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SOME FABRICATION TECHNIQUES OF SPECTRAL LAMPS AND GAS ABSORPTION CELLS FOR RUBIDIUM MAGNETOMETERS

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JUNE 1965

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GREENBELT, MARYLAND

Prepared for presentation at the 10th Annual Symposium and Exhibition of the American Scientific Glassblowers Society

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Abstract: Although still a relatively new scientific instrument, the Rubidium vapor magnetometer has rapidly become an important tool in the measurement of magnetic fields in many different applications. Experimental development of the spectral lamps and resonant absorption cells, which comprise the heart of the magnetometer, is being conducted at the Goddard Space Flight Center with the intent of optimizing these components. The early phases of this work have been directed toward perfection of fabrication technique. This has led to: (1) a technique for manipulation of the rubidium metal such that it is available in stored quantities in the pure metal form, (2) methods of controlling the cleanliness in the filling operation and the amount of metal per cell, (3) the design of a liquid N_2 cold trap for a bakeable system, and (4) novel fixtures for fabricating glass components. The initial components fabricated by these techniques are currently being evaluated for performance and long life reliability.

Introduction

1. In this era of so many rapidly expanding disciplines of science none has been more spectacular than the technology concerning various optical pumping systems.

For an example: the Atomic Clock - so accurate that it will neither gain nor lose a second in a thousand years, and The Laser[1,2] and its ability to drill holes in diamonds, fasten the retina of an eye, track missiles and satellites, and provide means for deep space communication.

Another one of these quantum devices is the Rubidium vapor magnetometer. We are told how it can be used to find oil deposits deep in the earth's crust, locate skiers buried in avalanches, measure magnetic fields of the earth, and help plot the wake of the moon through the solar wind.

The heart of this instrument consists of an alkali metal spectral lamp and a pair of gas absorption cells. The lamps are less than a centimeter in diameter and contain a precise amount of isotopic Rubidium and a rare gas at about 2mm pressure. The resonance cells are typical cylindrical optical gas absorption cells about two inches in diameter and are similarly filled.

By experimenting with the design, materials, and fabrication procedures of these lamps and cells we hope to learn how we can improve their performance and reliability. A number of the methods employed can be applied in the construction of other types of glass apparatus. It is the purpose of this paper to describe some of these techniques.

2. Rb Processing

Rubidium, like most alkali metals, reacts with moisture in the air and is usually supplied in a more stable form such as an azide or a chloride. The separation process can be in conjunction with the filling procedure or processed separately. To add another measure of quality control and to simplify the filling apparatus, we process the Rubidium in a separate operation and stockpile it in breakseal ampoules. We are presently using the chloride and the following reaction is necessary to isolate it:

$$RbCl + CaH_2 \rightarrow Rb\ CaCl + H$$

One arrangement for doing this is shown schematically in Fig. 1.

In a reasonably good vacuum the initial heating is gradual, not exceeding 90°C for several hours, then we slowly raise the temperature in the oven to about 600°C. As the reaction proceeds, the trapping of Rb is easily maintained with ice water. When the reaction is completed we remove the reaction chamber by sealing it off with a torch. The free Rubidium is then directed into the ampoules by heating locally with a torch or encasing the whole manifold in an oven and leaving only the desired condensation places exposed for cooling.

3. Lamps

The two most important factors in both cell and lamp fabrication are cleanliness and extremely thorough outgassing. The lamps are less than a centimeter in diameter with a tubulation tube of only 3mm O.D. so stringent cleaning presents a problem. We found that cleaning the blanks prior to blowing and then keeping the interior of the bulbs completely isolated from the air was easier and more reliable then cleaning the finished bulbs.

We manage this by storing each blank, which is a 3mm tube butt-sealed to a 5mm tube, in distilled water immediately following a very thorough cleaning process.

When removed from the distilled water they are quickly connected to a remote or proxy blowing arrangement[3] using dry nitrogen. The water is blown out, the tube flame dried, and the bulb is formed. The stem is then sealed off and the bulb stored until it is sealed to the system at which time the stem is opened in an inert atmosphere and immediately sealed to the manifold. The manifold system is always connected to a similar remote blowing arrangement thereby eliminating air from the system completely.

Outgassing is accomplished by standard vacuum bakeout proceedure and ion bombardment. For the latter we use a small portable oscillator which we can move from lamp to lamp on the manifold, this is shown in Fig. 2.

