national accelerator laboratory

TM-349
2701

DESIGN GUIDE FOR LIQUID HYDROGEN FILLED TARGETS

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February, 1972

CONTENTS

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1. General Remarks

1.1 Liquid hydrogen targets for use at NAL will, in general, be refrigerated flasks of small volume. NAL will have small refrigerators available for assignment to specific experiments and will maintain a target design and fabrication capability. Experimenters who intend to provide their own targets are urged to coordinate the design and testing through the appropriate beam line liaison physicist.

1.2 The use of large-volume reservoir target systems will be considered on an individual basis.

1.3 A sketch of a typical target is shown in Figure 1 and a photo in Figure 2. Figure 3 is a plumbing diagram of the system. Figures 4, 5, and 6 show, respectively, the control console, gas handling pump cart and refrigerator compressor module.

1.4 The design of the target should be in accordance with good engineering practice for low temperature equipment.

2. Specific Design Guidelines

2.1 Liquid hydrogen flask

2.1.1 Typical geometry: Circular cylinder, diameter 1 to 3 inches, length 2 to 48 inches. Dished heads on end of cylinder.

2.1.2 Acceptable materials: Mylar or Kapton film, Teflon, Kel-F, Vespel, epoxy fiberglass (G-10 and G-11), 300-series stainless, copper, brass and aluminum.

2.1.3 Design pressure: Failure at not less than 40 psia internal at 77°K., with 0 psia external. A prototype flask shall be tested to failure at 77°K to insure that this criteria is satisfied.

2.1.4 Test pressure: 40 psia internal, with 15 psia external, at 77°K.

2.1.5 Relief pressure: 20 psia internal.

2.1.6 Normal operating pressure: 15 psia internal, 0 psia external.

2.1.7 Multilayer insulation: a minimum of 20 layers of 0.00025 inch aluminized Mylar film is applied to the flask to reduce the heat load to the hydrogen system.

2.1.8 Liquid level resistors: at top and bottom of flask.

2.2 Internal liquid hydrogen reservoir

2.2.1 Purpose is to store the liquid hydrogen from the target within the refrigerator cryostat to allow "target empty" experiments.

2.2.2 Volume is at least equal to volume of flask.

2.2.3 Connected directly to the flask.

2.2.4 Material: 300-series stainless.

2.2.5 Design pressure: Failure at not less than 200 psia internal at 77°K., with 0 psia external.

2.2.6 Normal operating pressure: 15 psia internal, 0 psia external.

2.2.7 Liquid level resistors: at top and bottom.

2.2.8 The flask-reservoir volume is equipped with a relief valve (RV-3). The line leading to the relief valve and the valve itself shall be sufficiently large to pass hydrogen gas at a rate of (a) 20 scfm for a hydrogen volume of less than two liters or (b) 40 scfm for a hydrogen volume of between 2 and 6 liters, with a total pressure drop of 2 psig or less in each case.

2.3 Target/refrigerator cryostat

2.3.1 This is the outer vacuum container. The "target cryostat" encloses the hydrogen flask, the "refrigerator cryostat" encloses the refrigerator, internal reservoir and piping. The two cryostats have common vacuum.

2.3.2. Typical geometry: Target cryostat: metal cylinder with end windows; metal box with window along side or bottom, end windows.

2.3.3 Acceptable materials: Windows, aluminum, 300-series stainless, Mylar or Kapton film; body, 300-series stainless, copper, brass or aluminum

2.3.4 Design pressure: Body--failure at not less than 200 psia internal, with 15 psia external.

2.3.5 Design pressure: Windows--failure at 65 psia internal at 300°K, with 15 psia external. Cryostats designed for window failure at lower pressure will be considered on an individual basis.

2.3.6 Test procedure; with windows: a. 15 psia external, 0 psia internal. b. 15 psia external, 25 psia internal. c. Prototype tested to failure, with 15 psia external.

2.3.7 Relief pressure: 1 mm Hg gauge internal.

2.3.8 Normal operating pressure: 0 psia internal, 15 psia external.

2.3.9 Ratio of liquid volume to vacuum volume. The volume of the vacuum space should be equal to about 50 times the target liquid volume. For example, a 2-liter target should have a total vacuum space, target cryostat plus refrigerator cryostat, of about 100 liters. With a vacuum space accordingly sized, a flask rupture will generate an initial pressure in the vacuum space of 15 psia or less. Subsequent expansion of the hydrogen gas will take place through the rupture disk vent line. The system is designed to contain the hydrogen. The advantages of retaining the integrity of the system and not releasing hydrogen to the experimental area are obvious.

