LOS ALAMOS SCIENTIFIC LABORATORY

of the

UNIVERSITY OF CALIFORNIA

Report written:
October 1, 1951

LA-1387(Del.)

REMOTE CONTROL EQUIPMENT FOR PLUTONIUM METAL PRODUCTION

by

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Declassified with deletions June 9, 1960

Photostat Price $ 34.80

Microfilm Price $ 9.90

Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

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ABSTRACT

This report describes the design and construction of remote control equipment for plutonium metal production installed at the Los Alamos Scientific Laboratory.

The design of the equipment was guided by the following principles:

1 - Complete elimination of rubber gloves.

2 - All mechanisms to be built as integral units to facilitate replacement through use of the plastic bag technique.

3 - All units to be tested in mock-ups before final design.

4 - No accessory equipment such as switches, valves, piping or cylinders to be inside the contaminated enclosure unless required to handle the plutonium.

The time schedule for various phases of the project is given below:

Engineering Development	January 1949 - June 1950
Design	February 1950 - December 1950
Construction and Installation	May 1950 - April 1, 1951
Testing	April 1, 1951 - May 22, 1951
Half capacity break-in	May 22, 1951 - August 13, 1951
Full capacity production	August 13, 1951

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ACKNOWLEDGEMENTS

This project could not have been successful without the wholehearted cooperation of many individuals in different sections of the laboratory and the enthusiasm and teamwork of those assigned full time to the problem.

Certain individuals, by virtue of their assigments, were in a position to contribute significantly to the final installation. Of these, particular mention should be made of J. W. Anderson who supervised the installation as well as being responsible for all the purchasing specifications, R. L. Thomas who designed and supervised the installation of all the electrical circuits, and W. D. McNeese who was responsible for much of the engineering development installation.

Special credit is due to the design-draftsmen for their ingenuity and interest. These included T. E. Carman, C. G. Delano, David Moskowitz, and N. P. Armenis.

The contribution of all those in the shop department who helped with ideas as well as craftsmanship is gratefully acknowledged. Mr. E. M. Risley, shop foreman deserves special mention for his aid and encouragement. Since no installation as complex as this can be any better than the calibre of the craftsmen who install it, particular tribute is paid to the four machinists who actually put the equipment together. These were W. R. Cormack, John Boyd, Irving Goldfarb and G. A. Spooner.

Thanks are also due the craftsmen of the Zia Company who put in the piping and wiring. Among these were Cecil Gooch, Raymond Romero, Don Walker, Wallace Sparks, George Warren, Robert Waugh and Jose Ortiz.

The entire proolem from start to finish was under the guidance of R. D. Baker, Group Leader of CMR-11, who not only contributed ideas and ingenuity during design but who established the basic philosophy and atmosphere which created a most effective spirit of team effort.

CONTENTS

CHEMICAL PROCESS

The chemical process for metal production consists of the following steps:

1 - Precipitation of plutonium peroxide from nitrate solution by the controlled addition of hydrogen peroxide.

2 - Filtration of the peroxide slurry and direct conversion of dry plutonium peroxide to tetrafluoride with hydrogen fluoride gas.

3 - Reduction of plutonium tetrafluoride to plutonium metal with calcium.

In addition to the above steps the remote control equipment described in this report was designed for direct hydrofluorination of plutonium metal turnings to the tetrafluoride and for addition of metal turnings to the reduction charge. A flow sheet of this process is presented in Figure 1.

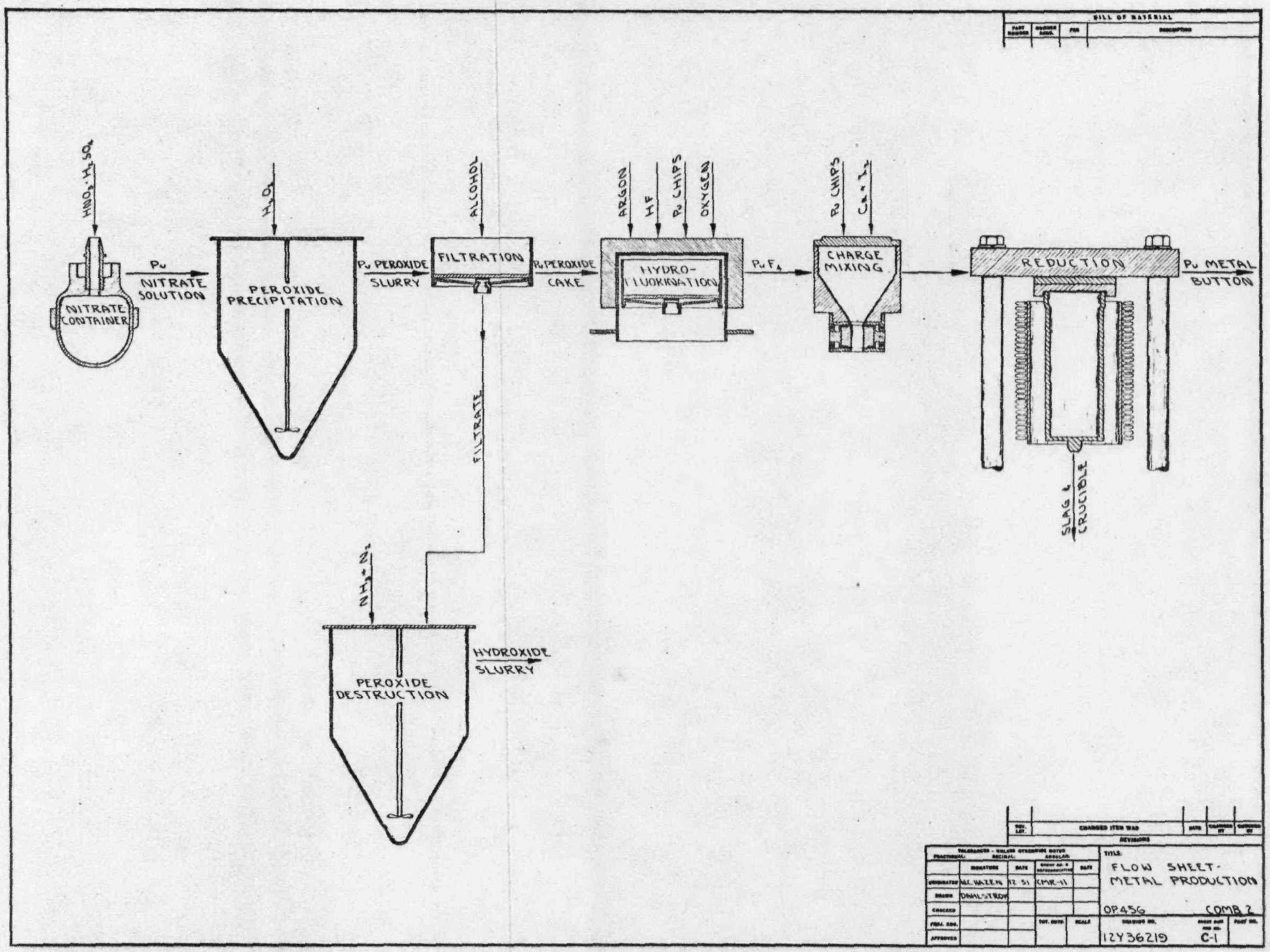


Fig. 1. Metal production flow sheet.

GENERAL LAYOUT AND OPERATING FUNCTION

The operating equipment consists of two duplicate lines in a room measuring 40' x 50'. These lines are on opposite sides of a control section which is sealed from the rest of the room by tight plaster walls containing safety glass windows.

Each line is basically an air tight box 20" wide by 30" high by 28' long on which the operating mechanisms are flange-mounted. On each line there are two precipitation - hydrofluorination assemblies at opposite ends of the box with the reduction unit occupying the center section. In the complete installation, therefore, there are four precipitation units, four hydrofluorination furnaces and two reduction assemblies.

The floor plan of the installation is shown in Figure 2 and a schematic drawing of one line is shown in Figure 3.

The sequence of operation is as follows:

1 - A nitrate container holding 160 grams of plutonium as nitrate solution is introduced into the "Bomb Introduction" unit at either end of a line.

2 - The nitrate solution is transferred by vacuum into the precipitation unit where the plutonium is precipitated as the peroxide.

3 - The plutonium peroxide slurry is vacuum filtered on the sintered platinum disc in the traveling filter boat. The filtrate goes to the filtrate receiver where the excess peroxide is destroyed by making the solution alkaline with

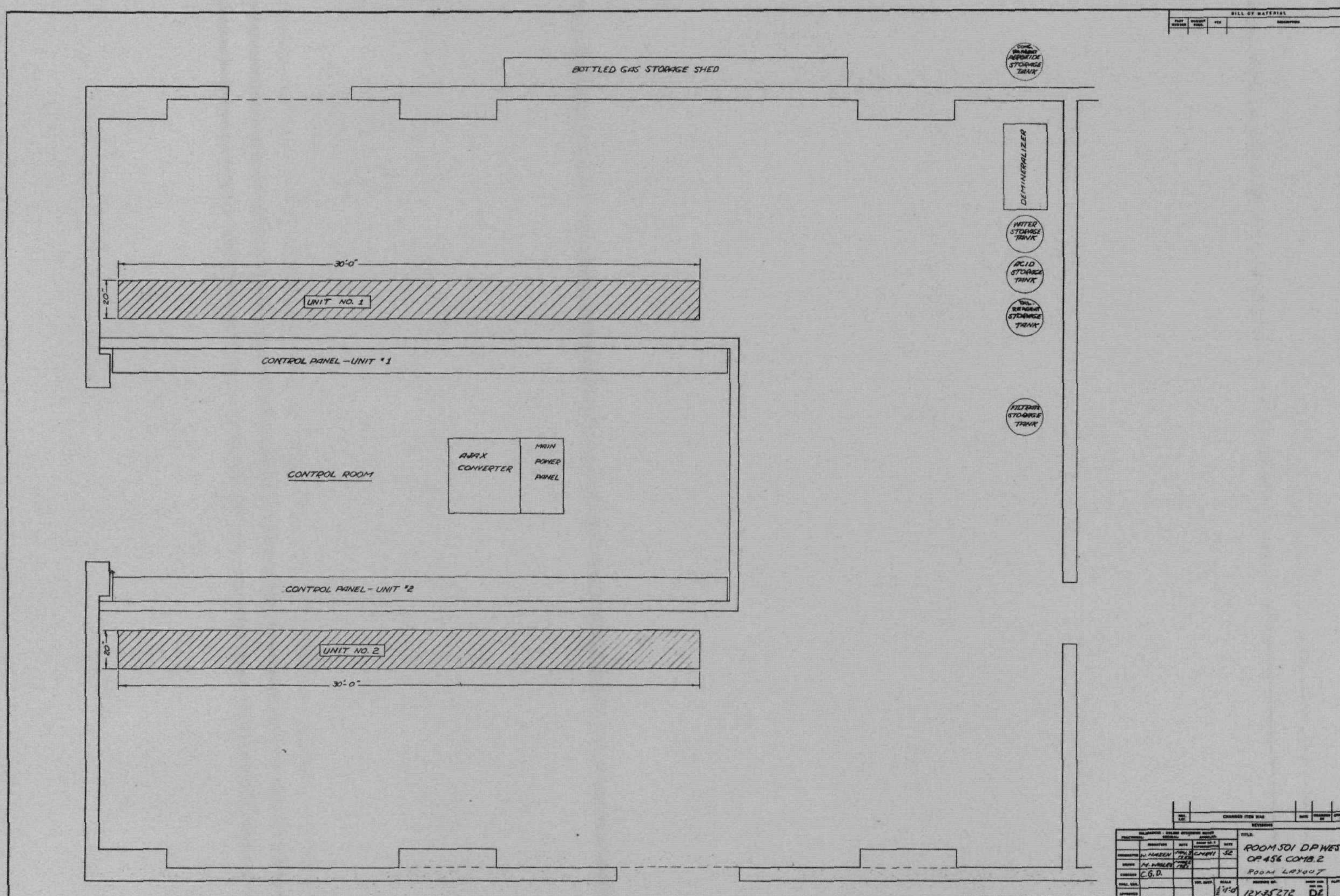
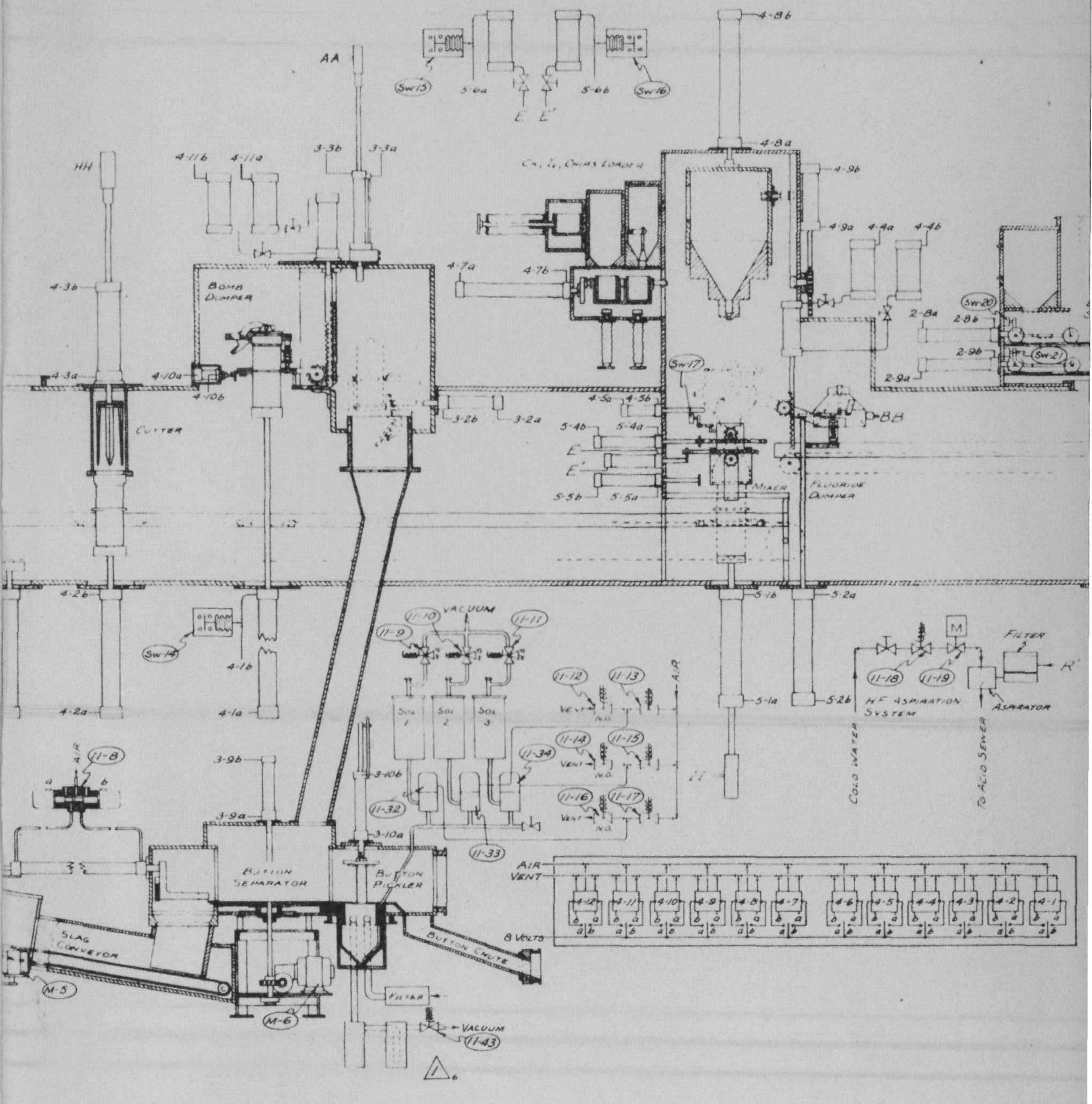


Fig. 2. Floor plan of metal production equipment.


AA
HH
Sw-15
5-6a
5-6b
Sw-16
4-8b
4-8a
4-9b
4-9a
4-4a
4-4b
4-11b
4-11a
3-3b
3-3a
BOMB DUMPER
4-7a
4-7b
4-3b
4-3a
4-10a
4-10b
CUTTER
3-2b
3-2a
Sw-17
4-5a
4-5b
5-4b
5-4a
5-5b
5-5a
MIXER
FLUORIDE DUMPER
BB
Sw-20
Sw-21
2-8a
2-8b
2-9b
2-9a
4-2b
4-2a
Sw-14
4-1b
4-1a
5-1b
5-2a
5-1a
5-2b
VACUUM
11-9
11-10
11-11
11-12
11-13
11-14
11-15
11-16
11-17
11-34
11-32
11-33
SOL 1
SOL 2
SOL 3
VENT
N.O.
AIR
11-18
11-19
FILTER
HF ASPIRATION SYSTEM
ASPIRATOR
COLD WATER
TO ACID SEWER
11-8
3-9b
3-9a
3-10b
3-10a
BUTTON SEPARATOR
BUTTON PICKLER
SLAG CONVEYOR
BUTTON CHUTE
M-5
M-6
FILTER
VACUUM
11-43
AIR
VENT
8 VOLTS
4-12
4-11
4-10
4-9
4-8
4-7
4-6
4-5
4-4
4-3
4-2
4-1

ammonia gas.

4 - The filter containing the peroxide cake is lowered into a carriage and transported to the hydrofluorination station where it is elevated into the furnace and converted to the tetrafluoride by a stream of anhydrous hydrogen fluoride and oxygen gas.

5 - After hydrofluorination, the filter is lowered into its carriage and transported to either the boat storage station where it can be held for future use or to the fluoride dumper if it is to be used immediately. The boat storage station also contains mechanism for introducing plutonium metal into a boat for direct conversion to plutonium tetrafluoride.

6 - The fluoride dumper picks up the filter boat, inverts it, and pours the contents into the mixer.

7 - Metallic calcium, iodine, and plutonium turnings are poured into the mixer on top of the plutonium fluoride through the equipment mounted above the mixer.

8 - The mixer is then turned through alternating 540° rotations until the contents are intimately mixed, after which it is left upside down ready to discharge its contents into a crucible for reduction.

The above operations are duplicated at each end of each line. The center section of each line is devoted to the reduction of plutonium fluoride to metal. It contains a carriage and track mechanism in which a steel reduction bomb can be carried to various stations.

9 - The reduction bomb is first loaded with an MgO crucible and the annular space between crucible and bomb packed with MgO sand at the crucible loader station.

11 - The crucible and bomb are then moved to the mixers where the mixed charge is poured into the crucible and tamped by vibration.

12 - An aluminum gasket is placed in a groove on top of the reduction bomb at the gasket dispenser.

13 - At the reduction furnace the bomb is raised by a hydraulic cylinder and squeezed against the furnace head after which it is evacuated and filled with argon at atmospheric pressure and heated by an induction coil until it fires. After cooling it is returned to the carriage.

14 - In the gasket remover and groove cleaner unit the gasket is punched from the bomb and the groove scrubbed with a wire brush.

15 - The bomb is carried then to the bomb dumper where it is picked up, inverted, and the contents allowed to fall down a chute to the button separator.

16 - At the button separator unit the slag and broken crucible are scraped off one side of the table and the plutonium button pushed off the other side onto the perforated plate of the button pickler.

17 - Here the button is lowered into a glass pot where it is pickled with nitric acid, washed and dried and transferred to a button chute for removal in a plastic bag.

18 - After the reduction bomb has discharged its contents at the bomb dumper it is returned to the carriage and taken to the bomb pickler where it is scrubbed inside, and dried out for re-use.

19 - The head of the reduction furnace is scoured after each reduction by moving the dummy bomb,containing a motor driven wire brush,from its rack to the reduction furnace and raising it on the hydraulic lift.

Figures 4 and 5 are photographs of the equipment taken from the back side.

All of the operations described above are controlled by switches on the panel boards in the control room, photographs of which are shown in Figures 6 and 7.

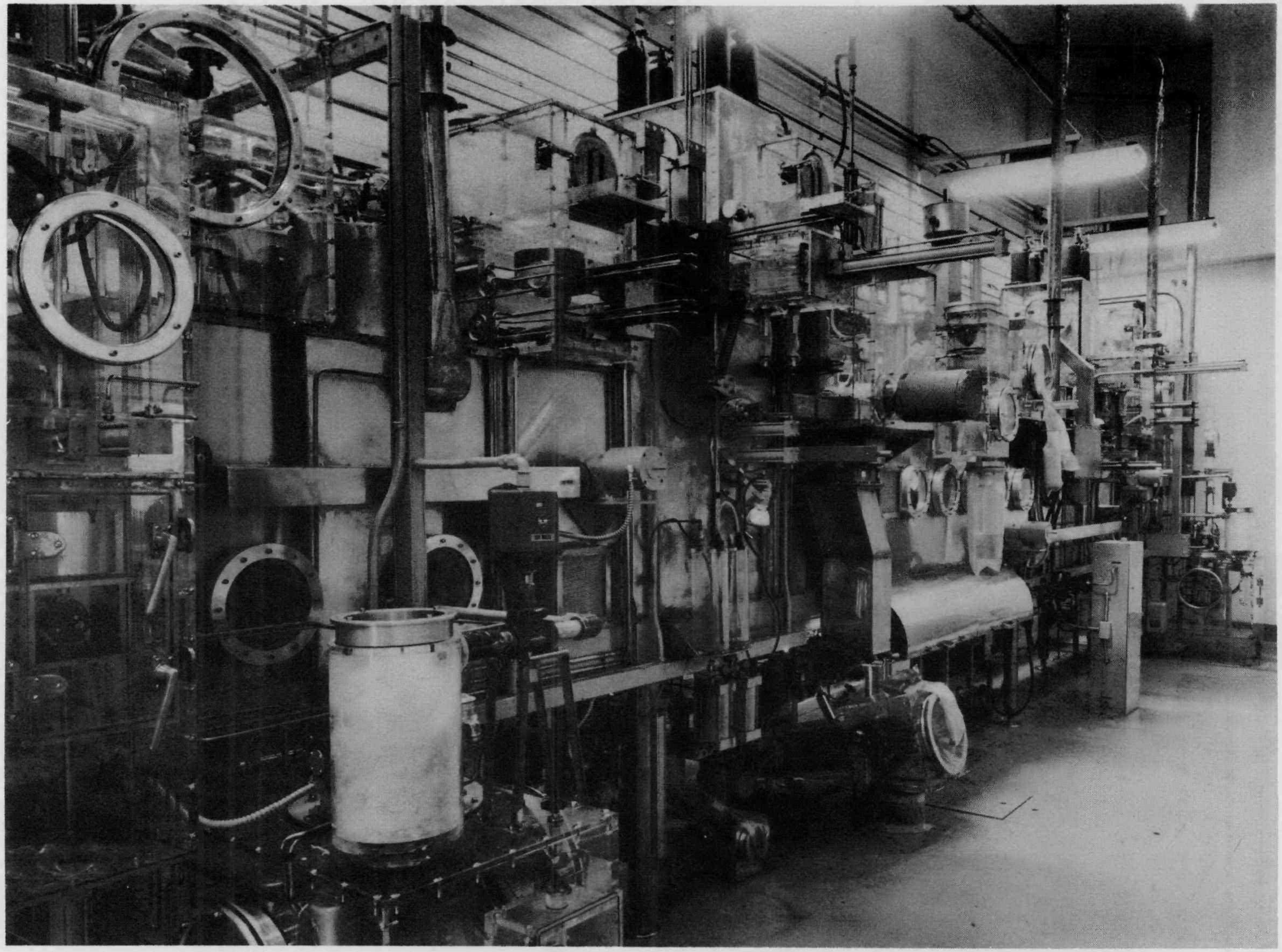


Fig. 4. Back side of east remote control line looking north.

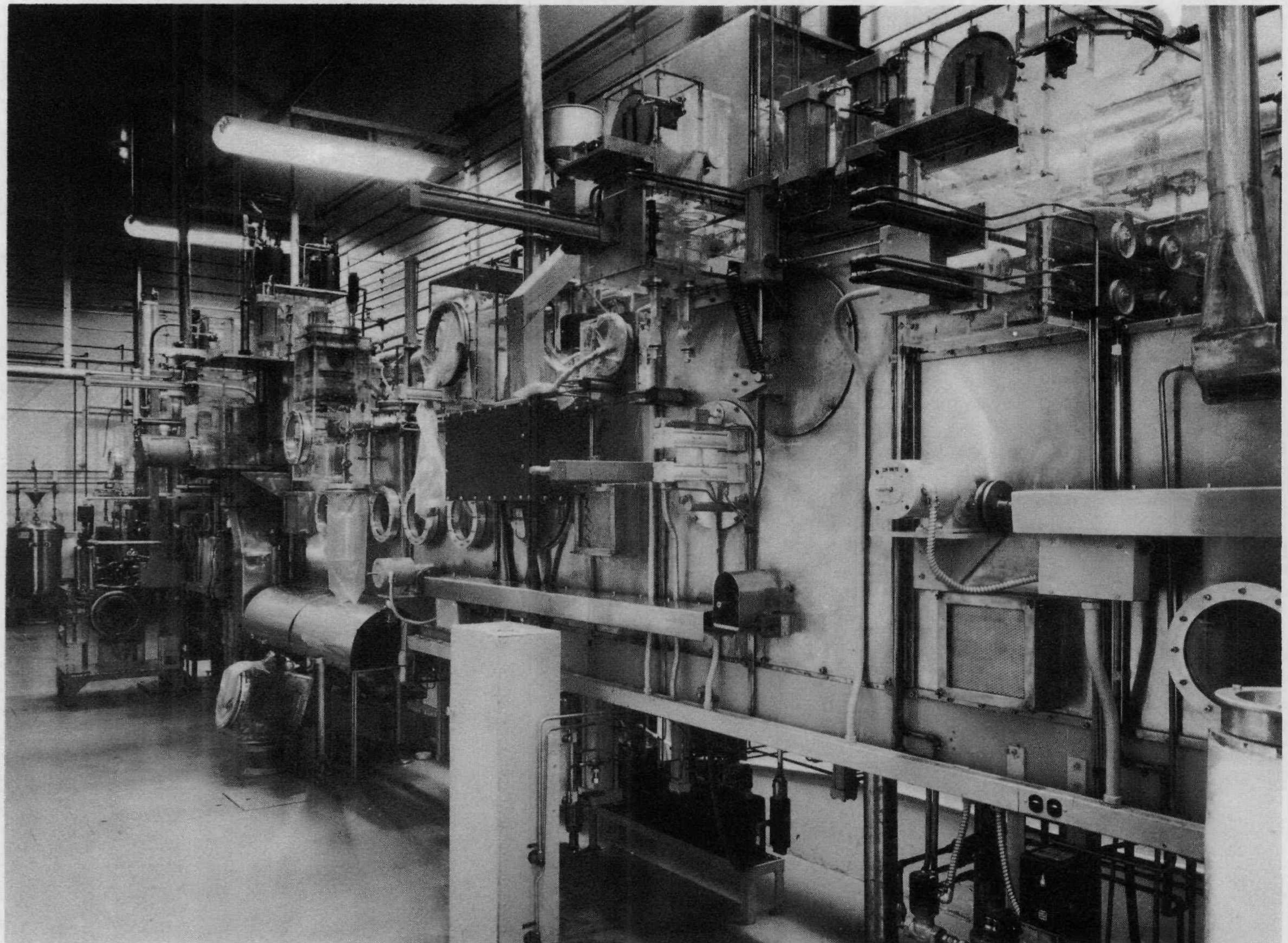


Fig. 5. Back side of east remote control line looking south.

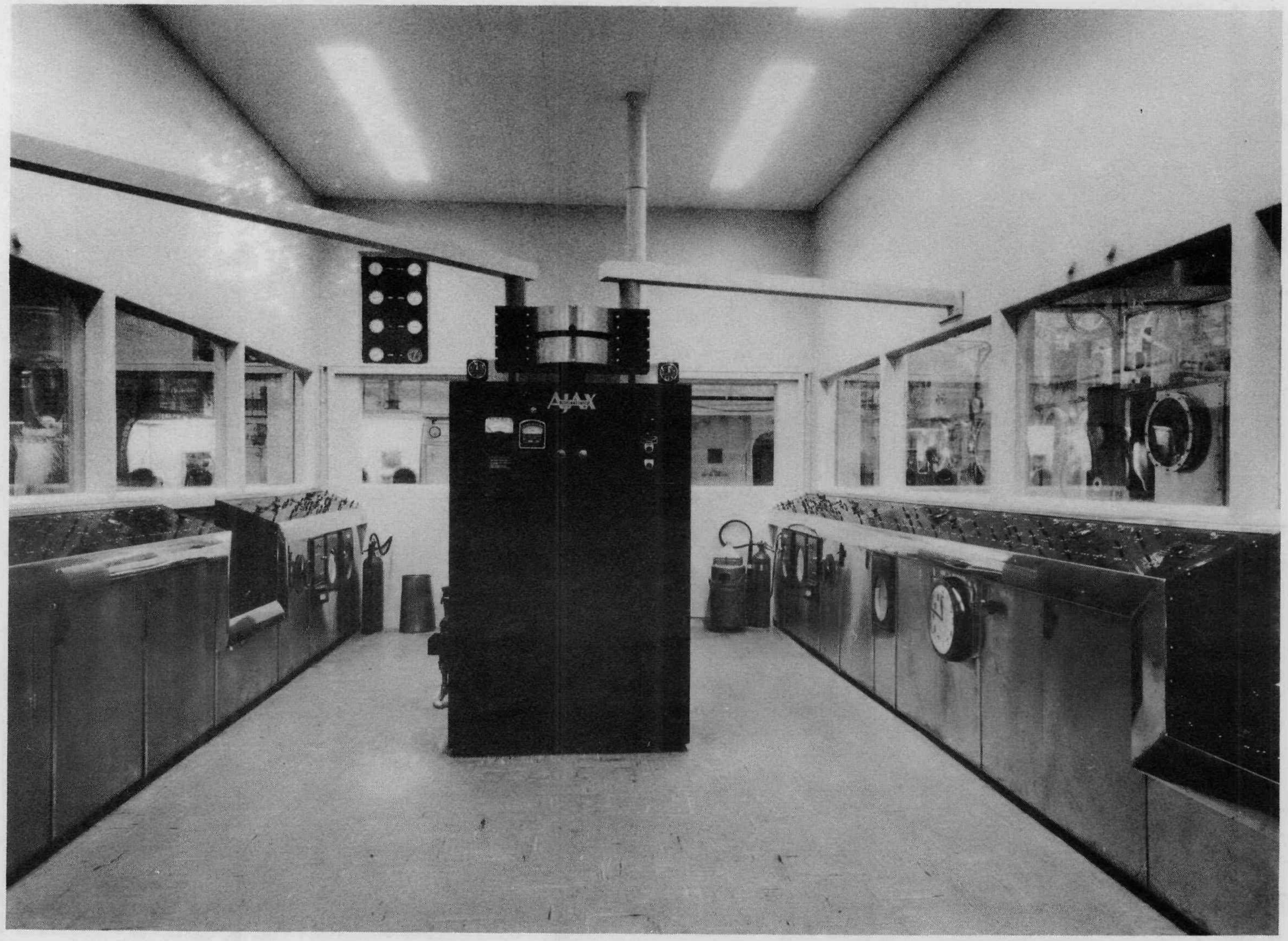


Fig. 6. Control room.

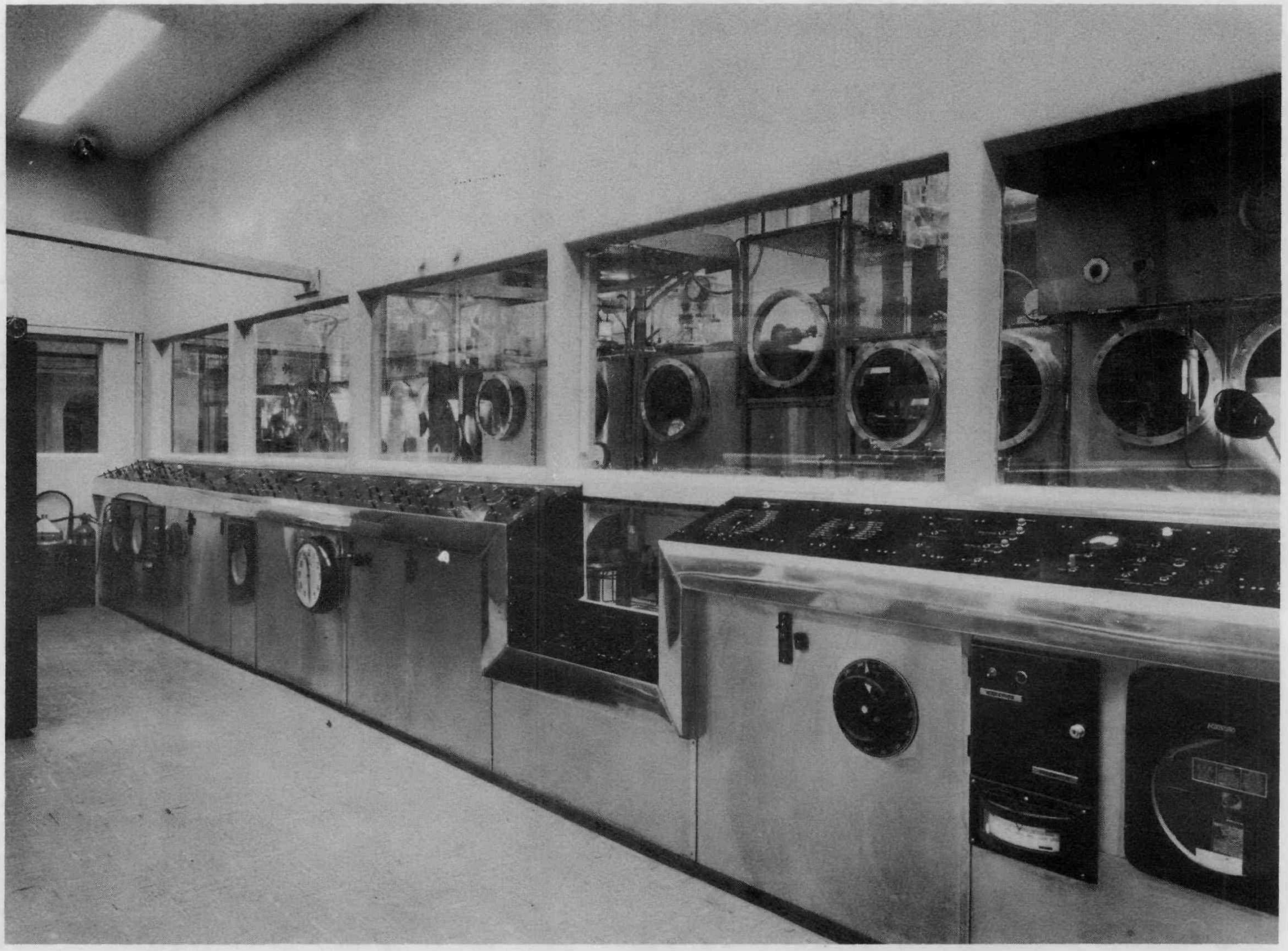


Fig. 7. Control panels for west line.

MECHANICAL UNITS

NITRATE SOLUTION INTRODUCTION

This unit contains the equipment for transferring plutonium nitrate solution into the precipitation vessel. There are four of these units in all; one at each end of each line. A design layout of the equipment is shown in Figure 8.

In operation, the Hanford sample can ("Bomb") is placed manually in the holder (300) by the back operator and the door closed. A ventilation outlet on the side of the lower half of the unit pulls 150 CFM of air through the door when it is open.

The lower air lift (148) operated from the control room raises the holder assembly until the lucite adaptor in the top of the sample can seats against the sealed thrust bearing (124). The small trap door lid (116) is then opened and the dip tube (200) lowered into the sample can by actuating the upper air cylinder (142). This dip tube consists of a spring loaded assembly of two concentric tubes. The center tube, which touches the bottom of the sample can, is connected by flexible tubing to the precipitation vessel. The outer tube, which is just long enough to enter the mouth of the sample can has small holes drilled near the end and is connected by flexible tubing to the acid solution lines.

When a vacuum is pulled on the precipitation vessel the nitrate solution is drawn out of the sample can up through the center of the dip tube. After the nitrate has been removed the acid solution is turned into the outer portion of the dip tube, where it squirts out

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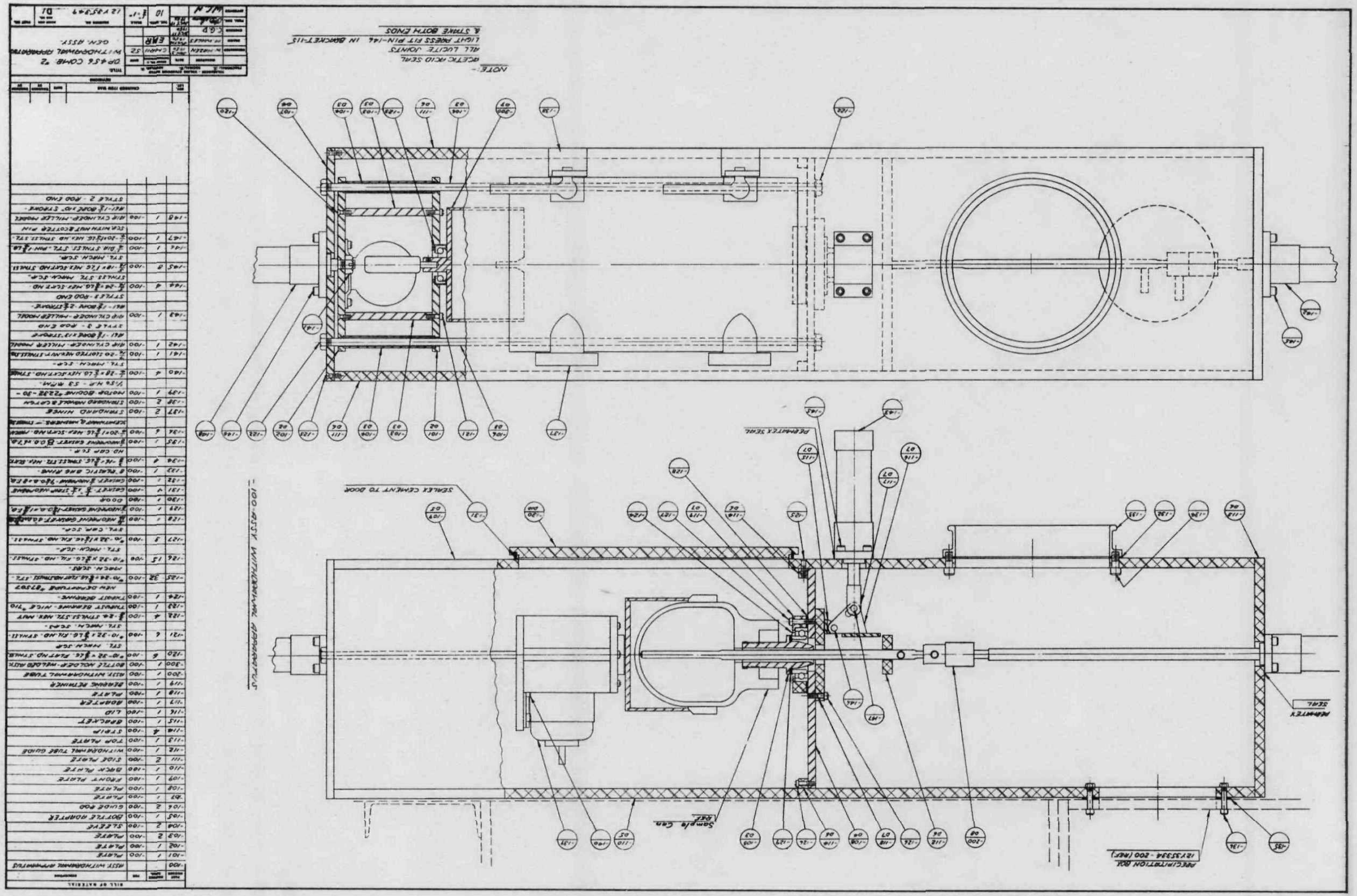

Fig. 8. Design layout of equipment for introduction of nitrate solution.

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through the holes in the end and sprays the wall of the sample can and thence up the center tube to the precipitation vessel thereby diluting the plutonium nitrate.

Since the sample can is rotated at 57 RPM by the motor (139) the interior is thoroughly washed by the acid spray.

The can is left in position until after precipitation and filtration are completed because the alcohol used for washing the filter cake is introduced through the outer portion of the dip tube in the same manner as the acid in order to aid in drying the bomb. After air has been pulled through the can via the dip tube for 30 minutes the tube is raised, the trap door closed and the sample can lowered for removal by the operator.

Figure 9 is a photograph of the southeast unit taken during the installation.

The piping layout for this unit is included in the section on the Precipitation System.

Since the electrical controls are on the same panel as the precipitation controls they are discussed in connection with that equipment.

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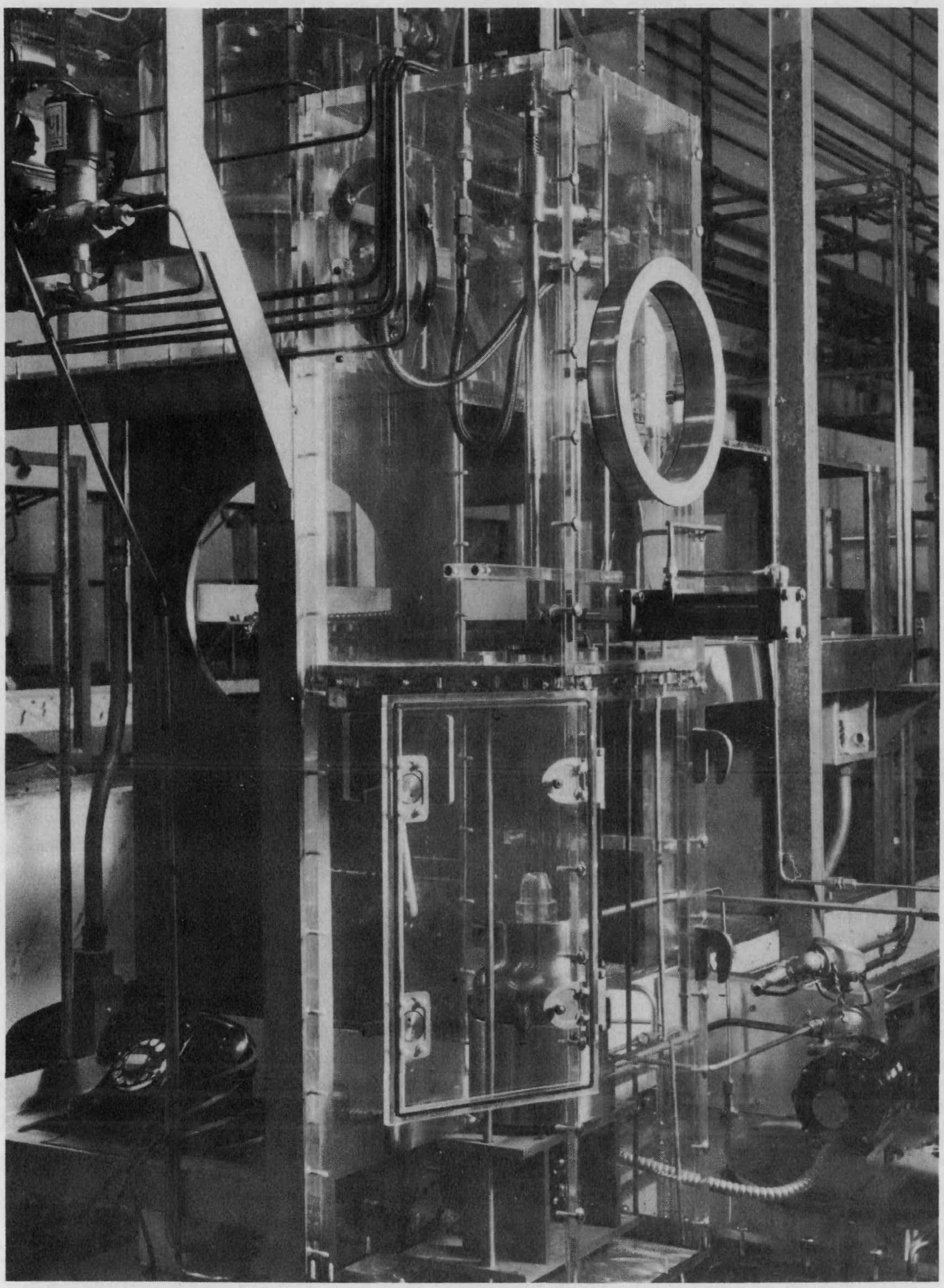

Fig. 9. Photograph of southeast unit for introduction of nitrate solution.

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PRECIPITATION SYSTEM

Mechanical Features

A precipitation vessel is mounted on each end of each of the two remote control lines. In these vessels the plutonium nitrate solution is diluted to the proper acidity and plutonium concentration, cooled to 15°C, and the plutonium precipitated as the peroxide by the controlled addition of 30% hydrogen peroxide. The peroxide slurry is digested for the desired time, then cooled to 10°C and sucked from the precipitation vessel into the filter boats.

The design layout of a precipitation unit is given in Figure 10 and a photograph taken during installation in Figure 11. The vessel itself is a twelve liter cone-bottom pyrex pot (Figure 10, 300 D 14) supported in a lucite container (300, D 1). The lucite container is suspended from a circular stainless steel lid 1/2" thick which serves as the cover for the pyrex vessel. When the bolts holding the lucite jacket to the lid are tightened the pyrex vessel is squeezed against a neoprene gasket in the underside of the lid. All connections to the precipitation pot are made through this lid.

The function of the lucite jacket is to contain the solution in case the pyrex vessel should break.

The lid of the vessel is suspended by shoulder bolts from a stainless steel flange plate. This basic assembly of flange plate, pot lid, pyrex vessel and lucite container is shown in Figure 12. On installation, the entire assembly was lowered through a hole in a

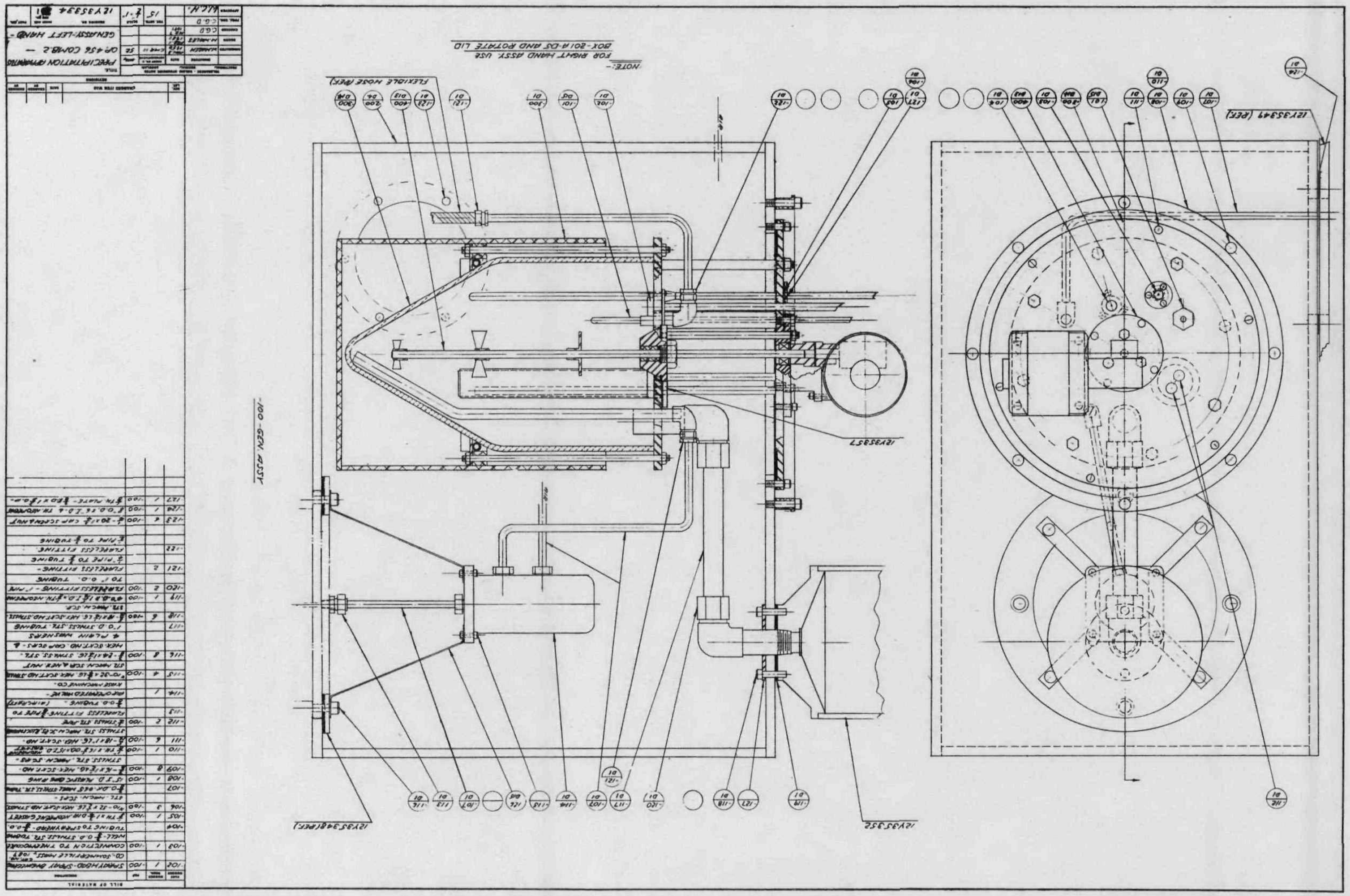

Fig. 10. Design layout of precipitation unit.

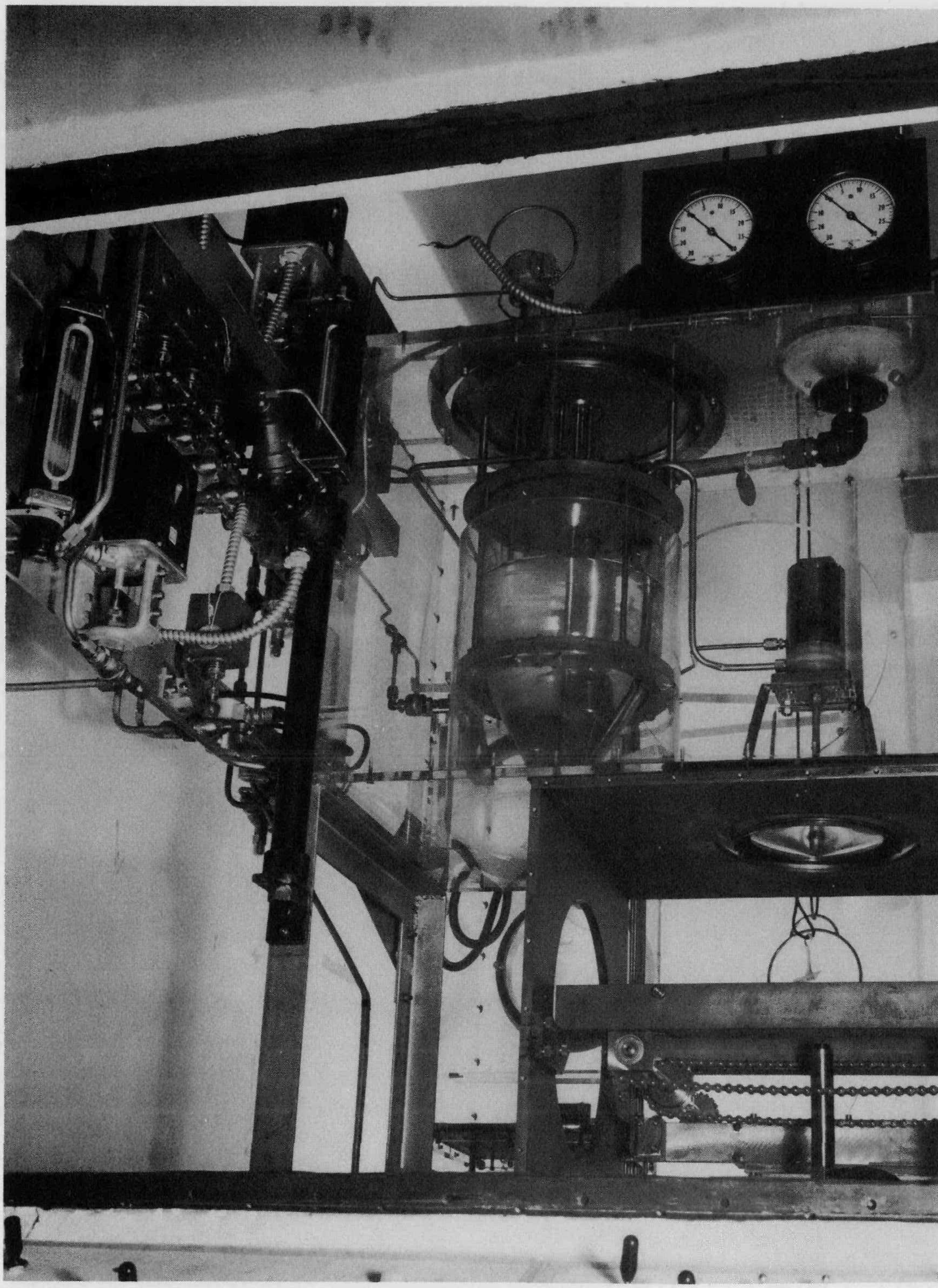

Fig. 11. Photograph taken during installation of north east precipitation unit.

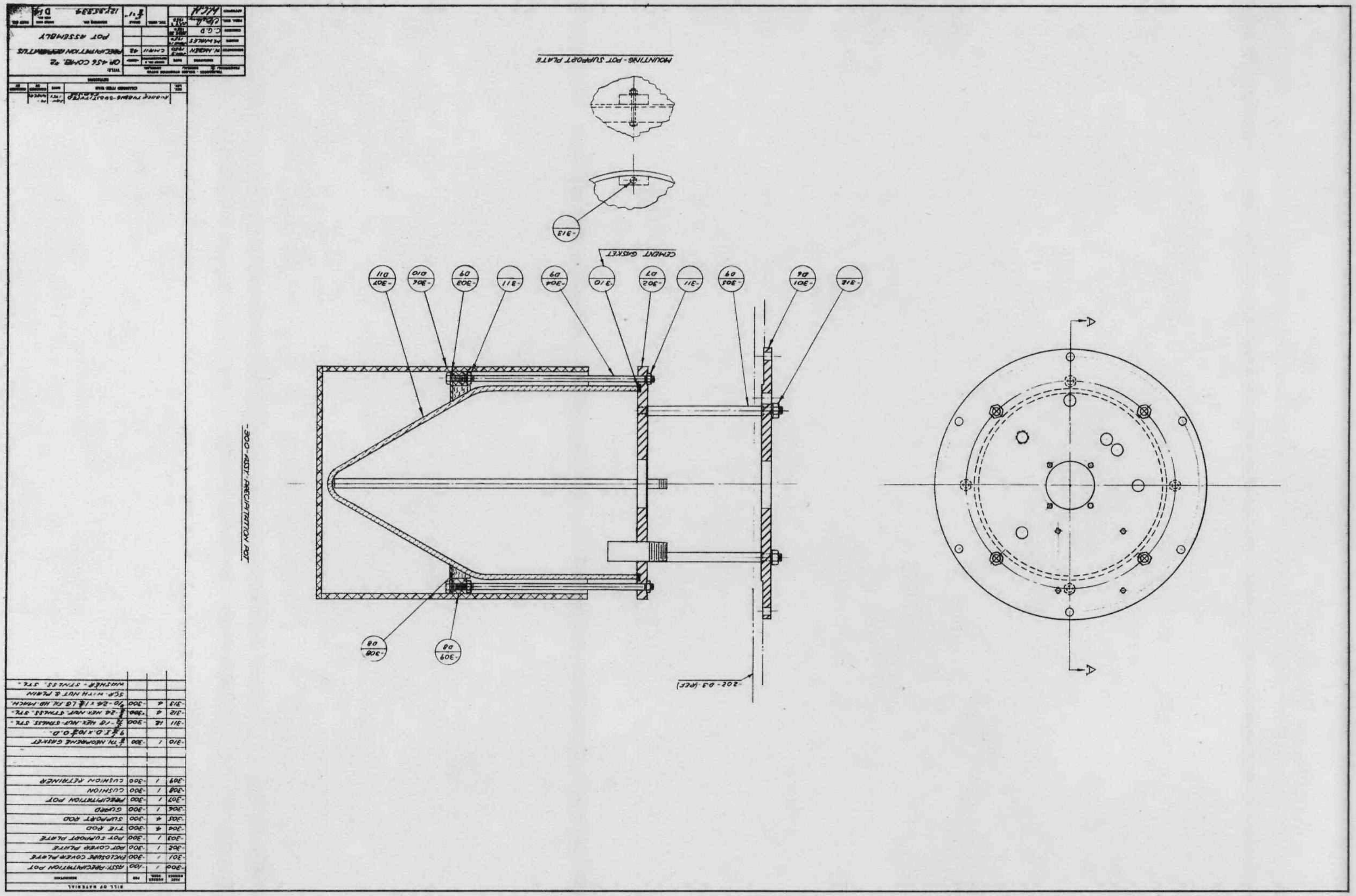

Fig. 12. Basic assembly of precipitation vessel.

large lucite box until the upper flange plate rested on a gasket around the rim of the hole in the lucite. A Dural "plastic bag ring" was installed on the lucite around the upper flange plate. The purpose of designing the unit in this manner was to make it possible to remove the complete precipitation assembly in case it was required for maintenance or if at some future data a different precipitation method is developed requiring a different design.

Agitation is accomplished by two four-bladed propellers mounted on a stainless steel shaft which runs through one teflon packing gland in the vessel lid and another in the upper flange plate to a universal joint and motor drive. This assembly is shown in Figure 13. The electric motor, which rotates the agitator counter-clockwise at 500 RPM, is mounted on the upper flange plate and is therefore in Zone 3 completely outside the contaminated area. The two packing glands are connected by shoulder bolts so that it is only the upper bearing gland that is bolted to the unit. The lower gland is squeezed against a gasket on top of the pot lid by the shoulder bolts from the upper gland. Although this method of mounting the agitator was more difficult to align accurately in the shop when fabricated, it permits easy removal of the entire agitator shaft assembly from the operating zone without requiring any work inside the enclosure. This packing gland-agitator assembly has operated satisfactorily for many months with no contamination and no maintenance. A circular disc of stainless steel mounted on the agitator shaft serves as a "flinger" plate to throw

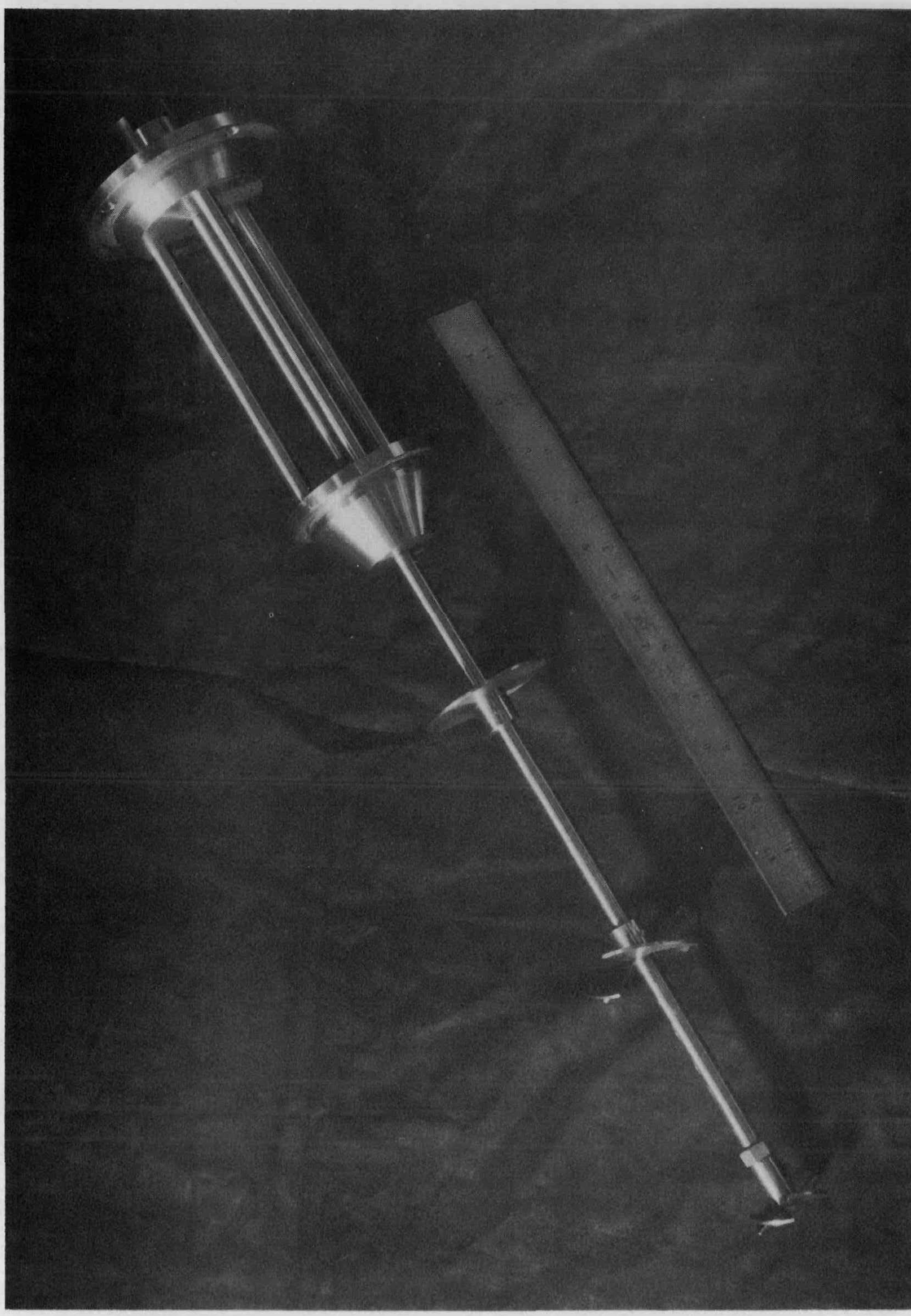

Fig. 13. Precipitation vessel agitator assembly.

wash solution against the wall of the pyrex vessel.

A one inch stainless steel tube runs from the vessel cover to the bottom of an entrainment trap (12Y-35352, Figure 10) made of lucite and packed with glass wool. The vacuum and vent lines are connected to the top side of this trap. This not only decreases entrainment but serves as added volume in case of foaming during precipitation.

Plutonium nitrate is introduced into the vessel through the line marked (D-1, 121) on the layout (Figure 10), terminating just inside the pot cover.

A withdrawal tube (107), extending down to the bottom of the cone of the pyrex vessel, permits the slurry to be transferred to the filtration unit through the Saran valve (114).

The three connections listed above, i.e., vacuum-vent line, plutonium entry tube, and withdrawal tube are the only lines that run directly to the pot cover from inside the enclosure. The other lines enter the pot lid by way of the upper flange so that they can be disconnected entirely from the operating zone.

Chemicals that are to be added directly to the precipitation pot are introduced through a small tube which extends a few inches below the inside of the pot cover. This tube is capped at the end and has a small hole drilled in the side pointing toward the agitator shaft flinger plate. The purpose of this design is to allow 30% H_2O_2 to drip directly into the bulk of the solution only when it is being added slowly. When solution is added faster than 150 cc per minute it spurts from the tube onto the flinger plate attached to the agitator shaft and is thrown to the walls of the vessel thus washing them relatively clean of precipitate.

Cooling is achieved by a "cold-finger" made of 1-1/2" stainless steel tubing 10-3/4" long. This is piped to a Freon refrigeration unit. Each precipitation vessel shares a small refrigeration unit with the adjacent filtrate pot. The cooling rate with eight liters of solution in the vessel is about 1°C per minute in the temperature range of 50°C to 0°C.

A 3/8" stainless steel tube thermocouple well extends down through the flange plate and pot lid to a point inside the pyrex vessel below the normal solution level.

Screwed into the top of the pot lid and extending just inside the vessel is a stainless steel spray nozzle which is connected to the distilled water manifold. This is an emergency device which can be used to break down foam and dilute the solution in the event that the hydrogen peroxide decomposes swiftly during precipitation.

Piping and Controls

Figure 14 is a schematic diagram of the piping connections for the precipitation assembly including the equipment for transferring the nitrate slurry from the Hanford Sample Can to the precipitation vessel. All of the solution lines are 1/4" Type 316 stainless steel tubing connected with flareless fittings.

