

The coils on the solenoid valves will normally last indefinitely in this intermittent service, unless the radiation field should finally damage the insulation. Replacement is readily made.

After a long period of operation it may be necessary to dismantle the air cylinder and replace the O-rings on the piston and piston rod seals. A few drops of light oil may be put in the cylinder occasionally to reduce wear on these parts.

IV. SERVICE

1. The shutter does not operate when the switch is raised or lowered.

   a. Check to see if the building air supply is turned on to the solenoid valves.

   b. Check to see if control power is turned on.

   c. Inspect the cylinder and target to see if it can be moved freely by hand. If not, locate the cause of the binding and free it.

   d. Uncouple the air hoses and see if air comes out when the switch is operated. If not, open the motor box exposing the solenoid valves, and check to see if voltage appears across the coils. If the valve is defective, remove it, and repair or replace it.

2. The shutter operates but does not turn the beam on and off properly.

   a. Check to see that it goes through its full swing when operated.

   b. Check the position of the crank relative to that of the flag, and adjust, if necessary, so that the flag positions are vertically down and horizontal.

3. The target water-flow light remains on, and the beam cannot be turned on.

   a. Check the water-supply and-return valves, and the hoses.

4. There is a vacuum leak which is suspected to be in the shutter target.

   a. Withdraw the target into the airlock, close the gate, and bleed the airlock up to atmospheric pressure. If the tank pressure returns to normal, the leak is in the target. Inspect the O-ring seal in the bearing, clean and grease it. Check the flag and its joint with the tube, to find any leaks there.

Target Chamber Assembly

DESCRIPTION

The target chamber is a vacuum-tight box built into the wall of the cyclotron chamber where the ion beam emerges. There is a vacuum gate at the inner end, through which the beam passes. Its purpose is to provide an air lock which permits changing target equipment without disturbing the cyclotron chamber vacuum, and to provide protection for the chamber vacuum in case of failure of some element of target equipment, such as a foil window. The outer end of the target chamber is a flat aluminum plate with a rectangular opening. Target equipment can be attached to this plate. See outline drawing T-9794991 and assembly drawing TT-8600812.

Vacuum Gate

A light-weight flat plate is pivoted to a supporting arm so that it can swing down and seal to an O-ring carried in the groove around the rectangular entrance opening. The gate is held open by a solenoid, which is operated from the control console. The control circuit automatically closes the gate when the pressure in the chamber is excessive. An interlock switch on the mechanism prevents the beam from being turned on unless the gate is open.

Vacuum Gage

A thermocouple vacuum gage is attached to the target chamber to monitor the pressure in the chamber. The gage circuit components are housed in the vacuum instrumentation cabinet (17-4) behind the control console and give an indication of target chamber pressure. A relay, included in the circuit, automatically closes the vacuum gate when the pressure rises above a predetermined level and prevents it from being reopened as long as the pressure remains above that level.

Vacuum Pumping System

The target chamber is connected to the cyclotron roughing pump manifold through a solenoid-operated valve which is controlled by a switch at the control console. A manually-operated bleed valve is located in the vacuum piping between the solenoid valve and the chamber.

When the beam focusing and extraction system is in place, the target chamber may be evacuated through the beam tube by the vacuum pump at the deflector magnet.

Entrance Diaphragm

The entrance end of the target chamber is protected by a detachable water-cooled aluminum plate. The purpose of this assembly is to protect the entrance wall of the chamber from damage by stray portions of the beam which do not enter the rectangular aperture. All inner surfaces of the cyclotron chamber, including the entrance plate of the target chamber, which may be subject to bombardment by stray ions or to the r.f. field, are sheathed in copper to prevent sputtering of aluminum onto the dee or liner surfaces. Such sputtering, if allowed to occur, would seriously reduce the maximum dee voltage that could be maintained.

The cooling water, supplied from the cyclotron closed-circuit system, is carried to the plate in aluminum tubing through a sealed feed-through fixture in the chamber mounting flange. A water-flow switch prevents the beam from being turned on unless the flow is adequate.

Exit Window and Target

The exit end of the target chamber is machined flat on the outside with a rectangular opening and an O-ring groove around the opening. It is provided with studs by means of which target equipment may be secured to the chamber.

