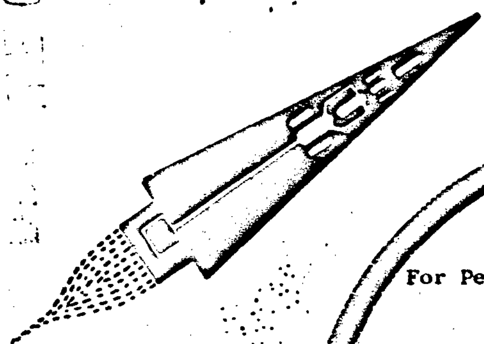
SPACE POWER AND PROPULSION SECTION



QUARTERLY REPORT #7

For Period Ending January 15, 1964

DYNAMIC SHAFT SEALS IN SPACE

Under Contract #AF33(657)8469

For

Aeronautical Systems Division
Wright Patterson Air Force Base, Ohio

MISSILE and SPACE DIVISION

GENERAL ELECTRIC

CINCINNATI, OHIO

SPACE POWER AND PROPULSION SECTION

QUARTERLY REPORT NO. 7

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RE-ENTRY SYSTEMS DEPARTMENT

MISSILE AND SPACE DIVISION

GENERAL ELECTRIC COMPANY

CINCINNATI 15, OHIO

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I. SUMMARY

The Space Power and Propulsion Section of the General Electric Company has been under contract to the Aeronautical Systems Division, Wright Patterson Air Force Base, Ohio, since April 15, 1962, for the development of dynamic shaft seals for space applications. The objective of this program is to acquire the techniques for sealing high speed rotating shafts under the operating conditions of high temperature liquid metals and vapors, the near-vacuum environments of space and to provide long seal life.

A. The contract specifies the following requirements:

1. The fluid to be sealed shall be potassium.
2. The seals shall be operative at fluid temperatures from the melting point of the fluid selected to 1400°F.
3. The pressure on the fluid side of the seal shall be 15 psi and the external pressure shall be 10^{-6} mm Hg.
4. The speed of the rotating shaft shall be a maximum of 36,000 rpm.
5. The seal, or seal combinations, shall be designed for 10,000 hours of maintenance-free life.
6. The working fluid, potassium, shall be used as the seal lubricant.
7. The seal, or seal combinations, shall be capable of maintaining zero leakage - in the technical sense - under all conditions of operation.
8. The seals shall be designed for a 1.0 inch diameter shaft.
9. The seals shall be capable of operating in a zero "g" environment.

B. The seal evaluation shall consist of:

1. Preliminary experiments with water.
2. 100-hour operational screening test with liquid metal.
3. Thermal-cycling test with liquid metal.
4. 3000-hour life test with liquid metal.

This Quarterly Report covers progress during the quarter ending January 15, 1964. The main events of this reporting period are:

(1) Investigation of modifications to the dynamic zero leakage seal, hereafter called, DZL seal, was continued. The investigations were performed in Building 301 using the 20,000 rpm water seal test rig. However, the investigation was conducted entirely using ET-378 oil instead of water. The investigations were used to determine configuration changes which would improve the capabilities of this seal.

(2) Seal testing for the SNAP-8 project using Bendix ET-378 oil was completed. This work was performed under a sub-contract from the General Electric Advanced Technology Laboratory. The DZL seal was applied to the SNAP-8 Generator system during this investigation.

(3) The DZL seal developed at Evendale for the SNAP-8 project was checked out at General Electric's Advanced Technology Lab using ET-378 oil. A successful test run of 36 hours with a vacuum of 29.5 mm. Hg. sealed from atmosphere was successfully performed without any visible leakage.

4) A computer program was adapted for use in the reduction of the test data obtained during the water seal testing. The program is presently adapted for use with the rotating housing seal tests, however, minor modifications will adapt it for use with the rotating disk and squeeze seal tests.

5) The liquid metal seal test rig manufacturing continued during this quarter. The major components of the test rig have been machined. However, the delivery date is now set at March 15, 1964.

6) Manufacturing of the liquid metal seal test facility was completed during this quarter. The facility has been received and installed in our Bldg. 314. Final instrumentation and checkout of the facility is presently in process.

Since funding for this project had been depleted by the start of this quarter, primary progress was directed toward the liquid metal test rig and facility manufacturing which did not require contract funding.

