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LANSCE LIQUID HYDROGEN MODERATOR SYSTEM HARDWARE-CHARACTERISTICS-OPERATION

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Introduction

In this paper, we report the current status of the hardware development and testing program for a liquid hydrogen moderator system currently being fabricated for installation into the Los Alamos Neutron Scattering Center (LANSCE) upgraded target system.[1][6]

Facility Upgrade

The PSR has been commissioned with first beam[2] and the WNR/LANSCE proton transport system was upgraded to transport the higher current beam required for the PSR era[3][4](Figure 1). The upgrade work for the target crypt and the TMRS assembly is progressing. All new target crypt shielding and a new water-cooled beam stop have been installed. The new 500 KW target/shield cooling system has been fabricated. The ambient temperature moderator cooling package is to be delivered this month. Our objective for completing all remaining tasks is August 1985.

Hardware and Design Considerations

1. Refrigerator

   We were very fortunate to locate a Koch 1400 He Liquifier/Refrigerator unit as surplus equipment at our laboratory. The unit was equipped with the three compressor option. Although it was a 1975 model, it had relatively few operating hours on it, 2500 total. After talking to the manufacturer of the unit about our intended application, it was suggested that we return it to the factory for modifications to give a cooling capacity of 450-500 watts. Upon the return of this unit to Los Alamos, it was put through a heat-load test(Figure 2). Preliminary studies indicated a desirability to have 300 Watts of cooling capacity inside the upgraded TMRS. The total capacity of the refrigerator (450-500 watts) gives us a margin for line losses and heat leaks in our cryogenic exchange unit.

2. He/H_2 Heat Exchanger Assembly
Having watched the hydrogen moderator design progress our colleagues at the SNS Project[(5)] were making, we decided to pursue a similar approach by using a circulating pump for the liquid hydrogen. Lacking any cryogenic expertise within our group at Los Alamos, we sought help from another division for developing the fabrication specification for such an assembly (Table I). The design and fabrication package for the heat exchanger and transfer line components was awarded to a vendor with a history of cryogenic dewar fabrication. A simplified heat exchanger schematic is shown (Figure 3). The process of fabrication and testing proved to be a learning experience for both the vendor and ourselves.

3. Thermodynamic Operation
We initially favored a low-pressure, subcritical operating region for the hydrogen with the intent that this would permit us to design a thinner moderator canister. Actual testing demonstrated that our pump would not efficiently circulate the hydrogen gas during cooldown. Thus the liquid that condensed in the heat exchanger was pumped through warm transfer lines resulting in surges that equalled the supercritical range. Our earlier decision to design all components for 17 ATM of operation permitted us to cooldown and charge at the supercritical level of 15 ATM. This mode of operation eliminated the pressure surge problem.

4. Ortho-Para
In order to attain a known ortho-para concentration, we have designed a hydrogen catalyst chamber to be installed into the loop at a later date. Because of the added pressure drop across such a unit, we will initially use the long cooldown approach to attain an equilibrium mixture with an ortho-para ratio of 99.8% para-hydrogen at liquid temperatures.

5. Moderator Canister
Since our test program had forced us into the 15 ATM operating region, we looked into the flat verses curved shaped approaches for

the canister walls. After discovering the cost and time delay to investigate the complex curved shapes by finite element analysis, we have elected to start with a flat head approach(Figure 4). This design can be improved at the same time we upgrade the target material to uranium. We selected to go with 6061 aluminum because of its mechanical properties and history of use for cryogenic applications. The canister dimensions are 13cm H x 13cm W x 5cm D with viewing side thickness of 6.4 mm.

6. System Location

The moderator is located in the TMRS assembly adjacent to the target flux-trap[1](Figure 5). This TMRS assembly is in the center of the target crypt and is viewed by 12 flight paths that pass through the biological shield and into the experimental hall. The hydrogen moderator will be viewed by three of these flight paths. The area above this crypt, the target cell, houses the proton beam transport components responsible for bending the beam from its horizontal transport plane into a vertical plane for transport into the target crypt(Figure 6). Remote handling equipment for servicing the TMRS assembly is also in this room. Maintenance to equipment within the target cell is a "hands on" operation with the beam off. The He/H_2 heat exchanger is located above and to the side of the target crypt with the hydrogen transfer lines passing up through the shielding connecting the moderator to the heat exchanger. This gives a very close couple for the hydrogen system. The He transfer lines route up from the heat exchanger and out into the service area where the refrigerator is located. The compressor trailer is positioned outside of the building. Since the heat exchanger has no organic dynamic seal applications, the moderate radiation levels in this vacinity during beam-on conditions should not effect its operation at this location.

7. Safety

Our approach in designing for safety was to keep the hydrogen volume as small as possible and dump the hydrogen into the vent stack upon any system malfunction. The hydrogen system volume has been minimized by the close mounting of the components. Total system volume is ~ 6 liters, which is the liquid equivalent of one size H hydrogen cylinder. The hydrogen components are located in three places - the target crypt, the target cell, and the service area(Figure 7). If a size H cylinder of gas was completely discharged into either the target cell or the service area, any dispersion would result in the hydrogen air ratio being well below the flammability level. However, two hydrogen monitor heads have been located in critical positions. The target crypt is always under a vacuum of at least 100 microns when we are operating. Any rise in vacuum pressure brought about as a result of a hydrogen leak will shut the system down venting the remaining hydrogen up the vent stack. This target crypt vacuum provides the triple containment for the moderator. The transfer lines and the heat exchanger enclosure have a double containment and are also monitored for a rise in vacuum pressure. Control of these safety features is by relay logic. All vacuum pump exhausts are vented into the hydrogen vent stack.

