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(NASA-CR-120303) VACUUM
DISTILLATION/VAPOR FILTRATION WATER
RECOVERY Summary Report for Phase 3
(General American Transportation Corp.)

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VACUUM DISTILLATION/VAPOR FILTRATION

WATER RECOVERY

Summary Report for Phase III

Contract No. NAS 8-27467
GARD Project No. 1528

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GENERAL AMERICAN RESEARCH DIVISION

FOREWORD

This report summarizes the activities accomplished for preparing to evaluate a Vacuum Distillation/Vapor Filtration water recovery system for low-gravity testing. The report documents only preparatory tasks completed or partially completed during the period 8 June 1973 to 16 January 1974; the low-gravity tests have not yet been conducted in aircraft parabolic flights. The work was conducted for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration under Contract NAS 8-27467 by the General American Research Division of the General American Transportation Corporation.

The NASA Project Monitor was Mr. James L. Moses, Deputy Chief, Life Support and Environmental Branch, Propulsion and Thermodynamics Division (S&A-ASTN-P). Personnel in the Chemical and Environmental Systems Group at GARD performed the activities under the direction of Mr. George A. Remus; Mr. Robert J. Honegger served as Project Engineer and Mr. Robert B. Neveril served as Design Engineer.

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Section 1

INTRODUCTION

This report summarizes the activities of the General American Research Division (GARD) of General American Transportation Corporation (GATX) to perform preparatory tasks for conducting low-gravity tests of a vacuum distillation/vapor filtration (VD/VF) system for recovering water from urine. Prior developments of the VD/VF system's basic components were accomplished during program Phases I and II and have been documented in Report NASA CR-124397.

1.1 Program Objectives

The overall program objectives were to develop and evaluate a vacuum distillation/vapor filtration (VD/VF) water recovery system. As a functional model, the system was to convert urine and condensate waste water from six men to potable water on a steady-state basis. The system was designed for 180-day operating durations and for function on the ground, on zero-g aircraft, and in orbit.

The objectives for program Phase III were to make the necessary preparations for and conduct low-gravity testing of the VD/VF water recovery system developed in Phases I and II.

1.2 Program Summary

The preparations for low-gravity testing were divided into the following tasks:

- a. Design and fabricate frames and assemble system on frames
- b. Procure and/or fabricate test support components
- c. Write test plan for low-gravity tests
- d. Obtain the required preflight indoctrination and training

e. Conduct ground performance testing of system.

To date, item (a) is partially completed. Design and fabrication of the tie-down frames was completed, but some finishing work remains to complete the system assembly on the frames. The hardware, in its present status of assembly, was reviewed with Man/Systems Simulations (S&E-ASTN-SMS).

Item (b) was completed.

Item (c), low-gravity test plan, was prepared in preliminary form. Detailed test procedures need to be determined during ground performance testing and incorporated in the final test plan.

GARD personnel who will assist in the low-gravity flights have completed the security clearance, the FAA Class II physical, and the physiological training requirements. The personnel have yet to complete the survival training requirement of item (d), preflight indoctrination and training.

Item (e), ground performance testing of the system in its flight testing configuration, remains to be completed.

Although the contract Scope of Work provides for making preparations for low-gravity tests, assisting in conducting the low-gravity tests aboard a parabolic flight aircraft, and producing the necessary documentation of the tests, the preparations only have been partially completed to date. This incompleteness is due primarily to more time actually required than estimated to design and fabricate the frames and mount the VD/VF components on the frames.

Section 2

SYSTEM OPERATION

The VD/VF Water Recovery System is comprised of an evaporator, catalytic oxidation unit, and condenser, as well as auxiliary heat exchangers, valves, pumps, and controls. The evaporator boils urine and humidity condensate into raw vapor; the catalytic oxidation unit removes organic contaminants and bacteria from the vapor; and the condenser condenses the catalytically oxidized and filtered vapor into potable water. The auxiliary components provide the proper temperature, pressure, and flow conditions for the evaporator, catalytic oxidation unit, and condenser to function properly and provide for continuous and essentially automatic system operation.

A schematic flow diagram of the VD/VF system is shown in Figure 2-1. During normal operation pretreated urine and humidity condensate mixture is metered into the evaporator by a timer-actuated feed control. At preset intervals, a repeat cycle timer signals the feed control to transfer a metered volume of urine into the evaporator. A liquid level switch overrides the timer signal; when the liquid volume in the evaporator reaches a predetermined high limit, it prevents the feed control from operating. A small amount of air continually bleeds into the evaporator through the liquid level sensor probe. The back pressure necessary to bubble the bleed flow through the liquid is transmitted to the high pressure side of a Δp switch. The low pressure side of the switch is connected to sense the vapor pressure above the liquid in the evaporator. When the amount of liquid increases to the maximum desired level, the Δp switch is actuated and the feed control cannot be energized until the Δp switch is again closed. The switch closes when the liquid level is reduced by boil-off to below the maximum desired level.

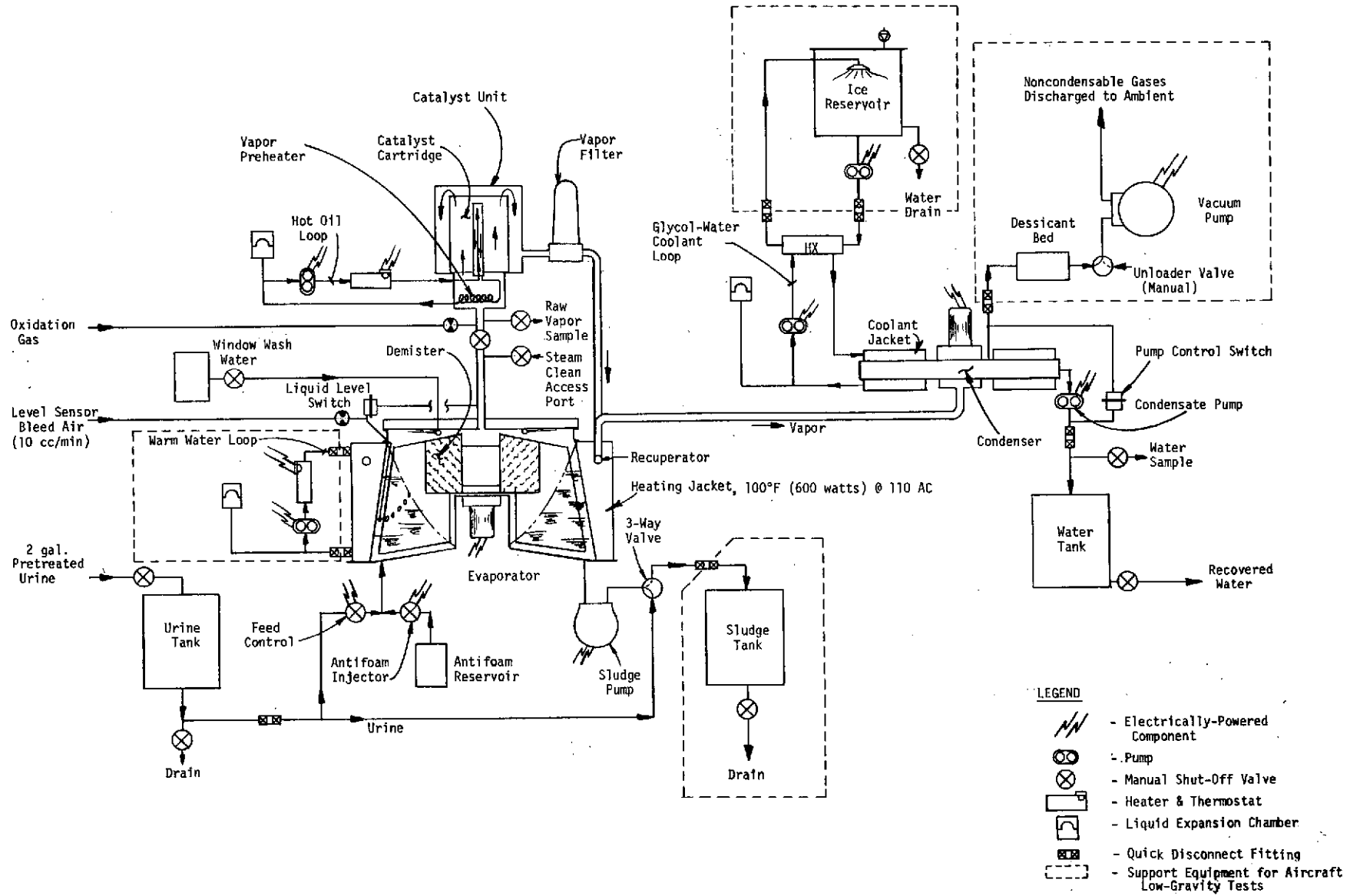


Figure 2-1 VD/VF FLOW DIAGRAM

The bleed air entering through the level sensor probe prevents fouling and clogging, and eventually reacts in the catalytic oxidizer with volatiles generated during urine distillation.

A rotating impeller inside the evaporator provides centrifugal acceleration for low-gravity separation of liquid and vapor and provides the desired velocity of liquid along the heat transfer surface. The impeller also has a de-misting mesh to coalesce fine droplets which escape the main body of liquid during boiling. The impeller rotates about its vertical axis; the vapor flows radially inward through the de-mister mesh and then axially through the outlet-tube which is concentric with the centerline of rotation. The centrifugal effect provides sufficient force to constrain the main body of liquid against the wall.

Heat input is provided from a heat transport loop to a liquid jacket which then transfers heat across the evaporator wall to the urine. During low-gravity testing the heat will be supplied by electric heating elements (115-volt, 400 Hz) and maximum loop temperature will be limited by a thermostatic switch.