Immediately following the first bakeout the system is flushed a few times with the buffer gas to obtain the optimum pressure. This is followed by several periods of RF excitation and then a final bakeout and the filling.

The Rubidium metal is distilled out of the break-seal ampoule into the manifold which is housed in a demountable oven, as shown in Fig. 3, that leaves just the bulbs exposed to a cooler temperature. The bulbs are cooled by a beaker of cold water or a cold jet of air. When the correct amount of rubidium has been condensed in the bulbs, the oven is removed, the buffer gas is admitted, and the lamps are sealed off.

4. Cells

The outgassing and filling procedure for the cells is essentially the same as for the lamps. Standard methods for fabricating optical absorption cells are used, such as the grinding and polishing of all components to the required demensions prior to sealing at the proper ambient temperature. The order of assembly is presentec in Fig. 4.

The cylinder is ground and polished parallel and flat to about 5 wave lengths of H_g light. The windows are ground and polished to the same tolerances and one window is drilled for the tubulation seal. Note: A bevel is necessary in grinding and polishing the discs. Thus if an especially well matched seal is desired it is recommended that the discs be made oversize and, after polishing, edgeground down to a square corner which will exactly match the cylinder O.D.

The window is sealed using an oxy-hydro torch, directing the flame on seal with oven about 600°C and then annealed. The oven consists of 2 commercial semi-cylindrical heaters with fiber glass and asbestos tape insulation. The above arrangement as shown in Fig. 5 is very quickly set up by utilizing a vertical lathe. The lower head stock is the turn table and the upper tail stock, disengaged, holds the oven in a stationary position. This has the added advantage of providing controls for raising and lowering.

Another feature of this arrangement shown in Fig. 6 is the holder set which is simply three stainless steel bars with a radius machined in the end that has the same radius as the cells. These bars replace the asbestos grips of the juck jaws by loosening two Allen head bolts in each jaw and sliding out the asbestos grips and sliding in the steel ones. Figure 7 shows how this holder arrangement is also convenient for centering holes for drilling by placing a core drill in the disengaged tailstock.

5. The vacuum system, as shown in Fig. 8 is typical of most custom gas filling systems. It provides a low ultimate vacuum, a fast pumping system, a convenient bakeout arrangement, and has provision for assorted gas insertion. These are familiar arrangements so a detailed description will not be of wide interest. I would like to point out, however, several innovations that contribute significantly to the effectiveness. One, is the liquid nitrogen traps as shown in Fig. 1.

The design is of the reentry type, which is a considerable spacesaver as it eliminates an external dewar flask. The long, small diameter, internal neck provides a low loss factor and the three bulb contour maintaining an annular orifice ratio of .62 [4] provides the maximum conductance with most efficient trapping. Aluminum foil on the exterior helps prevent radiation losses.

The other innovation is simply the changing of the vent from the foreline to the extreme end of the high vacuum side and using only dry inert gas for venting. This arrangement eliminated a lot of contamination and reduced pump down time considerably. Evidently when a system is vented from the foreline side it is analogous to the operation of a gas chromagraph[5] when the venting gas acts as the fluid phase and carries the constitutents of the sample mixture. (In this case the sample would be the contaminants that accumulate in the diffusion pump, forepump, and foreline).

6. <u>Summary</u>

I would like to emphasize that this presentation is concerned primarily with the techniques and methods of fabrication associated with the experimentation at Goddard Space Flight Center, and should not be misconstrued to be the original invention of alkali metal spectral lamps and gas resonant cells for magnetometers.

Several series of lamps and cells are currently being tested for performance and long life reliability. Present observations show the results of the lamps to be relatively good. A considerable improvement in the absorption cells is anticipated by modifying some of the filling techniques and incorporating some recent design changes in the configuration.

