FZK-164
14 JUNE 1963

KEYPUNCHED

**FIRE-INCIDENT AND DAMAGE REPORT
OF
30 MARCH 1963 MATERIALS EVALUATION
EXPERIMENT IN THE NARF GTR RADIATION
EFFECTS TESTING SYSTEM**

FILE COPY

Do not remove from

1-15011

Technical Information Center
Aerojet-General Corporation

Prepared for
Aerojet-General Corporation
Azusa, California

MASTER

NUCLEAR AEROSPACE RESEARCH FACILITY

operated by

GENERAL DYNAMICS | FORT WORTH

DISTRIBUTION OF THIS DOCUMENT UNLIMITED

MAY 22 1964

X-2845

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

FZK-164
14 JUNE 1963

MASTER

GENERAL DYNAMICS

NUCLEAR AEROSPACE RESEARCH FACILITY

**FIRE-INCIDENT AND DAMAGE REPORT
OF
30 MARCH 1963 MATERIALS EVALUATION
EXPERIMENT IN THE NARF GTR RADIATION
EFFECTS TESTING SYSTEM**

**Prepared for
Aerojet-General Corporation
Azusa, California**

Subcontract NP-5

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

GENERAL DYNAMICS | FORT WORTH

DISTRIBUTION OF THIS DOCUMENT UNLIMITED

MAY 22 1964

PREFACE

This document is a formal summary of information that was previously presented to Aerojet-General Corporation in the form of informal memorandums relative to the materials-test-program incident of 30 March 1963.

BLANK

TABLE OF CONTENTS

	<u>Page</u>
PREFACE	3
LIST OF FIGURES	7
INTRODUCTION	9
I. DESCRIPTION OF EQUIPMENT AND TEST SETUP	11
1.1 Equipment Description	11
1.1.1 Dewar	11
1.1.2 Pulling Assembly	12
1.1.3 Liquid-Hydrogen Transfer System	12
1.1.4 Liquid-Nitrogen Transfer System	14
1.1.5 Exhaust System	14
1.1.6 Instrumentation	14
1.1.7 Pressure-Relief System	16
1.2 Television Monitoring	17
1.3 Hydrogen Detection System	17
1.3.1 Description of System	17
1.3.2 Location of Sensor Heads	19
1.4 Responsibilities	20
II. DESCRIPTION OF EVENTS	23
III. DAMAGE SUMMARY AND ANALYSIS	37
3.1 Present Condition	37
3.2 Dewar History	47
3.2.1 First Dewar Configuration	47
3.2.2 Second Dewar Configuration	48
3.2.3 Third Dewar Configuration	48
3.3 Post-Test Analyses	50
3.3.1 Weld Metallography	50
3.3.2 Hydrotest of Dewars	54
IV. CAUSE OF DEWAR FAILURES	61
4.1 Control Dewar	61
4.2 West Dewar	61

TABLE OF CONTENTS (Cont'd)

	<u>Page</u>
4.3 East Dewar	62
4.4 North Dewar	62
V. EXPERIMENTAL EQUIPMENT AND PROCEDURAL MODIFICATION	65
5.1 Experimental Equipment	65
5.1.1 Dewars	65
5.1.2 Tensile-Test Assemblies	65
5.2 Operating Philosophy and Procedures	66
VI. BACKGROUND OF TEST PERSONNEL	67
APPENDIX A - NUCLEAR SAFETY COUNCIL REVIEW	77
APPENDIX B - SYSTEM ENGINEERS LOG RECORD	83

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Pulling Assembly, Showing Setup for Shear Tests	13
2	Simplified Flow Diagram of Cryogenic Fluid System	15
3	Perspective View - GTR Facility Showing Hydrogen Detectors	18
4	Pressure-Recorder Traces at Time of Incident	32
5	Dewar Temperatures at Time of Incident	33
6	Control Dewar after Failure	38
7	Control Dewar after Failure Showing Tear in Parent Material	39
8	West Dewar Upper Surface Reactor Side	40
9	West Dewar Reactor Side Close-Up	41
10	North Dewar Upper Surface Reactor Side	42
11	North Dewar Lower Corner Reactor Side: Front View	43
12	North Dewar Lower Corner Reactor Side: Side View	44
13	North Dewar Section Thru Bottom	45
14	North Dewar into Lower Corner	46
15	Photomicrograph (1.3x) of Weld Failure	51
16	Photomicrograph (9x) of Weld Failure	52
17	Photomicrograph (4x) of Weld Penetration (Keller's Etch)	53
18	East Dewar Hydrotest, Prior to Pressurization	56
19	East Dewar Hydrotest, Just Prior to Failure	57
20	East Dewar Hydrotest, Just After Failure	58
21	East Dewar Hydrotest, After Failure	59