The raw, de-misted vapor leaves the evaporator, is mixed with a small measured quantity of oxygen, and flows to the catalytic oxidation unit where the mixture is heated to approximately 300°F. Heat is supplied by an electric heater to a hot liquid loop which in turn heats the vapor and catalyst bed. The 300°F vapor and oxygen flow through a catalyst bed where the vapor is sterilized and trace organic contaminants are oxidized. A membrane filter serves as a sterilization back-up to the hot catalyst bed and filters particulates from the vapor stream.

Vapor flow from the catalytic oxidation unit passes through a recuperator before entering the condenser. The recuperator, a coiled tube submerged

in the evaporator heating jacket, transfers part of the heat from the vapor to the heating jacket liquid, thus reducing the amount of heat to be removed in the condenser.

Vapor flows to the condenser, enters near the center, and is distributed near the center of the rotating impeller by an inlet manifold. Vapors are then constrained to flow radially outward between one of two identical condensing surfaces and the rotating impeller plate. The vapor flows radially out and along the heat transfer surface with condensation occurring as it contacts the cool surface. Flexible wiper blades, attached to the rotating impeller, continually wipe the smooth condensing surface and collect the condensation droplets along the wipers. The rotating impeller and wiper blades impart a centrifugal force to the condensate to direct it radially outward to the outer housing of the condenser. Any vapor which is not condensed during the first pass along the condensing surface flows around the impeller plate, and then radially inward along the opposite cool surface to effect complete condensation. Noncondensable gases are removed at the center of the condenser on the side opposite the vapor inlet.

The condensate within the condenser collects along the inside surface of the housing; a timer (the same timer which is part of the urine feed control) periodically actuates a pump to transfer the condensate from low pressure to storage at ambient pressure. The pump is started by the timer and continues to operate until all the condensate is removed and the pump discharge pressure drops; this drop is sensed by a pressure switch located at the pump discharge and actuation of the switch shuts off the pump.

Identical coolant jackets located on each side of the condenser have radial flow guides to direct the coolant over the entire heat transfer surface. The flow guides not only direct coolant flow but also give this surface

the structural rigidity needed to remain flat when the internal pressure is reduced to the 10-20 mm Hg absolute operating level.

A recirculating coolant loop operating between the condenser and a heat sink supplies the required coolant flow and temperature level at the condenser. For the low-gravity tests, the heat sink is a reservoir of ice which melts to water when it receives the heat of condensation via the coolant loop. The ice is located within a cooling unit which sprays the cooling water over the ice and contains the water generated for draining at the conclusion of a test run.

The noncondensable gases removed from the condenser are drawn through a desiccant bed for partial moisture removal and then compressed by an oilless vacuum pump to atmospheric pressure and discharged into the cabin.

At various times during operation of the system, the antifoam injector is operated, as required, to maintain the proper antifoam concentration in the evaporator. The frequency of antifoam injector operation depends on the distillation rate and the ratio of urine to humidity condensate being fed to the evaporator. The injector is electrically operated but requires manual signaling by a momentary contact switch.

When the sludge, accumulating in the evaporator, reaches a predetermined concentration, the distillation process is manually shut down. The evaporator vapor discharge valve is closed (manually), and the sludge line 3-way valve is positioned (manually) to connect the sludge pump to the sludge collection tank. The sludge pump and evaporator impeller are then operated to pump sludge from the evaporator to the sludge tank. When the evaporator is emptied, the sludge pump is shut off, the 3-way valve is positioned to accept urine, the pump operational mode is reversed, and the evaporator is filled with fresh urine. As an additional option, after emptying the evaporator of sludge, and, prior to refilling with fresh urine, steam can be fed into the vapor discharge

duct to further clean the internal evaporator surfaces. The impeller and sludge pump would continue to operate during the steam cleaning process.

Section 3

PREPARATIONS FOR LOW-GRAVITY TESTING

To test the VD/VF system aboard a zero-g aircraft, the system must be contained in a supporting framework conforming to prescribed structural requirements and interfacing dimensions with the aircraft. Also, to obtain the desired test data, a transparent top over the entire evaporator is required in place of the metal top with sightglasses, and to make the system totally independent of the aircraft (excepting required electrical power), a cooling unit which receives the thermal heat rejected from the system should be installed as an integral part of the test equipment.

3.1 Analysis of Wave Motion During Aircraft Parabolic Flights

The rotating impeller inside the evaporator produces a continuous centrifugal acceleration of the liquid whose magnitude varies with the square of the angular speed. Based on information from the WPAFB Zero-G Test Office, the vertical acceleration (perpendicular to the aircraft floor) varies between zero and 2-g while lateral and longitudinal accelerations are essentially zero. The duration of zero-g is nominally 30 seconds including transients from 2-g to zero-g and zero-g to 2-g, as shown in Figure 3-1. Under steady-state conditions and for given evaporator dimensions, impeller speed, and fixed amount of liquid, the liquid-vapor interface assumes the configurations illustrated in Figure 3-2.

An analysis was conducted to predict solutions to two potential problems:

1. Does a surge of liquid reach the vapor outlet duct during the rapid transitions from 2-g to zero-g (and reverse)?

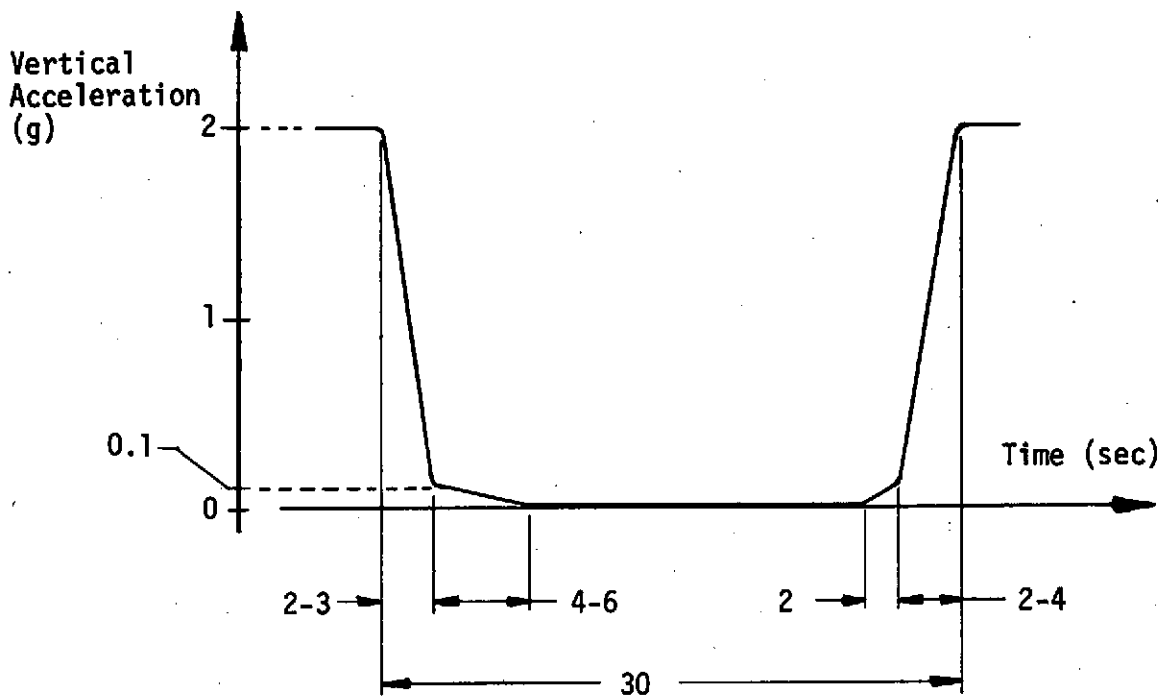


Figure 3-1 ANTICIPATED VERTICAL ACCELERATION DURING ZERO-G

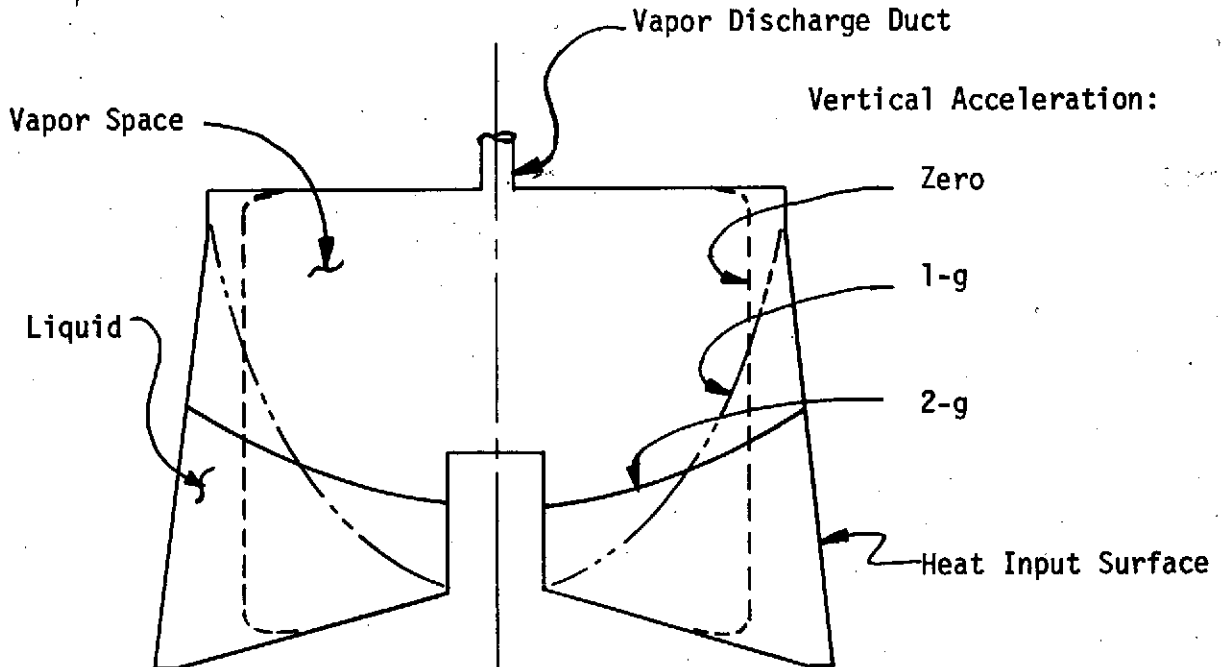


Figure 3-2 CONFIGURATION OF LIQUID/VAPOR INTERFACES IN EVAPORATOR

2. After the aircraft is decelerated to zero-g vertical, are waves damped enough for the liquid motion in the vertical direction to be essentially zero (as desired to simulate sustained zero-g)?