II. PRESENT STATUS

A. Fluid Dynamic Testing

Investigation of the DZL seal continued during this reporting period. The 20,000 rpm water seal test rig was used for this investigation. However, the operating fluid used for this testing was Dow Chemical's ET-378 oil instead of water. This allowed the investigation to include vacuum conditions as well as low pressurized conditions. The use of this DZL seal has completely eliminated the interface instability problem associated with the dynamic seal concept and has provided acceptable operations under high speed vacuum conditions.

Investigation of another modified version of the DZL seal was made during this reporting period. The seal was changed to allow rapid assembly and disassembly without inner connections which required tedious fastening or brazing. It was hoped that this seal would provide a solution to the difficult assembly problem associated with the presently conceived and working DZL seal. However, the testing indicated a small liquid leakage, about a drop every two seconds using the DOW ET-378 fluid. Leakage usually occurred at about 10,000 rpm but it did not increase significantly with speed. At 15,000 rpm, the leakage however, increased considerably to what could be considered an unacceptable level. This increase in leakage might indicate improvement was required in the control of the weight flow into the seal. No further studies, however, have been made because the seal configuration is not as good as a configuration already on the liquid metal seal test rig. If small leakage rates could be tolerated, however, the tested configuration might be applicable, since the assembly of the seal is very simple.

Continued testing of the above nature will proceed for the purpose of defining and simulating potential seal designs which may be applicable to the liquid metal seal operation throughout the next reporting period. However, these test periods will be of a very minimum nature and detailed test information will not be obtained; only the feasibility will be demonstrated.

A dynamic zero leakage seal was supplied to the Advanced Technology Laboratories for endurance testing under high vacuum conditions. The DZL seal was operated successfully at 12,000 rpm for 36 hours in a vacuum of 29.5 inches of mercury on a SNAP-8 generator simulator test rig using the synthetic oil ET-378 at 300°F. No leakage was detectable throughout all of the testing.

A computer program has been adapted for use in the reduction of the test data obtained during the water seal testing. The program is presently adapted for use with the rotating housing seal tests; however, minor modifications will adapt it for use with the rotating disk and squeeze seal tests. The program has been completely checkedout for the rotating housing data reduction. Input is presently being prepared for reduction of all the rotating housing seals tests.

B. The Liquid Metal Seal Test Rig

Manufacture of the liquid metal seal test rig continued during this reporting period. The original quotation covering the manufacture of this test rig detailed a rotating disk seal configuration mounted on the seal test rig. This configuration, it has been learned after extensive testing with the water seal test rig would not function properly from a zero leakage standpoint. The preliminary testing has revealed that, while the rotating disk provides an acceptable sealing device from a pressure standpoint, there were surface instabilities which allowed small amounts of leakage from the seal cavity. Therefore, it was necessary to redesign the back end of the seal test rig in light of the seal technology made available from the preliminary testing. This redesign was performed on the seal test rig and the design drawings and specifications were transmitted to the manufacturing vendor. This redesign test configuration was an application of the DZL seal developed in the preliminary testing.

A complete report has been issued during this reporting period covering the design philosophy behind the liquid metal seal test spindle. This design philosophy includes the heat transfer considerations, the vibration considerations, as well as the overall gas bearing design work. The design data included within the report were identical to that reported earlier in the Fifth Quarterly Report except for the critical speed calculations. A re-evaluation of the critical speed calculations utilizing the redesigned spindle revealed that first system critical speed was in the neighborhood of 20,000 rpm whereas the second system critical speed was well above the maximum operating rpm of 36,000 rpm.

The test spindle for liquid metal seal operation and the seal configuration are in the following stages of manufacturing: Refer to Figure 1 - the front end or turbine support end of the test rig has been completely manufactured and is ready for assembly within the test rig. The gas bearing shaft has been completely machined and is presently being heat-treated prior to final grind. The gas bearing housing has been fully machined and is presently being heat-treated before plating of the inner bores. After final plating of the inner bores, it will be necessary to lap the bore surfaces to the required diameters. The back end, or seal configuration end, has been partially machined and is presently being expedited to completion as quickly as possible. The manufacturing vendors date for shipment to General Electric however, has slipped to March 15.

When the final liquid metal seal test rig has been received at General Electric it is intended that the rig be set up within the liquid metal test facility as soon as possible. The necessary instrumentation and facilities are presently being set up so that there is no delay in the initial operation of the spindle once the test rig arrives. The present plan of operation for the test spindle requires that the spindle be checked out in a low vapor pressure oil prior to operation in liquid metal. This will insure that the test spindle operates properly as designed, and operation of liquid metal should then proceed with good confidence.