System Testing

The He/H_2 heat exchanger assembly and transfer lines arrived at the Laboratory as an untested unit. The transfer lines had been fabricated to reach the required positions for the operating mode. This resulted in locating the test set-up in a somewhat awkward manner, adjacent to the target cell(Figures 8 & 9). A test moderator canister was simulated by joining the transfer lines with an enlarged tube section. The support systems for the test ie. instrumentation and controls, and vacuum and vent piping were fabricated by our group. As I indicated earlier, our tests were not at all boring. Our initial attempts to cooldown at the lower pressure settings created temperature and pressure surges that resembled bolt threads when data plots were made. Our vendor was not without fault himself. For example, pump housing seals failed; heaters burned up, melting diodes; rupture diaphrams blew out; noncalibrated diodes were installed; and electrical feedthroughs were overtightened, shearing wires.

After these minor setbacks were corrected, we increased our charging pressure to 15 ATM giving the results as shown(Figure 10). Cooldown at the supercritical region went quickly and very smoothly. The heat load was applied on the hydrogen piping inside the heat exchanger enclosure. While the pump flow appears less than we had specified, we believe we can maintain the required temperature at 300 watts of load. Additional testing is planned when we finish the production moderator prior to inserting it into the crypt.

Cost

A cost summary is listed in Table II.

Acknowledgements

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References

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2. F. Morse, (1985) Status Report On the Los Alamos WNR/PSR Facility, ICANS VIII
3. G. P. Lawrence, (1984) Los Alamos Proton Storage Ring, ICANS VII
4. C. D. Bowman, (1984) Status Report on the WNR/PSR, ICANS VII
5. B. R. Diplock, (1983) Cryogenic Moderator Design, ICANS VI
6. G. J. Russell, (1983) "WNR High-Power (200μA) Target-Moderator-Reflector-Shield," Los Alamos National Laboratory Internal Report, TN-GJR/P-9-006

TABLE I

SYSTEM SPECIFICATIONS

He GAS REFRIGERATOR

KOCH PROCESS SYSTEM, INC.

MODEL 1400 3 COMPRESSORS + LN2

MAXIMUM CAPACITY · 450 WATTS

FLOW RATE : 13.8 G/S

SUPPLY TEMPERATURE: 13 K - 20K

H2 MODERATOR

CANISTER SIZE: 13 Cm H- 13 Cm W- 5 Cm D

CANISTER VOLUME :≃.86L

CANISTER MATERIAL : ALUMINUM 6061

PIPING SIZE : 19mm

H2 SYSTEM VOLUME · ≃ 6L

H2 CHARGING PRESSURE · 15 ATM (SUPERCRITICAL)

TEMPERATURE . 26K

DESIGN HEAT INPUT : 300 WATTS

DESIGN FLOW RATE : 40 G/S

TRANSFER LINE LENGTH : ≃10m TOTAL

TABLE II

SYSTEM COST

	U.S. DOLLARS
* He REFRIGERATOR REWORK	46K
REFRIGERATOR INSTALLATION	2.5
He / H2 HEAT EXCHANGER	44
INSTALLATION HARDWARE	6
INSTRUMENTATION & CONTROL	12
MODERATOR FABRICATION	3.5
REFRIGERATOR CONSULTANT	1.2
DESIGN CONSULTANT	20
DESIGN & INSTALLATION SUPPORT	40
TOTAL	175.2 K