The results of the analysis are summarized as follows:

The initial wave crest accompanying a rapid transition from 2-g to zero-g (and reverse) will be approximately the same height as the body of liquid just prior to the transition in acceleration. Figure 3-3 shows the 2-g to zero-g liquid movement. A solution to this potential problem is to incorporate wave deflectors at strategic locations inside the evaporator, to prevent waves and/or spray from reaching the vapor outlet duct, as shown in Figure 3-4. A solid plate under the de-mister basket will aid in deflecting waves set up during the 2-g pull-out. A cylindrical deflector attached to the under side of the transparent top will aid in deflecting waves set up during the 2-g to zero-g transition.

The primary period of oscillation of vertical motion along the heat input wall was calculated to be 0.38 second. During the 4- to 6-second transition time in which the aircraft establishes zero-g there could be between 8 and 16 complete oscillations if the liquid were ideally nonviscous. These oscillations will probably die down by dissipation (viscous effects, breaking of the liquid surface) in two or three cycles. Therefore, it is predicted that liquid will cover the heat input wall for a major portion of the zero-g test time in a behavior similar to what would be expected in sustained zero-g.

3.2 Evaporator Modifications

The evaporator assembly, as constructed and tested in program phases I and II, had three sightglasses in the top cover. Each sightglass was

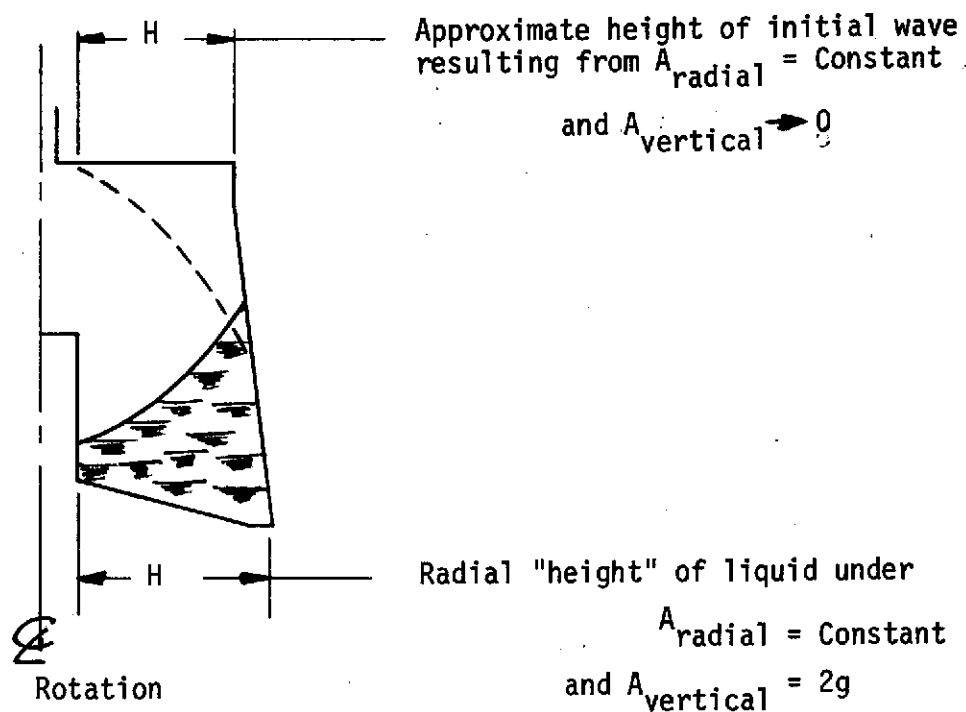


Figure 3-3 INITIAL WAVE CREST RESULTING FROM RAPID CHANGE IN VERTICAL ACCELERATION

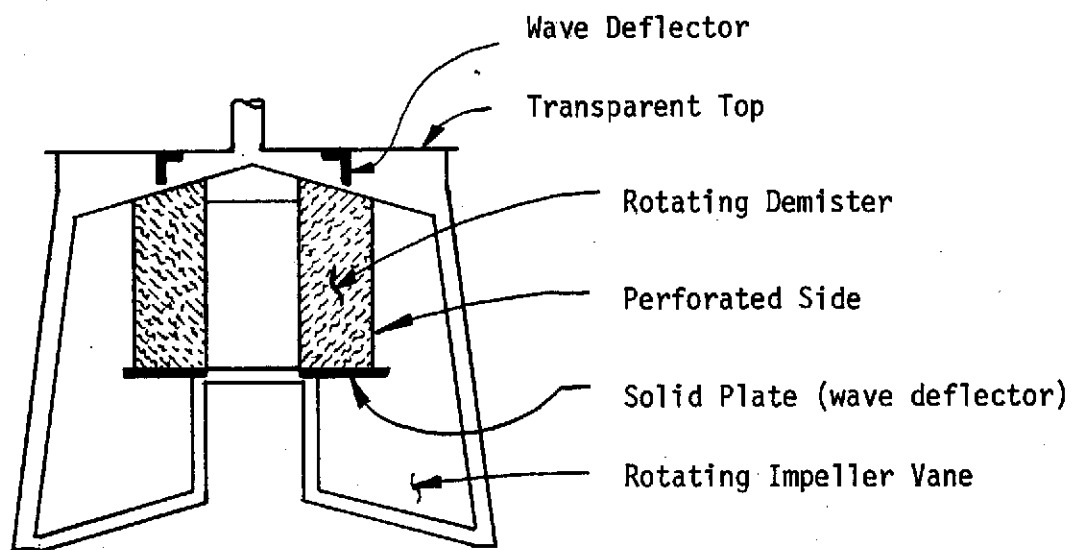


Figure 3-4 WAVE DEFLECTORS IN EVAPORATOR

2-3/4-inch diameter; this size permitted observation of impeller rotation and the general profile of the rotating liquid inside the evaporator.

To evaluate the de-misting action of the rotating impeller and de-mister assembly during low-gravity testing, it will be necessary to view and photograph into the evaporator better than the three sightglasses permit. To provide better visibility, a transparent top was designed, fabricated, and assembled on the evaporator. The overall construction of the top modification is shown in Figure 3-5. The transparent top will be used to evaluate the performance of the impeller and de-mister during low-gravity operation; it will be necessary to view through the top and to photograph the area immediately below the transparent top and outside the cylindrical de-mister. A typical view is shown in Figure 3-6. It will be necessary to use minimum lighting primarily to minimize heating of the transparent top of the evaporator. When operating at the nominal 6-man distillation rate, the evaporator receives 650 watts of thermal power from its heating jacket at approximately 100°F; if the photolights heat the evaporator appreciably, this amount of heat will have to be considered in evaluating the evaporator thermal performance.

The evaporator modifications also included the addition of wave deflectors within the evaporator; the purpose of these deflectors is to prevent small masses of liquid from reaching the vapor outlet tube during the 2-g to zero-g transitions, as discussed in Subsection 3.1. A cylindrical skirt-shaped deflector was attached underneath the transparent top as shown in Figure 3-5. The solid bottom of the de-mister basket is shown in Figure 3-6.

3.3 Structural Design of Support Frame

Initially, a conceptual arrangement of the VD/VF system components and supporting test equipment was determined. Primary factors considered were:

