**EVALUATION OF CRYOGENIC INSULATION
MATERIAL AND COMPOSITES FOR USE
IN NUCLEAR RADIATION ENVIRONMENTS**

**MATERIAL TEST
AND
PROPELLANT HEATING TEST**

Quarterly Progress Report
1 November through 31 January

George W. Harshbarger
Huntsville, Alabama

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Quarterly Progress Report
1 November through 31 January

E. E. Kerlin
R. A. Elliott
R. D. Crabtree

Prepared for
George C. Marshall Space Flight Center
Huntsville, Alabama 35812

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MASTER

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This report was prepared by the Fort Worth Division of General Dynamics Corporation under Contract No. NAS8-18024, Evaluation of Cryogenic Insulation Materials and Composites for Use in Nuclear Radiation Environments, for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration. The work was administered under the technical direction of the Propulsion and Vehicle Engineering Division, Engineering Materials Branch of the George C. Marshall Space Flight Center, with Dr. R. L. Gause acting as project manager.

FOREWORD

The Fort Worth Division of General Dynamics Corporation (GDFWD), under contract NAS8-18024 with the National Aeronautics and Space Administration, undertook a study that is part of the overall effort necessary to develop the technology required for the design of a Nuclear Rocket Vehicle. The study consists of two different but related programs, each involving reactor radiation and cryogenic fluids. The first program was to evaluate the effects of a combined environment of reactor radiation and cryogenics on selected materials for use as cryogenic insulation, valve seats, and transducer sensors. The second program was to perform an analytical evaluation of the effects of reactor radiation on the fluid thermodynamic state of liquid hydrogen in a large tank. The initial work on these programs has been completed and reported.

This report is the third quarterly progress report to be issued under the new modification to the contract, Modification 5. The work consists of expansions and continuations of the initial two programs. The previous work on the Materials Program has provided valuable data on the performance of various materials in combined environments of nuclear radiation, cryogenic temperature, and acoustic excitation. However, analyses of this data revealed areas where further information

is needed. It is the purpose of this task to continue the previous investigations in order to advance the technology related to radiation effects on materials composing cryogenic insulations, valve seats, and transducer sensing elements.

Previous work on the Propellant Heating Test resulted in the conceptual design of the experiment and the preliminary design of the test tank and LH₂ piping system. The current program will consist of compiling the necessary detail information for procurement of the test hardware.

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I. INTRODUCTION

In the program to develop a flight-qualified Nuclear Rocket Vehicle, technology experiments have been performed to investigate the physical properties of materials considered as potential candidates for design application. The severe environments, including nuclear radiation, liquid hydrogen temperature, and acoustic excitation, to which a nuclear rocket will be subjected place stringent requirements on the equipment associated with the engine propellant system. A thorough understanding of the effects of radiation in combination with other application environments on system components and propellant characteristics is necessary before the reliability and system operating characteristics can be quantitatively assessed. Components and systems utilizing organic materials are particularly vulnerable to nuclear radiation and deserve special attention.

The Fort Worth Division of General Dynamics Corporation (GDFWD), under Contract NAS8-18024 with the National Aeronautics and Space Administration, undertook in June 1966 a study that is part of the overall effort necessary to develop the technology required for the design of a Nuclear Rocket Vehicle (NRV). The program was expanded in April 1967 (Modification I) and again in June 1967 (Modification II). The results of the work on the

Basic and Modification I of the program (Refs. 1 through 4) have provided valuable data on the performance of various materials in combined environment of nuclear radiation, cryogenic temperatures, and acoustic excitation; however, analysis of these data has revealed areas where further information is needed. The results of Modification II program (Refs. 5 and 6), an analytical evaluation of the effects of reactor radiation on the fluid thermodynamic state of liquid hydrogen in a large tank, provided the facility design requirements used in this program.

This quarterly progress report is the third of the progress reports (Ref. 7 and 8) to be issued on the continuation of the basic contract under Modification 5. The program is divided into two major tasks: the Materials Evaluation Program, presented in Section II; and the Propellant Heating Test Program, presented in Section III.

The radiation tests for the materials evaluation program are scheduled to be conducted during the summer of 1969. This change in schedule was necessitated by recent delays incurred in receiving test approval from the Directorate of Nuclear Safety.