* REFRIGERATOR ACQUIRED FROM SURPLUS- REPLACEMENT COST $ 260 K

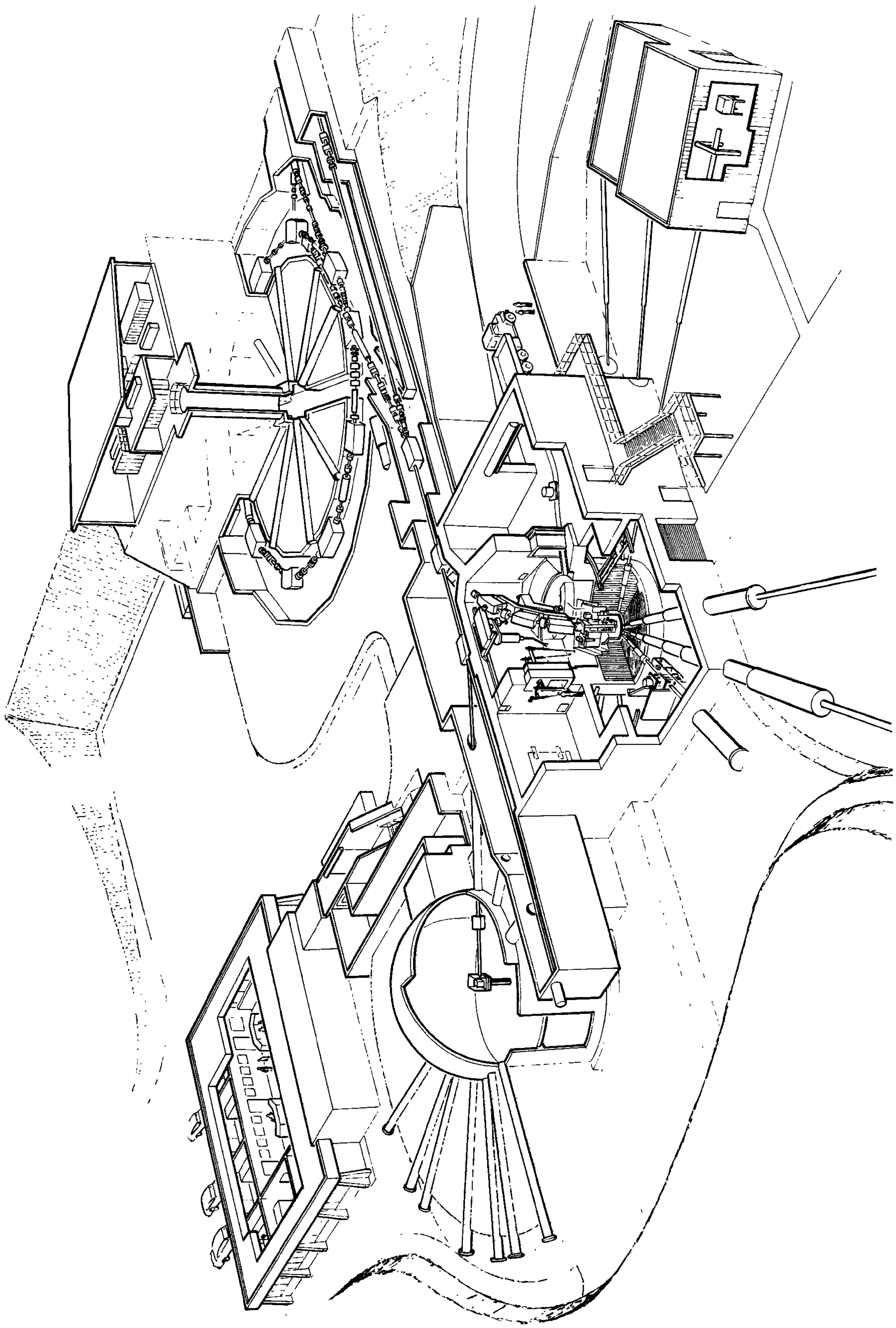

Figure 1. WNR-PSR/LANSCE Facility