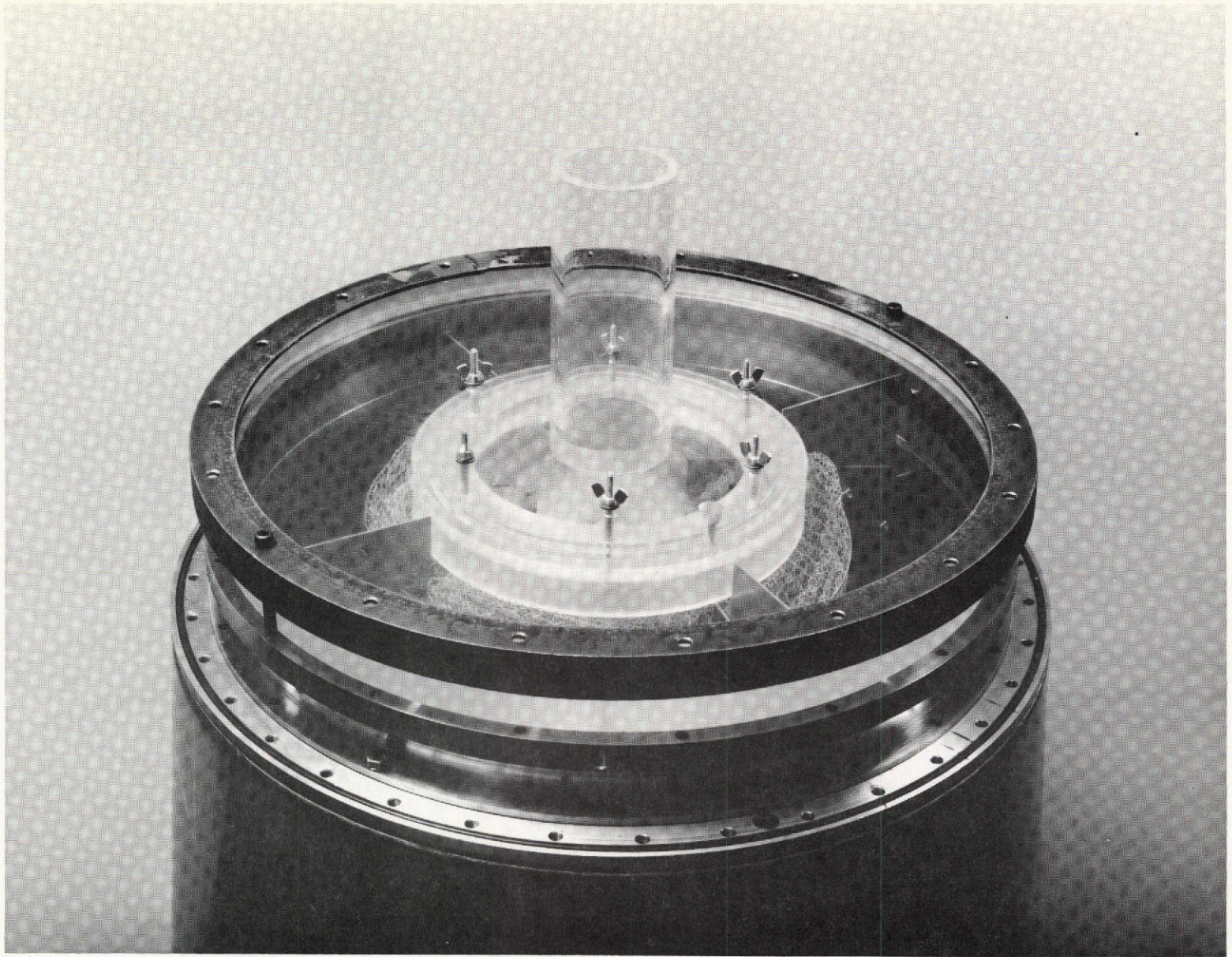


Figure 3-5 EVAPORATOR TRANSPARENT TOP

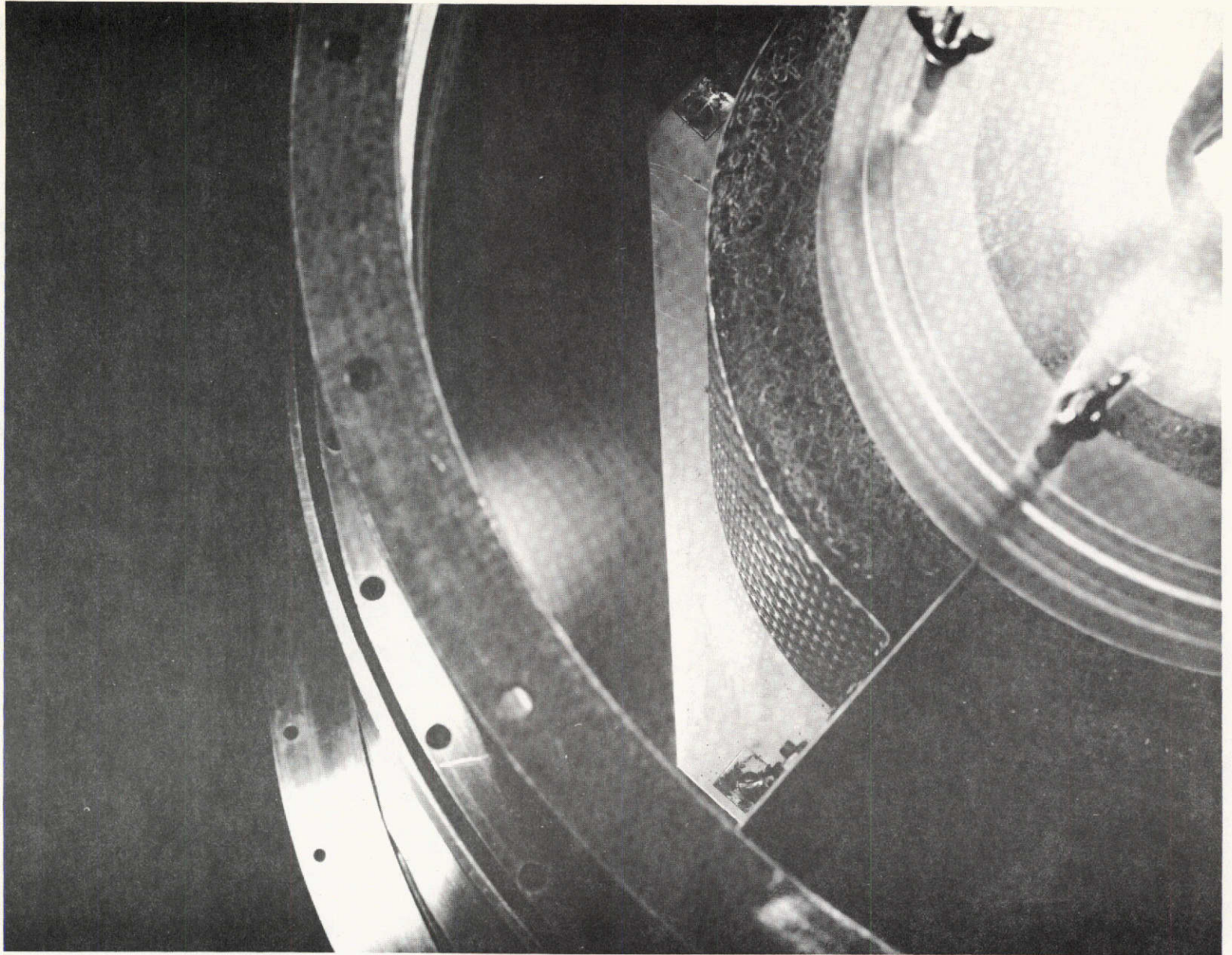


Figure 3-6 VAPOR AND LIQUID SEPARATION AREA AS VIEWED THROUGH THE TRANSPARENT TOP

1. Open area above evaporator for visibility into transparent top
2. Access to major components that require adjustments or servicing during testing of the system
3. Ease of access to electrical components (drive motors, pumps, heating cartridges) for ready replacement, if required.

The most suitable arrangement was to mount all test equipment and test support components in two separate frames. Each frame could be individually handled and tied-down in the aircraft. Fluid connections between the frames could be made through flexible lines and quick-disconnect fittings. The evaporator, condenser, catalyst unit, and controls and instrumentation are mounted in the main package; the secondary package contains tanks, supporting vacuum pump, cooling unit, etc.

After conceptual frame design, structural analyses of anticipated critical areas in the frame were performed. The structural requirements were those listed in the "Unofficial Syllabus for Zero-G Test Programs", prepared by the WPAFB Zero-G Office.

All test equipment (components, instrumentation, support frame) must withstand the following accelerations:

<u>Direction</u>	<u>Acceleration</u>
Forward	16.0 g
Down	8.0 g
Up and Lateral	4.0 g
Aft	1.5 g

The test equipment may be stressed to ultimate material strength and allow permanent deformation, but not fracture, while accommodating the above accelerations.

It was assumed that the requirements to withstand the above accelerations already include a factor of safety; therefore, no additional factor was considered. The structural design criteria were: calculated stress \leq allowable ultimate strength.

The material selected for basic frame members was extruded angles and channels of aluminum alloy 6061-T6. Joining was by welding with AA 4043 filler alloy; there is no heat treatment after welding.

The allowable design stresses recommended by the task committee on light-weight alloys, Structural Division of the American Society of Civil Engineers, are listed in Table I.

TABLE I
BASIC STRENGTH DATA

Property	6061-T6 Parent Material	Weld Joint and Parent Material in Heat-Affected Weld Zone
Ultimate Tensile Strength	38 ksi	24 ksi
Tensile Yield Strength	35	20
Compressive Yield Strength	35	20
Ultimate Shear Strength	24	15
Shear Yield Strength	20	12
Ultimate Bearing Strength	80	15
Bearing Yield Strength	56	30

The VD/VF system components are fastened to the frame, directly or through intermediate brackets, with steel bolts (AN 3 through 20 type) whose strength properties are: ultimate tensile strength, 125 ksi; and ultimate shear strength, 75 ksi.

Calculations were performed for the anticipated critical stress areas only; these areas were for the primary frame members to withstand 16-g forward and 4-g lateral acceleration (independently). The primary vertical support members are loaded in flexure by the forward and the lateral accelerations and are loaded in direct tension or compression by the down and the up accelerations. Because the load-carrying capacity of a frame member is less under flexure loading, the highest (critical) stresses result from forward and lateral accelerations.

The structural calculations were submitted to S&E-ASTN-SMS for review and were approved.

3.4 Cooling Unit

During ground testing of the VD/VF system in Phase II, a commercial vapor-cycle refrigeration unit was used as the system heat sink. This unit is unsatisfactory for zero-g operation, and the test aircraft does not have a readily available refrigeration system onboard. To support the aircraft tests, a cooling unit was designed, assembled, and installed in the secondary frame.

The design performance requirements of the cooling unit are:

Heat Load	3000 Btu/hr
Operational Time	4 hours
Glycol Coolant Flow Rate	1-1/2 gpm
Glycol Coolant Temperature Leaving Coolant Unit	38 ± 4° F

Two methods of providing the required cooling, sublimation of dry ice (solid carbon dioxide) and the melting of water-ice, were considered. The water-ice method was chosen because it provides the following advantages:

1. The problem of coolant freeze-up is eliminated because the coldest part of the unit is 32°F with water-ice as contrasted to -110°F with solid carbon dioxide.