C. Liquid Metal Seal Test Facility

The manufacture of the liquid metal seal test facility has been completed. The test facility has been moved to General Electric's Evendale Building #314. The installation within the building has now been completed. The installation of the liquid metal seal test facility within Bldg. 314 required many modifications to the existing building and the installation of many facility services for the seal rig to be properly operated.

Work is now progressing on the completion of the set-up for checkout of the liquid metal loops without the seal test rig. This will require that the facility be operated using jumper lines in place of the seal configuration for checkout of the facility operation. The operation of both the liquid metal and the argon supply can be checked at this time with special attention given to the facility's ability to separate the argon from the liquid potassium. This checkout will allow the problems encountered in the operation of the facility to be corrected in time for actual usage when the liquid metal seal test spindle arrives. For a discussion on the capabilities of the potassium facility and the schematic covering the facility, a review of the Third Quarterly Report is recommended.

Enclosed are several photographs showing the installation of the test facility in Building #314. Figure #2 shows an overall view of the test rig installation. It may be seen that the test rig is centrally located in the center of the building and that numerous service facilities have been provided on the building wall. This will allow maintenance of the equipment in an easy manner which would otherwise be difficult, if the entire service facility had been installed within the liquid metal facility enclosure. Figure #3 shows an end view of the seal facility with the seal test chamber enclosure doors open. This is the chamber in which the seal rig will be placed and where operation of the vacuum equipment will take place. The vacuum diffusion pump is shown therein. Figure #4 shows the operating panel for the test facility. This operating panel, along with a yet-to-be-installed instrumentation panel is within the control room beside the test facility. From within this control room, it will be possible to control the test facility, as well as monitor the performance of the liquid metal seal. Figure #5 shows the nitrogen and argon receivers for supplying gas to the seal facility. These receivers are installed outside the Building #314. The argon will be used for the test spindle gas bearings and as a cover gas over the liquid potassium. The nitrogen will be used in the facility cold traps.