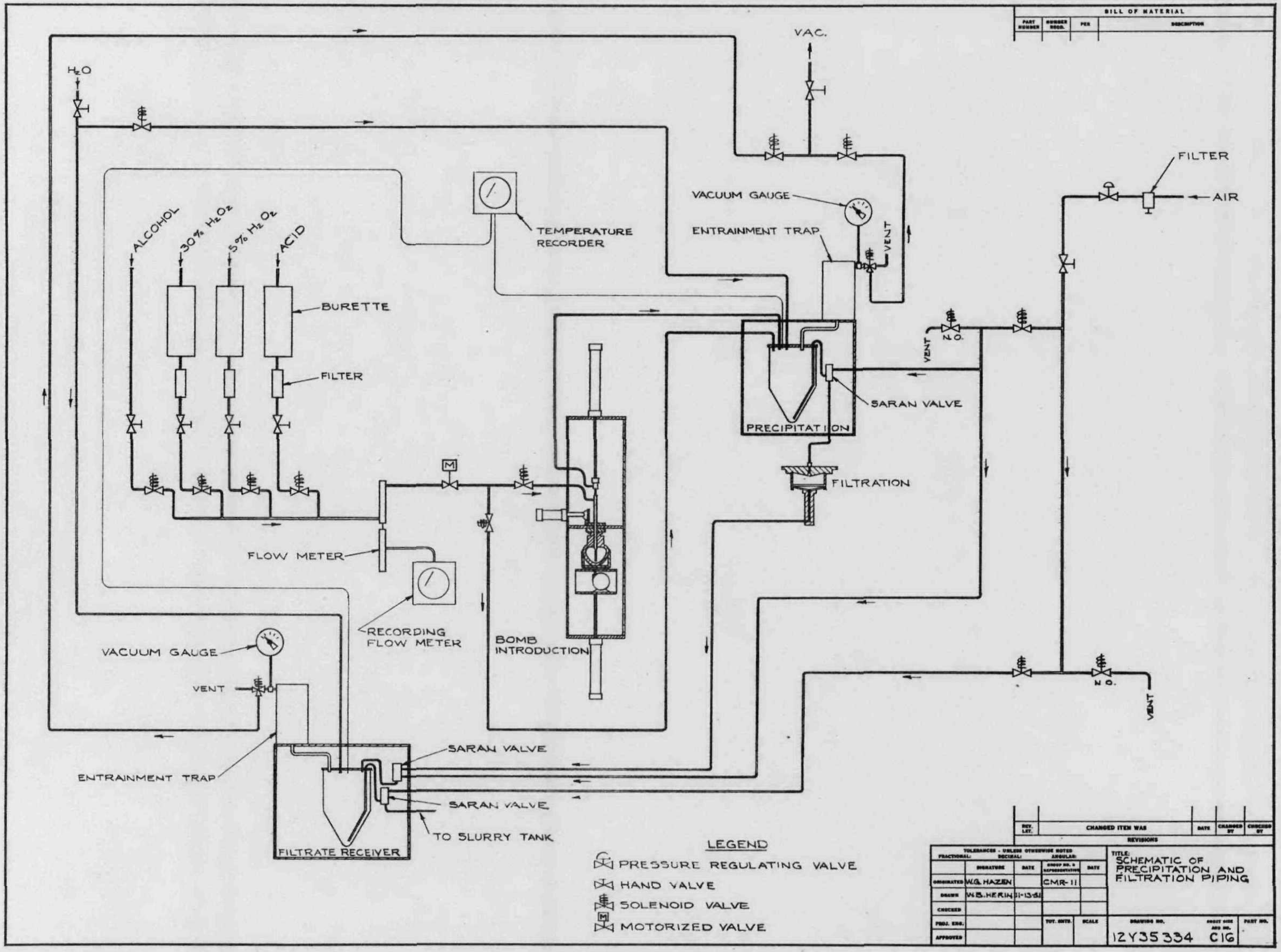

Fig. 14. Schematic piping diagram of precipitation-filtration assembly.

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Control valves are of the 110V solenoid type; made of stainless steel with a Hastelloy C insert seat and a teflon shut-off disc. The valve proper has proven to be excellent although trouble has been encountered because the solenoid actuator is too small. Many of these valves have been modified to incorporate a small air cylinder in place of the solenoid with very satisfactory results.

The panel board for controlling the precipitation-filtration operation and the peroxide destruction step is shown in Figure 15. This control panel is laid out on a flow sheet basis as can be seen from the photograph.

Certain portions of this control installation are sufficiently unique to justify special comment here.

In the entire assembly particular attention was paid to having all valves of a type such that in the event of electrical power failure all solution flows would stop and all vessels would be vented. The solution solenoid valves are therefore of the normally closed type and the vent valves of the normally open type.

In operation, after the nitrate solution has been transferred to the precipitation vessel a solution of 1.75N HNO_3 - .3N H_2SO_4 is added to the sample can through the dip tube spray line and sucked into the vessel. It is important that the total volume of this acid solution be known with reasonable accuracy and that the rate be controlled. To achieve this, the solenoid from the acid manifold is opened by pushing the four-way switch on the panel to the HNO_3 - H_2SO_4 position. This puts acid in the manifold and lines up to the motorized valve. The motorized valve was modified to give accurate throttling at low flow rates. Since these valves were modified during installation and are not available commercially a drawing is given in Figure 16. As this valve is slowly opened acid begins to flow through the rotameter and into the sample can (Hanford Bomb).

The rotameter is part of a Fisher-Porter "Flowrator" instrument. The rate indicated by the float in the rotameter is recorded by the instrument mounted on the front of the control board below the switch panel (See Photograph Figure 15). This instrument not only records the rate of flow but indicates a running total.

The circular dial (Flowrator-Counter) on the panel is an alarm device. The hands on this dial are set by the operator to the value corresponding to the desired total volume. When this volume has passed through the rotameter the contacts behind the dial activate a buzzer alarm and light circuit to call the operator's attention. This device is useful since in some cases solutions are added slowly (H_2O_2 particularly) over a 20 - 30 minute period and the operator can tend to other duties during this time. The other counter on the panel is connected to the Flowrator totalizer and carries a running total of the volume for the convenience of the operator. It is manually reset for each solution.

The reason for using a four-way electric switch for adding the different solutions is to make it impossible to forget to shut one

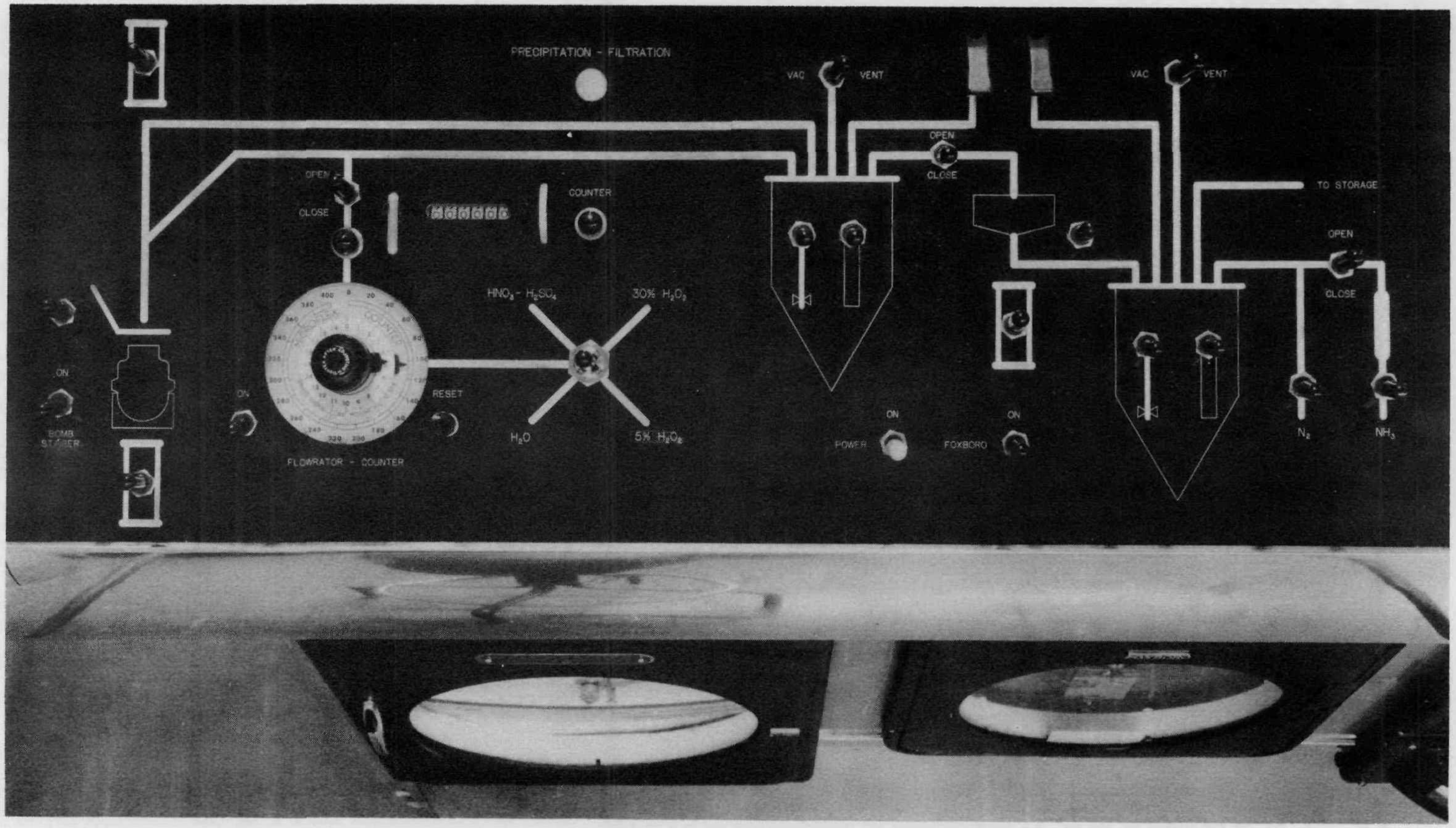

Fig. 15. Control panel for nitrate solution introduction, precipitation, filtration and peroxide destruction.

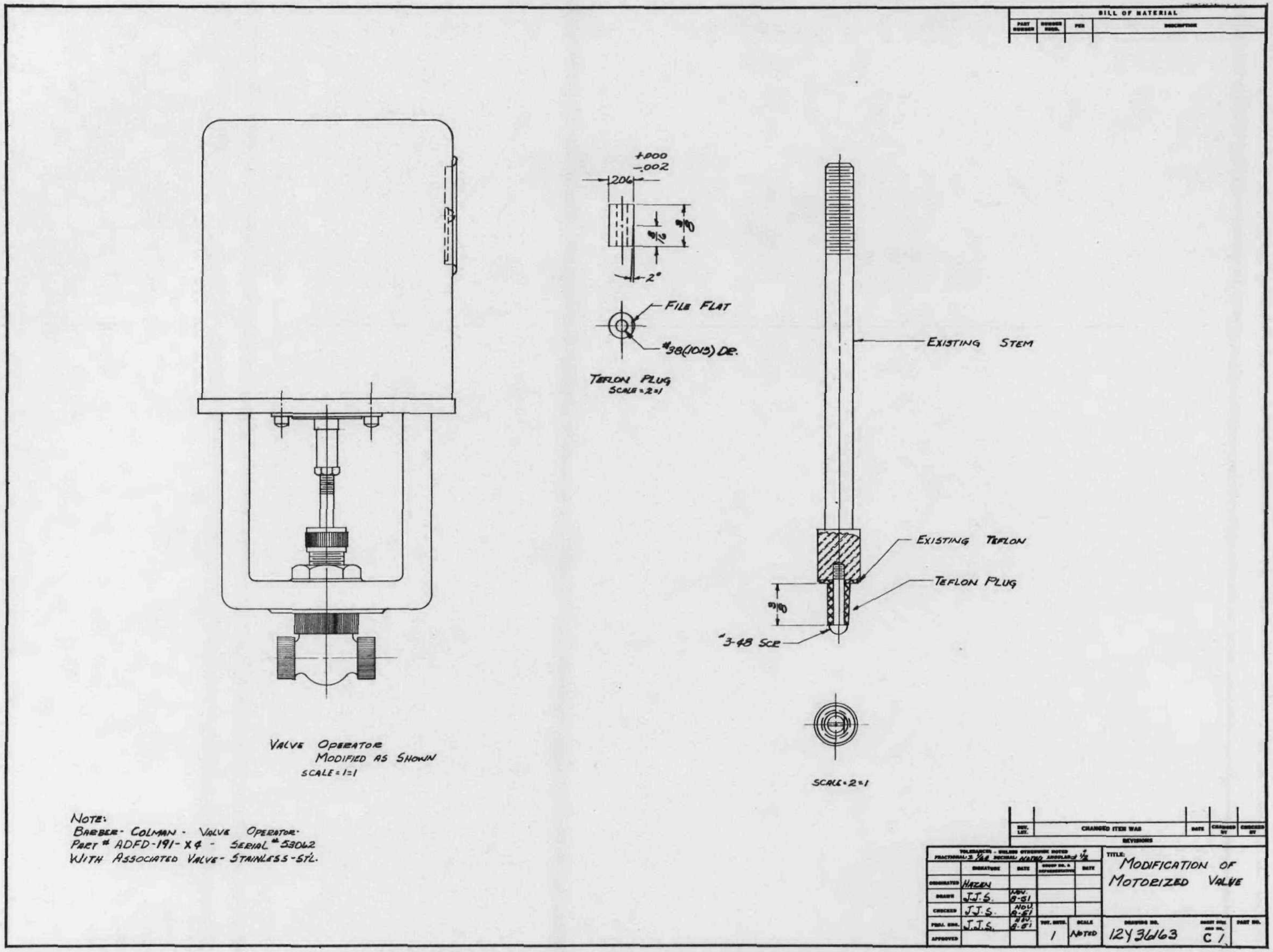

Fig. 16. Modified motorized valve for flow control.

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solution off before starting another. This switch also permitted a simple wiring circuit for the solenoids so that when acid or alcohol are called for they are shunted through the sample can whereas the 30% and 5% H_2O_2 are sent directly to the precipitation pot.

A Foxboro Dynalog recorder is connected to chromel-alumel thermocouples in both the precipitation and filtrate vessels to record temperatures.

The rest of the control circuits and instruments are so straightforward that no comment is required.

FILTER BOAT AND LIFT PLATE

The filter boat is used for filtration of the peroxide slurry from precipitation and also for hydrofluorination of the peroxide. The lifting plate serves not only as the support for the boat when it is in the conveyor carriage, but also contains the gaskets for sealing the hydrofluorination furnace, and provides the means of lifting and holding the boat in the fluoride dumper.

Figure 17 is a drawing of the boat and Figure 18 of the lift plate. The boat is made of 1/8" Hastelloy C rolled and welded in the form of a cup 7 inches in diameter. A lining of sheet platinum .020" thick was spun into the upper portion of the cup and into the recess (enlarged view at B). After the lining was spun in and rolled over the upper rim, a disc of sintered platinum (nominal 50% porosity) 1/4" thick (103) was pressed into place and peened into the recess.

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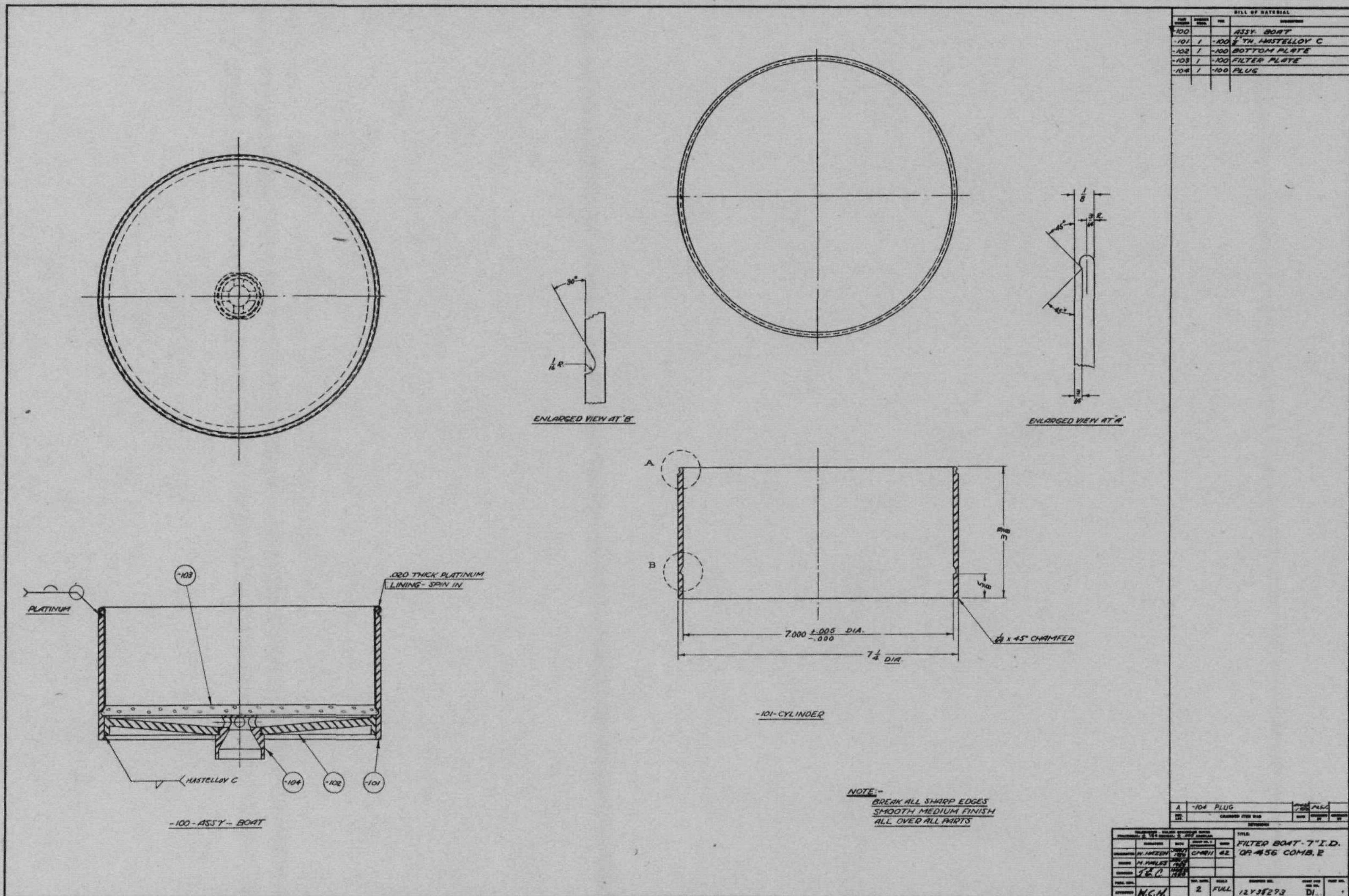

Fig. 17. Filter boat.

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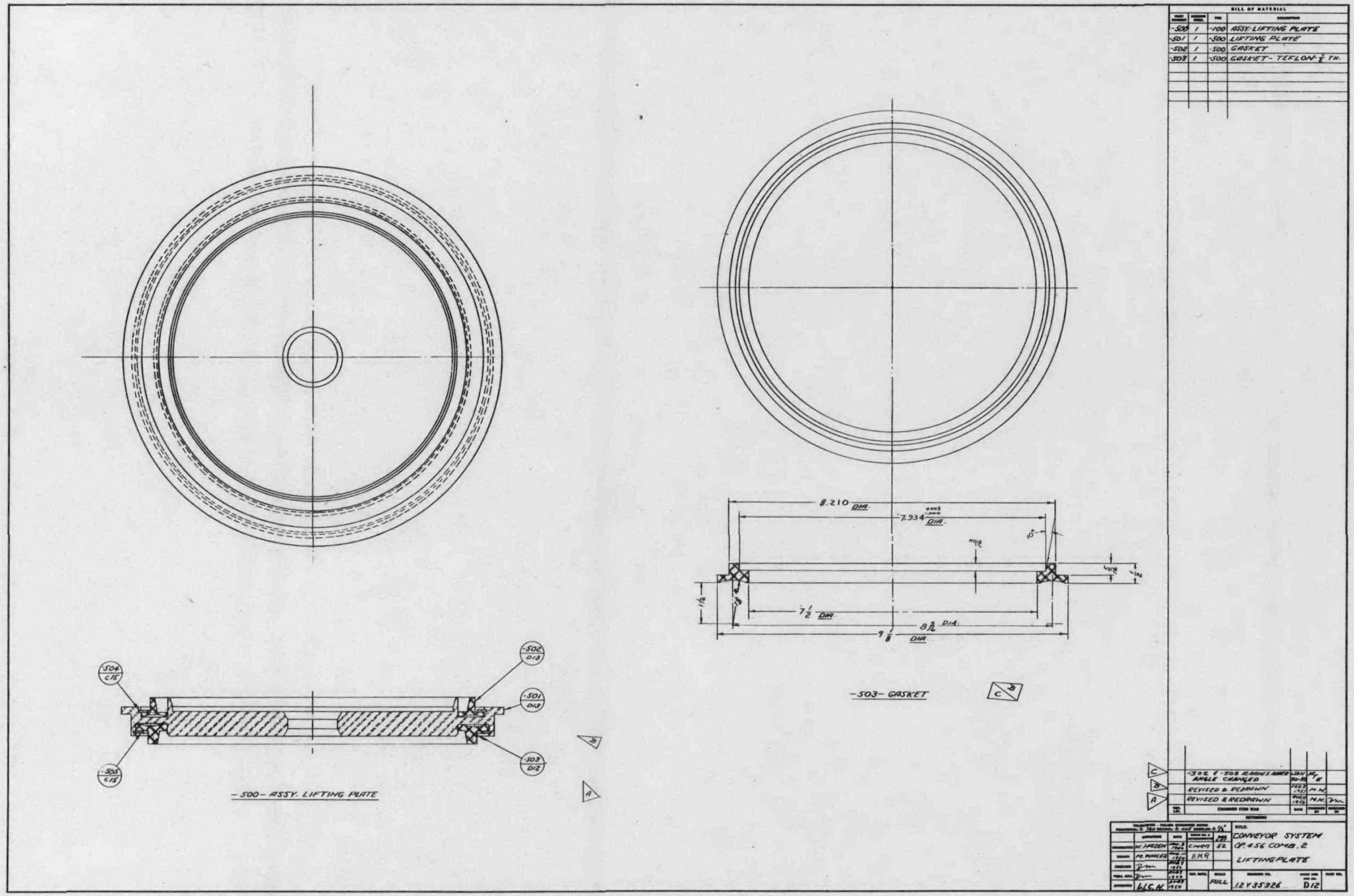

Fig. 18. Lift plate.

[redacted]

This peening forms the seal against the platinum lining and at the same time holds the disc in place.

There is a Hastelloy C tapered plug (104) in the bottom center of the boat. This plug provides the means of lifting the boat on cylinder shafts and also for drawing off liquids or gas from under the sintered platinum disc during filtration or hydrofluorination.

The lifting plate is made of Hastelloy C machined as shown (Part 500, Figure 18). The two Teflon gaskets (502, 503) are fitted into this plate. The rim (501) is used in the boat dumper to raise the plate and boat into place on the dumper cone.

The resistance to air flow of one of these boats when new is shown in Figure 19. The resistance when loaded with dry fluoride is discussed in the section on Hydrofluorination.

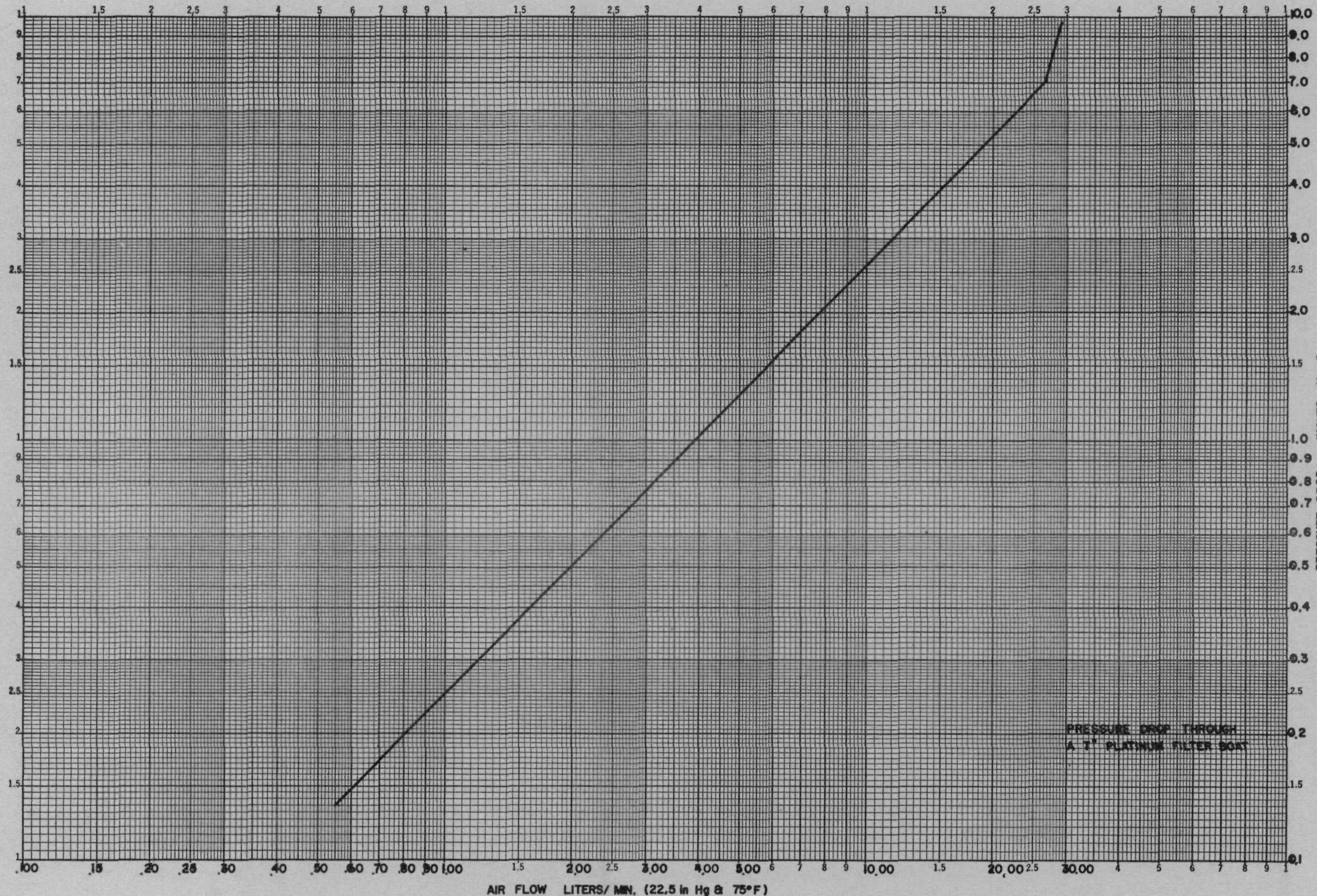

Fig. 19. Air flow resistance of new 7 in. diameter sintered platinum filter disc.

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FILTRATION

At the filtration station the plutonium peroxide slurry formed in the precipitation vessel is filtered on the sintered platinum disc and the peroxide cake is washed with dilute hydrogen peroxide, then with absolute ethyl alcohol and finally air dried.

In operation the carriage assembly (Figure 20, 12Y 35326) carrying the platinum lined filter boat (105) is rolled into position underneath the filter head (101). By actuating the air cylinder (113) the boat is lifted vertically on the tapered plug of the hollow lift adaptor (104) until the rim of the boat presses against the neoprene gasket (103) in the filtration head. Since the lift adaptor is connected by flexible stainless steel tubing to a pipe leading to the filtrate pot a vacuum can be applied to the under side of the sintered disc in the boat by pulling a vacuum on the filtrate pot. When this vacuum is applied, the peroxide slurry is sucked from the precipitation vessel into the boat where it filters, leaving a peroxide cake about 1-1/2" deep for 320 grams of Pu in the boat. The cake is washed with dilute hydrogen peroxide and then with absolute alcohol to remove excess liquid. Air is pulled through the filter to dry the peroxide after which the boat is lowered into the carriage assembly and is ready for hydrofluorination.

The controls for this operation are part of the precipitation control panel shown in Figure 15 in the section on Precipitation, and have no features different from the standard electrical system.

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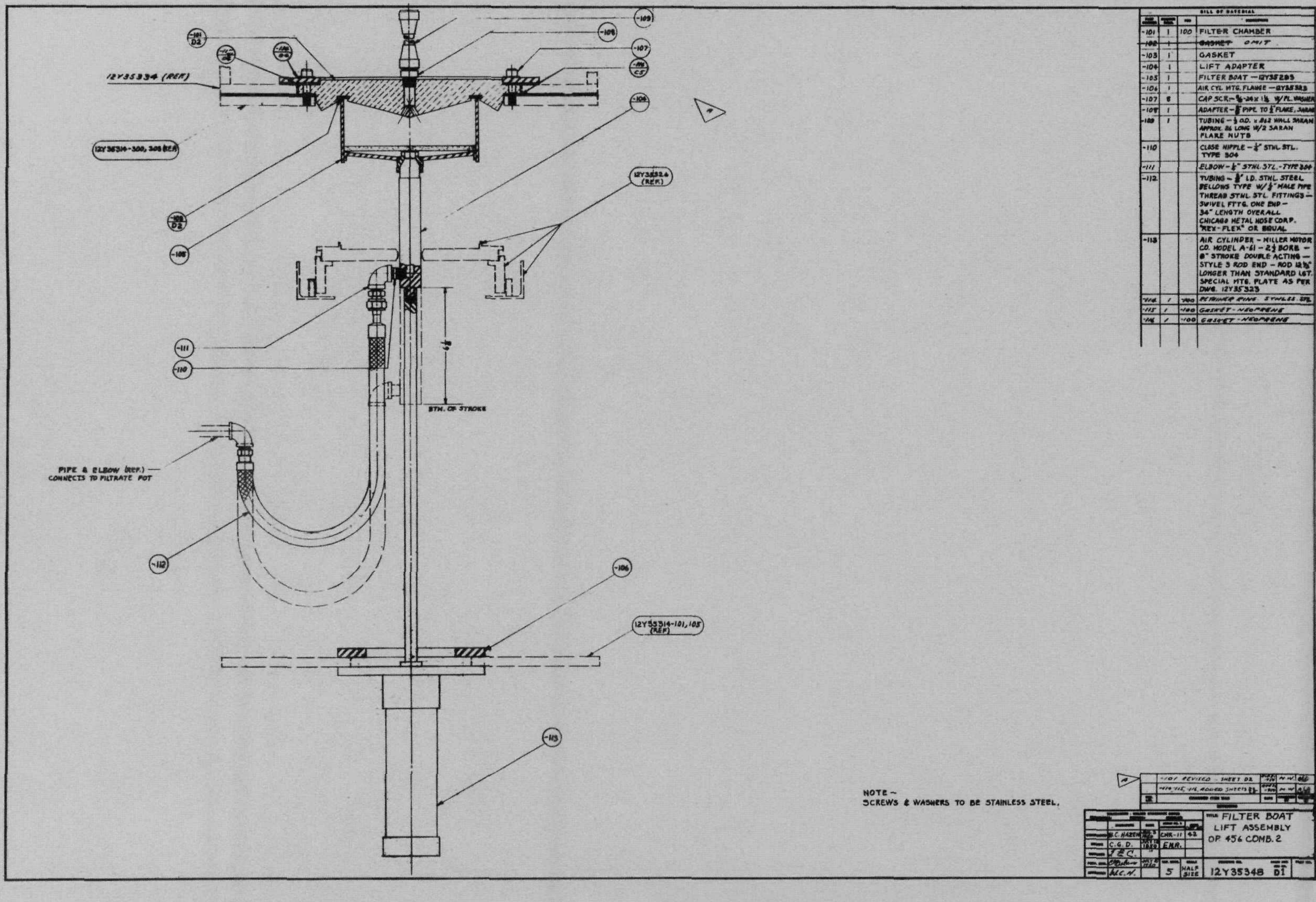

Fig. 20. Design layout of filtration assembly.

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FILTRATE RECEIVERS

Mechanical Features

The filtrate vessels are used not only as receivers for the peroxide filtrate but also as reaction vessels for destroying excess hydrogen peroxide by addition of ammonia. There is one filtrate pot located at each end of each line. The glass vessel, lid, agitator, guard, and mounting flange plate are duplicates of the precipitation vessel described in the section concerning that unit.

Figure 21 is a layout of enclosure housing the receiver and Figure 22 is a layout of the equipment. A photograph of one unit taken during installation is shown in Figure 23.

In Figure 22 a cross section of the sampling mechanism can be seen in its enclosing box.

Piping and Controls

Figure 24 is a layout of the piping for this unit.

After the filtrate is in the receiver a sample is taken for plutonium assay. The solution is then ready for peroxide destruction. This is accomplished by bubbling nitrogen at a fixed rate (approximately 5 liters per minute) through a tube below the solution level. Into this nitrogen stream anhydrous ammonia is passed at 4 liters per minute controlled by a modified motorized valve.

The ammonia neutralizes the excess acid and as the pH rises, plutonium, iron and aluminum precipitate as the hydroxide. Ammonia addition is continued for 15 minutes after the appearance of these

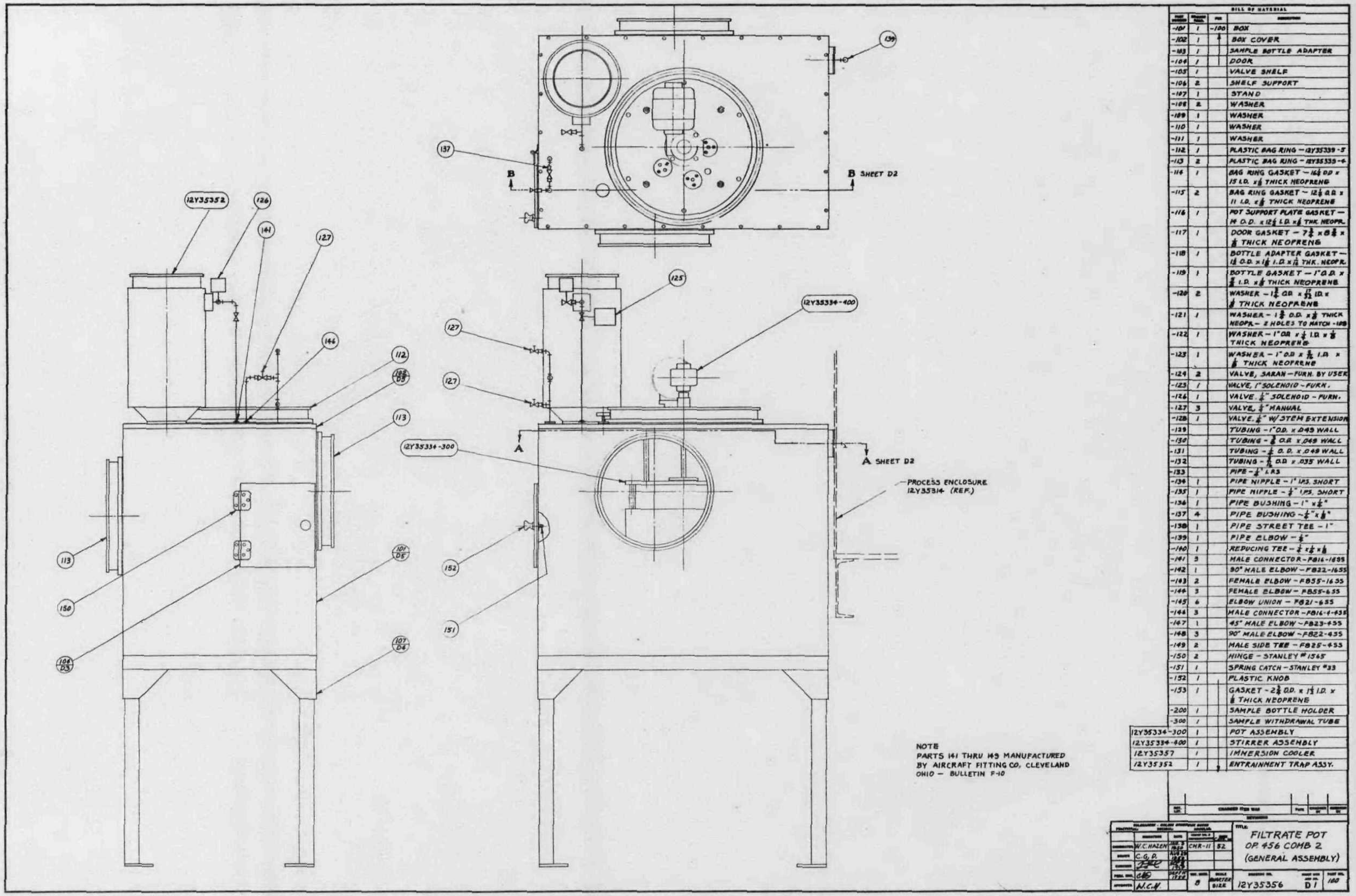

Fig. 21. Filtrate receiver housing.

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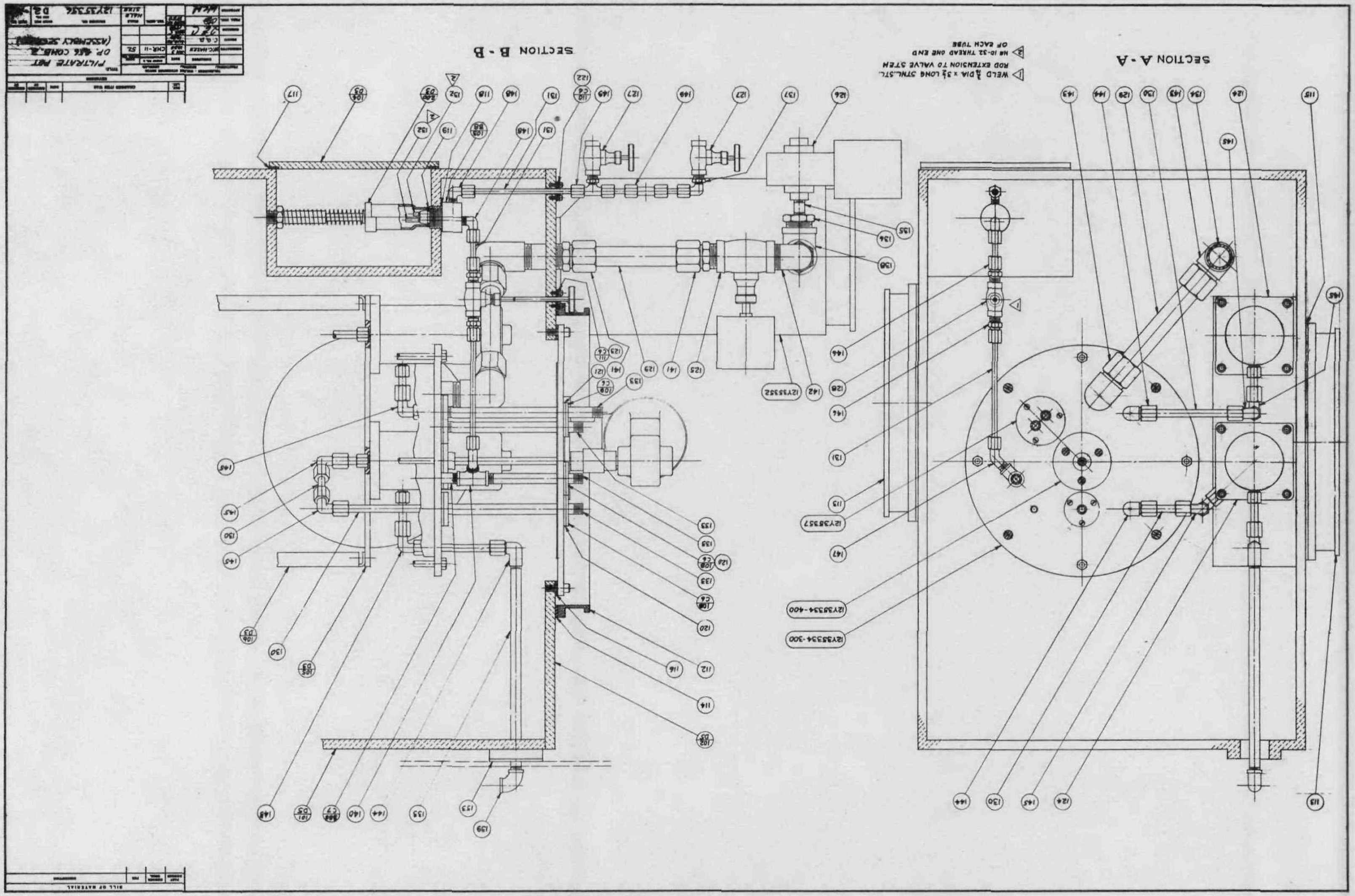

Fig. 22. Filtrate receiver layout.

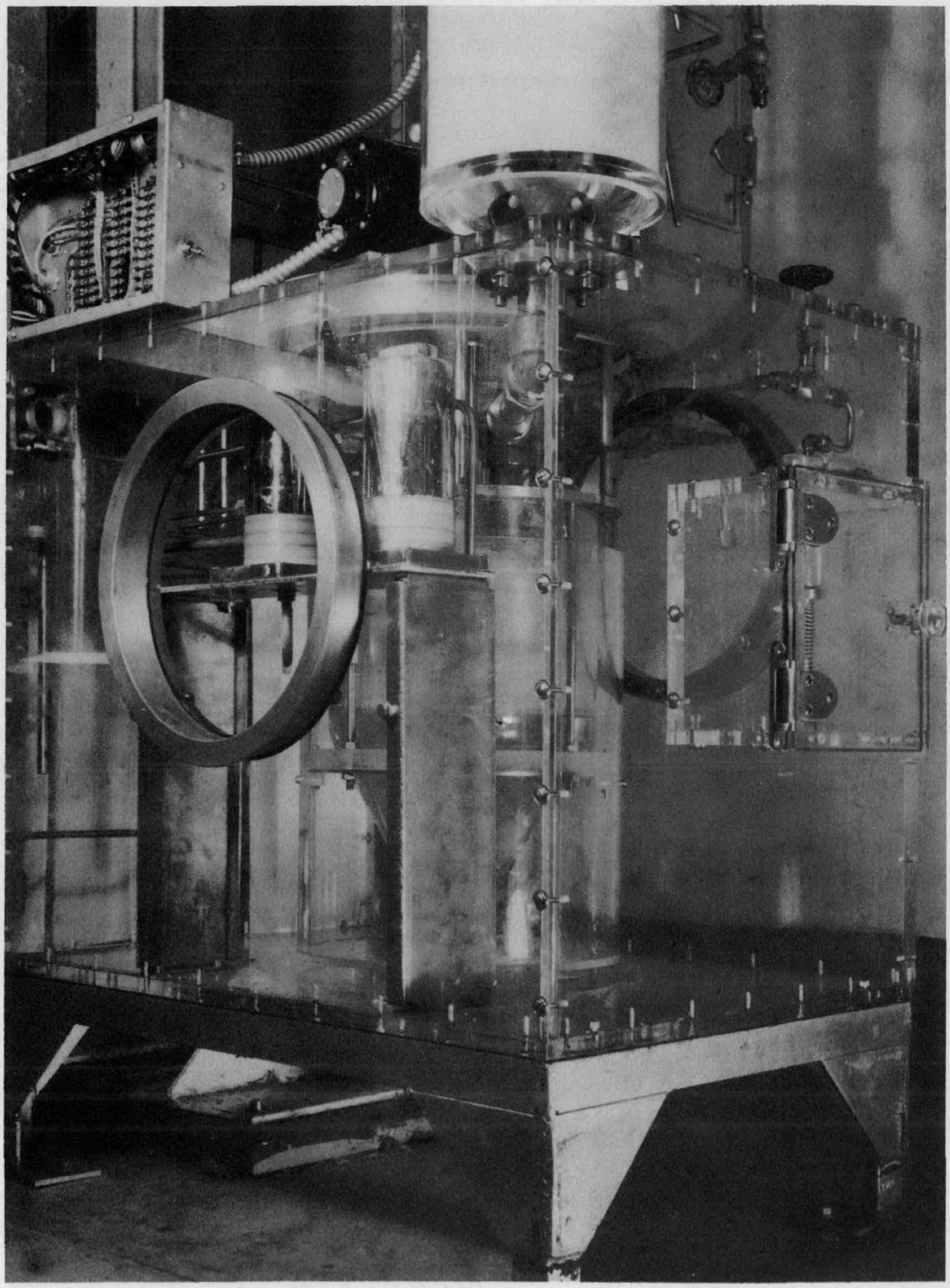

Fig. 23. North east filtrate vessel assembly.

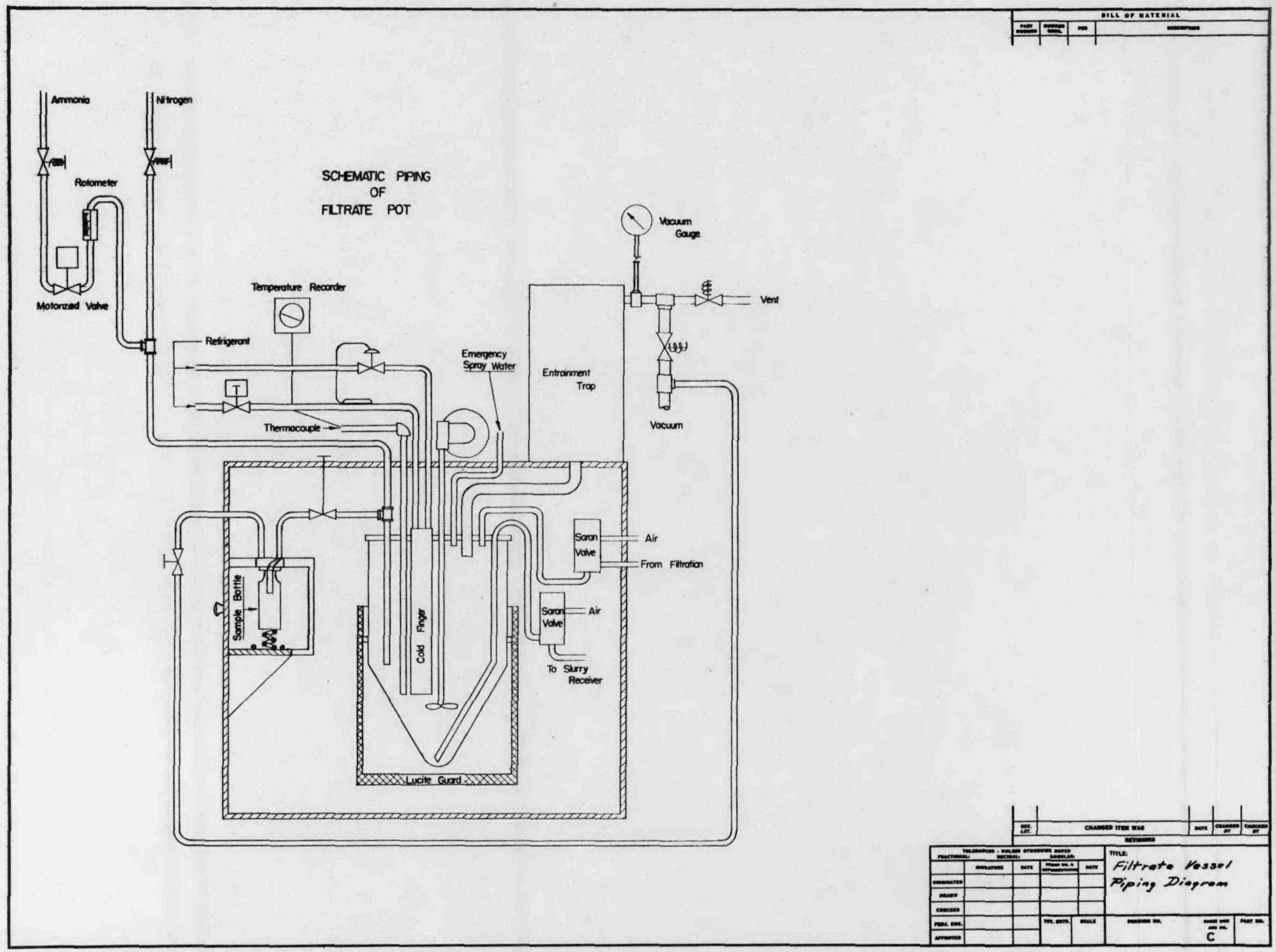

Fig. 24. Filtrate vessel piping.

precipitates which is sufficient to cause decomposition of the hydrogen peroxide. After a suitable digestion period the hydroxide slurry is transferred by vacuum to the slurry system at the south end of the operating room.

The controls for this unit are part of the precipitation control panel shown in the photograph (Figure 15). The temperature of the solution is recorded on the same chart as the precipitation vessel temperature. This vessel is equipped with a water spray nozzle in the lid to serve as a foam breaker in case the peroxide destruction step becomes too vigorous.

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HYDROFLUORINATION FURNACE

In the hydrofluorination furnace the dry plutonium peroxide in the platinum lined filter boat is converted to plutonium tetrafluoride by reaction with a mixture of anhydrous hydrogen fluoride and oxygen at 550°C. The same equipment is used also for the direct hydrofluorination of plutonium metal chips.

The general description of the operating procedure for conversion of peroxide to tetrafluoride is as follows: the boat containing the dry peroxide is elevated into the furnace which is sealed by the gaskets in the lift plate. The furnace heat and the aspirator are then started. Oxygen is turned into the furnace at 50 grams per hour and when the material temperature is 110°C the hydrogen fluoride is turned on at 300 grams per hour. The material temperature is maintained at 550°C for the time specified in the operating procedure after which the furnace heat is shut off. When the temperature drops to 300°C the HF is turned off and the oxygen left on until the temperature is 270°C or lower, at which time the oxygen is shut off and the boat lowered into the carriage.

When plutonium metal chips are to be hydrofluorinated the initial procedure differs radically from that above. In this case after a boat containing the chips is in the furnace, argon is flushed through for fifteen minutes at 400 grams per hour. Following this, HF is passed through the system at a rate of 50 grams per hour and the temperature watched for the start of the reaction. If the temperature

[redacted]

begins to rise too rapidly, the HF rate is decreased to retard the reaction. If there is no temperature rise in 15 minutes the furnace is heated to 80°C until the reaction does start. When the reaction begins it is allowed to continue for two hours after which the furnace temperature is raised to 550°C and the argon is shut off. The HF flow is raised then to 300 grams per hour, and oxygen started at 50 grams per hour. After this the cycle is the same as that for hydrofluorination of peroxide.

For descriptive purposes the equipment for performing these operations is divided into two main parts; (1) the furnace and lift assembly and (2) the piping and control system.

(1) <u>Furnace and lift assembly</u>

A cross section of the furnace and lift assembly is shown in Figure 25. A photograph of the furnace taken during installation is shown in Figure 26. The furnace shell (104) detailed in Figure 27 is fabricated of 1/8" Hastelloy C rolled and welded into a cylinder 7-3/4" ID by 6-1/4" deep. A Hastelloy C mounting flange is welded near the open end and a 1/4" Hastelloy pipe for gas introduction is welded into the shell above this flange. A short length of 1/4" Hastelloy pipe welded into the top end serves as a holder for the platinum thermocouple well (103). Around the shell is a heating jacket of mild steel (102) with 16 holes drilled in it at equal intervals for the heating cartridges. The heating jacket is insulated with 1" of magnesia. The Hastelloy shell is bolted by the flange to

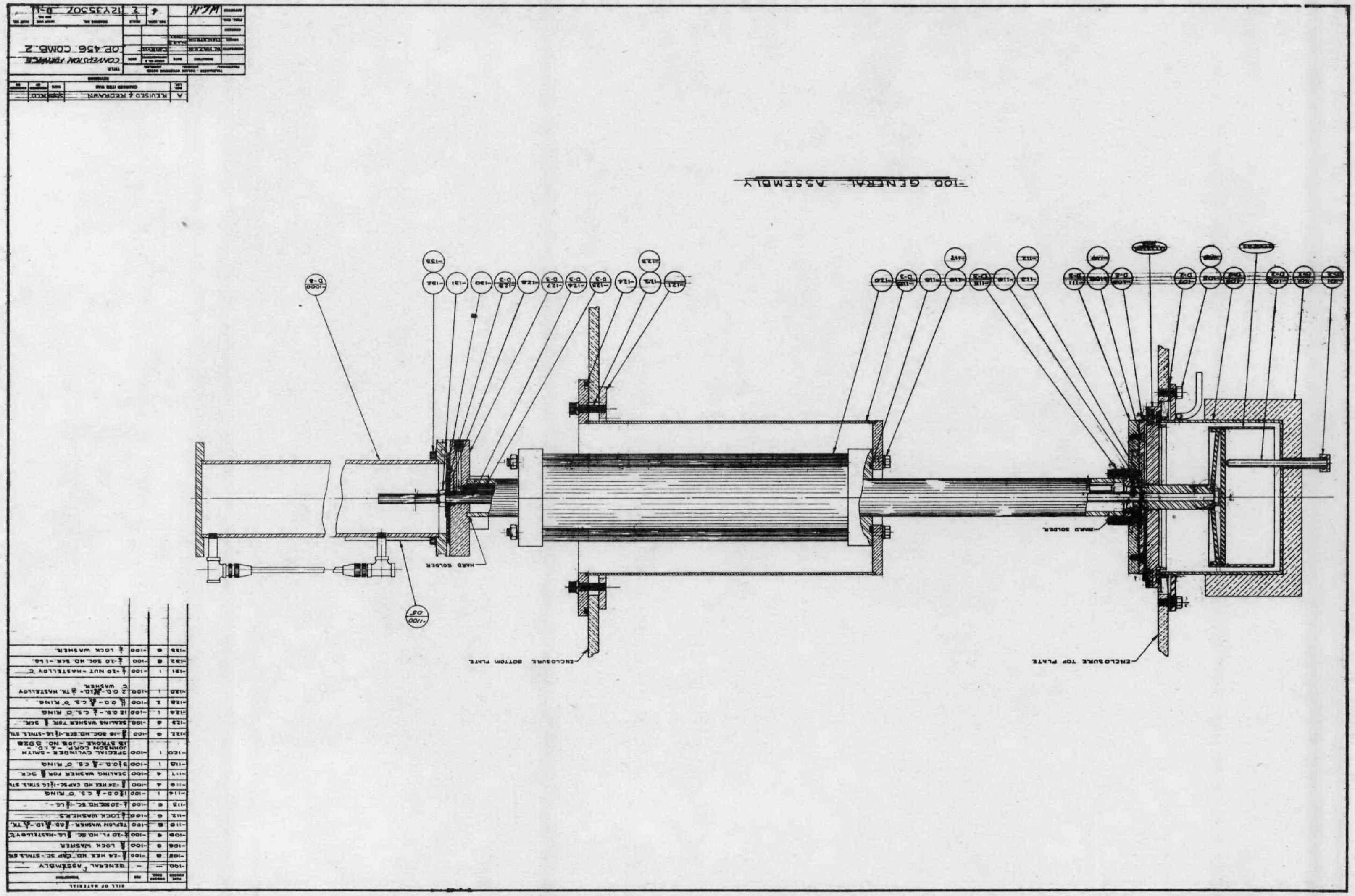

Fig. 25. Cross section of hydrofluorination furnace and lift assembly.

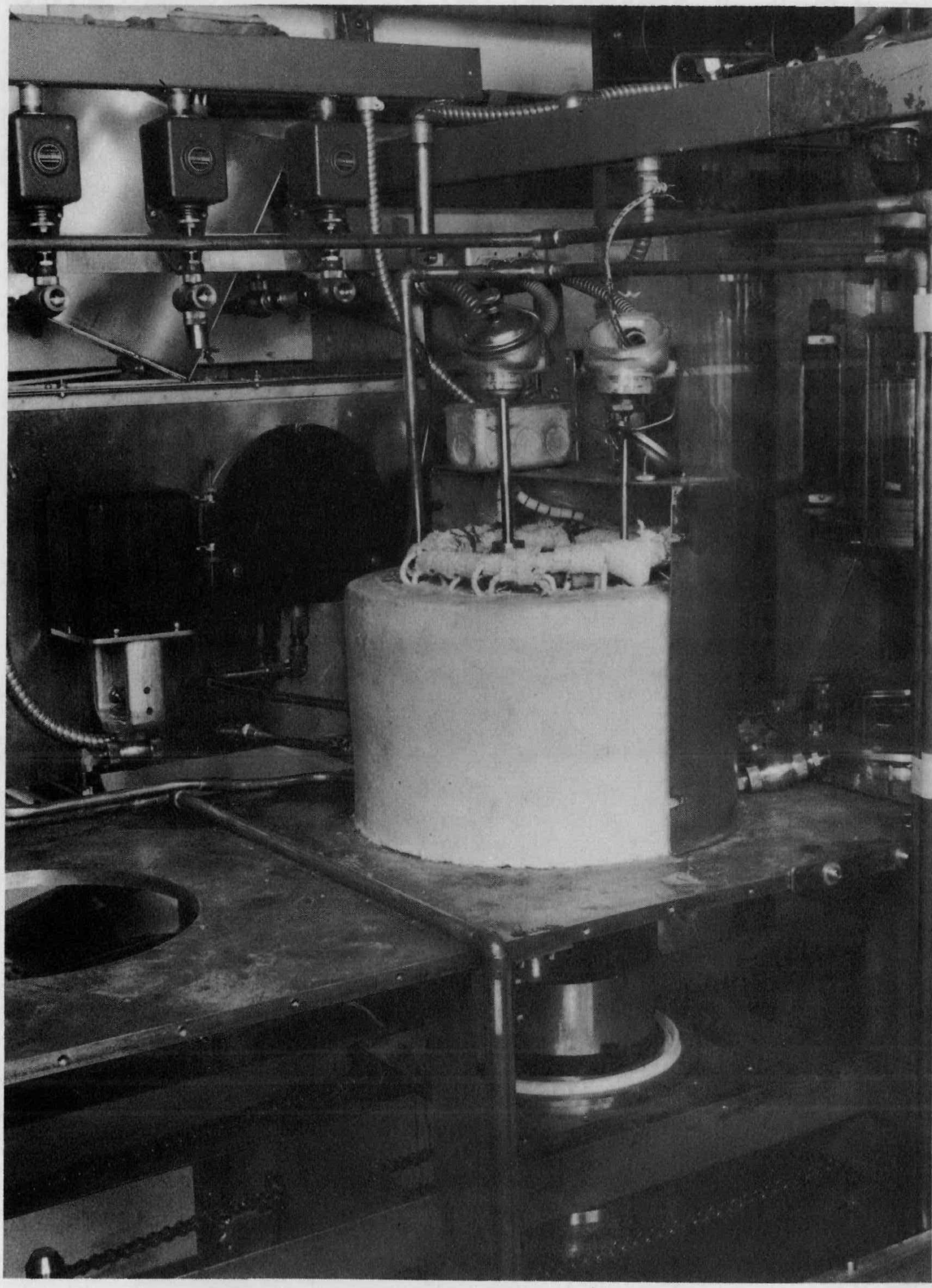

Fig. 26. Photograph of north east hydrofluorination furnace during installation.

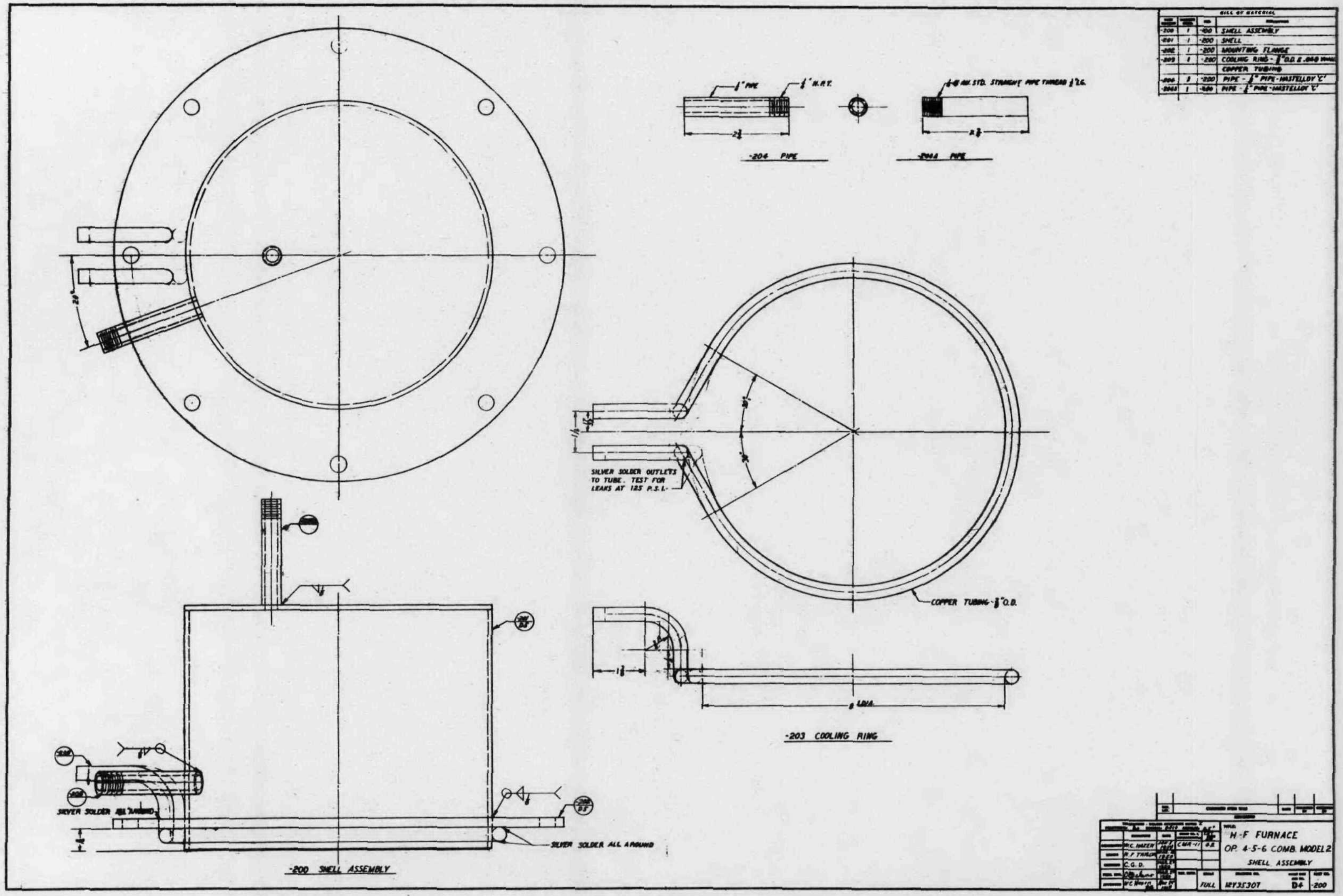

Fig. 27. Hydrofluorination furnace shell.

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the top plate of the main enclosure. This method of mounting leaves the heating elements, pipe connections and thermocouple outside the enclosure and directly accessible from the operating zone.

The lift assembly consists of a 4" ID double ended air cylinder (120 Figure 25) with a two inch diameter mild steel tube serving as the piston rod. This hollow piston rod has a Hastelloy adaptor head (108 Figure 25) (Also see Figure 28) brazed to the lower end. A 1/4" Hastelloy pipe screwed into the adaptor head runs straight down through the piston shaft and extends out through the brass plate on the bottom. Water connections permit cooling water to flow inside the piston shaft around this 1/4" Hastelloy pipe.

There is a trap (1000) made of 4" diameter Hastelloy tubing bolted to the brass plate on the bottom of the piston shaft. This trap has a sight tube of fluorothene and a welded side arm connection of Hastelloy pipe to which is attached the Saran aspirator.

A monel valve on the lower Tee of the trap sight glass serves as a trap drain.

The air cylinder is bolted to a brass bell (119) which in turn is "wobble-plate" mounted to the bottom plate of the main enclosure.

In operation the filter boat containing plutonium peroxide is picked up by the tapered head of the lift adaptor (401 Figure 28). As the adaptor continues to rise the plate portion (402 Figure 28) fits into the lower teflon gasket of the lifting plate (503 Figure 29) and carries the lifting plate up until the upper teflon gasket (502)

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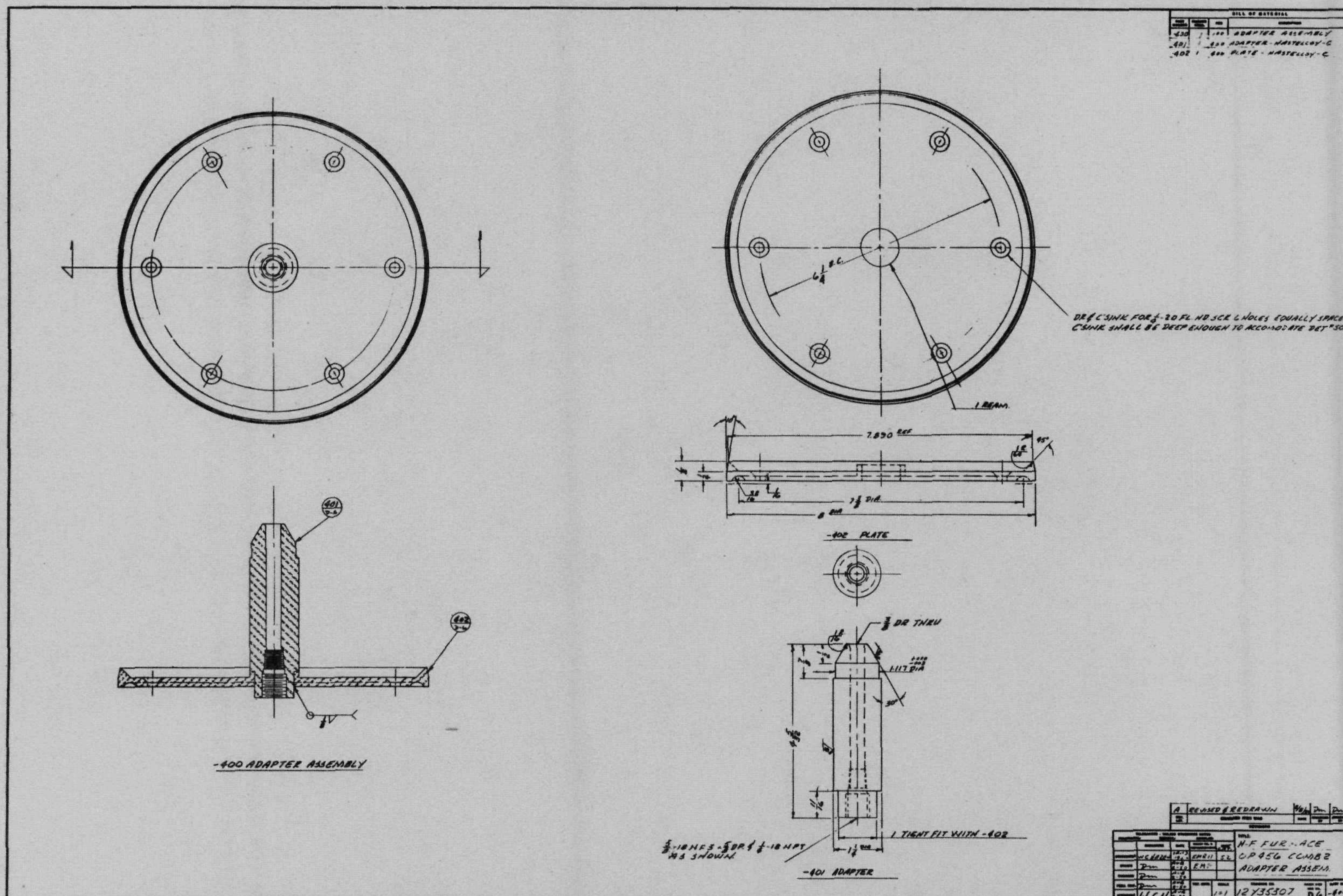

Fig. 28. Hydrofluorination furnace lift adaptor.