The radiation tests for the Propellant Heating Test program are scheduled to be conducted during the following winter.

II. MATERIALS TEST

Previous experiments conducted under Contract NAS8-18024 have consisted of evaluating various materials in the simulated environmental conditions of a nuclear vehicle. These conditions included nuclear radiation, cryotemperature (LH₂), acoustic excitation, and thermal cycling.

Initially, the program was limited to evaluating insulation materials and composites, candidate materials being selected jointly by NASA-MSFC and GDFWD. These materials were exposed to nuclear radiation in both air and LH₂ and then subjected to mechanical property tests. As a result of these tests, certain materials were selected for further evaluation in application tests which included acoustic noise and thermal cycling as added test conditions. These tests produced vital information including the discovery that exposure of cork-type insulation to nuclear radiation and LH₂ temperatures can result in detonations in the insulation system. The acoustic noise and thermal cycling revealed a possible problem area in the application of foam-type insulation.

While the experimental efforts to date have provided valuable experimental data, the results indicate the need for continuing the program on an expanded basis to include materials used in components such as liquid-level sensors, nuclear radiation measuring devices, and LH₂ control valves.

2.1 Test Items

The materials to be tested in this program include those used for (1) thermal insulation, (2) liquid-level sensing, (3) radiation measuring (active type), and (4) valve seals. The test items and materials are listed in Table 2-1.

Table 2-1

TEST ITEMS

Items	Remarks
Insulation	Applied to RIFT tank by NASA-MSFC
Prevalve, 17-in.	Whittaker Corp. Part 138025, modified
Fill Valve, 10-in.	North American Aviation, Inc. Part V7480450
Liquid-Level Sensors	Six Acoustica Model STS 505 One Trans-Sonics continuous capacitance probe Three United Control Model 2641-1 Three Powertron Model UP10045-5 Three Trans-Sonics Model L4447 Three Scientific Instruments Inc. Model 140
Fissioncouples	Three Phillips Petroleum Co. units Three E.G.&G. developmental units, if available
Pressure Transducers ^a	Two potentiometer-type, 20-psia units

^aThe pressure transducers will not be tested in the RTT, but will be included in a GTR test (GTR 20) in order to obtain higher radiation levels.

2.2 Test Cycles

The test will make use of a RIFT-model tank supplied by NASA-MSFC, and will consist of five irradiation cycles performed with the tank filled with LH₂ to a level of 140 in., or approximately 4000 gal. After each of the irradiation cycles, the reactor will be lowered, the RIFT tank will be pressurized to 30 psig, and leak rates of the two test valves will be measured. At the end of the third cycle, these additional steps will be accomplished:

1. Drain LH₂ back into supply tank.
2. Purge RIFT tank.
3. Raise tank and inspect insulation for damage.
4. Make activation measurements.

After the final irradiation cycle, a small area of the tank will be exposed for one hour to acoustic noise at an overall sound pressure level of 141 dB while the tank is filled with LH₂ and pressurized to 30 psig.

A cross-section view of the experimental arrangement is shown in Figure 2-1. The fabrication of the experimental hardware is essentially complete. The insulated RIFT tank and all test items except the 17-in. pre-valve and 3 developmental fissioncouples have been received. The status of the experimental hardware and test items is reviewed below.

Figure 2-1 Cross-Section View of Material Test

2.3 Experimental Hardware

The experimental hardware includes the spider web and thimble, tank support assembly, LH₂ and GH₂ systems, and the basic electrical harness.

2.3.1 Spider Web and Thimble

The spider web and thimble (Fig. 2-2) will be placed inside the silo and positioned above the ASTR tank as shown in Figure 2-1. The spider web will provide protection for the reactor. The thimble, which rests inside the inclined members of the spider web, will exclude water in the ASTR tank from the lower portion of the RIFT tank. In the irradiation position, the bottom of the shroud around the lower test valve will be approximately 1 in. above the bottom of the thimble.

2.3.2 Tank Support Assembly

The tank support assembly has been completed but has not been installed. The assembly consists of four adjustable legs and a work platform that will surround the shroud at the top of the tank. The legs will be attached to the four external longitudinal stiffeners on the tank and will rest on the cover over the spider web. The support assembly will be installed and the tank will be fit-checked in the thimble before any of these items are moved into the silo.