Two target equipment assemblies are supplied. One is a plate supporting a magnetically-shielded channel and flexible bellows connections to the beam extraction and focusing system. This is described elsewhere in these instructions, along with the rest of that system. The other is a plate which supports a foil window assembly through which the beam may be brought out to any target it may be desired to bombard at that point. The plate is shown in drawing 663B373 and the foil window assembly in drawing 451C856.

The foil window assembly consists of a stack of three aluminum rectangular frames in which stainless steel foil of about 0.001 inch thickness is clamped to both sides of the center frame. Appropriate O-ring seals are provided to make the assembly vacuum tight. Air passages are provided in the center frame and connected to the cyclotron compressed air supply for the purpose of cooling the foils. The exhaust air is vented outside the building. A solenoid valve automatically turns the air on before conditions for a beam are established, and an air-flow switch prevents turning on the beam unless the flow is adequate.

OPERATION

Vacuum Gate

The operating switch for the vacuum gate is on the lower right panel of the control desk. Green and red signal lamps indicate the position of the gate (green, closed; red, open). The gate will not respond to the switch unless the target chamber is evacuated and the vacuum gage relay is closed, and the master switch is on. The gate must be open before a beam can be obtained.

Vacuum Gage

The thermocouple vacuum gage is energized continuously as long as control power is on. Its operation is entirely automatic.

Vacuum Pumping System

If the target chamber is to be evacuated, be sure the bleed valve is closed. Then, at the panel on the vacuum cabinet (17-1), start the rough pump. After the pump has run a few minutes, open the target chamber valve with the switch on the lower right panel of the control console. Signal lights (green, closed; red, open) indicate the position of the valve. Observe the indication of the vacuum gage, and in a few minutes the pressure will be seen to decrease if the chamber is vacuum-tight. Observe also the tank ion gage. As the pressure in the chamber falls, the tank pressure may begin to rise quickly until the ion gage goes off. This is due to a slight leakage which develops at the gate as the pressure which holds the gate against its O-ring seal decreases. This rise in tank pressure is only momentary, and the tank ion gage can be reset again after the target chamber pressure has dropped further. When the target chamber pressure has dropped to about 50 microns, close the vacuum valve and open the gate, again watching the tank ion gage. There will be another rise in tank pressure which may trip the ion gage as the residual gas in the target chamber is pumped into the tank. If there are no leaks in the target chamber, the ion gage can quickly be reset and the tank pressure will return to normal immediately. Continued high tank pressure indicates leakage in the target chamber.

Bleeding the target chamber to atmospheric pressure is accomplished by opening the bleed valve just in front of the chamber, making sure first that the gate and the solenoid vacuum valve are both closed. There will be a brief rise in tank pressure due to leakage through the gate before sufficient pressure has built up behind it to completely seal it.

Entrance Diaphragm

Operation of the entrance diaphragm is entirely automatic. It is permanently fixed in place on the target chamber. The cooling water is automatically turned on as needed, and a flow switch prevents the beam from being turned on unless the flow is adequate.

Exit Window and Target

Installation and operation of the entrance shield and bellows connection for the beam extraction system is described elsewhere. The plate and foil window assembly, 663B373 and 451C856, are easily installed. Be sure all O-ring seal surfaces and grooves are clean and free from nicks, and that the O-rings are clean and covered with a film of vacuum grease. (Note: In clamping the foils in the window frames, use grease only in the grooves and not on the rings or on the foils.) The support plate is held to the target chamber by means of studs through slotted holes which permit adjustment of position vertically. The optimum position can be obtained by measuring the beam current coming through the foil windows and adjusting to a maximum. Another method is to expose a series of copper plates to the beam just outside the window, and make autoradiographs from these. Adjust the window so that the densest portion of the beam is centered vertically in the window.

The air supply and vent lines must be connected to the foil window assembly, and the operation of the automatic air valve and the air flow switch must be checked before attempting to pass a beam through the foil windows.