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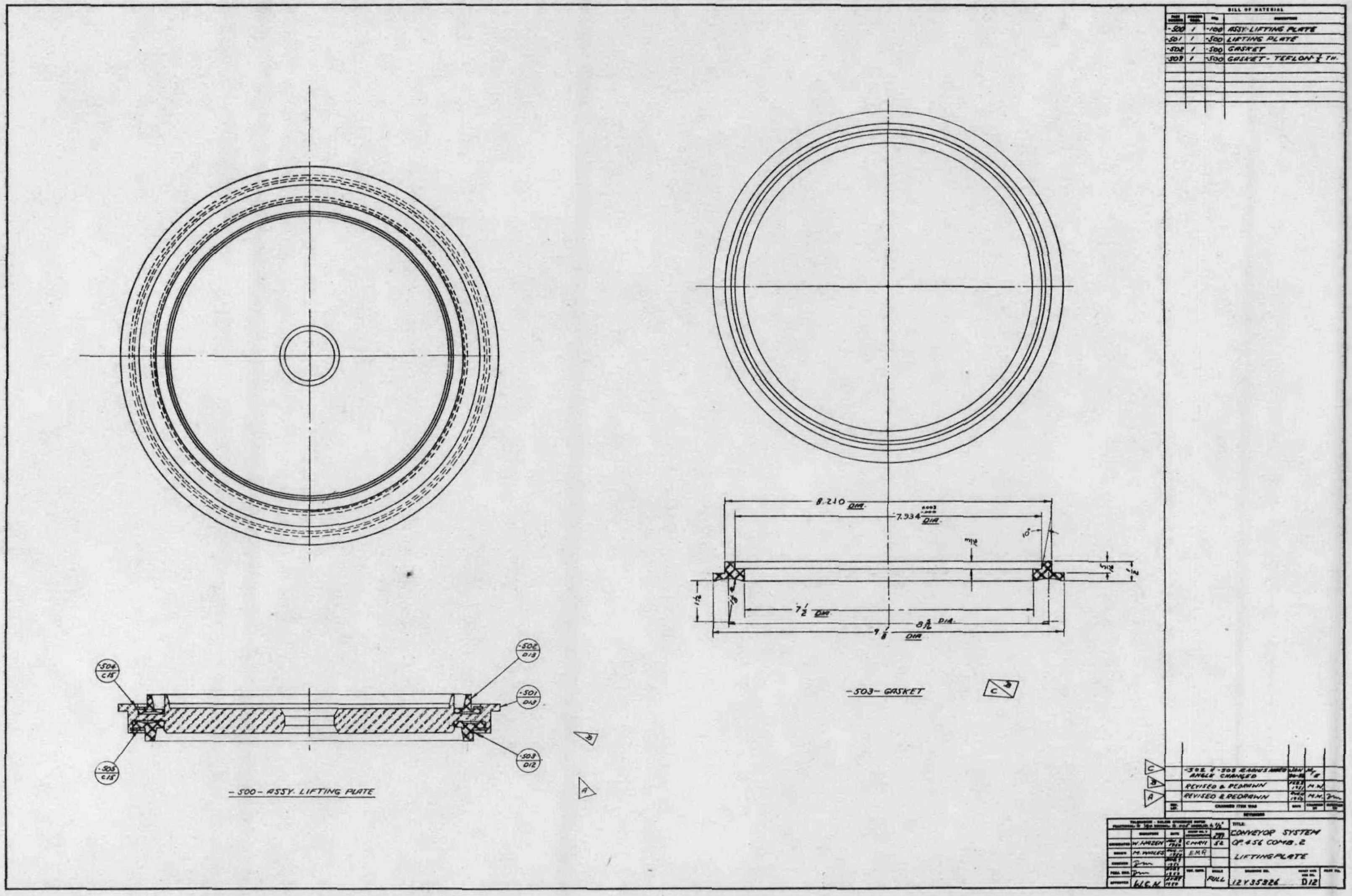

Fig. 29. Filter boat lift plate.

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seats on the lower rim of the Hastelloy furnace shell. By this design the boat is placed in the proper position in the furnace and the furnace sealed by the vertical motion of the one air cylinder. This also holds a constant force of 800 pounds on the furnace sealing gasket during the hydrofluorination operation.

Piping and Control System

A schematic diagram of the piping system for the hydrofluorination furnace is presented in Figure 30. Monel tubing is used for all lines carrying gases to the furnace and copper tubing for the water lines. As shown in the diagram, gases to the furnace pass through fluorothene rotameters for flow measurement and motorized valves for flow control.

The solenoid valves are made with a monel body, Hastelloy C insert seats and teflon shut-off discs. The motorized flow control valves are also of monel and modified in the same manner as that described for solution flow control on the precipitation units.

The gases flow into the furnace, through the filter boat, down through the center tube to the trap and then out the aspirator. The aspirator not only provides the vacuum for the operation but acts as a scrubber to remove HF and dispose of it down the drain. A drawing of the Saran aspirator is given in Figure 31. This aspirator was designed to incorporate a sintered nickel disc (1109) to act as a dust filter ahead of the aspirating chamber. Sintered platinum was the only material that would stand the corrosive atmosphere to which the filter was exposed but the gas flow resistance was too high for continued use, probably because of the moisture in the gas. The aspirators have been used, therefore, without the sintered filter discs.

The aspirator is made entirely of Saran except for the nozzle which is of Hastelloy C. This nozzle has three .052" holes drilled in

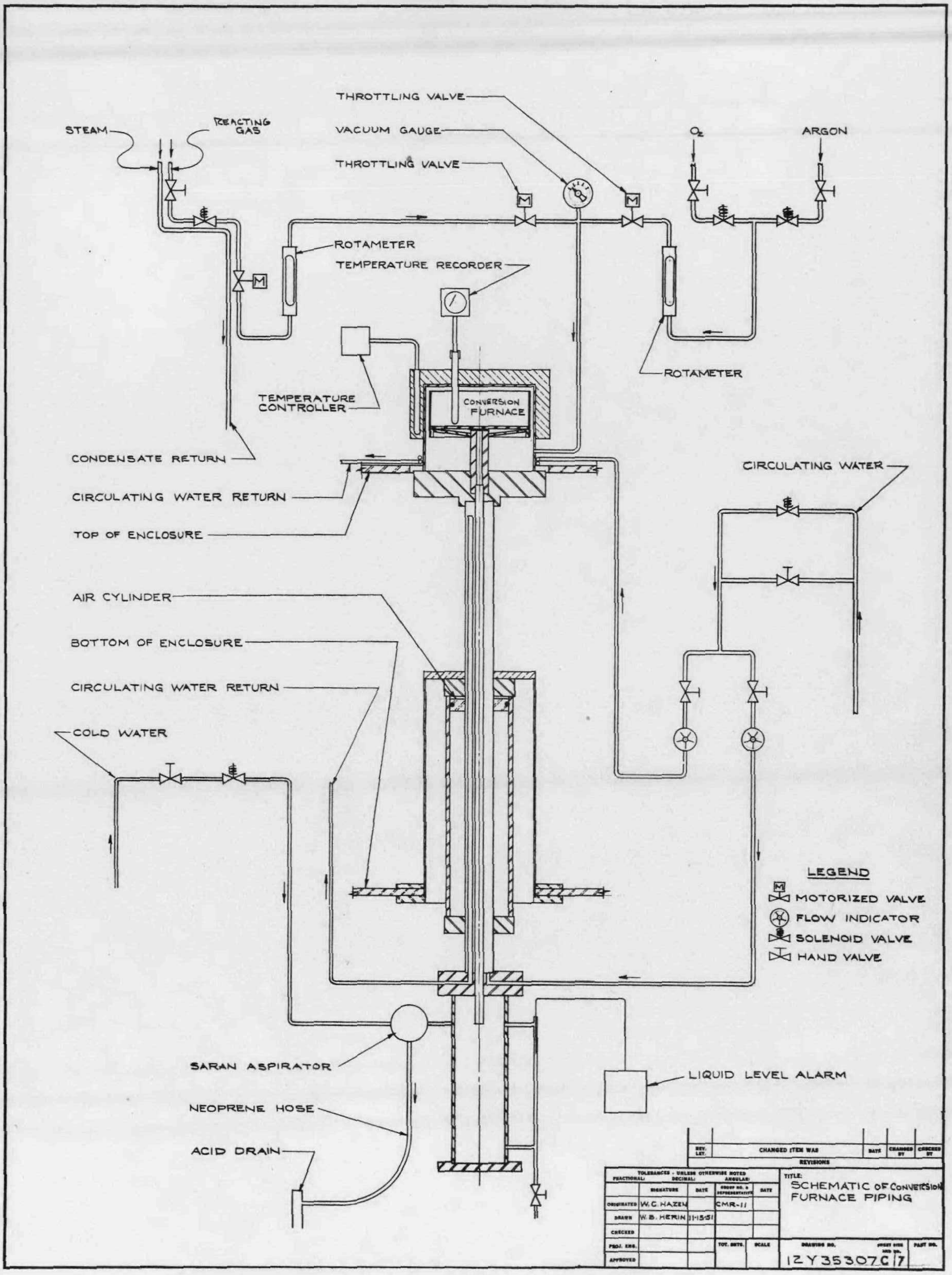

Fig. 30. Piping diagram of hydrofluorination assembly.

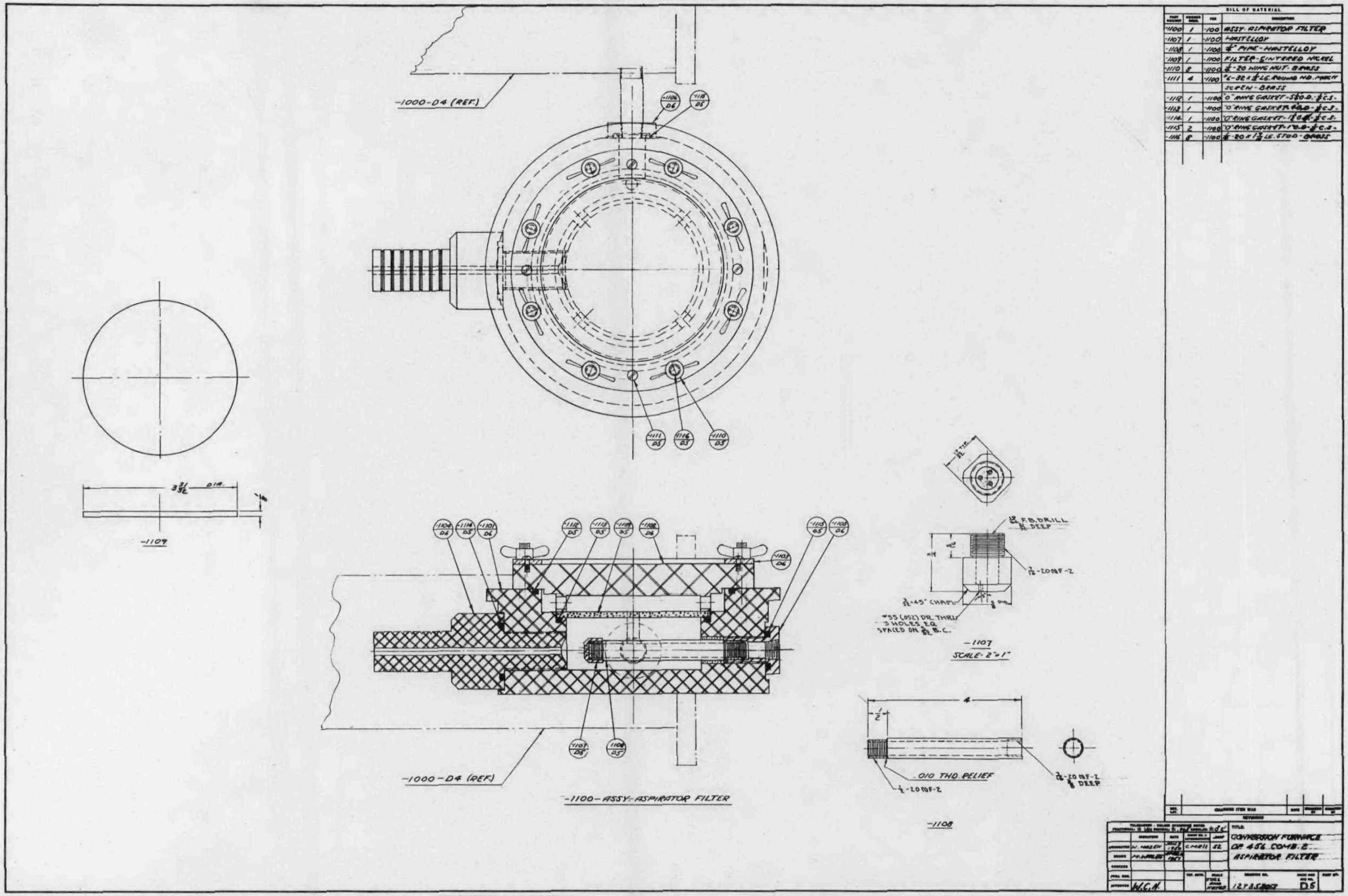

Fig. 31. Layout of Saran aspirator.

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the end on a 5/32" diameter circle and slanted inward at a 5° angle. This converges the water jet about half an inch from the nozzle just above the discharge throat and gives a water flow of 1.08 GPM at 30 psi nozzle pressure.

The size of the discharge throat is apparently critical where aspirator performance is concerned and a 9/64" hole 3 inches long was finally adopted.

Water for the jet is supplied by a separate centrifugal pump in order to eliminate fluctuations in pressure and resultant variation in gas flow.

The performance data for this aspirator are graphed in Figures 32 and 33.

A graph of the pressure drop across the system in operation with the filter boat containing a 320 gram fluoride batch is given in Figure 34.

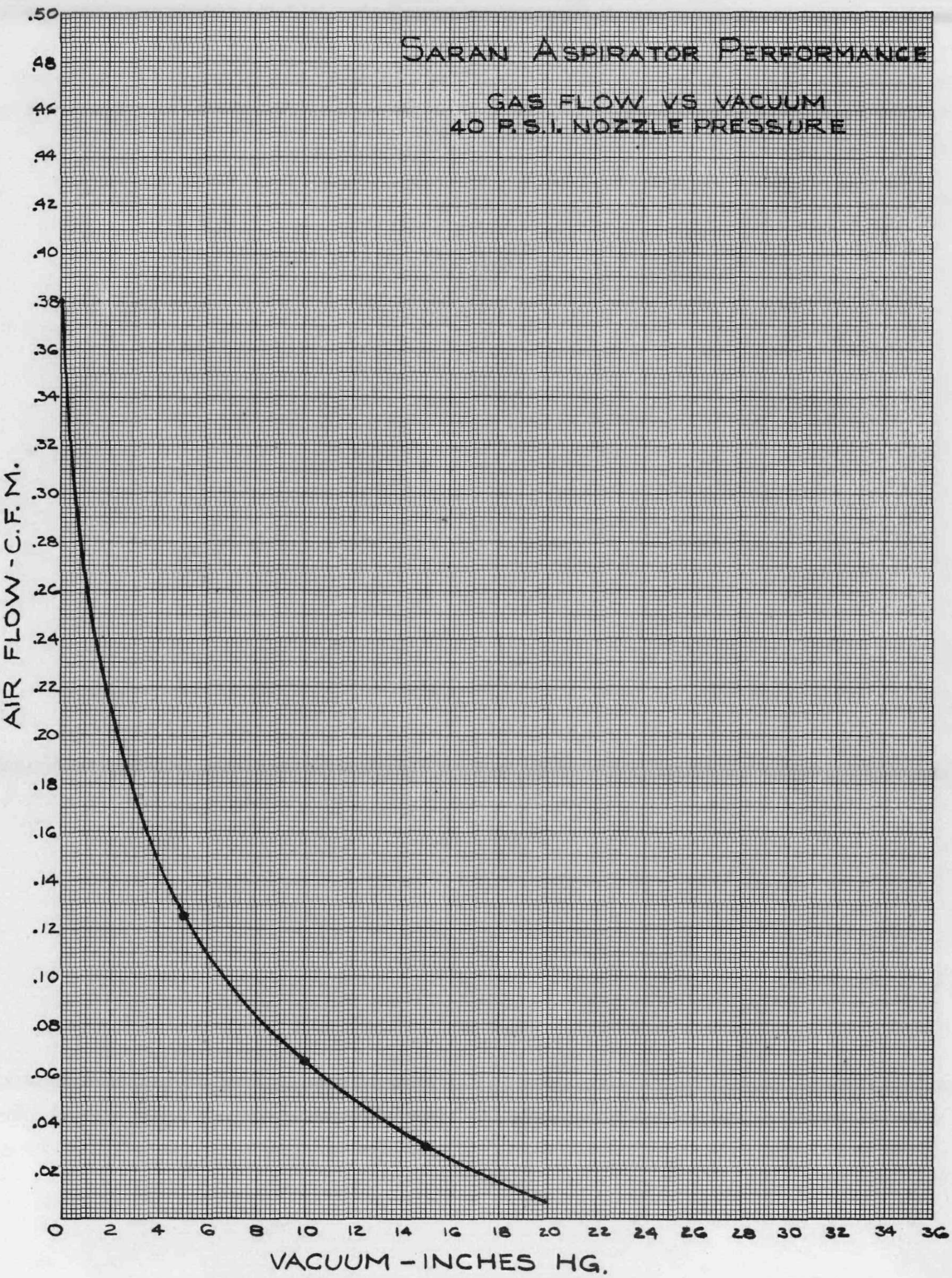

Fig. 32. Saran aspirator performance curve: Gas flow vs vacuum.

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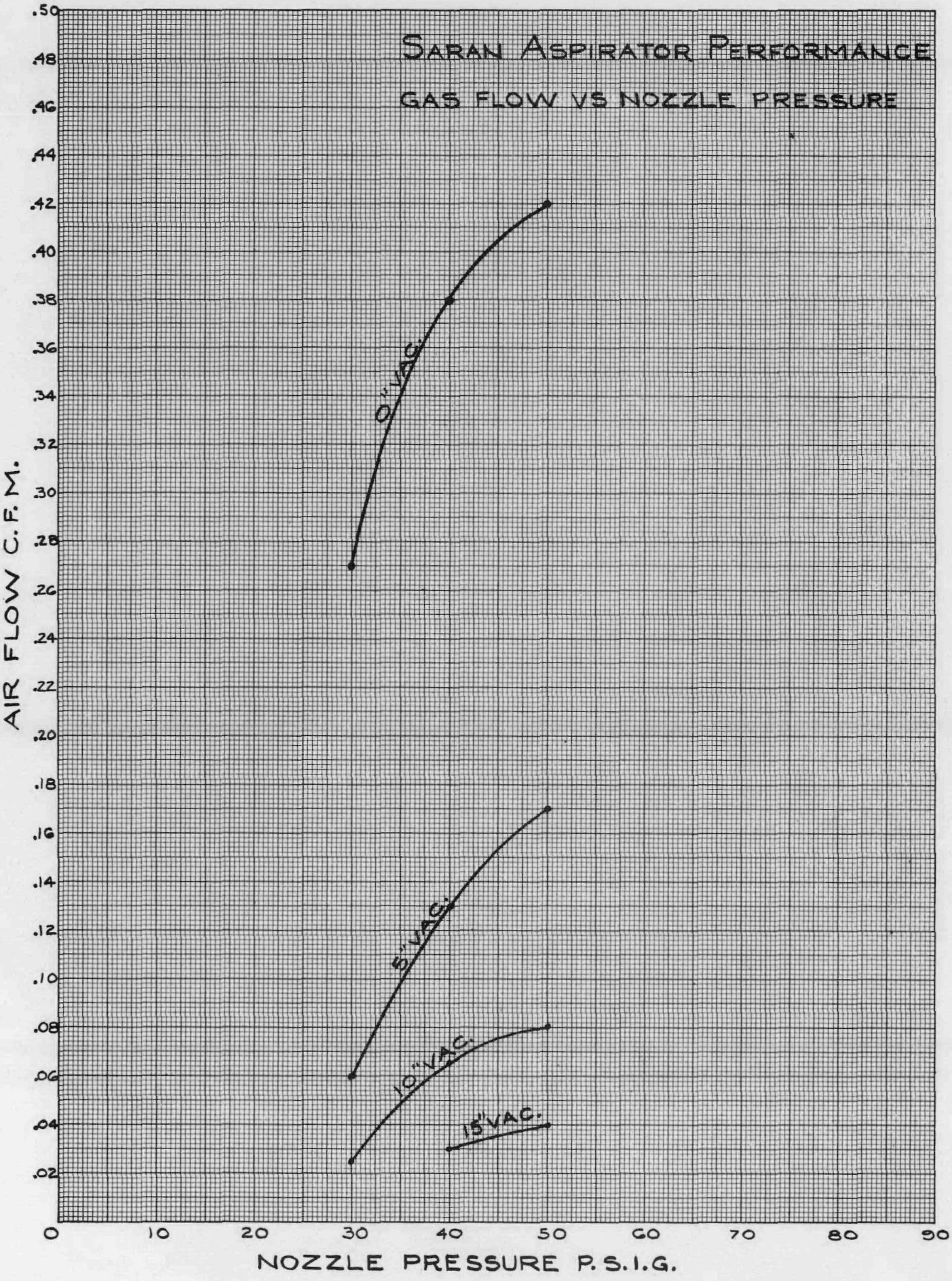

Fig. 33. Saran aspirator performance curve: Gas flow vs nozzle pressure.

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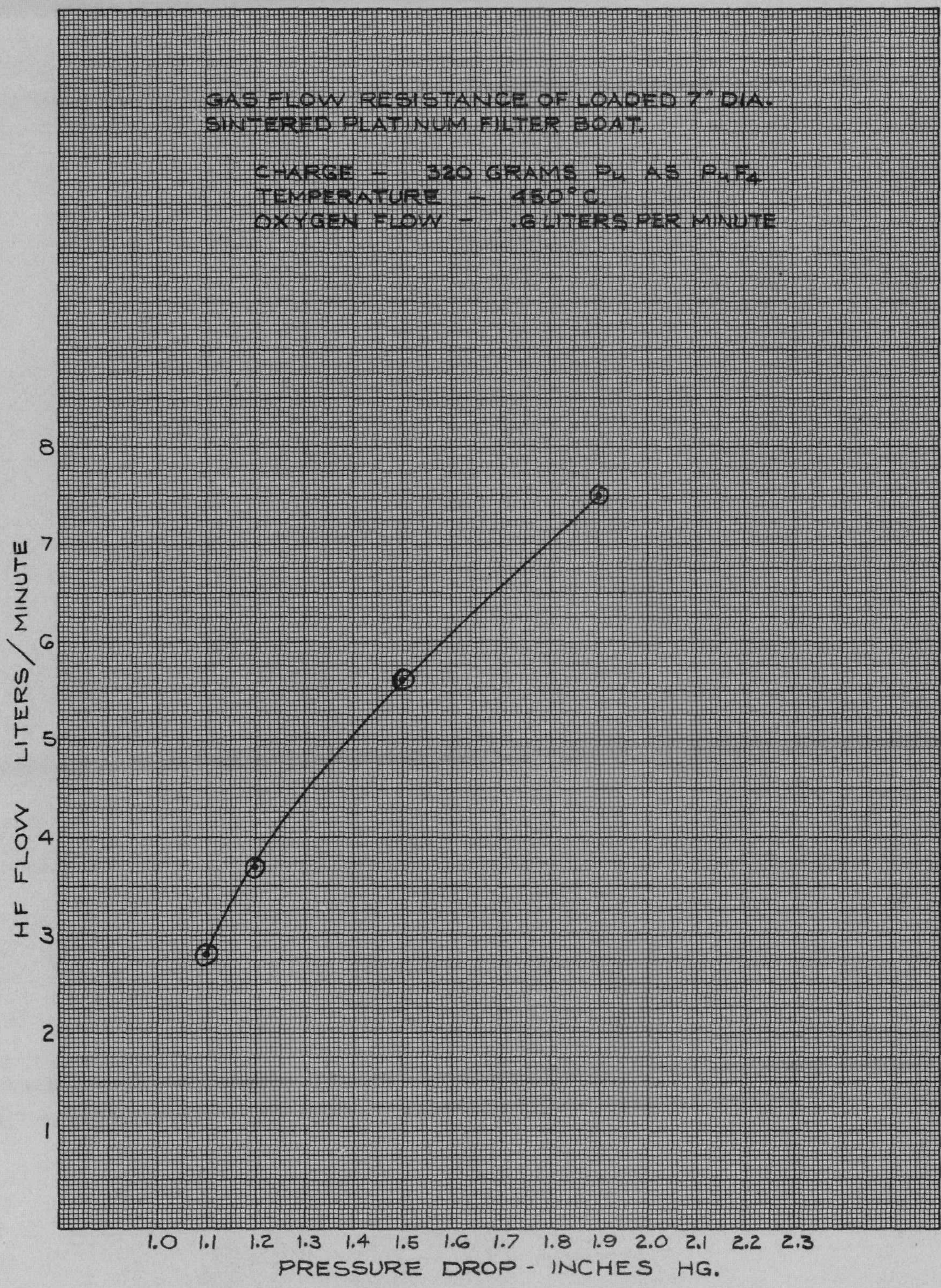

Fig. 34. Pressure drop across loaded filter boat.

The control panel for operating the hydrofluorination furnace is shown in Figure 35. With reference to this figure the three switches on the extreme right are for control of gas flow.

A vacuum gauge on the intake line to the furnace is equipped with contacts to light the alarm bulb and sound a warning buzzer in the event that the vacuum falls below a certain minimum while the HF switch is energized. This alarm system is also activated by a sensitive relay connected to a contact probe in the fluorothene sight gauge on the trap to warn of an accumulation of liquid. From each 320 gram hydrofluorination approximately 750 cc of liquid analyzing 50% HF are collected.

The heating units in the furnace jacket are 240 watt, 110V stainless steel jacketed cartridge resistance heaters. These are wired in groups of two in series to permit operation from a 220 volt supply. The current to the heaters passes through a Variac controller on the front surface of the control desk and through an ammeter on the panel. At full power the heaters draw 13.2 amperes. This is cut back to 11 amperes when maximum temperature is reached at which temperature the furnace is controlled by a Wheelco controller operating from a chromel-alumel thermocouple in the steel heating jacket.

Temperature of the material in the filter boat is recorded on a Foxboro Dynalog recorder from the thermocouple in the platinum thermowell extending from the top of the furnace shell down to within 1/4" of the sintered disc in the boat. This recorder is used for both

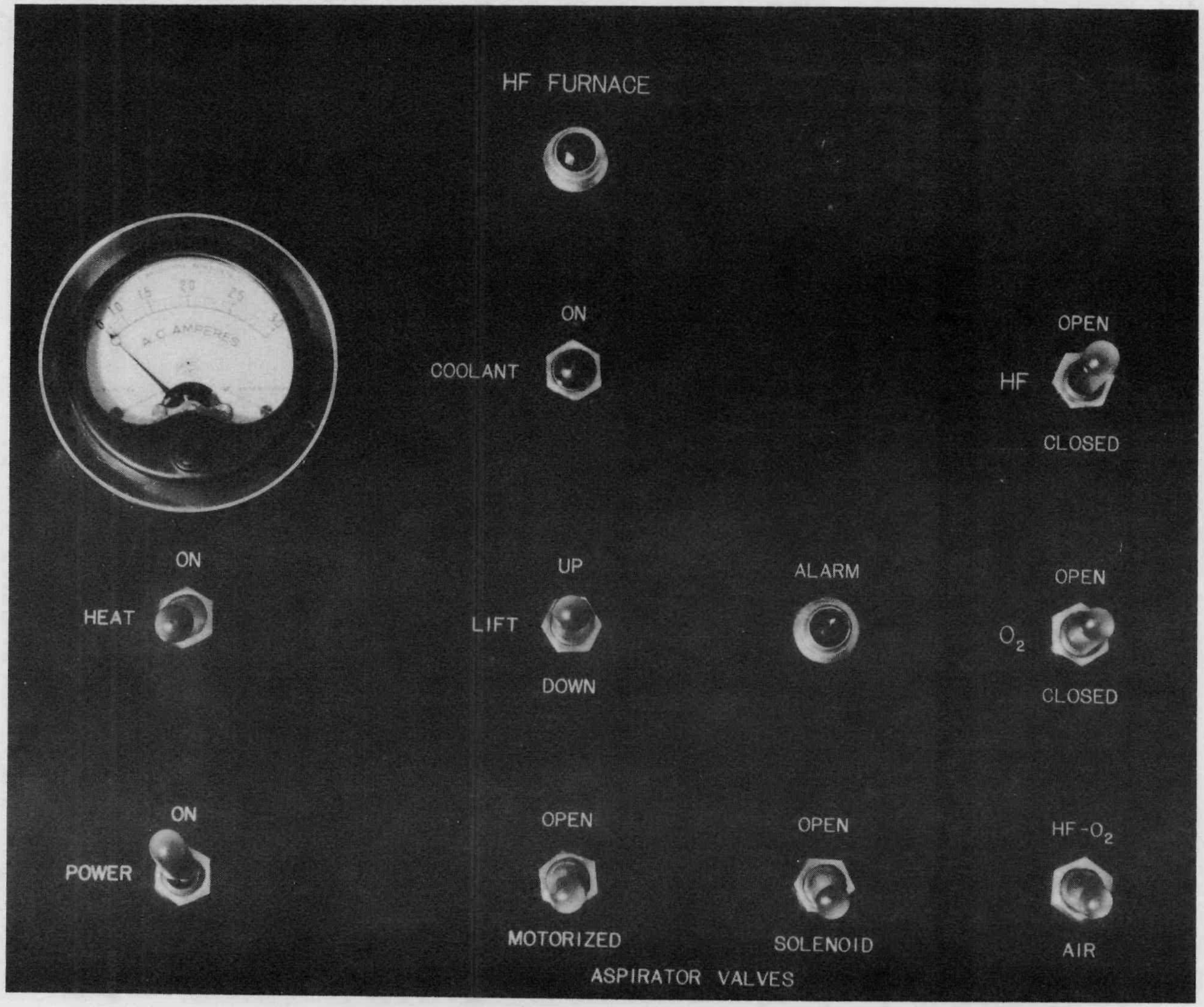

Fig. 35. Hydrofluorination furnace control panel.

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HF furnaces and the reduction furnace of one line.

The heating curve for this furnace is given in Figure 36.

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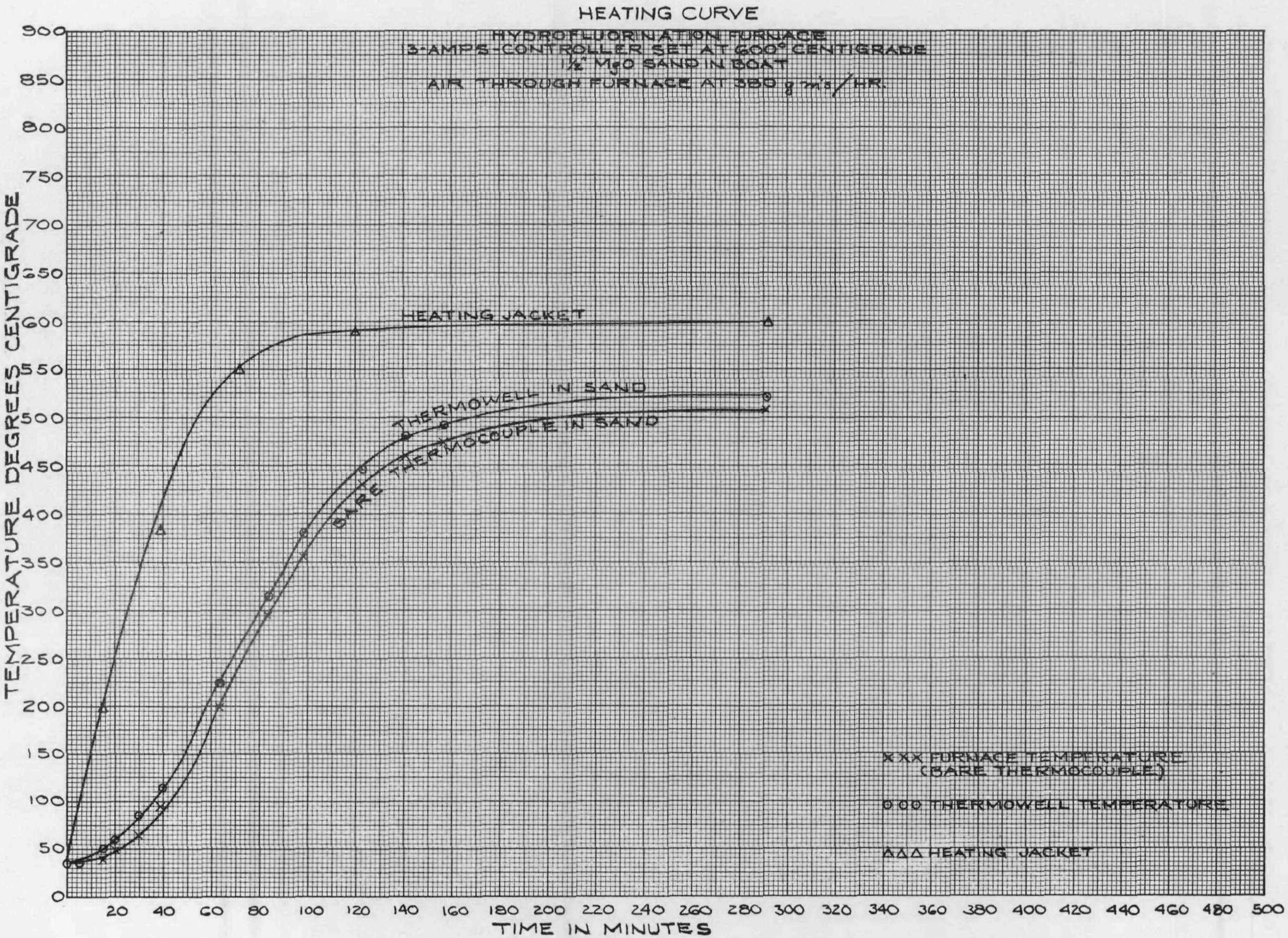

Fig. 36. Hydrofluorination furnace heating curve.

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FILTER BOAT STORAGE

The purpose of the filter boat storage station is twofold; (1) it serves as a storage point for a spare boat to give operating flexibility and (2) it is the station where plutonium chips from fabrication are loaded into a boat for conversion to fluoride.

The design layout of the storage unit is shown in Figure 37. The unit consists of a lucite box in which are mounted two carriages driven by air cylinders, and a lucite hopper and door mechanism. The assembly is bolted to the top of the main enclosure in position over the boat carriage track. To store a boat in the unit the main carriage is stopped under the hole in the storage unit and the boat raised vertically as shown in the layout. The appropriate storing carriage is then moved forward by its air cylinder until the U-shaped plate comprising the storing carriage is under the boat. The boat is then lowered onto the plate and retracted to the stored position.

When it is necessary to add chips to a boat for hydrofluorination the top storing carriage is used. When this carriage is retracted it places the boat directly under the opening of the hopper. The chips are then poured into the hopper by means of the chip transfer box and thus fall into the boat.

The chip transfer box is shown in Figure 38. In operation this box is brought to the appropriate station with plutonium chips in the lucite cup (314). The box is locked against the unit so that the Dural door on the box is attached to the Dural door on the loading

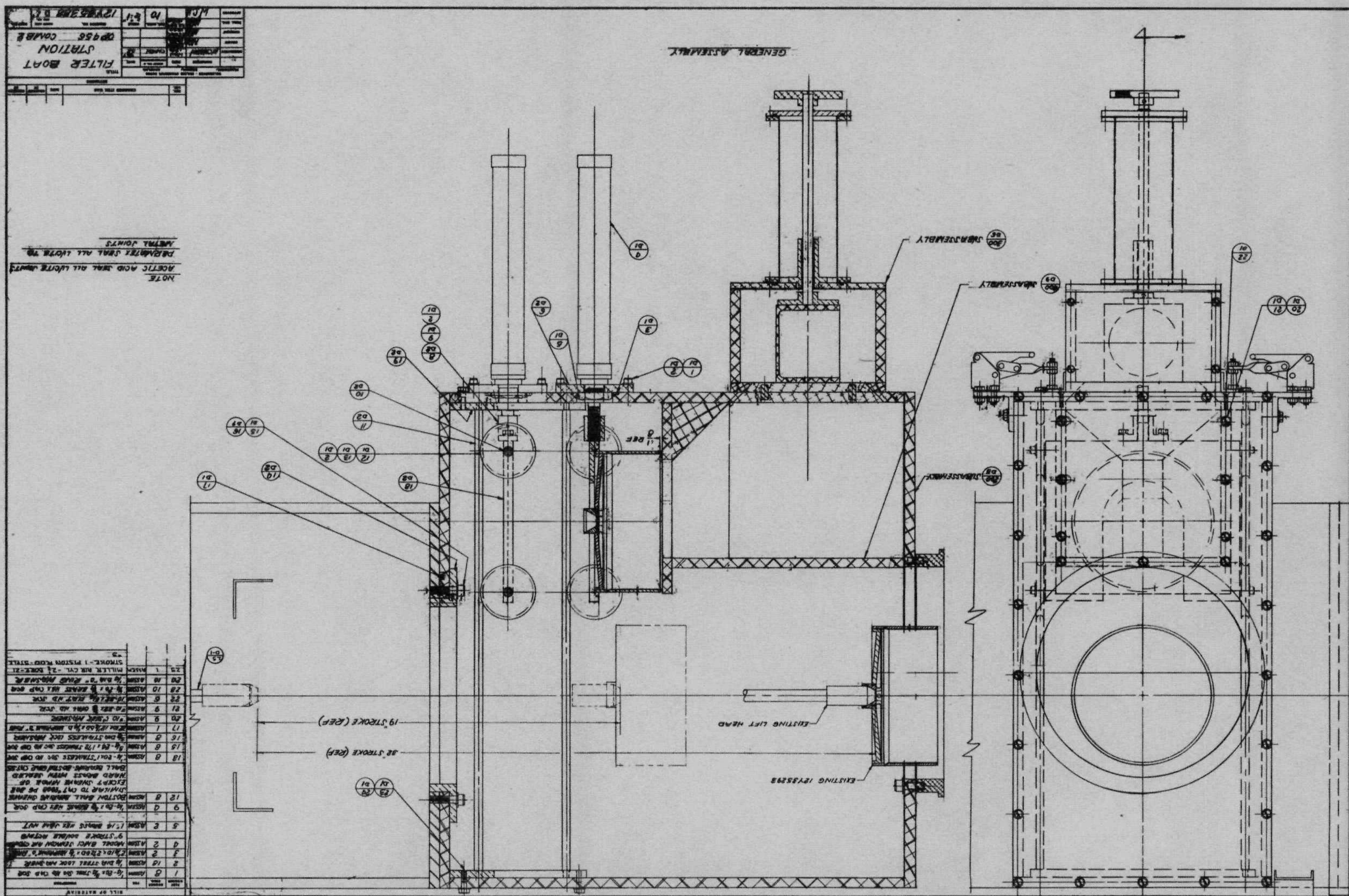

Fig. 37. Design layout of filter boat storage assembly.

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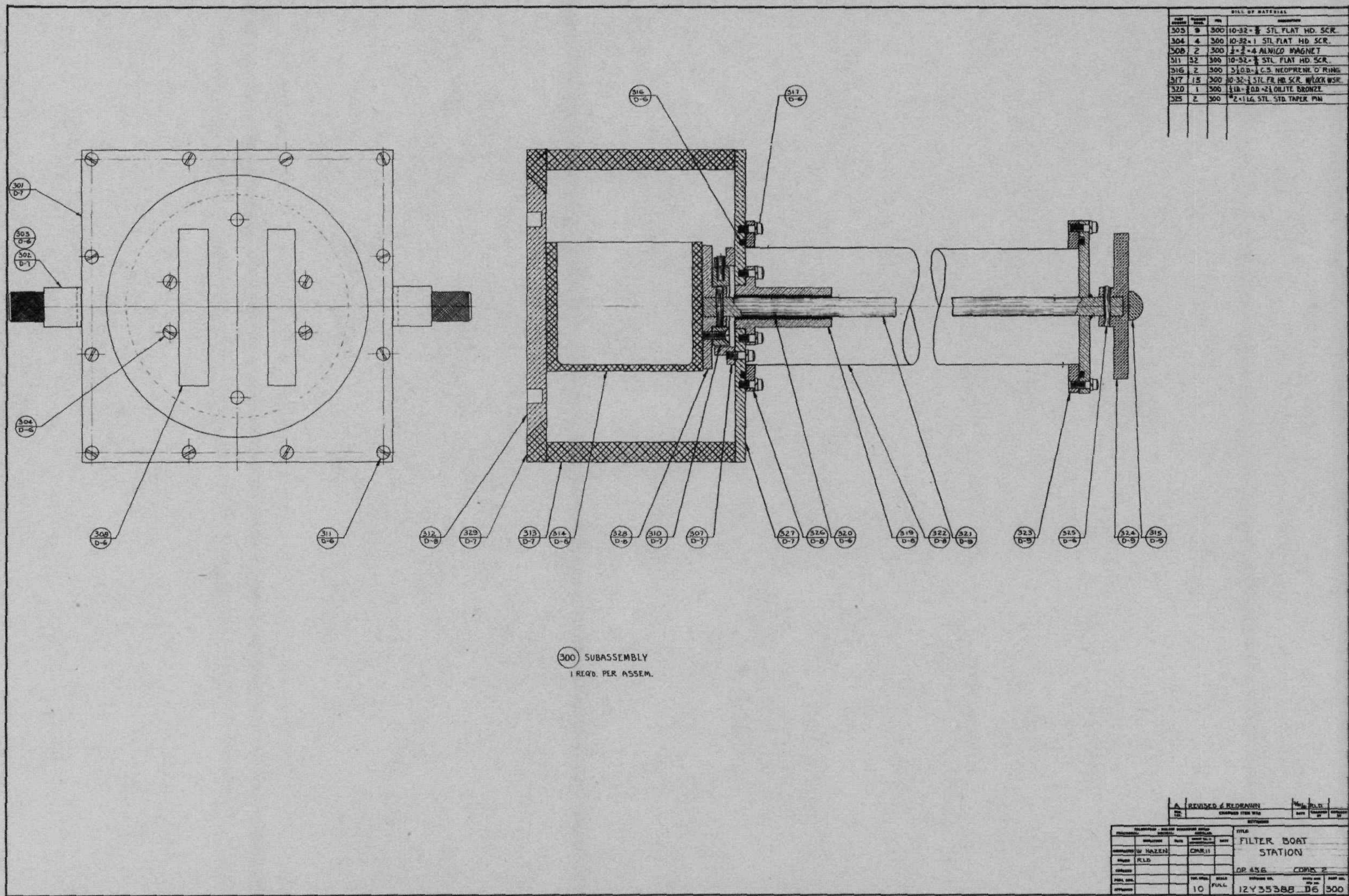

Fig. 38. Chip transfer box.

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hopper by the two dowel pins. By turning the handle (324) on the transfer box a fraction of a turn both Dural doors are unlocked after which the lucite cup can be pushed forward carrying the doors ahead of it by the rod (321) until it is inside the hopper. The plastic sleeve (322) around the rod is an adequate contamination seal.

By inverting the lucite cup the contents are poured into the hopper after which the cup is retracted and the Dural doors locked in place.

The principle of the contamination seal in this device is that the two "cold" surfaces of the Dural doors are held together by magnets set in the doors at the time of entry into the "hot" area and therefore these two cold surfaces protect each other from contamination.

The loading device for filling the lucite cup with chips in another room is of the same design.

In the equipment as installed the storage box is behind a panel where it is not easily visible to the control room operator. Microswitches are therefore mounted on the box to indicate the position of the carriages by means of red and green lights on the control panels. The control panel is shown in Figure 39.

There is a large Dural ring mounted around a hole in the top of the lucite storage box. Through a plastic bag on this ring boats can be removed or replaced if required.

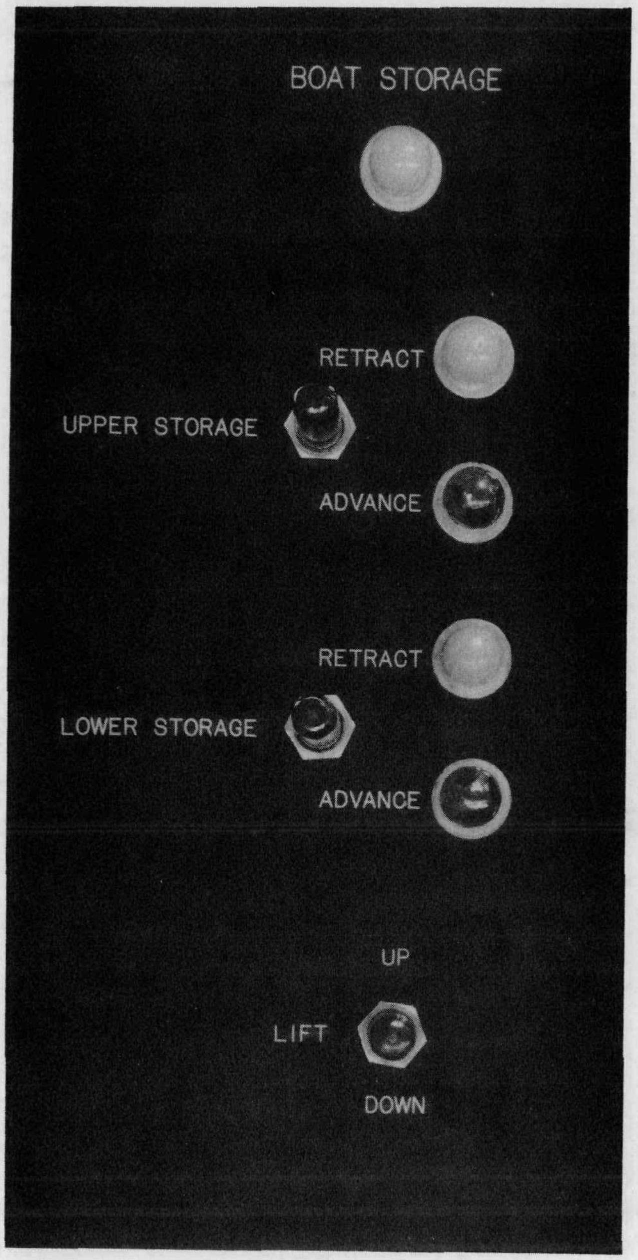

Fig. 39. Storage station control panel.

FLUORIDE DUMPERS

The fluoride dumper assembly lifts the platinum-lined filter boat containing the plutonium tetrafluoride and turns it upside down in position over the mixer. There are two of these boat dumpers on each of the remote lines. Since these two dump from opposite directions, one is right hand and the other left hand. Other than obvious differences required by this lack of symmetry the designs are identical. Only the right hand assembly is discussed here. Figure 40 is a layout of the assembly as installed.

The dumper is mounted as a complete unit on a stainless steel flange plate (126R) which is bolted to the back of the main enclosure plate (12Y 35314 - 429). As mounted, the main shaft (117) which turns the dumper is at right angles to the filter boat carriage track and about 9 inches above it. A photograph of one of the dumpers after several months of use is shown in Figure 41.

The operation of this unit can best be described by breaking it down into three functional steps; (1) lifting the filter boat vertically a short distance until it seats against the gasket in the cone, (2) inverting the entire assembly, (3) operation of the valve in the cone.

The filter boat containing the fluoride is rolled in its carriage and lift plate assembly to the dumping station. As the boat moves in place under the dumping cone the rim on the lift plate slides into a semi-circular groove in the lifting fork (120) of the dumper.

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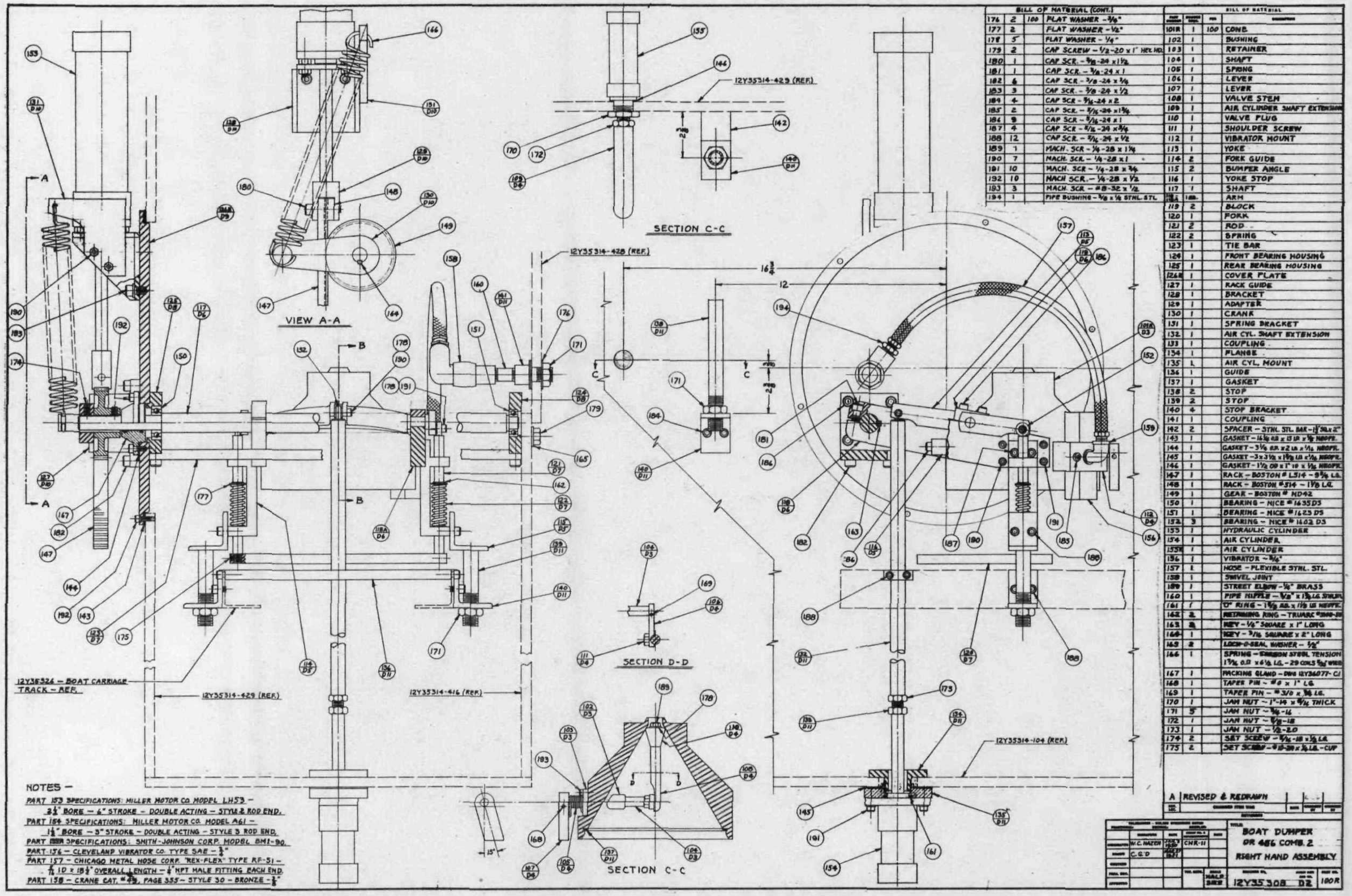

Fig. 40. Fluoride dumper assembly.

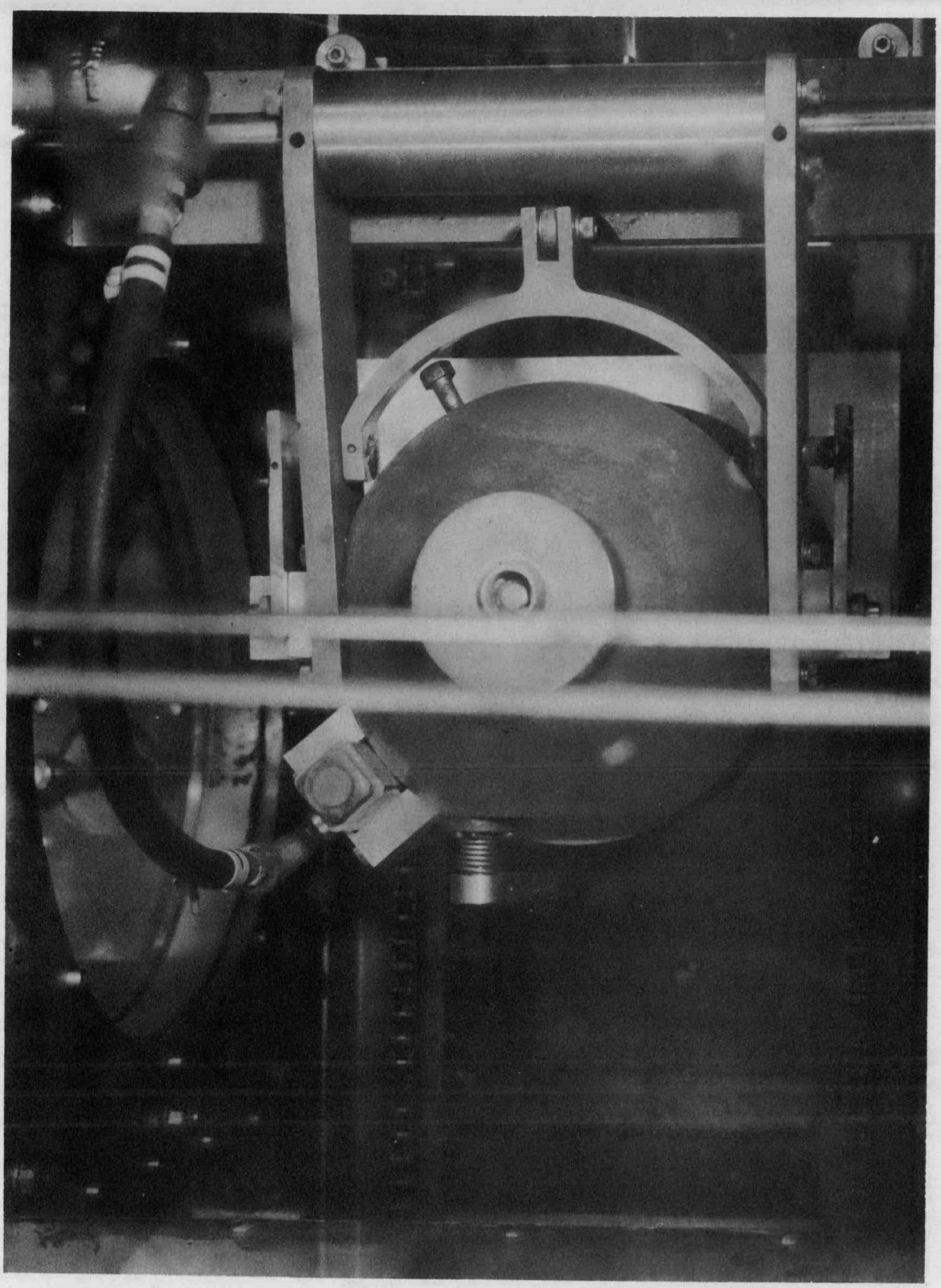

Fig. 41. Fluoride dumper.

When the air cylinder shaft extension (132) is lowered the lifting fork rises vertically because of the compression springs (122) and raises the filter boat and lift plate until the rim of the boat seats on the neoprene gasket in the dumper cone. (137 on Section C-C). The total force exerted by these two springs is about 40 pounds. When the boat is seated the unit is ready to dump.

By actuating the low pressure hydraulic cylinder (153) the gear (149 View A-A) is slowly turned, which swings the entire cone and boat assembly around the center line of the main shaft (117) until the bumper angles (115) strike the stops (138) bolted to the back plate of main enclosure. By the time this has been accomplished most of the fluoride has fallen from the filter boat into the cone. The "stopper" valve (110 on section C-C) prevents any powder from spilling out during this operation. The unit is then ready for transferring the powder into the mixer vessel. Figure 42 is a sketch of the dumper in position to discharge fluoride into the mixer.

The stopper valve (110) is a fluorothene plug mounted on a lever arm connected through a brass sleeve bearing to the spring loaded lever (107). When the dumper is in the inverted position over the mixer this lever is in front of an air cylinder shaft extension (109 Section C-C). By actuating the air cylinder (155) the stopper is raised from its seat in the cone and the powder flows into the mixer.

A 3/4" air actuated vibrator (156) is bolted to the side of the

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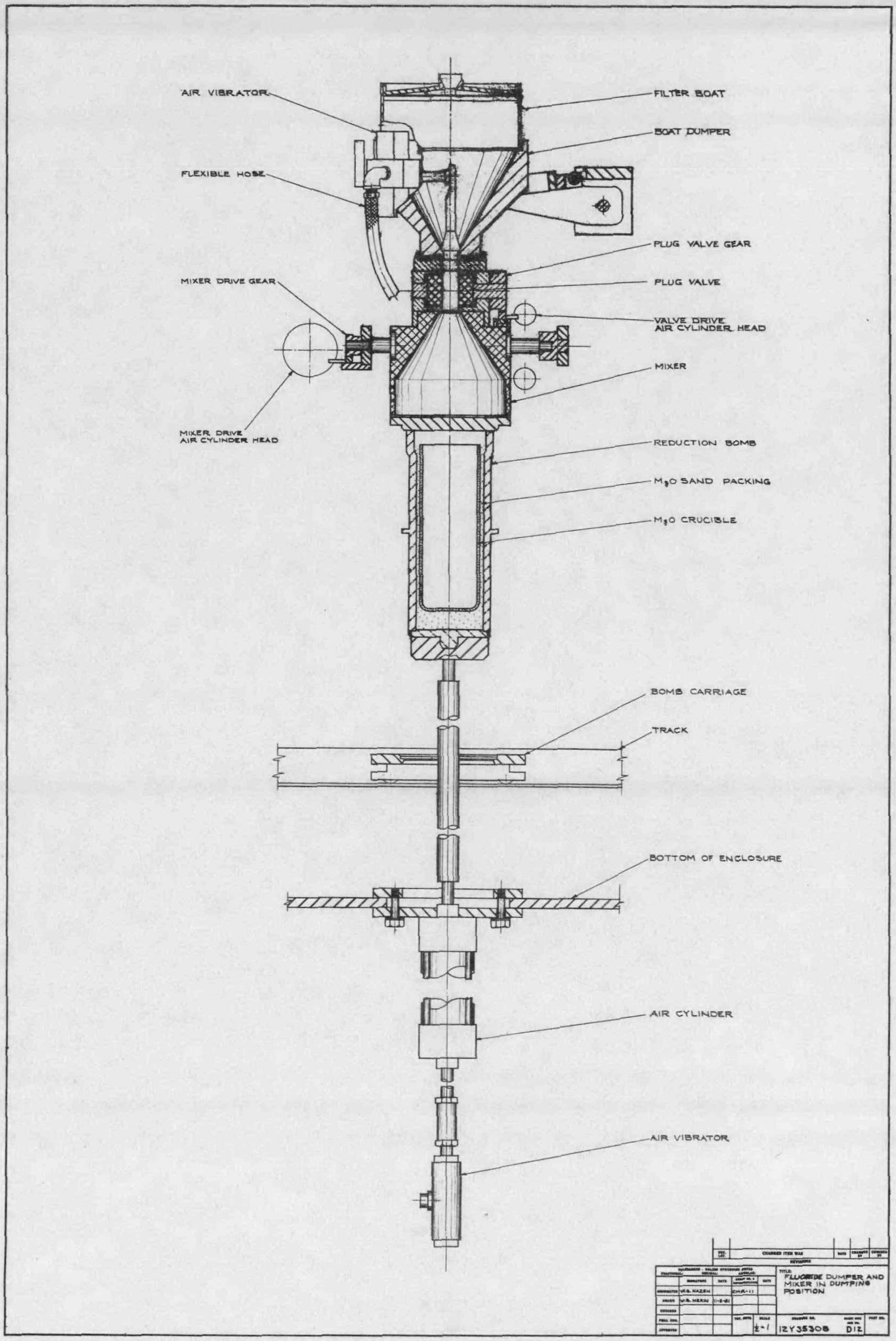

Fig. 42. Sketch of fluoride dumper in position to transfer fluoride to mixer.

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dumper cone and connected to the compressed air supply by a flexible stainless steel hose (157) and swivel joint (158). This vibrator is used to make sure all the fluoride is removed from the boat and cone before returning the dumper.

After the fluoride has been dumped into the mixer the fluorothene stopper valve is closed by retracting the shaft extension (109), the dumper is returned to its position over the track until the bumper angles (115) rest on the stops (139) and the boat and lift plate are returned to the carriage by extending the shaft of the air cylinder (154).

The dumper cone (137) is made of monel with the interior surface highly polished. Monel is used because there is a possibility that occasionally a small amount of gaseous HF may still be in the fluoride powder as it comes from the hydrofluorination furnace.

Because of the off-center load on the dumper assembly a spring (166 View A-A) was provided on a lever arm attached to the drive gear (149) to act as a counterbalance.

A photograph of the control panel for operating the Fluoride Dumper is given in Figure 43. This utilizes the operating sequence switch method of control. The center switch is turned to select the desired operation after which the momentary contact switch below it is actuated to perform the operation selected. This principle is described in more detail in the section titled "Electrical System".

This station is one of the few places in the installation where an

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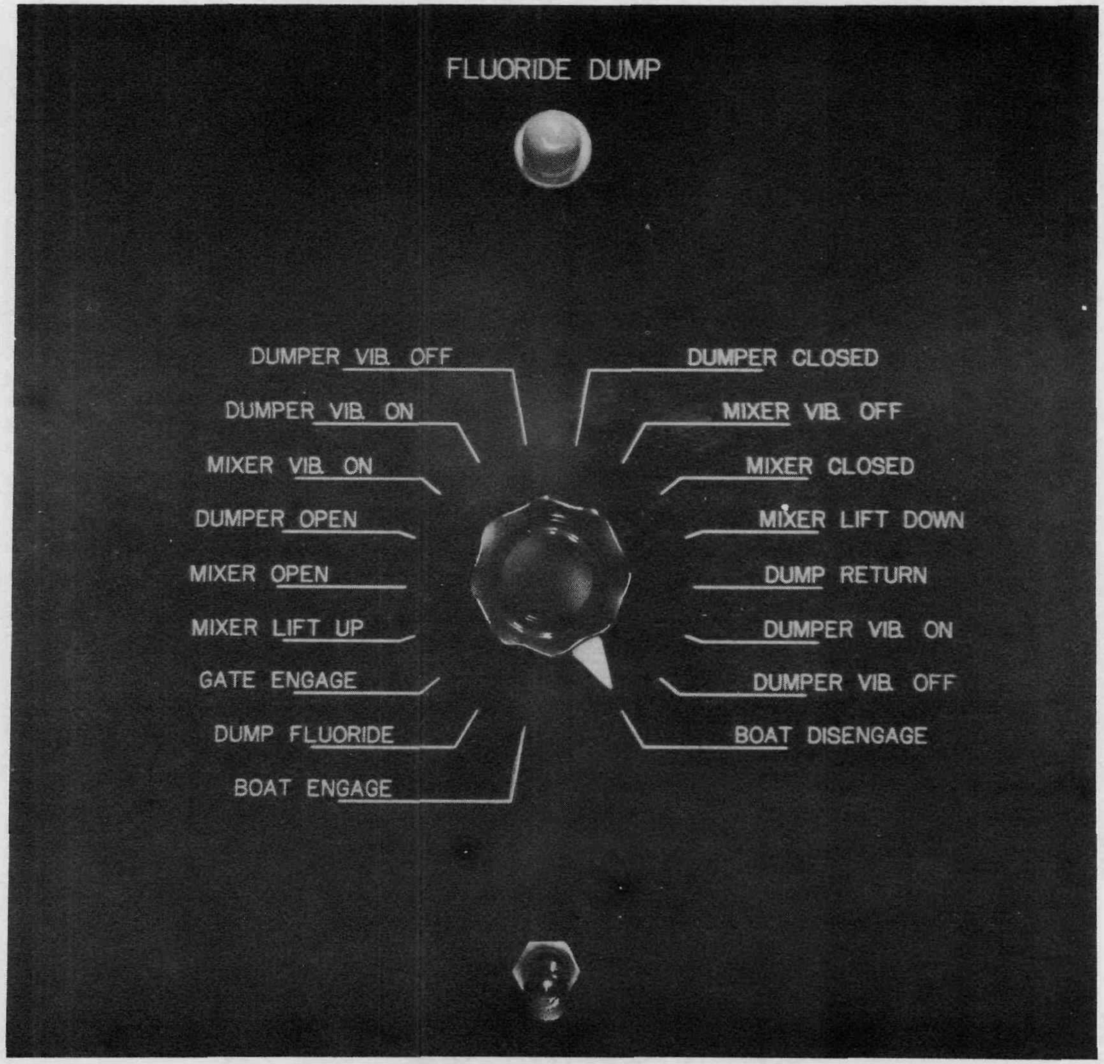

Fig. 43. Fluoride dumper control panel.

electric interlock is used to prevent operator error. The electrical system is wired so that a microswitch of the normally open type is in series with the sequence switch on the "Dumper Open" contact which operates the "stopper" valve in the dumper cone. This normally open microswitch is closed only when the mixing vessel is raised vertically to seat against the bottom of the dumper. The purpose of this is to prevent accidental discharge of the dumper without having the mixing vessel in position to receive the fluoride.