Acknowledgements

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List of Figures

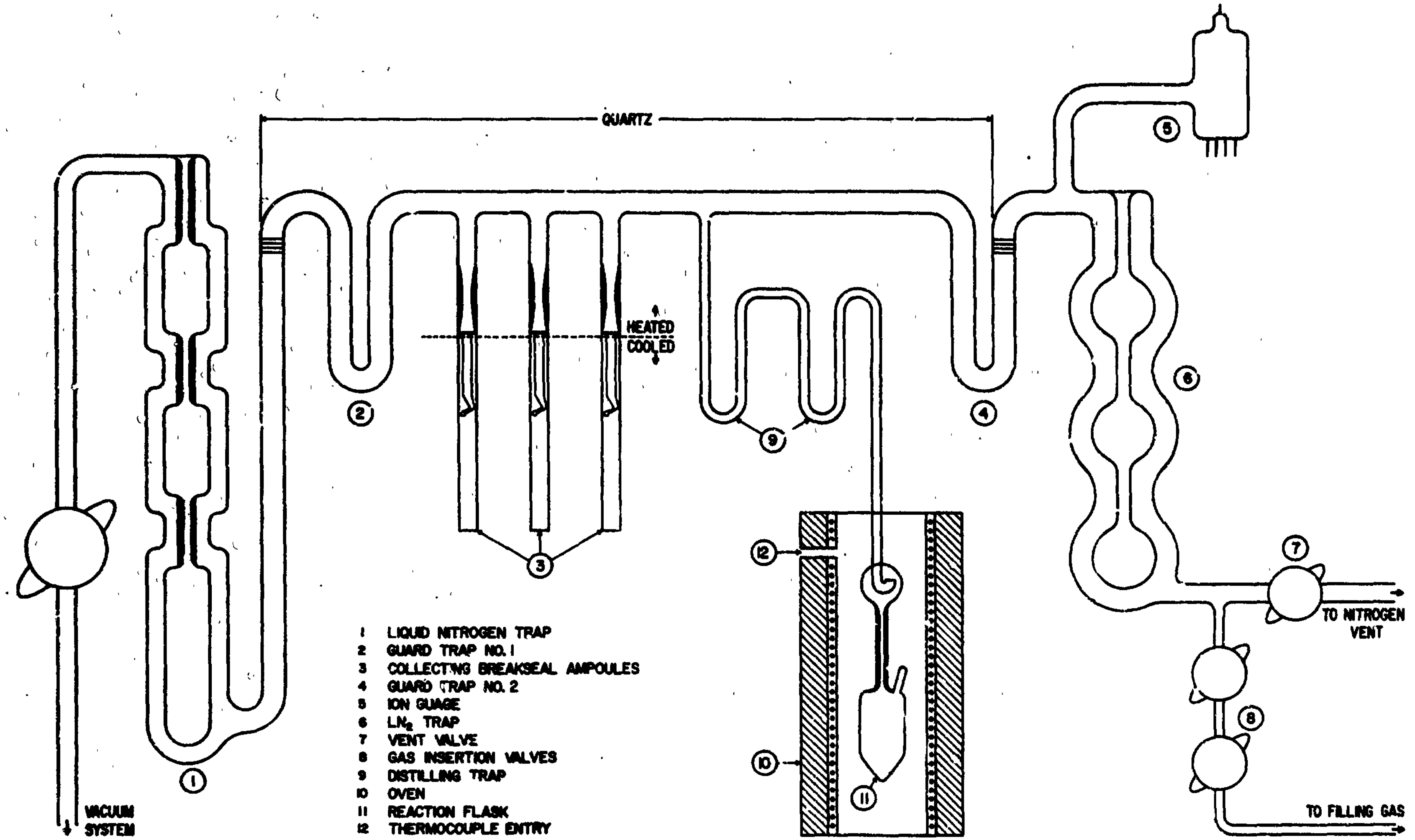
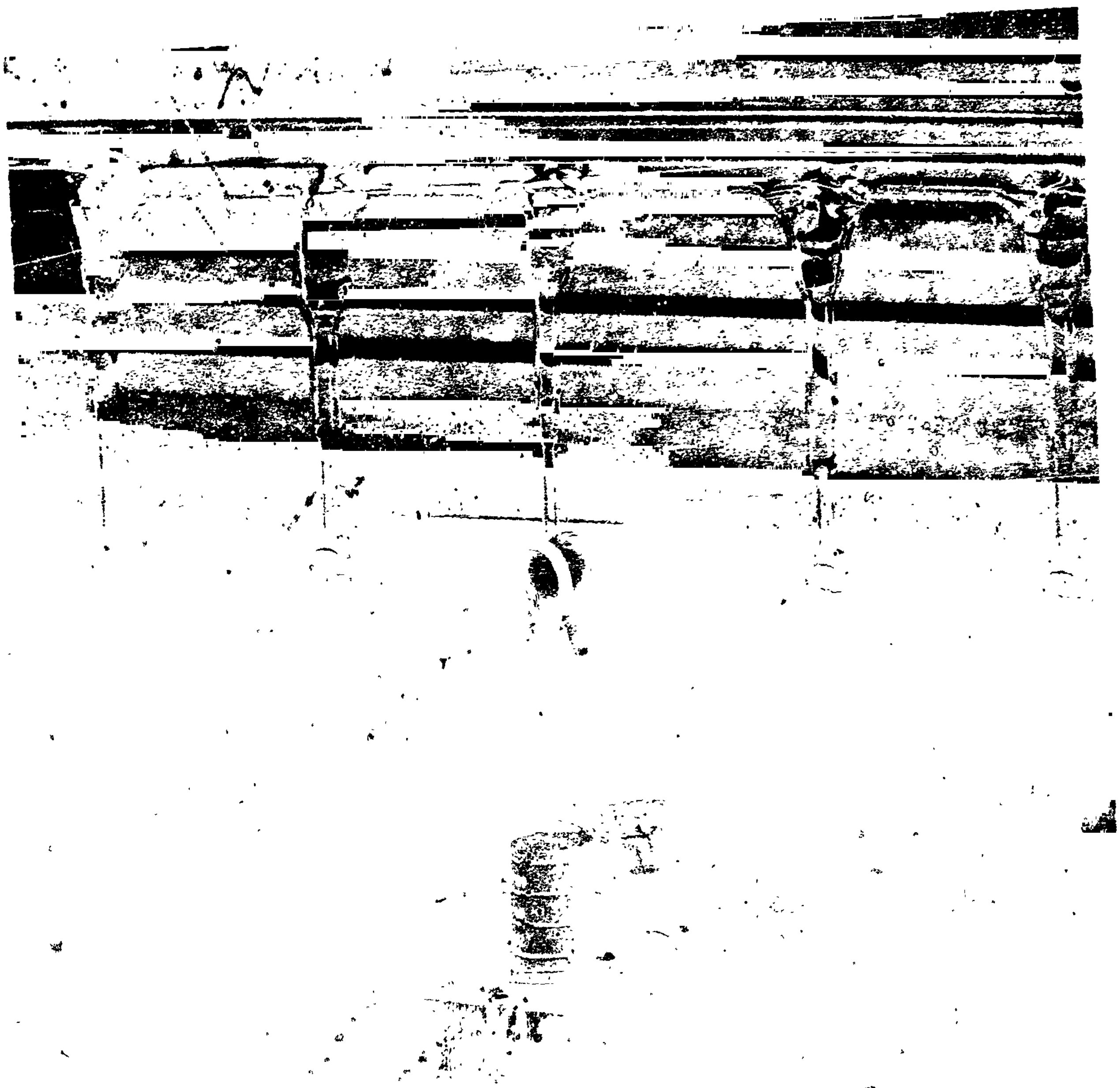