A water-cooled target plate is provided with the foil window assembly. This may be kept insulated from the window frame by the O-ring gasket, and connected to an indicating microammeter at the control console to measure beam current. The space between the target plate and window may be evacuated, if desired, by connecting the pipe at the bottom to the rough pump manifold system. The water supply and drain hoses are in two sections with a short length of aluminum tubing connecting the sections, and these aluminum tubes should be electrically grounded. This will reduce spurious indication of beam current caused by galvanic voltage developed between the aluminum target and the copper water and drain pipes in the treated cooling water. Other target or beam-collecting devices may be attached as desired to the foil window frame.

MAINTENANCE

Vacuum Gate

No regular maintenance is required by the vacuum gate. All parts may be expected to operate for long periods of normal use without attention. Reference to Drawing #TT8600812 will show how the different parts may be replaced when it becomes necessary. All parts of the vacuum gate are radioactive and must be treated with adequate safety precautions.

Possible failures to operate, together with possible causes are:

1. The gate fails to close tightly:

   The O-ring seal needs replacement or cleaning.
   The gate surface is warped or scratched or needs cleaning.
   The gate pivot shaft is bent or twisted.
   The spring is broken.
   The linkage has been damaged or the pivots damaged.
   The cranks have sheared their pins and slipped on the shafts.
   The main shaft seal may have become dry and the bearing jammed by corrosion or wear products.
   The solenoid may have failed mechanically.

2. The gate fails to open:

   The above mechanical difficulties may have occurred, resulting in failure to open as well as failure to close.
   The solenoid coil may have failed.

3. The indicating lights at the switch do not operate:

   The microswitch at the solenoid has failed.
   The bar which operates the microswitch has been bent or loosened.

Vacuum Gage

Maintenance required by the vacuum gage will be limited mainly to replacement of the galvanometer lamp in the relay unit and replacement of the thermocouple gage unit at the target chamber after long intervals. Failure of the relay to operate, together with possible erratic indication of pressure, will indicate probable failure of the galvanometer lamp. Failure of the ammeter to indicate any thermocouple current or to respond to adjustment of the current rheostat, together with continued indication of high pressure, indicates probable failure of the thermocouple gage unit. Before replacing the unit it is well to plug the new unit into the end of the connecting cable to see if it gives a current indication. This will insure that the new unit and the cable are all right. A further check is to plug a portable thermocouple gage onto the old gage unit before removing it from the target chamber to be sure it is inoperative. Observe all necessary precautions to make a vacuum-tight joint when installing the new gage unit. The old gage unit may be radioactive and should be treated with suitable safety precautions.

The current adjustment may be different for the new gage unit. The correct value will be higher than the value marked on the gage unit because of the length of the leads between the gage unit and the control circuit. This can be determined by first setting the current at the marked value while evacuating the chamber and opening the gate. Then, with the gate open to the normal operating tank vacuum, adjust the current until the pressure indication is zero. Record this current value and adjust the current to it whenever target chamber pressure is read.

Entrance Diaphragm

No regular maintenance is required. If the target chamber is removed from the tank at any time, care must be exercised not to damage the aluminum water tubes lying along the outside surface of the chamber inside the tank. If the tank is open for other purposes it is desirable to inspect the entrance diaphragm and its copper shield for evidence of damage by the beam, and if the copper has been melted back severely it should be replaced. It will be very radioactive and must be handled with proper health physics supervision.

Exit Window and Target

The foils may require replacement after long periods of operation with a large beam. This is readily done. Remove the outer frames of the window assembly and dispose of the used foil, handling it with caution as very radioactive material. Inspect and clean the O-rings and grooves. Apply vacuum grease lightly to the bottom of the grooves, but not to the rings. Cut new foil from one-mil thick stainless steel sheet to the correct size to just fit inside the clamping screws. The foil must be thoroughly clean with a smooth, bright surface and must lie flat without wrinkles. Lay the foil in place on the center frame, and, with O-rings in the grooves, set the outer frame in place on the foil and put in the screws. Tighten the screws lightly at first, then tighten in small steps until all are completely tight. Be sure the air connections are properly made when the assembly is put back on the target chamber.

The target plate will be very radioactive after having absorbed a beam for even a short period of time, and it must be handled with due caution. Be sure the water cooling connections are properly made each time the plate is put on. Maintenance of other target equipment which may be used will depend on the nature of the equipment and the usage made of it.