BLANK

INTRODUCTION

General Dynamics/Fort Worth is under contract with Aerojet-General Corporation to perform a series of experiments on various selected materials in a combined low-temperature (liquid hydrogen) and nuclear-radiation environment. After approximately ten hours of operation of the second experiment in this series, a fire broke out in the Ground Test Reactor pool and the experiment was terminated. This report presents facts pertinent to the incident, discusses probable causes, outlines proposed steps necessary to preclude recurrence, and defines the responsibilities of GD/FW and of Aerojet-General in connection with the conduct of the test program.

BLANK

I. DESCRIPTION OF EQUIPMENT AND TEST SETUP

1.1 Equipment Description

1.1.1 Dewar

The dewar is a four-walled vessel constructed of aluminum. The inner chamber, formed by the inner wall is the hydrogen vessel and encloses the lower portion of the pulling assembly, including the test specimens. The hydrogen chamber is surrounded on four sides at the bottom by a vacuum chamber. Similarly, the inner vacuum chamber is surrounded by a liquid-nitrogen chamber and then by an outer vacuum chamber. The outer vacuum chamber originally contained a foam insulation intended for thermal insulation. Following complications associated with this insulation, it was decided to convert this space to a vacuum wall. The fill and vent lines to the liquid-nitrogen chamber extend through the outer vacuum wall. The vacuum port to the inner vacuum chamber extends through the nitrogen chamber and the outer vacuum chamber. The liquid-hydrogen fill line and gas exhaust line are located in the pulling-assembly flange plate which mates with the dewar. Liquid-hydrogen and liquid-nitrogen vessels were earth-grounded before any hydrogen flow was initiated. The hydrogen exhaust manifold was also grounded.

1.1.2 Pulling Assembly

The pulling assembly consists of a framework containing the specimen pull-rod assembly, hydraulic pulling cylinders, and lower specimen mounting brackets (Fig. 1). The pull rods extend through Teflon sealing glands located above the flange plate. Between the seals and flange plate, the rods are enclosed by tubes containing ball-bushing rod guides and into which warm helium gas is bled. The pulling assembly also contains an extensometer mechanism which consists of two concentric aluminum tubes extending from the specimen area to a point above the flange plate. A plug and a double gland seal using a spring-backed Teflon seal is used to seal the annular space between the inner and outer tubes. The outside of the outer tube is also sealed with a double gland seal similar to that described above and is in turn secured and sealed to the pulling-assembly upper flange. An assortment of hydraulic and pneumatic cylinders are used to actuate and control the pulling and extensometer assemblies.

1.1.3 Liquid-Hydrogen Transfer System

The liquid-hydrogen transfer system has been enlarged to a nominal 3/4-inch ID. A manifold equipped with remotely operated shutoff valves is located outside the facility shield. The larger size transfer lines facilitate the flow rates required for these test assemblies without the near-critical tank pressures and line-pressure drops encountered with the previous system. The remote-control valves facilitate liquid-level control with the three-dewar system and

NPC 17,705
31-6979

Figure 1. Pulling Assembly, Showing Setup for Shear Tests

quick termination of cryogen flow in the event of an emergency. The manifold is equipped with two inlets to permit changing hydrogen trucks without interrupting cryogen flow to the dewars. Each inlet is manually valved. A simplified flow diagram of the complete cryogenic fluid system is shown in Figure 2.

1.1.4 Liquid-Nitrogen Transfer System

Liquid nitrogen is supplied to the dewars from a liquid-nitrogen-transfer trailer located adjacent to the reactor pool. Flexible 1/2-inch copper tubing insulated with a 1-inch-thick layer of Armstrong Armaflex thermal insulation is used as the transfer line.