2. There is no potentially undesirable contamination of the aircraft cabin; the ice melts into water which is contained in the cooling unit and drained at the end of the flight. Solid carbon dioxide sublimates into gaseous carbon dioxide and could entail a large increase in volume or pressure in the unit or within the aircraft if not properly vented. The gaseous carbon dioxide could be vented overboard but precautions would be required to avoid freeze-up or clogging of the overboard vent regulator.
3. Less insulation is required with a water-ice heat sink because the temperature difference between ambient and the heat sink is much lower with ice than with solid carbon dioxide.
4. The glycol coolant for the condenser is contained within a sealed unbroken loop. The desired arrangement of the components within two supporting frames has the condenser located in the primary frame and the cooling unit located in a secondary frame. With the ice-type cooling unit the uncoupling of lines between packages may conveniently be the cold water lines at disconnect fittings, rather than glycol coolant, thus avoiding potential spillage of coolant during installation or removal aboard the aircraft.
5. It is anticipated that the availability of ice will be better than for solid carbon dioxide. It will be necessary to reload the cooling unit prior to each daily test flight.

The cooling unit is shown schematically in Figure 3-7. The ice reservoir is a 60-gallon drum with removable cover. Prior to each daily low-gravity flight, the reservoir will be drained of water (the melted ice from the previous run) and loaded with 200 pounds of ice cubes. Approximately 20 pounds of ice will melt during the initial cooldown from ambient temperature to the 35°-40°F operating range temperature. The condenser heat load will be 3000 Btu/hour and heat input through the insulation and mounting is estimated to be 1000 Btu/hour. One-hundred-ten (110) pounds of ice will melt while receiving the 4000 Btu/hour during four hours of operation. The remaining 70 pounds of ice provides a safety margin for maintaining adequate cooling over a four-hour period.

3.5 Component Changes and Check-Out Tests

During the course of preparations for low-gravity testing, three components were altered from or added to the configuration of the VD/VF system tested in Phase II. These were the sludge removal pump, evaporator drive unit, and vacuum pump.

3.5.1 Sludge Removal Pump

The evaporator impeller produces a pumping action on the liquid inside the evaporator. Although liquid head produced was sufficient to empty the evaporator into a nearby container, it was not sufficient to pump the sludge through piping, shut-off valves, and into a closed tank as desired in the low-gravity test installation.

A high-capacity peristaltic pump, Masterflex Model 7019 with 3/8-inch ID by 5/8-inch OD Tygon flexible tube and operable up to 650 rpm, was evaluated for use as a dual-function sludge removal and urine fill pump. A bench check-out test, simulating pressure levels involved when emptying the vacuum evaporator

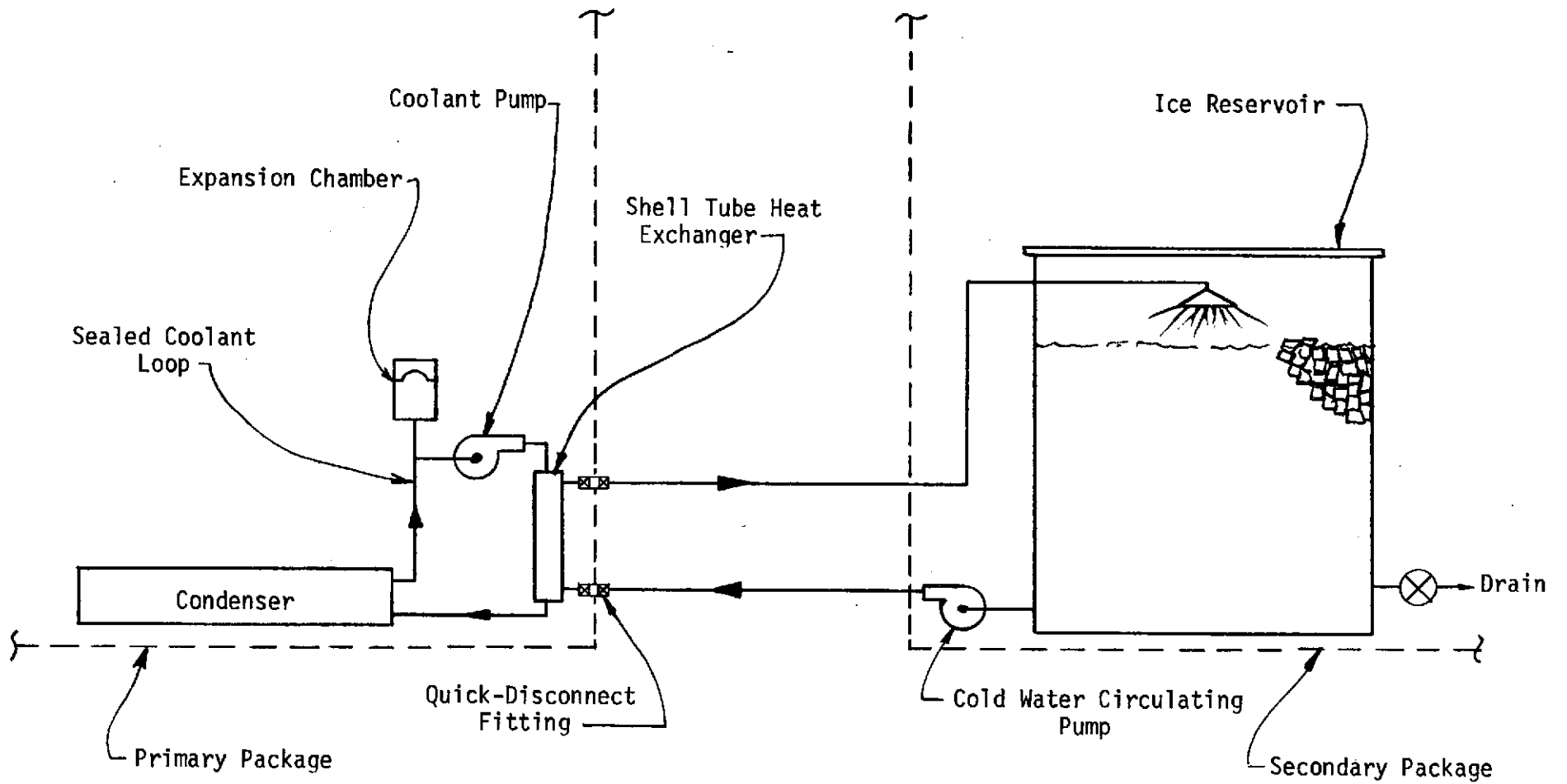


Figure 3-7 WATER-ICE COOLING UNIT SCHEMATIC

to a sludge tank, was conducted with a pumping rate of 0.4 gpm of water at a pump speed of 280 rpm; the water was pumped from a vacuum jar at 50 mm Hg absolute to a container at atmospheric pressure.

By reversing the direction of the rotation, the pump was also operated in the opposite mode, simulating the transfer of urine into the evaporator.

Since the Masterflex High Capacity peristaltic pump was found suitable for the dual functions of sludge removal and initial urine fill, it was coupled to a 1/10-HP, 280-rpm gear motor for assembly into the VD/VF system.

3.5.2 Drive Motor and Speed Reducer for Evaporator Impeller

The evaporator assembly, as developed and tested in phases I and II, utilized a brushless-dc motor for the impeller drive. A 3-stage gearbox with steel spur gears reduced the motor output speed from 6000 rpm to 100 rpm (the impeller operating speed). Although this drive assembly nominally did the job, there were some problems with gear wear and lubrication, and the spur gears are inherently noisy.

During the check-out tests of the sludge pump (described in Subsection 3.5.1), it was observed that the gear motor selected for the pump would be more suitable than the motor presently used for the evaporator impeller drive. This motor was installed on the evaporator and bench check-out tested. A reduction of noise was realized (as desired); also, the latter gear motor has a 1/10-HP rating as contrasted to the approximately 1/30-HP rating of the previous motor. Because of the higher load capacity, it is anticipated that the gear wear problems will be lessened.

3.5.3 Oilless Vacuum Pump

A vacuum source is required to initially reduce the VD/VF system pressure to the correct operational level and then to remove noncondensable gases from

the system. During phase II performance tests, a conventional oil-filled vacuum pump was used. A dry ice and acetone-cooled freeze-out foretrap was used to reduce the specific humidity of the noncondensable gas stream entering the pump.

For the aircraft low-gravity tests an oilless pump is preferred because the pump discharge will not contaminate the fuselage with oil and oil vapor.

An oilless vacuum pump and desiccant adsorbent bed was connected to the VD/VF system in place of the oil-filled pump and freeze-out foretrap. The oilless pump is actually two units with two diaphragm heads per unit interconnected to function as a vacuum pump with a single intake port and a single discharge port.

The oilless vacuum pump was capable of removing noncondensable gases from the condenser and maintaining the desired level of absolute pressure in the system. (The system pressures are affected by both noncondensable flow rate and vapor flow rate through the system.) Pertinent pressure data for three rates of oxygen feed to the catalyst are summarized in Table II.

TABLE II
SYSTEM PRESSURES WHEN OPERATING WITH OILLESS VACUUM PUMP

Oxygen Feed (cc/min, STP)	Recovery Rate (#/hr)	Pressure (mm Hg)			
		Evaporator abs.	Condenser abs.	Catalyst Δp	Filter Δp
400	2.3	23	15	1.6	6.2
600	2.3	24	17	1.5	6.0
700	2.5	28	18	1.7	7.0

The above tests and results indicated the oilless vacuum pump will be satisfactory for the aircraft low-gravity tests.

3.6 Frame Fabrication and System Assembly

Two structural tie-down frames, a primary frame for mounting the basic VD/VF system and controls and instrumentation and a secondary frame for mounting test support equipment, were fabricated. The two frames, as constructed, support all equipment, except cameras and lighting, for conducting low-gravity testing.

The support frames and mounted components are shown in their anticipated orientation in Figure 3-8. Figures 3-9 and 3-10 show side views of the main frame assembly. Each frame is constructed of structural aluminum extrusions (primarily 3-inch channel) and formed sheet bracketry. The basic construction is heliarc welding; threaded fasteners are also used where removable brackets are required.