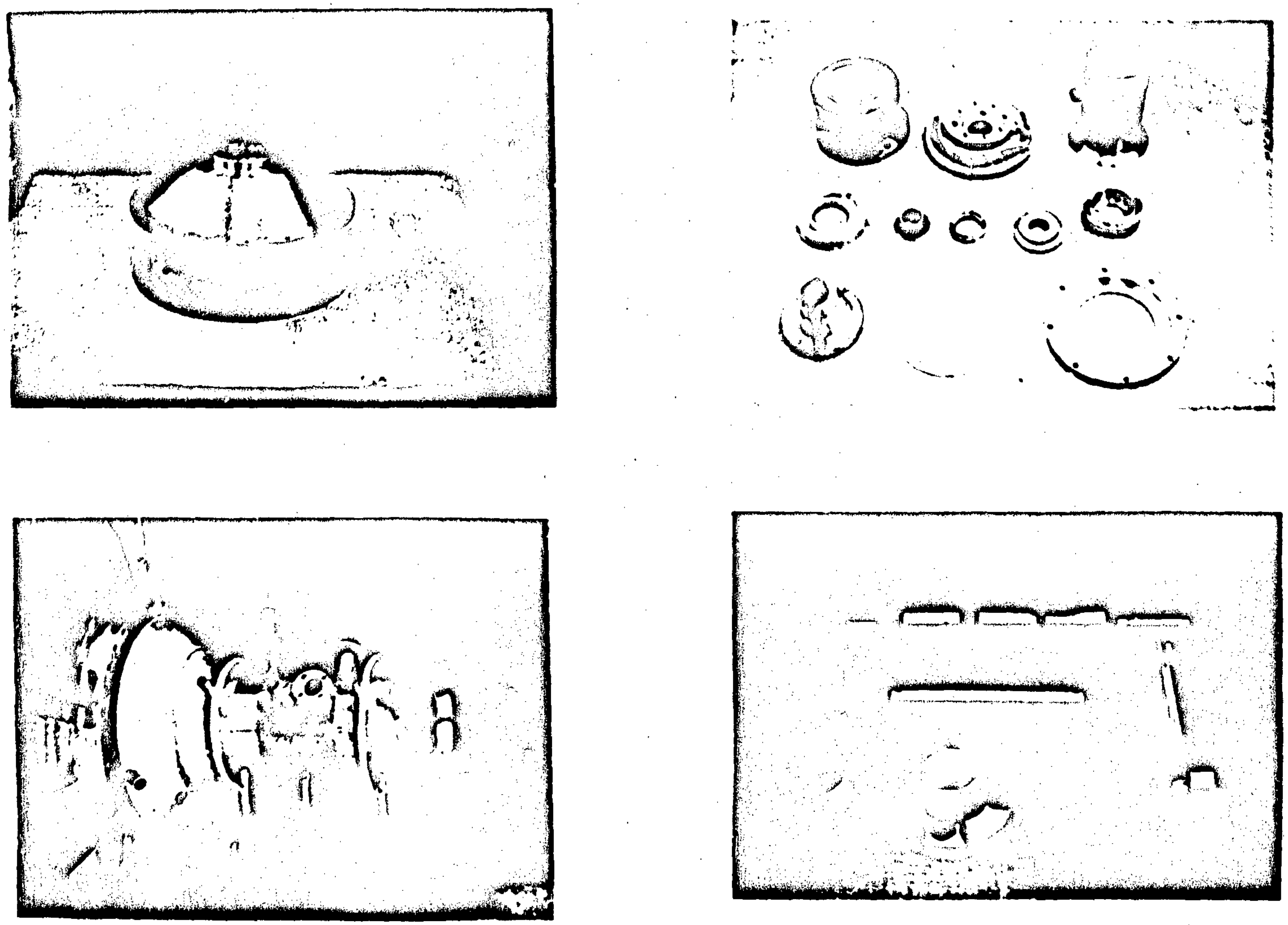

Figure 1. Seal Test Rig Hardware.