2.3.10 If this ratio cannot be achieved, the design of the cryostat and vacuum relief system will be submitted to NAL for review. Depending on the actual ratio and the system design, special requirements for the immediate environment of the target may be stipulated.

2.3.11 The vacuum system shall be equipped with a rupture disc assembly (RV-1) as shown on NAL Drawing 2726.001-ME-7810. The discharge of this rupture disc shall be piped to a point where hydrogen can be safely released into the environment. The diameter of the line connecting the rupture disc with the vent point shall be at least 2 inches in diameter and unrestricted over its full length.

2.4 Hydrogen gas system

2.4.1 Hydrogen gas supplied to the target shall be certified to be pure and shall contain less than 50 ppm total impurities. The supply source shall be analyzed for purity upon receipt by the laboratory with a mass spectrometer.

2.4.2 Hydrogen gas is admitted to the system through a pressure reducing valve or regulator with a flow capacity not exceeding 2 scfm. The supply line connecting the hydrogen source with the target shall be equipped with a valve operated from a pressure switch. The switch will close this valve when the pressure in the target exceeds 17.5 psia. A manual reset will open the valve, when the pressure in the target has been reduced below 17.5 psia.

2.4.3 The valve in the supply line between hydrogen gas source and target is also controlled by a pressure switch on the cryostat vacuum. The valve will close when the pressure in the vacuum space exceeds 50 microns absolute.

2.4.4 During operation of the target, the hydrogen supply gas system will be maintained at a pressure above atmospheric by means of the regulator mentioned above. A pressure switch will sound an alarm when this pressure drops below 15.5 psia.

2.5 Vacuum pump system

2.5.1 If a high vacuum pump (diffusion or ion pump) is used to pump the insulating vacuum space, an automatic shutoff valve shall be used to isolate the pump from the vacuum space. This valve shall close when the pressure reaches 10^{-3} torr.

2.5.2 An interlock device shall be installed which will prevent evacuating the target flask if the insulating vacuum is greater than 50 microns. The purpose of this device is to eliminate the possibility of imploding the target flask.

3. System Testing, Installation and Operation

3.1 Safety Review: Before fabrication of the target the design will be reviewed by NAL to assure compliance with the "Design Guide for Liquid Hydrogen Filled Targets". At this time the following information will also be made available for review:

3.1.1 Operating procedure, including startup and shutdown.

3.1.2 Flow diagram and electrical schematics.

3.1.3 Failure mode analysis outlining the probable events and consequences following failure of a single component of the system.

3.1.4 Emergency procedures required to put the system in a safe condition after failure of a component has occurred.

3.2 Target systems will be tested at NAL under operating conditions prior to installation in the beam line. During the test, equipment will undergo at least the following: (1) Filling and steady state operation for 24 hours, including transfer of the liquid from flask to reservoir. (2) Pressure test of the flask at 25^{o}K without liquid to 25 psia internal, 0 psia external. (3) Loss of all AC power. Test results will be submitted to NAL for all targets brought by experimenters from their home institutions.

3.3 Installation:

3.3.1 All hydrogen equipment shall be installed by NAL personnel. The user shall assist in the installation.

3.3.2 The refrigerator compressor module and pump cart for the target shall be located in one area and at floor level, more than six feet from target. The electronics control rack shall be located more than ten feet from the target, and up to 300 feet from the target.

3.3.3 Electronics equipment (counters, etc.) within 5 feet of the target must meet the requirements of Electrical Classification, Class 1, Group B, Division 2 (all possible sparking sources in gas tight enclosures).

3.4 Operation and personnel training:

3.4.1 Copies of "Operating Guide for Liquid Hydrogen Filled Targets" will be made available to all user personnel.

3.4.2 All hydrogen equipment shall be initially operated by NAL personnel.

3.4.3 The user shall assist NAL personnel in the initial operation of the target.

3.4.4 Adequate records shall be maintained during the operation of the target.

3.4.5 Subsequent operation of the system is the responsibility of the experimenter; NAL will provide supervision, assistance and maintenance as required.