VII. Cooling System

Cooling System

I. DESCRIPTION

Most of the heat dissipating components of the NACA cyclotron are water cooled, either directly or indirectly. Reference to the schematic diagram included will facilitate understanding the operation of the cooling system.

With the exception of the deflector heat exchanger and the vacuum pumps, all of the equipment is cooled by treated distilled water flowing in a closed system. Heat is removed from the distilled water by a Bell and Gossett water-to-water heat exchanger unit which incorporates a centrifugal circulating pump, temperature regulating valve, and protective by-pass. City water is used in cooling the vacuum pumps, the deflector heat exchanger and the main heat exchanger.

II. OPERATION

The usual pressure of the incoming city water is 60 to 80 p.s.i.; this pressure will be indicated on the pressure gage located near the 4-inch inlet gate valve. A treated-water pressure gage is located near the treated-water outlet of the Bell and Gossett heat exchanger. This gage provides a means for checking the load on the treated-water circulating pump. Treated water is circulated at a pressure of 90 p.s.i. at the pump. It emerges from the heat exchanger treated-water outlet at a maximum temperature of 80°F through line (13) and thence to the various branches which feed the individual components.

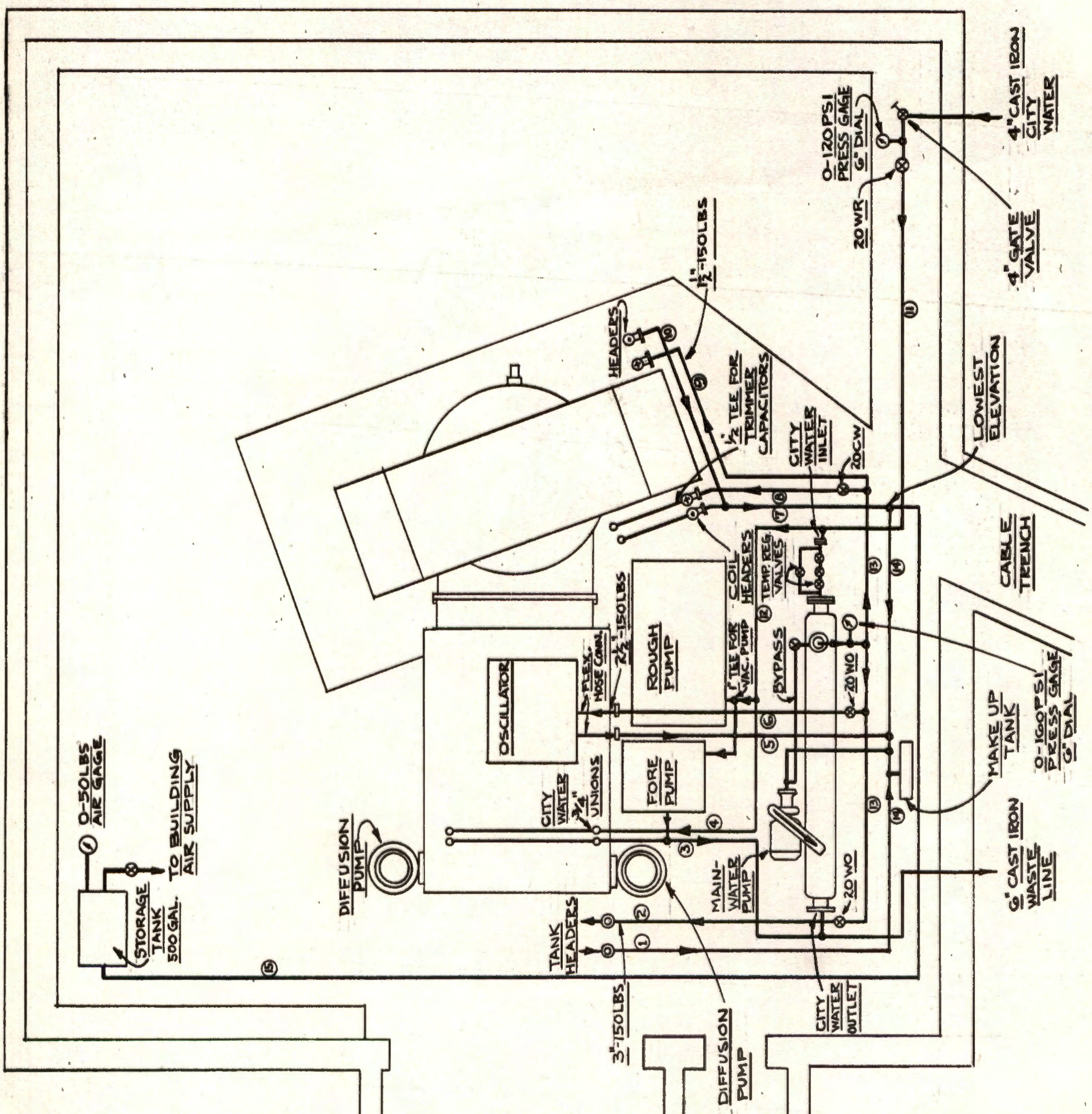
Line (2) joins the inlet header at the rear of the cyclotron tank which supplies cooling water to the dee system and the vacuum chamber. Motor-operated shut-off valve 20 WE controls flow in line (2). An outlet header from the cyclotron tank drains into line (1) which connects with the main return line (14).