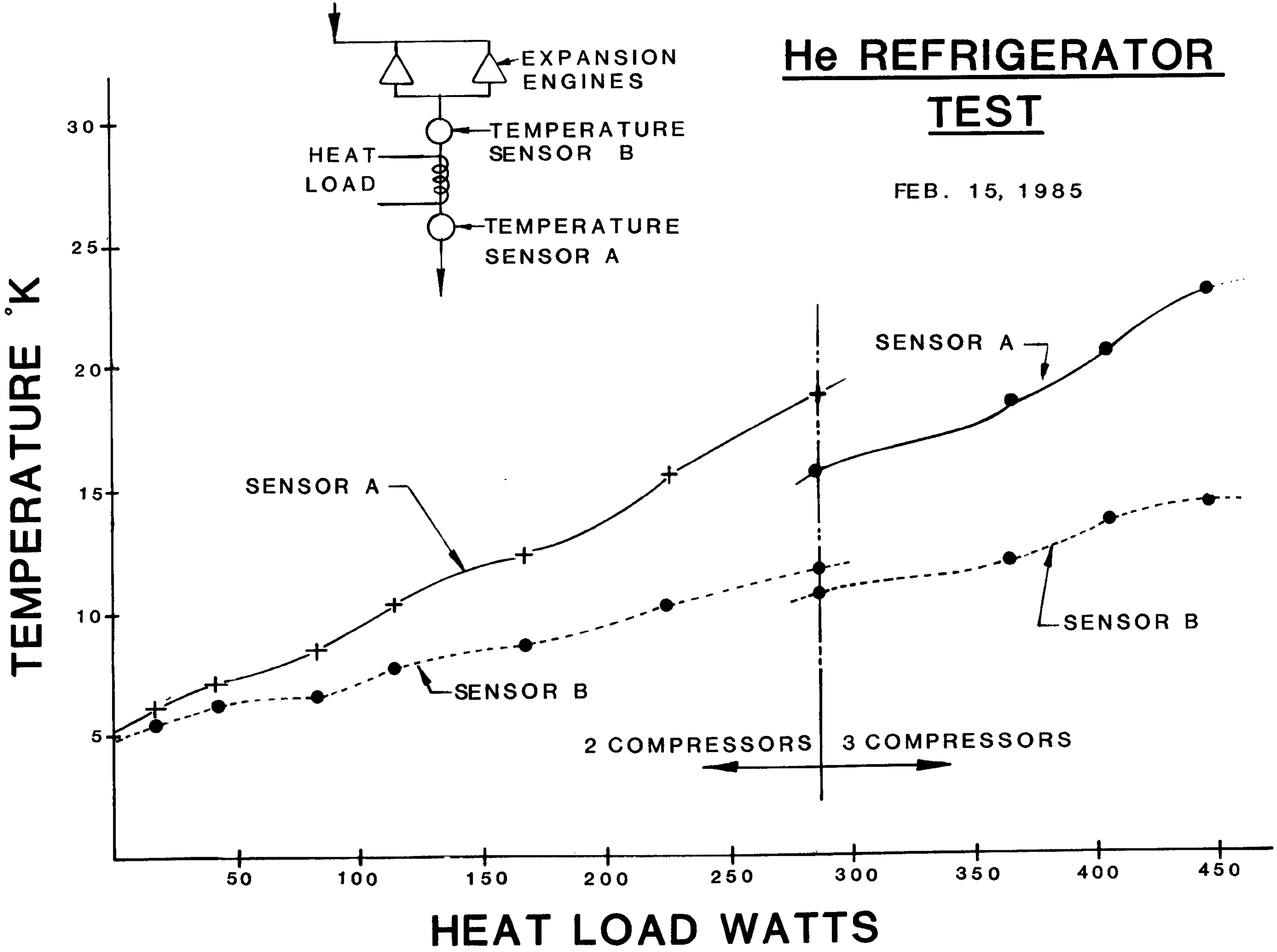

Figure 2. He Refrigerator Test

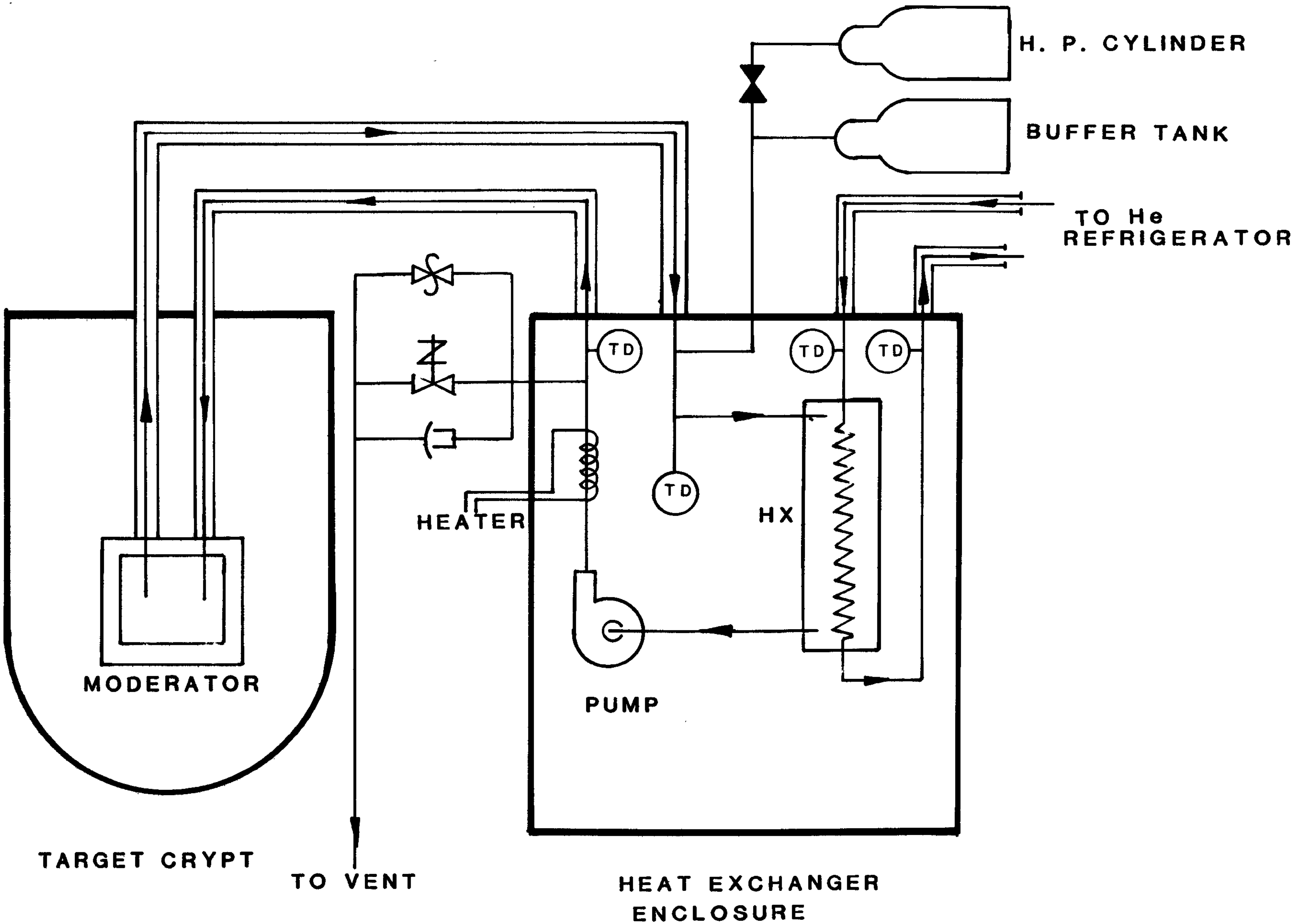