CALCIUM-IODINE LOADER

This equipment is used for introduction of plutonium turnings, calcium and iodine into the mixing vessel on top of the plutonium fluoride previously dumped there by the fluoride dumper. A cross section sketch of this equipment in loading position is shown in Figure 44.

With reference to the figure, the operating sequence is as follows: with the mixing vessel in the upright position and held up by the bomb, the loading chamber is lowered until the spout seats on the gasket in the mixer plug valve. The lucite cups containing calcium, iodine and plutonium chips are then advanced by means of the air cylinder until they are in the loading chamber and the bayonet lock is engaged in the inverting mechanism. In this position the neoprene gasket on the back portion of the yoke holding the cups presses against the loading chamber thereby effectively closing the opening. The mixer plug valve is then opened and the cups turned upside down by the inverter air cylinder. With the aid of the air vibrator mounted on the shaft of the cylinder supporting the bomb the particles pour down into the mixer. After this the cups are turned to the upright position, the mixer plug valve closed, the cups withdrawn and the loading chamber lifted up out of the way. The reduction bomb can then be lowered back into its carriage which also lowers the mixer back into position for tumbling the charge.

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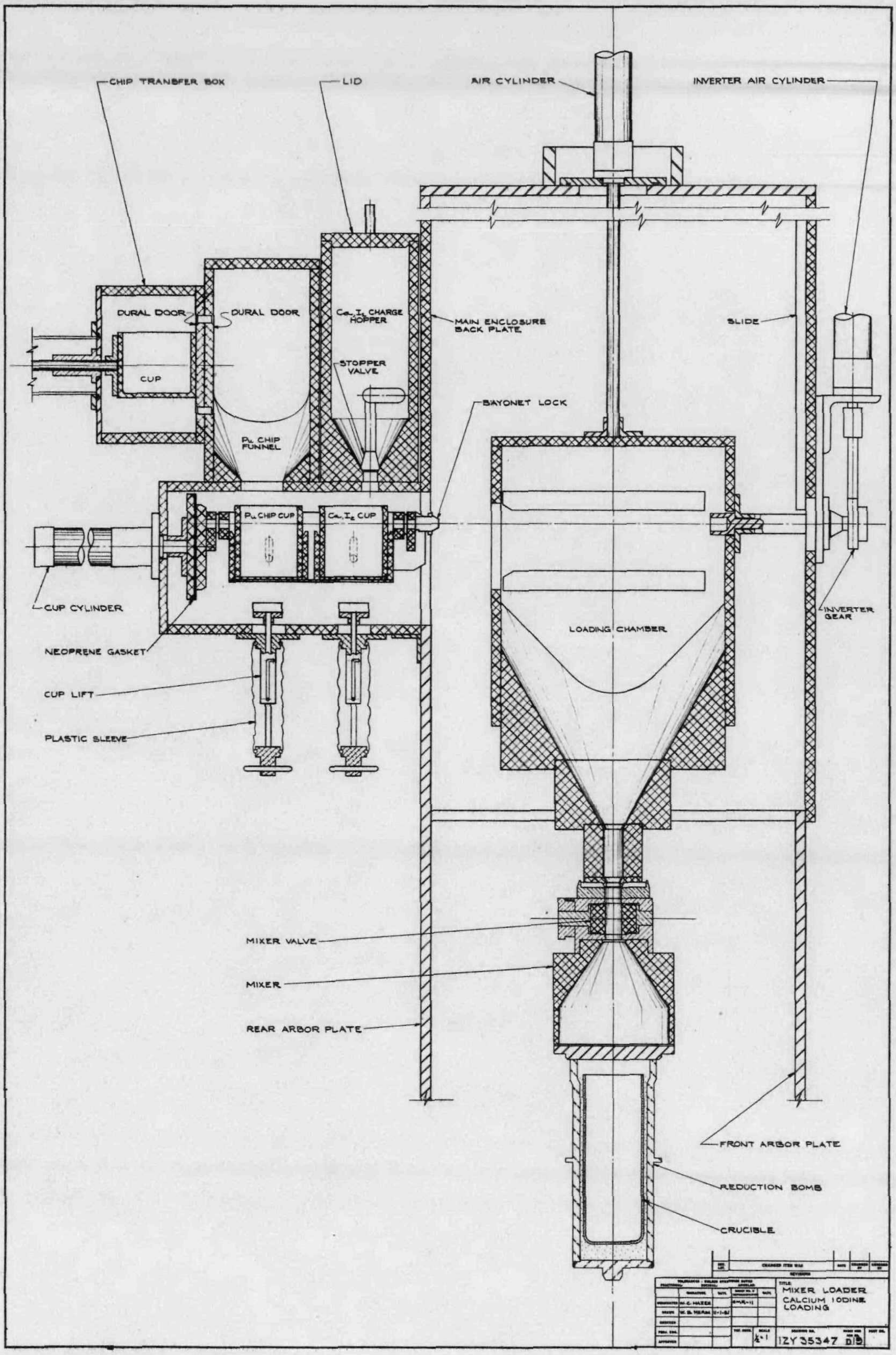

Fig. 44. Sketch of loader for transferring calcium, iodine and chips to mixer.

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The hoppers for addition of plutonium chips and calcium-iodine are shown on the sketch and in more detail in the design layout Figure 45. The photograph (Figure 46) is a picture of this equipment. The use of the chip transfer box for introduction of chips is described in the section headed "Filter Boat Storage" and the description is not repeated here since the design is exactly the same. During chip loading the Pu chip cup is lifted by the manually operated cup lift until it presses against the bottom of the chip funnel. This is to prevent chips from bouncing out of the cup during the loading process.

The hopper for loading calcium and iodine is made of lucite, with a lid on top and a manually operated stopper valve in the outlet. The calcium-iodine charge is poured into the hopper and the lid replaced. With the lucite cup raised by the cup lift the stopper valve is lifted from its seat permitting the particles to flow from the hopper into the cup. After several months of use in production no contamination has been found in the hopper.

Controls

The controls for this loader are part of the mixer operation and comprise a portion of the operting sequence switch shown in the photograph of the control panel presented in the section titled "Mixer".

There is one interlock on this unit. If, through operator error, the loading chamber were to be raised while the cups were in the advanced position the cup yoke could be damaged. To avoid this, there

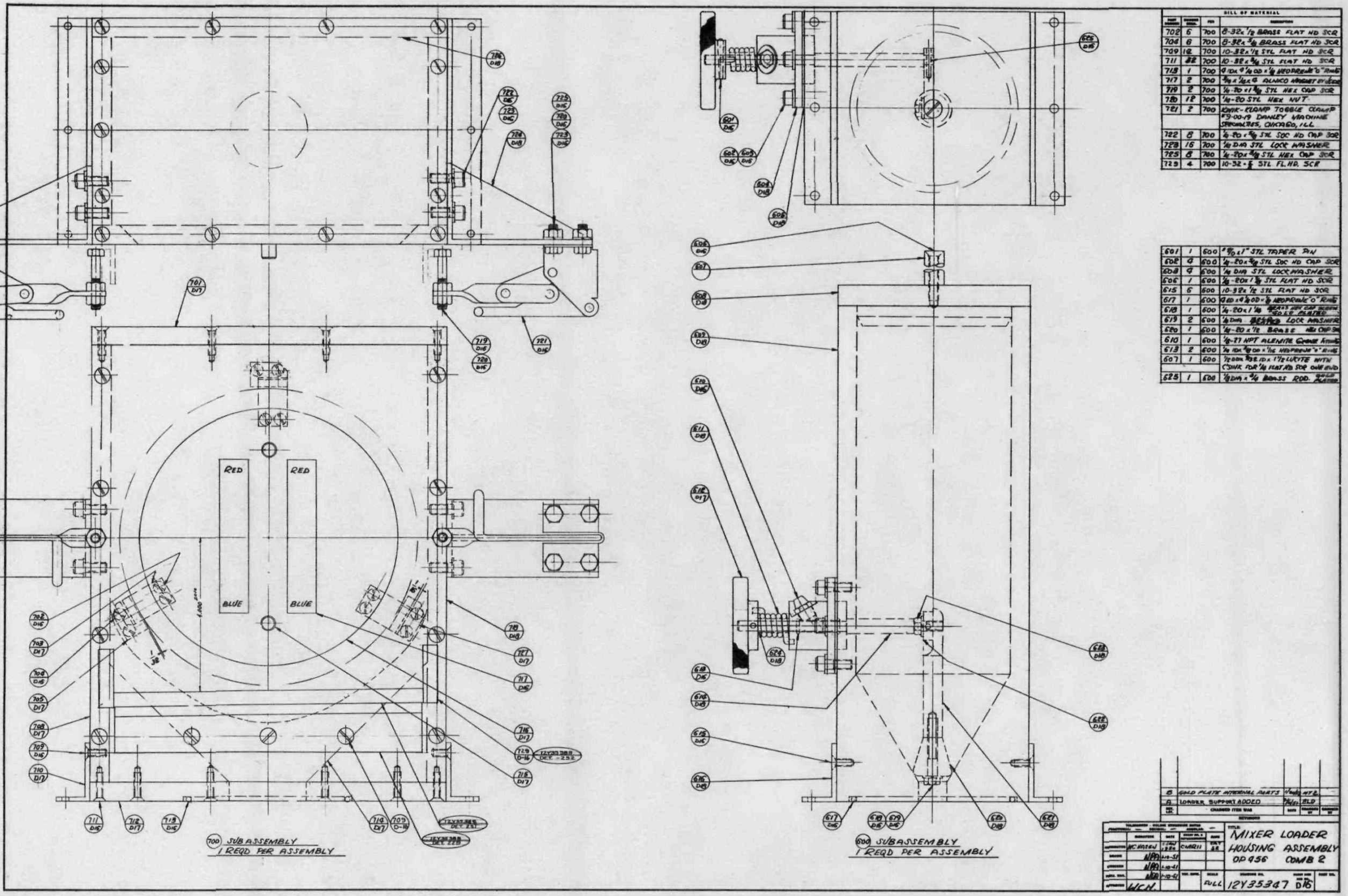

Fig. 45. Hoppers for addition of plutonium chips and calcium-iodine mixture.

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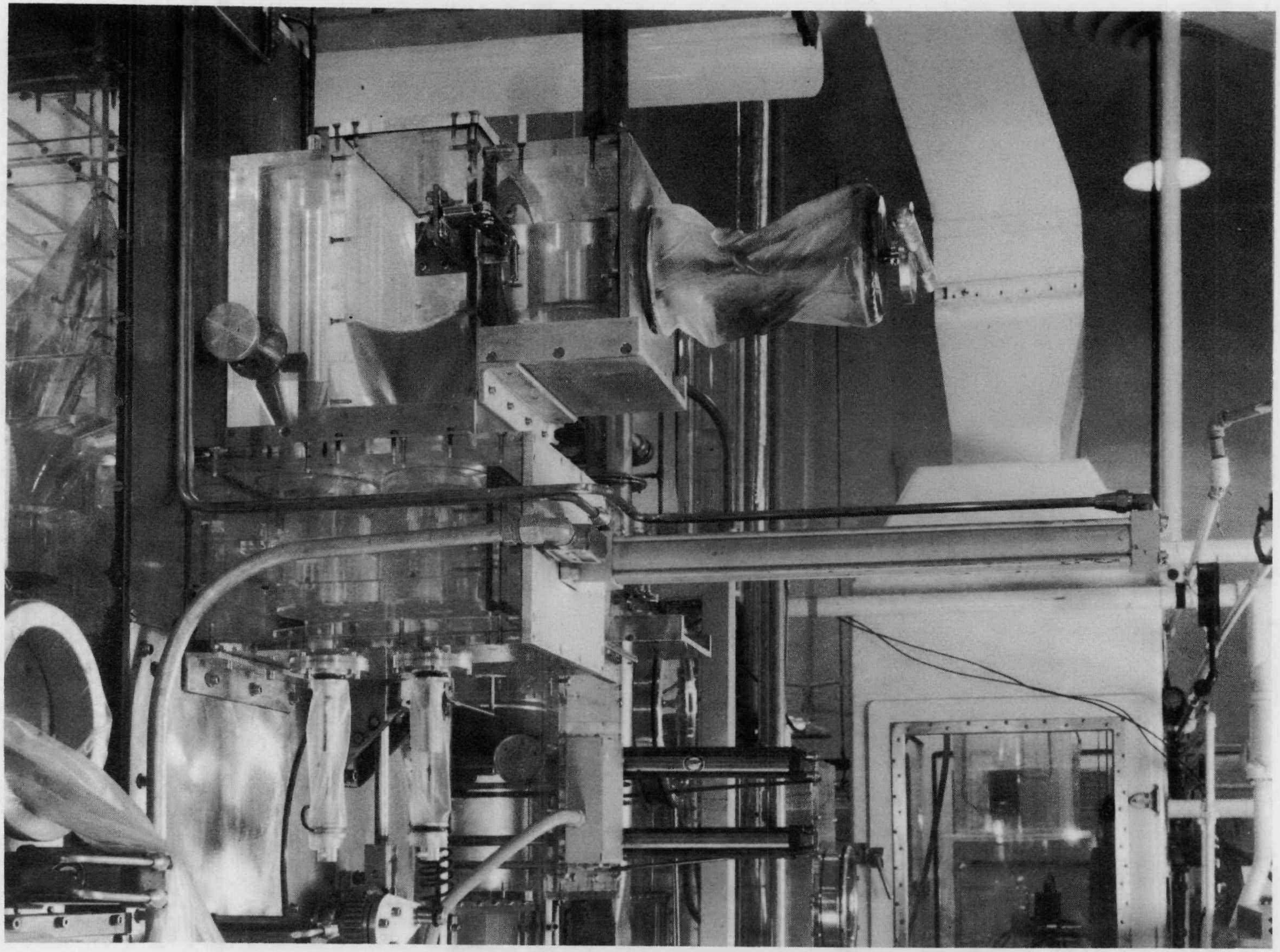

Fig. 46. Loading hoppers with chip transfer box in place.

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is a microswitch mounted outside the housing next to the cup cylinder which is closed with the cups are retracted. This switch is in series with the chamber lift circuit so that the loading chamber cannot be moved unless the cups are retracted.

[redacted]

MIXERS

Mechanical Features

The mixers are used to mix the plutonium fluoride, calcium, iodine and plutonium chips prior to introduction into the crucible. There are two mixers for each remote control line, one over each end of the bomb carriage conveyor directly under the fluoride dumper when that is in the dump position. The mixers are also directly under the calcium-iodine loading chamber.

The mixing vessel is a conical lucite chamber mounted on trunnions so that it can be revolved. On one end of the chamber is a plug valve which is operated through a rack and gear assembly.

Figure 47 is an assembly of the mixer and Figure 48 is a photograph of one unit prior to installation in the enclosure. The assembly is mounted on a flange plate to make removal of the entire unit possible.

The sequence of operation of this unit is as follows: with the mixer in the upright position the reduction bomb is conveyed directly underneath the flat bottom of the lucite mixing chamber. The fluoride dumper with a boat of fluoride in place is then turned to the dump position which places the spout of the dumper about 1/4" above the gasket in the mixer plug valve. The reduction bomb is then raised vertically so the top rim of the bomb presses against the bottom of the mixer and raises the assembly on the four guide posts until stopped by the caps (115 Figure 47). This vertical 1/2" motion of the mixer has

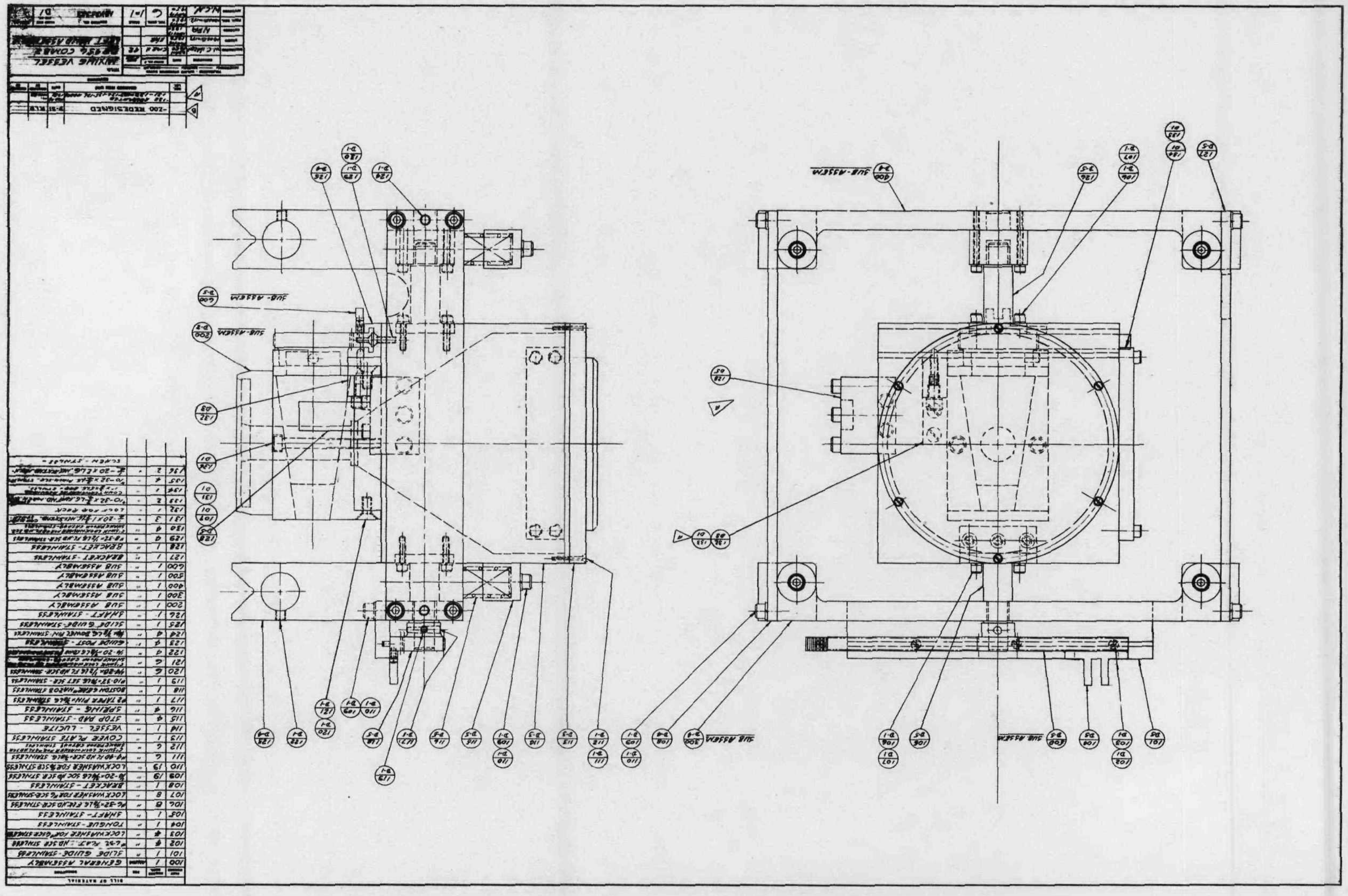

Fig. 47. Design layout of mixer assembly.

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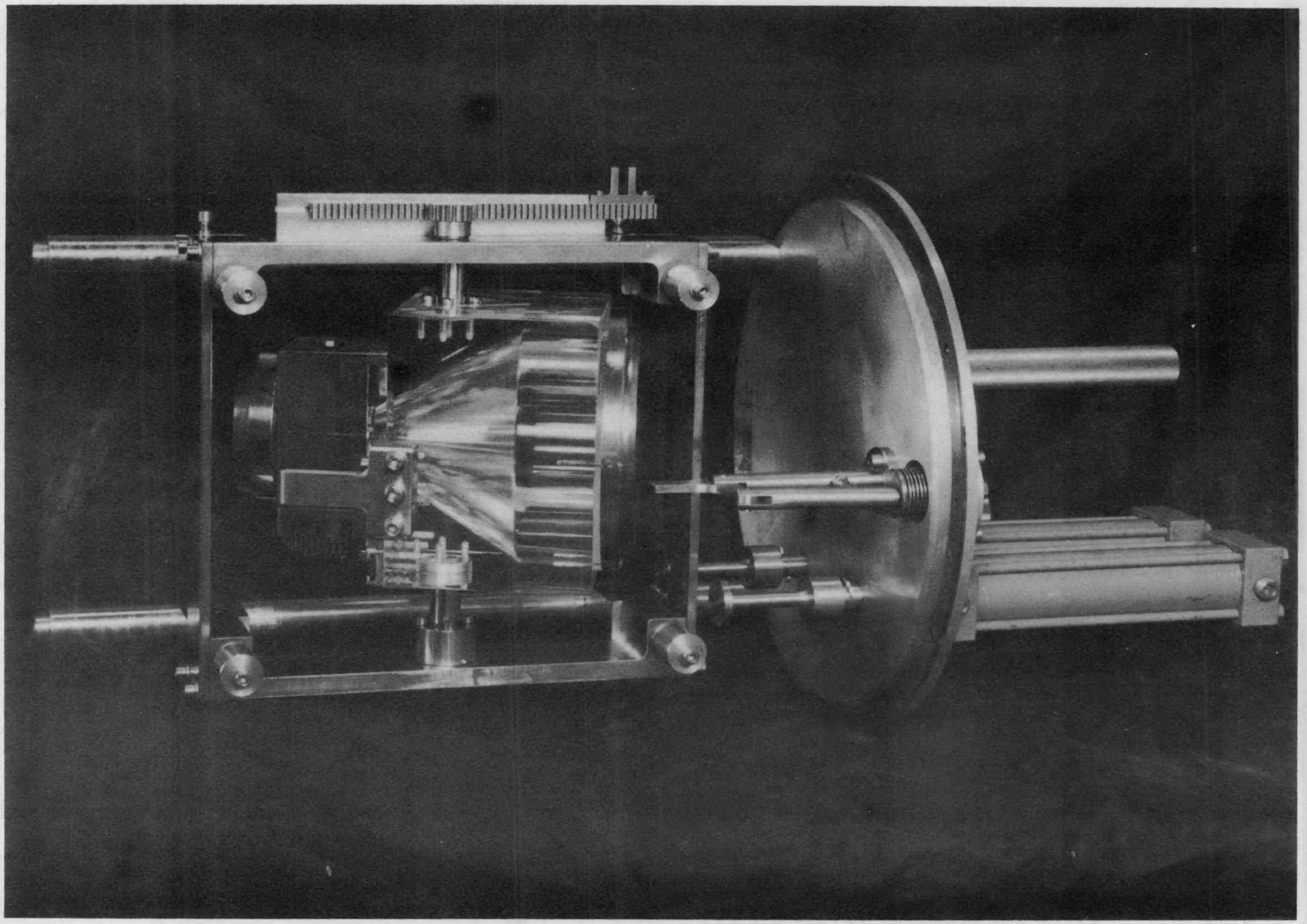

Fig. 48. Photograph of mixer assembly.

[redacted]

three purposes: (1) it causes the plug valve to seat against the spout of the fluoride dumper to make a dust tight seal, (2) it causes a yoke (600 Figure 47) on the rack which operates the plug valve to engage a mushroom head on an air cylinder, and (3) closes a switch contact which is part of the control system. A sketch of the dumper in position over the mixer is given in the section titled "Fluoride Dumper".

When the sequence has reached this point the plug valve in the mixer is opened by energizing the proper air cylinder, the stopper valve in the dumper is opened, and with the aid of the air vibrator on the dumper and another on the cylinder which raises the bomb the fluoride flows into the mixer. When this transfer is complete the mixer plug valve is closed, the fluoride dumper valve closed and the dumper returned to its rest position over the boat conveyor track.

After the fluoride is in the mixer the calcium-iodine loading chamber is lowered into place with its spout gasketed on the mixer valve just as the dumper was. In the section titled "Calcium-Iodine Loader" a sketch (Figure 44) shows the loading chamber in this position on the mixer. The mixer plug valve is then opened and the calcium-iodine and chips are introduced into the mixer after which the plug valve is closed and the loading chamber lifted up to its rest position. When all the ingredients have been added to the mixer the reduction bomb is lowered, which permits the mixer to descend to the mixing position with the plug valve drive disengaged. By means of a rack and gear drive on one of the supporting trunnions the mixer is revolved through alternate 1-1/2 revolution turns thereby tumbling the charge to get an intimate mix. Fifteen complete cycles are ample to accomplish the desired mixing. At the end of the mixing period the mixer is stopped in the down position with the plug valve at the bottom and therefore directly over the reduction bomb and its contained crucible.

When the bomb is raised the outside of the spout of the plug valve fits inside the bomb and the gasket seats against the rim of the magnesia crucible. As the bomb continues to rise, the mixer assembly lifts up to the stops on the guide posts as before but this time it is the crucible pressing on the gasket of the plug valve that raises the mixer. The assembly in this position is shown in Figure 49. In this manner a dust tight seal is made between crucible and mixer. The 1/2" rise also engages the fingers of the plug valve drive on a mushroom head attached to the shaft of an air cylinder. By actuating this cylinder the plug valve is opened and the mixer charge flows into the crucible with the aid of the air vibrator on the shaft of the bomb lift cylinder. This vibration also tamps the charge in the crucible. The plug valve is closed and after an interval of a few minutes to let dust settle in the crucible the bomb is lowered into its carriage once more. The mixer is then rotated to the upright position which completes the mixing-loading sequence.

The plug valve shown in the design layout (Figure 47) was made as a tapered fluorothene plug in a monel body. Although this valve was tested successfully hundreds of times with a mixture of uranium fluoride

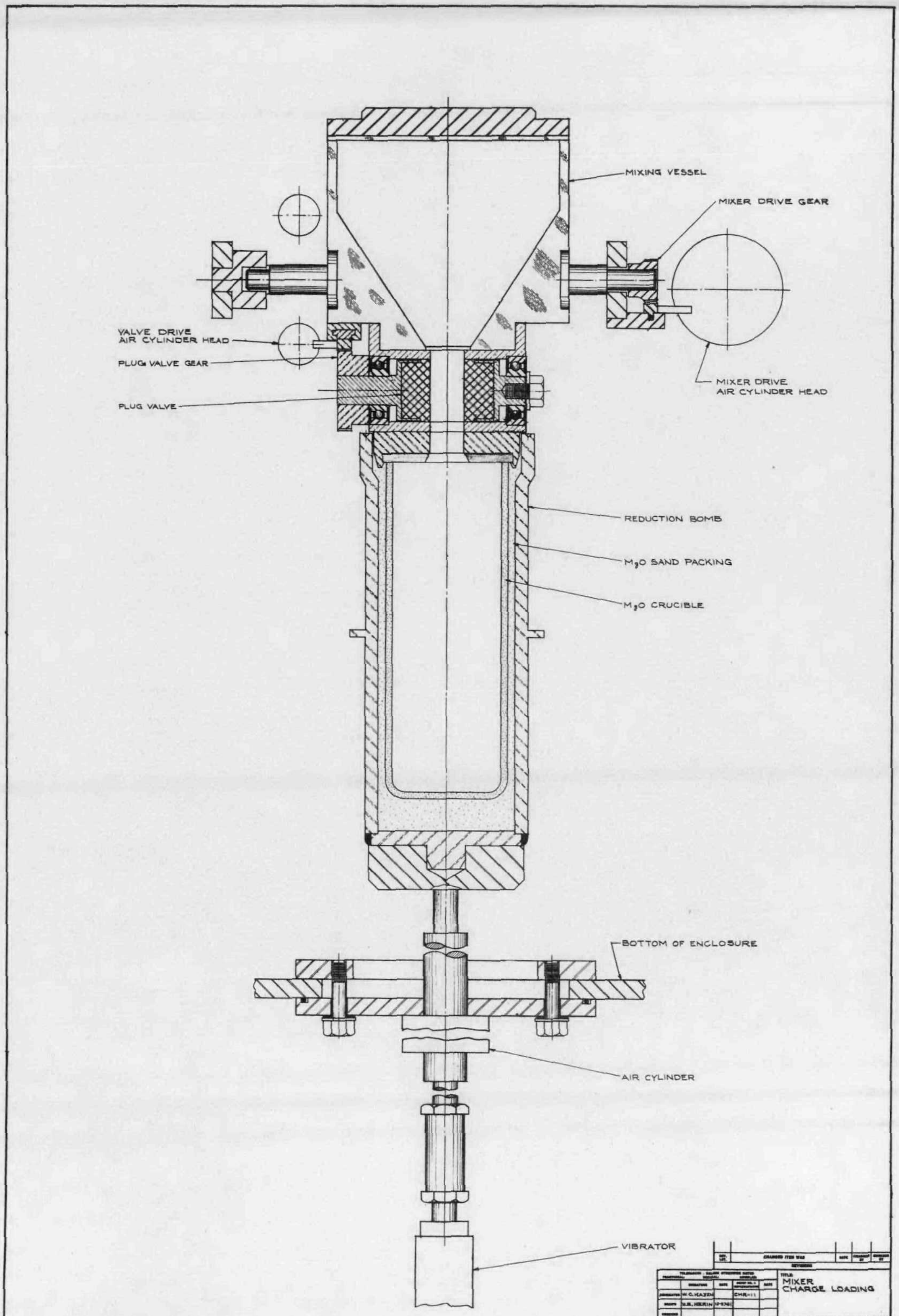

Fig. 49. Sketch of mixer-bomb assembly in position for transferring charge to crucible.

calcium and iodine, nevertheless when operation with plutonium was started this plug valve jammed after a few weeks operation. Although the exact reason for the failure is not known the valve was redesigned to eliminate the taper and incorporate double sealed ball bearings at each end of the plug. This seems to be perfectly satisfactory. The new design is shown in the drawing Figure 50. Continued testing has indicated that brass is satisfactory for the body of the valve.

Controls

A photograph of the control panel for operating the calcium-iodine loading, mixing, and charging into the reduction crucible is given in Figure 51. The control portion of the calcium-iodine loader is discussed in the section concerning that unit.

As far as the mixer is concerned there are two items of interest electrically. The first is the mixing cycle mechanism. The cylinder which causes the mixer vessel to rotate on the trunnions is double ended and flange mounted on the enclosure. The end of the piston rod which extends into the operating area (Zone 3) has a knob which strikes a microswitch at each end of its travel to reverse the stroke. This makes cycling of the vessel automatic when the sequence switch on the panel board is turned to "Mixing Cycle" and the operating switch pushed momentarily. When the vessel has completed the desired number of cycles the sequence switch is turned to "Mixer Down" and the operating switch actuated which shunts the reversing microswitches out of the

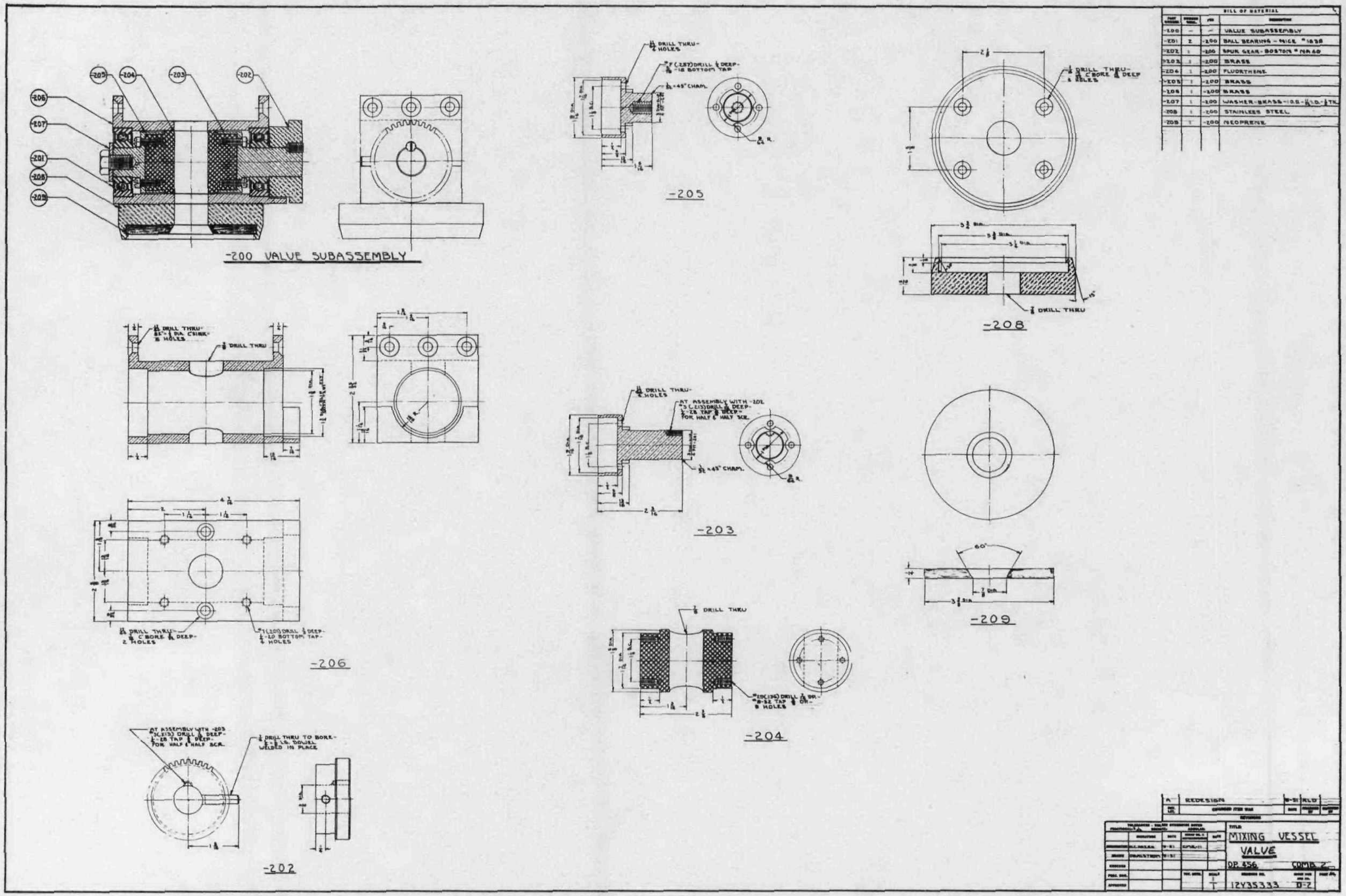

Fig. 50. Drawing of mixer plug valve.

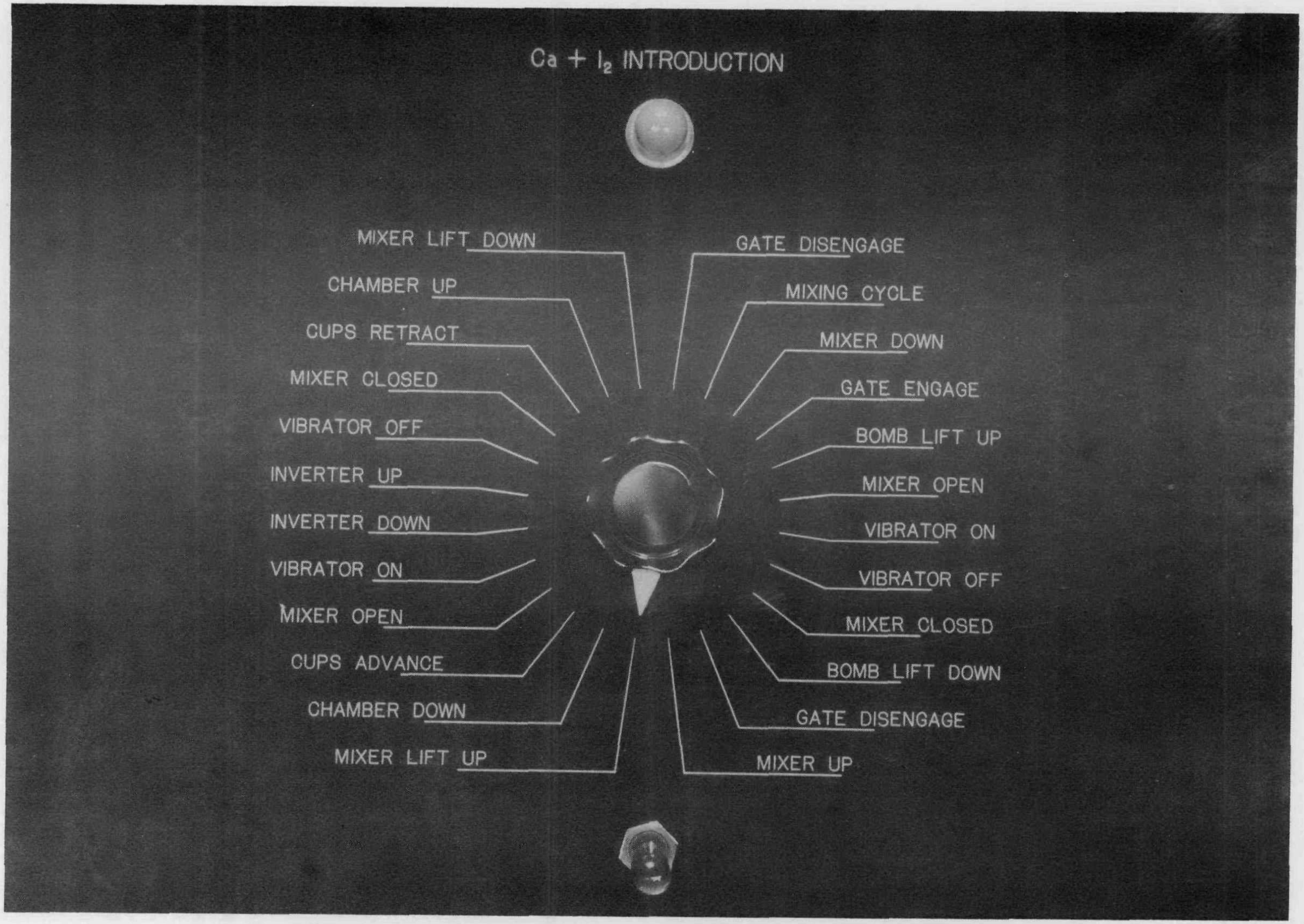

Fig. 51. Control panel for calcium-iodine-chip loading, mixer operation, and transferring charge to reduction crucible.

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circuit and stops the vessel with the spout down.

The second point is the interlock with the stopper valve on the fluoride dumper. There is a stainless steel arm screwed to the side of the mixing vessel near the plug valve. When the mixer is upright and raised under the discharge spout of the dumper this arm strikes the lever arm shown as part 110 of Figure 52. Through the linkage and bellows assembly (104) a microswitch mounted outside the enclosure is closed by the upward motion of the mixer. This microswitch completes the circuit controlling the operation of the stopper valve in the fluoride dumper. In this manner the fluoride cannot be discharged from the dumper unless the mixer is lifted into receiving position.

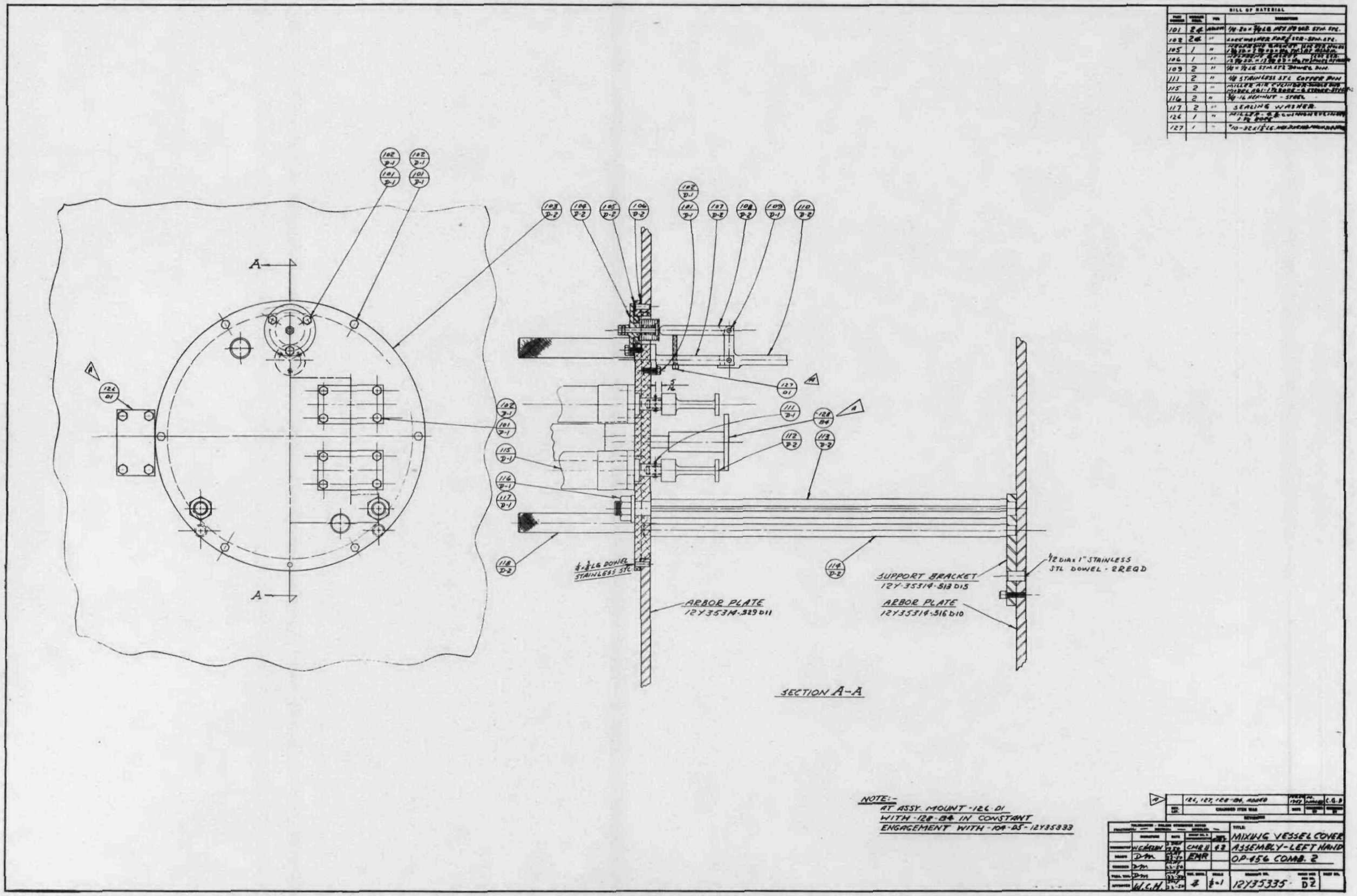

Fig. 52. Flange plate assembly for mixer mounting.

REDUCTION BOMB AND GASKET

The reduction bomb is a pressure vessel for holding the crucible and charge during the reduction of plutonium tetrafluoride to plutonium metal by calcium. Figure 53 is a drawing of the bomb (100, 102) and of the lid of the reduction furnace (103) against which the bomb is pressed during reduction. Since the furnace lid and the gasket are such important parts of the assembly when the bomb is in the reduction furnace they are discussed here with the bomb. A drawing of the gasket is presented in Figure 54.

Materials of Construction

The material of construction of the bomb has been the subject of considerable experimental work. Various materials such as Hastelloy C, S-816,Stainless Steel, Aluminized Steel, Nickel Plated Steel and Chrome Plated Steel have all been tried. Ordinary 1020 steel with $\sim$2 mils of chrome plating on the outside surface was selected as the best. From test work it was concluded that this steel was amply resistant to corrosion, had the requisite strength at reduction temperature, had the best heat transfer rate and was by far the cheapest. The chrome plating is necessary to prevent scaling on the outside of the bomb during heating in the reduction furnace.

The gasket is made of pure aluminum to give the maximum deformation when squeezed by the hydraulic press in the reduction furnace.

The insert disc in the aluminum gasket is made of copper. There may be other materials, i.e., iron that can be adopted after adequate

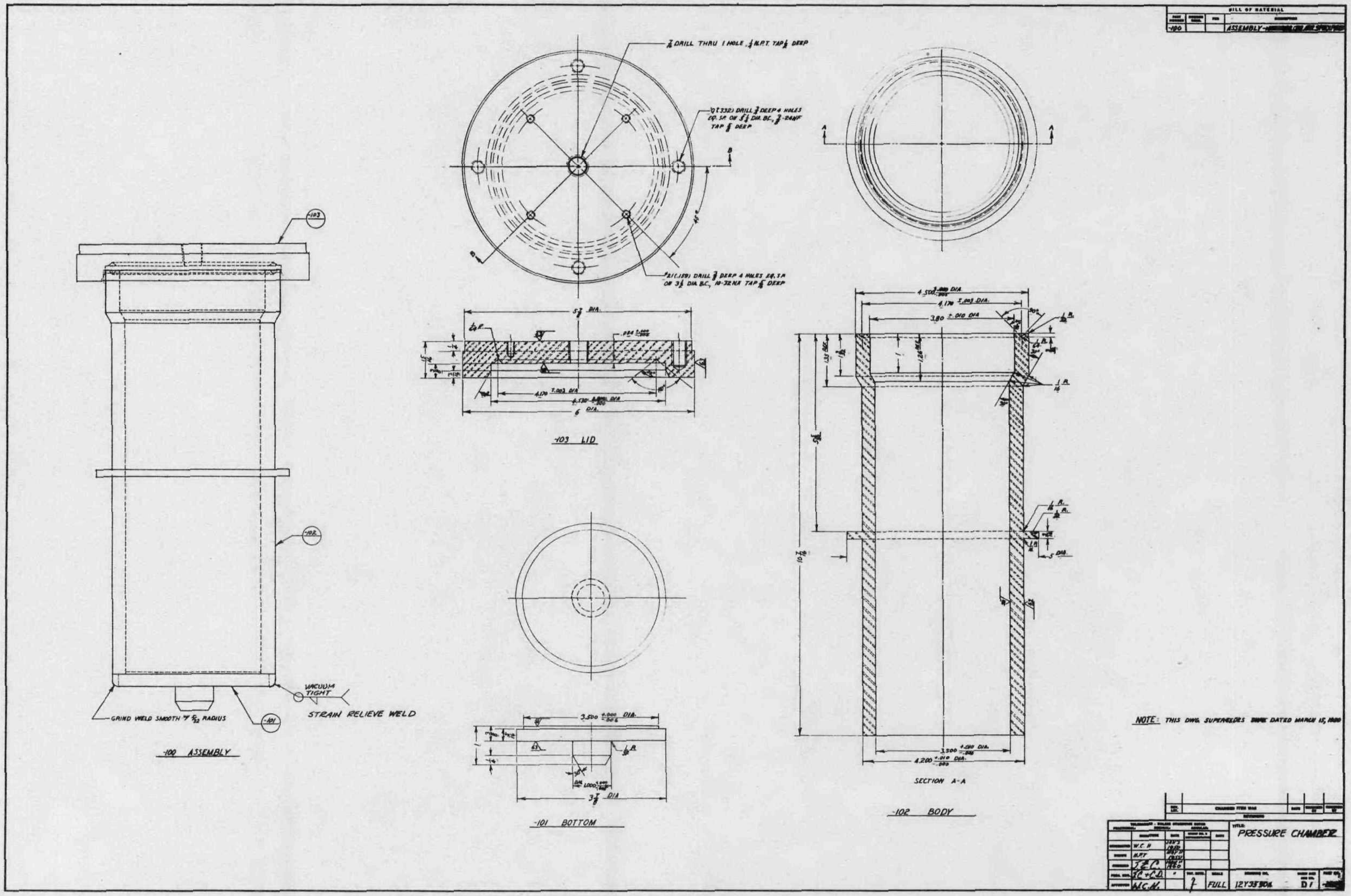

Fig. 53. Reduction bomb and reduction furnace head.

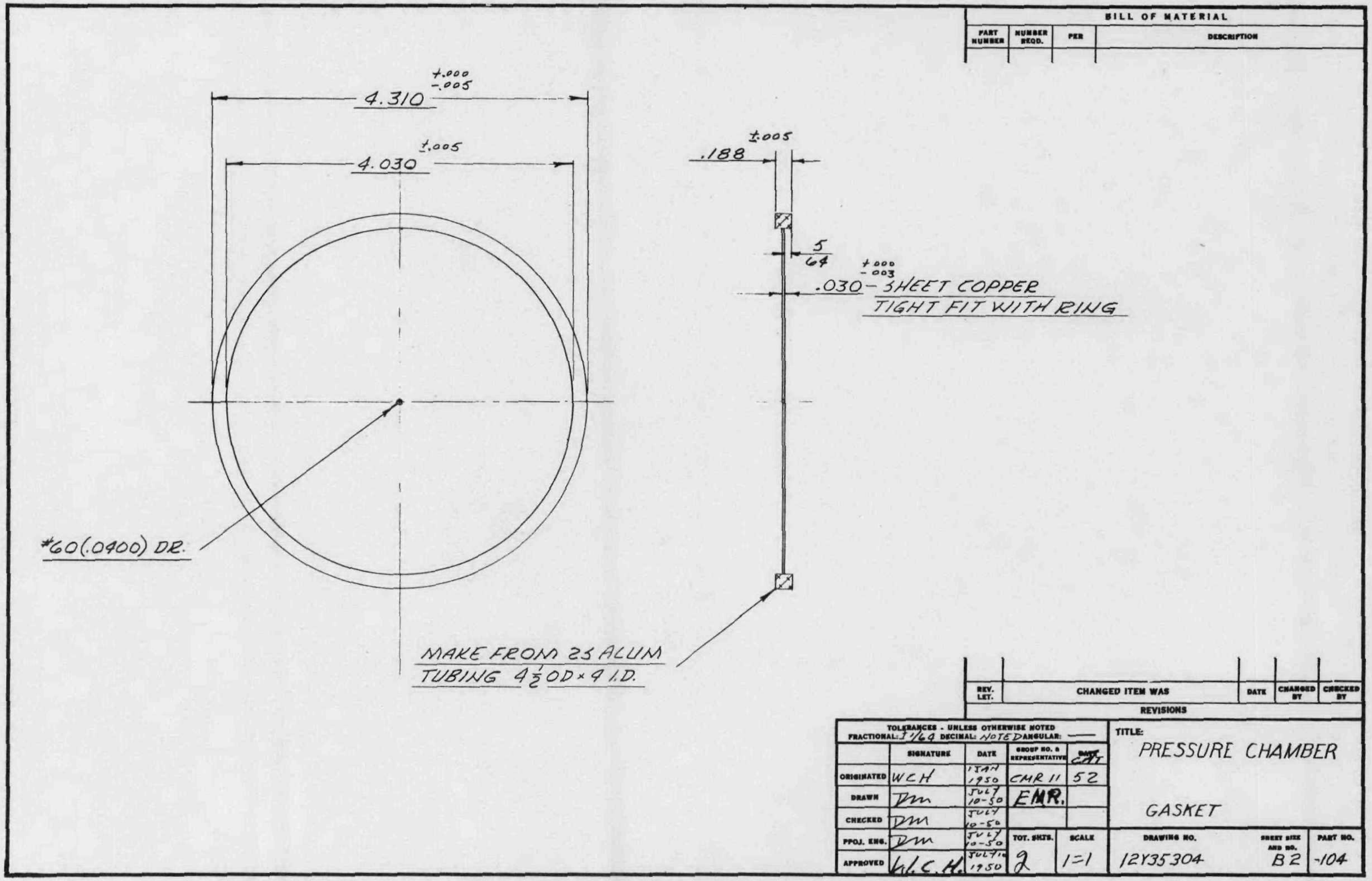

Fig. 54. Reduction bomb gasket.

testing.

The reduction furnace lid is made of Hastelloy C because of its resistance to corrosion and scaling.

Design

Certain features of this bomb lid and gasket designs are of considerable practical importance. These are discussed with reference to Figures 53 and 54.

1. The groove in the upper rim of the bomb which holds the gasket has a 90° included angle while the mating groove in the reduction furnace lid has an angle of 100°. This difference in angle is sufficient to insure that the gasket always sticks to the bomb and never to the reduction furnace lid when the bomb is lowered after reduction.

2. The flared section near the top of the bomb is required to facilitate the introduction of MgO sand during crucible loading. (See drawing of the packed assembly under "Crucible Loader").

3. The flange near the middle of the bomb supports it when in the carriage moving from one station to the next.

4. The projecting tip on the bottom of the bomb seats in a mating hole in the head of each lift that raises the bomb. This gives alignment as well as stability.

5. The sheet copper insert in the aluminum gasket not only prevents deformation of the gasket during handling but of greatest importance it protects the furnace lid in case of splatter during

reduction. This disc insert has a small hole in the center for evacuation and packing with argon prior to reduction.

CRUCIBLE LOADER

The function of the crucible loader is to place a magnesium oxide crucible in the proper position in the reduction bomb, fill the annular space between crucible and bomb with dry magnesium oxide sand and tamp this into place by vibration.

The equipment for this is in two parts; (1) the loader and (2) the MgO reservoir and feeding system. Figure 55 is a layout of the crucible loader and Figure 56 shows the magnesium oxide sand hopper and metering system. A cross section of the bomb with crucible and bomb in place is presented in Figure 57. The photograph (Figure 58) shows the crucible loader before installation while Figure 59 shows the assembly in place on top of the main enclosure.

When a crucible is to be loaded the operator brings the reduction bomb to the loading station on the bomb conveyor and raises it vertically until the rim seats in the flange (101 Figure 55) of the crucible loader. In this position it is under a sliding gate which separates the main enclosure from the crucible loader box. The gate is pulled back horizontally by means of an air cylinder (117) and shaft extension (110).

A magnesium oxide crucible is held against the neoprene gasket on the crucible loader head (102) where it is held by the vacuum pulled on the neoprene hose (125). The loading head with crucible attached is then lowered by the cylinder (115) until the flange on the head strikes the flange against which the bomb is seated. This puts the crucible in

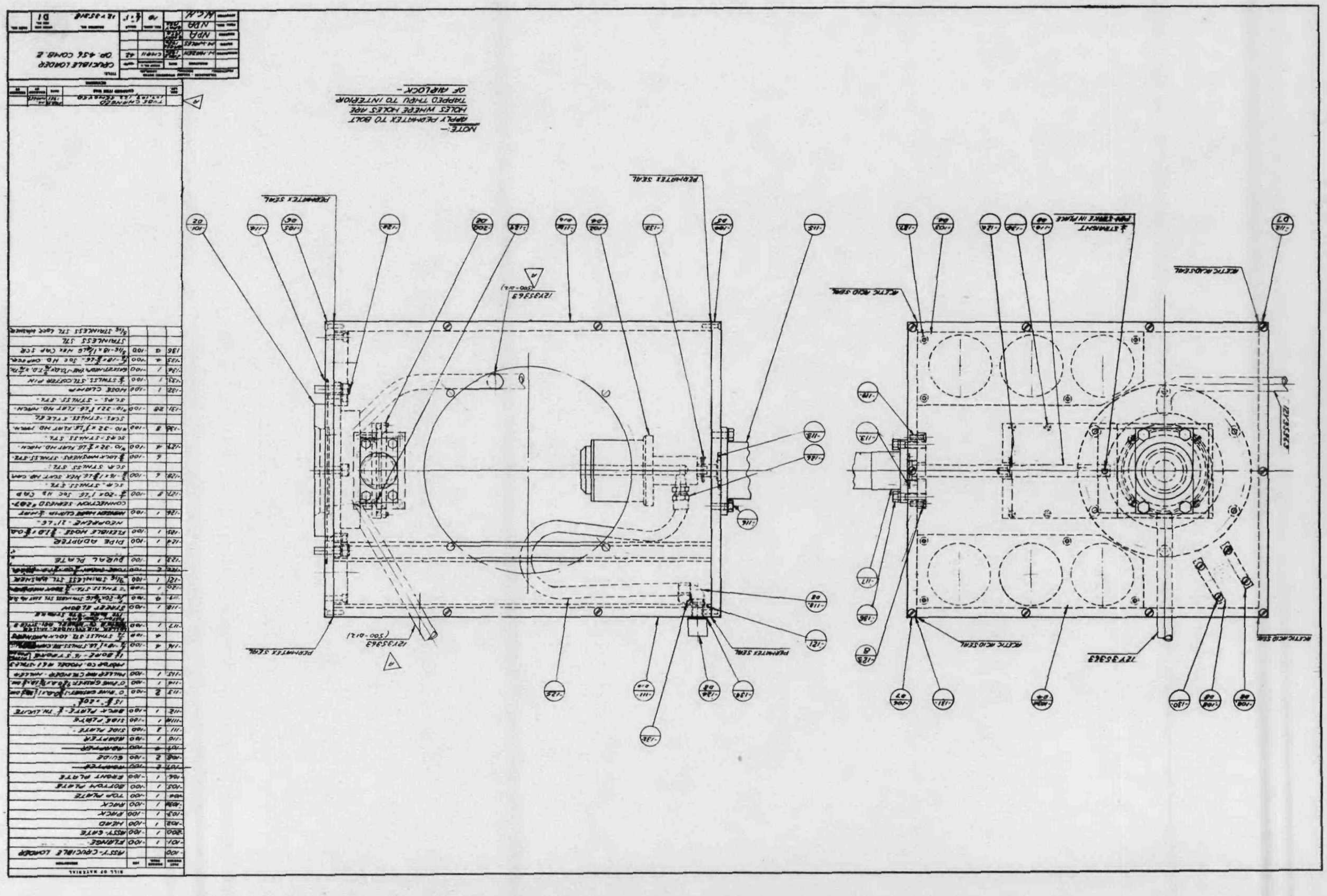

Fig. 55. Design layout of crucible loader.

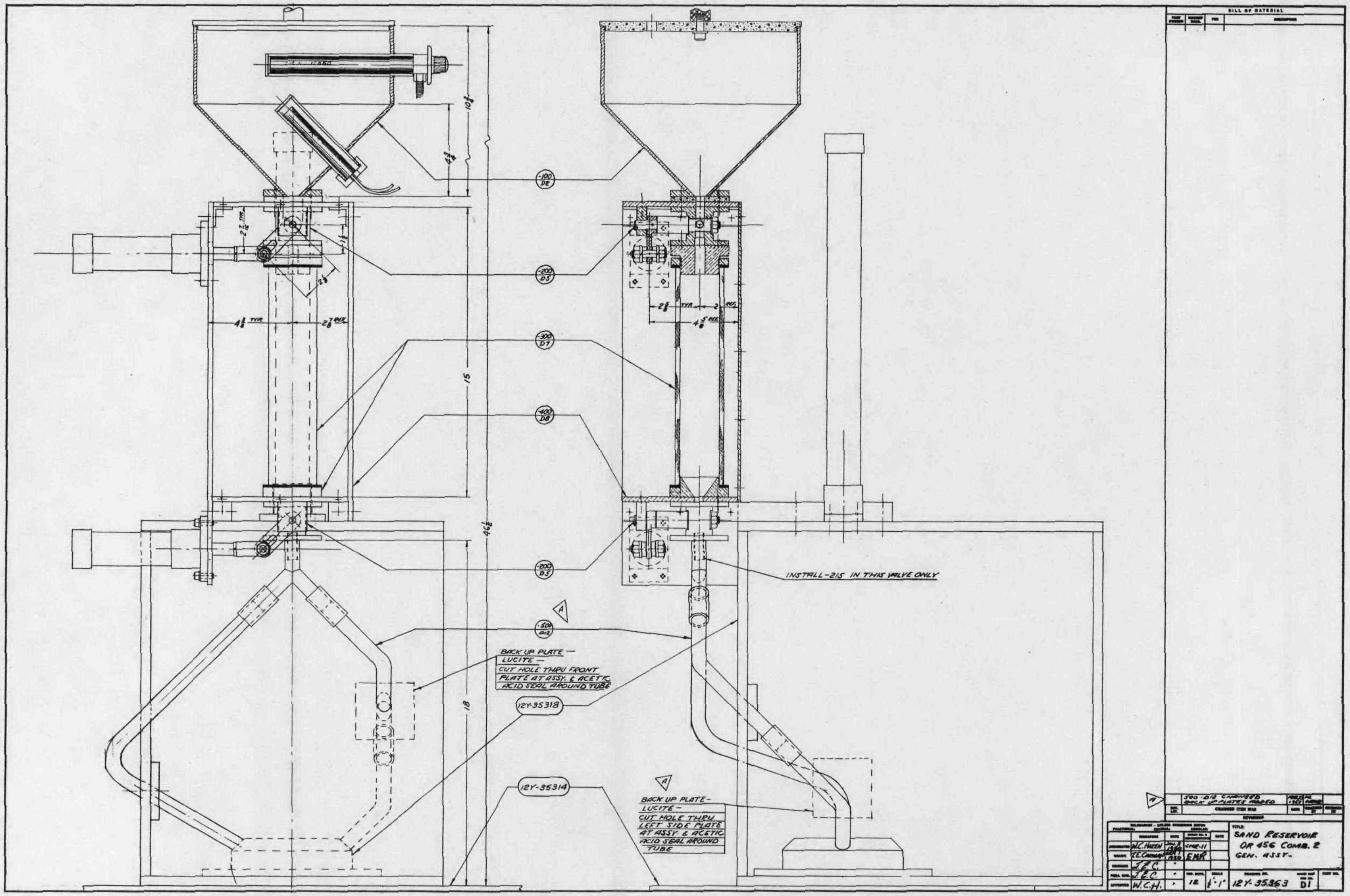

Fig. 56. Design layout of MgO hopper and metering system.

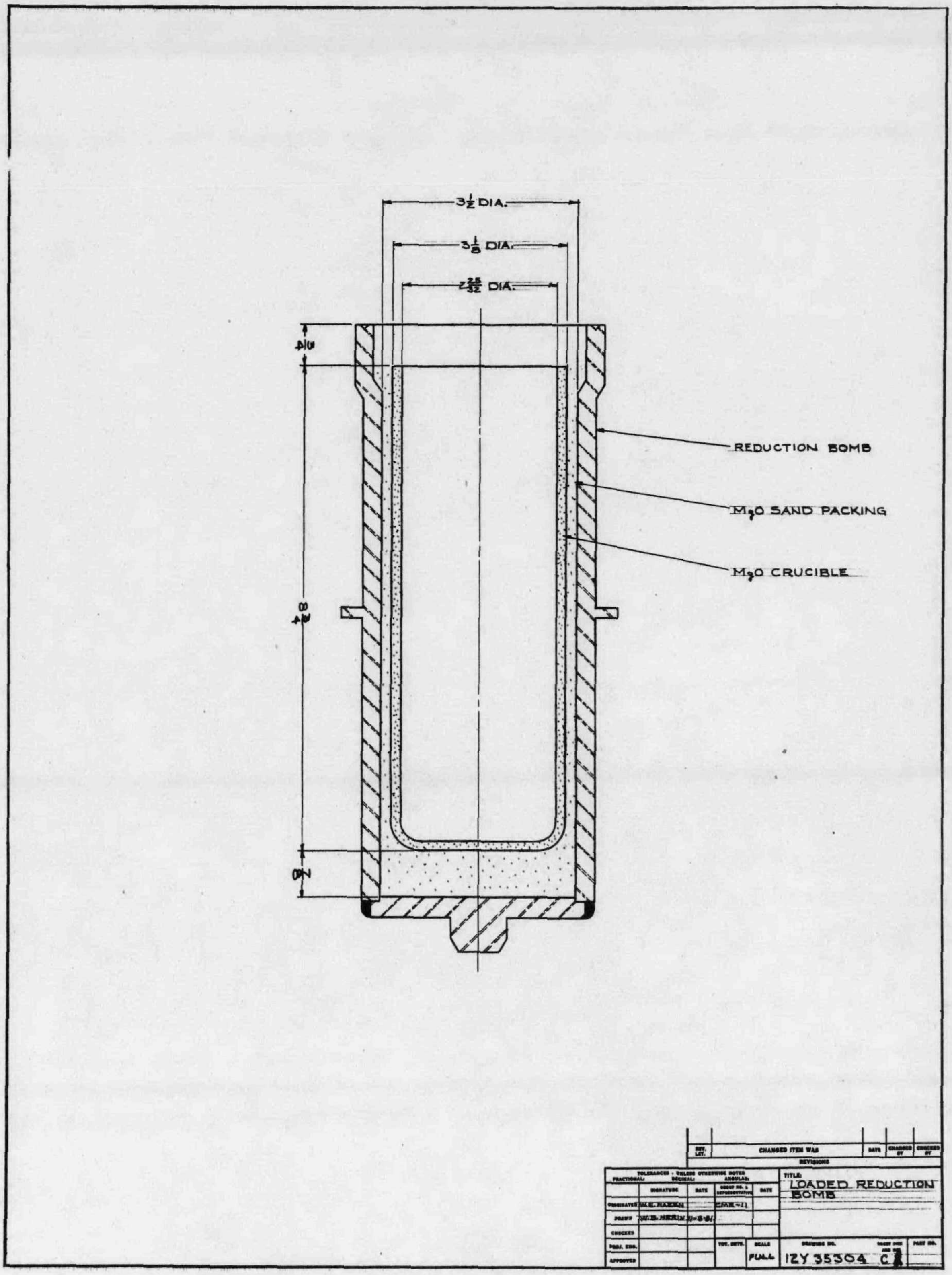

Fig. 57. Sketch of reduction bomb with crucible and MgO sand in place.