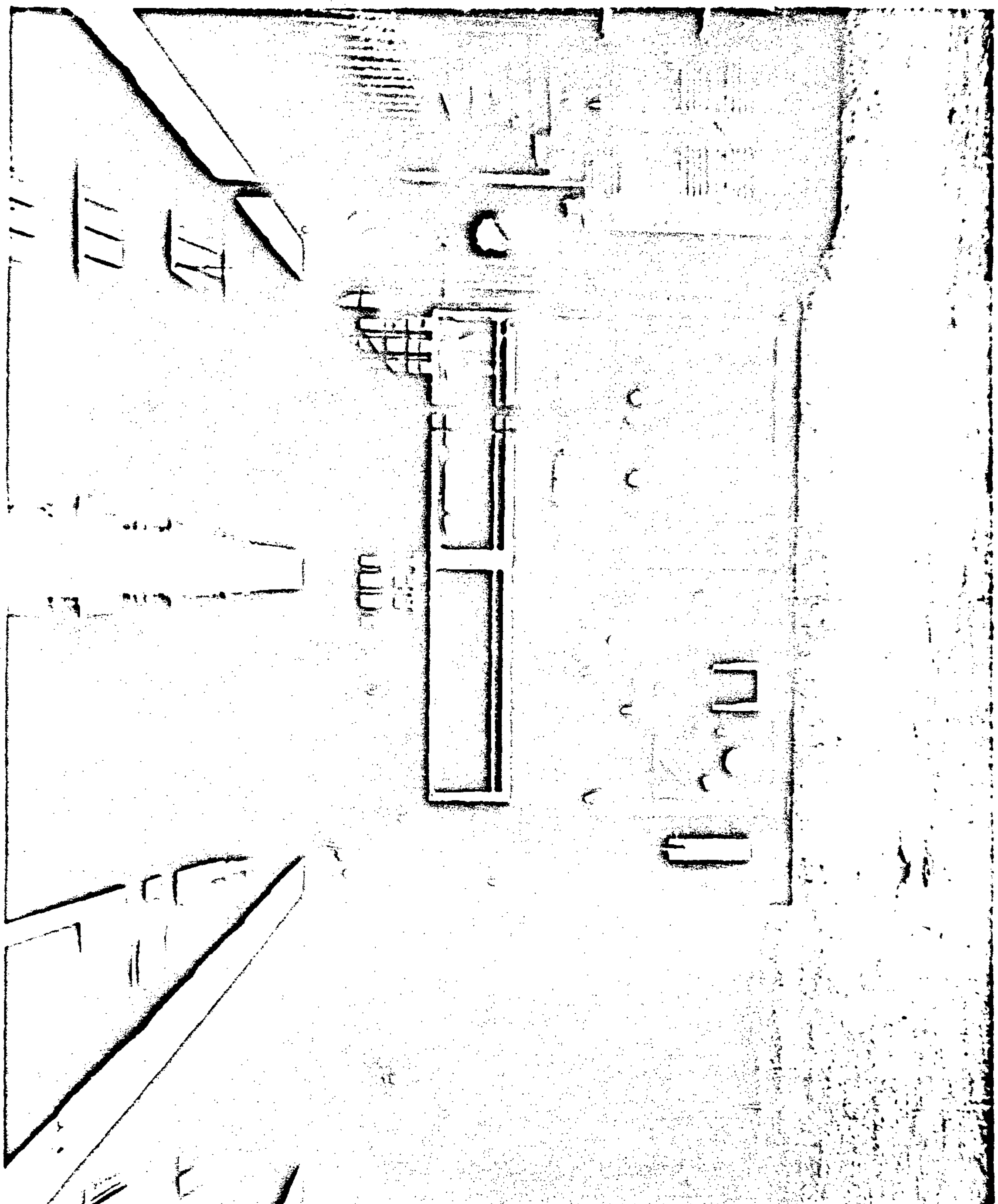

Figure 2. Liquid Metal Seal Test Facility (C62010222)