Figure 3. He/H_2 Heat Exchanger Schematic

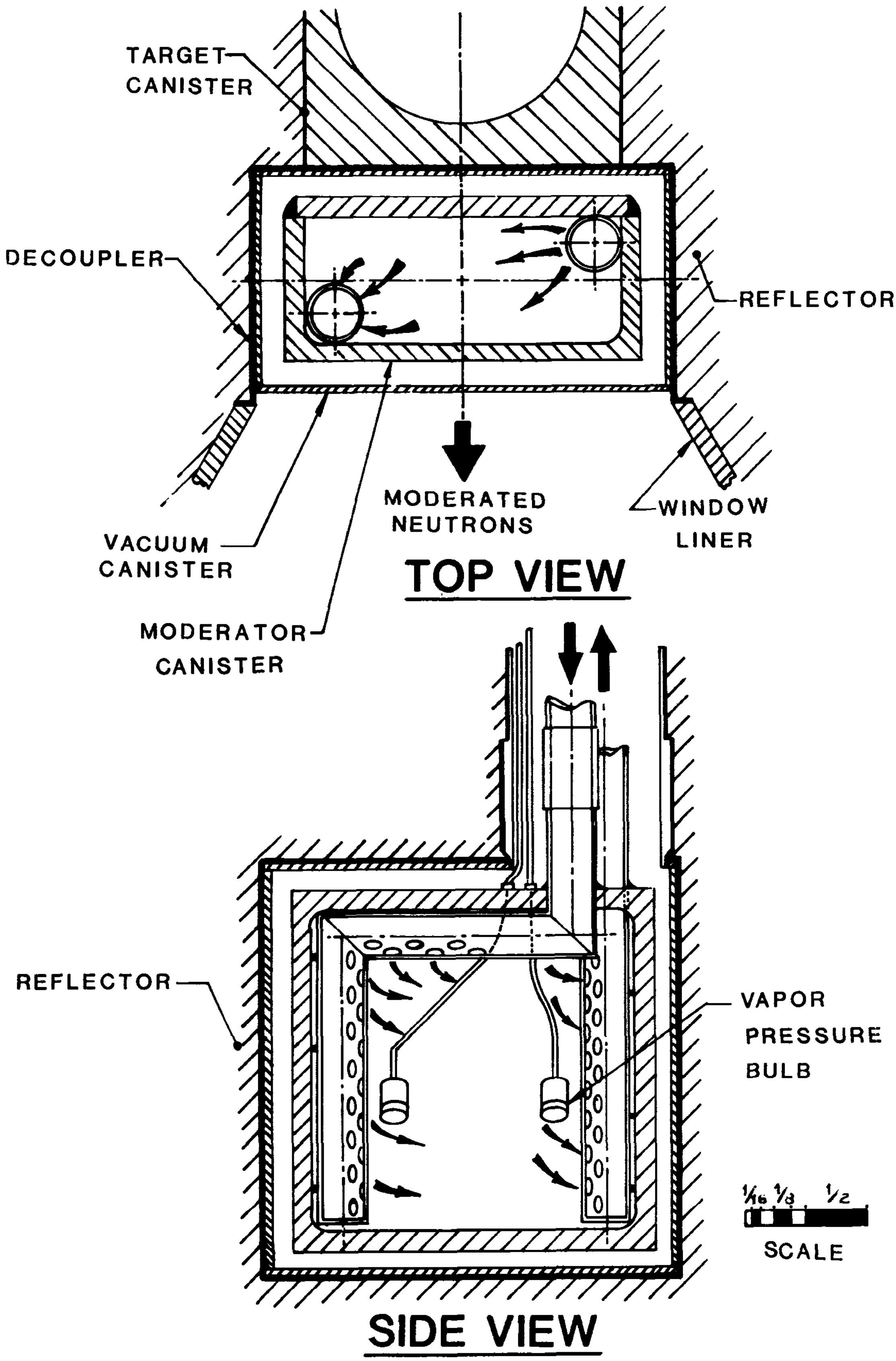

Figure 4. Moderator

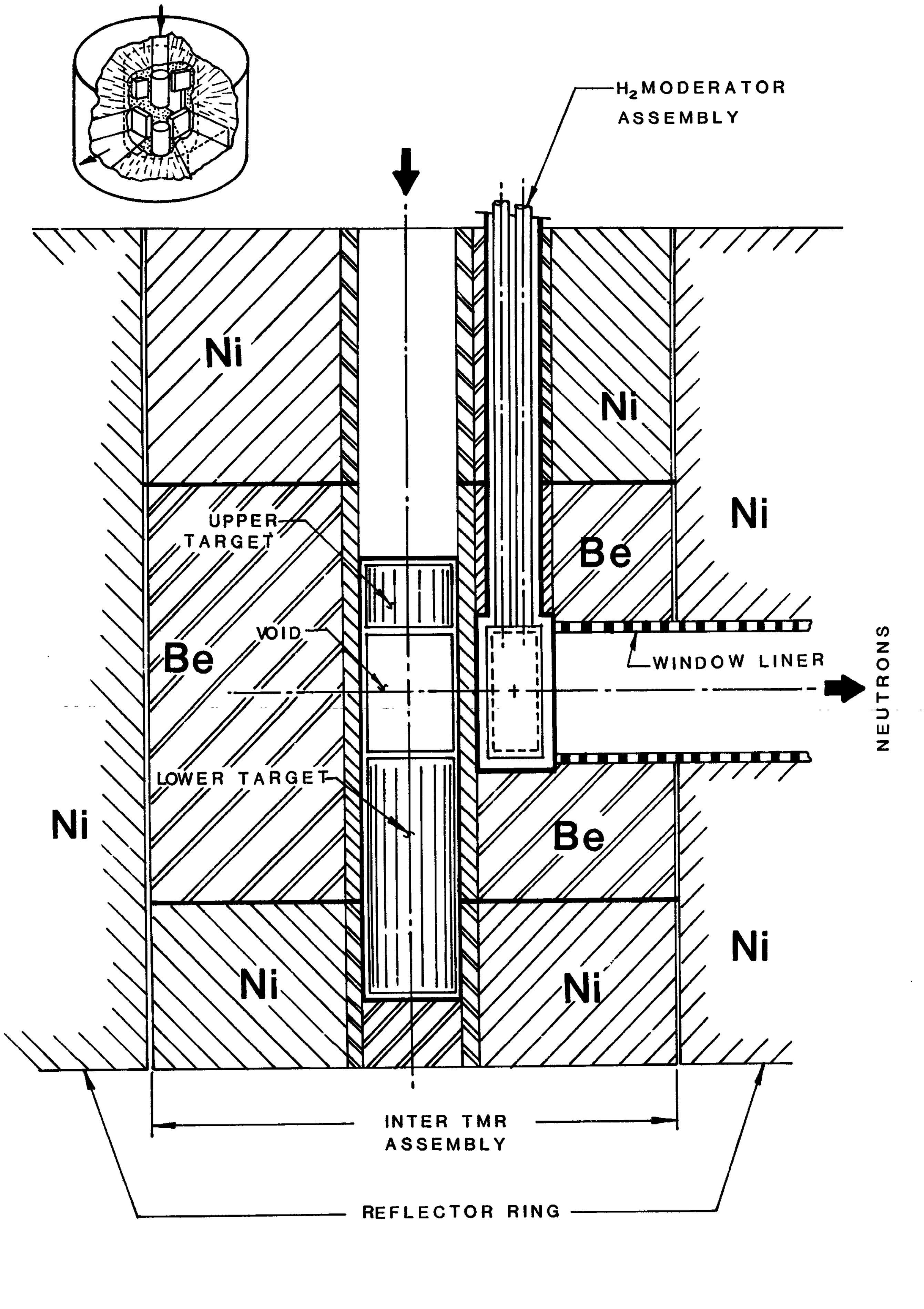