Coolant is supplied to the oscillator through line (6) by motor-operated valve 20 WO. In series with line (6) is a 66-gallon reserve tank which, by the action of a check valve, provides a flow of coolant to the oscillator for approximately two minutes after normal flow has ceased. The oscillator is thereby protected from overheating in the event of a failure of either the circulating pump or valve 20 WO. Return flow is through line (5) to main return line (14).

Motor-operated valve 20 WC admits coolant to line (8) which supplies the magnet coil header from which four inlet lines feed the water, two to each coil. Four drain lines join to an outlet header which is connected to the main return by line (7).

The ion source and target chamber are supplied by a header mounted on the front of the magnet frame. This header is fed by line

PIPE NO.	SIZE
1	3"
2	3"
3	1"
4	1"
5	2½"
6	2½"
7	2½"
8	2"
9	1½"
10	1½"
11	4"
12	1½"
13	4"
14	4"
15	3/4"



Cooling System Schematic
60" Cyclotron

1a

(9). Each of the branches from the header contains a solenoid-operated shut-off valve. Return flow from the ion source and target chamber is into an outlet header to line (10) and then to line (7).

Main return line (14) is the highest positioned flow line in the system. An 82-gallon distilled water make-up tank is mounted on the wall of the room and feeds into line (14). This tank serves as an expansion unit as well, and, in conjunction with line (14), operates to cause all air bubbles in the system to rise into the tank and allows them to escape through the vent at the top.

Drain cocks which allow the cooling water to be completely drained from all branches are installed at various places in the system.

City water is admitted to the system from a 4-inch riser through a hand-operated gate valve. Flow into the heat exchanger is controlled by motor-operated valve 20 WR located in line (11). Another branch line (4) carries city water to the diffusion pumps and the deflector heat exchanger. City water from line (4) is also used to cool the vacuum fore pump and rough pump. All city water drains into line (3) where it is carried through the pipe duct to a 6-inch waste line.

Flow in all branches of the cooling system is adjustable by hand throttling valves in addition to the shut- off valves installed. Each flow circuit is protected by a magnetrol flow alarm unit which interrupts the power to the appropriate component. Installed with each flow alarm is a Weston temperature gage, which similarly interrupts the component power in the event of overheating of the coolant. A proper balance in the adjustment of throttling valves, flow alarms and temperature switches is necessary for the most efficient distribution of flow throughout the system.

An electrically-operated water distilling apparatus is provided for supplying make-up water to the system. The make-up water is introduced at the inlet of the 82-gallon make-up tank. The distilled water is treated with sodium chromate, a corrosion inhibitor, before it is placed in service in the cooling system.

A special low capacity heat exchanger is provided for cooling the deflector. Toluol, rather than distilled water, is used as a coolant. City water cools the shell side of the deflector heat exchanger.

The heat exchanger, provided for use in the main cooling system, is manufactured by the Bell & Gossett Company, Morton Grove, Illinois.