Components secured in the main frame are:

1. Evaporator assembly
2. Catalyst unit with heating loop
3. Vapor filter
4. Condenser
5. Urine feed control valve and metering chamber
6. Evaporator level sensing switch
7. Evaporator heating loop
 - a. Heater and thermostat
 - b. Recirculation pump
 - c. Liquid expansion chamber
8. Sludge pump and 3-way valve

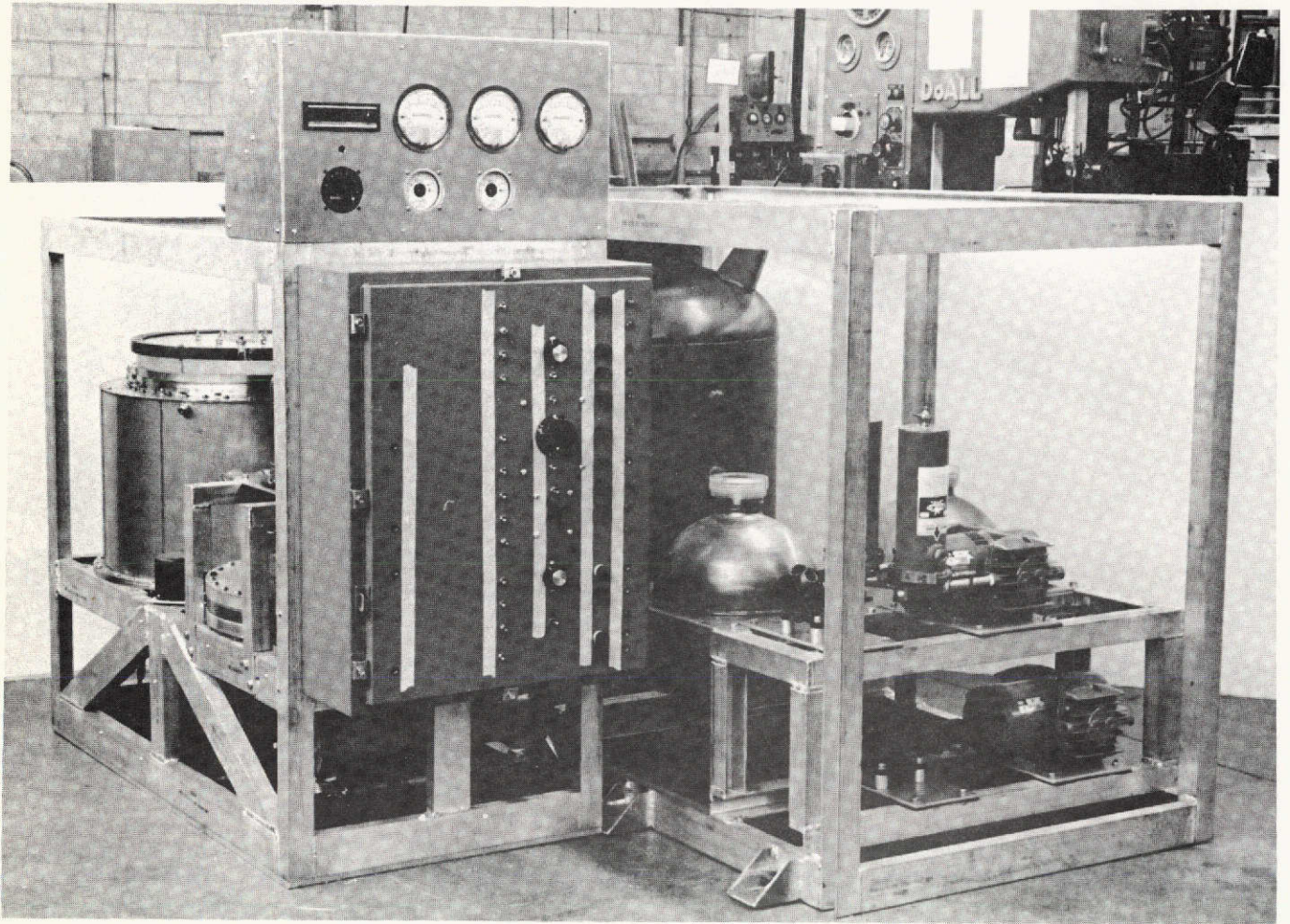


Figure 3-8 PRIMARY AND SECONDARY TEST EQUIPMENT PACKAGES

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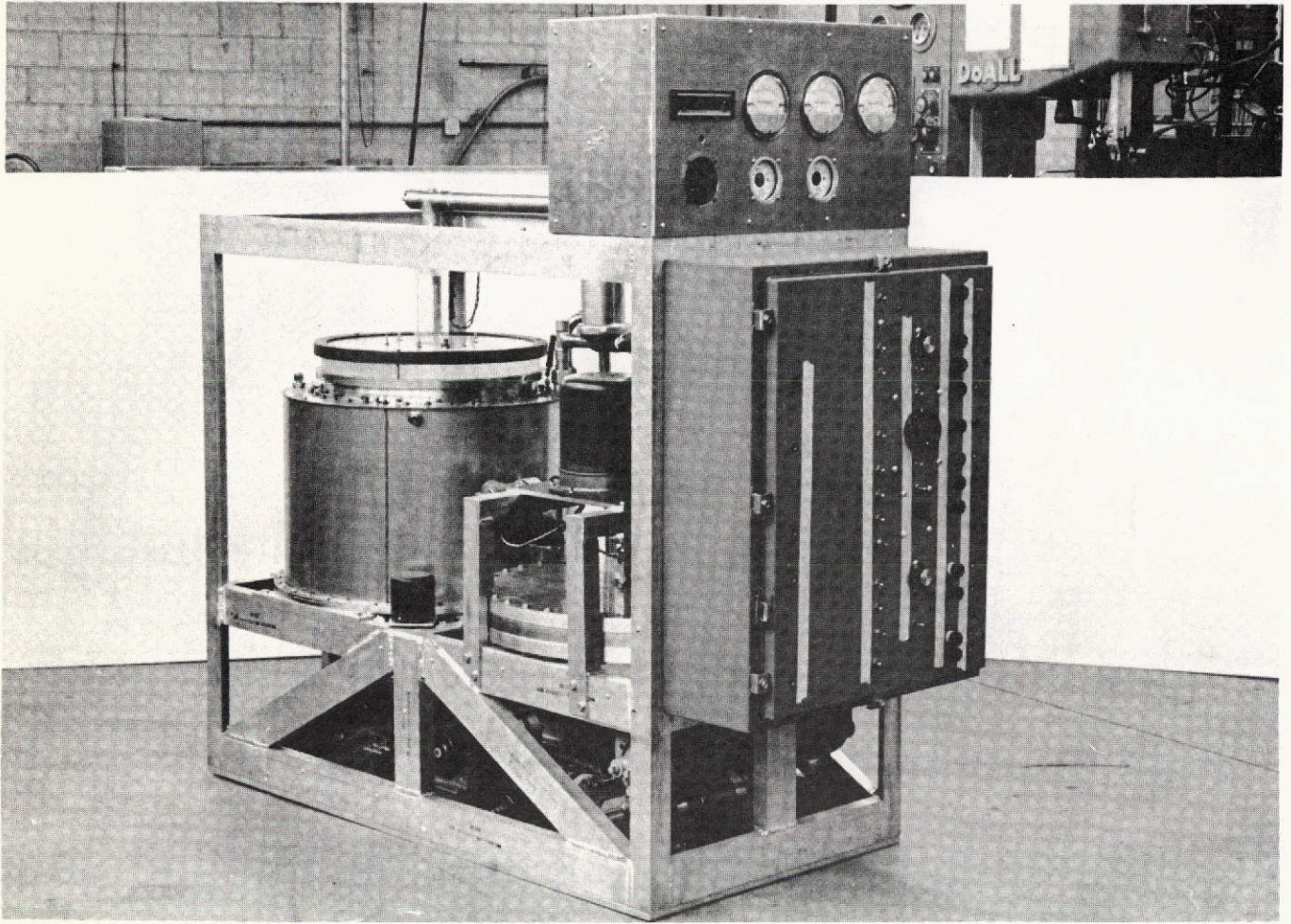