Figure 5. TMRS Assembly

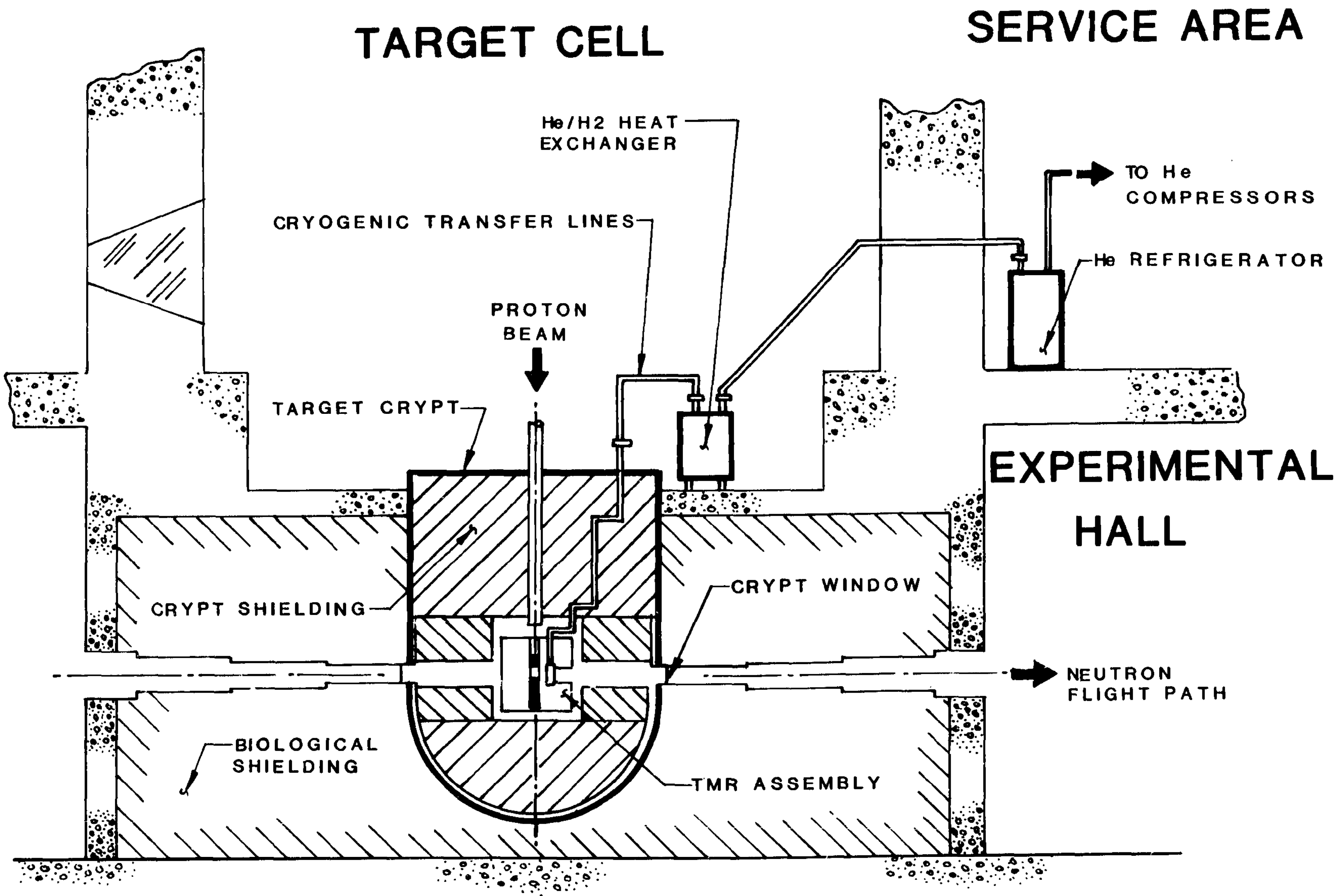

Figure 6. Target Cell Layout