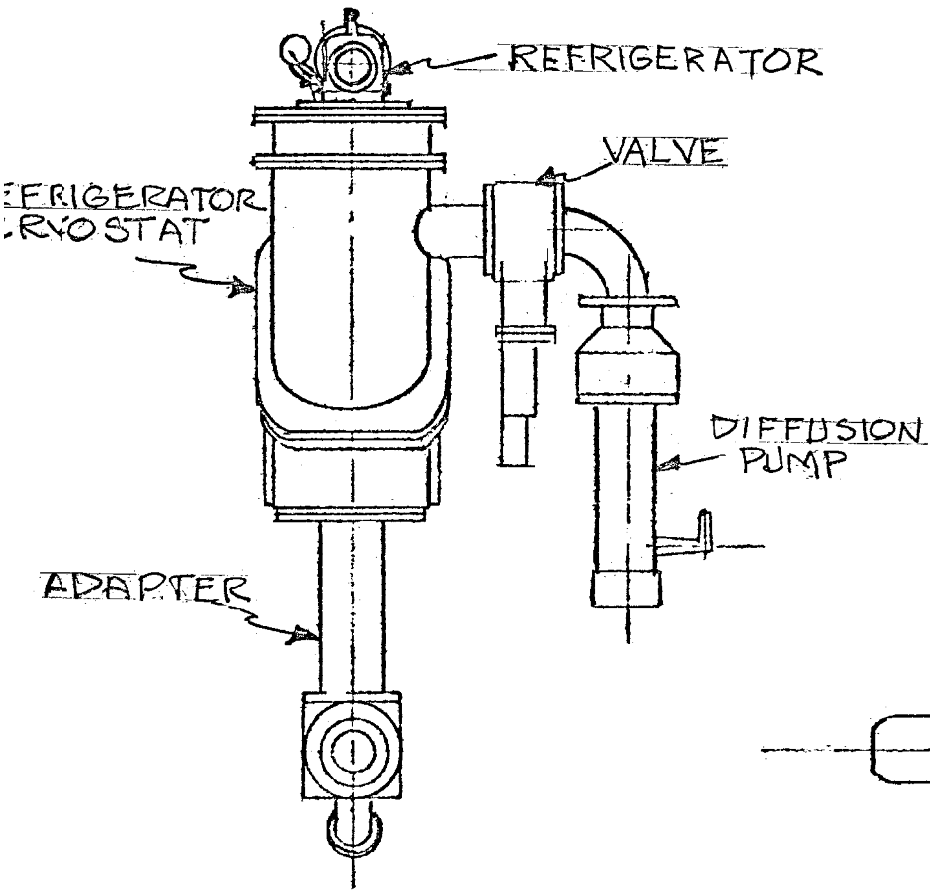
4. Special Target Systems

4.2 The system may include a second or third hydrogen flask of different length, either in the same target cryostat. The guidelines still apply.