QUARTZ
HEATED
COOLED
1 LIQUID NITROGEN TRAP
2 GUARD TRAP NO. 1
3 COLLECTING BREAKSEAL AMPOULES
4 GUARD TRAP NO. 2
5 ION GUAGE
6 LN_2 TRAP
7 VENT VALVE
8 GAS INSERTION VALVES
9 DISTILLING TRAP
10 OVEN
11 REACTION FLASK
12 THERMOCOUPLE ENTRY
VACUUM SYSTEM
TO NITROGEN VENT
TO FILLING GAS

Figure 1



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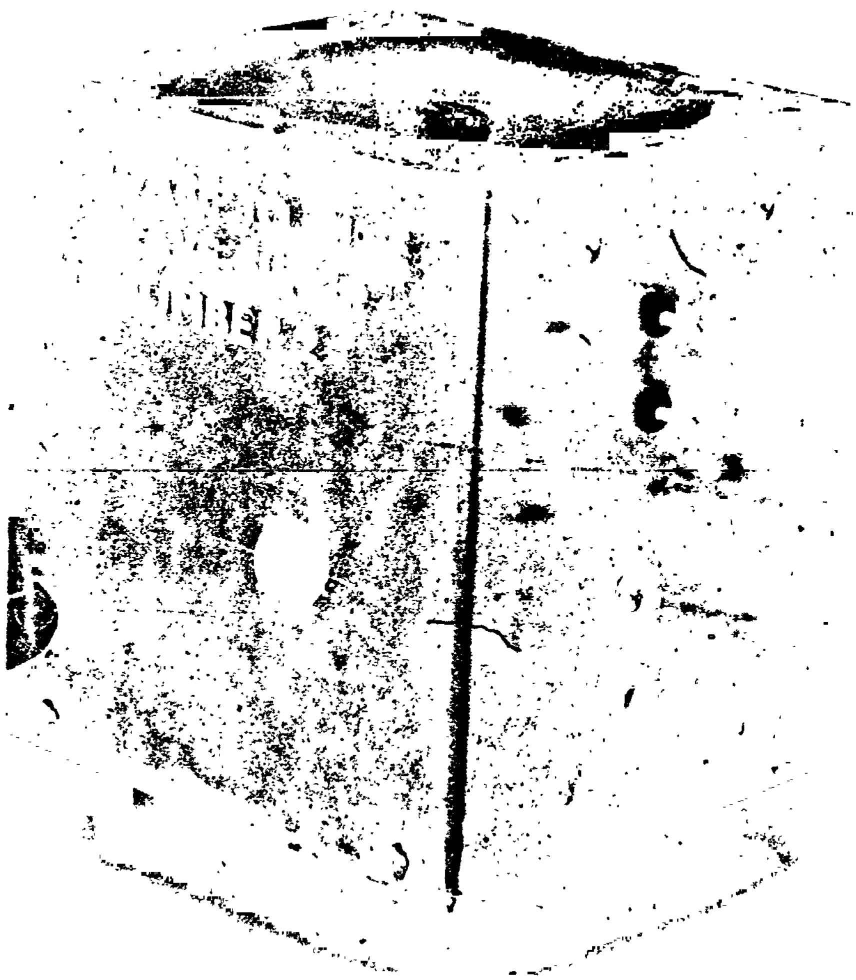

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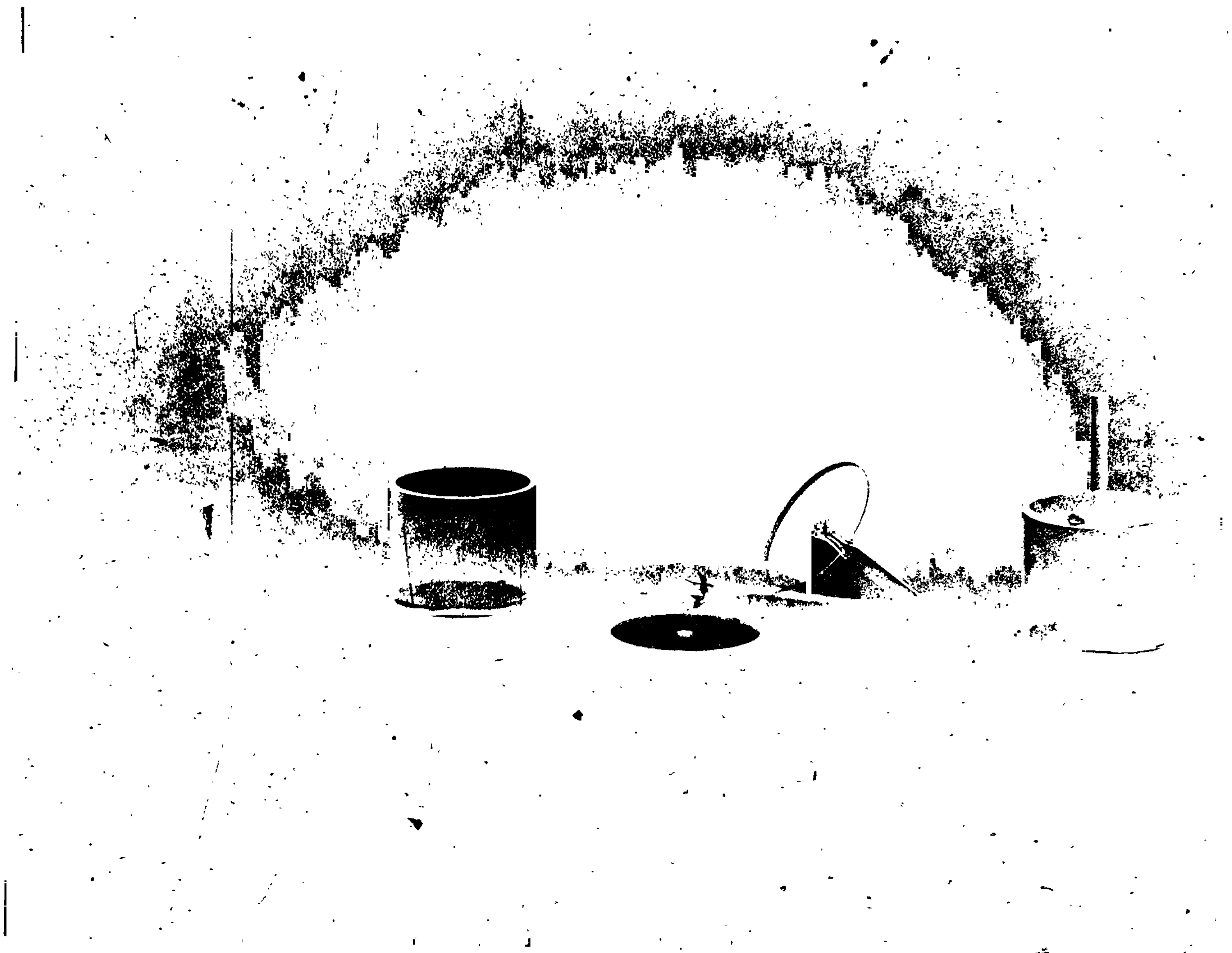