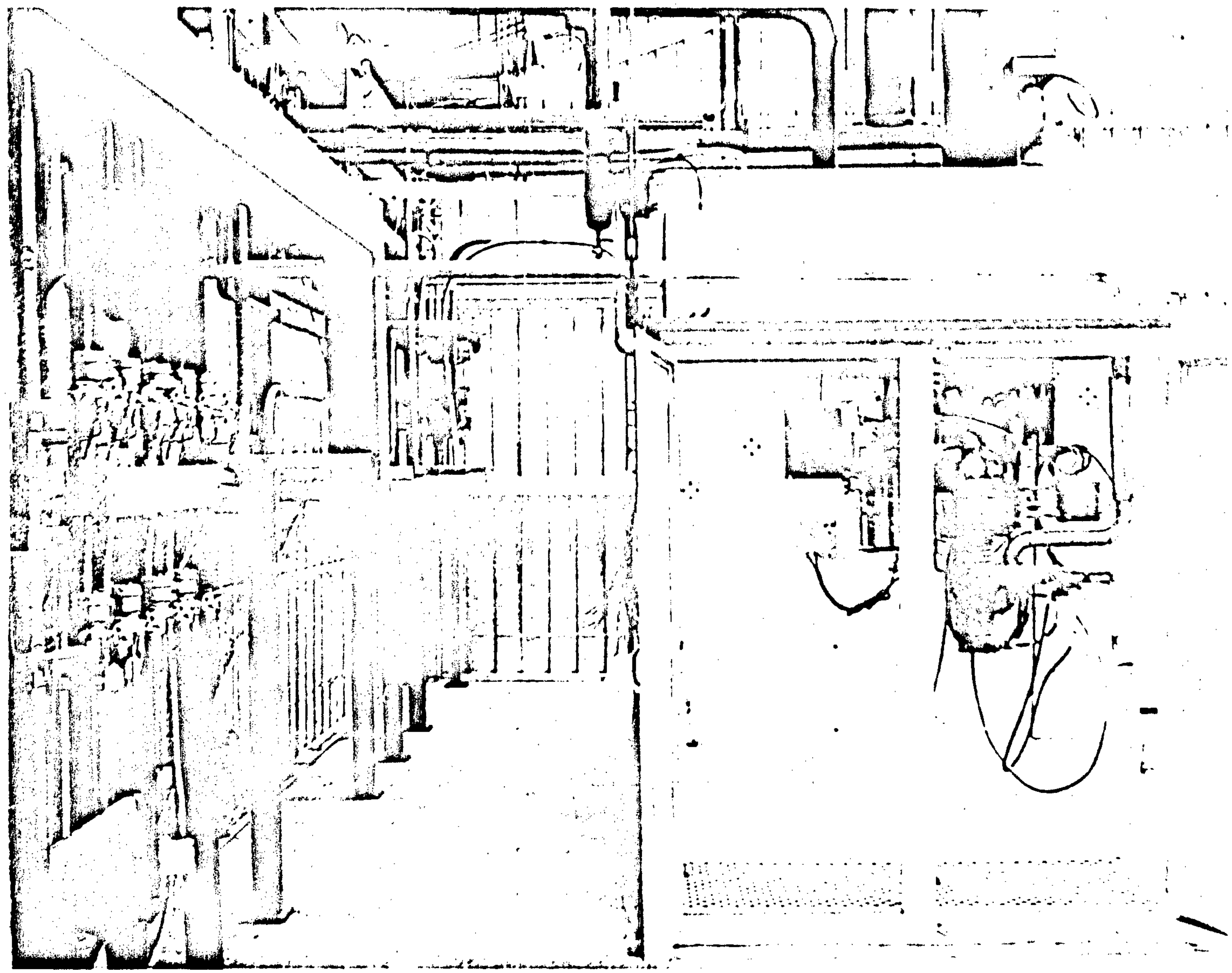

Figure 3. Test Chamber (C64010223)

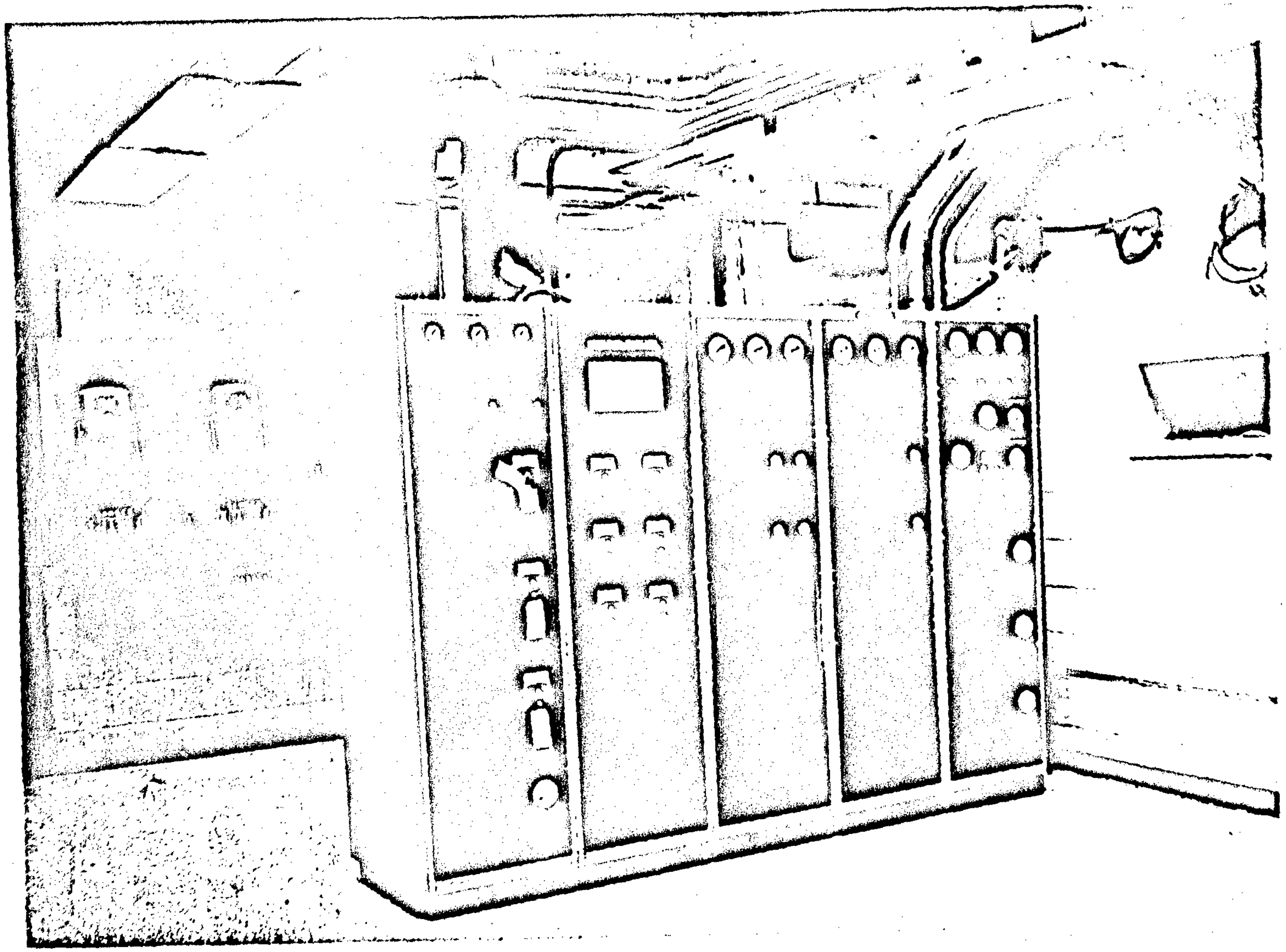

Figure 4. Facility Control Panel (C64010221)