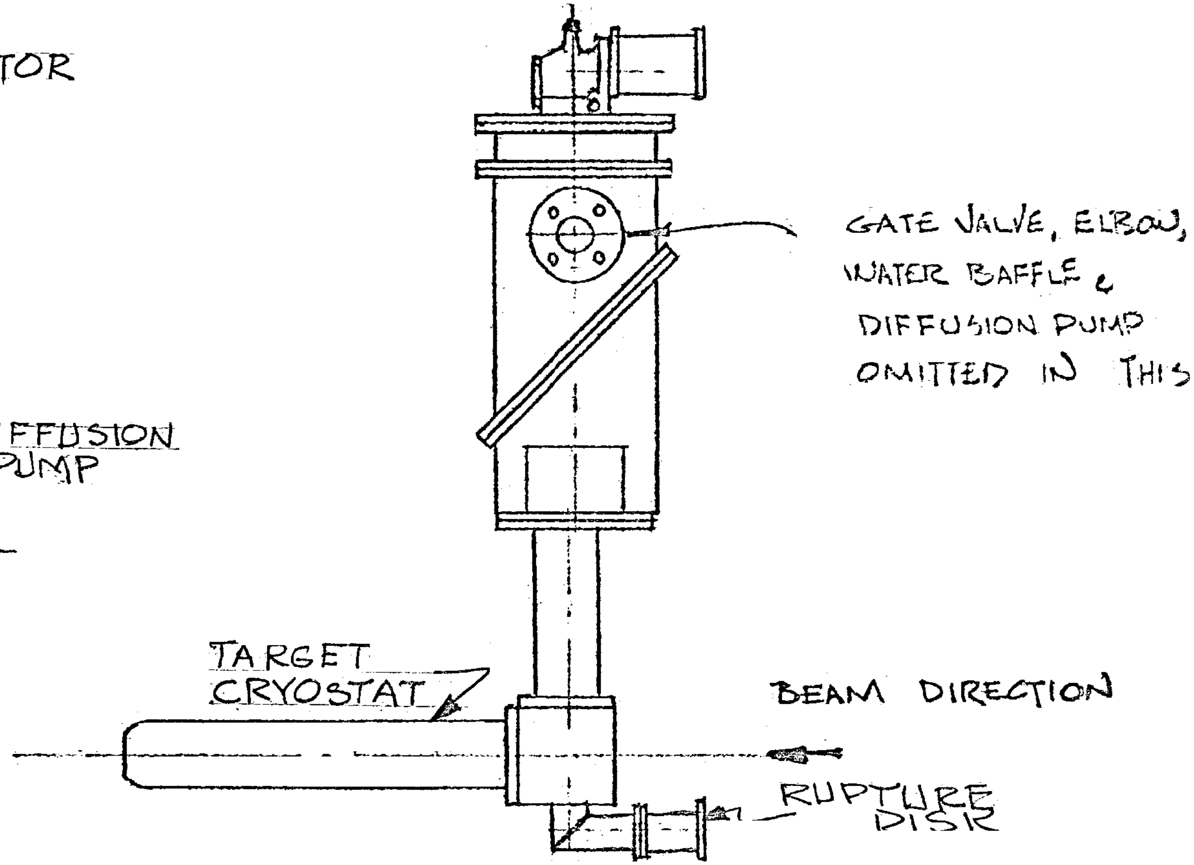
4.3 The system may include a liquid deuterium flask in addition to the liquid hydrogen flask. Two separate gas handling systems would be used, but the guidelines remain the same.

4.4 Users are encouraged to consult with NAL Experimental Services Section regarding special or unusual target requirements. These conversations should begin well in advance of the experiment turn-on date.

REFRIGERATED LIQUID HYDROGEN TARGET ASSEMBLY



VIEW UPSTREAM



TARGET ORIENTATION.

SCALE 1" = 1'-0'