Figure 4

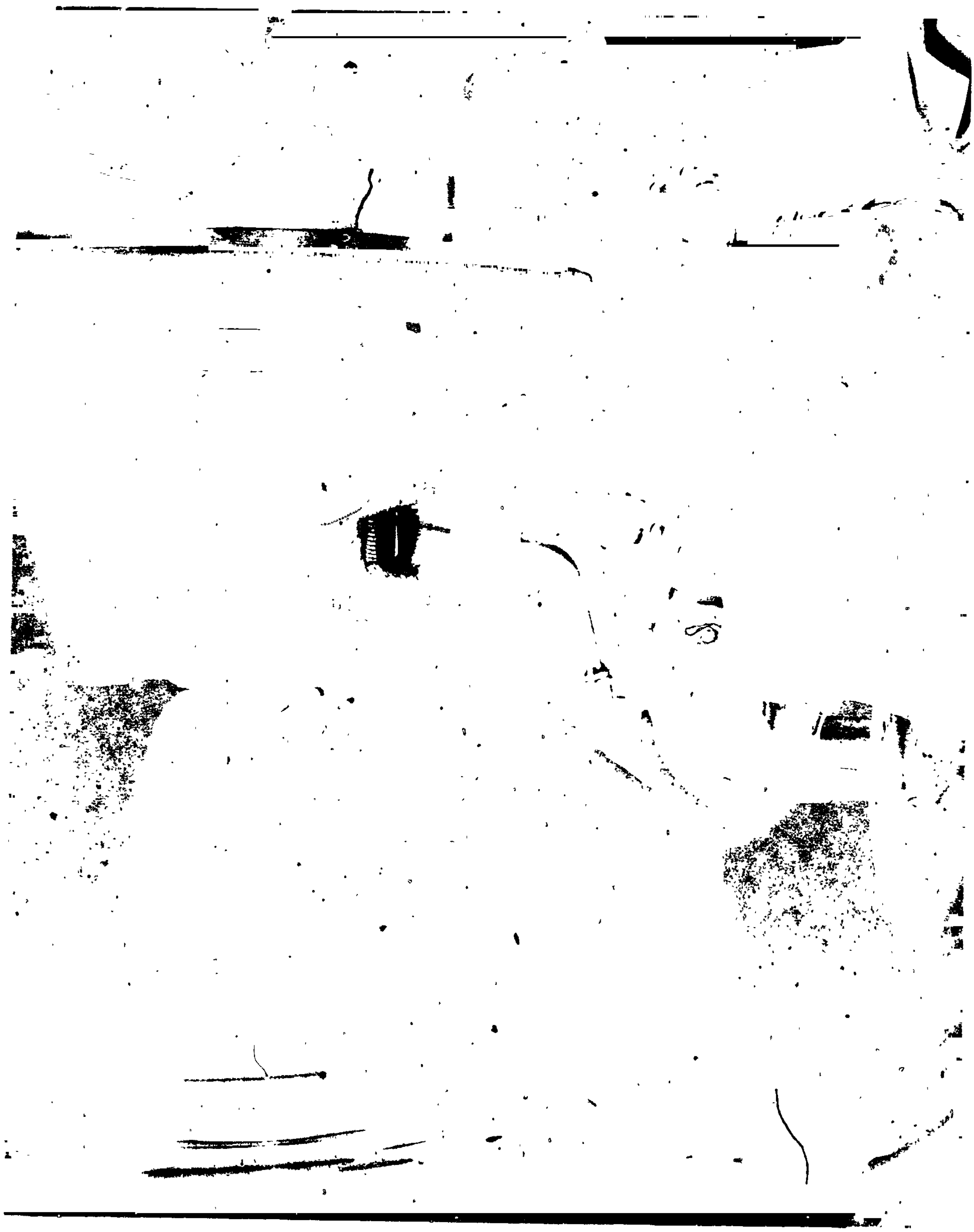

Figure 5