Figure 2-2 Spider Web and Thimble

2.3.3 LH₂ Systems

During the irradiation cycles, the RIFT tank will contain approximately 4000 gal of LH₂ which will be supplied from a 26,000-gal supply tank. The LH₂ supply tank has been moved into position (Fig. 2-3) south of the silo. This tank has been modified slightly so that LH₂ in the RIFT tank can be returned to the supply tank between the irradiation cycles. The supply tank exhaust line has been equipped with a remotely-controlled 6-in. valve and has been extended to connect into the facility exhaust line that leads to the GH₂ vent stack. Also, a larger vaporizer has been installed to enable better pressure control and a water-spray system (a safety feature) has been attached to the tank. The supply tank and all piping and valves attached to it have been cleaned.

From the supply tank, LH₂ will flow through a 2-in.-diam vacuum-insulated line containing a 40-micron filter and to the cryogen manifold. From the manifold flow will be through control valves to a 1/2-in.-diam line and/or a 2-in.-diam line. The 1/2-in. line will be routed through the 10-in. test valve and thence into the RIFT tank. The 2-in. line will be connected directly into the tank. Normal flow during irradiation will be through the 1/2-in. line so as to keep the test valve filled with LH₂.

Figure 2-3 LH₂ Supply Tank

Adapters to enable connecting the LH_2 lines to the RIFT tank at a point inside the top shroud have been completed and installed on the tank. The 2-in. fill-line adapter is shown in Figure 2-4. Both the 2-in. and 1/2-in. adapters are vacuum insulated and extend through the 2-in.-thick top plate on the tank. Pipes extending to the bottom of the tank are connected to the adapters inside the tank. Bellows are incorporated in the adapters to facilitate alignment of the fill lines and to prevent undue stresses resulting from contraction when the tank is filled with LH_2 .

2.3.4 GH_2 System

GH_2 will be vented from the RIFT tank through an 8-in.-diam line. A 20-ft section of flexible line will extend from the top plate of the tank to the GH_2 exhaust manifold outside the silo. The tank end of the line contains two flanges and a bellows. One of the flanges bolts to the top of the tank; the other bolts to the top of the shroud.

The GH_2 exhaust manifold, shown in Figure 2-5, contains an 8-in. pneumatic valve, a 4-in. pneumatic valve, and an 8-in. 40-psi burst disc mounted in parallel. The assembly has been leak checked and is ready for installation. The 8-in. valve, normally open, will be closed during pressure cycles on the tank. The 4-in. valve, a normally-open proportional control

Figure 2-4 Fill-Line Adapter, 2-in.

Figure 2-5 GH₂ Exhaust Manifold

valve will be operated from an electro-pneumatic recorder-controller. A pressure transducer and a pressure switch will be connected into the manifold. The pressure transducer will be used to provide the electrical input for the recorder-controller. The set point of this instrument will be adjusted to regulate operation of the 4-in. valve to maintain a tank pressure of 30 psig during pressure cycles. The pressure switch will be set to operate at approximately 35 psig; upon actuation, the 8-in. exhaust valve will open and valves in the LH₂ lines to the tank will close.

2.3.5 Basic Electrical Harness

An electrical harness, referred to as the basic harness, has been installed between the control room and the silo. Data and control instrumentation inside the control room will be connected to the terminal strips in the junction box. A small metal shed near the silo houses similar junction boxes which contain connecting terminals for lead wires from the RIFT tank components and test instrumentation and from the electrical controls on the LH₂ and GH₂ systems. Controls on these systems (the gas distribution system, the LH₂ supply tank, and the GH₂ exhaust manifold) are either explosion proof or enclosed in shrouds that can be purged with gaseous nitrogen. Wiring between these controls and the terminal shed is enclosed in

electrical conduits. The basic harness and the LH₂ and GH₂ systems will be left in place for use in the Propellant Heating Test.

2.4 RIFT Tank

Figure 2-6 shows the tank with the 17-in.-valve shroud installed. This shroud has been leak checked satisfactorily. The top shroud has been leak checked twice. The first check was performed with blind flanges installed on all shroud and tank openings (as received); for the second check, all shroud and tank penetrations (LH₂ and GH₂ lines and adapters and electrical feed-throughs) were installed. No leaks were observed in either test.