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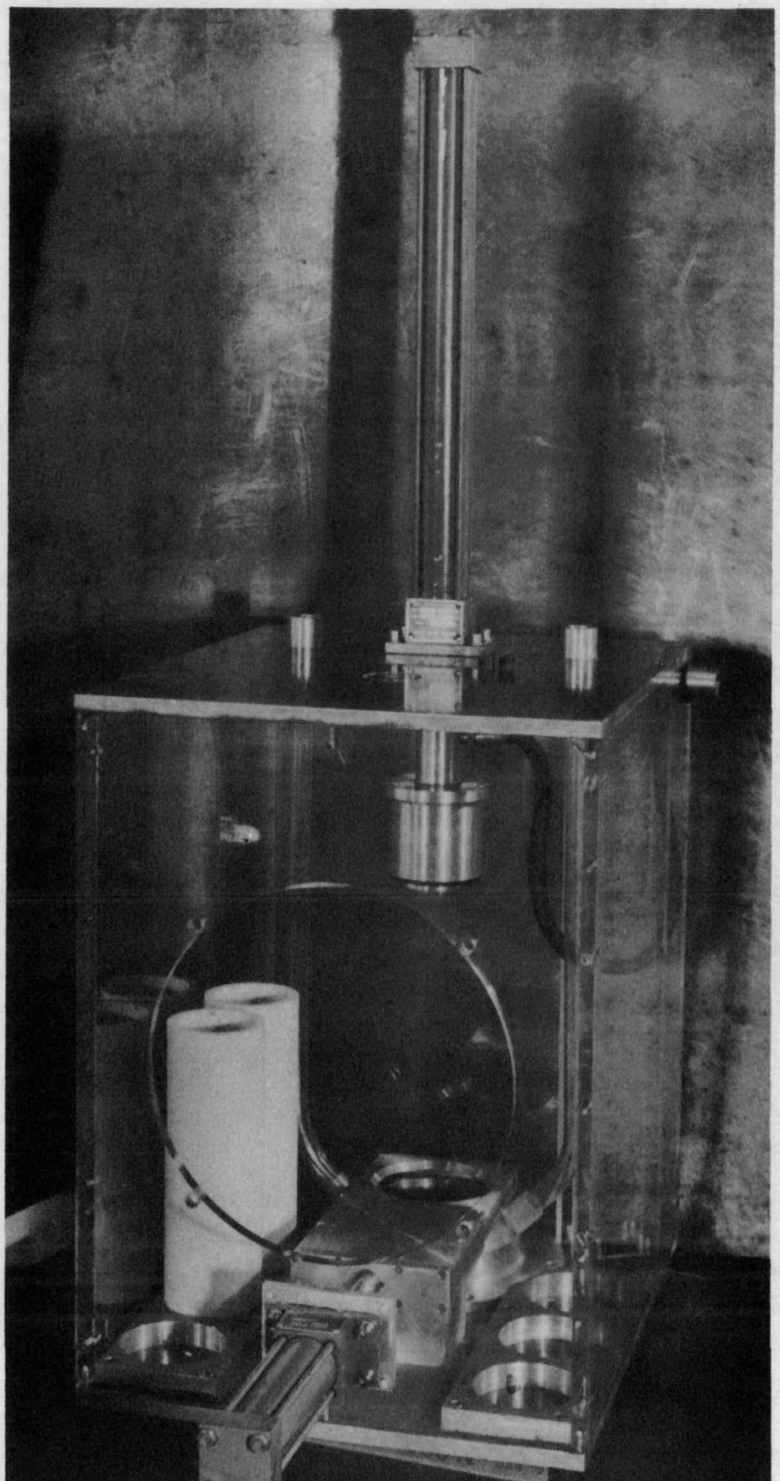

Fig. 58. Photograph of crucible loader taken during installation.

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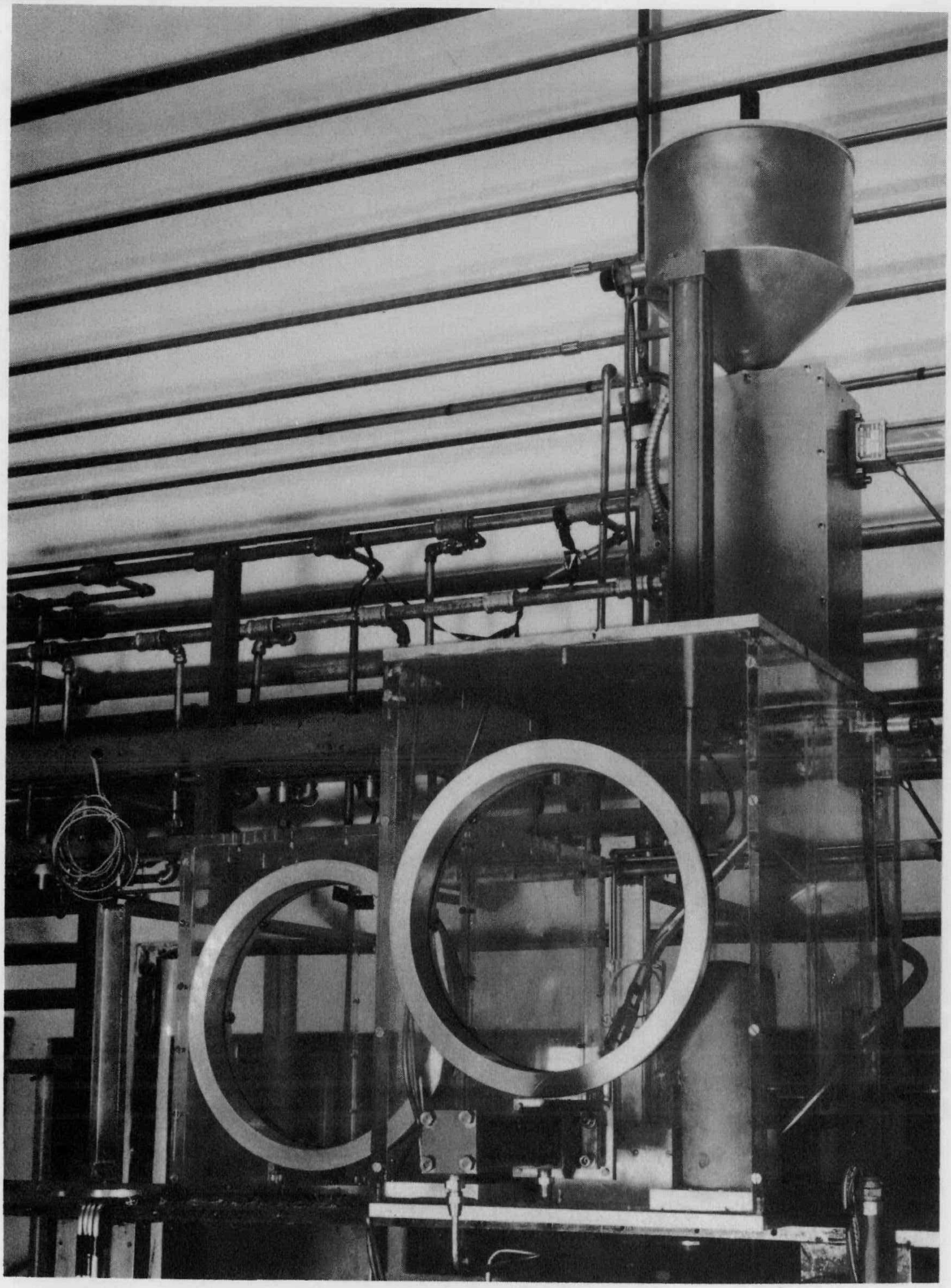

Fig. 59. Crucible loader and MgO hopper system as installed.

the proper position inside the bomb ready for the sand packing.

With reference to Figure 56 the MgO sand is kept in a brass hopper (100) which has a heating cartridge and thermostat control for keeping it warm and dry. When the crucible is in place in the bomb the top brass plug valve (200) directly under the hopper is opened permitting the sand to flow into the calibrated lucite measuring tube. After the proper amount is in the tube the top plug valve is closed and the bottom one opened. The sand flows through the bottom valve and divides into the two lucite tubes (500) which carry it down to the annular space between crucible and bomb. With 800 grams of MgO sand the level is one inch from the top edge of the crucible.

Tamping is accomplished by an air vibrator attached to the lower shaft of the double ended cylinder which holds the bomb against the crucible loader. In practice approximately half of the sand is run into the bomb before vibration is started. Vibration is continued for one minute after all the sand is in and the plug valve under the measuring tube has been closed.

By breaking the vacuum on the crucible loader head it can be raised out of the bomb leaving the crucible in place firmly held by the surrounding sand. The sliding gate is closed and the bomb lowered into the bomb carriage.

The MgO crucible used is type A-331 purchased from The Norton Co. The average weight of this crucible is 450 grams.

Controls

There are no interlocks or special circuits used for this station. A photograph of the control panel showing the operating sequence is given in Figure 60.

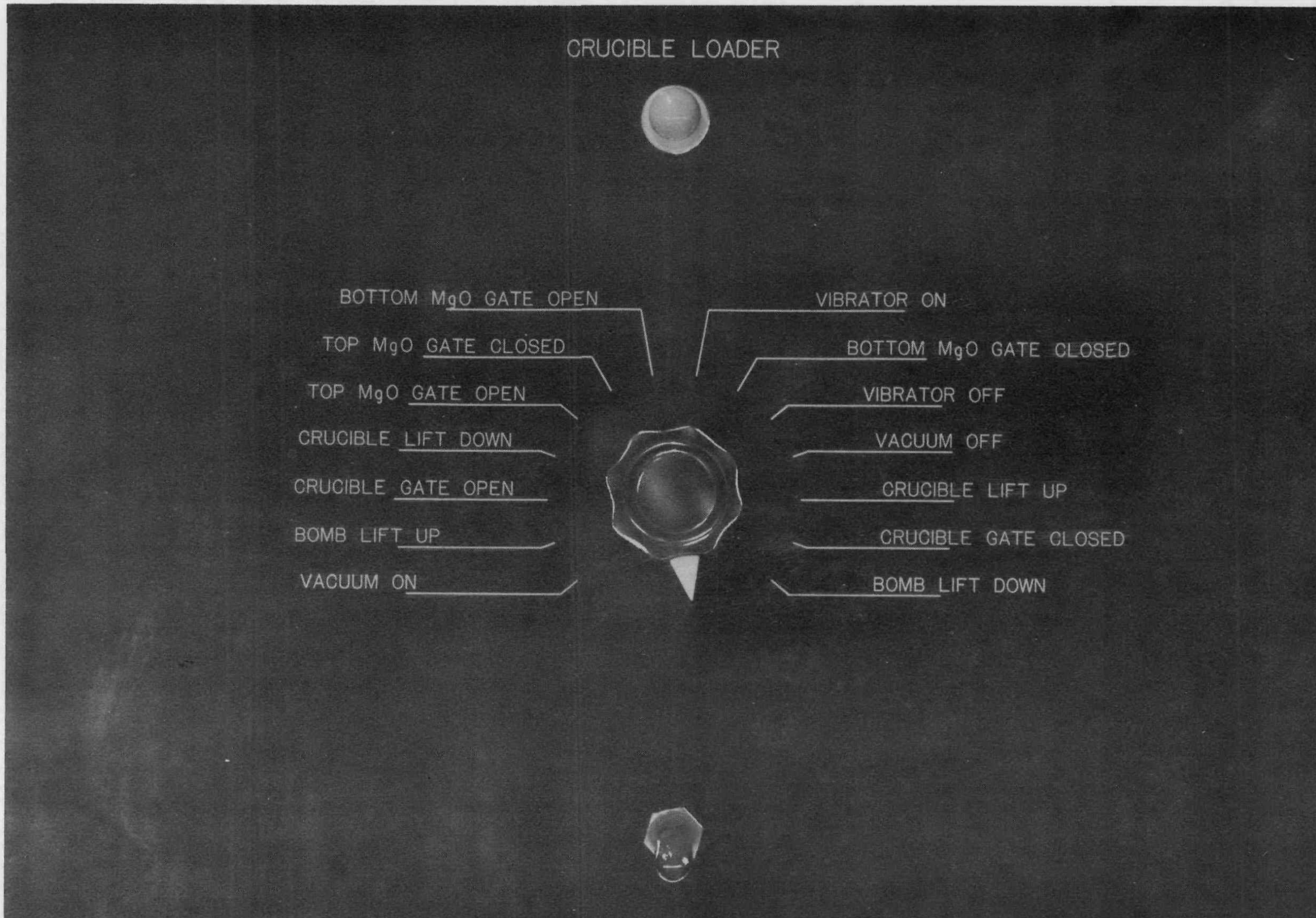

Fig. 60. Crucible loader control panel.

GASKET DISPENSER

At the gasket dispensing station an aluminum gasket is placed in the groove in the top rim of the reduction bomb. A drawing of the gasket is presented in the section marked "Reduction Bomb and Gasket".

Figure 62 is an assembly of the gasket dispenser mounted on the top plate of the main enclosure. There is a brass tube (104) which can hold 50 gaskets mounted over a sliding plate. When the reduction bomb is raised vertically on an air cylinder it seats against the rim of a hole in the bottom of the dispenser. This hole is just large enough for a gasket to drop through. When the air cylinder (114) is actuated the slide (107) pushes the bottom gasket of the stack over just far enough to drop through the hole in the dispenser into the groove in the rim of the reduction bomb.

There is a plastic bag ring (113) on top of the lucite housing through which a stack of gaskets can be loaded into the holding tube by a special loading clip.

A photograph of the control panel is shown in Figure 63.

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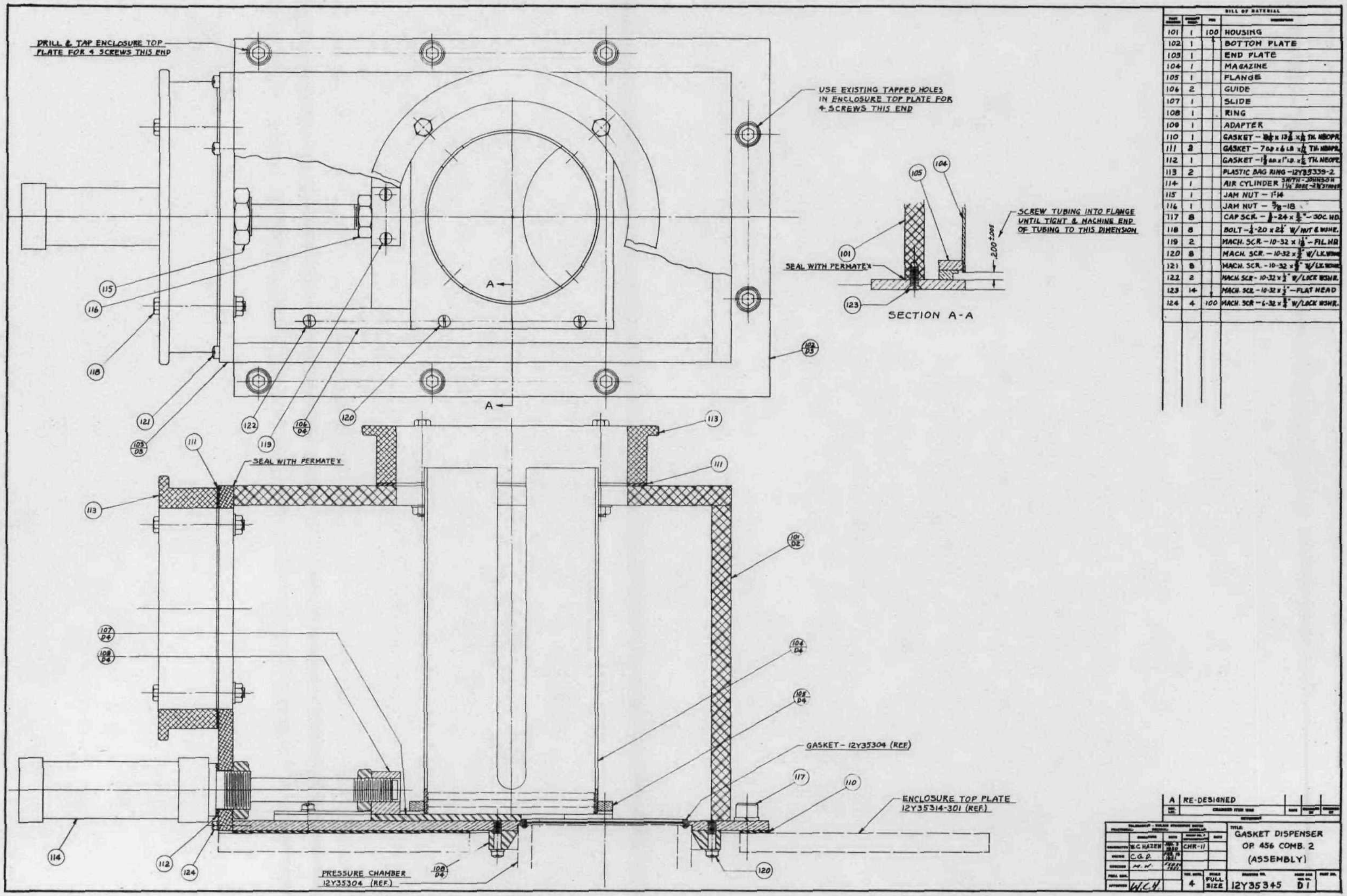

Fig. 62. Design layout of gasket dispenser.

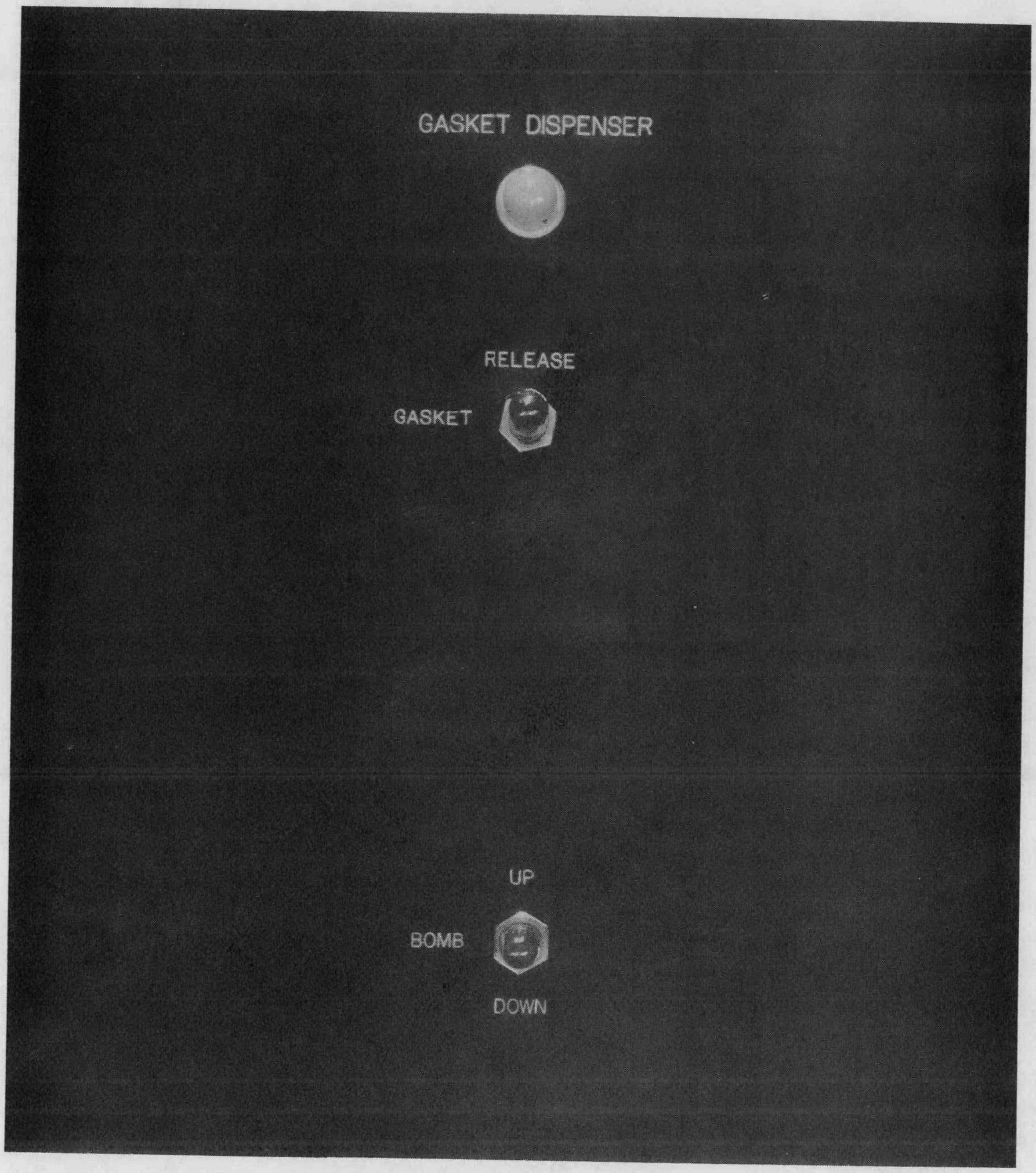

Fig. 63. Gasket dispenser control panel

REDUCTION FURNACE

Design and Operation

At the reduction furnace station plutonium tetrafluoride is reduced to plutonium metal by calcium. A cross section sketch of the equipment for performing this operation with the bomb in place is given in Figure 64 and the design layout in Figure 65. The following is a description of the equipment and operating procedure.

The structural framework of the unit consists of two stainless steel plates each two inches thick (201, 202, Figure 65) connected by four stainless steel tie rods (203). These plates are the platens of a hydraulic press. A hydraulic cylinder is mounted on the bottom platen with its piston rod extending upward through a hole in the center. This hydraulic cylinder is powered by an air-oil booster system to give a total force at the piston head of 7000 pounds.

A lid made of Hastelloy C is bolted to the under side of the top platen.

The unit is installed so that the tie rods straddle the bomb conveyor tracks with the top and bottom plates mounted on asbestos gaskets on the outside of the stainless plates which form the top and bottom of the main enclosure.

When the bomb is ready for firing it is conveyed to the reduction station where it is stopped automatically in position over the head (300) of the piston rod in the retracted position. When this piston is lifted by the booster system it raises the bomb upward through the

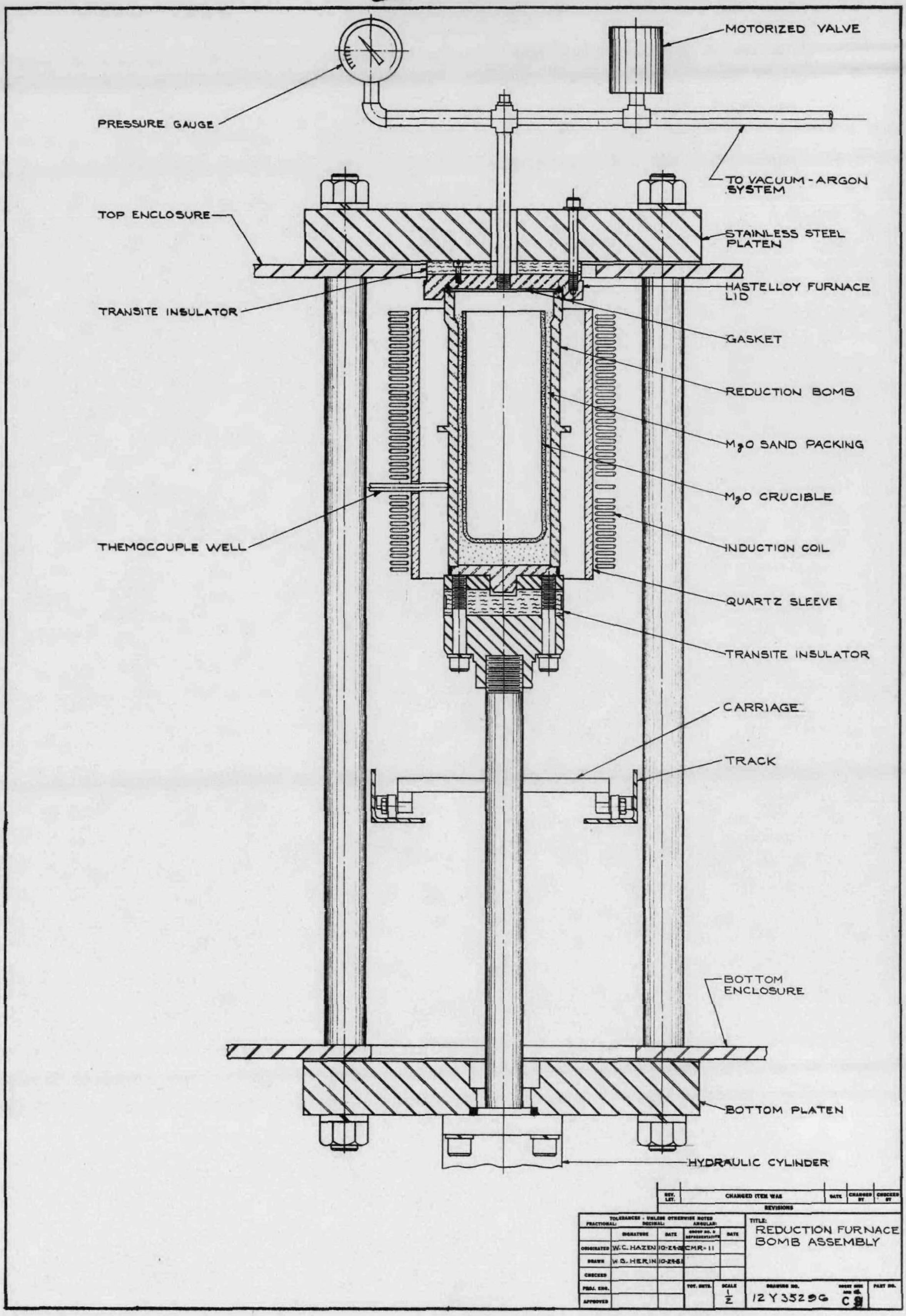

Fig. 64. Sketch of reduction furnace with reduction bomb in place for firing.

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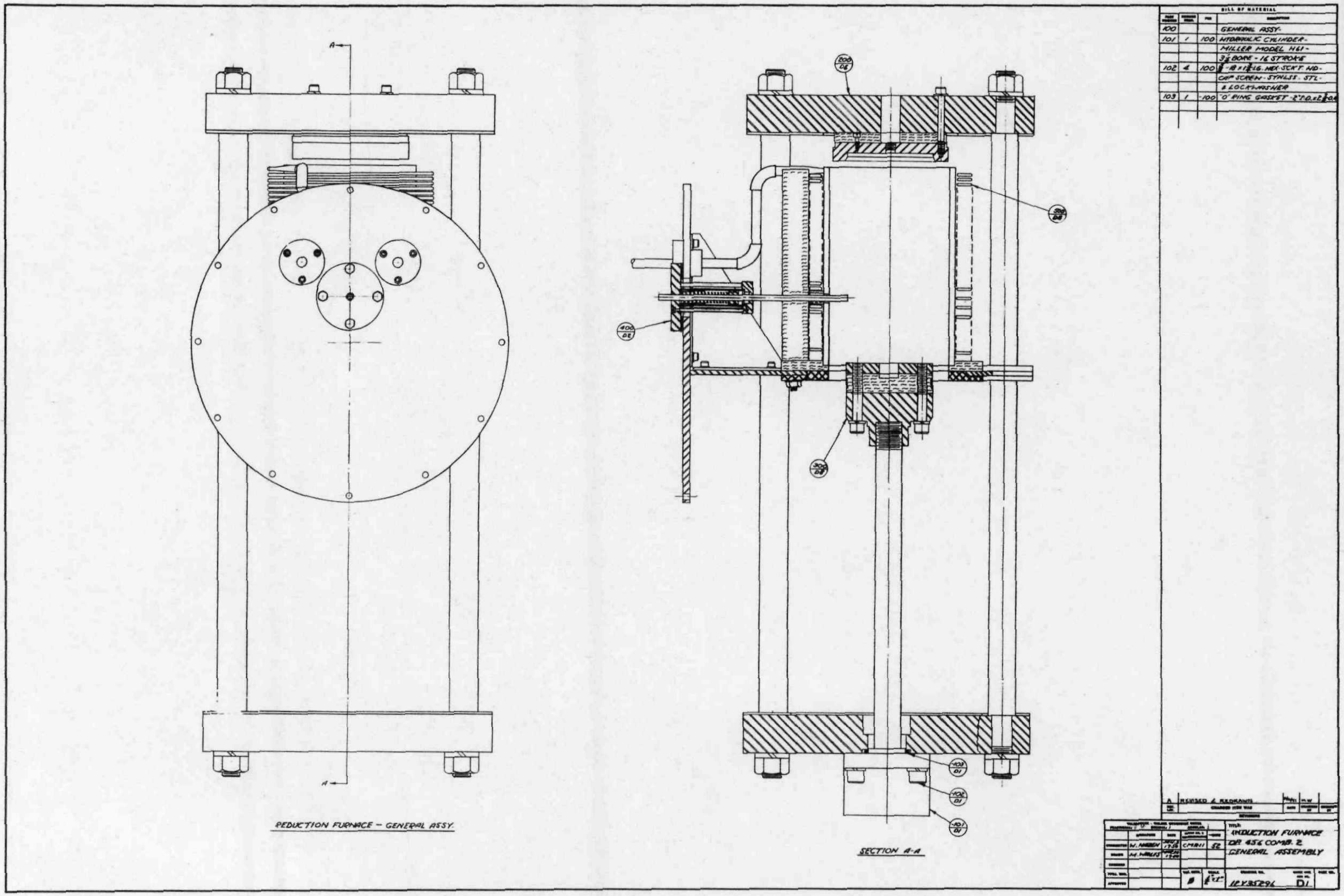

Fig. 65. Design layout of reduction furnace.

center of a quartz sleeve (102) inside a water cooled induction coil, (101) until the gasket on top of the bomb seats in a groove in the Hastelloy C Bomb Lid. When the bomb gasket seats in the groove the increased resistance against the piston shaft causes the booster system to switch to the high pressure cycle and build the oil pressure up to 900 psi thus compressing the gasket between bomb and lid and obtaining a tight seal.

There is a 1/4" hole drilled through the center of the Hastelloy bomb lid and piped to the vacuum argon system. After the bomb is raised, the air inside is removed by the vacuum system and replaced with argon after which the bomb is ready to fire.

The water cooled copper induction coil is connected by welding cable leads to a 20 KW Ajax converter located in the control room. The leads are placed inside a wooden trough and separated by a 1/2" thick wooden divider. The leads to the East line are 15 feet long and those to the West line 15 feet. Figure 66 is a drawing of the coil and Figure 67 is a photograph of coil and quartz sleeve.

The Ajax converter is turned on and set to 8 KW for the firing cycle. There is a pressure gauge on the pipe connected to the bomb lid which registers an increasing pressure as the bomb heats. After about eight minutes of heating this pressure gauge shows a sharp increase in pressure followed by a marked drop. This indicates that the firing has taken place and the converter is then turned off. The usual firing pressure on this cycle is between 20 and 35 psig. with the sudden

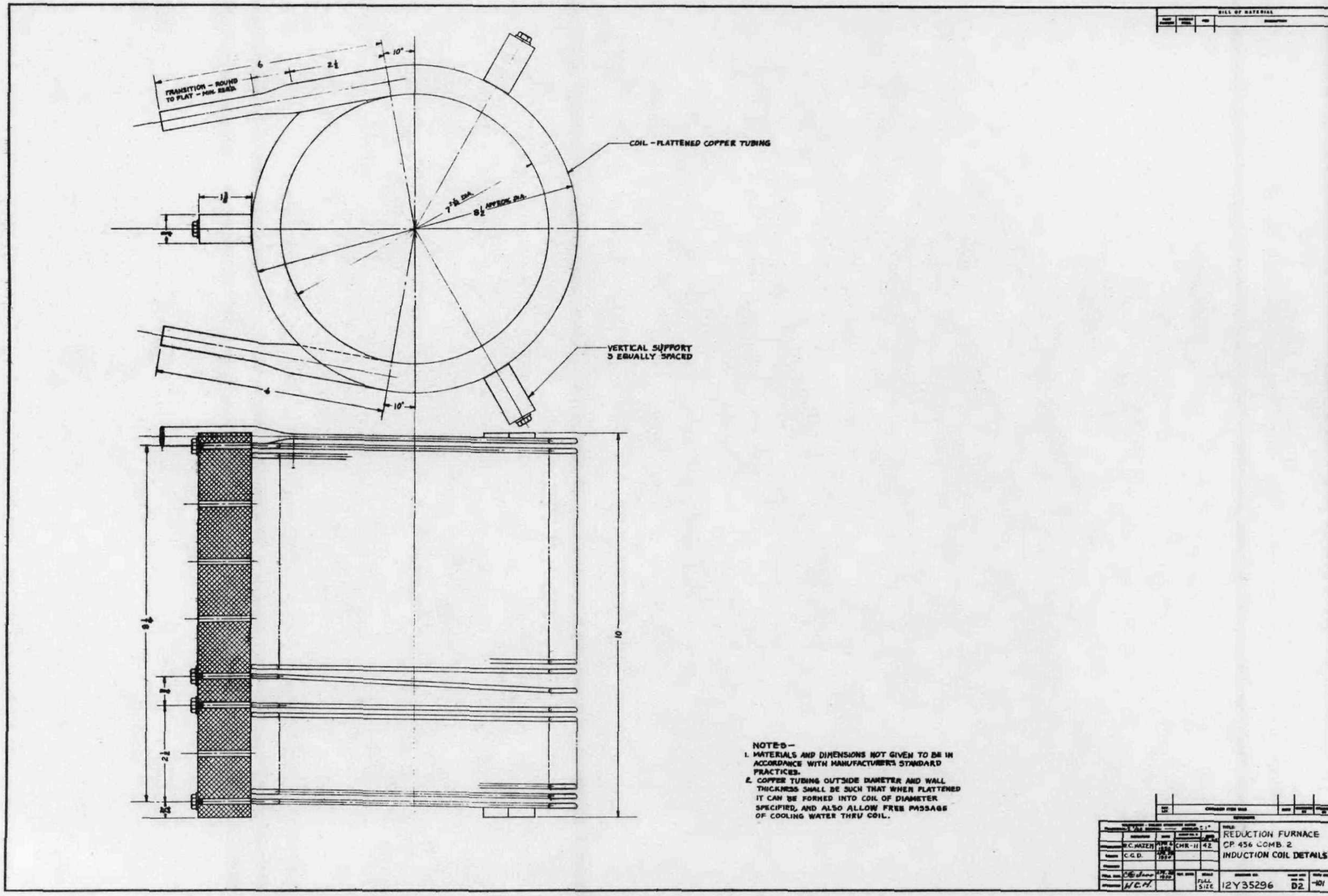

Fig. 66. Drawing of reduction furnace induction coil.

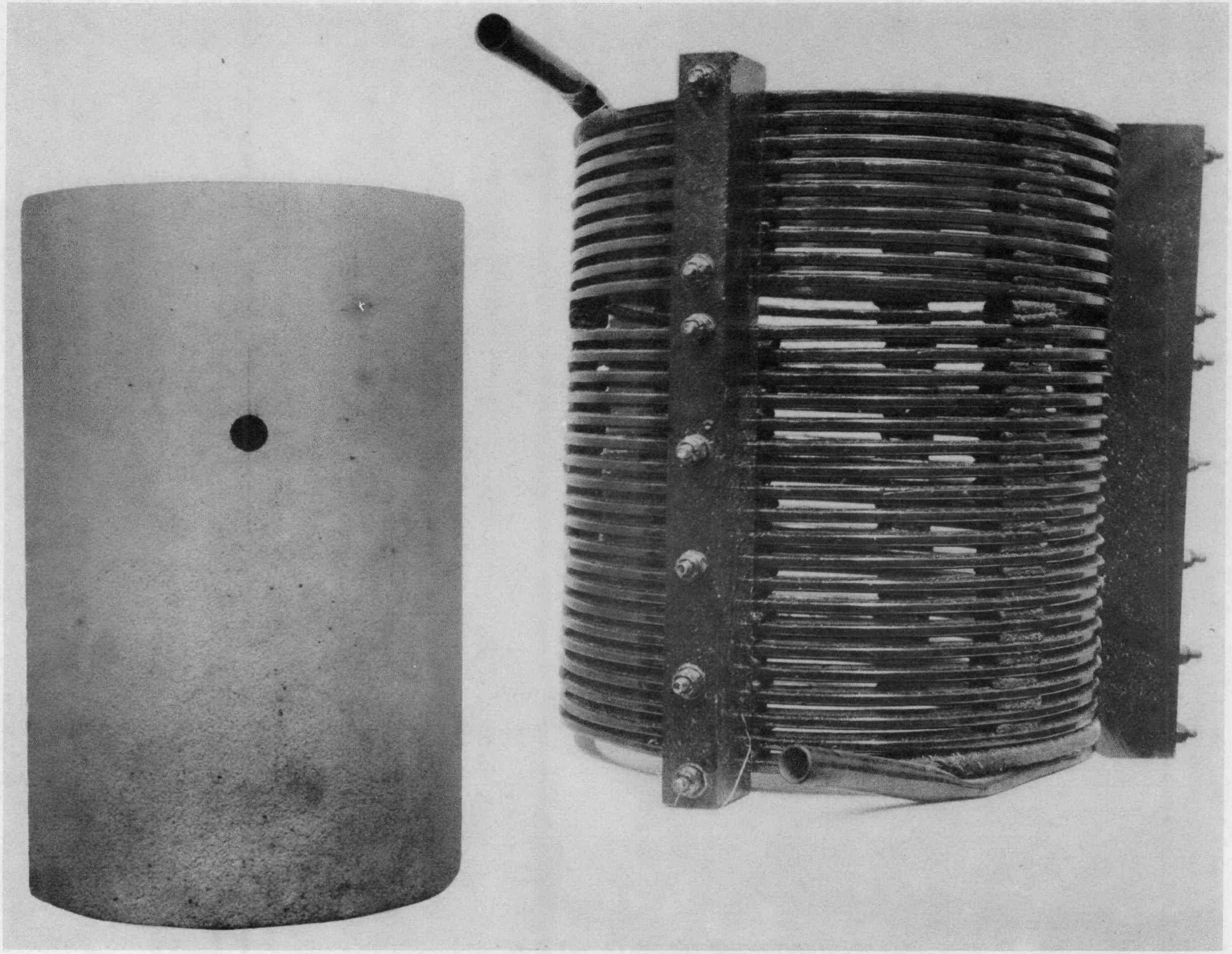

Fig. 67. Photograph of reduction furnace coil and quartz sleeve.

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increase on firing being 25-40 psig. higher. The bomb is held in place for 2-1/2 hours to cool after which it is lowered into the carriage and is ready to be unloaded.

There are a number of points in the design of this unit of particular interest.

1 - The induction coil and quartz sleeve are mounted on a support plate (112 Figure 65) which is attached to the circular flange cover plate (103 Figure 65). The mounting plate slides in grooves cut in blocks clamped to the tie rods. The cover plate is gasketed and bolted to the side of the main enclosure with the leads to the coil and the thermocouple well assembly going through it. By unbolting the cover plate from the enclosure the entire coil-sleeve unit can be pulled out without disturbing the press assembly. A picture of this mounting plate taken during installation (Figure 68) shows the thermocouple and induction coil leads as well as the relation of this mounting plate to the rest of the assembly. Figure 69 is a design layout of the coil and plate assembly.

2 - The Hastelloy C bomb lid is bolted to the upper platen by cap screws extending into Zone 3. A piece of transite serves to insulate the lid from the platen. By unscrewing the cap screws, with the bomb raised, the lid can be detached from the platen and lowered down on top of the bomb to the carriage. The bomb and lid can then be transported to a convenient place

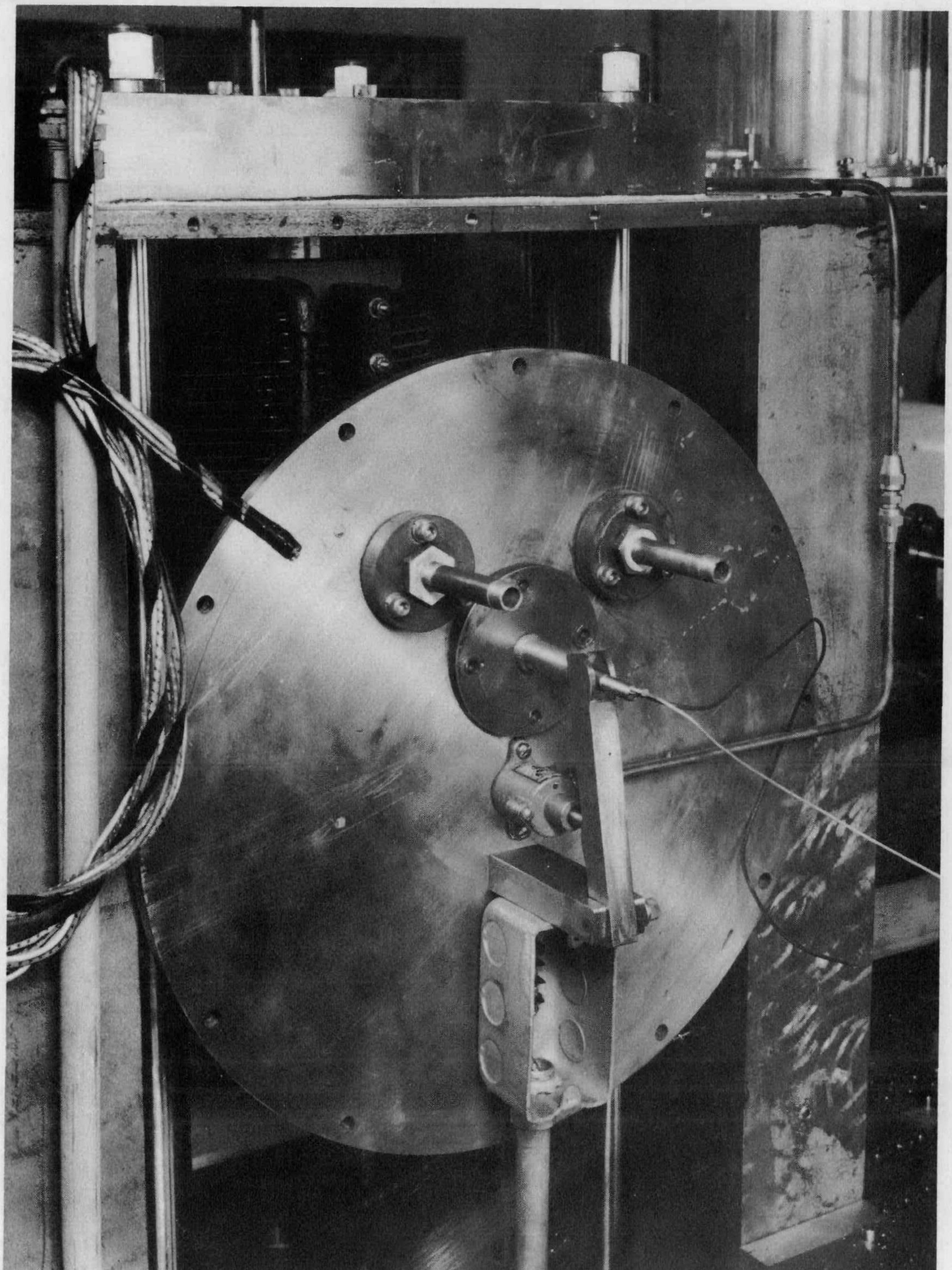

Fig. 68. Photograph of induction coil flange mounting plate.

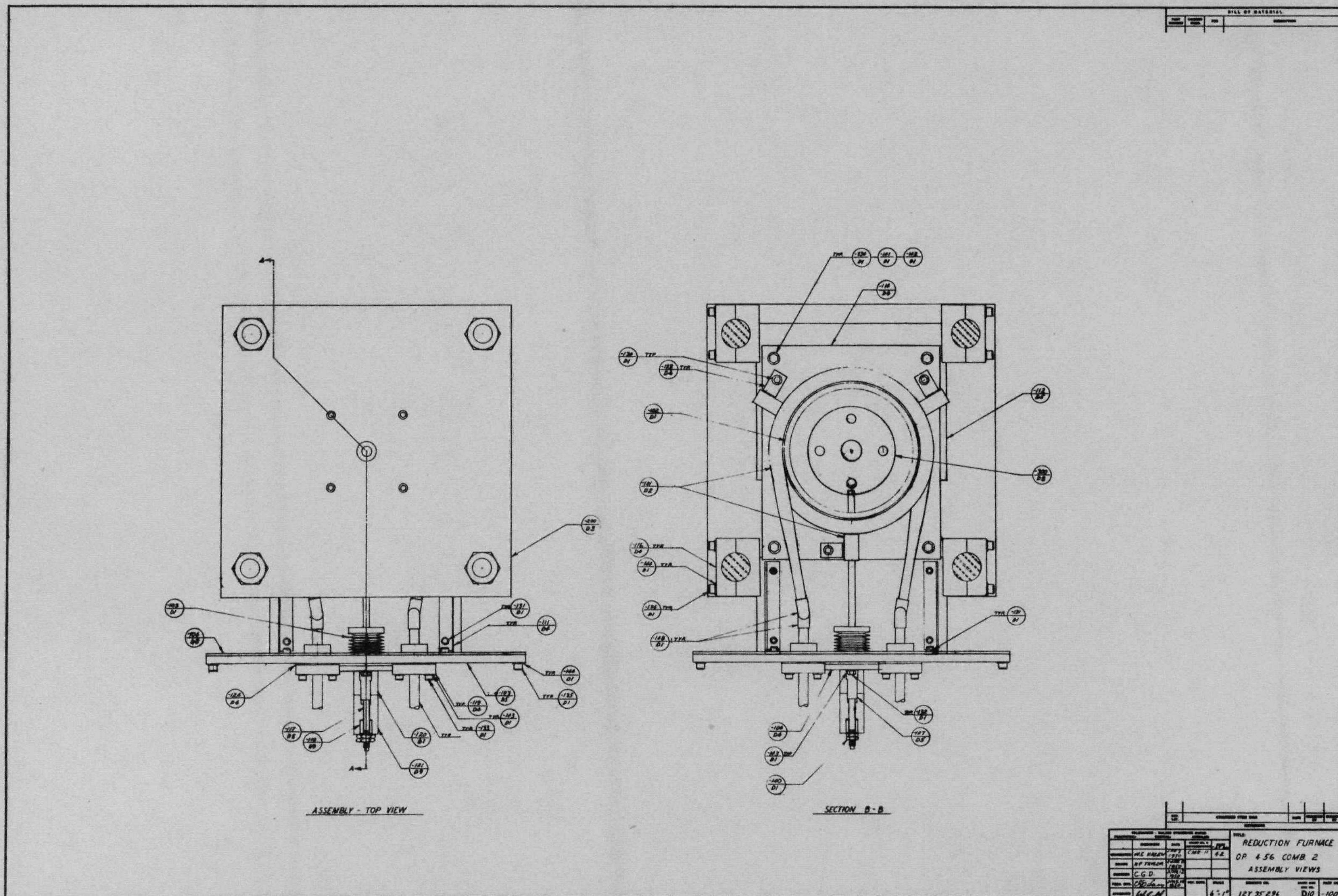

Fig. 69. Design layout of reduction furnace coil and sleeve mounting assembly.

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where the lid can be taken out of the unit through a plastic bag. The process can be reversed to install a new lid if this should ever prove necessary.

3 - The thermocouple well assembly passes through a metal bellows in the cover plate, through a spacing in the induction coil and a hole in the quartz sleeve. The design layout for this is given in Figure 70. This well is retracted by a small air cylinder when the bomb is being raised or lowered.

Since the well is made of stainless tubing welded closed on the inner end only the thermocouple can be easily changed from Zone 3.

4 - An air-oil booster system is used for raising the bomb and holding the pressure during reduction in preference to other hydraulic methods so that full force can be maintained in the event of power failure.

5 - To make sure that the gasket does not stick in the lid after firing instead of coming down with the bomb, the included angle of the gasket groove in the lid is 100° and that in the bomb rim is 90°.

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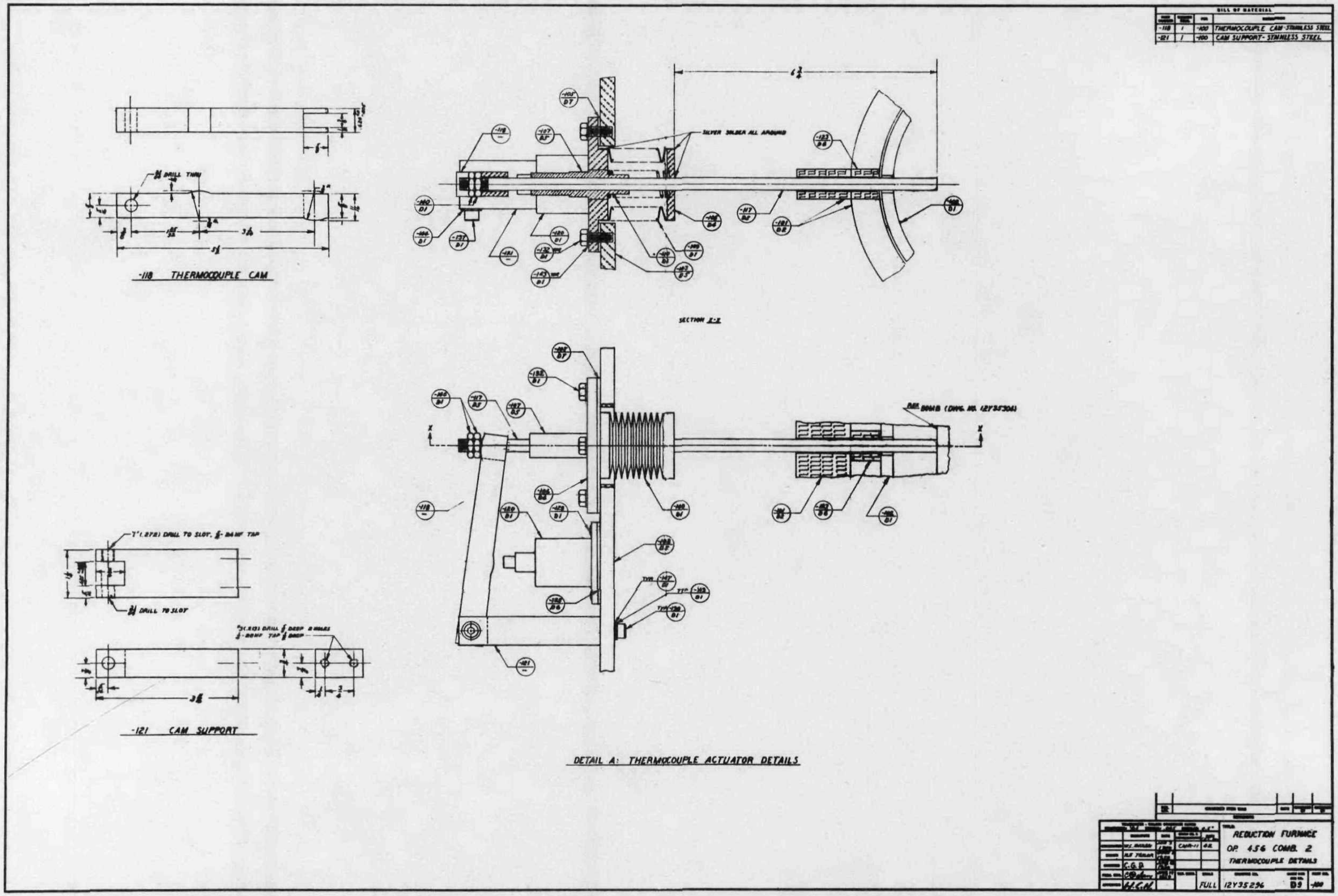

Fig. 70. Design layout of reduction furnace thermocouple well assembly.

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Controls

The control panel for this assembly is shown in the photograph Figure 71. The ammeter and switch on the right are used for operation of the dummy bomb and are discussed in the section on that unit. Temperatures are recorded on the same recorder used for HF furnace temperature. A second thermocouple in the well held against the bomb shows the temperature on an instrument mounted on the Ajax in the control room.

The switch on the lower left controls solenoid valves in the vacuum and argon lines while the switch immediately above controls the gas flow rate during evacuation and argon packing.

There is one electric interlock at this station. If the thermocouple was extended at the time the bomb was being raised it is probable that the thermowell and quartz sleeve would be damaged. Therefore the switch controlling the thermocouple operates a relay in the booster system circuit (switch, center of panel) so that the bomb cannot be raised or lowered unless the thermocouple is retracted.

The cooling water through the coil is started automatically by a solenoid when the panel power switch is turned on. The flow is indicated by a "bulls eye" flow indicator mounted on the unit.

Booster System

A schematic drawing of the air-oil booster is given in Figure 72. No troubles have been encountered in the use of this equipment. A pressure gauge on the high pressure oil side is located in plain view

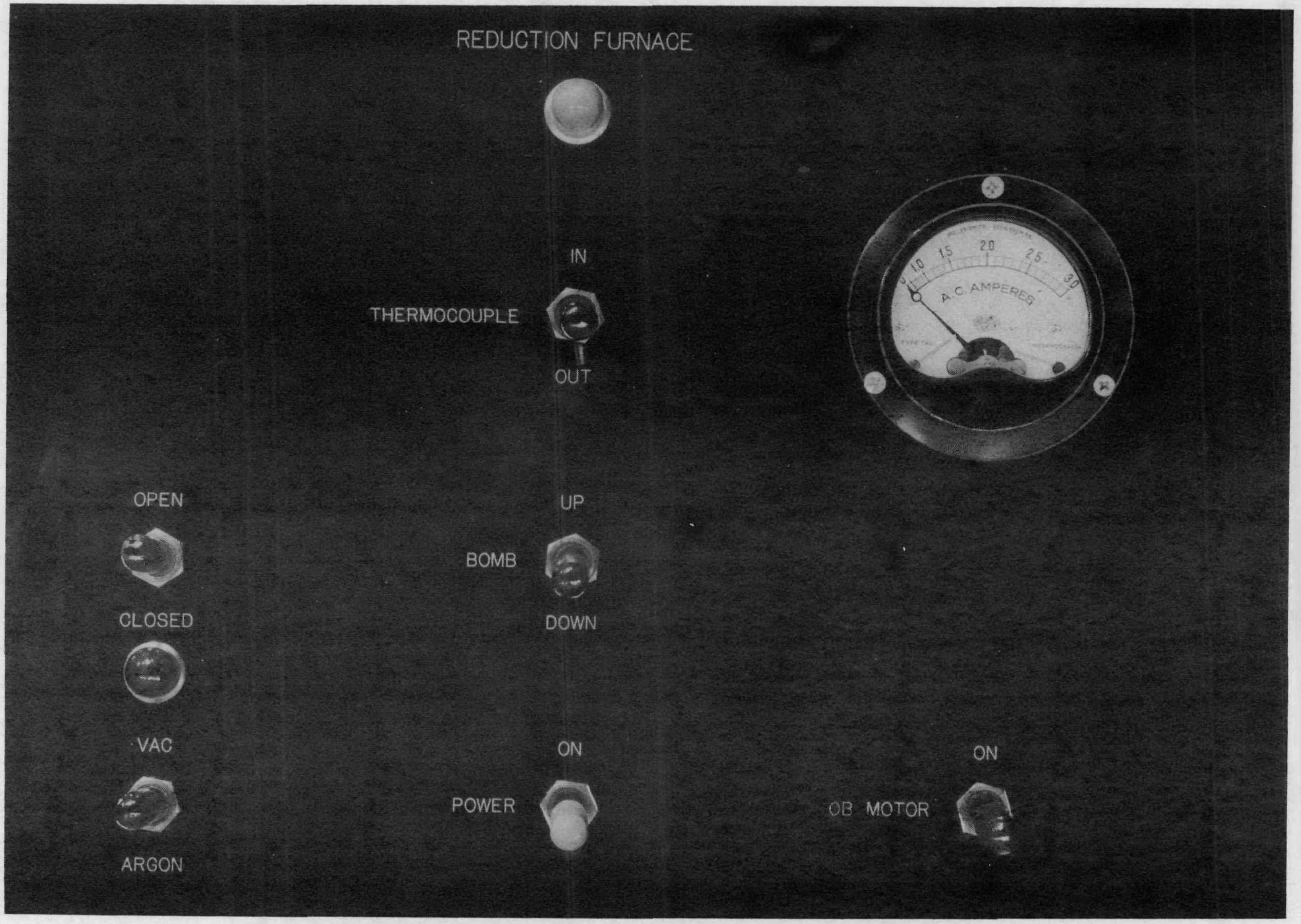

Fig. 71. Control panel for reduction furnace.

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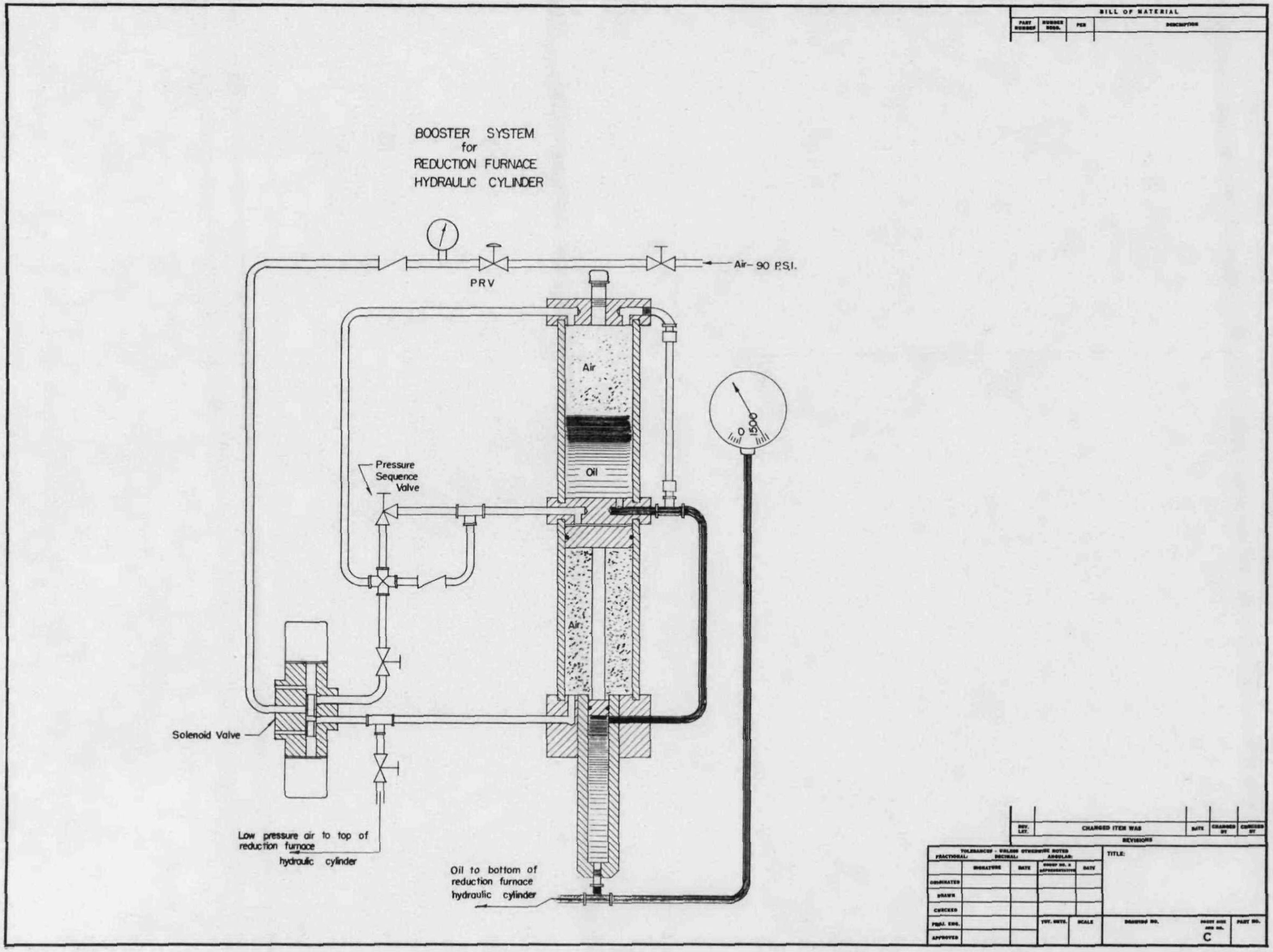

Fig. 72. Diagram of air-oil booster system for the hydraulic cylinder in the reduction furnace.

of the control room operator. A point of particular interest is that this oil pressure rises by several hundred psi during the firing cycle, probably because of expansion of the bomb upon heating.

Testing

The principle of the design of this reduction furnace assembly was tested in the engineering mock-up by 25 uranium reductions on the 500 gram scale.

In the final units heating cycles were determined as well as pressure tests at 300 psi using dry ice for obtaining the pressure. In addition to these mechanical tests a series of 500 gram uranium reductions were made to test not only the reduction equipment but all the other units other than precipitation and hydrofluorination. A summary of the uranium reductions is presented in Table I.

Heating curves for Hastelloy C and steel bombs are presented in Figures 73, 74, 75 and 76.

Table II shows the data for a standard production scale plutonium reduction.

Table I

Uranium Reductions in Remote Control Equipment

500 gram scale. Hastelloy C Bomb

Iodine Mol Ratio - 0.2

Ca = 25% excess

Run No.	K.W.	Firing Time (mins.)	Firing Temp °C	Firing Pressure p.s.i.	Max. pressure immediately after firing	Reduction Yield %
1	12	14	510	70		98.6
2	12-1/2	13	515	79	125	99.9
3	13	15-3/4	530	80	110	98.4
4	13	14	500	120		99.7
5	13	15	510	105	130	100.0

Typical Spectrographic Analysis of Uranium Buttons
(ppm)

C	240
L	<.1
Be	<.1
B	0.2
Na	2
Mg	15
Al	3
Si	20
Ca	<5
V	<10
Cr	3
Mn	2
Fe	60
Co	<5
Ni	30
Cu	50

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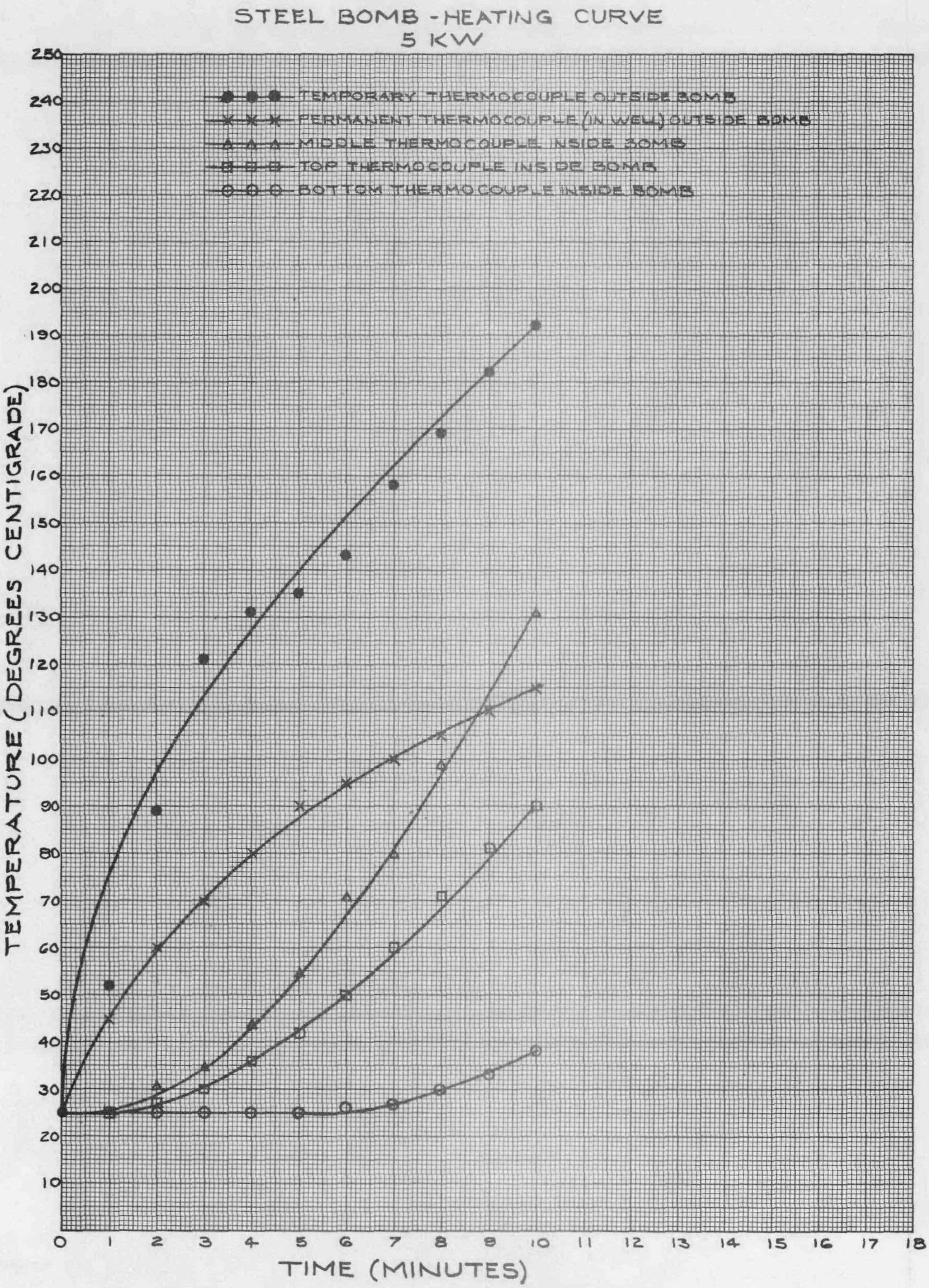

Fig. 73. Heating curve for steel bomb. Ajax converter set at 5 KW.