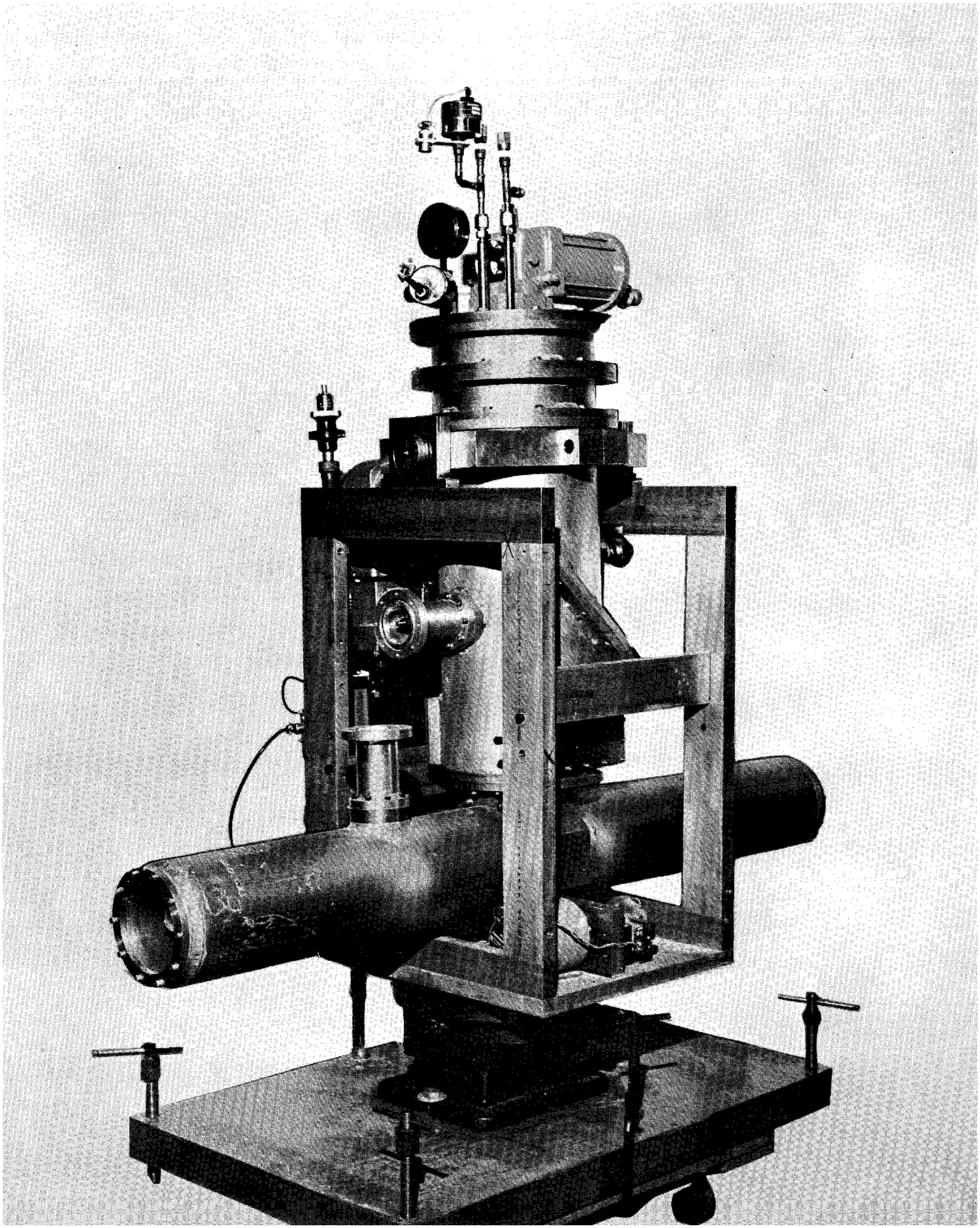


Fig. 2

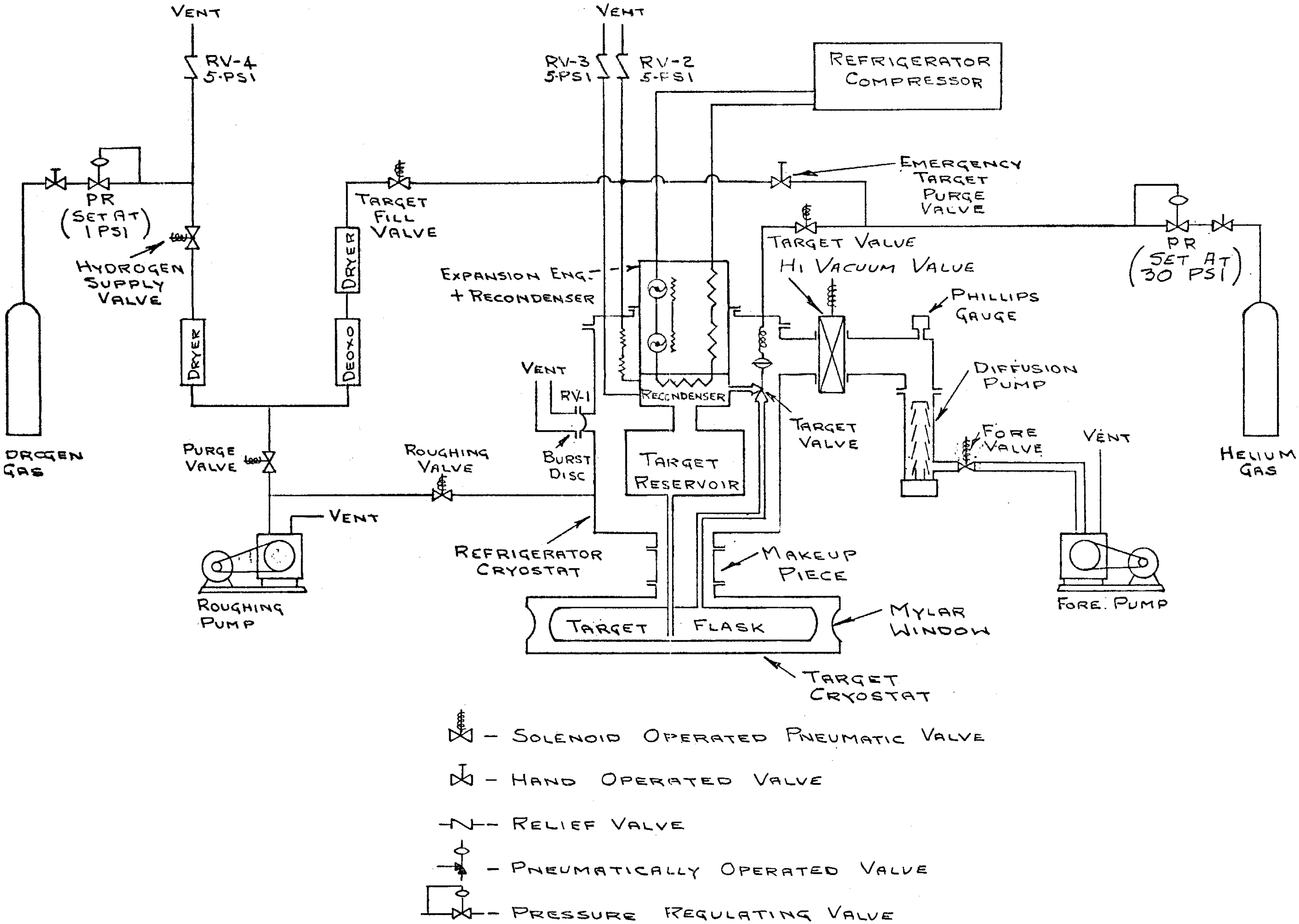

VENT
RV-4 5-PSI
PR (SET AT 1 PSI)
HYDROGEN SUPPLY VALVE
DRQGEN GAS
DRYER
DEOXO
DRYER
TARGET FILL VALVE
PURGE VALVE
ROUGHING VALVE
VENT
ROUGHING PUMP
VENT
RV-3 5-PSI
RV-2 5-PSI
REFRIGERATOR COMPRESSOR
EMERGENCY TARGET PURGE VALVE
TARGET VALVE
HI VACUUM VALVE
PHILLIPS GAUGE
EXPANSION ENG. + RECONDENSER
RECONDENSER
VENT
RV-1
BURST DISC
TARGET RESERVOIR
TARGET VALVE
DIFFUSION PUMP
FORE VALVE
VENT
FORE. PUMP
PR (SET AT 30 PSI)
HELIUM GAS
REFRIGERATOR CRYOSTAT
MAKEUP PIECE
TARGET FLASK
MYLAR WINDOW
TARGET CRYOSTAT
- SOLENOID OPERATED PNEUMATIC VALVE
- HAND OPERATED VALVE
- RELIEF VALVE
- PNEUMATICALLY OPERATED VALVE
- PRESSURE REGULATING VALVE