Figure 3-9 PRIMARY TEST EQUIPMENT PACKAGE, LEFT SIDE VIEW

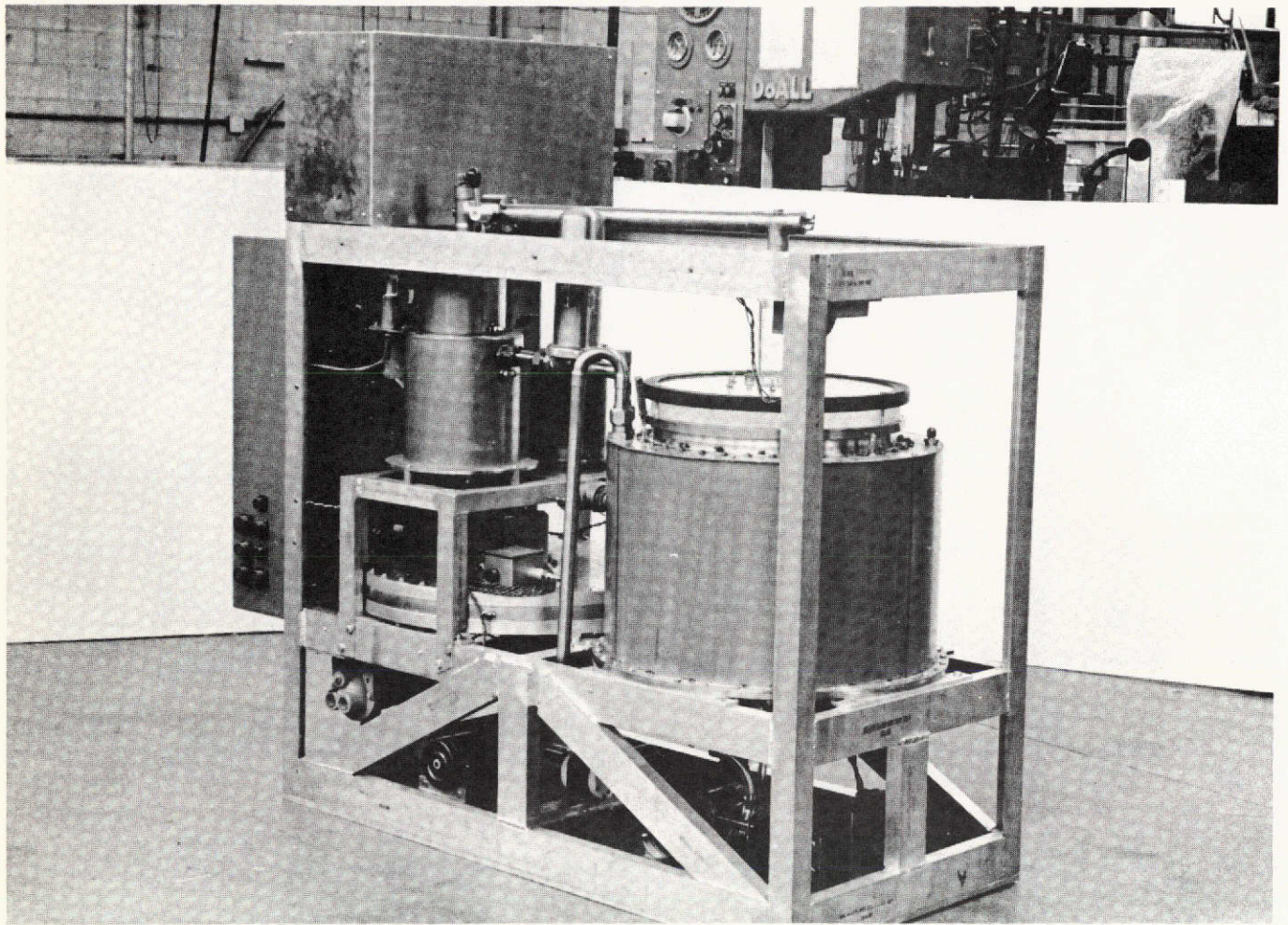


Figure 3-10 PRIMARY TEST EQUIPMENT PACKAGE, RIGHT SIDE VIEW

9. Antifoam reservoir and metering valve
10. Condensate water pump (pumpout from condenser)
11. Condenser coolant loop
 - a. Liquid-to-liquid heat exchanger
 - b. Recirculation pump
 - c. Liquid expansion chamber
12. Electrical control box and panel
13. Instrumentation panel.

The evaporator, catalyst unit, vapor filter, and condenser (the components which process the distillate vapor) are interconnected by stainless steel tubing, preformed bends, and have O-ring seals at flanged joints. Heat transfer liquid loops (not yet assembled) will be constructed with small diameter tubing and flareless swagelok fittings.

Components secured in the secondary frame are as follows:

1. Cooling unit (ice reservoir) and cold water loop recirculating pump
2. Vacuum pumps and pre-dryer (desiccant bed)
3. Urine tank
4. Recovered water collection tank.

The secondary frame is on the right side in Figure 3-8. The urine tank and the recovered water tank are the spherical-shaped components located near midlength of the frame. Two diaphragm vacuum pump units, each with its own drive motor are located in the near end of the frame. The cooling unit is the large cylindrical tank (partially hidden) at the rear of the frame. It is a 50-gallon steel tank with an 8-inch removable top cover for resupplying ice prior to each test run.

An electrical controls enclosure containing switches, circuit breakers, fuses, panel lights, transformers, variable resistors, terminal strips, power

relays, connectors, and a cycle timer was assembled. A view of the electrical enclosure internal assembly is shown in Figure 3-11. The enclosure is a standard industrial electrical box with appropriate cut-outs for connectors and panel mounted controls. Connectors for components on the main frame are located on the rear side of the box; connectors for components on the secondary frame and for power input are located on the right side of the box.

An instrumentation panel was fabricated and assembled on the main frame. The instrumentation, shown in Figure 3-12, consists of a single temperature indicator and 18-position thermocouple selector switch and individual pressure gauges for evaporator absolute pressure, condenser absolute pressure, catalyst bed differential pressure, and vapor filter differential pressure. A differential pressure gauge which will be connected to indicate oxidation gas flow is also located on the panel. The instruments will provide a visual indication of the desired temperature and pressure data which may be manually recorded. An alternate method of data recording would be to photograph the instrument panel continuously or at selected intervals during a test.

There are two main locations on the system where in-flight test data will be obtained. The processing instrumentation, shown in Figure 3-12, will provide a visual indication of the pertinent processing parameters. The other data acquisition location will be the vapor exit from the evaporator. Both photographic recording and visual observation will be employed to determine the effectiveness of the rotating impeller and demister to prevent mist or droplets from escaping the evaporator. The transparent top and transparent vapor exit tube which will be observed and photographed is shown in Figure 3-13.

3.7 Present Status of Low-Gravity Test Preparations

An initial review of equipment configuration and the low-gravity test plan by S&E-ASTN-SMS personnel was conducted at GARD in December 1973. Prior