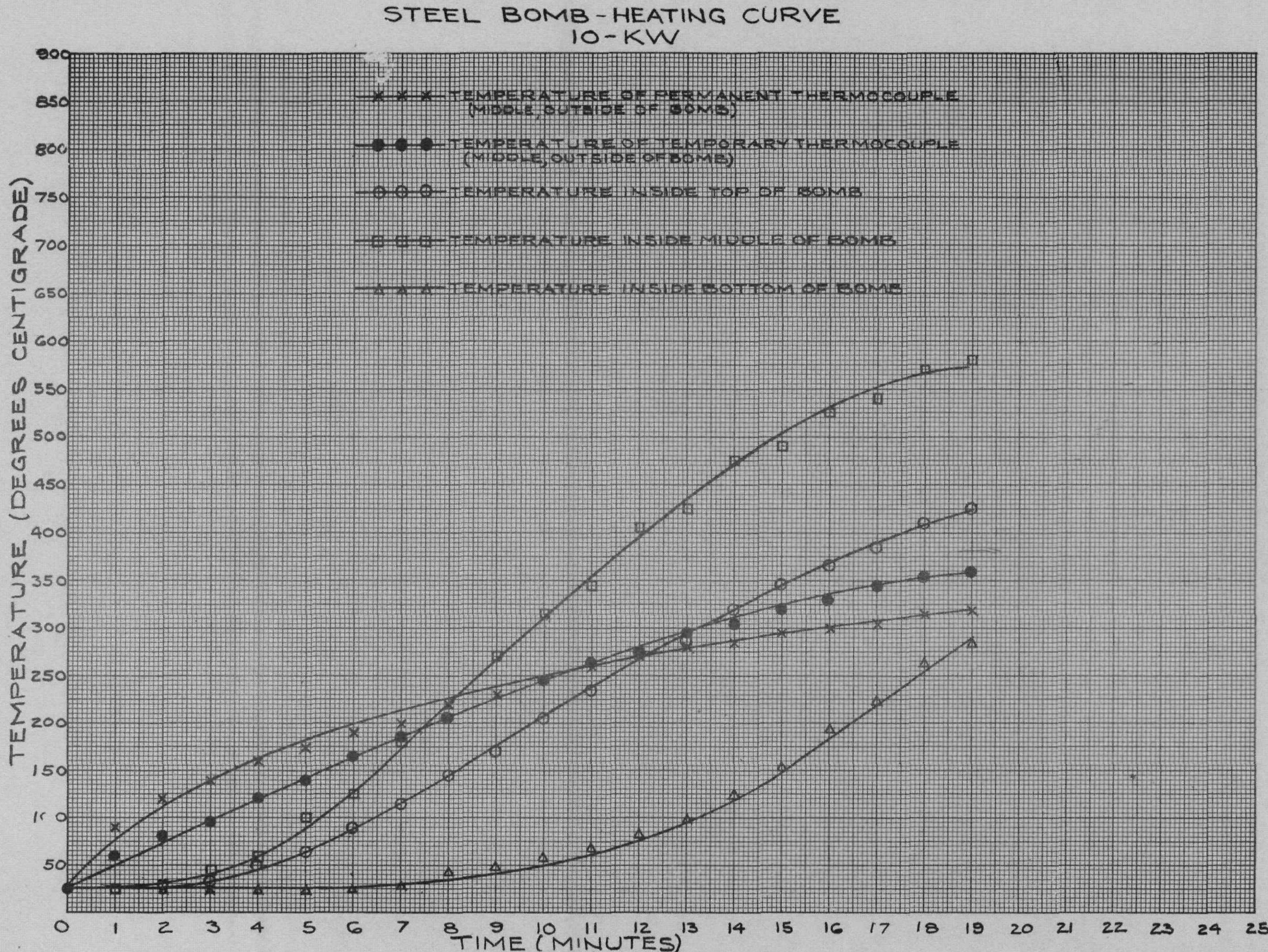

Fig. 74. Heating curve for steel bomb. Ajax converter set at 10 KW.

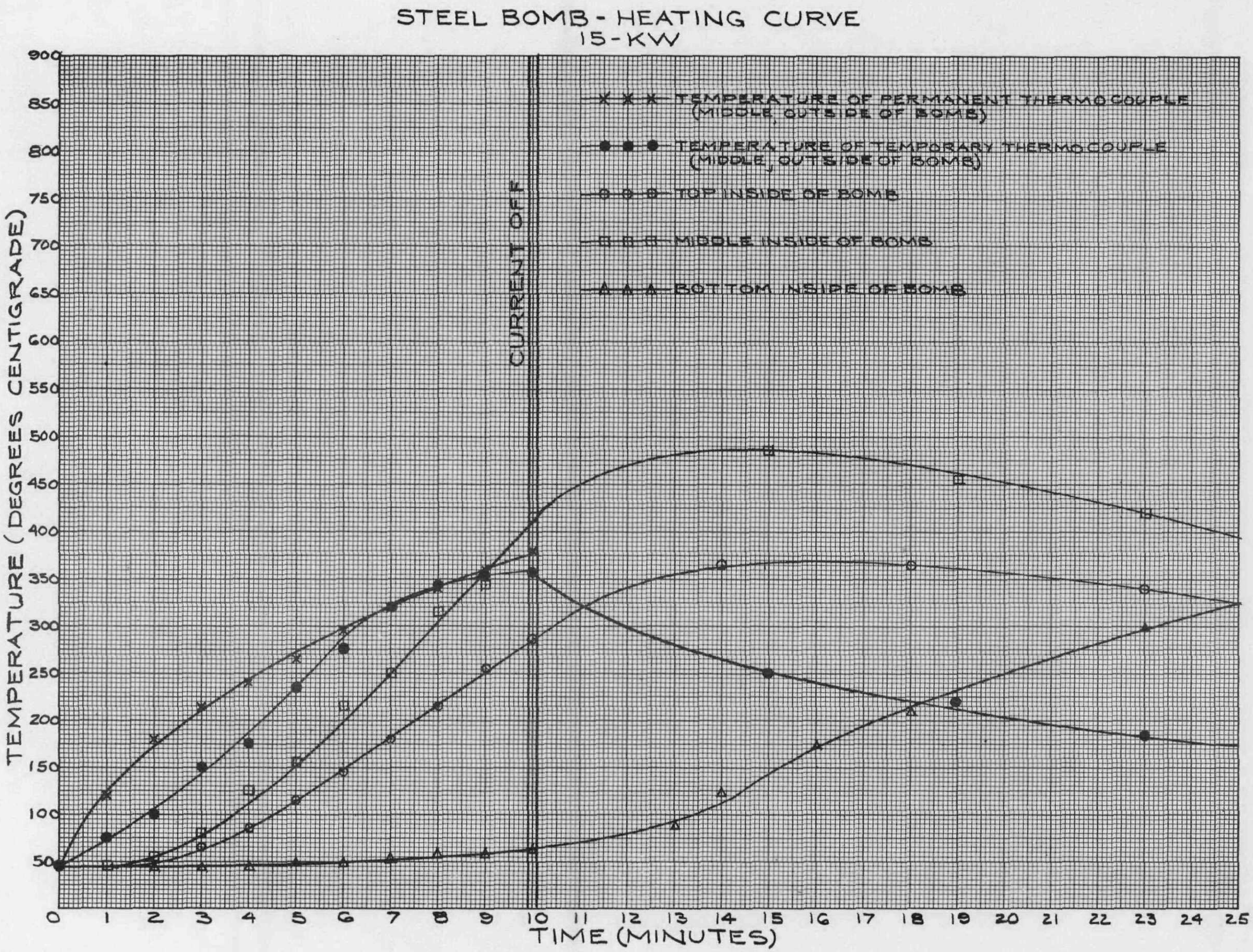

Fig. 75. Heating curve for steel bomb. Ajax converter set at 15 KW.

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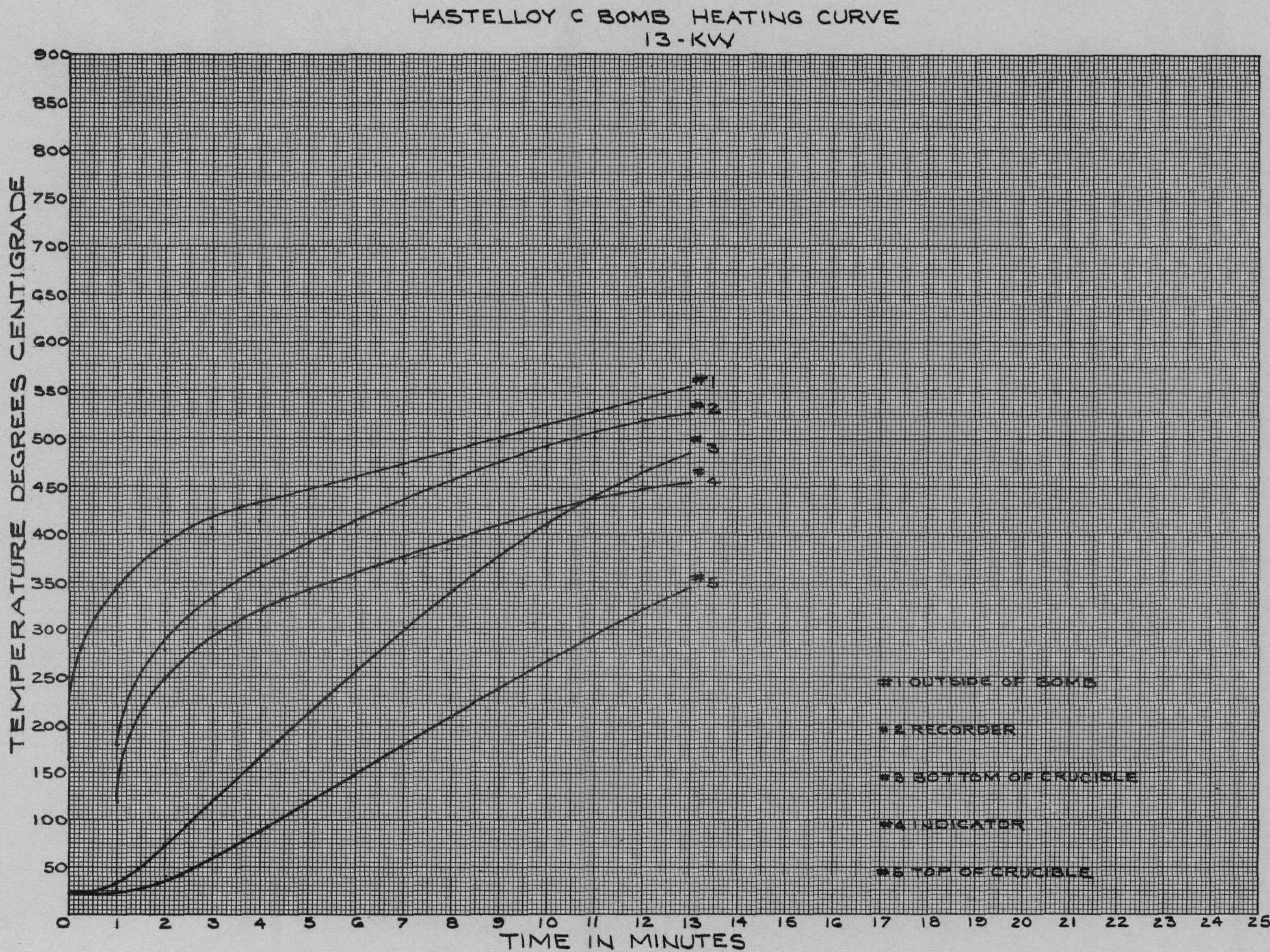

Fig. 76. Heating curve for Hastelloy C bomb. Ajax converter set at 13 KW.

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Table II

Typical Firing Data for Full Scale Plutonium Reduction

Charge - 300 grams Pu as PuF_4, 200 grams Pu turnings, Ca 144.6 grams, I_2 95.6 grams.

Bomb - 1020 Steel, chrome plated

Power input - 8 KW

Reduction yield - 99.6%

Times Minutes	Pressure p.s.i.g.	Hydraulic system pressure (p.s.i.g)
0	0	850
1	0	910
2	4	1040
3	6	1090
4	7	1140
5	10	1100
6	14	1100
7	17	1120
8	25	1110
9	30	1100
10	80	1100

GASKET REMOVER AND GROOVE CLEANER

When the bomb has been fired, cooled and returned to its carriage it still has the aluminum gasket in place in the rim groove. This must be removed before the contents of the bomb can be broken up and discharged. It is also necessary to have some facilities for insuring that the groove in the rim of the bomb is scrupulously clean before a gasket is set in place. Both of these functions; i.e., gasket removal after reduction and groove cleaning before reduction are provided at this station.

For gasket removal the bomb is raised on an air lift until the flange at the middle of the bomb strikes the rim of the brass tube (128 Figure 77). This places the top of the bomb even with the flat plate (131) with the gasket rising just above. The horizontal air cylinder on the right then extends the punch (118) which punches the gasket off the bomb to the left where it stops under the bag ring (2) and can be removed through the plastic bag.

When the gasket groove on the bomb is to be cleaned, the bomb is raised to the same position as for gasket removal. In this position it is under a stainless steel brush (127) which can be revolved by an electric motor (153) and pressed down in the groove by the air cylinder (102) and lever arrangement. There is a stationary circular copper tube (134) around the wire brush with small holes pointing toward the groove. This tube is connected to the compressed air supply so that while the groove is being scrubbed the air blast blows out any loosened

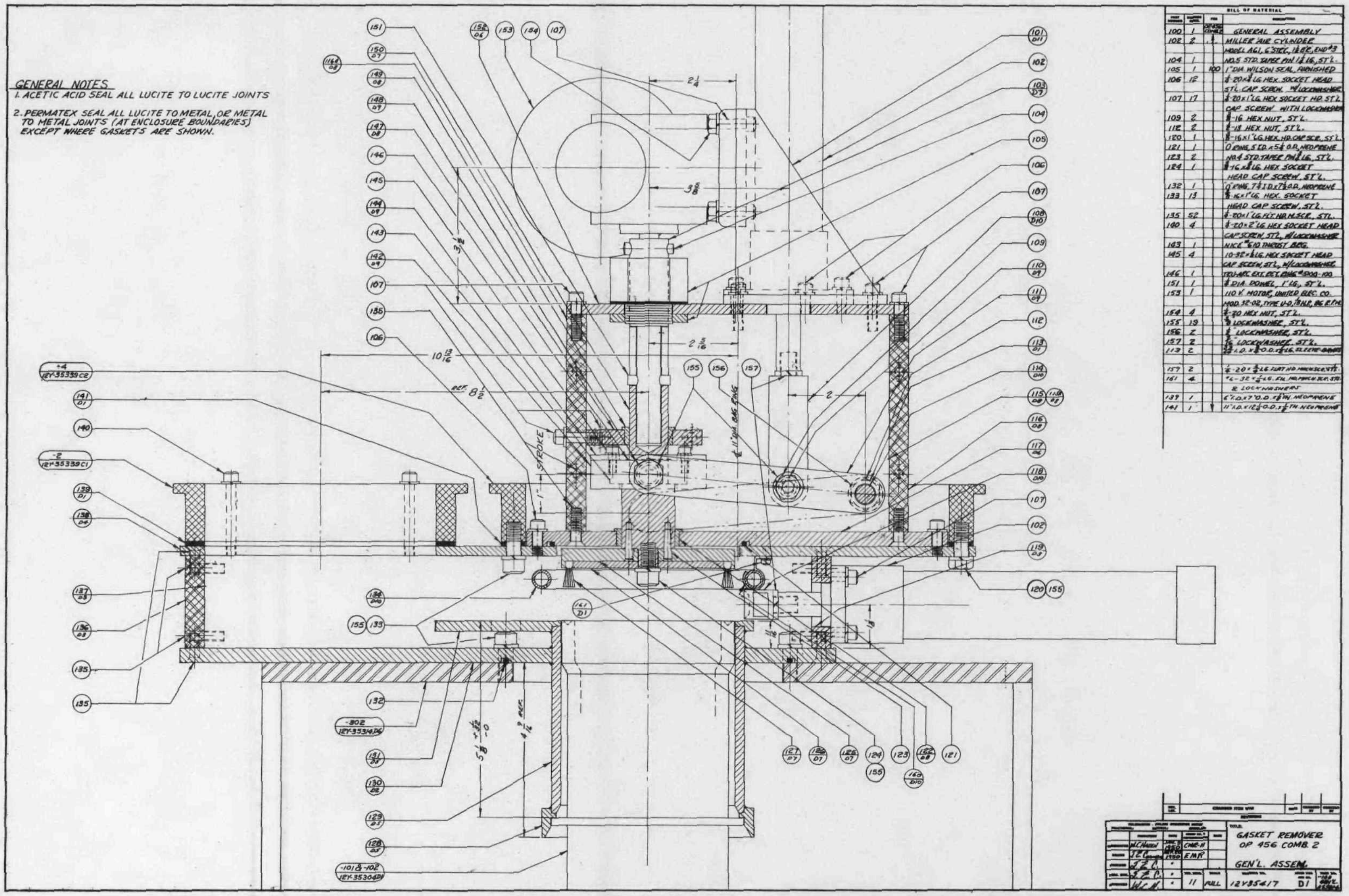

Fig. 77. Design layout of gasket remover and groove cleaner.

material.

The controls for this unit are standard and are shown in the photograph of the control panel Figure 78. The switch which energizes the wire brush driving motor also opens a solenoid on the air supply to the blowing ring.

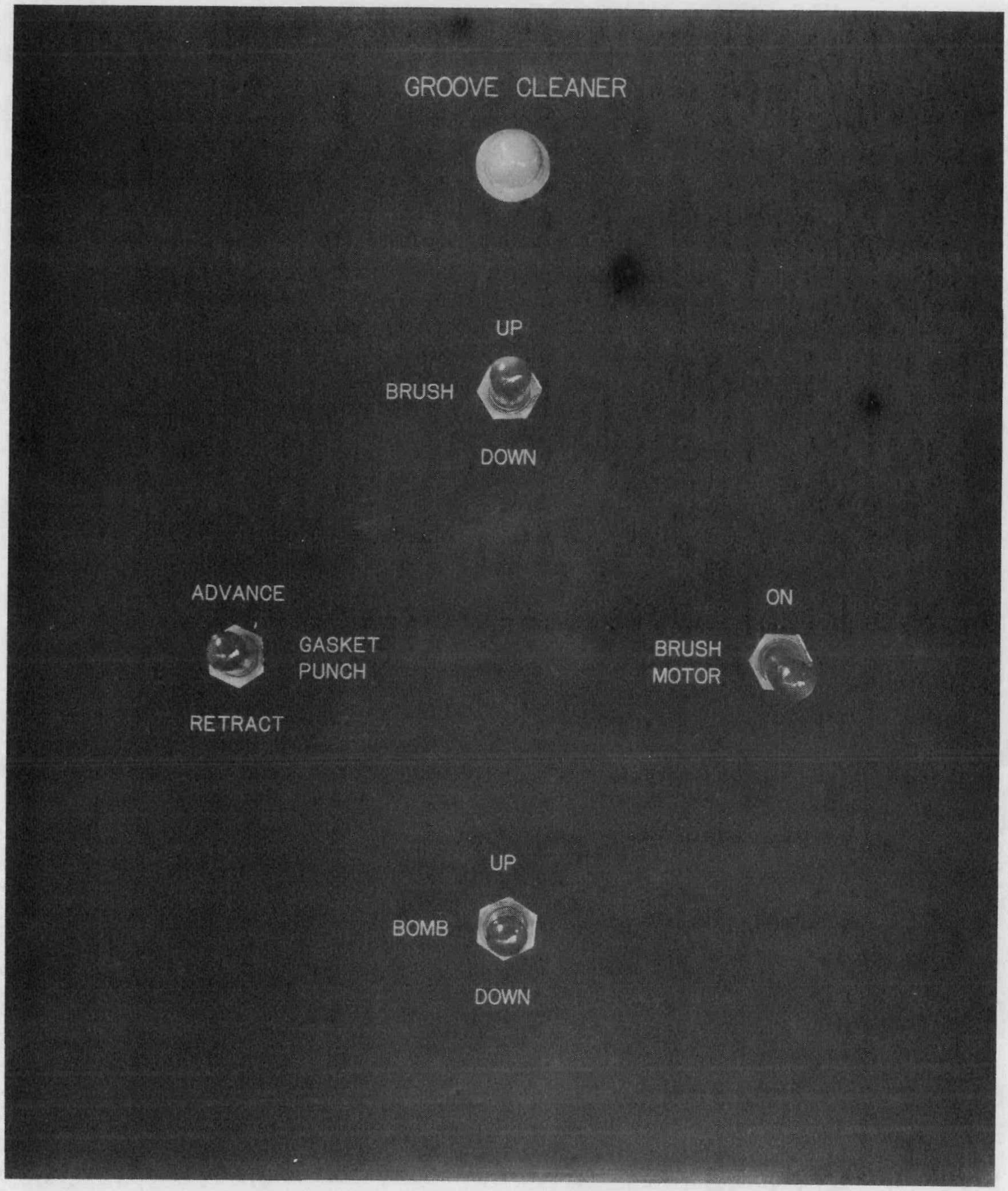

Fig. 78. Control panel for gasket remover-groove cleaner unit.

CUTTER

After the plutonium fluoride has been reduced to metal in the reduction step it sometimes happens that the MgO sand in the annular space between the crucible and bomb is packed so tightly that the contents of the bomb will not fall out when it is inverted by the bomb dumper. The purpose of the cutter is to loosen the bomb contents so that they will fall out at the dumper station.

To accomplish this the bomb is brought in its carriage to the cutter station after removal of the gasket and is raised by an air cylinder until the lip of the bomb seats against a neoprene gasket (118 Figure 79) in the bottom of the lucite housing (116). In this position the bomb is directly under five cast Hastelloy C daggers (115) set in a head (113) attached to the piston of a double ended air cylinder (104). An air vibrator is attached to the opposite end of the piston shaft which extends into Zone 3. By energizing the air cylinder and vibrator the cutter blades are driven down into the packed MgO sand Because of the ribs on the blades the crucible is broken inward as the blades descend. By raising and lowering the blades they can be driven far enough down to thoroughly loosen the bomb contents. The lucite housing and gasket arrangement prevent dust from spreading during this operation. After "cutting" is completed the bomb is lowered into its carriage and taken to the bomb dumper.

A photograph of this unit is shown in Figure 80, and a picture of

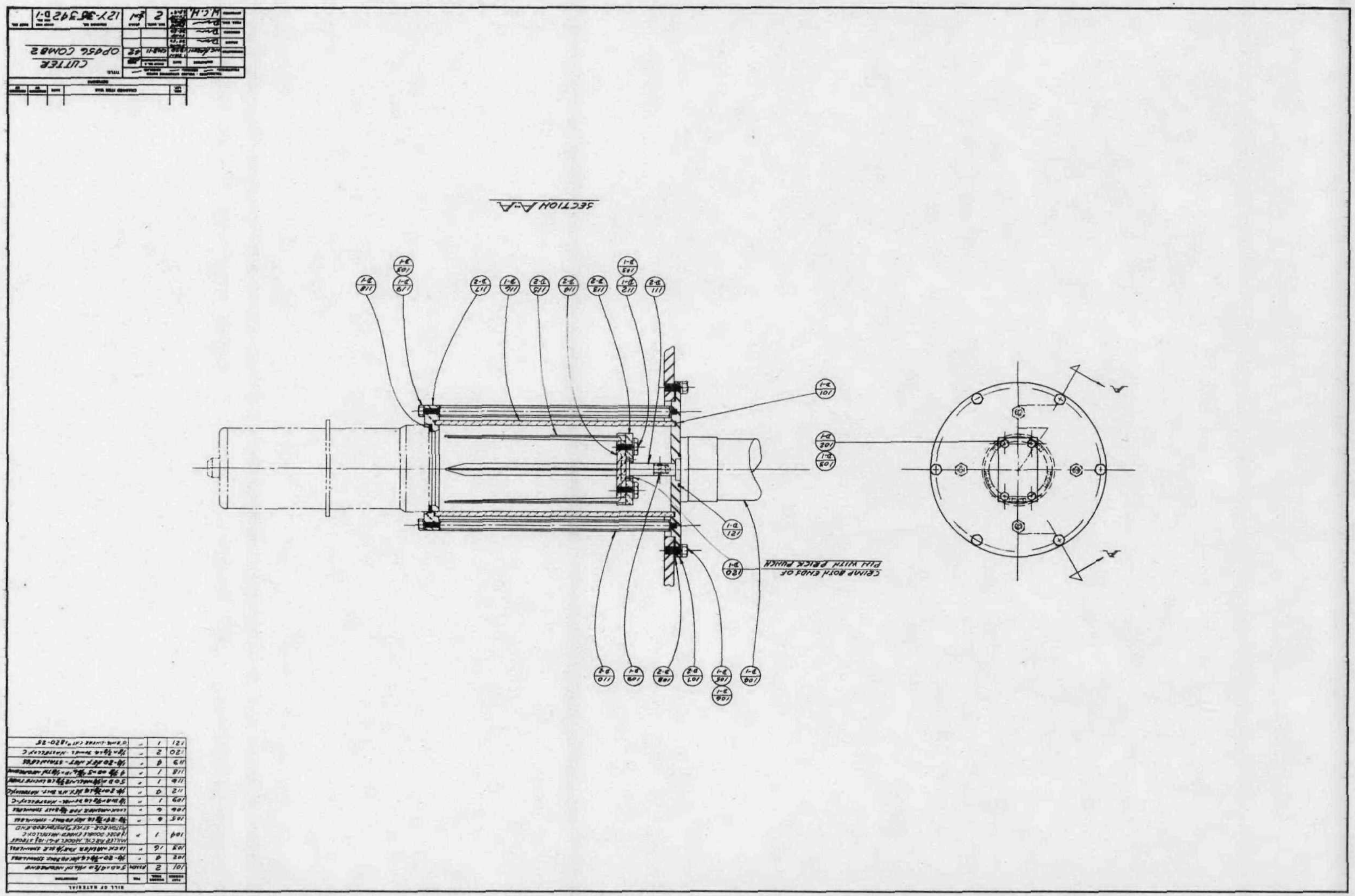

Fig. 79. Design layout of cutter.

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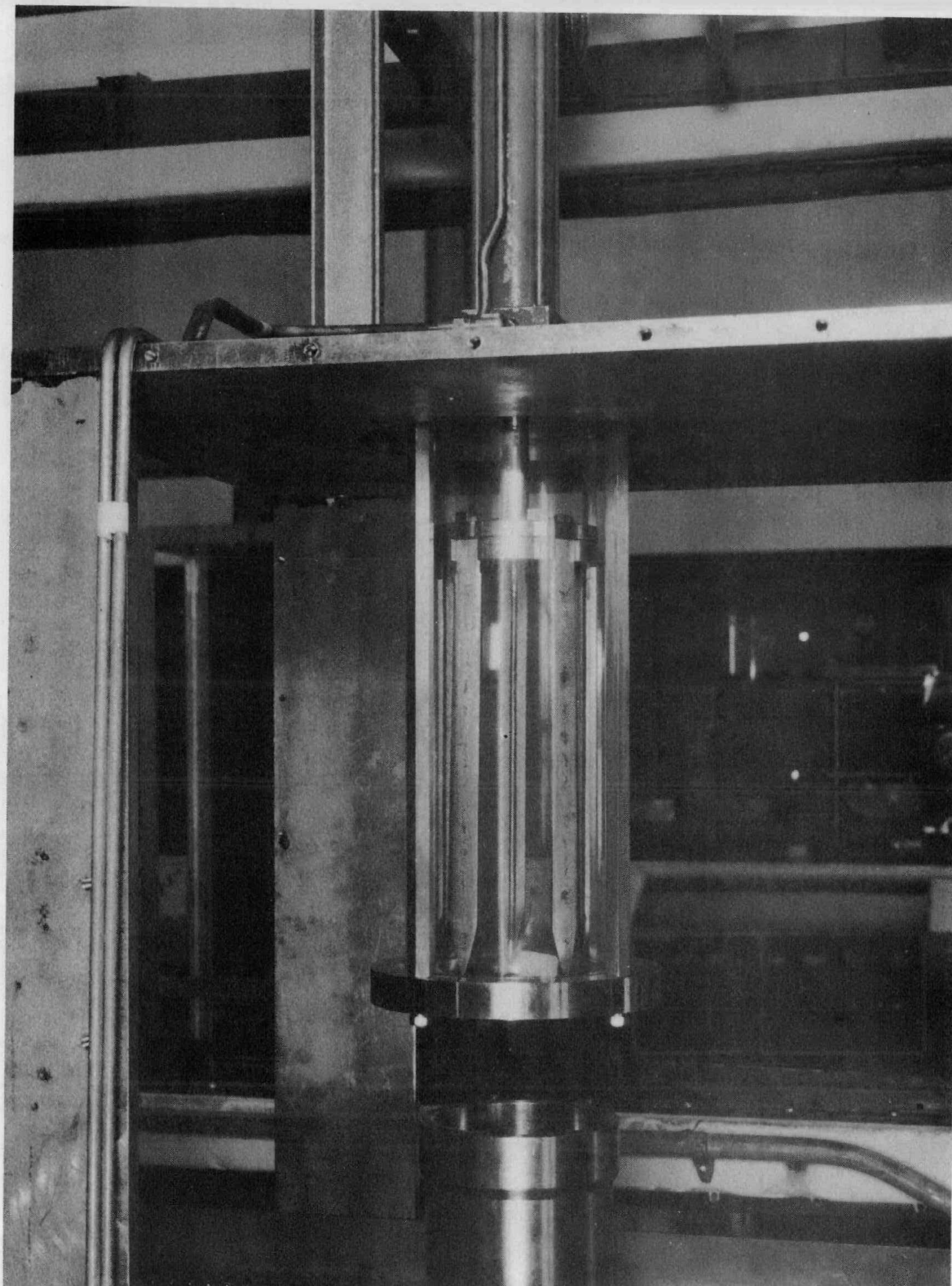

Fig. 80. Photograph of cutter taken during installation.

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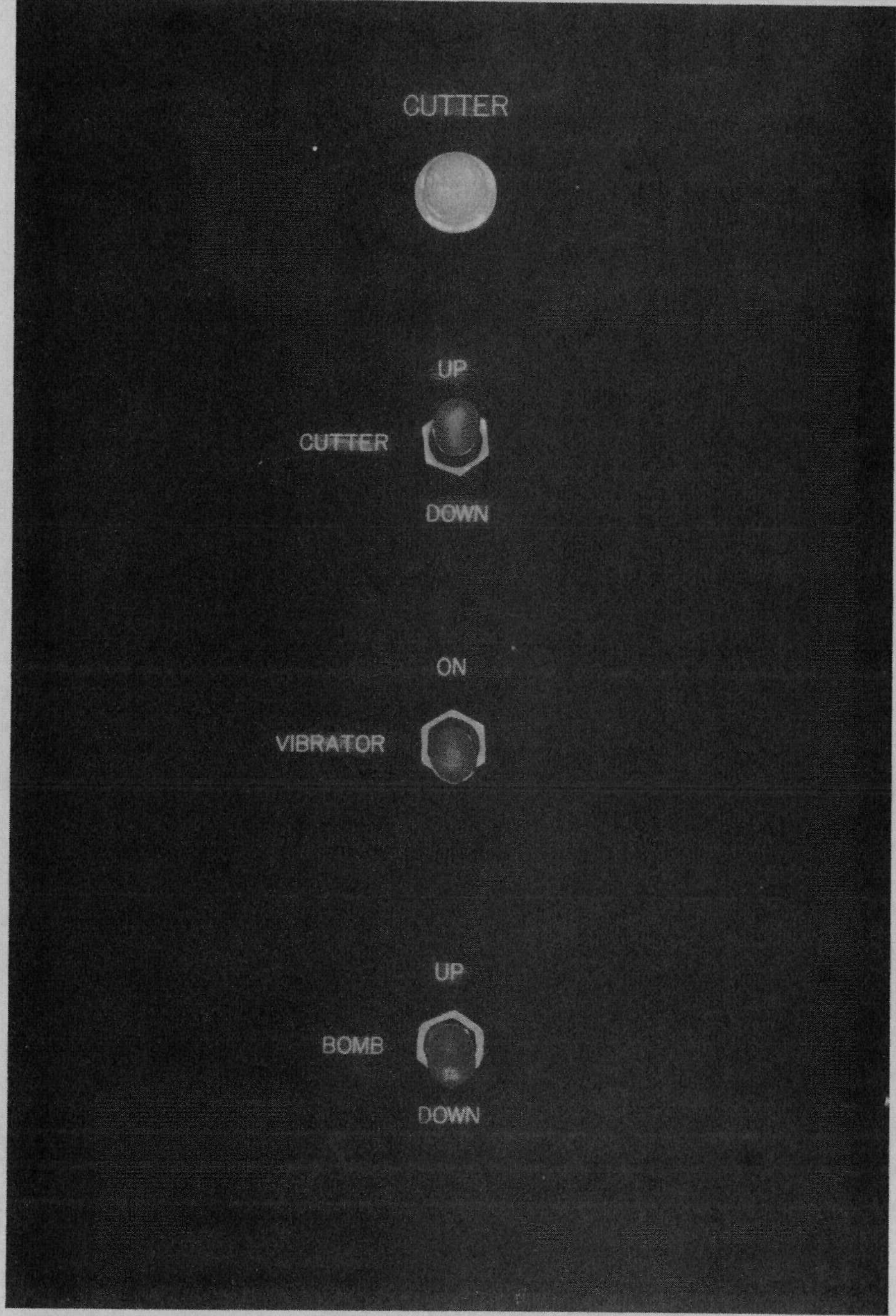

Fig. 81. Control panel for cutter unit.

the control panel in Figure 81.

BOMB DUMPER

Mechanical Design

When the contents of the bomb after reduction have been thoroughly loosened by use of the cutter it is ready to dump onto the separation table where the plutonium button can be separated from slag and crucible fragments and pickled in acid. The equipment for inverting the bomb is called the bomb dumper, layouts of which are shown in Figure 82 and Figure 83.

The dumper is mounted above the bomb carriage conveyor system in such a manner that the bomb is inverted at right angles to the track. In operation the bomb is brought to the dumping station and raised vertically by an air cylinder until the bomb lip seats on the neoprene gasket (56) under the dumper trap door (42) which is held closed by torsion springs (15 Figure 83). A U shaped gate (61 Figure 83) then slides into position under the flange on the bomb by actuation of the small air cylinder (11 Figure 83). The air lift which raised the bomb is then lowered leaving the bomb in the dumper. The four compression springs (27 Figure 82) hold the dumper head and gasket firmly against the bomb lip.

By means of an air cylinder and rack-gear assembly attached to the main shaft (32 Figure 82) the entire dumper assembly is turned through a 180° arc until it comes to rest on the gasketing material around the rim of a chute. The trap door, made of Hastelloy C, prevents material

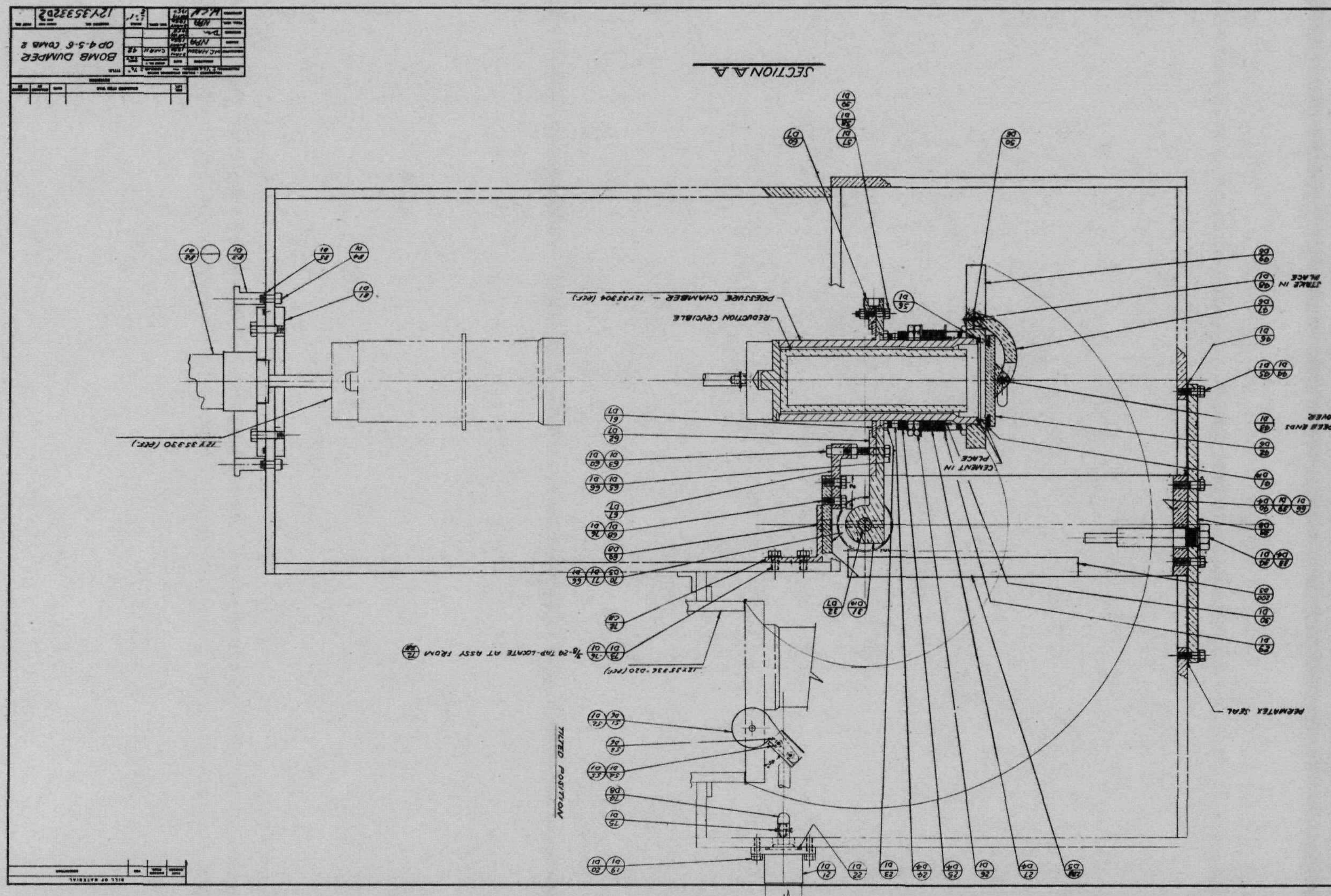

Fig. 82. Side elevation of bomb dumper.

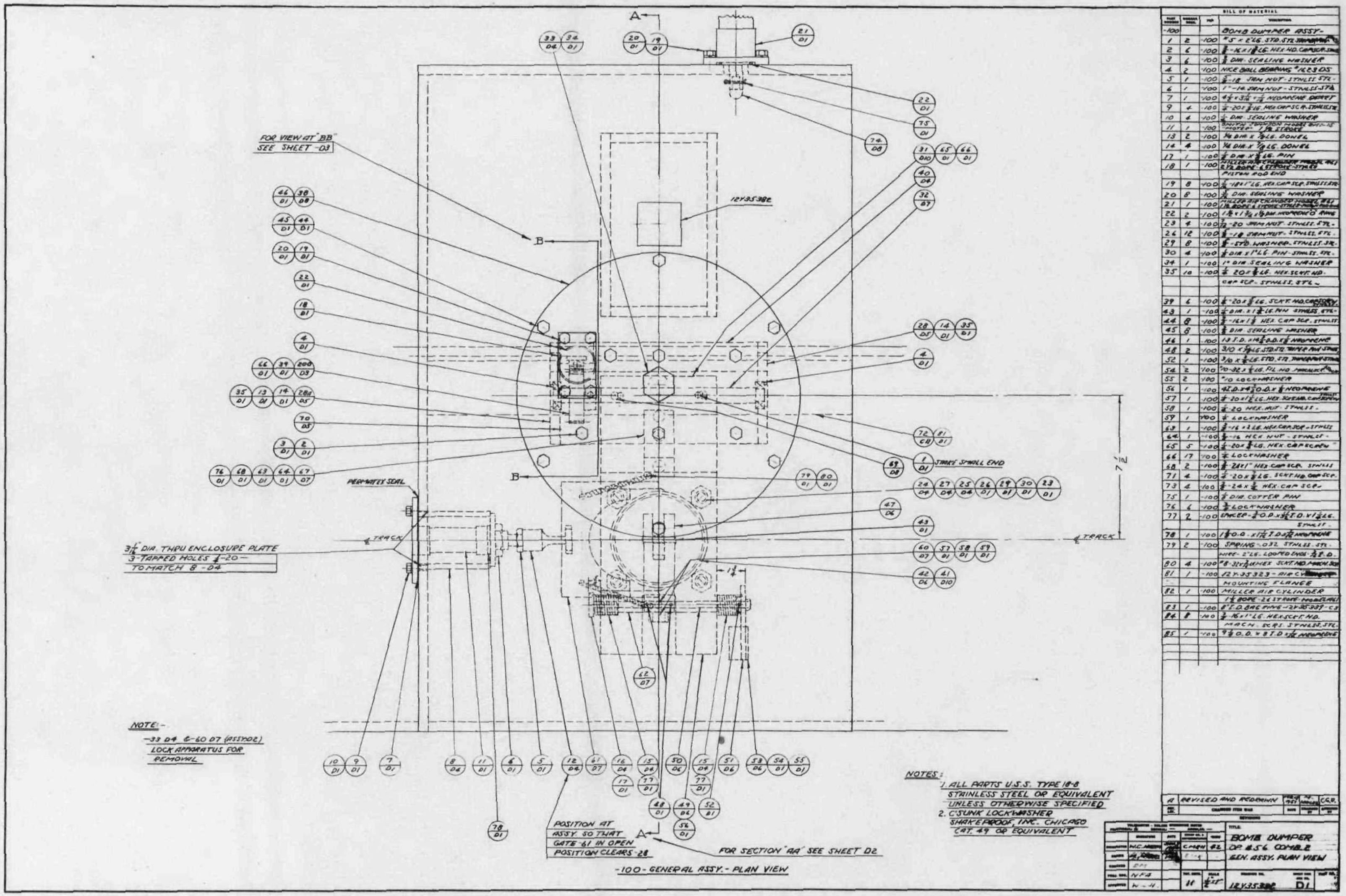

Fig. 83. Plan view of bomb dumper.

[redacted]

from falling out during this inverting operation. When the dumper is in place over the chute, the trap door is opened by pushing the lever arm (53) with the adaptor (74) mounted on the shaft of a small air cylinder (21 Figure 82). When the trap door is snapped open its pivot center is far enough to one side so that the contents of the bomb do not strike it on the way down the chute.

Although it is not shown on the drawing, a double ended air cylinder with an air hammer on the upper end is mounted over the chute in such manner that after the trap door has been opened the air cylinder shaft can be extended until it strikes the bottom of the upended bomb. The vibrator is then turned on to assist in shaking loose the contents. The cylinder is then retracted and the trap door snapped shut. The dumper assembly is returned to position over the track and the bomb lowered back into its carriage by reversing the procedure for putting the bomb in the dumper.

The bomb dumper assembly is suspended from a stainless steel flange plate (38) by the hangers (28). It is so designed that by rotating it into a vertical position and locking it with a plug in the adaptor (60 Figure 82) the entire assembly can be lifted out through the hole over which the cover plate is seated. The photograph (Figure 84) shows the assembly in this removal position. In the photograph the trap door has been blocked partially open to illustrate its operation.

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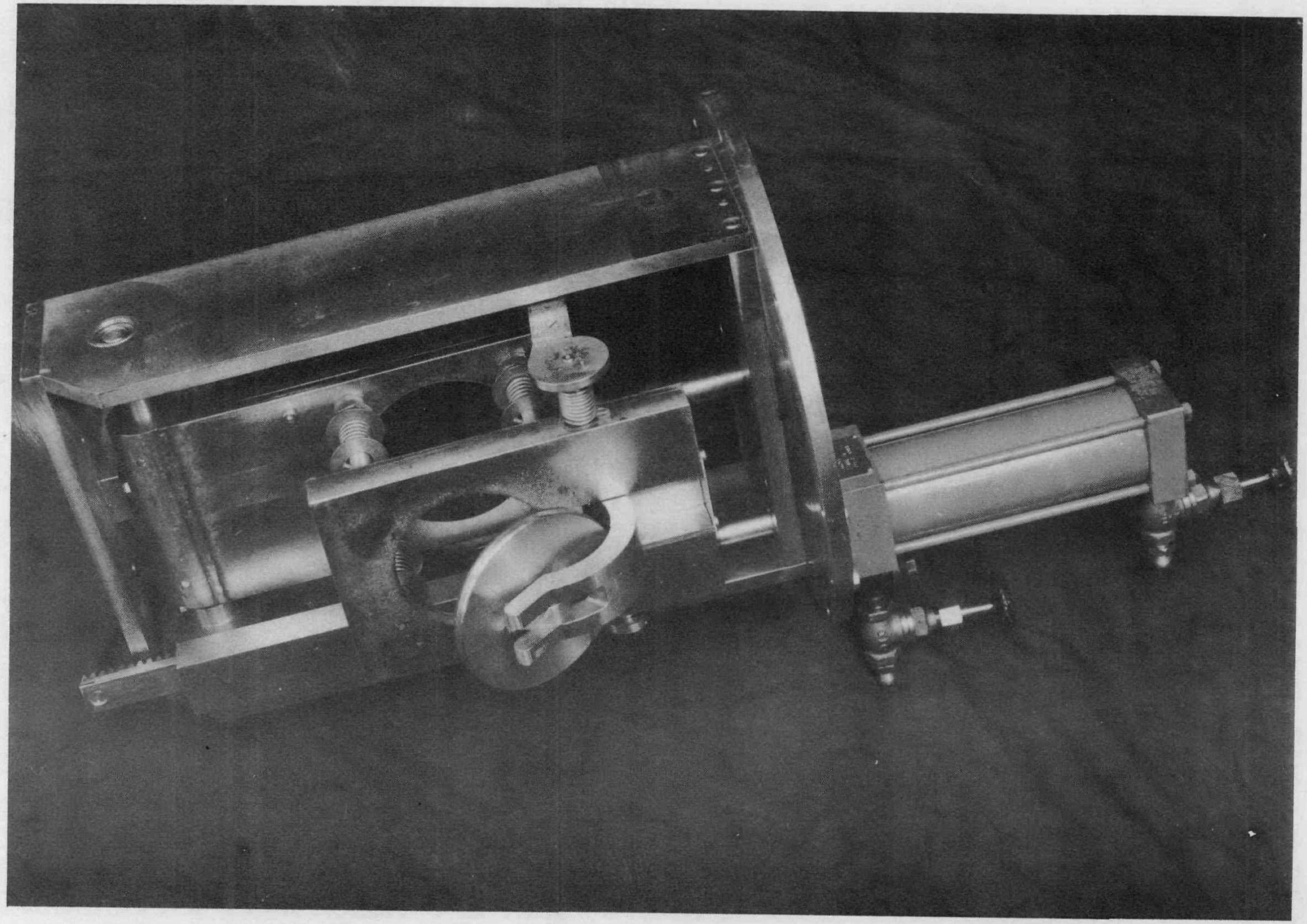

Fig. 84. Photograph of bomb dumper before installation showing trap-door lid blocked open.

Controls

A sequence switch and momentary contact button are used to control this unit. A photograph of the control panel is shown in Figure 85.

There is an interlock in the circuit controlling the sliding gate which locks the bomb in the dumper. This interlock is actuated by a pressure switch in the air line leading to the cylinder that raises the bomb to the dumper. When this cylinder lifts the bomb the air pressure in the cylinder does not rise to full line pressure until the bomb is seated in place and has raised the compression springs on the dumper head. When the air pressure builds up to full value it actuates a microswitch in series with the bomb lock control.

This prevents operation of the bomb lock unless the bomb lifting cylinder head is in the proper position.

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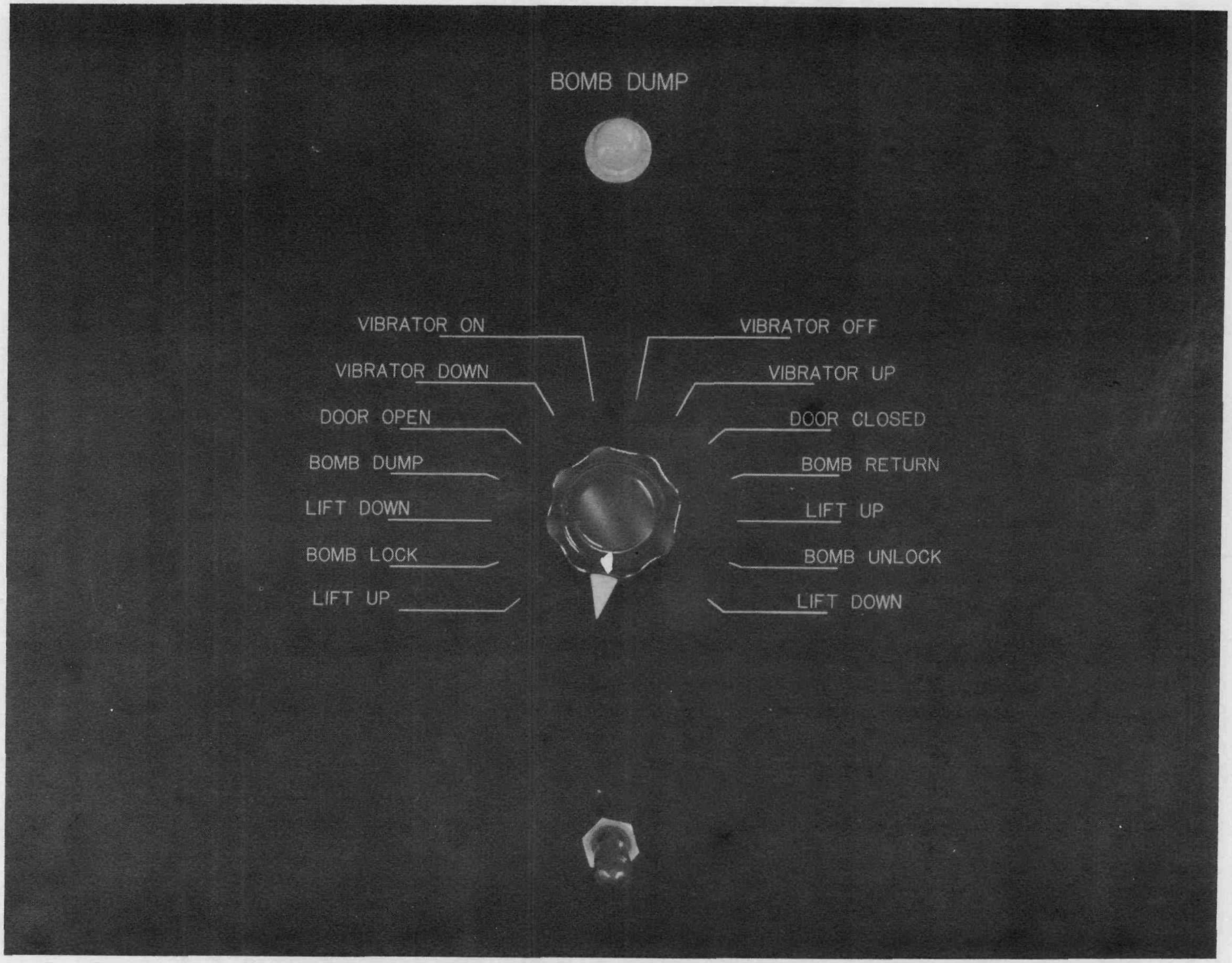

Fig. 85. Control panel for bomb dumper unit.

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SEPARATION TABLE AND BUTTON PICKLER

After the reduction operation has been performed the contents of the bomb are broken up at the cutting station and dumped down a chute onto the separation table where the button is separated from the slag and crucible fragments. After separation, the button is pickled, washed, dried and pushed out of the assembly down a chute into a plastic bag for removal from the equipment.

Figure 86 is a sketch of the dumper chute assembly through which the bomb contents drop down onto the separation table. The sketch shows this chute made of stainless steel. Testwork during installation demonstrated that a thick cake rapidly built up on this chute because of iodine and/or iodides clinging to the metal surface, absorbing water from the air thereby causing the next batch to stick even more. There was also evidence of considerable chemical attack of the stainless steel. To overcome these defects the stainless chute was completely lined with 1/8" Saran rubber, and 1/8" thick Hastelloy C plates were fastened on top of the Saran Rubber at those places where the material strikes the chute during its passage to the separating table. These changes were made during installation and are not shown in the drawing.

The mixture of slag, crucible, sand and button falls onto the separation table assembly a cross section of which is shown in Figure 87. The table is a circular Dural plate 18" in diameter with a 1/8" thick Hastelloy C plate bolted to the top surface. This circular table

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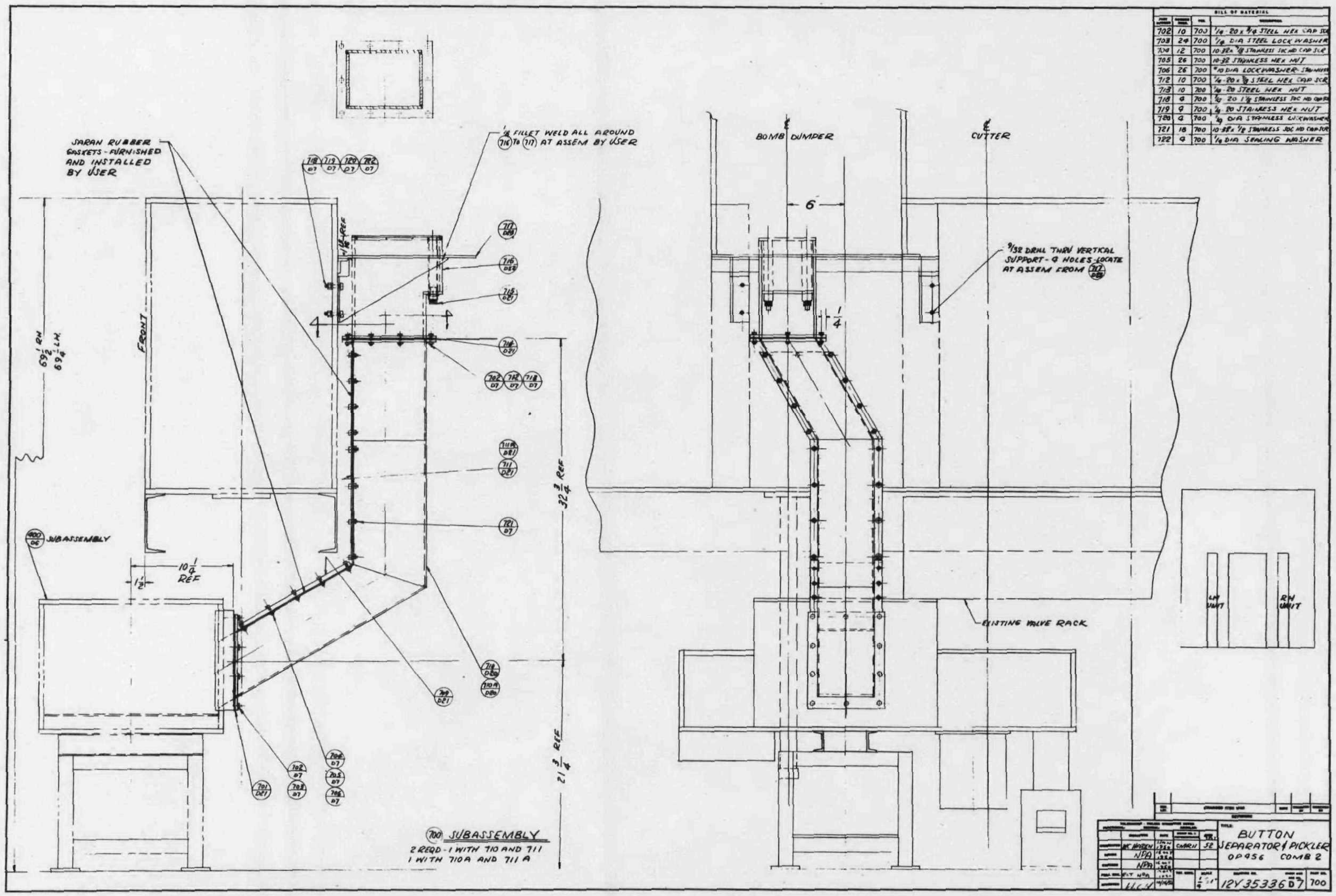

Fig. 86. Design layout of bomb dumper chute.

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SECRET

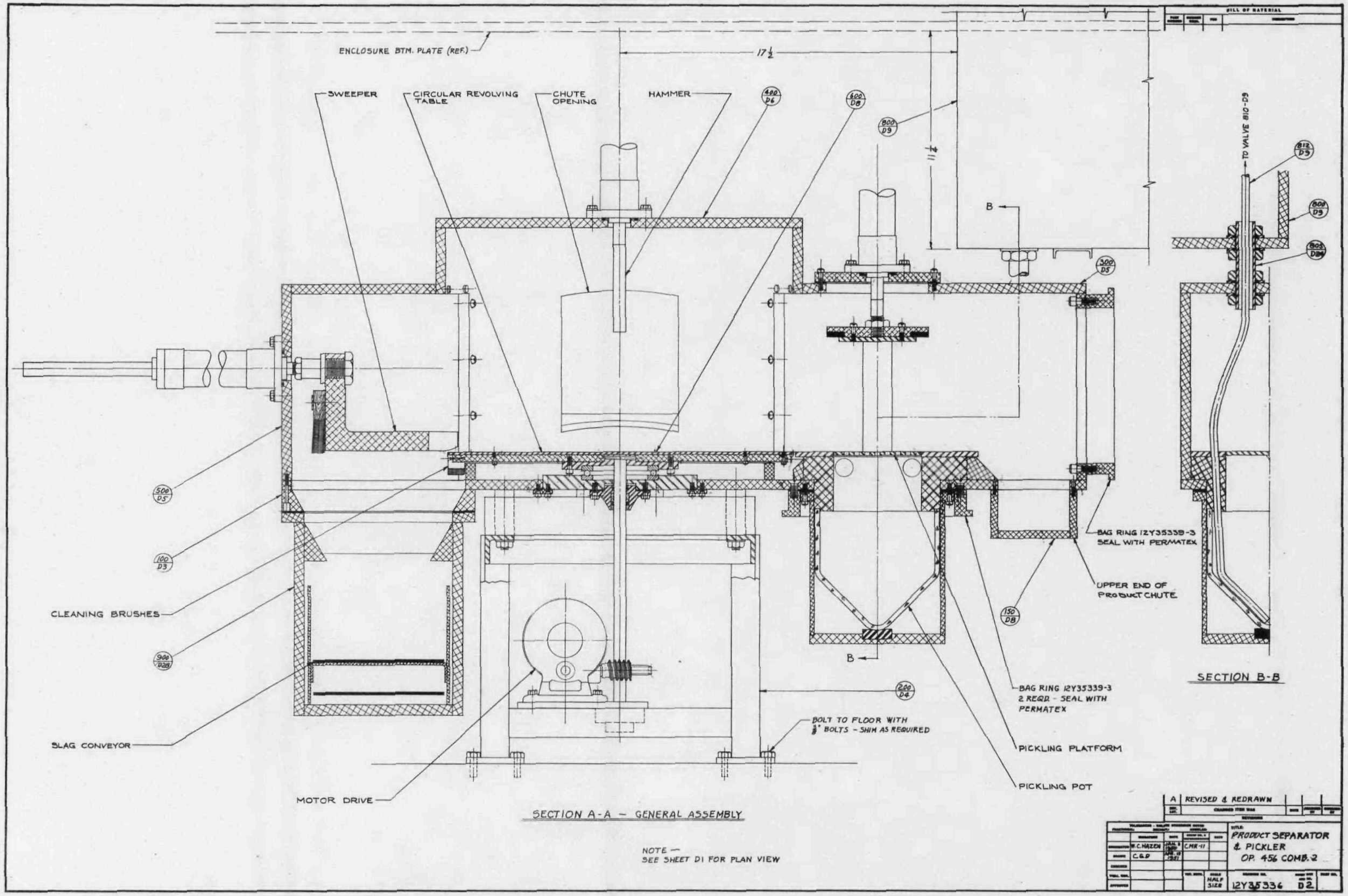

Fig. 87. Design layout of separation table and button pickler.

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is mounted on the end of a shaft which extends downward through a grease sealed thrust bearing to a worm gear driven by a reversible electric motor. The gearing is such that the table can be rotated at 3 RPM in either direction.

A "sweeper"head made of Dural is mounted on an air cylinder at one side of the table. When the reduction bomb contents are dumped onto the table the combination of table rotation plus sweeper movement permits the control room operator to drag the crucible fragments, slag and sand off to one edge of the table where they drop onto a conveyor leaving the button on the table. (This conveyor was found to be unsatisfactory in operation and was replaced by a steel bucket in a plastic bag into which the slag and crucible drop directly).

In case some fragments of crucible adhere to the button a drop hammer situated directly over the center of the table, can be used to knock them loose.

When the button has been cleaned and is separated from the residue it is pushed by the sweeper off the table and onto the perforated plate of the pickler. This plate is then lowered into the pyrex pickling tank. The gasket above this perforated plate assembly effectively seals the pot from the rest of the unit to avoid chemical attack by the corrosive fumes formed during pickling. When the button is in place, nitric acid (1:1) is run from a burette into the pickling tank until the button is well covered. When the pickling is completed as evidenced by cessation of bubbling (5-20 minutes) the nitric acid is sucked back into the burette and the tank filled with water to wash off the acid. The water is sucked out and iso-propyl alcohol is introduced to remove water, after which the button is raised on the plate back up to table level where it can be pushed off the edge by the sweeper into the button chute.

The pickling tank has separate ventilation connections so that during pickling a small current of air is pulled over the top of the liquid and out through a caustic trap.

The control panels for this operation are shown in Figure 88.

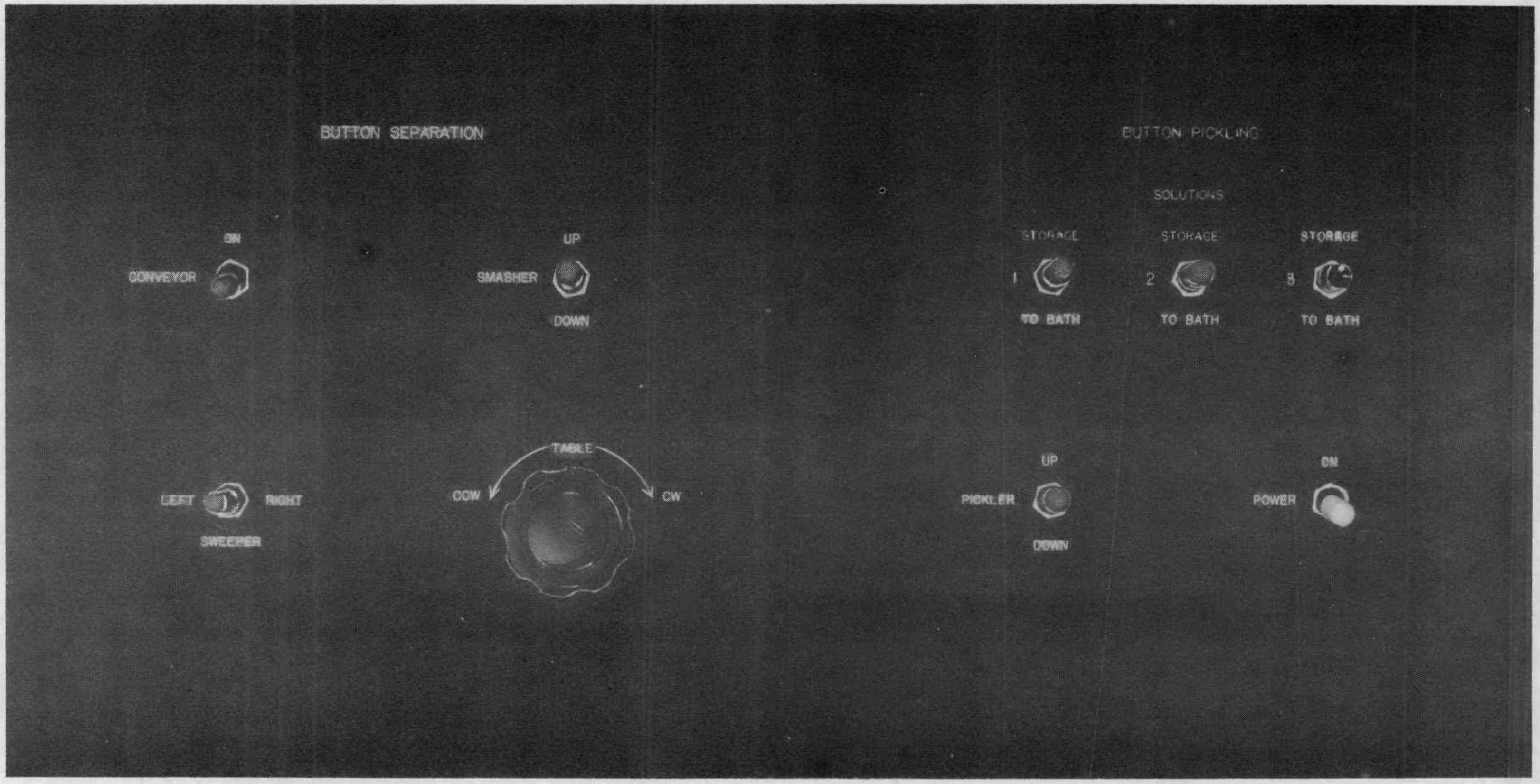

Fig. 88. Control panels for separation table and button pickler.

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DUMMY BOMB

It is necessary that the inside of the lid of the reduction furnace be cleaned regularly to remove any material that may condense or splatter there during reduction and to be sure that the gasket groove is clean and smooth.

To perform this cleaning the operator uses what is called the Dummy Bomb. This is merely a stainless steel brush attached to an electric motor enclosed in a cylindrical brass casing of the same critical dimensions and general shape as the reduction bomb. This motorized brush is stored in a rack when not in use. At the time the reduction bomb is in the bomb dumper the empty carriage is brought by the conveyor into position under the dummy bomb station, a layout of which is given in Figure 89. An air lift raises the dummy bomb slightly from its holding fork which is then withdrawn by the small air cylinder (11). The dummy bomb is lowered into the carriage and conveyed to the reduction furnace. At the furnace station the bomb is lifted by the hydraulic cylinder until the rim of the casing strikes the Hastelloy furnace lid. Figure 90 is a cross section of the dummy bomb in position in the furnace. In this position the wire brush is in contact with the inner surface of the lid. There are two contact arms on the side of the casing (212) which make electrical contact with a split ring on the lift head. Flexible cable carries the current to the lift head from fixed connections in the wall of the enclosure.