2.5 Test Instrumentation

Test instrumentation mounted inside the RIFT tank will include 19 liquid-level sensors and either 3 or 6 fission-couples. The liquid-level sensors and 3 fission-couples have been mounted to structure (Fig. 2-7) that will support them at the desired levels in the tank. Lead wires from these components will be routed through Deutsch electrical feed-throughs mounted in a flange that will be bolted to the top plate of the tank. Short harnesses will extend from these feed-throughs to others mounted in the top of the shroud.

Figure 2-6 RIFT Tank in Manufacturing Building

Sensor	Sensors Sta. Per		
	30	62	150
Acoustics STS-505	2	2	2
United Control Z641-1	1	1	1
Powertron Up 100455	1	1	1
Trans-Sonic L4447	1	1	1
Scientific Instr. Inc. 140	1	1	1
Fission Couples; 3 at Station 12	1	1	1

Figure 2-7 Instrumentation Mounted on Support Structure

In addition to the instrumentation on the support structure, 16 strain gages are mounted on the inner wall of the tank. Electrical leads from the strain gages will be routed out of the tank and through the shroud in the same manner as for the liquid-level sensors and fission couples.

A duplicate of the instrumentation support structure has been made for use in the mapping run which will precede the irradiation cycles. Foil packets will be attached to this structure at positions corresponding to those at which test items are installed on the instrumentation support structure.

2.6 Test Valves

2.6.1 Whittaker 17-in. Prevalve

Acceptance tests were performed on the modified prevalve by the NARMCO Division of the Whittaker Corporation. The valve is scheduled for shipment to GDFWD for the irradiation test.

2.6.2 NAA Valve

The NAA test valve will be enclosed in a separate shroud and mounted to the RIFT tank at the position shown in Figure 2-1.

Closure plates containing fittings for LH₂ lines will be mounted on the valve inlet and outlet. LH₂ will enter the lower hat-shaped closure plate to flow up through the valve and out a line connected to the top closure plate. Adapters for connecting the LH₂ lines inside the shroud are being fabricated.

The valve will be held in position inside the shroud by three stand-offs mounted between the top closure plate and the top of the shroud.

Penetrations in the shroud top include the LH₂ inlet and outlet lines, an electrical feed-through for thermocouples and the wires leading to the valve position indicator components, and tubing to the actuator and ports from which leakages will be measured.

The valve is being assembled in the test configuration (Fig. 2-8). These efforts are being performed in a clean room.

2.7 Future Work

The future work on the program will be reduced until safety approval is received from the Director of Nuclear Safety. During previous periods, all of the test items and experimental hardware were obtained and stored until the test setup phase can be started. The experimental tests are scheduled for the fall of 1969.

Figure 2-8 North American Aviation Test Valve and Shroud

III. PROPELLANT HEATING TEST

Under Modification II of Contract NAS8-18024, the Fort Worth Division of General Dynamics studied the requirements relating to the design of a test program to validate the analytical prediction models of nuclear heating of liquid hydrogen propellant and the resultant behavior of the propellant in the tank of a nuclear flight module. An investigation was made of the nuclear and thermodynamic factors influencing the behavior of LH_2 in a propellant tank in order to determine those factors most pertinent to an experimental investigation. Additional criteria for the design of the experiment were to scale the geometry and simulate the nuclear environment of a NFM to provide preliminary information with which to predict vehicle systems response. The results of the analytical study are reported in Reference 5.

The effort under the current Modification 5 of Contract NAS8-18024 is to prepare a test plan, receive the necessary test equipment from NASA, and conduct the tests. However, the NASA equipment is not available at this time, and a contract change (Modification 6) is being processed to authorize General Dynamics to purchase the following items: Dewar Tank, Data Acquisition System, Closed-Circuit Television System, Destratification Pump, and Cryogenic Flow-Measuring Components.

The experimental tests have been rescheduled because of the lengthy processes involved in obtaining the contract modification authorizing procurement of the support equipment. The current schedule sets the completion of the design phase of the dewar tank as June 1969. A reanalysis of the test plan presented in Reference 6 will be performed concurrently with the fabrication of the dewar and other support equipment.

During the reporting period, the major effort was directed toward: a review of the scaling groups, analysis of the proposals on the dewar, completion of specifications for the digital data acquisition system, and selection of a destratification pump.