The exchanger is incorporated in a unit which includes a circulating pump, temperature regulating valve and by-pass. The complete unit bears the manufacturer's designation Q-3589-Sc.

The heat exchanger is a water-to-water type mounted on the floor of the cyclotron room. The design specifications are indicated in the table below.

TABLE I

Heat Exchanger Specifications

	Tube Side	Shell Side
Substance	city water	distilled water
Flow (gal./min.)	300	300
BTU/hr.	2,700,000	2,700,000
Inlet Temp.	68°F	104°F
Outlet Temp.	86°F	86°F
Openings	6-inch flange	6-inch flange
Max. working pressure	125 p.s.i.	125 p.s.i.
Test Pressure	250 p.s.i.	250 p.s.i.

An automatic temperature control valve is located at the raw water inlet of the heat exchanger. This regulator is a Fulton Sylphon No. 931. The sensitive bulb of the regulator is located at the discharge side of the centrifugal pump and connected to the control valve by a 12-ft. armored cable. The temperature setting will be maintained at 85°F. No external electrical connections are required for operation of the control valve.

Treated water is circulated throughout the cooling system and heat exchanger by a Bell & Gossett series 1531 - type 2B centrifugal pump. The capacity of the pump is 300 gallons per minute at a pressure head of 140 ft. The pump driving motor is rated at 25 HP, 3450 RPM, 3-phase, 208 volts, 60 cycles.

The treated water make-up tank which is ordinarily mounted on the heat exchanger has been relocated on the wall above the unit where it serves as an expansion tank in addition to being the filling point for the system.

The heat exchanger has a one-inch by-pass line connecting the treated water outlet and the suction side of the circulating pump. This by-pass insures a flow of water for cooling the pump even though there is no flow in the rest of the system.

The ion source and target chamber are cooled by treated water supplied from a header mounted on the magnet frame. Each of these three individual flow circuits contains a solenoid shut-off valve, a hand throttling valve, a magnetrol flow alarm, and a Weston temperature gage. Return flow is through line 10.

Another system of headers mounted on the magnet frame and connected to line (8) supplies coolant to both magnet coils. Each coil is cooled by two separate flow circuits. Each of these four contains a throttling valve, flow alarm, and temperature gage.

III. MAINTENANCE

Coolant

The coolant selected for use in the treated water circuits of the 60-inch cyclotron is distilled water with added anhydrous sodium chromate (Na_2CrO_4) of commercial grade. A solution containing 0.1 per cent sodium chromate by weight is recommended for the best all year coolant.

For satisfactory corrosion protection, the resistivity of the coolant should be maintained between 600 and 800 ohm centimeters measured at 26°C. It is also necessary periodically to check the effectiveness of the corrosion inhibitor.

The sodium chromate should be added to the distilled water to make the recommended solution. The crystals are readily soluble and should be dissolved in distilled water and added to the system and the coolant circulated. For the initial filling, the cyclotron cooling system will require about four pounds of sodium chromate.

It is important that the solution be checked for its corrosion-inhibiting efficiency at least every six months. This check of effectiveness should be made according to the following instructions:

Apparatus Required

1. One six-ounce wide-mouth glass bottle.

2. One cork or rubber stopper provided with two polished iron wire electrodes protruding through the stopper and extending to within one-half inch of the bottom of the bottle. The electrodes should be iron wire, one-sixteenth inch in diameter and placed one-half inch apart.

3. A d-c source of power of five volts potential should be available.

Test

Fill the bottle with a sample of the sodium chromate solution in question. It is desirable that a convenient temperature between 25°C (77°F) and 60°C (140°F) be decided upon and this temperature maintained for all tests. The results will then be comparable.

Insert the stopper provided with the electrodes and apply approximately five volts across the electrodes.

Should the solution be of such weak strength that corrosion of iron would occur in service, a cloudy grayish precipitate will form within five to thirty minutes. After several minutes the gray precipitate changes to the brown color of iron oxide.

This visible electrochemical action is a definite indication that the sodium chromate solution is weak and should be strengthened. If the solution is of sufficient strength to retard corrosion, no precipitate will form around the electrodes.