By switching on the electric current to the brush motor the

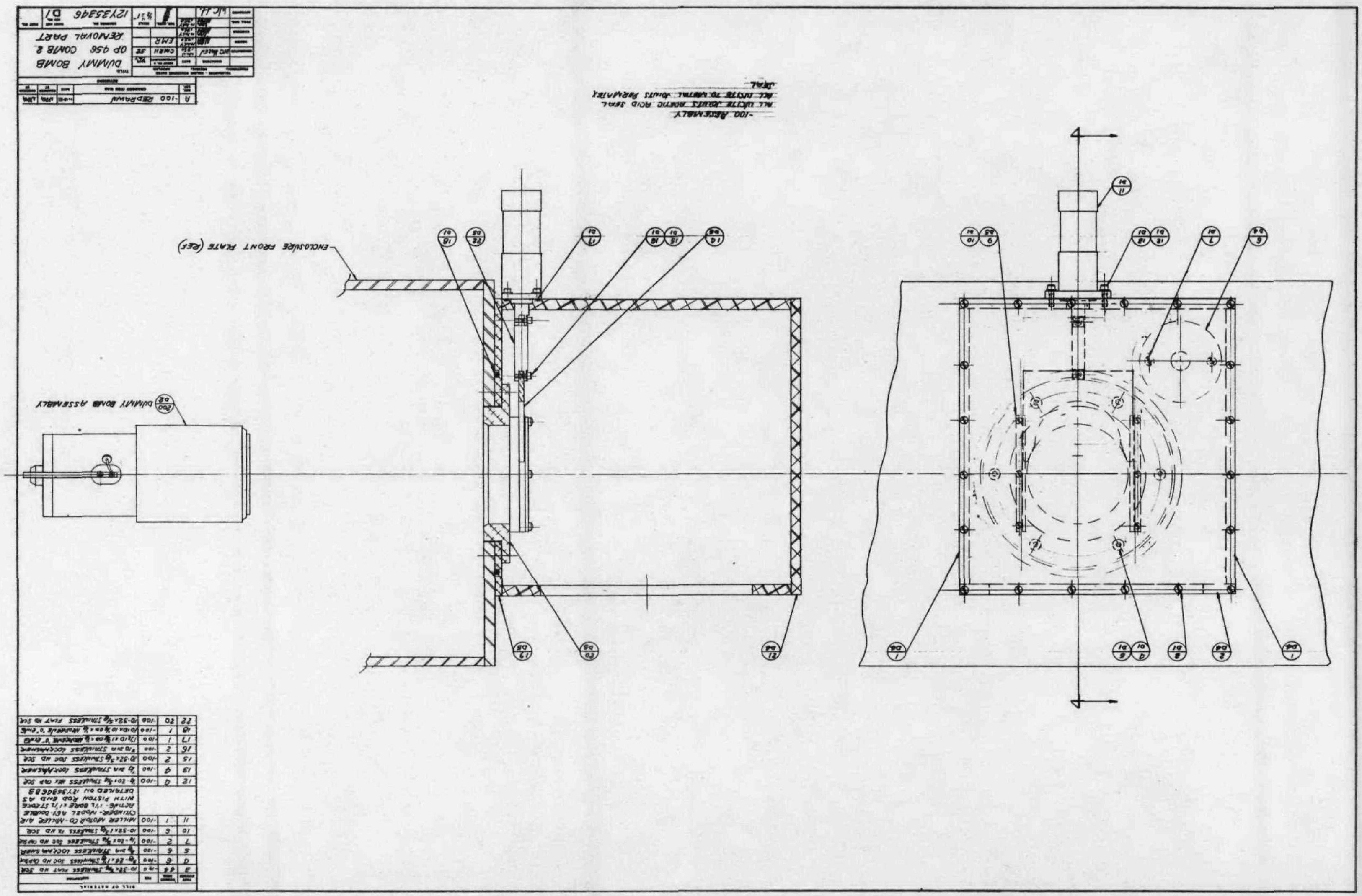

Fig. 89. Design layout of dummy bomb storage rack.

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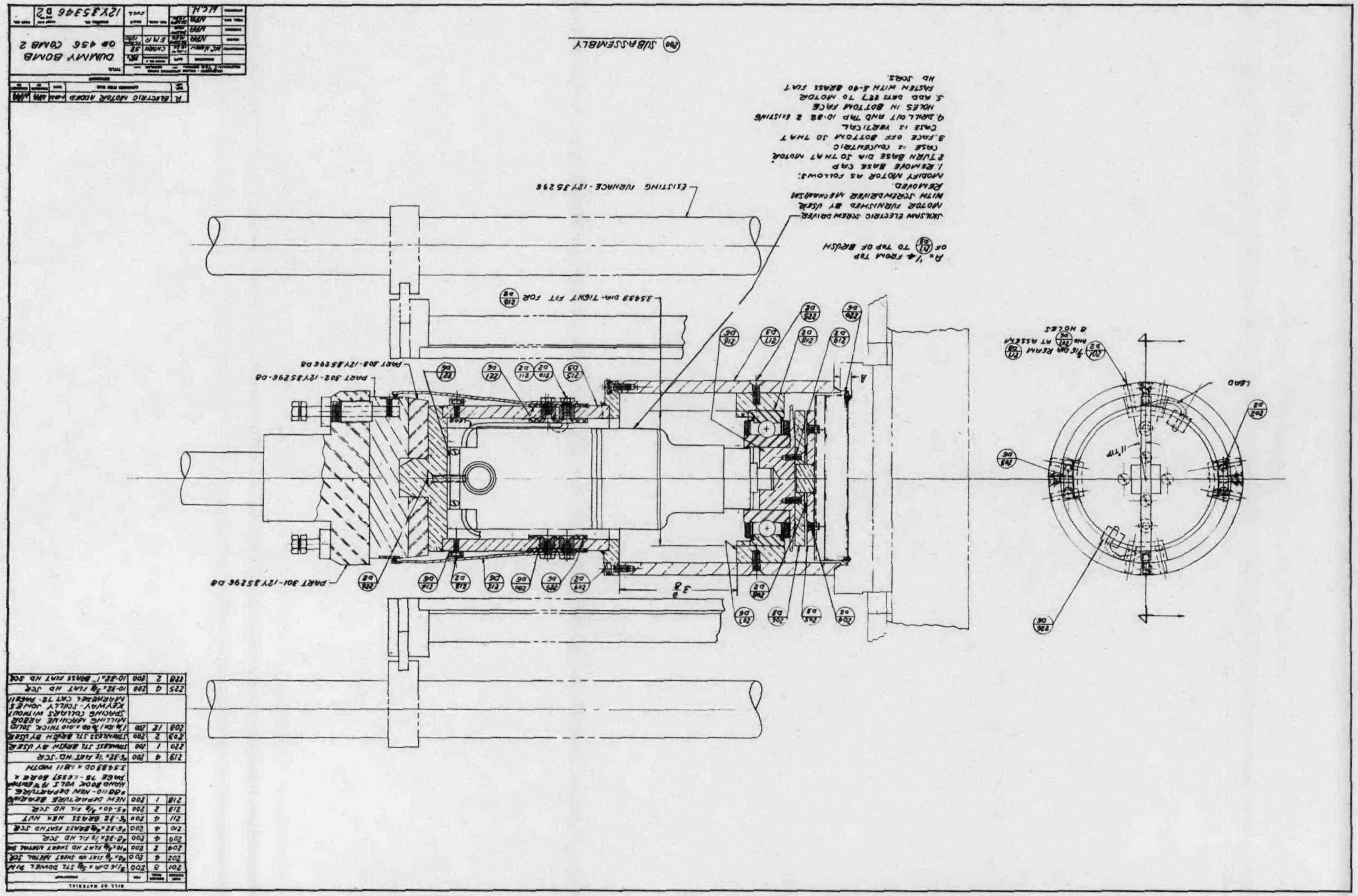

Fig. 90. Design layout of dummy bomb in position for scouring reduction furnace lid.

Hastelloy lid is thoroughly brushed. Any material scrubbed from the head drops into a space under the brush. This is cleaned out at the end of each accountability period.

The motor driving the brush was adapted from a "Skildriver" electric screwdriver and rotates the brush at 1000 RPM unloaded.

The wire brush is shaped to the contour of the lid to insure good brushing in the gasket groove.

Controls

The controls for the storage of the dummy bomb are shown in the photograph of the control panel (Figure 91). The locking switch is connected through a relay energized by the bomb lift to the locking cylinder valve. In this way the dummy bomb cannot be unlocked unless the lift has first been raised in position.

The controls for the operation of the reduction furnace lid scrubbing are part of the reduction furnace panel shown in the section titled "Reduction Furnace". On this panel are mounted a switch to operate the scrubber motor and an ammeter in the motor lead circuit. Since the operator cannot see the operation he watches the amperage fluctuation to see that the motor is operating satisfactorily.

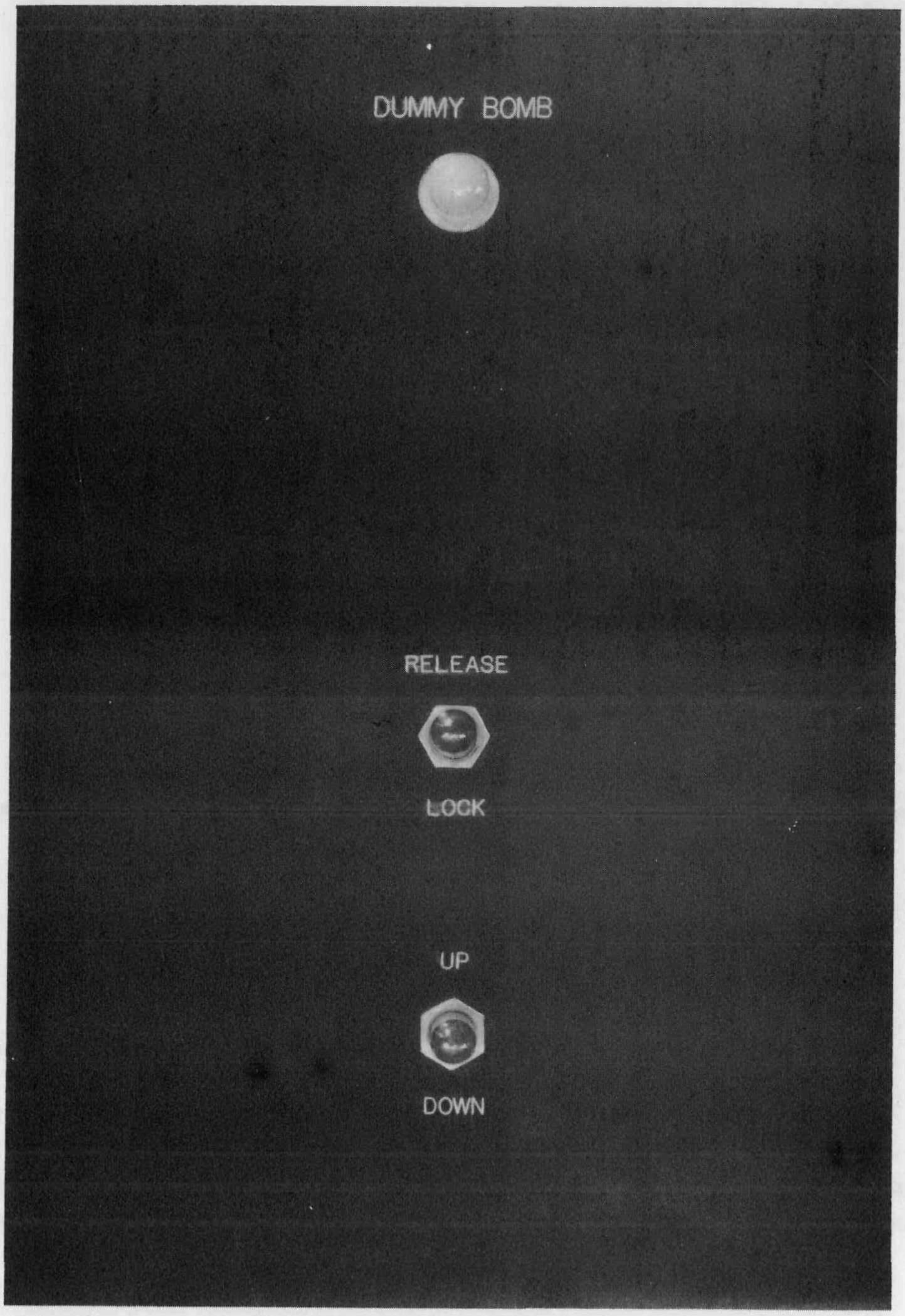

Fig. 91. Control panel for dummy bomb storage rack.

BOMB SCRUBBER

From experience with reduction operations it has been found that on the inside wall of the bomb a thin coating of hygroscopic material will accumulate that picks up moisture and interferes with subsequent reductions. It is therefore necessary to have some method of cleaning the inside of the bomb at intervals. The equipment for doing this is called the bomb scrubber.

The principle of operation is that water is flushed through the bomb while a neoprene disc is raised and lowered to scrub the walls. The bomb is then warmed to dry it thoroughly before returning it for reduction.

The equipment is divided into two parts; (1) the scrubber (2) the water wash and filtering system.

A layout of the scrubber is presented in Figure 92. Referring to this layout, the bomb is raised until it seats against the neoprene gasket (111). In this position it is under a neoprene disc held in a Hastelloy C head which in turn is attached to a hollow Hastelloy C tube (200). This tube extends up through an O ring seal inside a lucite cylinder (300) and is attached to the shaft of an air cylinder (105). The piston rod of this air cylinder is also made of Hastelloy C which was used because of its corrosion resistance.

There is a small hole in the upper end of the hollow Hastelloy shaft inside the lucite cylinder. This entire assembly is flange mounted (108) on top of the main enclosure with the head (109)

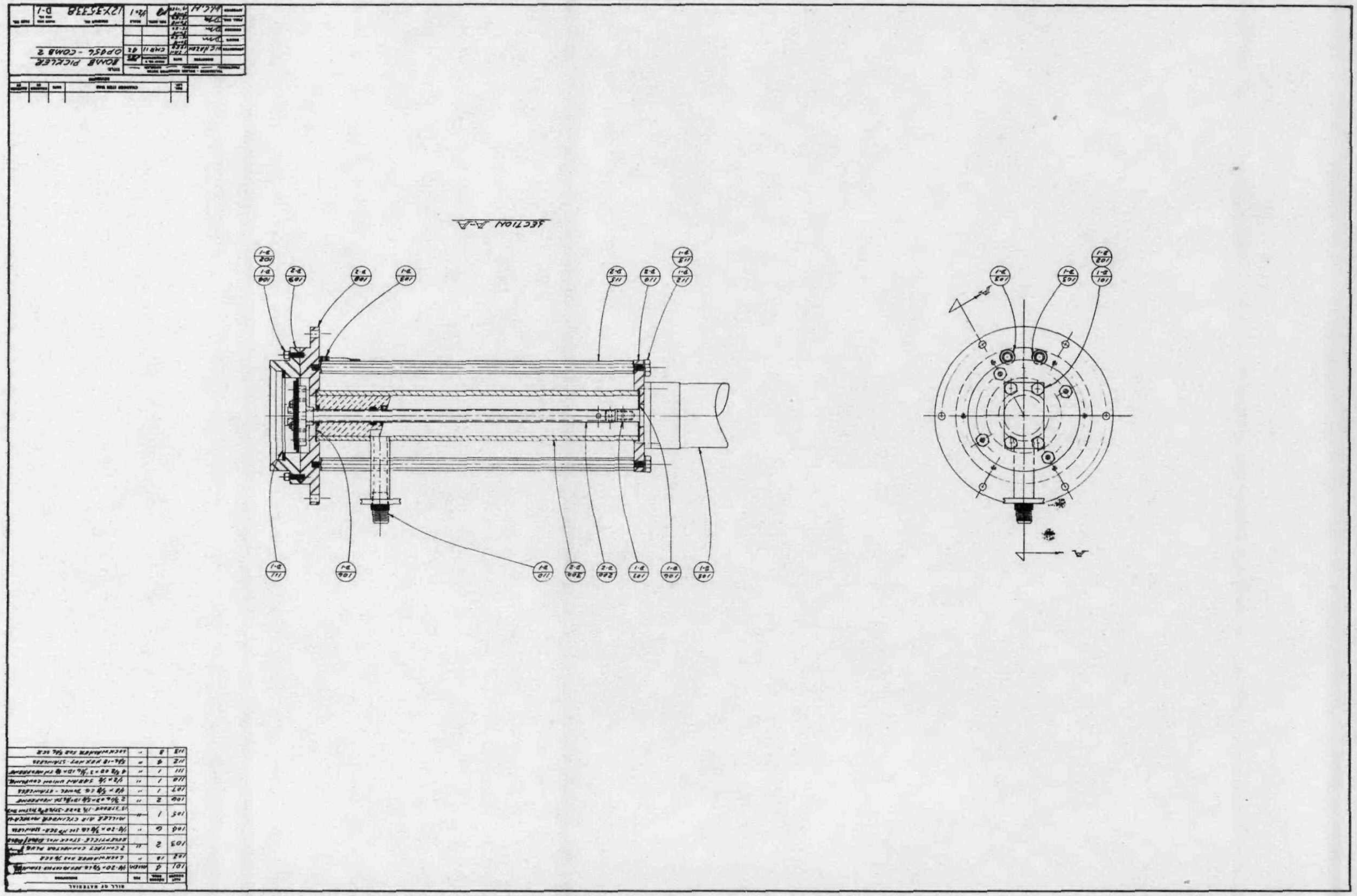

Fig. 92. Design layout of bomb scrubber.

extending inside the unit. A threaded hole (not shown) in the flange plate is piped to the water reservoir so that the scrubbing water can be introduced into the bomb.

When the bomb is in position a vacuum is pulled on the lucite cylinder through the saran connection (110) which in turn causes a vacuum in the bomb and pulls in the wash water from a reservoir described below. By actuating the air cylinder on the scrubber the neoprene disc is alternately raised and lowered in the bomb thereby scrubbing the walls. The wash solution plus solids scrubbed from the bomb are sucked up the hollow scrubber shaft, into the lucite cylinder and out the saran connection. When the reservoir is emptied the scrubber is left down at the bottom of the bomb with the vacuum on. There is a strip heater clamped to the scrubber head. By turning on this heater the bomb is warmed and the water vapor pulled out through the vacuum system.

The second part of this system consists of the filter reservoir unit. Three views of this unit are given in Figures 93, 94 and 95. It consists of an upper filter reservoir system containing a lucite cup with a glass cloth filter bottom connected by a Saran valve to a lower reservoir. In Figure 93 the saran fitting (145) is connected by saran tubing to the connection on the lucite tube of the scrubber. The line from the bottom reservoir connects to the scrubber hole leading to the inside of the bomb. A vacuum line is connected to the space directly under the glass cloth filter in its cup. With the Saran valve closed,

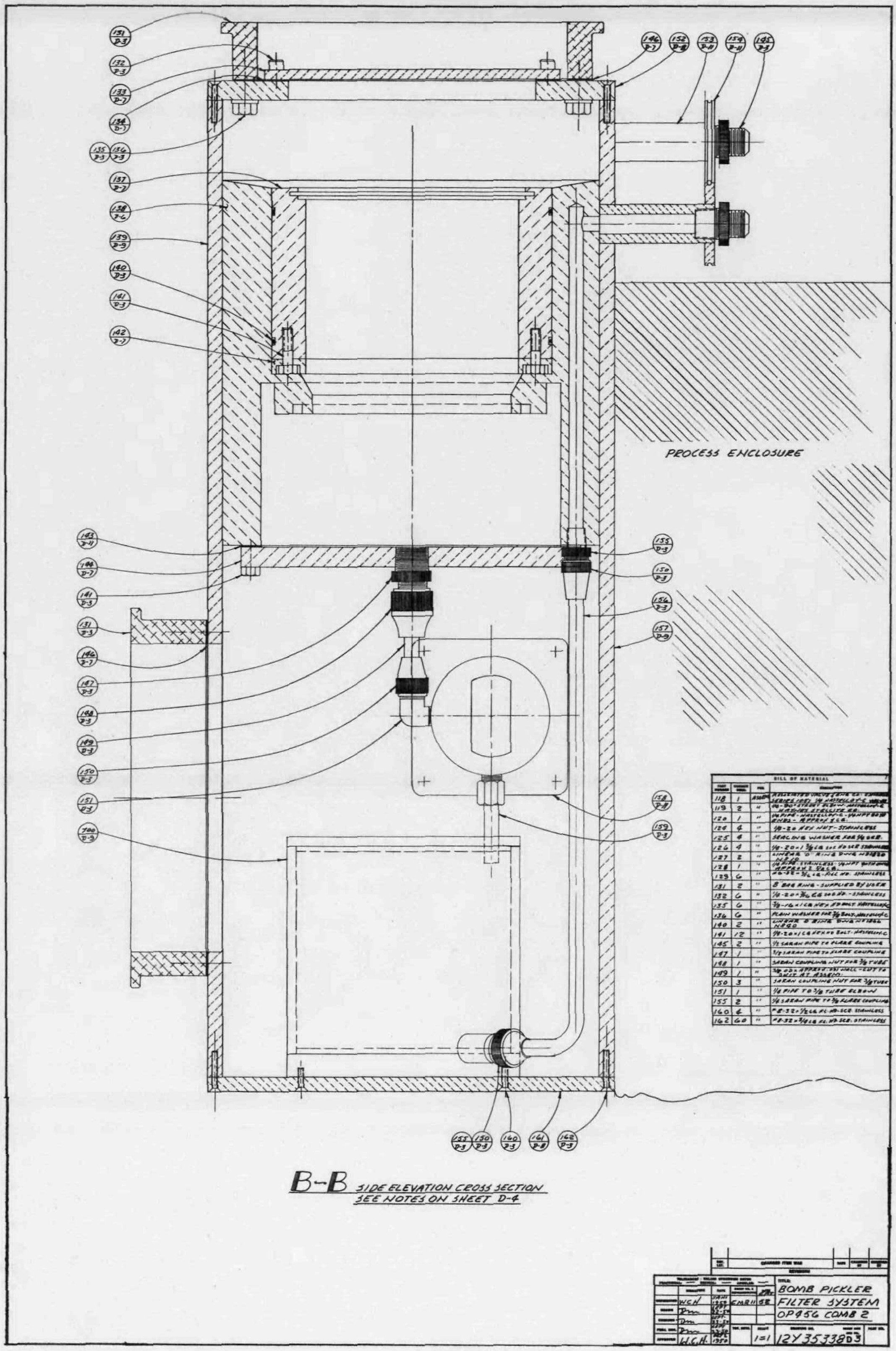

Fig. 93. Side elevation of filter-reservoir for bomb scrubber.

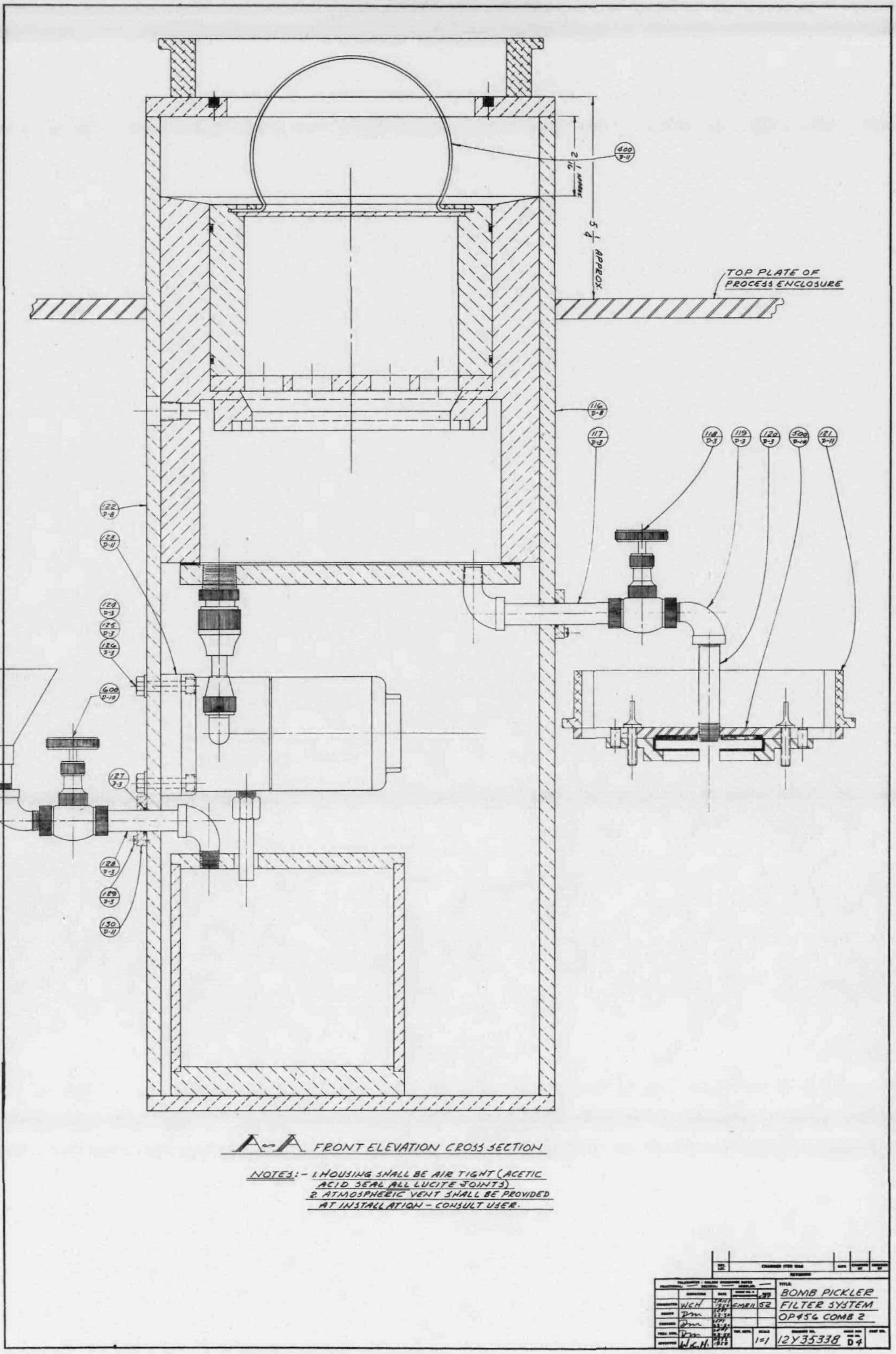

Fig. 94. Front elevation of filter-reservoir for bomb scrubber.

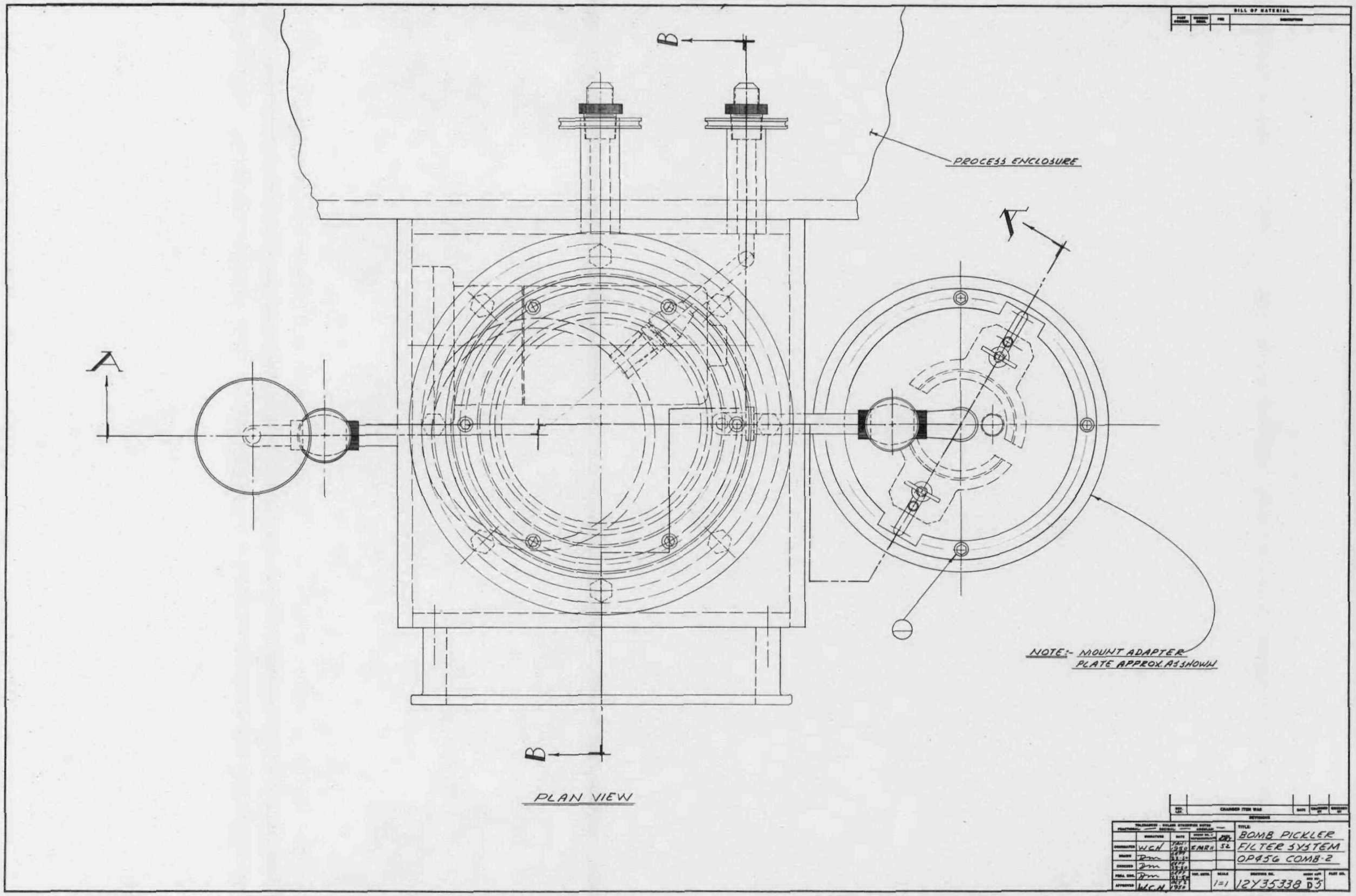

Fig. 95. Plan view of filter-reservoir for bomb scrubber.

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by evacuating the space under the filter the solution can be drawn from the bottom reservoir, through the bomb and scrubber and back into the filter. Solids remain on the glass cloth while the solution flows through. After the bottom reservoir is emptied and the bomb dried the wash solution is all in the upper reservoir below the filter. It flows to the lower reservoir by gravity when the saran valve (158) is opened. There is a bag ring (131) around a hole in the top of the filter box through which the glass cloth can be changed when necessary.

A pipe leading into the bottom reservoir (Figure 94) is used to add fresh wash solution as required. A drain line (117 Figure 94) from the bottom of the upper reservoir to a bottle-holding clamp (500 Figure 94) is used for removing the contaminated wash solution at the end of accountability periods.

The frequency with which the bomb must be washed has not yet been determined although it is probable that water washing will be required only at long intervals. As of the date of this report it seems that, if the bomb is stored between reductions in the strip heater with the vacuum on, no scrubbing will be necessary although this has not been demonstrated often enough yet to be final.

Controls and Heater

Figure 96 is a photograph of the control panel for this operation. The electrical circuit is standard throughout with no interlocks or instruments other than an ammeter and "Variac" in the strip heater circuit.

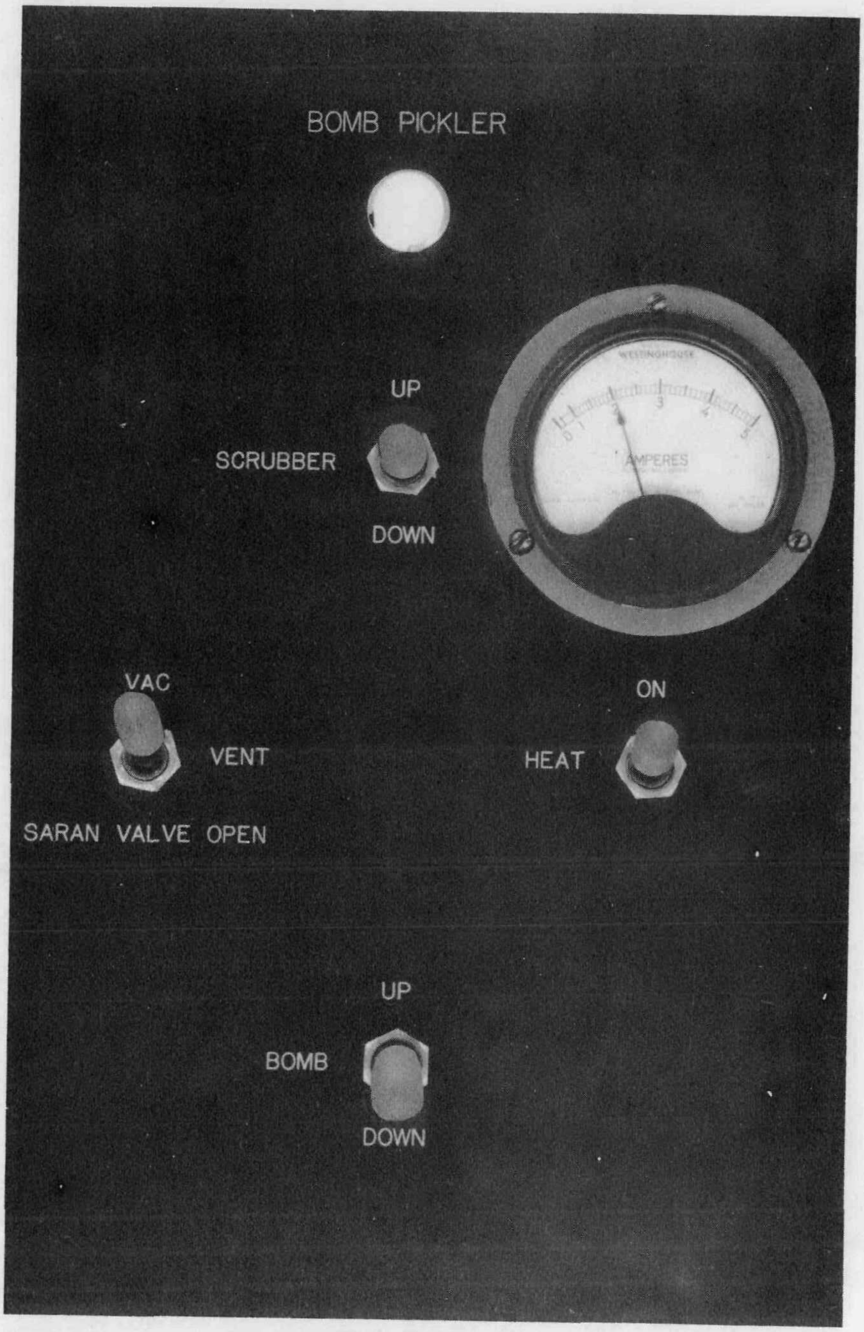

Fig. 96. Control panel for bomb scrubber system.

The heater which is used for drying the bomb is a 300 watt resistance element, a drawing of which is given in Figure 97. In order to determine the rate of temperature rise and terminal temperature inside the bomb a mild steel bomb was lifted on the air cylinder at this station and readings of the inside temperature at the bottom taken with a thermocouple with the input power set at 3.0 amps. These data are graphed in Figure 98.

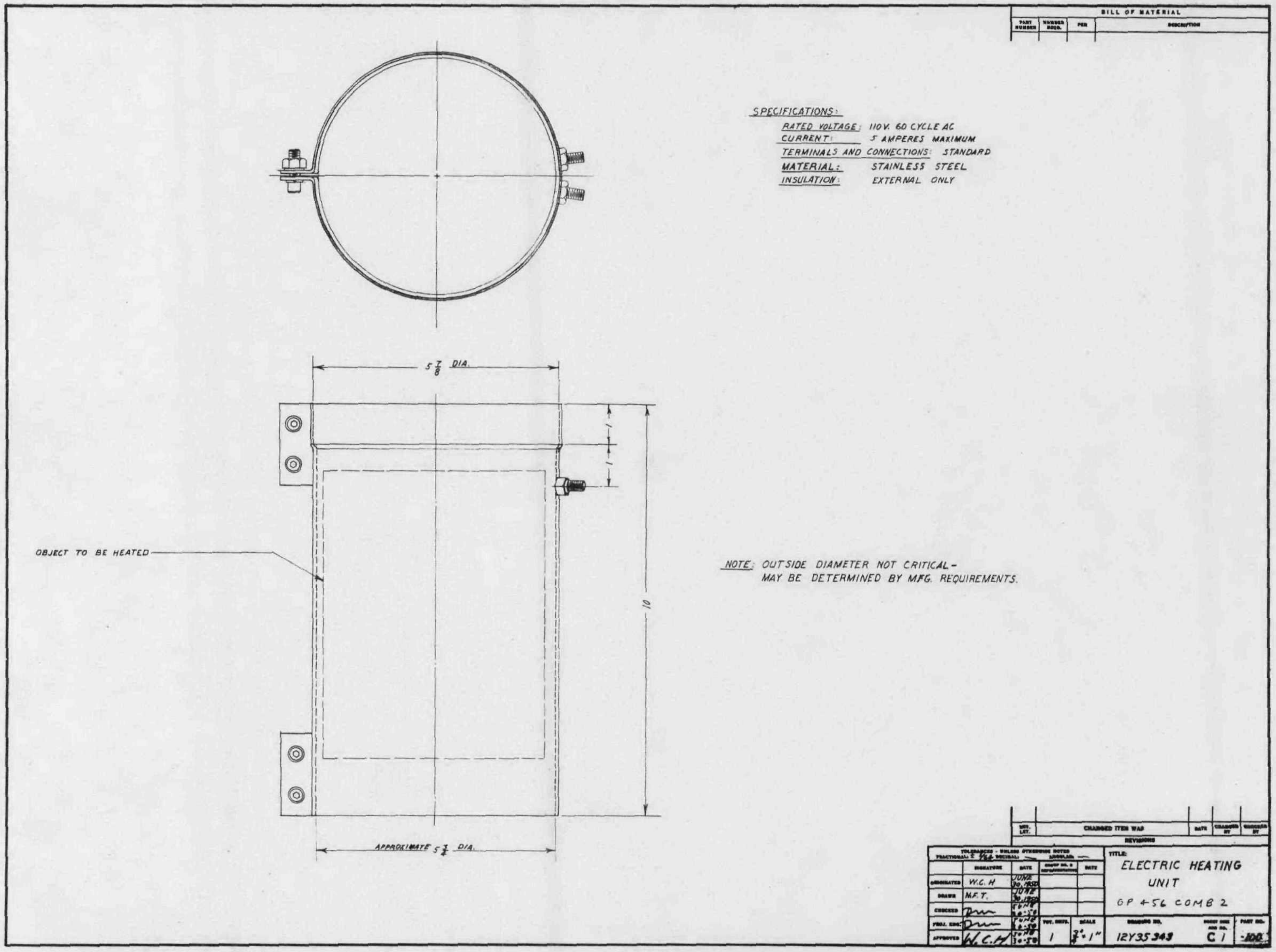

Fig. 97. Strip heater for bomb scrubber unit.

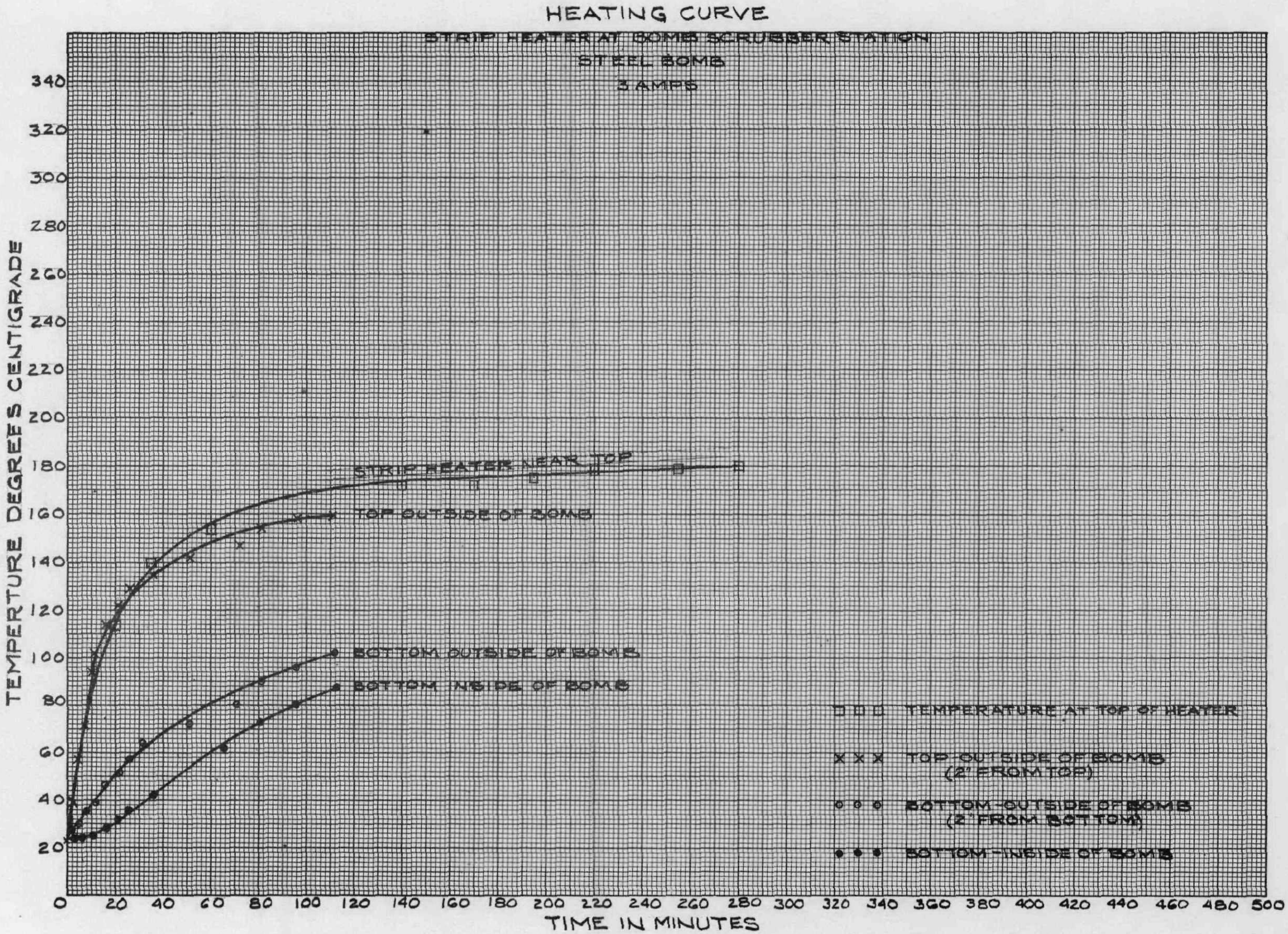

Fig. 98. Heating curve for steel bomb placed in strip heater at bomb scrubber station.

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CARRIAGES AND DRIVES

Mechanical Assemblies

The filter boats in the end sections of each remote control unit and the reduction bomb in the center section are moved from one station to another in carriages which roll on stainless steel angle iron tracks. The carriages are linked to a roller chain passing over sprockets at each end of the tracks. The sprockets at one end of each track unit are driven by a worm gear assembly which is on the end of a long motor driven lead screw outside the enclosure. A nut riding on this lead screw passes microswitches set at intervals corresponding to the space between operating stations inside the enclosure. These microswitches, when tripped by the moving nut, shut off the drive motor thereby giving automatic positioning of the carriage along the track. Figure 99 is a schematic layout of these conveyors and their relation to the operating stations in the main enclosure. Figure 100 and 101 are design layouts of the drive mechanism showing the motor drive, throw out clutch, lead screw and worm gear. The throw out clutch shown in the layouts was changed during installation to use leather faced friction plates. Figures 102 and 103 are layouts of the boat carriage and bomb carriage assemblies. A photograph of the lead screw and microswitches for one of the boat carriages during installation is shown in Figure 104.

Boat carriages move at 5-1/2 feet per minute and the bomb carriage at 7-1/2 feet per minute.

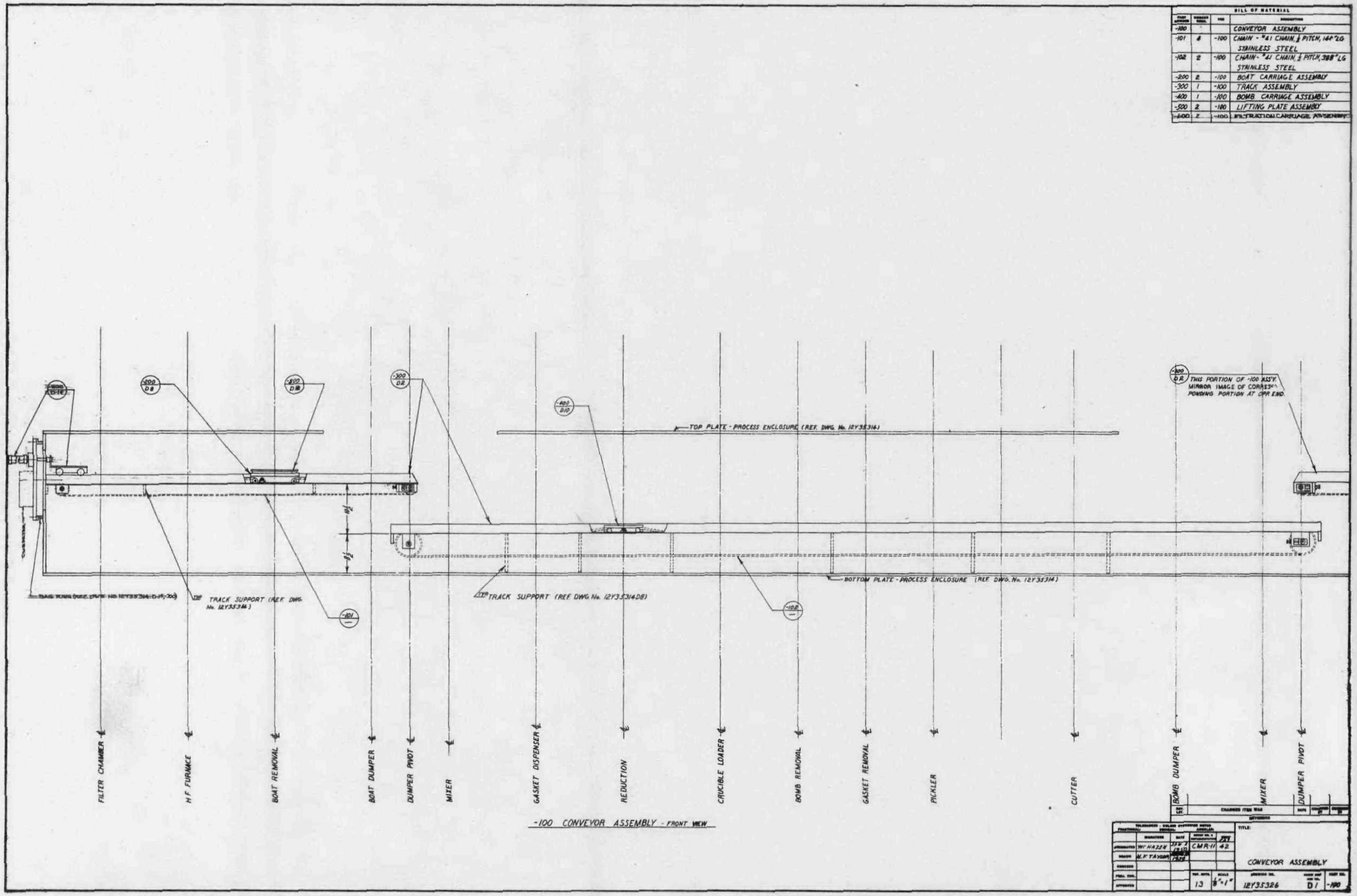

Fig. 99. Layout of carriage tracks in remote control line.

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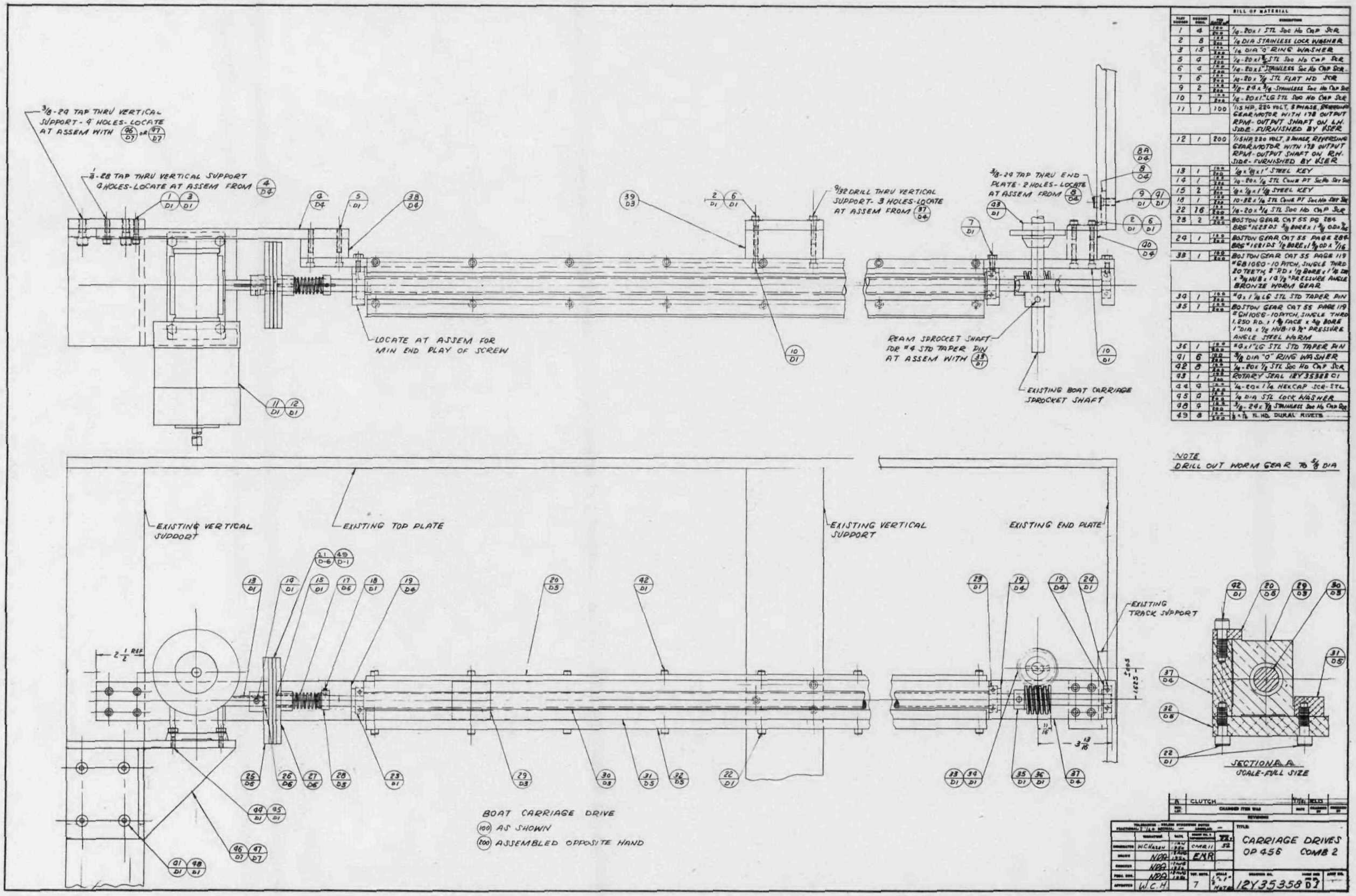

Fig. 100. Design layout of boat carriage drive mechanism.

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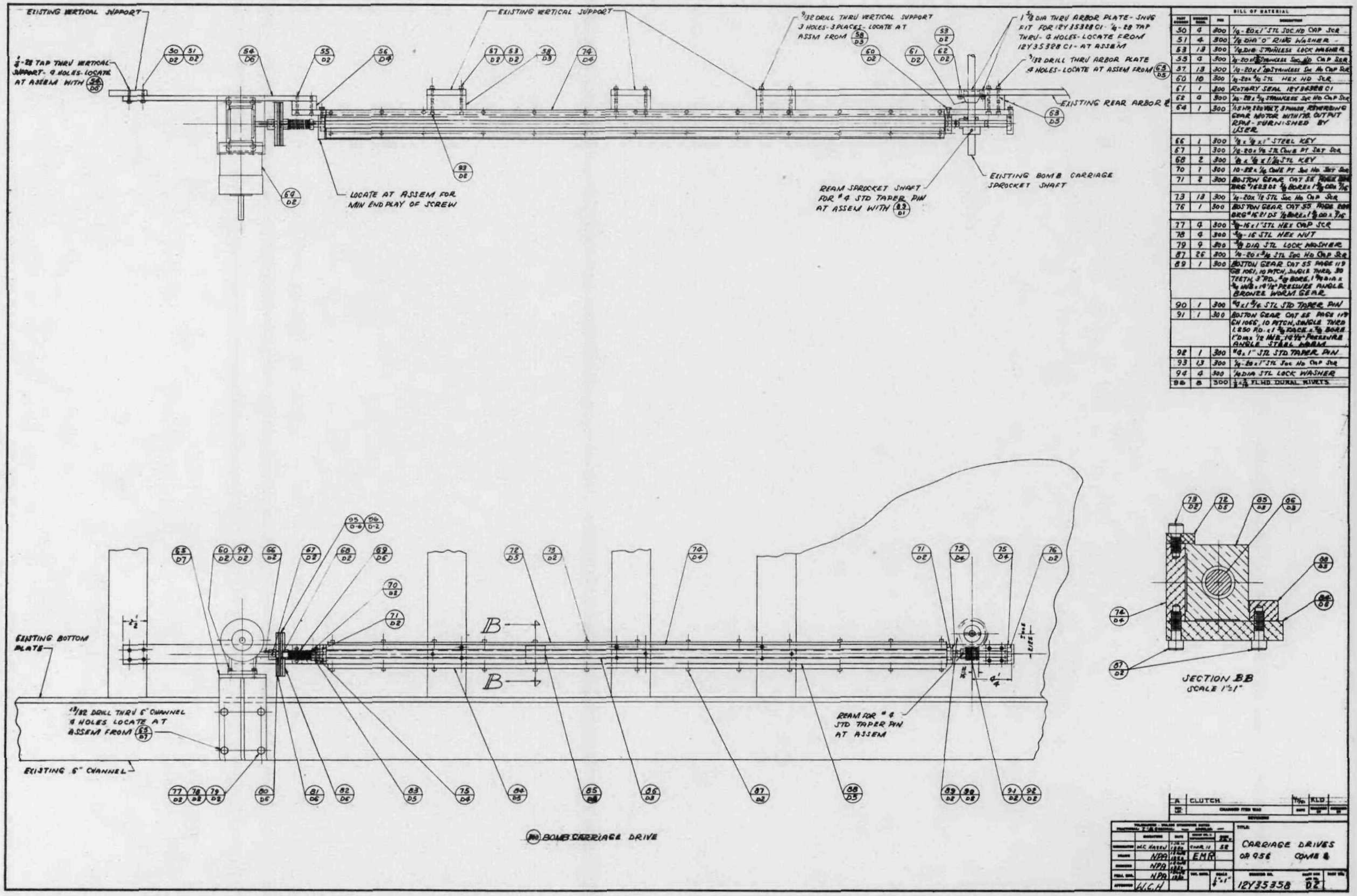

Fig. 101. Design layout of reduction bomb carriage drive mechanism.

[redacted]

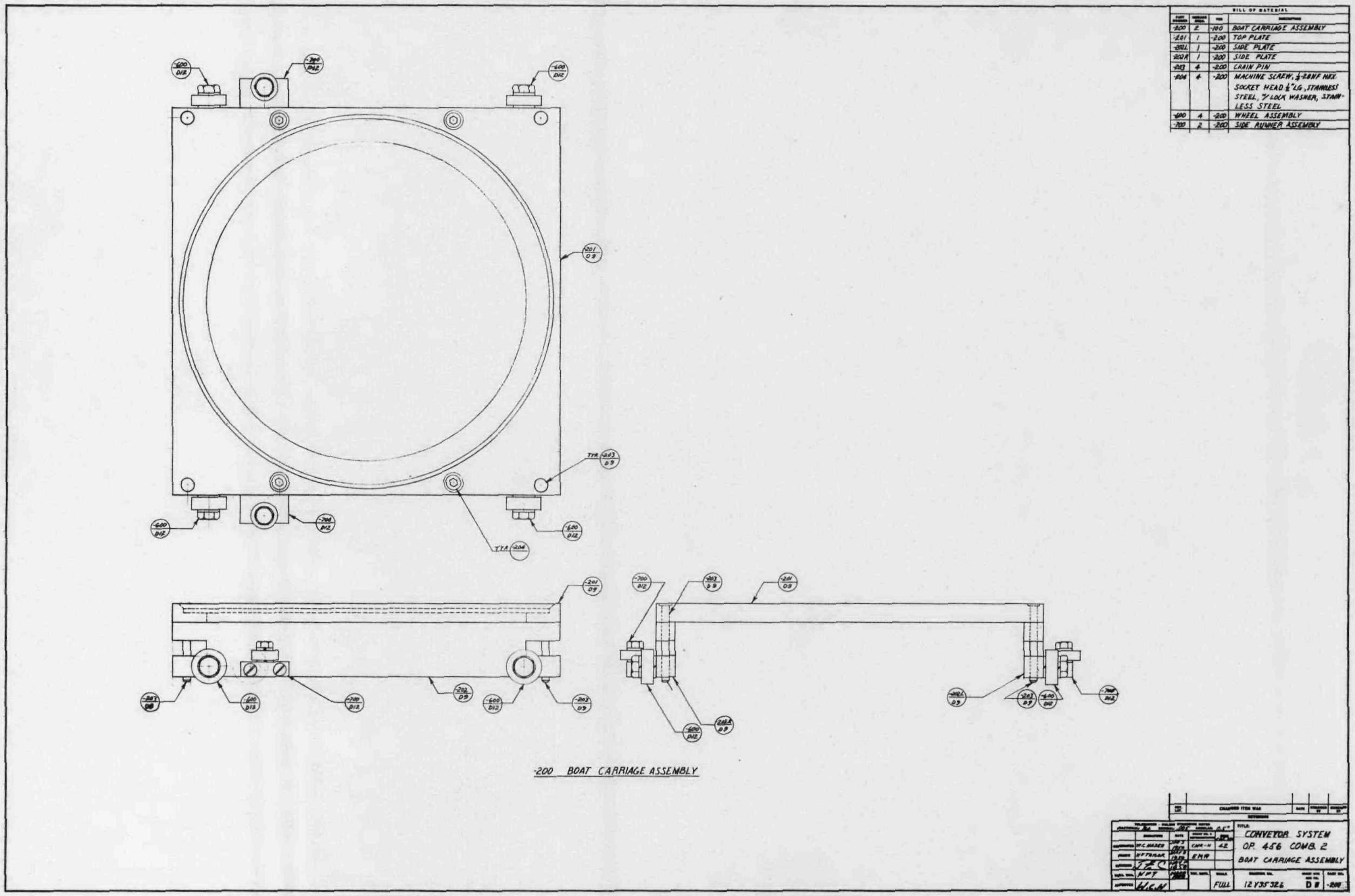

Fig. 102. Design layout of filter boat carriage.

[redacted]

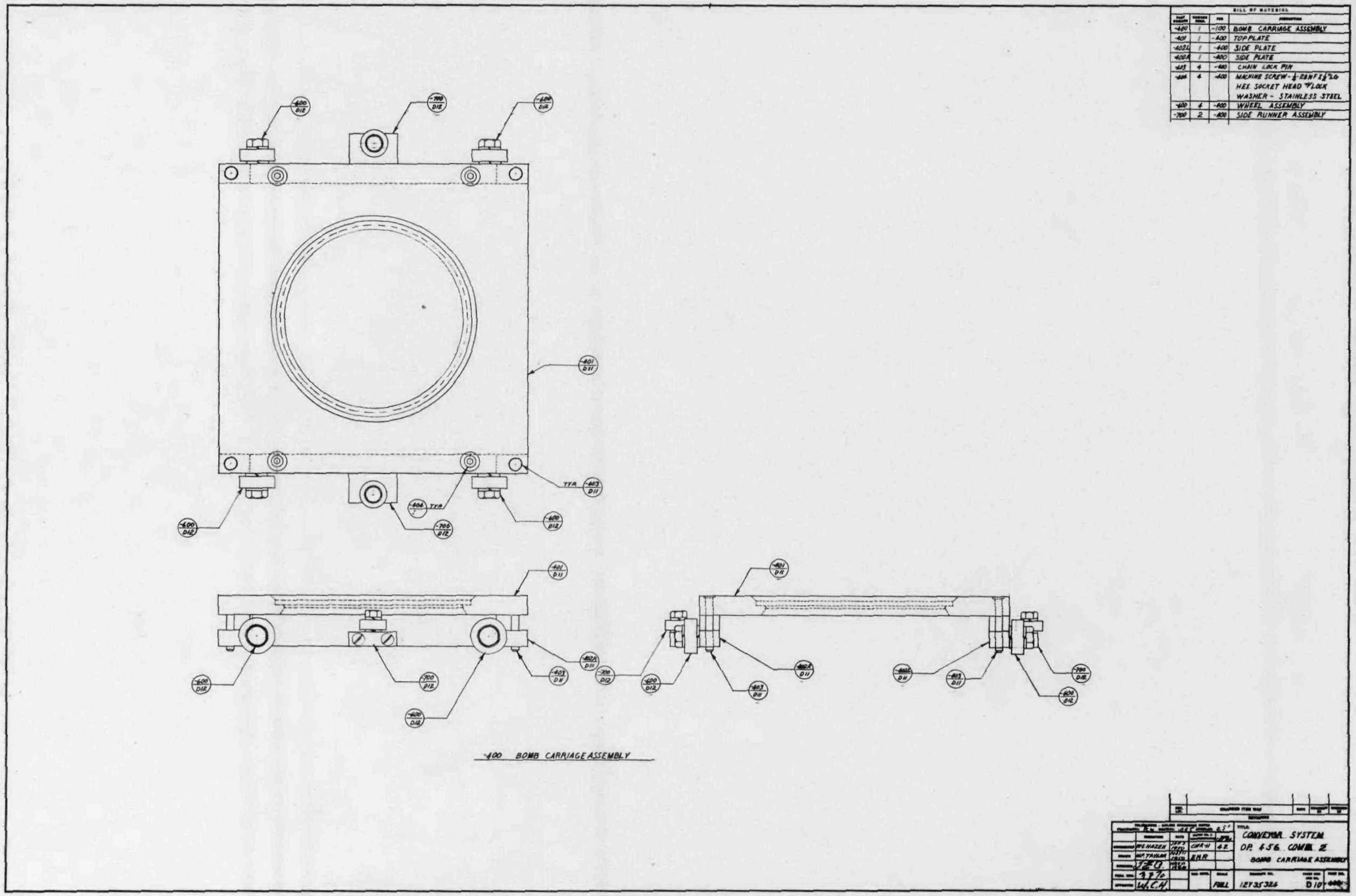

Fig. 103. Design layout of reduction bomb carriage.

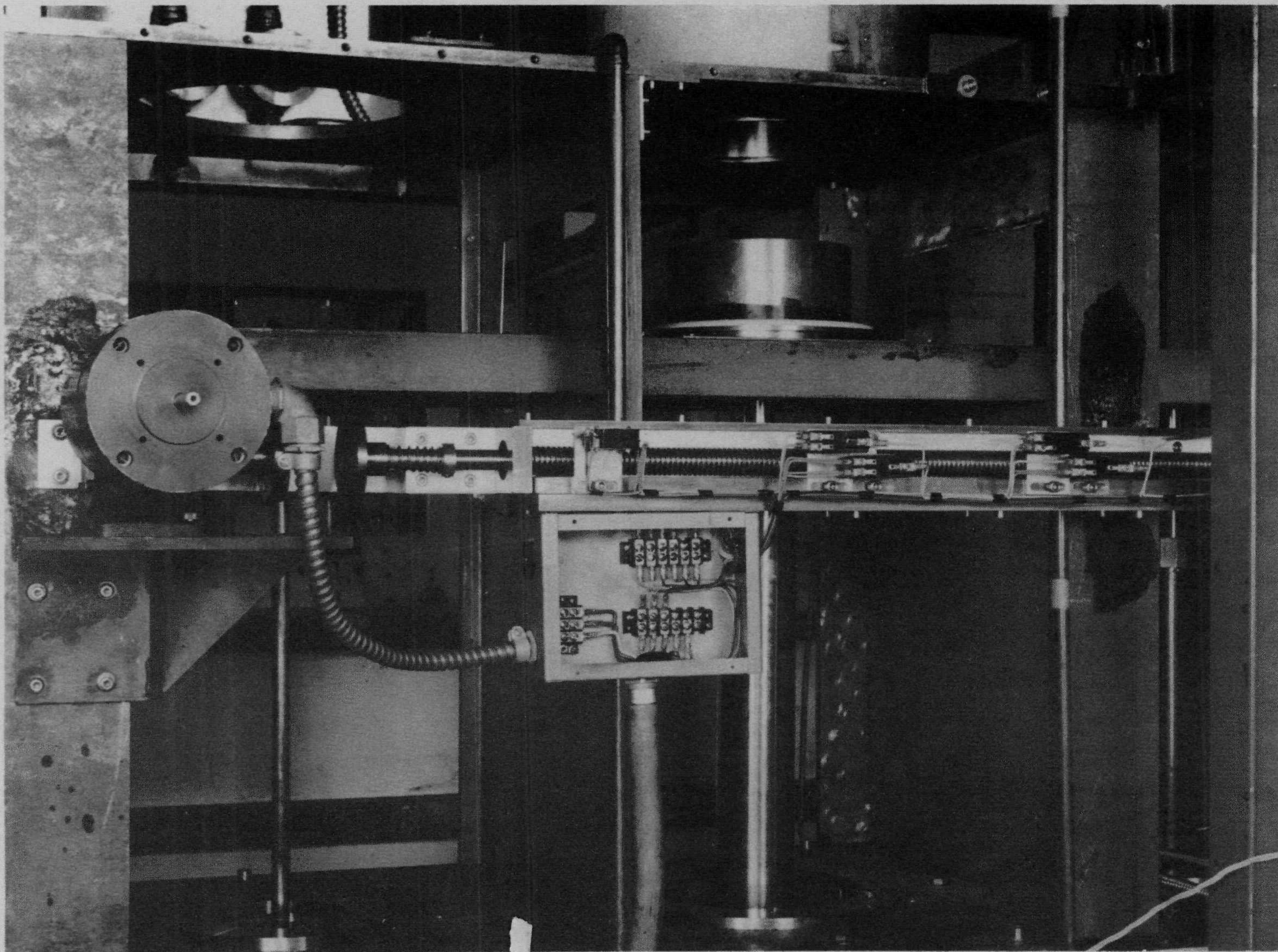

Fig. 104. Photograph of filter boat carriage drive mechanism taken during installation.