Fig. 3

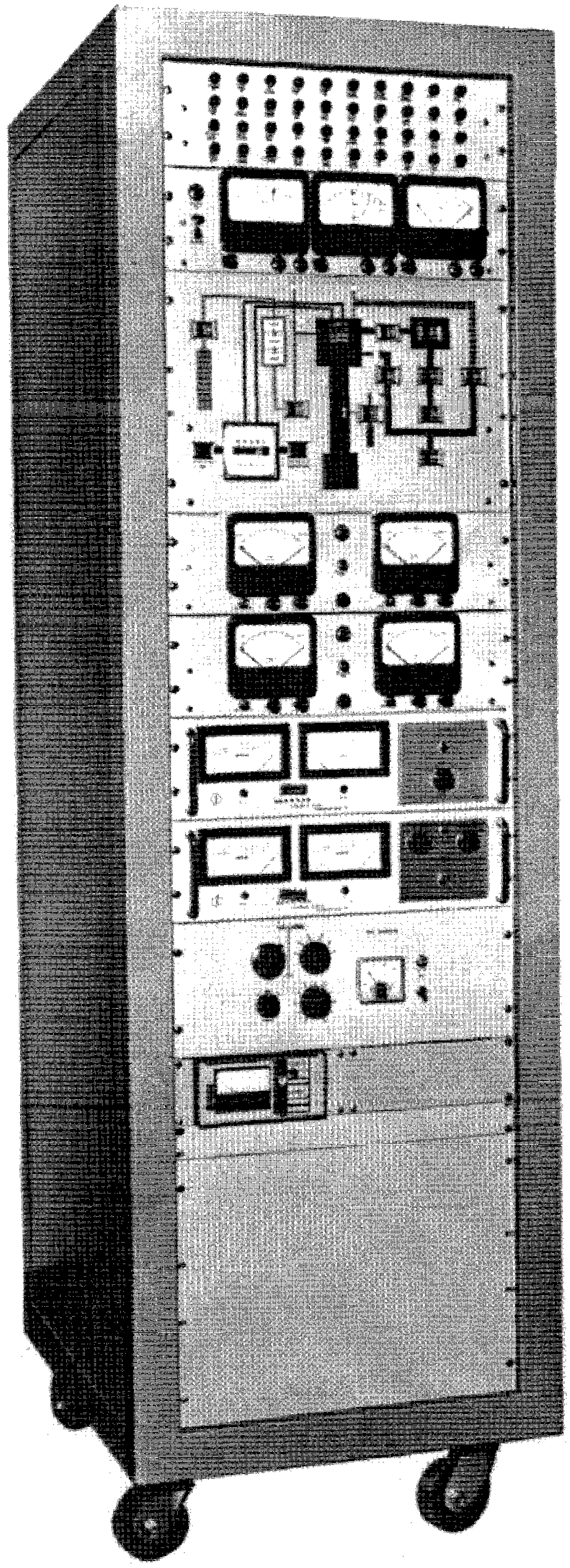


Fig. 4

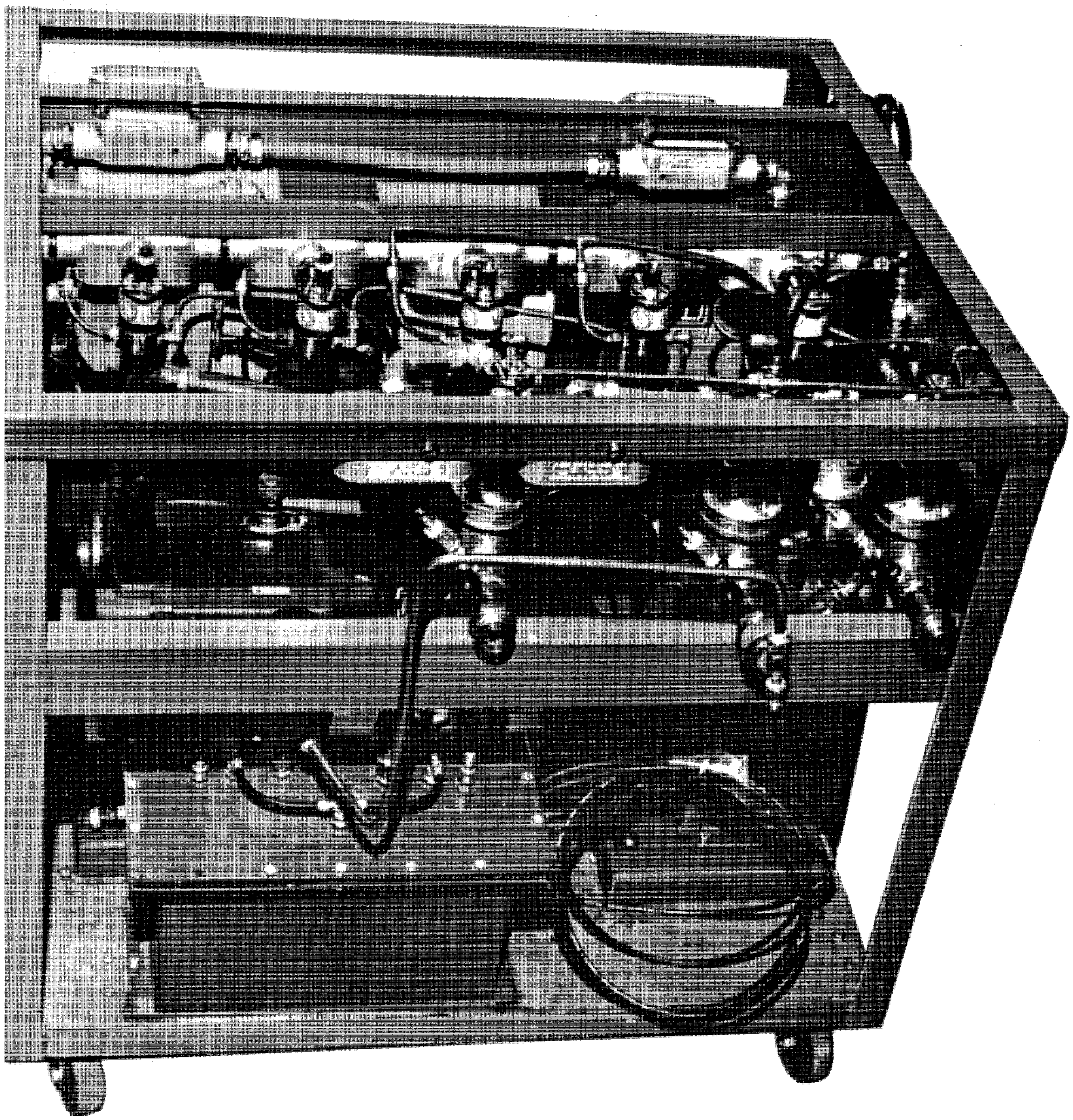