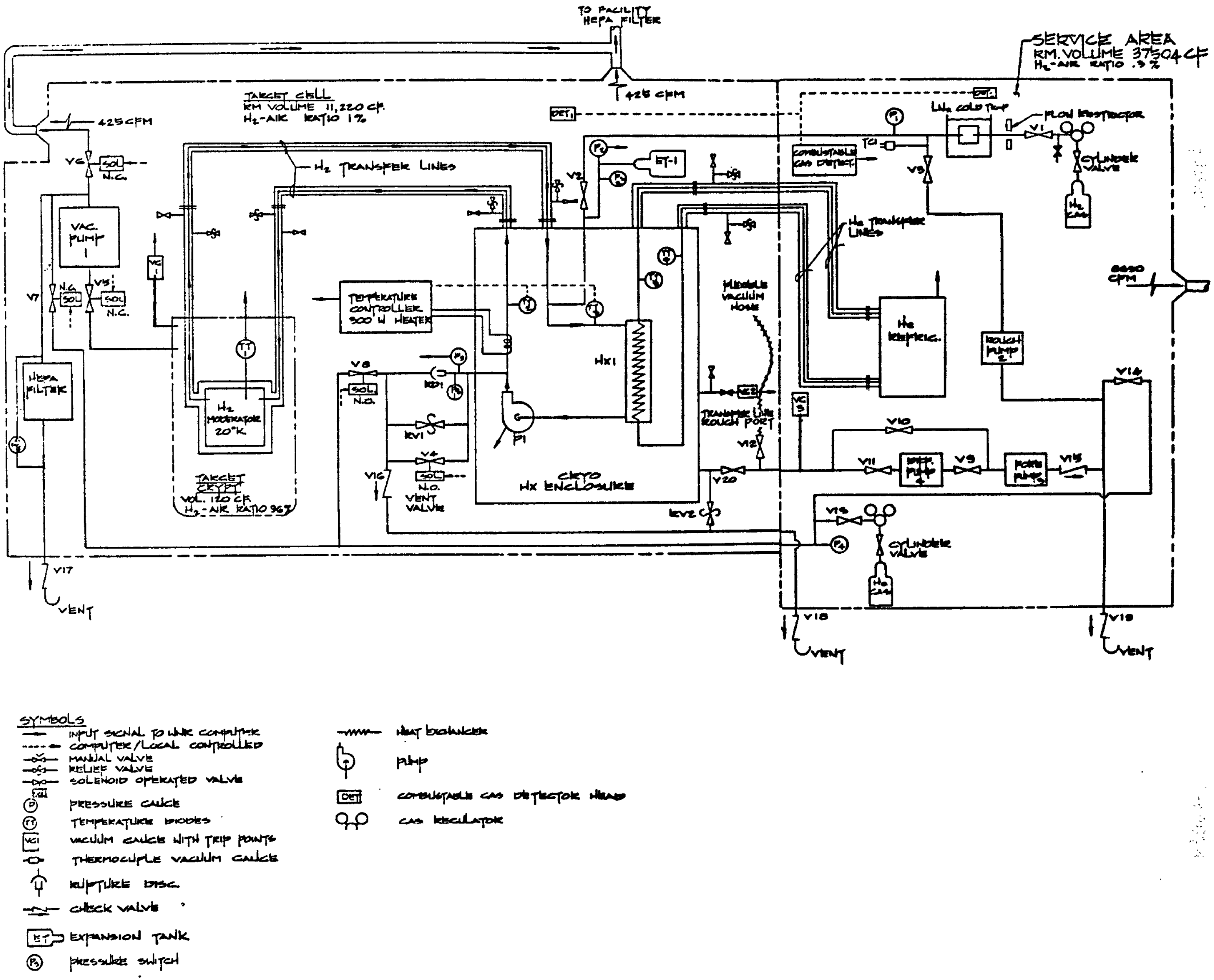

Figure 7. System Schematic

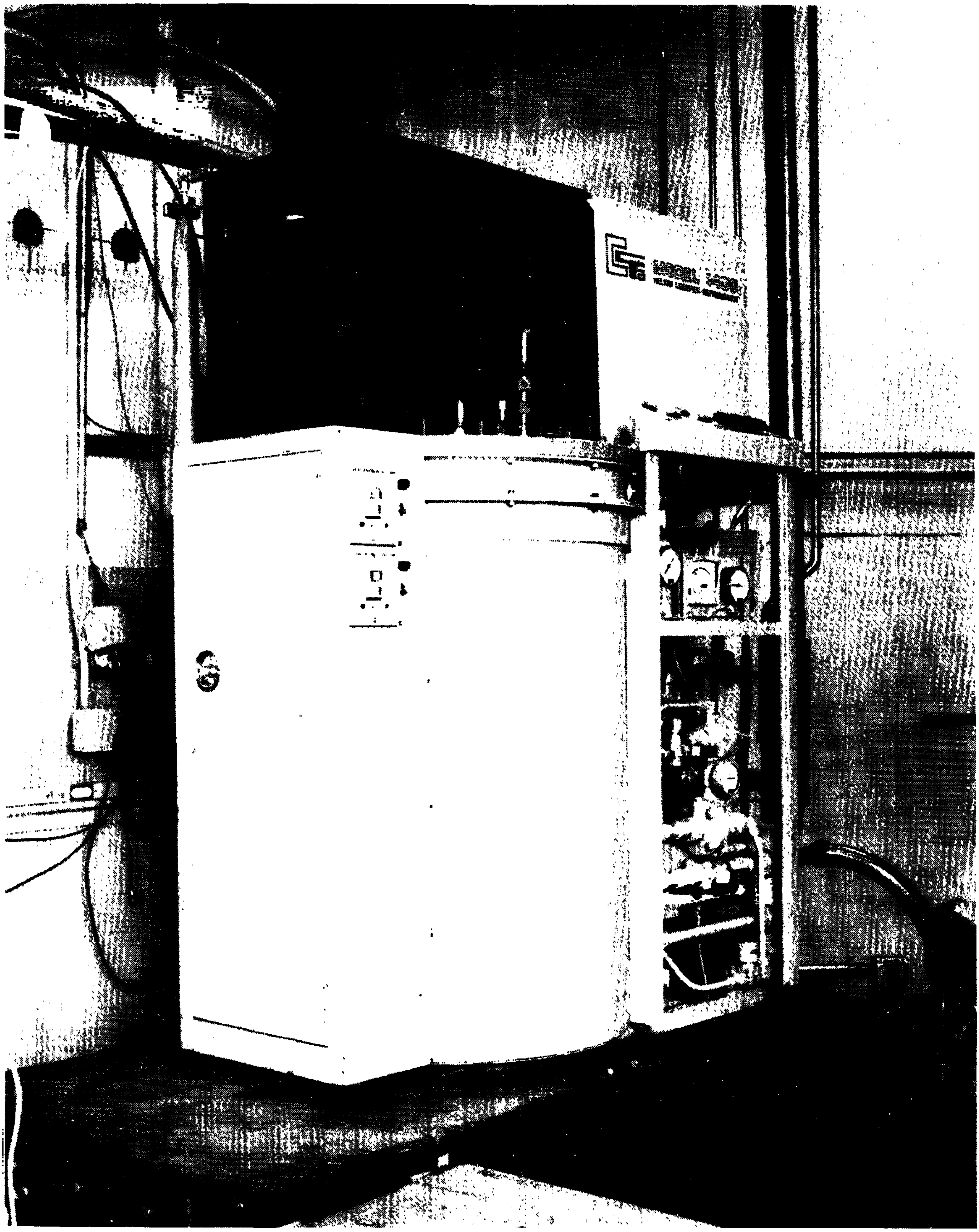

Figure 8. He Refrigerator