[redacted]

[redacted]

Electrical Controls and Stop Precision

The motor driving the lead screw is a 220 volt three phase 1/15 HP, 1725 RPM gear head type with a magnetic brake. The output shaft turns at 173 RPM.

There are sets of adjustable microswitches mounted on the frame holding the lead screw; one set of two switches for each station. In order to obtain accurate stopping it was necessary at each station to have one microswitch for one direction of travel and a second switch for the reverse direction. When the traveling nut trips one of these microswitches it breaks the circuit to the drive motor thereby stopping the carriage.

Figure 105 is a photograph of a carriage control panel. The bottom switch controls the direction of motion and has a center neutral for stopping. The upper switch shunts out the microswitches in order to allow the carriage to pass a station. When the carriage is in motion if this control switch is in the "Automatic" position the carriage stops automatically at the next station in the line. If the control switch is in the "Stop Bypass" position the carriage will continue traveling until stopped by the directional control switch or until it reaches the end of the track when the lead screw nut trips a limit switch.

Each stop microswitch is of the single pole double throw type. Therefore, when tripped, it opens the motor drive circuit and closes a second circuit which is part of a general interlock system. The eight

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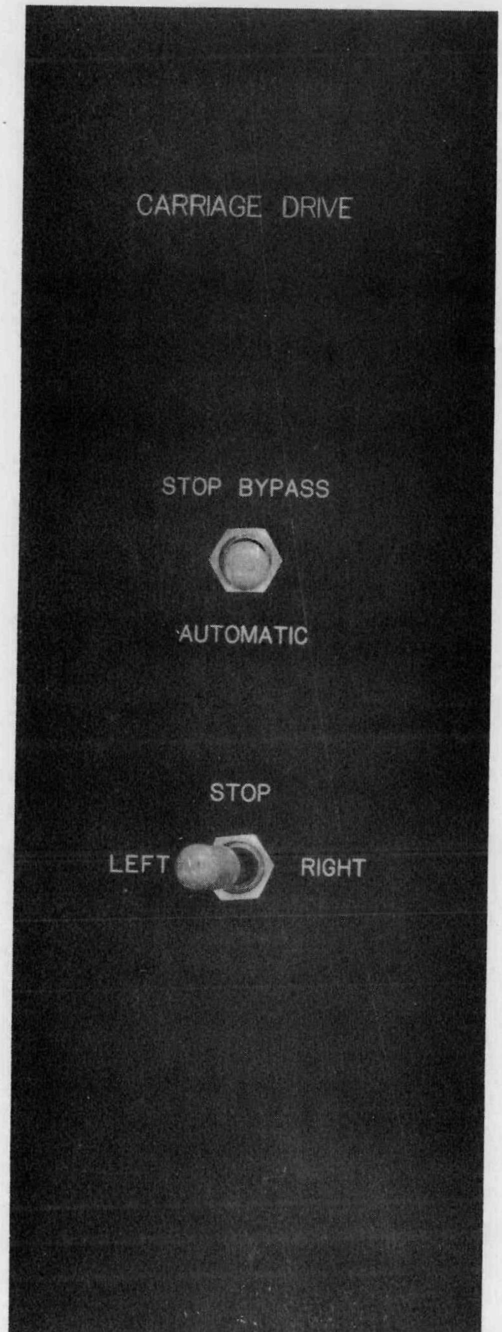

Fig. 105. Carriage control panel.

volt power for the control panel at each station feeds through the station microswitch. Therefore unless the carriage is at a particular station and the stop switch tripped the eight volt circuit to this panel is open. This is true for the eight volt controls only and not the 110V circuits. Since all cylinders are operated by eight volt valves this means that no motions can be performed at a given station unless the carriage is at that station. This switch also lights the lamp on the control panel to indicate the carriage position.

Circuit diagrams of the reduction bomb carriage control and one boat carriage control are given in Figures 106 and 107.

The precision with which these carriages stop was determined by clamping a dial gauge across the track and allowing the carriage to strike it as it stopped automatically at a station. The tests were run for many stations under a variety of conditions of direction and length of travel. The maximum stopping error in any test was ±1/64 inch which is well within the required limit (±1/8).

[redacted]

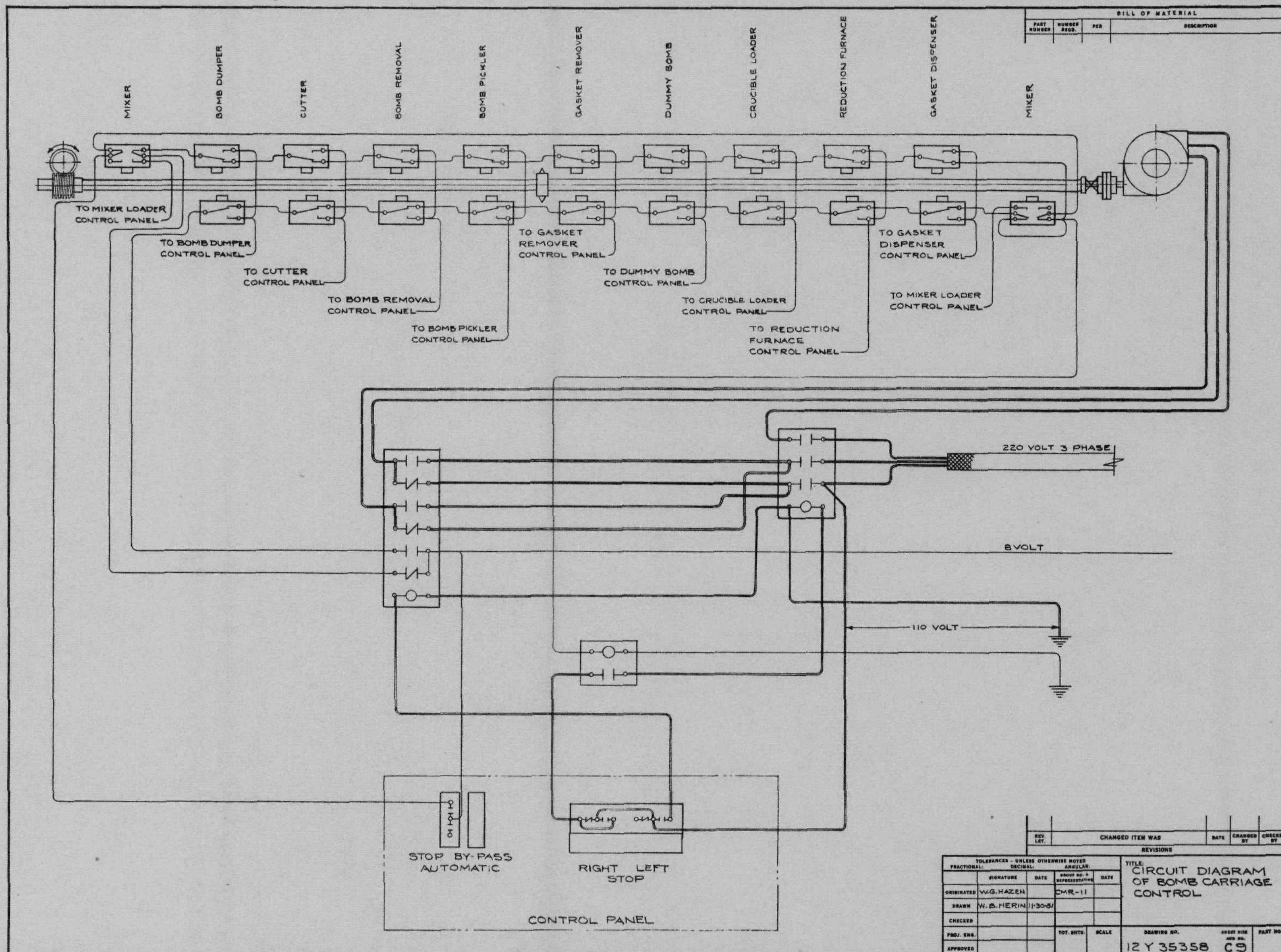

Fig. 106. Circuit diagram for bomb carriage control.

[redacted]

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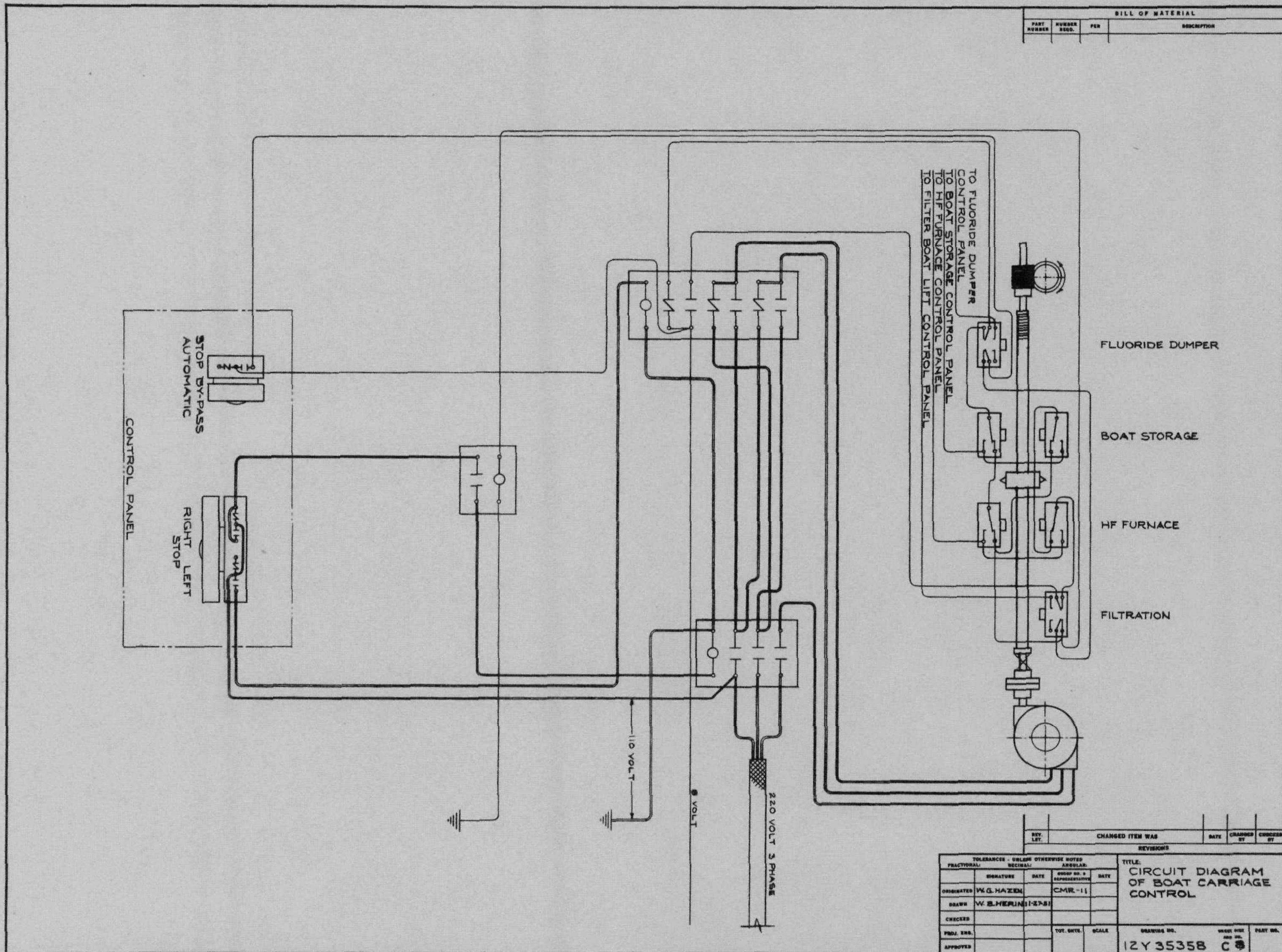

Fig. 107. Circuit diagram for boat carriage control.

[redacted]

CYLINDER MOUNTING FLANGES

Since most operating units are mounted on the top plate of the main enclosure while the air cylinders raising the boat or bomb to the station are mounted on the bottom plate which is 30 inches below, the problem of alignment is critical. To allow some adjustment in the position of the bottom cylinders the mounting method shown in Figure 108 was developed. The name "Wobble Plate Mounting" has been given to this design.

A circular ring of stainless steel is set on the inside of the bottom plate of the main enclosure over the hole for each air cylinder. This is shown as part 101 in Figure 108. The flange plate on the nose of each cylinder (100) is screwed to this ring or "Wobble Plate". Since the bolt circle is smaller than the diameter of the hole in the enclosure bottom plate the cylinder and wobble plate can be shifted 1/4 inch in any direction. The "O" ring (102) in the cylinder flange and the "O" ring washers (105) under the bolt heads serve as contamination seals.

A Dural bag ring (not shown in drawing) is mounted around each hole in the bottom enclosure plate so that the cylinder can be changed using the plastic bag method.

This mounting design has been entirely satisfactory both from the standpoint of alignment and contamination.

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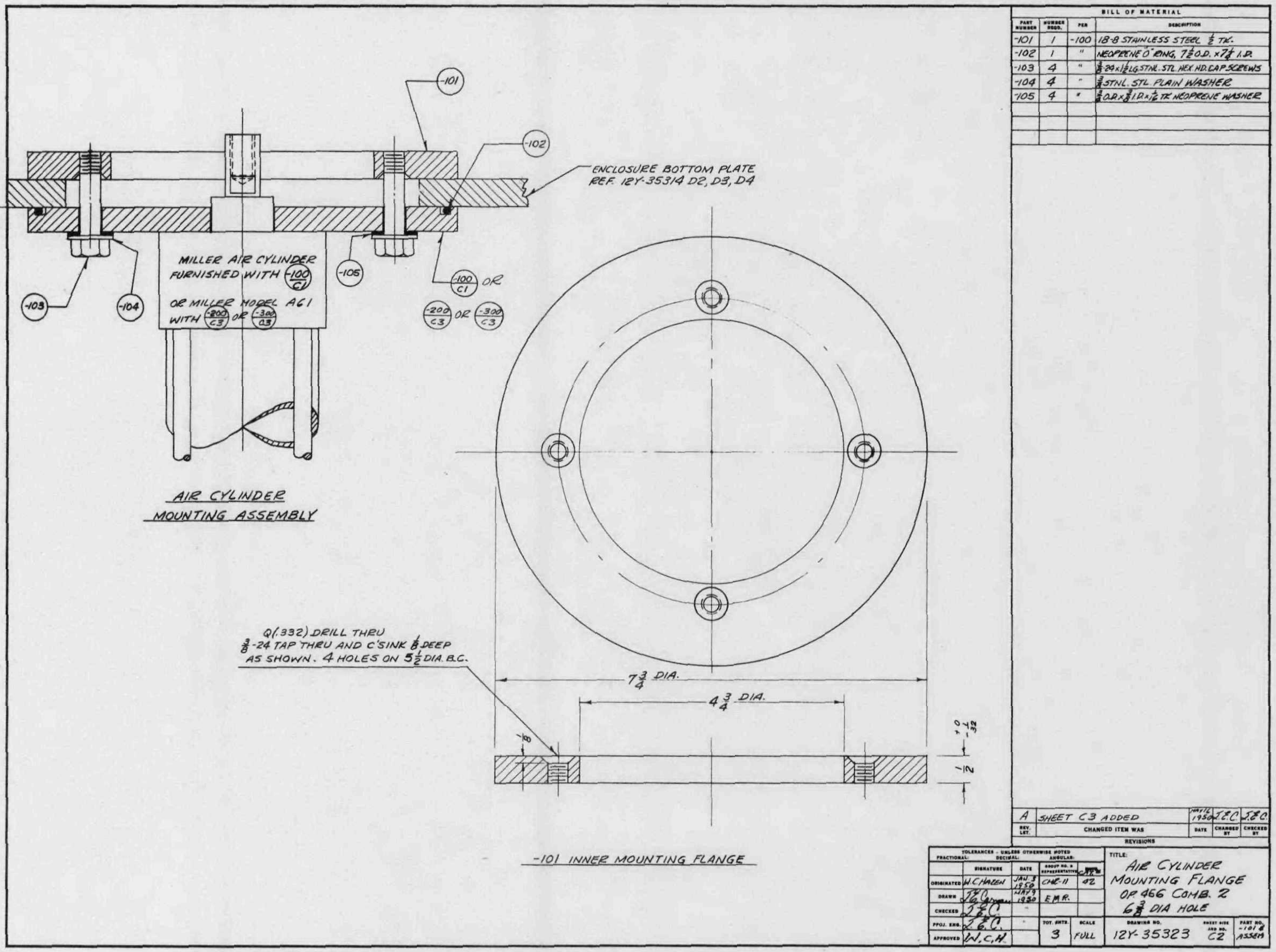

Fig. 108. Design layout of air cylinder mounting.

VALVE RACKS

The solenoid valves used to control the flow of air to pneumatic cylinders are of an 8 volt pilot operated type. There are sixty of these valves for each of the two remote control lines. These are grouped in sets of twelve in racks, with each rack having an intake and exhaust header and an air lubricator. The racks are bolted to the channel iron supports for the main enclosure.

The eight volt wiring comes from the control panel in cables through conduit to the racks. Above each valve is a single pole double throw momentary contact switch paralleling the control panel switch to operate the valve for testing or emergency use.

A design layout of one of these racks is given in Figure 109 and a photograph in Figure 110.

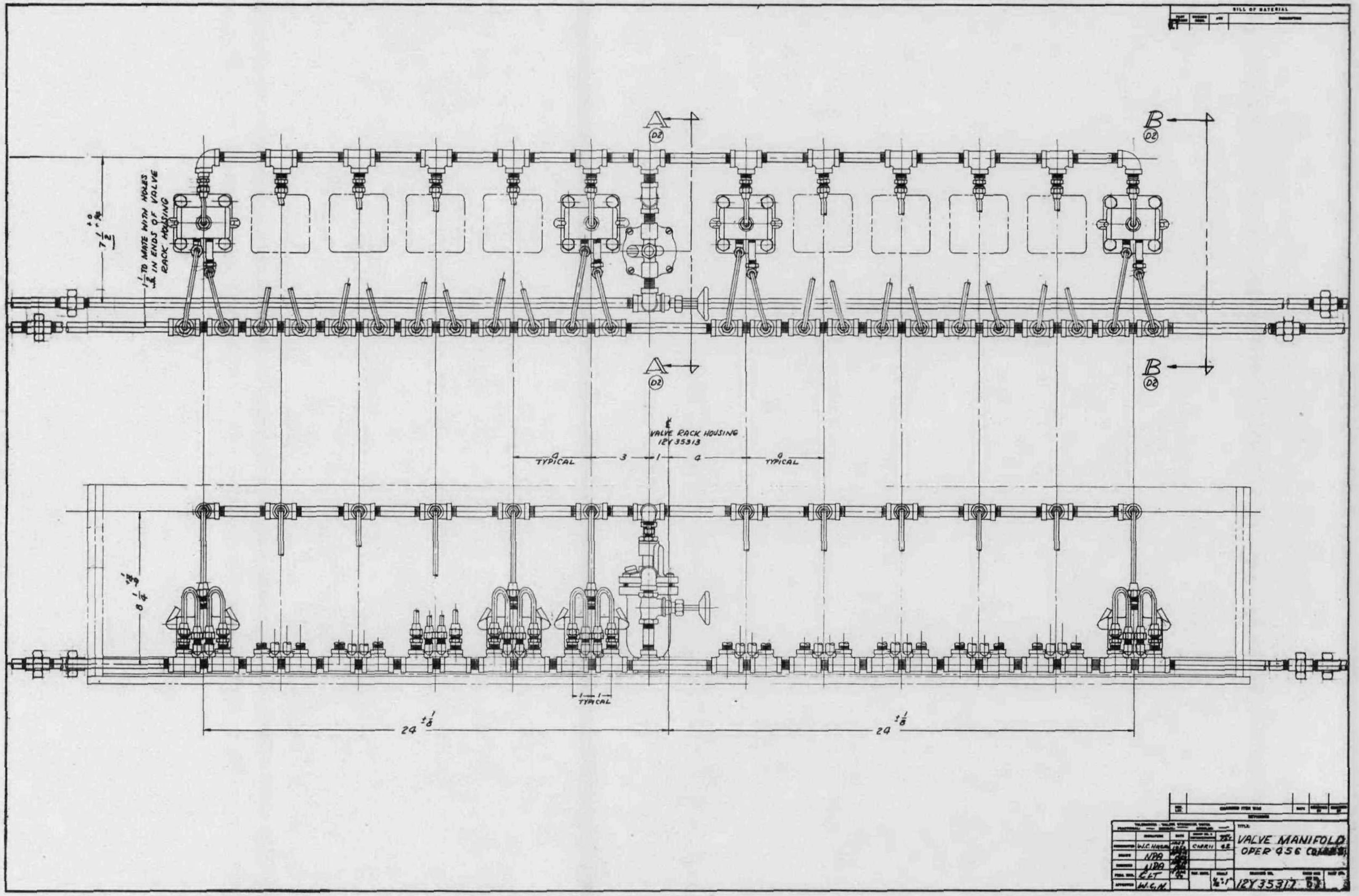

Fig. 109. Design layout of solenoid valve rack for control of air cylinder.

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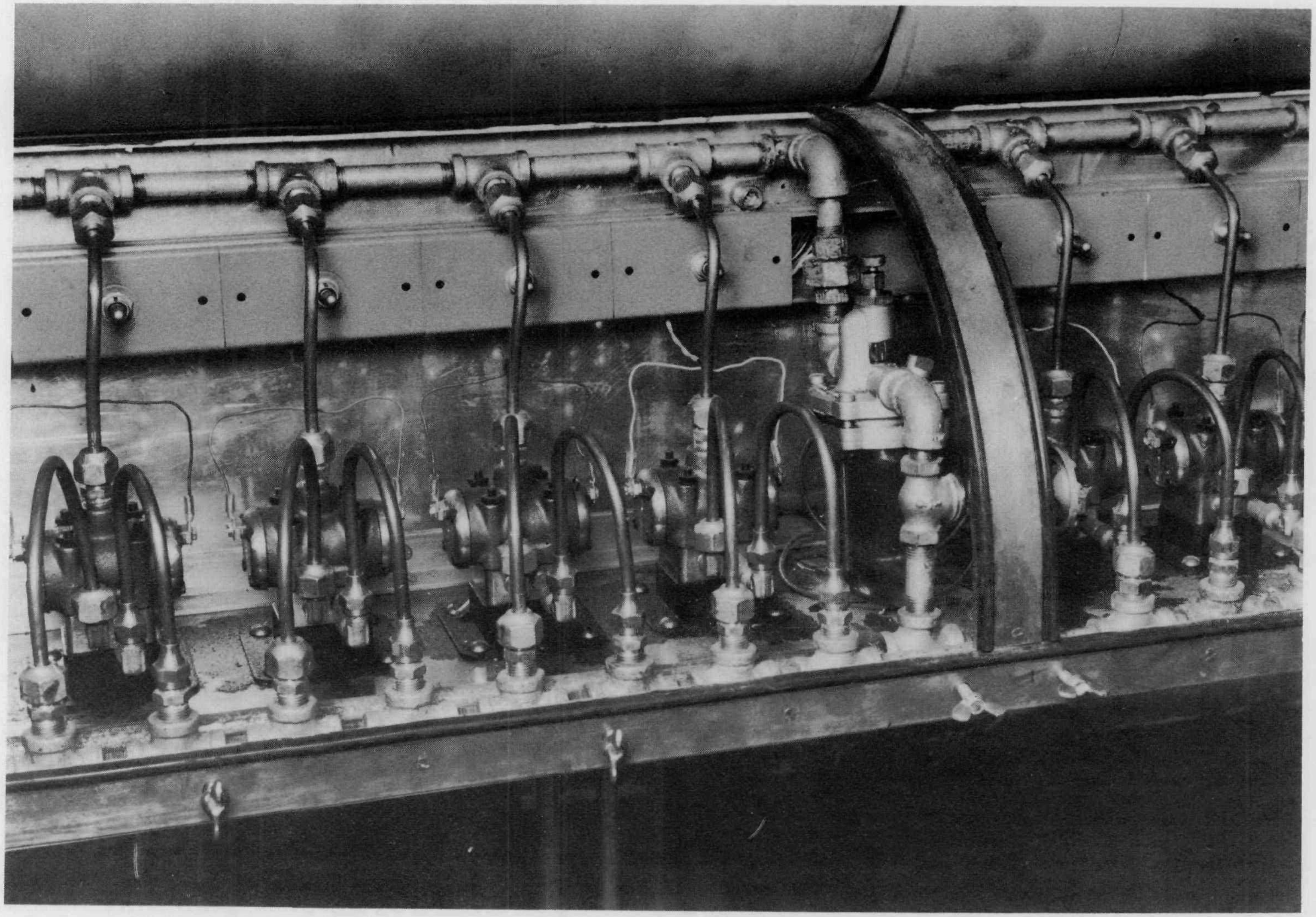

Fig. 110. Solenoid valve rack for control of air cylinders.

ELECTRICAL SYSTEM

GENERAL DESCRIPTION

It is not practical to include the complete wiring diagram of the electrical circuits of the remote control equipment in this report primarily because it is nearly thirty feet long and if reduced to manageable proportions is no longer legible. This diagram is available however as Eng.-C-1278.

Since there is nothing particularly unique in any of the electrical circuits the following general description should suffice for understanding what was done. Instrumentation is not discussed here since it is covered under sections dealing with specific operating units.

Throughout the electrical system a design specification rigidly applied was that in the event of power failure all elements would assume a safe position. This applies particularly to solution and gas flow solenoid valves which are of the normally closed type and vent valves which are of the normally open type.

The communication system between control room and Zone 3 consists of battery powered head sets.

For descriptive purposes the circuits are broken down into five categories; 8 volt controls, 110 volt controls, 220 volt 3 phase motor controls, HF furnace heating circuit and interlocks.

8 Volt Controls

This includes the valves for operating all pneumatic cylinders. This circuit is basic therefore to the control of almost all motions.

The 110V feed line to the control room passes first through the main breaker then to a smaller panel switch and then to a filament transformer rated at 6 - 8 volts and 4 amps. One transformer feeds all eight volt circuits for one remote line and has a voltmeter and ammeter on the output. One terminal of this transformer is grounded. The hot side goes to each control panel where it connects through a momentary contact single pole "Operating" switch to the center terminal of a rotary selector switch. The contacts of the rotary selector switch are connected by wires running in 12 pair cables in conduit through the partition separating the control room from Zone 3 to the solenoid valves. The valves are grounded to complete the circuit.

The purpose of the rotary selector switch is to allow the operator to turn to the desired operation and then actuate the proper cylinder by pressing the "operating" switch momentarily. This made it possible to set up the step-by-step operating sequence on the rotary selectors and considerably simplify the control room operators work.

The control panels are made of Dural which was anodized black with lettering engraved through the black surface.

Where it was required that one of the contacts on the selector switch operate a 110 volt piece of equipment instead of an 8 volt valve the contact was wired to an 8 volt relay which in turn operated the 110 volt equipment.

The simplicity of this circuit has been amply justified by its trouble free performance.

[redacted]

110 VOLT CONTROLS

All valves other than the 8 volt pneumatic cylinder actuators are wired for 110 volt service. This includes the motorized valves for gas and solution flow as well as the regular solenoid shut off valves. All electric motors on agitators and brushes are 110 volt also. For this equipment the 110 volt power leads to the control room pass through main switches and then to the control panel power switch located on each panel which uses 110 volt current. After passing through the appropriate control switch the leads go in conduit to binding posts mounted in a lucite panel which is part of the room partition. The Zone 3 side of binding post is wired directly to the item of equipment concerned.

220 VOLT 3 PHASE MOTOR CONTROLS

These circuits are used only for carriage drive and separation table motors where 3 phase current was required for reversing. Since the separation table control merely utilizes a reversing switch on the control panel and since the circuit for the carriage drive is discussed in detail in that section of this report no further comment is needed here.

FURNACE HEATING CONTROLS

The hydrofluorination furnaces are heated by resistance heaters set in a steel furnace jacket. These heaters are connected in sets of two in series operated from the 220 volt power source. This source passes first through a Variac and then through an ammeter to the heaters.

[redacted]

[redacted]

Temperature control is achieved by a Wheelco controller operated from a thermocouple set in the furnace jacket.

INTERLOCKS

There are five specific interlocks and one general one in the control wiring. These are as follows:

1 - Interlock to prevent opening fluoride dumper stopper valve unless the mixer is raised.

2 - Interlock to prevent operation of bomb dumper locking lever unless bomb lift cylinder is raised.

3 - Interlock to prevent operation of $Ca\text{-}I_2$ loading chamber unless the loading cups are retracted.

4 - Interlock to prevent dummy bomb lock from being operated unless the bomb lift cylinder is raised.

5 - Interlock on reduction furnace thermocouple.

6 - General interlock which energizes control circuit for a given unit only when boat or bomb carriage is at that station. These int rlocks are achieved by either relays or pressure switches and are discussed under the unit concerned.

[redacted]

HYDROXIDE SLURRY SYSTEM

When the filtrate from the peroxide precipitation is neutralized with ammonia to a pH between 7 and 9 not only is the excess peroxide destroyed but plutonium, iron, aluminum, etc., are precipitated as the hydroxide. The hydroxide slurry system provides for the disposition of this neutralized filtrate.

The slurry in the filtrate pot is transferred by vacuum to a stainless steel cone-bottom settling tank of 110 liter capacity at the south end of the room. The transfer line is saran tubing inside stainless steel pipe. The settling tank is equipped with a supernatant withdrawal tube extending part of the way inside the tank and a second withdrawal tube extending clear to the bottom of the cone. When the contents of the filtrate pots have been transferred, the slurry is allowed to settle overnight and the clear supernatant pulled out through a paper filter and into either of two steel disposal tanks of 48 liter capacity. Here the liquid is sampled and its disposition determined.

When the hydroxide slurry in the settling tank has accumulated to an amount containing 160 grams of Pu or at the end of an accountability period the settled precipitate is first washed with water and then dissolved in nitric acid. After dissolving, it is transferred to recovery in a stainless steel tank mounted on a cart.

A schematic piping diagram of this system is given in Figure III.

Since this operation was started, difficulty has been experienced in consistently obtaining a filtrate of discard level. There is

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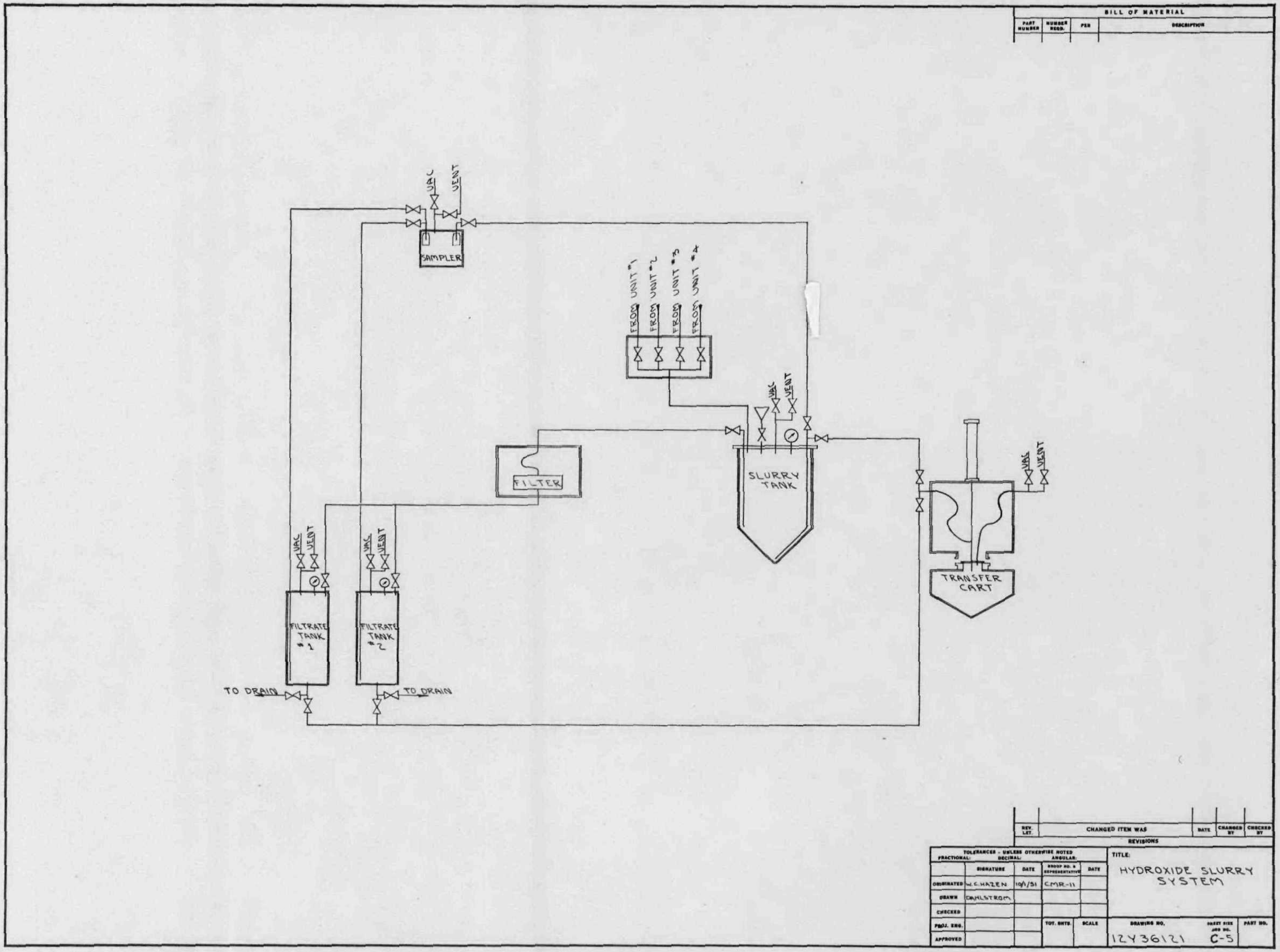

Fig. 111. Piping layout of hydroxide slurry system.

[redacted]

evidence that the activity of the clear solution obtained by filtration of the hydroxide slurry is in some cases dependent upon the length of time the solids and liquid have been in contact. Long standing in general results in high activity in the solution. At the time of writing of this report the cause and cure have not been definitely established. It is known that much of this high activity in filtrates is due to Americium.

CHEMICAL TANKS AND MANIFOLDS

Solutions for use in the remote line are stored in 50 gallon stainless steel tanks. These solutions are 30% H_2O_2, 6% H_2O_2, $1.5\underline{M}$ HNO_3 + $.15\underline{M}$ H_2SO_4 solution, and distilled water. The distilled water is supplied by a demineralizing unit at the south end of the room. All solution tanks except the 30% H_2O_2 are inside the Zone 3 also. The refrigerated 30% H_2O_2 tank was placed outside the room to facilitate loading.

Lines from the bottom of each of these tanks connect to a manifold system running along the wall of the control room partition. Individual vessels are fed from these manifolds. The chemical storage tanks are pressurized at from 7 - 10 psi to provide the head necessary on the manifolds. This method was chosen instead of a gravity feed partly because of space limitation but more importantly because the entire chemical feed system can be shut off by means of a switch in the control room which controls a solenoid vent on the storage tanks. This would be useful in the vent of valve failure and is particularly useful during shutdown at the end of an operating shift when the pressure is automatically relieved from the manifold system at the time the electric current is turned off. In addition to these points another factor is that the 30% H_2O_2 manifold is automatically drained back to the tank every night so that when started in the morning full strength hydrogen peroxide fills the manifold to the precipitation vessels. Although the H_2O_2 is stabilized, breakdown does occur upon standing in the stainless steel pipe manifold.

Bottled gases are stored in a tank shed built outside the room on the east wall.

A diagram of the chemical storage system is shown in Figure 112 and the manifold system in Figure 113.

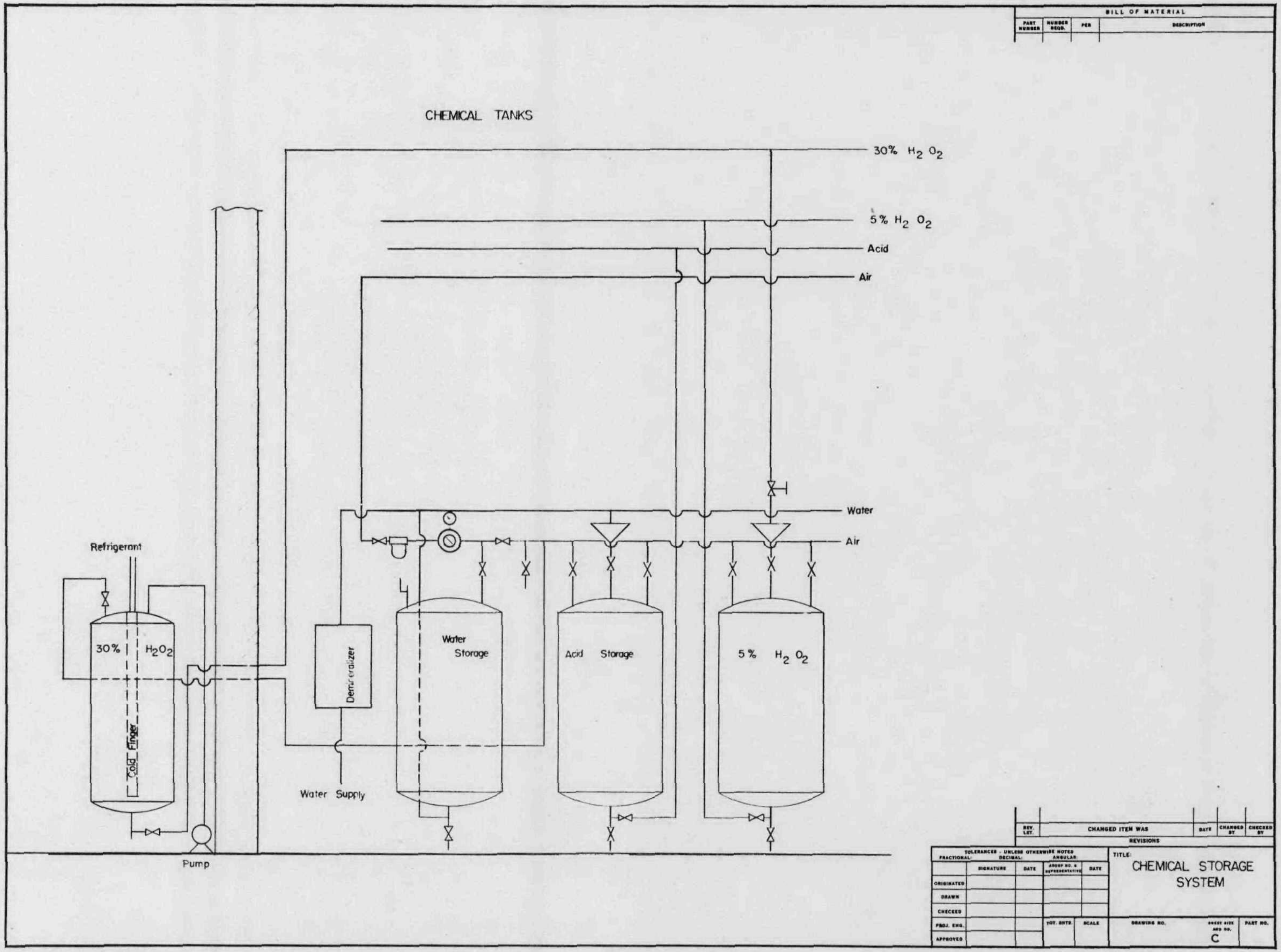

Fig. 112. Chemical storage system.

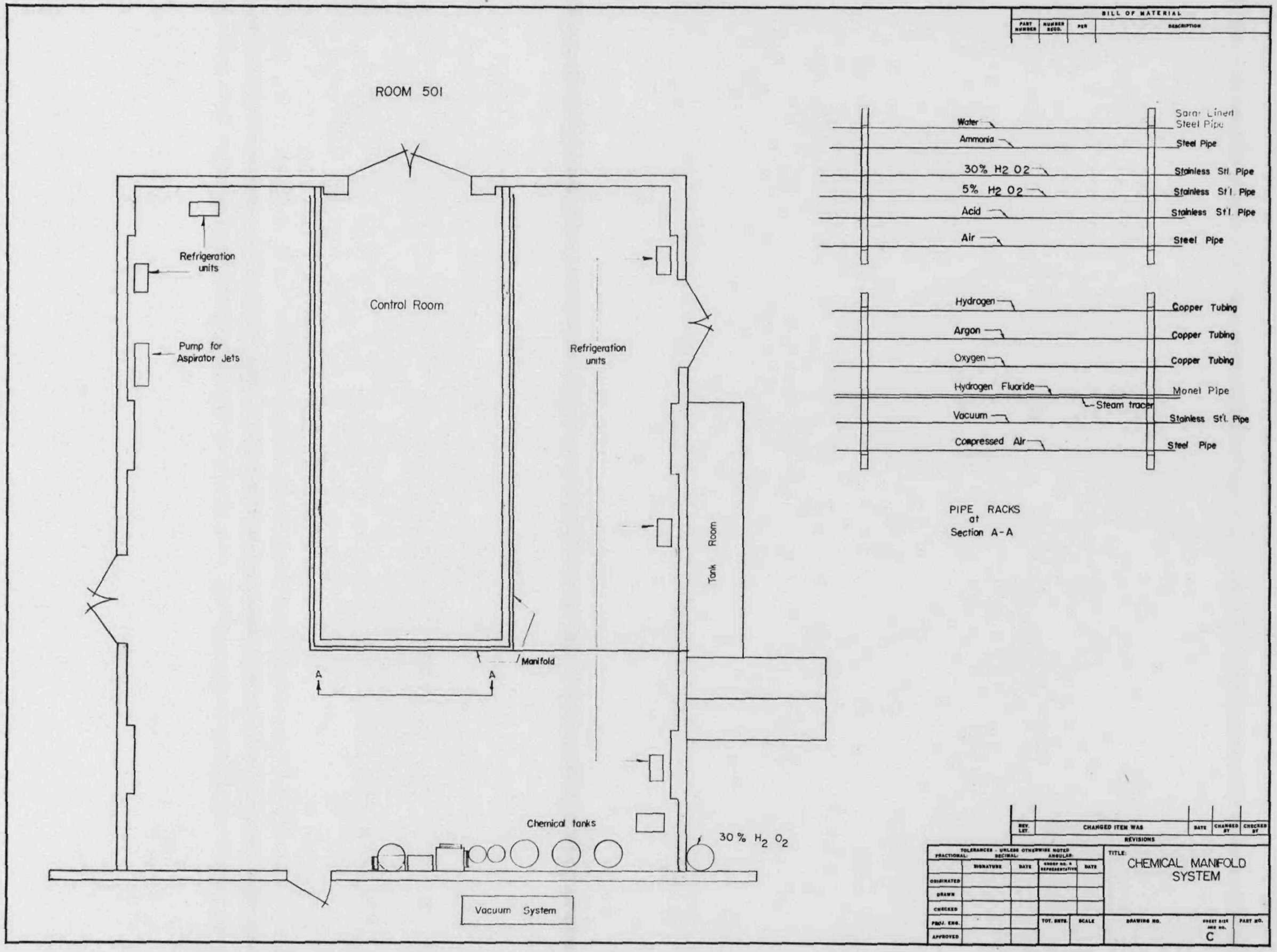

Fig. 113. Chemical manifold system.

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VENTILATION

The ventilation system is composed of 6, 8" x 8" x 3" CWS filter inlets on the main enclosure of each remote line and three exit ducts on each line. The ducts from the two lines connect and go to a filter chamber containing 2, 24" x 24" x 6" CWS filters. The exit from these filters passes through a 1/2 HP blower the discharge of which leads to the main air duct in the building exhaust system. The design is such that 150 CFM passes continuously through each remote line.

The exhaust ducts are placed at each hydrofluorination and reduction furnace. This is to minimize the diffusion of corrosive vapors in the event that any of these units should leak.

In addition to the steady ventilation, additional ducts lead to the lower portion of the nitrate removal station so that when the door is opened on this unit to load or unload a nitrate container 150 CFM of air is pulled through the open door. This gives a face velocity of 190 feet per minute through the opening.

Air is blown into the control room from the outside by fans and exhausted through a louvre in the door. In operation the control room is kept 1/4 inch (H_2O) positive with respect to Zone 3 which is at substantially atmospheric pressure and Zone 4 is kept 1-1/2 inches negative with respect to Zone 3. Magnehelic gauges installed at appropriate points give the control room operator a visual check on the pressure differentials.

A diagram of the ventilation system is shown in Figure 114.

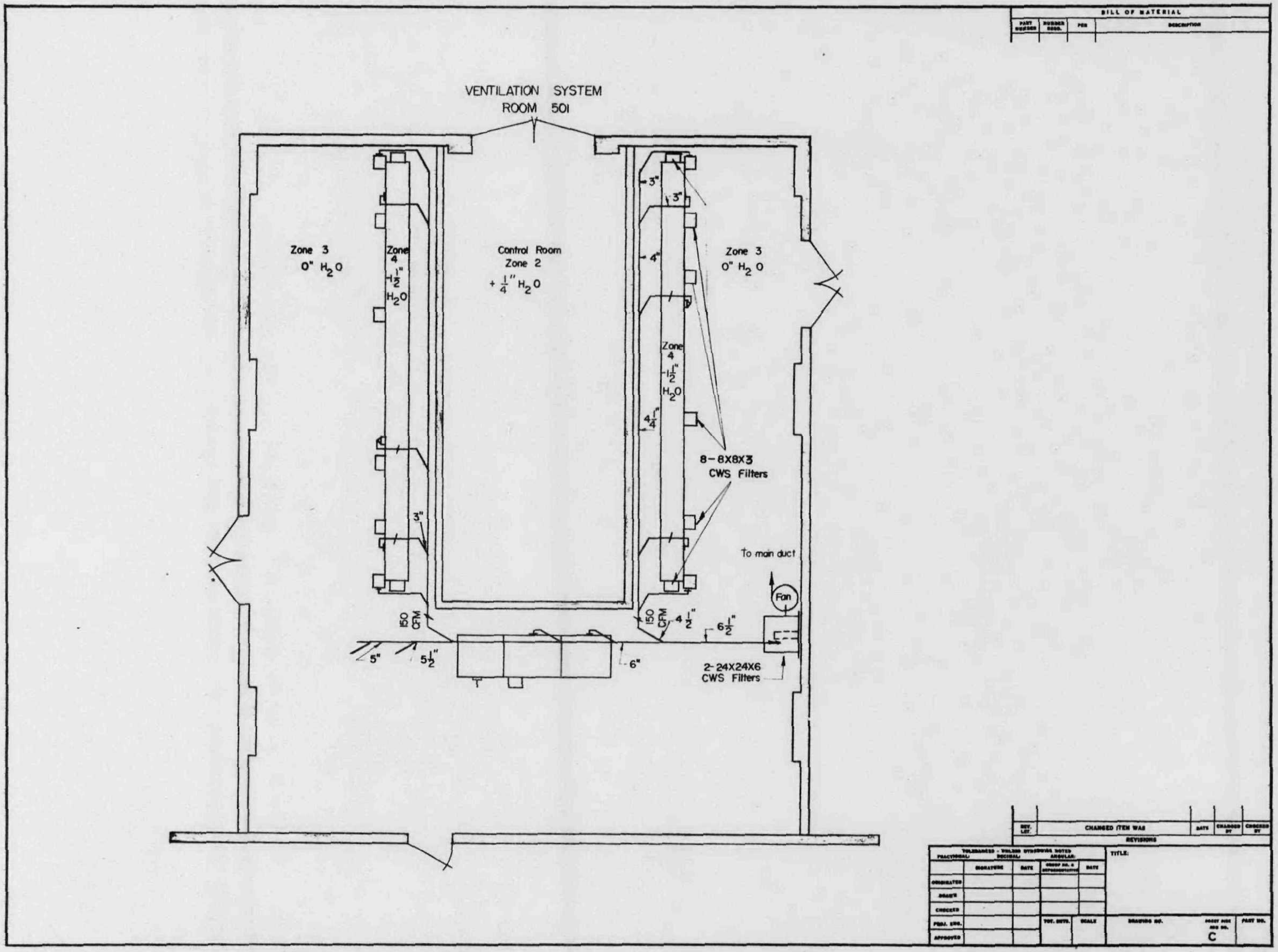

Fig. 114. Layout of ventilation system.

APPENDIX

DRAWING LIST

The following table is a list of all drawings for the remote control installation.

Title	Drawing Number
Room Layout	
Room 501 DP West	12Y 35272, D-2
Control Room Partition	ENG-4-711
Unit Enclosure	
Process Enclosure	12Y 35314, D-1-8, E-9, D-10-27
Includes top and bottom plates, front and rear skins, vertical and track supports, arbor plates, view port windows, end plates.	
Support Frame for Process Enclosure	12Y 35322, D-1-2
Enclosure Support (Legs)	12Y 35383, D-1-2
Stations or Sub Assemblies in Unit	
Withdrawal Apparatus	12Y 35349, D-1-10
Precipitation Apparatus	12Y 35334, D-1-15
Precipitation Unit Valve Rack	12Y 35423, D-1-3
Filtrate Pot	12Y 35356, D-1-5, C-6-7, B-8
HF Furnace and Lift	12Y 35307, D-1-6, C-17, 12Y 36098, D-1-2
HF Panel	12Y 35364, D-1-3
HF Furnace Bulkhead	12Y 35373, D-1-2
Filter Boat Lift Assembly	12Y 35348, D-1-2-3-4-5-6
Filter Boat	12Y 35293, D-1-2
Filter Boat Removal and Storage	12Y 35388, D-1-10
Mixing Vessel	12Y 35333, D-1-7
Mixing Vessel Cover	12Y 35335, D-1-3
Mixer Loader	12Y 35347, D1-19
Boat Dumper	12Y 35308, D-1-12, C-10
MgO Reservoir	12Y 35363, D-1-12
Crucible Loader	12Y 35318, D-1-10
Gasket Dispenser	12Y 35345, D-1-4
Gasket Remover	12Y 35417, D-1-11
Reduction Furnace	12Y 35296, D-1-10, C-11
Reduction Bomb	12Y 35304, D-1, B-2
MgO Cutter	12Y 35342, D-1-2

[redacted]

Title	Drawing Number
Cutter Blade (Punch)	12Y 35341, B-1
Bomb Dumper	12Y 35332, D-1-10
Vibrator Mounting Bomb Dumper	12Y 35382, D-1, C-2
Bomb Pickler	12Y 35338, D-1-11
Bomb Pickler Electric Heating Unit	12Y 35343, C-1
Separation Table and Pickler	12Y 35336, D-1-31, C-32-33
Dummy Bomb	12Y 35346, D-1-6, B-3, B-7
Miscellaneous Unit Parts	
Spray Nozzle	12Y 35367, B-1
Immersion Cooler	12Y 35357, D-1
Entrainment Trap	12Y 35352, D-1-3
Gasket (Reduction)	12Y 35304, B-2
Air Cylinder Mounting Flange	12Y 35323, C-1-3
Valve Rack Housing (8 volt air)	12Y 35313, D-1-5
Valve Manifold (8 volt air)	12Y 35317, D-1-2
Plastic Bag Rings	12Y 35339, C-1-3
Carriage Drives	12Y 35358, D-1-7, C-8-9
Conveyor System	12Y 35326, D-1-13, C-14-15
Control Wiring	ENG-C-1278
Miscellaneous Equipment	
Filtrate Transfer System	12Y 36204, D-1-4
	12Y 36205, D-1-3
Tank Room	12Y 35324, D-1-6
Vacuum System	12Y 35315, D-1
Chemical Storage Tank System	12Y 35419, D-1, C-2-3
Water and Drain System	12Y 35316, D-1-6
Equipment Ventilation	12Y 35418, D-1-3, C-4
Schematic Layout of One Line	ENG-C-1277
Sound Trap (Control Room)	12Y 35375, D-1
Perforated Ceiling (Control Room)	12Y 35422, D-1
Rotary Packing Gland	12Y 35328, C-1

PURCHASED COMPONENTS

The following lists show the special items purchased for the remote control equipment, the University purchase requisition number and the vendor. Material and parts of standard type such as nuts, bolts, wire and common metals are not included.

[redacted]

ITEM	USE	PR NO.	VENDOR
Bearings:			
Ball, 1/4" ID, DS, Plated No. 1602	Carriages	123957	1
Ball, 5/16" ID, DS, Plated No. 1605	Carriages	125927	1
Ball, 3/8" ID, DS, Plated No. 1614	Stirrer	128392	1
Ball, 1/2" ID, DS, Plated, No. 1616	Carriage Drive	124068	1
Ball, 5/8" KD, DS, Plated, No. 1623	Mixer Carriage Drive	128577	1
Ball, 3/4" ID, DS, Plated No. 1635	Bomb Dumper	123957	1
Ball, 1/2" ID, DS, No. 1621	Carriage Drive	129303	1
Thrust, XW2, 7/9"	Separation Table	128150	2
Thrust, No. 710, plated	Withdrawal Unit	128934	1
Thrust, No. 87507	Withdrawal Unit	128935	3
Thrust, No. 610	Groove Cleaner	131633	1
Thrust, No. 88110	Dummy Bomb	132861	3
Bellows:			
1" x 3" Brass	Reduction Unit	127966	4
Monel	Mixer Interlock	128666	5
Cylinders (Air, Hydraulic)			
Air, Miller, 2-1/2" x 26"	Station Lifts	126177-9	6
Air, Miller, 2-1/2 x 4"	Station Lifts	126177-9	6
Air, Miller, 2-1/2 x 21, 1" Rod	Boat Removal Lifts	136396	6
Air, Miller, 2-1/2 x 16", Double Ended	Crucible Loader Lifts	126177-9	1
Air, Miller, 1-1/2 x 13", Hastelloy C	Bomb Scrubber	127969	6
Air, Miller, 1-1/2 x 1", Spring Return	Reduction Unit	129531	6
Air, Miller, 1-1/2 x 30, Double Ended	Button Separator	128252	6
Air, Miller, 1-1/2 x 10-1/2, Double Ended	Cutter Unit	128295	6

ITEM	USE	PR NO.	VENDOR
Cylinders (Air, Hydraulic)			
Air, Miller, 1-1/2" x 18"	General	128598	6
Air, Senacon, 4" x 13", hollow shaft	HF Unit Lift	137501	7
Air, Senacon, 1-1/2 x 9", Double Ended	Bomb Dumper	134163	7
L.P.H. Miller, 2-1/2 x 6"	Bomb and Boat Dumpers	126400	6
Electrical Equipment			
220V, A.C. 3 phase, 1/15 HP, 86 RPM	Separation Table	128108	8
220V, A.C, 3 phase, 1/15 HP, 173 RPM	Carriage Drives	129302	8
110V, A.C., 500 RPM 1/10 HP	Stirrers	128556	9
110V, A.C., 1/7 HP, 57-1/2 RPM	Withdrawal Unit	134944	9
110V, A.C, 1/20 HP, 86 RPM	Groove Cleaner	131632	8
110V, A.C., Model 312	Dummy Bomb	128355	10
Cartridge Heaters	HF Furnaces	130995	11
Special Heater	Bomb Pickler Unit	127979	
Thermoswitch, Fenwal	MgO Hopper	130961	12
Switches, Rotary, 18 Position	Control Panel	139542	13
Switches, Rotary, 24 Position	Control Panel	139542	13
Switches, 5 pos. lever	Control Panel	128907	14
Switches, General Control, Assorted	Control Panel	127289	14
Relays, 8V, Latching	Control Panel	133109	15
Induction Coil	Reduction Unit	139545	16
Gears and Racks			
Spur ND-36 Plated	Bomb Dumper Unit	126368	1
Spur ND-42, Plated	Bomb Dumper Unit	126398	1
Spur NB-32, Plated	Mixer Loader	124285	1
Worms, GH-1056 Steel	Separation Table	128107	1
Worms, G-1051, 12 pitch	Separation Table	128107	1
Worms, GB-1061	Carriage Drive	129303	1
Worms, GB-1060	Carriage Drive	129303	1
Worms, 1066	Carriage Drive	129303	1
Rack L-514	Boat Dumper	126368	1
Sprockets, 1/2" pitch, 16 teeth, 2.56" PD	Boat Conveyor	123954	1
Sprockets, 1/2" pitch, 32 teeth, 5.10" PD	Boat Conveyor	124285	1

[redacted]

ITEM	USE	PR NO.	VENDOR
Gears and Racks			
Chain Roller, No. 41 SS	Carriage Conveyor	123954	1
Sheaves, No. 2008 Plated	Boat Storage	134502	1
Flexible Metal Hose			
Flexible, SS, 3/8"IDx34"	Filtration Unit	136371	4
Flexible,SS,3/8"ID x 29"	Withdrawal Unit	131634	4
Flexible,SS,3/8"ID x 29"	Withdrawal Unit	131634	4
Valves			
Hand, 1/4" SS	General	130447	26
Hand, 3/8" SS	General		
Hand, 3/8" Monel	General	137593	26
Solenoid, 8 V, Air	Air to cylinders	124379	7
Solenoid, Monel, 3/8" NC	HF Unit	137593	26
Solenoid, Monel, 3/8" NC	HF Unit	136362	26
Solenoid, 1/4"NC, Steel	Chemical Lines	128388	26
Solenoid, SS, 1/4"NC	General	139529	27
Solenoid, SS, 1/4" NO	General	139529	27
Solenoid, 3 way, SS,1/4"	General	139529	27
Solenoid, 3/8" Double Spring Return	Separation Unit	139530	28
Solenoid, SS, 1" NO	Vent Lines	129144	26
Saran, NC	General	139532	29
Motorized, Monel, 3/8"	HF Unit	128579	26
Hand, Hastelloy C,1/4"	Bomb Scrubber	132876	26
Sequence	Reduction Booster	136349	30
Rack, L-512	Mixer Loader	128885	1
Rack, L-509	Mixer Unit	131615	1
Hastelloy "C"			
Castings, Special	Cutter Unit Blades	128888	17
Tubing, 4"OD x 16"L	HF Unit Trap	130688	17
Nuts, 1/4" - 20	HF Unit	130688	17
Bolts, 3/8" 16 x 1"	Bomb Scrubber	132882	17
Bolts, 1/4" 20 x 1" Hex Head	Bomb Scrubber	132882	17
Screws, 1/4 20 x 1-1/4", Flat Head	HF Unit	130688	17
Instruments			
Gauge, Compound Alarm	HF Unit	129146	19
Gauge, Compound Monel	HF Unit	127748	20
Gauge, Compound SS	Filtration Units	132877	19
Gauge, 0-1500 psi	Reduction Booster Unit	133040	19
Counter, Electric	Precipitation Control panel	136809	41

ITEM	USE	PR NO.	VENDOR
Instruments			
Rotameter, O_2	HF Furnace	139528	21
Pressure Switches, 50-150 psi	General	139527	22
Temperature Recorder	Prec. Filtration	125733	37
Rotameter, Recording, Totalizing	Prec. Filtration	127686	38
Rotameter, NH_3	Filtrate Vessel	128351	38
Counter, Electric	Prec. control panel	136809	41
Miscellaneous			
Pyrex vessel	Prec. Filtration	128000	23
Pyrex vessel, 6-1/2 OD	Button Pickling	131190	24
Lucite Cylinder	Vessel guard	128390	
Coupling, Flexible	Stirrer Drives	128392	1
Quartz Sleeve	Reduction Furnace	124562	16
Spray nozzles, SS	Prec. Filtration	131624	33
Vibrators, Air 1-1/4"	Cutter	126776	35
Vibrator, Air 3/4"	General	131180	35
Strainers, SS, 1/4"	Chemical Lines	130679	34
Washers, Lock-O-Seal	General	126831	40
Swivel Joint	Boat Dumper	136644	42
Lubricator, Air	General	124081	35
Ajax Converter 20 KW	Reduction	130695	16
Pump, Aluminum	Hydrogen Peroxide Tank	133161	43
Demineralizer, Water	Distilled Water	128356	47
Tank, Aluminum	Hydrogen Peroxide	133163	46
Tank, SS	Chemical Storage	128357	48
Tubing Fittings	Piping	130444	18

[redacted]

VENDORS

1. Boston Gear Works (Nice Bearings)
   Division of Murry Co.
   955 W. Washington Blvd.
   Chicago-7, Illinois
      Distributed by:
         Garrett Supply Co.
         3844 S. Santa Fe Avenue
         Los Angeles, 11, California

2. Norma-Hoffmann Bearing Corp.
   Stamford, Connecticut

3. New Departure
   Division of General Motors Corp.
   Bristol, Connecticut

4. Chicago Metal Hose Corp.
   Maywood, Illinois

5. Clifford Manufacturing Co.
   564 East First Street
   Chicago, Illinois
   Division of Standard Thomson Corp.

6. Miller Motor Co.
   4027-33 N. Kedzie Ave.
   Chicago, 18, Illinois
   Distributed by Haskel Engineering and Supply Co.
   Glendale, California

7. Smith-Johnson Corp.
   727 East Pico
   Los Angeles, 21, California

8. United Electric Machining Co.
   Chicago, Illinois

9. Bodine Electric Co.
   Chicago, Illinois

10. Skilsaw, Inc.
    Chicago, Illinois

11. Glenn Electric Heater Co.
    239-41 Canal Street
    New York, 13, New York

12. Fenwal Incorporated
Ashland, Massachusetts

13. Shallcross Mfg. Co.
Collingdale, Pennsylvania

14. General Control Co.
1200 Soldiers Field Road
Boston, 34, Massachusetts

15. Struthers Dunn Inc.
150 N. 13th Street
Philadelphia, 7, Pennsylvania

16. Ajax Electrothermic Corp.
Ajax Park
Trenton, New Jersey

17. Haynes Stellite Co.
Kokomo, Indiana

18. Aircraft Fitting Co.
1400 E. 30th Street
Cleveland, 14, Chio

19. Ashcroft Gauge Division
Manning, Maxwell, and Moore
Bridgeport, Connecticut

20. Helicoid Gage Division
American Chain and Cable Co., Inc.
Bridgeport, 2, Connecticut

21. Brooks Rotameter Co.
Lansdale, Pennsylvania

22. Saral Inc.
1915 E. 51st Street
Los Angeles, California

23. Corning Glass Works
Corning, New York

24. Phillips Petroleum Co.
Instrument Section
Bartlesville, Oklahoma

25. Dow Chemical Co.
Midland, Michigan

26. Associated Valve and Engineering Co.
1150 W. Marquette
Chicago, 21, Illinois

27. Skinner Electric Valve Division
Skinner Chuck Co.
Norwalk, Connecticut

28. Modernair Corp.
4222 Hollis Street
Oakland, California

29. Kase Machine Co.
18421 Buffalo Avenue
Cleveland-19, Ohio

30. C. A. Norgren Co.
222 Santa Fe Drive
Denver, Colorado

31. C. W. Marwedel
Oakland, 7, California

32. Brown and Sharpe Mfg. Co.
Providence, 1, Rhode Island

33. Spray Engineering Co.
Sommerville, Massachusetts

34. Zurn Western
Erie, Pennsylvania

35. Cleveland Vibrator Co.
2828 Clinton Avenue
Cleveland-13, Ohio

36. Haskel Engineering and Supply Co.
Glendale, California

37. Foxboro Company
Foxboro, Massachusetts

38. Fischer and Porter Co.
Hatboro, Pennsylvania

39. Golden State Rubber and Latex Products Co.
    Los Angeles, California

40. Franklin C. Wolfe Co.
    407 Commercial Center Street
    Beverly Hills, California

41. Veeder-Root Inc.
    Hartford, Connecticut

42. Crane Co.
    836 South Michigan Avenue
    Chicago, 5, Illinois

43. Portable Pump Co.
    St. Louis, 18, Missouri

44. Revolvator Co.
    North Bergen, New Jersey

45. Barrett-Cravens Co.
    3255 W. 30th Street
    Chicago, Illinois

46. Becco Sales Corp.
    Buffalo Electro-Chemical Co., Inc.
    34 Sawyer Avenue
    Buffalo, 7, New York

47. Barnstead Still and Sterilizer Co.
    Forest Hills
    Boston, 31, Massachusetts

48. Alsop Engineering Corp.
    Milldale, Connecticut