3.1 Scaling Groups

A review of the scaling groups used in the Propellant Heating Test final analytical report was made and the nomenclature compared to those used by other groups in industry. The results were found to be consistent with the other groups.

In reviewing the GD derived groups, it was found that a clear distinction between the groups derived by the Pi Theorem and the groups selected as scaling parameters had not been made in the final analytical report (Ref. 6). The description in the report (pg. 34) leaves the impression that the groups N_1 through N_{11} are a consistent set of pi groups. This is not

true as they are a consistent set of scaling groups which were derived from the pi groups as well as from the nondimensionalization of the governing differential equations. They were selected because they have physical meaning and contain all the variables associated with those physical phenomena felt to be dominant. In deriving the various pi groups, a group arose which was not a standard dimensionless product but existed due to the mathematics of the pi theorem. Therefore, this product was not included in the scaling groups. Instead, group $N_{11} [\beta (T_s - T_i)]$ was listed. This group arises in nondimensionalization of the governing equations if buoyancy effects are included. It should be remembered that the choice of variable grouping is based upon current knowledge and may not be optimum. The most appropriate choice will be brought out in future testing.

3.2 Dewar Tank

A set of specifications and blueprints of the dewar tank were completed and mailed to five prospective fabricators for quotations. Of the three bids received from the vendors, two were accompanied by technical proposals. There was a considerable price range and some discrepancies in the bids. The fabricators will be asked to supply additional information on the dewars after Modification 6 becomes effective.

A cross-sectional view of the tank is shown in Figure 3-1. The changes in the tank design as presented in the final

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E-E(see Figure 3-2)

NPC 26,972

Figure 3-1 PHT Tank, Cross-Sectional View

analytical report (Ref. 6) which affect the thermodynamic considerations are: (1) the location of the heaters and their power density, (2) the size and mounting technique of the anti-vortex baffles, and (3) the location and size of the destratification pump.

The basic requirement for the electric heaters is to provide simulation of local heat shorts and penetrations. The heaters are to be mounted such that there is a uniform heat flux over the heated area with no hot spots. The heaters will be mounted on the interior wall of the inner tank. The internally mounted heaters should provide better heating of the LH_2 , and, since in most tests the heat input will be below that required to produce incipient boiling, no vapor generation problems should occur. As can be seen in Figures 3-1 and 3-2, there will be three heaters located on the cylindrical section of the tank, eight quadrant heaters, and four spot heaters. The latter twelve heaters are to be located on the bottom of the tank. The exact locations for the heaters and the energy requirements are:

Heaters Per Location (No.)	Location Z (ft) Y (ft)		Required Power (watts)	Area (ft ²)
1	ullage area		3000	8 (minimum)
1	14.00	4.00	1500	8.35
1	5.66	4.00	1500	8.35
1	2.08	4.00	1500	8.35

Figure 3-2 PHT Tank, Quadrant and Spot Heaters

Heaters Per Location (No.)	Location		Required Power (watts)	Area (ft ²)
	Z (ft)	Y (ft)		
4	1.375	3.8	300	7.9 (total)
4	1.0	2.5	320 (total)	1.04 (total)
4	0.15	1.5	300 (total)	2.25 (total)

The sets of quadrant heaters will be wired such that they may be operated by quadrant with any one or all quadrants being controlled simultaneously.

The antivortex baffles have been reduced in height approximately one foot; they will be attached to the bottom of the tank by skip welding. The smaller mass (shorter baffle) and skip-welding mounting will reduce the nuclear heating of the baffle and will, therefore, reduce the LH₂ heating in the bottom of the tank.

3.3 Destratification Pump

The following destratification pump requirements were determined using data and criteria developed under Contract NAS8-20330:

Service: Liquid hydrogen, submerged while operating
in a nuclear radiation environment

External Pressure at Operating Conditions: 16 to 60 psia

External Temperature at Operating Conditions: 35° to 45°R

Type: Axial Flow

Flow: Variable from 70 gpm minimum to 200 gpm maximum when operating in liquid hydrogen at a density of 4.36 lb/ft³. Flow will be upward along vertical axis of tank.