Figure 6

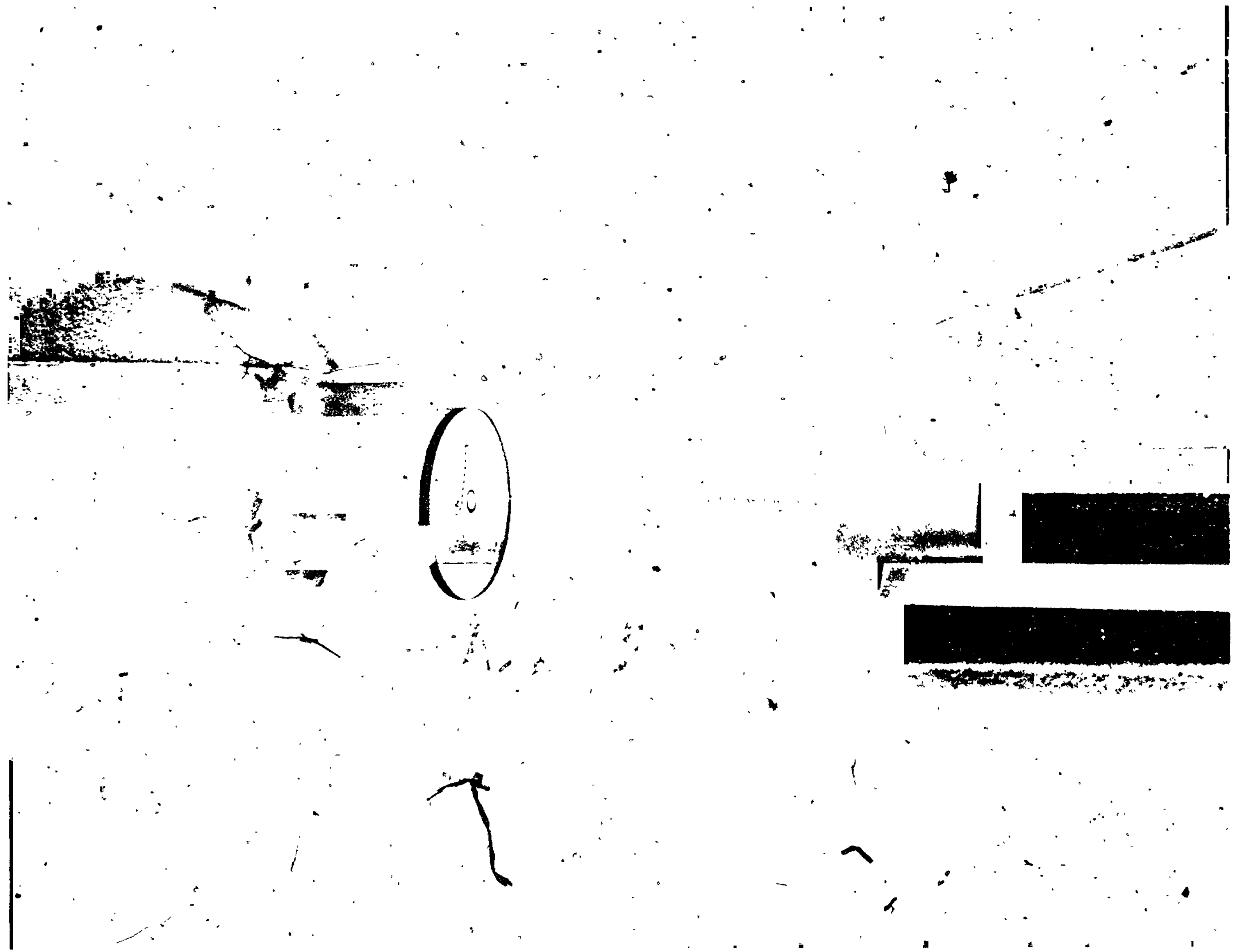