Distilled Water Apparatus

The cooling system is provided with a Barnstead electrically-heated water distilling apparatus. A continued supply of make-up water is thus made available. It is not anticipated, however, that this still will be used for the initial filling of the system. Its capacity is 2 gal./hr.

The heating element of the still operates on 110 volts a-c or d-c. Because of the high amperage required to operate this still, it is necessary that electrical connection be made through a heavy duty switch directly to a heavy duty power line; under no circumstances should it be connected to an ordinary outlet.

Approximate Capacities of Branch Circuits

	Circuit	Gal./Min.
1.	tank (header)	175
2.	oscillator	80
3.	magnet coils	60
4.	ion source	2
5.	target chamber	10
6.	deflector	3
7.	diffusion pumps (2)	2 each

Filling Instructions

The capacity of the make-up water distilling apparatus is not sufficient to provide distilled water for the initial filling of the cyclotron cooling system. It would be expedient, therefore, to obtain about 500 gallons from another source.

The actual filling of the system can be accomplished in several ways; one suggested method is described below:

1. Close all drain cocks and blow-offs.

2. Completely open all hand throttling valves, solenoid valves and motor-operated valves except 20 WR (raw water inlet valve).

3. Coolant will be introduced into the system through an inlet at some low point, thereby reducing the possibility of trapping air. The distilled water should be stored in enclosed barrels that are assembled on the floor of the cyclotron room. A flexible hose will be connected between the barrel and the inlet. In the barrel an inlet pipe will extend from the hose connection to the barrel's bottom.

A second connection on the barrel will be employed to supply air at a pressure of approximately 20 p.s.i. gage. Water in the barrel will be forced through the hose into the make-up tank at a velocity low enough to prevent excessive turbulence.

The sodium chromate corrosion inhibitor may be added to the distilled water in the barrels and mixed there.

When the system, including the make-up tank and the oscillator reserve tank, is filled, the centrifugal pump should be started and the coolant allowed to circulate throughout the entire system. After allowing the system to operate for a few hours, it would be advisable to clean out the various strainers which will have collected an accumulation of pipe compound, scale, and dirt. Thereafter it should be necessary to clean the strainers only once a month.

Adjustments

The cooling requirements of the dee system, oscillator, magnet coils, etc., will depend on the amount of power consumed in each individual component. It is recommended that the flow of coolant be apportioned between the various branch circuits so that the temperature never exceeds 40°C in any branch. This can be accomplished by reading the coolant temperature at the time power is turned on and then adjusting the hand throttling valves in the various circuits so that the proper temperature is maintained during full power operation.

Contact settings on the thermometers at each circuit outlet should be adjusted so that power interruption will occur when coolant temperature rises to 45°C.

Each cooling circuit is provided with a magnetrol flow alarm. This device will shut off power to the appropriate component if any cooling circuit becomes stopped or if the throttling valve is left closed by mistake. Any magnetrol unit may be tested by closing the throttling valve while operating at low power. When the flow drops to about 10 percent of normal, the magnetrol contacts should operate and interrupt power until proper cooling is restored.

Power interruption due to excessive temperature rise or flow failure in a given cooling circuit operates an indicating light on a flow-temperature panel.

The location of the flow-temperature panel is shown on the schematic diagram.

From the information on the inside cover of these panels, the operator can tell which branch circuit caused the interruption.

Thermal and Flow Protective System

I. DESCRIPTION

The thermal and flow protective system serves two purposes. The first is to introduce the appropriate interruptive action necessary to protect the cyclotron components in case of failure of portions of the cooling system. The second is to give the operator visual indication of the location of the failure.

II. OPERATION

The operation of the thermal and flow protective systems is semi-automatic.

The protective portion of the circuit is automatic, but the indication of the location requires that the operator observe the indicating lamps on the extreme left side of the control console. In some cases, it is also required that the operator inspect the indicating panels 7-2, 10-2, and 1-4 in order to find out which branch of the cooling circuit has caused the alarm.

The indicating lamps will remain on, even after the fault is corrected, until the reset switch, labeled Water Flow Reset, is depressed.

III. MAINTENANCE

The occasional replacement of an indicating lamp on the control console may be necessary.

Periodic disassembly of the magnetrol flow alarms and cleaning of the plungers is recommended.