Static Head Rise: 15-ft liquid hydrogen maximum

Drive: Electric motor

Control: Variable speed control on motor to achieve flow control over entire flow range

A tentative destratification pump has been selected. The pump, shown in Figure 3-3, is a Pesco Products Model 185032-020 motor/fan type modified for liquid hydrogen service. The pump will be driven from a variable-frequency, 115 V, single-phase power supply. The fan diameter is 3.2 in. and the pump will supply 200 gpm of LH₂ at a shaft speed of approximately 2300 rpm.

Testing of these units requires a liquid hydrogen tank and flow system, a flow-measuring device, pressure-measuring equipment, a speed-indicating unit, accurate temperature-measuring capability, and remote recording instrumentation capable of simultaneous data acquisition. Also required is a power supply with provision for varying output frequency over a range sufficient to control output flow.

The output flow and pressure of the units will be calibrated by the vendor in a short duct assembly mounted inside a LH₂ tank. The calibration will consist of varying the speed

Figure 3-3 Destratification Pump

through the required range while continuously recording speed, flow, output pressure, and fluid bulk temperature. Speed variation will be accomplished by selectively changing input frequency and voltage.

The cleaning and assembly of the pump will be in accordance with the appropriate NASA specifications. The equivalent Pesco Products engineering process specification is P-114 entitled "Cleaning Procedures for Components Used in Liquid Oxygen, Liquid Hydrogen or Liquid Helium."

3.4 Liquid and Gas Piping Systems

The Aerojet-General Corporation is to provide the LH_2 piping system and turbopump under a separate contract with the Space Nuclear Project Office in Cleveland (SNPO-C). Several meetings were held with representatives of AGC to establish the required interfaces. Figure 3-4 presents a schematic of the liquid and gas flow system.

3.4.1 LH_2 Drain Line

Liquid hydrogen will be transferred from the test tank to the supply tank by an interconnecting line as shown in Figure 3-5.

The LH_2 turbopump will be located approximately midway between the supply tank and the test tank, which are 77 ft apart. The turbopump will be used to pump the LH_2 between the two tanks in some instances, while in others pressurized flow

Figure 3-4 PHT, Liquid and Gas Flow Schematic

FIGURE 3-3 LH₂ Piping System Supplied By
Aerjet-General Corp

will be used. For the pressurized flow, the turbopump will be physically disconnected from the system and replaced with a line assembly.

The drain line consists of three major sections: (1) the line from the test-tank outlet to the edge of the silo, (2) the line from the silo to the turbopump, and (3) the line from the turbopump to the storage tank.

The first segment of the drain line will mate with the 4-in. rigid vacuum-insulated line on the test tank. The 4-in.-diam line will extend through the silo wall and couple with a 6-in. flow-start valve and 6-in.-diam vacuum-insulated rigid line.

Approximately 11 ft downstream from start of the second section at the flow-start valve will be the 6-in. LH_2 flowmeter. Discharge from the flowmeter to the LH_2 pump inlet will use 6-in. vacuum-insulated line which will terminate at the pump transition spool, some 16 ft downstream.

The pump discharge line will be a 4-in. rigid line with foam insulation. The line will terminate at a 4-in. flow-control valve some 40 ft downstream from the pump. The valve will be mounted on the supply tank manifold and will be used to control the pump discharge pressure head.

For test conditions not utilizing the turbopump, the pump inlet and outlet lines will be disconnected and a bypass line installed. The bypass line will contain the necessary transition spool and will connect the 6-in. and 4-in. liquid lines; it will be fabricated from foam-insulated 4-in. lines.

All lines will be of stainless steel and will employ clamp-type connecting flanges to minimize possibilities of leaking. Some items will be flange mounted using ASA bolt-type flanges due to availability of commercial components.

Exit through the silo wall will be 6 ft above ground level; the supply tank manifold is located approximately $5\frac{1}{2}$ ft above ground level. Adequate line support, allowing for line movements, and pump support will be provided.

3.4.2 LH₂ Fill Line

The test-tank fill line will be a 2-in. vacuum-insulated line which bypasses the turbopump and flowmeter.

In the filling process, the liquid will enter the 4-in. test-loop line through a 2-in. remotely operated valve. The valve will be installed on a 2-in. vacuum-insulated stub immediately upstream from the LH₂ flow-start valve. All LH₂ entering the fill loop will pass through a filter.