Fig. 5

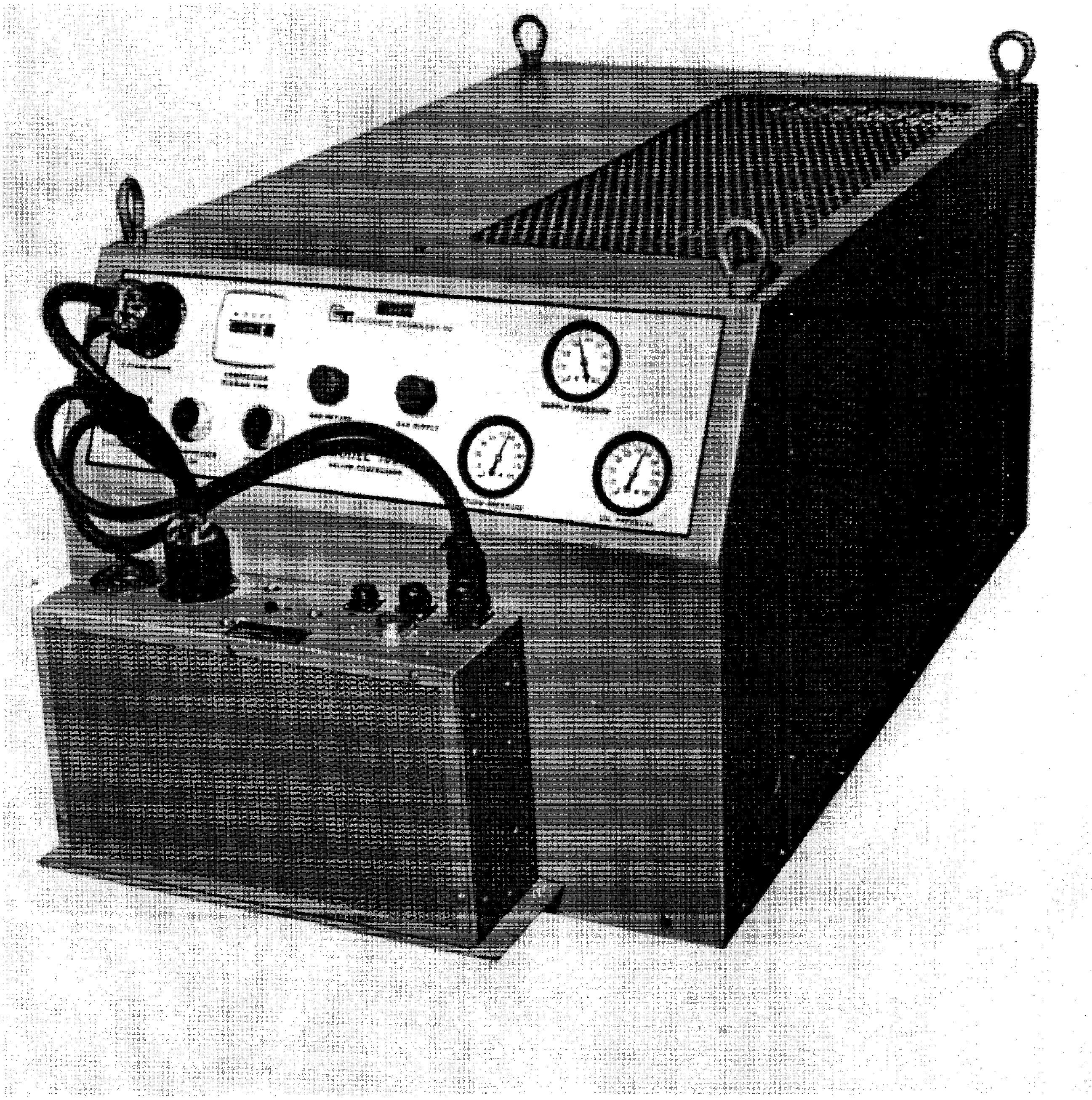


Fig. 6