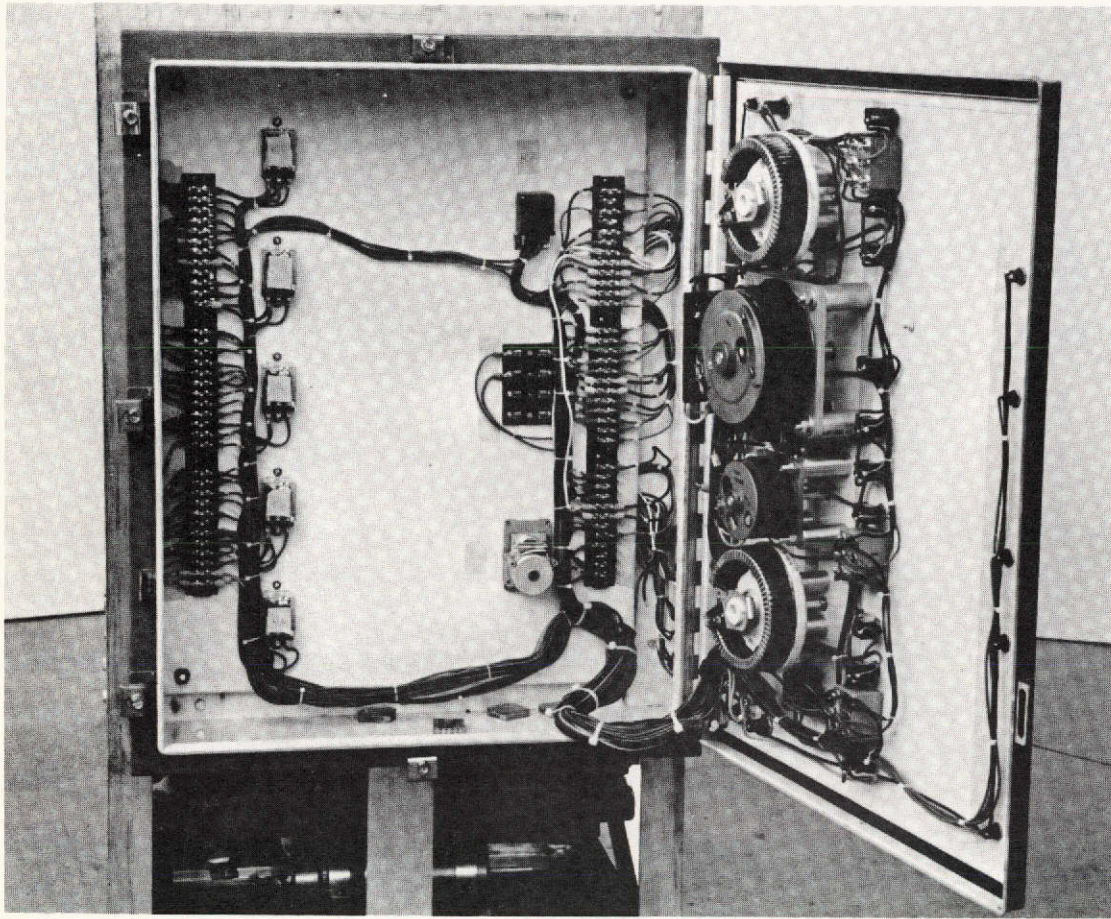


Figure 3-11 ELECTRICAL ENCLOSURE INTERNAL ASSEMBLY

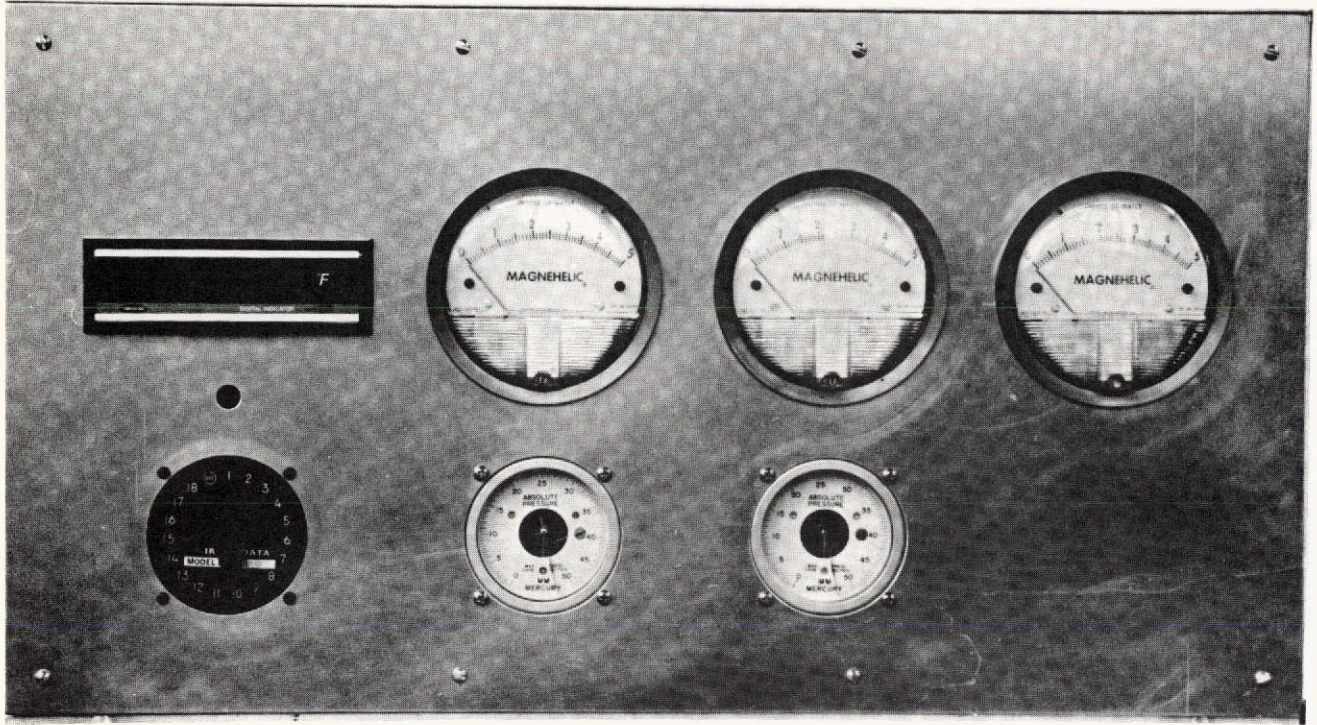


Figure 3-12 INSTRUMENTATION PANEL

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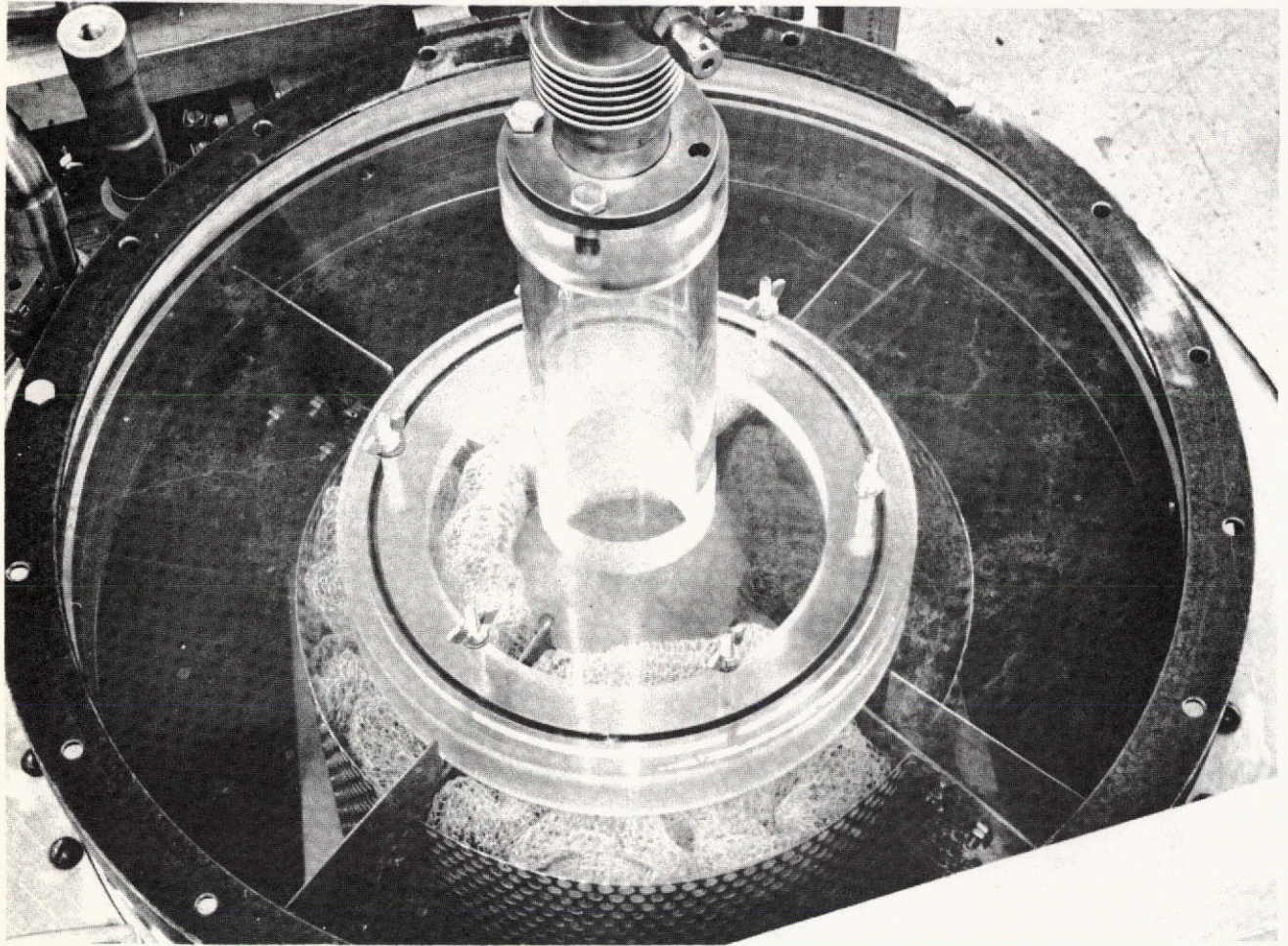


Figure 3-13 VIEW OF EVAPORATOR WITH TRANSPARENT TOP

to delivery of the system to NASA/JSC for low-gravity testing, certain work items remain to be completed. These tasks are in the areas of system assembly, ground performance tests, final low-gravity test plan, and NASA and GARD coordination.

3.7.1 System Assembly

Equipment as Assembled - The following assembly tasks are to be completed:

1. Labeling of control panel
2. Installation of thermocouple assemblies and extension leads to temperature indicator
3. Installation of pressure sensing lines between component and instrumentation panel.
4. Installation of tubing for the four liquid loops, namely
 - a. Glycol coolant
 - b. Ice water
 - c. Hot silicone oil
 - d. Warm water.
5. Installation of thermal insulation on catalyst unit, condenser, and ice reservoir.

Modifications to Equipment as Assembled - A review by S&E-ASTN-SMS of the VD/VF equipment to be installed in the test aircraft indicated that the following modifications are necessary:

1. Round-off of edges, corners, and protrusions
2. Installation of padding on outermost frame members for test personnel safety
3. Extension of base plate on main frame so that floor tie-down holes are outside of frame
4. Addition of camera and photolight mounts above evaporator

5. Provision of 20-foot power cable with fuse box
6. Provision of a separate 20-foot cord from cameras and photolights.

3.7.2 Ground Performance Tests

The VD/VF system is to be tested in the laboratory in the configuration which will be low-gravity tested. This check out testing will include all system components and support components as they will be used in low-gravity tests. Prior to low-gravity testing, the system will also be subjected to continuous testing of three days duration. The check-out testing will be concerned with determining suitable lighting and camera operation and with test operator familiarization with camera operation and data recording. A three-day duration test is to be conducted to obtain performance data for ground tests; this test data may subsequently be compared to low-gravity test data.

With the exception of water quality analyses, the same instrumentation and procedures as for low-gravity tests are to be employed to obtain the following measurements and analyses:

1. Duration of test run
2. Volume per test run of:
 - a. Urine feed
 - b. Water recovered
3. Flow rate of oxidation gas to catalyst bed
4. Temperature of:
 - a. Heating liquid entering evaporator heating jacket
 - b. Heating liquid exiting evaporator heating jacket
 - c. Urine liquid supplied from storage
 - d. Urine liquid inside evaporator
 - e. Vapor exiting evaporator

- f. Heating liquid entering catalytic oxidation unit
 - g. Heating liquid exiting catalytic oxidation unit
 - h. Vapor entering preheater
 - i. Vapor exiting preheater (entering catalyst bed)
 - j. Vapor exiting catalyst bed (entering vapor filter)
 - k. Vapor entering recuperator
 - l. Coolant entering condenser
 - m. Coolant exiting condenser
 - n. Vapor entering condenser
 - o. Condensate within condenser
 - p. Condensate pumped to storage
 - q. Ambient air temperature
5. Absolute pressure of:
- a. Vapor exiting evaporator
 - b. Noncondensable gases exiting condenser
6. Differential pressure of:
- a. Vapor entering and exiting catalytic oxidation unit
 - b. Vapor entering and exiting vapor filter
7. Twice daily samples of potable water pumped out of condenser to determine levels of:
- a. Total carbon
 - b. Total organic carbon
 - c. pH
 - d. Ammonia
 - e. Conductivity
 - f. Turbidity
 - g. Viable bacteria density (MPN)

3.7.3 Low-Gravity Test Plan

A test plan has been prepared in preliminary form and reviewed by S&E-ASTN-SMS. The test procedures need to be expanded to describe the variables to be controlled by the test operator(s). Detail procedures will be determined during ground check-out testing; these will be listed in the final test plan.

3.7.4 NASA/MSFC and GARD Preparations Coordination

GARD personnel who will be assisting in the low-gravity tests have completed the following preflight requirements:

1. Security clearance
2. FAA Class II physical
3. Physiological training.

Resulting from the NASA/MSFC and GARD coordination meeting in December 1973, the following known areas of coordination have been identified:

1. MSFC recommends that GARD try out the cameras and lighting during ground testing; NASA/MSFC will request a loan of a normal speed camera (24 frames per second) and a high-speed camera (64/120 frames per second) to GARD for use in fabricating camera mounts and trying out the lighting during ground testing.
2. A hand-held camera may be used to photograph the transparent outlet tube at the evaporator. If used, the hand-held camera will be operated by a NASA photographer.
3. GARD will include the weights of each test rig along with the installation instructions.