Figure 7

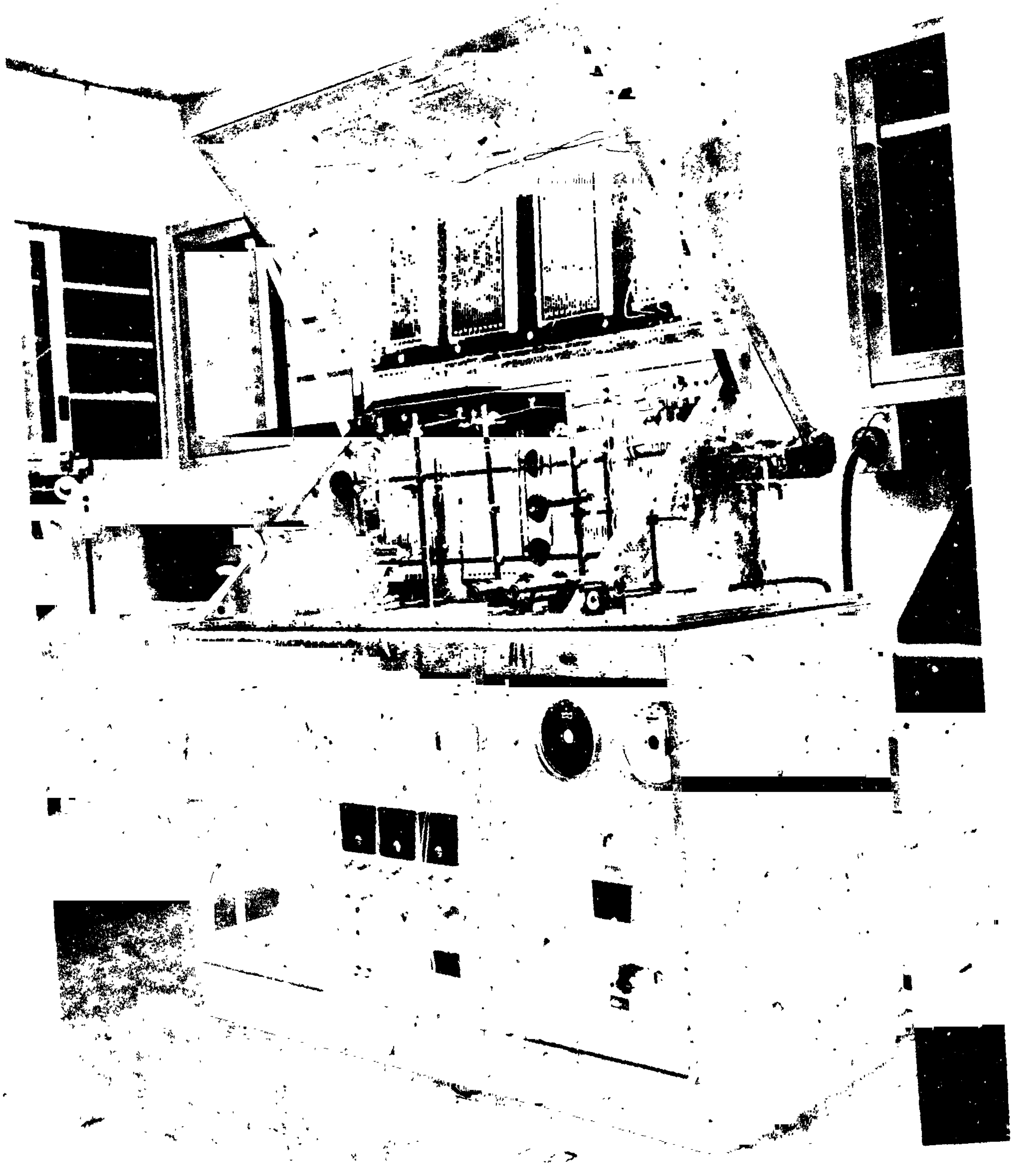

Figure 8