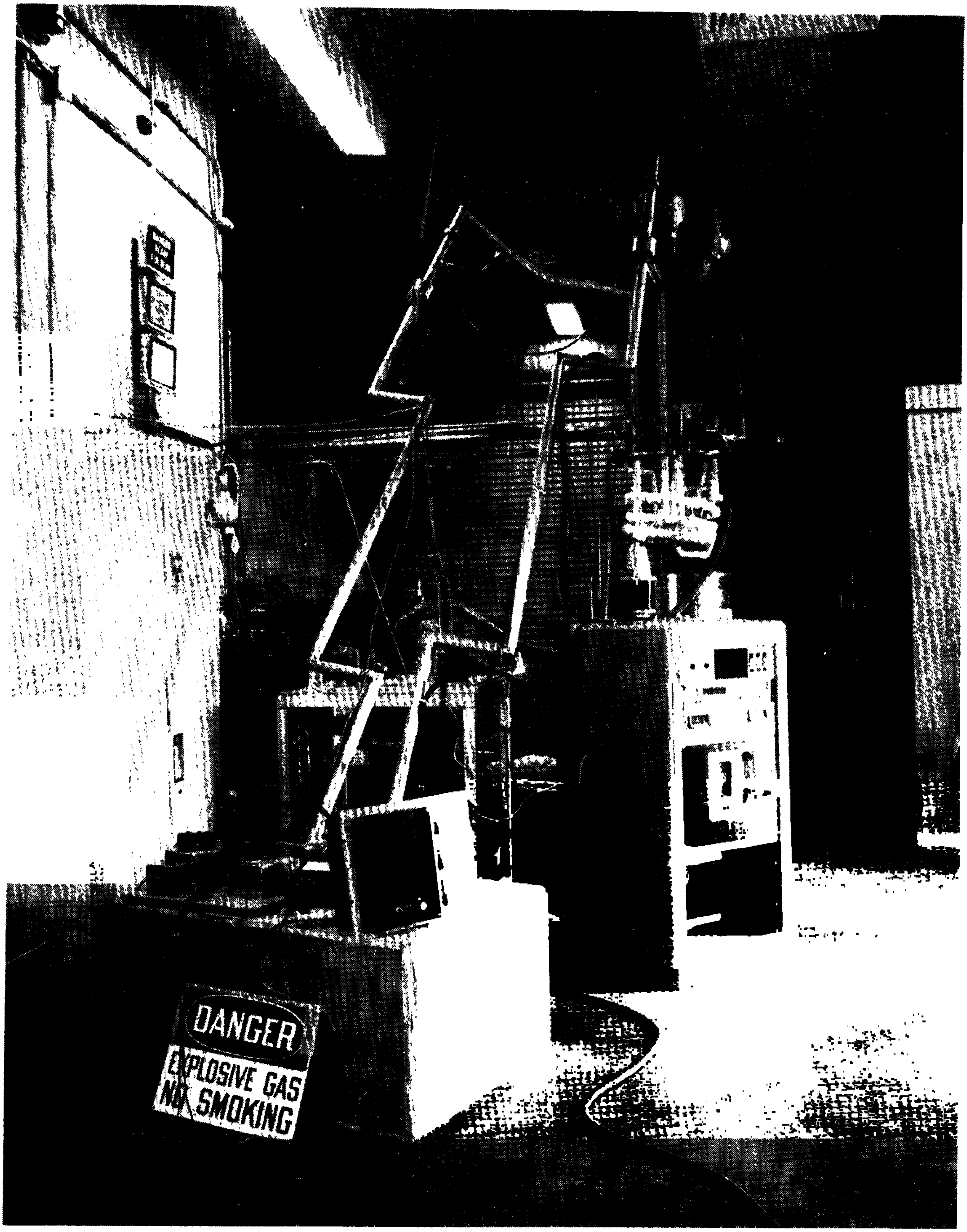

Figure 9. Test Setup

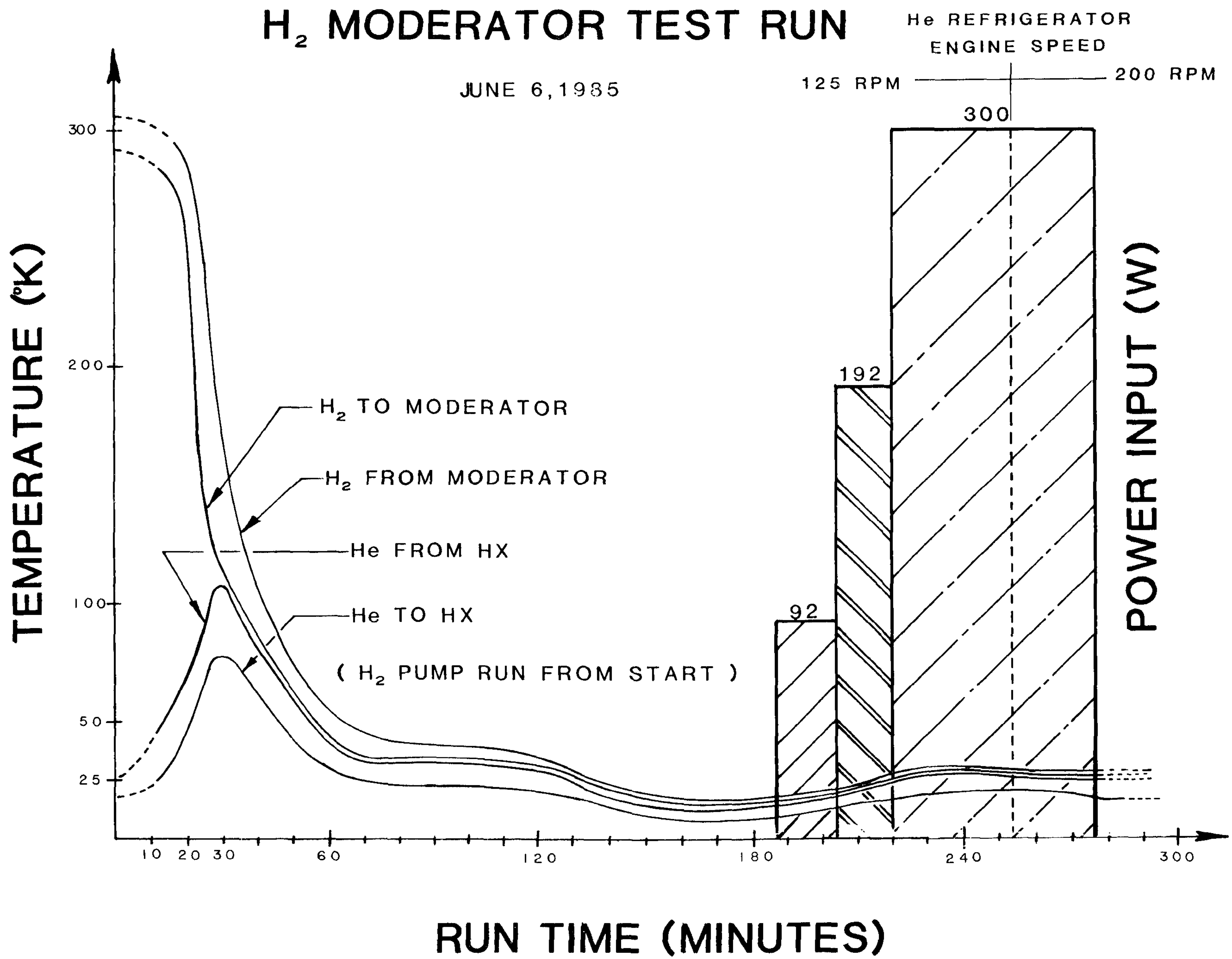

Figure 10. Test Results