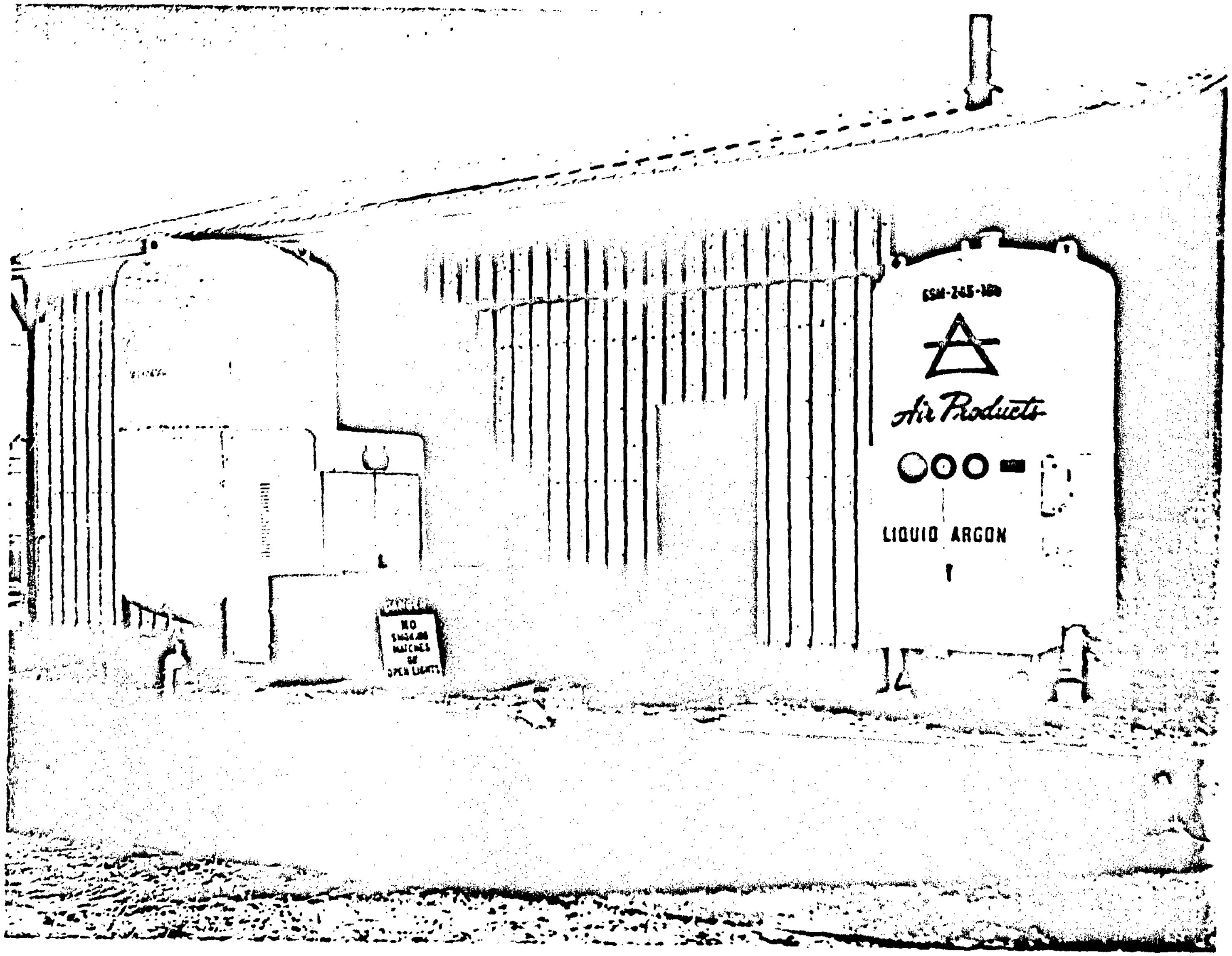

Figure 5. Argon and Nitrogen Receivers (C64010220)

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