The cryogenic manifold assembly, to be located near the 2-in. fill-control valve, will be an integral component of the fill loop. The manifold assembly has three remotely operated

valves tee-mounted to the main flow line.

One of these valves will be utilized in connecting the cool-down supply line to the test loop. The remaining two valves shall be adapted to purge supply and control.

3.4.3 Purge System

Although GN_2 will be used initially to purge the tanks, components, and connecting lines, the final purge will utilize a combination of system evacuation and GHe purge. A chemical analysis of the resultant exhaust gas will determine when a safe oxygen content has been reached.

Compressed-gas trailers will supply the GN_2 and GHe used for purge, tank pressurization, and valve actuation. Control of the gas flow rates and pressures will be accomplished by use of the Gas Distribution System (GDS). The GDS provides for selection of a gas and its flow conditions; thus a pad or trickle flow of purge gas can be maintained once complete purge has been accomplished.

3.4.4 Pressurization System

Tank pressurization will be accomplished by the use of either GHe or GH_2 supplied from pressure tube trailers and controlled by the GDS. Pressurant gas may be directed to either tank; however, the supply tank will contain a heat exchanger with which tank pressure can be increased by vaporizing LH_2 .

The tank pressurization system will maintain a given pressure within the tank ullage by a remotely controlled pressure regulator. A Bristol controller will slave the regulator and will receive its signal from a transducer sensing tank pressures of 15 to 65 psia.

Inlet and outlet Venturi systems will be used to determine the net mass used for pressurization.

3.4.5 LH₂ Piping System Operation

It will be necessary to precool the LH₂ drain line prior to initiating LH₂ flow. This will be accomplished by introducing LH₂ into the drum line from the fill line and cryogenic manifold. LH₂ entering the manifold will be directed out one of the three side valves. A 2-in. vacuum-insulated stub, located adjacent to and downstream from the flow-start valve, will be connected to the manifold side valve with a 2-in. vacuum-insulated line.

Flow of LH₂ will thus be directed into the 6-in. flowmeter toward the LH₂ pump inlet. Passing through the pump, the hydrogen will travel toward the flow-control valve. Adjacent to the pump side of the flow control valve will be a vacuum-insulated 2-in. stub having a 2-in. valve. Opening this valve will vent the cool-down gas and, eventually, the liquid/gas phase to the facility vent system for disposal.

The time of readiness will be determined by monitoring the LH₂ pump cavity with a resistance-type temperature probe.

Because the unjacketed pump assembly contains the greatest heat mass, indication of LH_2 within the cavity will indicate system readiness.

Having the flow-start valve closed during the line cool-down period will allow test tank pressure to maintain liquid within the tank drain line. However, nuclear heating predictions indicate sufficient energy deposition to cause boiling within the drain line. To vent this entrapped gas, a valve will be stubbed in immediately upstream from the flow-start valve. The exit from this line will be plumbed back into the tank, thus allowing the return of the boiloff gas to the tank.

3.4.6 GH_2 Vent and Measuring System

The venting system requires sufficient capacity to handle the boiloff during the cool-down cycle prior to filling the LH_2 test tank. A gas-measuring system integrated into the venting system will have a range sufficient to handle the boiloff with ambient heat leakage and with ambient heat leakage plus nuclear heating. It is planned that these measurements will be made with two venturies having overlapping capabilities; the upper and lower capabilities will cover the boiloff range anticipated during the test. The piping and valve arrangement will permit the use of either venturi or both venturies in parallel.

A pressure-control valve downstream from the venturies will be actuated by a Bristol controller which will receive a signal from a pressure transducer measuring the test tank pressure. This system will permit a constant pressure to be maintained in the test tank during the boiloff measurements.

Figure 3-6 shows a schematic of the GH_2 vent and measuring system. This system is the same as the one presented in Reference 6 with the addition of a pressure relief valve in parallel with the burst disc.

3.5 LH_2 Pump

The LH_2 pump selected for the test is a NERVA Technology turbopump developed and manufactured by Aerojet-General Corporation (AGC). The pump (Model No. 708800-89, Serial No. 889016) has previously been used in evaluation tests at Lewis Research Labs and will be inspected and serviced by AGC before being sent to GDFWD for service in the PHT. Figure 3-4 shows the location of the pump in the LH_2 piping system.

The LH_2 pump is nonjacketed and close-coupled to a turbine driven with GHe , GH_2 , or both. The turbine driving gas will be supplied from a 117-ft³ compressed-gas trailer and controlled with a remotely operated turbine shutoff valve (TSO). Pump speed will be measured and used as the speed control signal. Calibration for individual flow rates will determine the operational parameters. The system will be instrumented such

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Figure 3-6 GH₂ Vent and Measuring System

that the approach of overspeed will terminate the gas flow and dump the pressure. The required instrumentation for the turbopump are shown in Table 3-1.

Although the design speed of the pump is in the 20,000-rpm range, the pump will be used at approximately 10,000 rpm to obtain the required flow rate of 22.4 lb/sec. This speed is within the operational envelope of the pump.

3.6 TV System and Lighting

The television system selected for monitoring the LH₂ inside the tank is a COHU Electronics, Inc., Model 2500 camera with a nonbrowning videocon enclosed in a stainless steel sleeve. The camera will be continuously purged with GN₂. A zoom lens attachment will be used to provide close-up coverage of specific areas within the tank.

The primary thermodynamic consideration is the heat input to the tank due to the light level required for TV coverage. This problem has been reduced by selecting a special sealed-beam lamp (made by General Electric) which rejects approximately 70% of the thermal radiation through the back side (reflecting surface) of the lamp. Two 300-watt, 7-in.-diam lamps will be mounted external to the tank.

Another problem that has been resolved is that of "black out" due to specular reflections within the tank. The tank

Table 3-1

TURBOPUMP INSTRUMENTATION FOR PROPELLANT HEATING TESTS

Type of Measurement	No. of Measurements	TPA Parameter	Range	Type
Pressure	2	Pump Inlet Pressure	0-70 psia	Taber S.G. Press
	2	Pump Discharge Pressure	0-500 psia	Taber S.G. Press
	2	Turbine Inlet Total Pressure	0-150 psia	Taber S.G. Press
	2	Turbine Discharge Pressure	0-50 psia	Taber S.G. Press
	1	Bearing Housing Pressure	0-500 psia	Taber S.G. Press
	1	Turbine GH ₂ Orifice Line Pressure	0-70 psia	Taber S.G. Press
Differential Pressure	1	Bearing Housing to Turbine	0-500 psid	Statham S.G. P
	1	Turbine GH ₂ Orifice Pressure	Unspecified	Statham S.G. P
Temperature	1	Turbine GH ₂ Orifice Line Temp	300-600°R	Cr/Al Thermocouple
	2	Turbine Inlet Temperature	300-600°R	Cr/Al Thermocouple
	2	Turbine Discharge Temperature	300-600°R	Cr/Al Thermocouple

Table 3-1 (Cont'd)

Type of Measurement	No. of Measurements	TPA Parameter	Range	Type
Temperature	2	Pump Inlet Temperature	20-70 ^o R	Rosemount RTT
	2	Pump Discharge Temperature	20-70 ^o R	Rosemount RTT
LH ₂ Flow	2	Pump Flow Rate	0-5000 gpm	Potter 5- $\frac{1}{2}$ -136
GH ₂ Flow	1	Turbine Flow Rate	0-5 lb/sec nominal 1.1 lb/sec	
Speed	2	TPA Shaft Speed	0-20,000 rpm	(Speed probes integral with TPA)

interior will be "sand blasted" with glass beads to produce a uniform diffuse surface. This will eliminate the use of Scotchlite within the tank and aid in producing a more uniform light level.

3.7 Digital Data Acquisition System

Specifications for the digital data acquisition system are complete, and feasibility studies from several system vendors have been reviewed. Only one vendor, Trans-Sonics, Inc., Burlington, Massachusetts, has been able to meet the 0.5- μ v sensitivity specification. Another vendor sent in several amplifiers to be evaluated as possible input devices, but none of them would meet specifications. Several amplifiers will be evaluated during the next reporting period.

3.8 Future Work

The primary objective during the next period will be to obtain authorization to purchase the special test equipment for the program. During this period several amplifiers will be evaluated for application in the data acquisition system. Contacts with bidders of the dewar tank will be maintained to resolve some of the problem areas.

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