1.1.5 Exhaust System

The hydrogen exhaust system consists of three flexible 1-1/2-inch lines extending from the dewars to a 4-inch exhaust manifold located over the handling area and extending up a 20-foot stack at the northeast corner of the north shield test area. A clapper-type check valve is located on top of the stack.

1.1.6 Instrumentation

A pressure transducer with a range of 0-10 psig was installed through the flange plate to monitor pressure in the dewar. The output of this pickup is recorded continuously.

Two copper-constantan thermocouples were provided in each dewar to monitor the temperature of LH_2 ; they were located at distances of 12- and 24-inches below the lower surface of the pull-assembly flange plate. The normal

Figure 2. Simplified Flow Diagram of Cryogenic Fluid System

cryogen level was approximately 1 to 3 inches above the 12-inch thermocouple. The output of each thermocouple was monitored throughout the test.

A liquid-level-indicating system consisting of five carbon resistors mounted in a rake was provided in each dewar. The resistors were spaced at 10, 14, 18, 22, and 27.2 inches down from the dewar lid.

1.1.7 Pressure-Relief System

A pressure-relief system is installed in each test assembly to provide automatic relief in the event that the exhaust line or stack becomes restricted. This system consists of a T-fitting in the exhaust line adjacent to the dewar outlet fixture - a tube which is routed up beside the pulling assembly to approximately the level of the pulling cylinders. An all-metal pop safety relief valve set to relieve at 7.5 psig is installed at the end of the vertical tube. The valve selected is a Lunkenheimer Figure 1227, 1-1/2-inch NPT. This valve opens fully at the preset pressure and will not close until the pressure falls back below this value. The valve was selected to handle a gas flow greater than that which would result from a liquid flow of 135 gallons/hour being flashed to gas. With the valve located well above the dewar, freeze-up of the device would present no problem. To prevent entrapping air in the relief stack, a helium bleed tap is installed at the upper end of the stack so that warm helium gas is continuously purged into the stack.

1.2 Television Monitoring

A closed-circuit television system is used to provide visual coverage of all test fixtures.

1.3 Hydrogen Detection System

1.3.1 Description of System

The primary hydrogen gas-leak-detector system used in this experiment is a Model H200-FS system of General Monitors, Inc. It consists of ten detector heads and corresponding modules. The detector heads (or transducers) for this system are located as shown in Figure 3.

The detector heads each consist of a catalytic ac bridge element, one-half of which is exposed to the atmosphere but completely enclosed by a double-walled sintered flame arrestor. A solid-state ac amplifier amplifies the signal from the bridge proportionally to the amount of hydrogen gas present in the atmosphere being tested. An output of as much as 1 vdc is sent from the transducer to the control module.

The control module has a series of adjustments, including alarm levels, visual alarms, and connections for permanent recordings. In the event that a concentration of hydrogen gas reaches the calibrated alarm level of the system, a red light goes on and an audible alarm sounds.

This system, consisting of 10 channels, is calibrated and set for either a 10% or 50% lower explosive limit. Channels 1 through 5 are set for a 50% alarm level, or a 2% concentration of H_2 in air by volume. Channels 6-10

Figure 3. Perspective View - GTR Facility Showing Hydrogen Detectors

are set at a 10% alarm level, or a 0.4% concentration of hydrogen in air. This corresponds to full-scale readings of 4% H₂ and 0.8% H₂ by volume, respectively. Accuracy of this system is about 2% of the reading at 10% of the lower explosive limit.

A secondary leak-detector system was used in this experiment. It was a Davis explosion meter consisting of eight channels, each of which senses explosive mixtures of any hydrocarbon. A vacuum pump draws air into a burning chamber so that, in the event a burnable concentration of gas is present, alarms (both visual and audible) are set off. Since this system can only sense one channel at a time, the sensors are used as backups to the General Monitors type of leak detectors.

Calibration for hydrogen with the Davis monitor is made by exposing a known concentration of hydrogen and air to one of the detectors and marking the alarm panel scale accordingly.

1.3.2 Location of Sensor Heads

Ten sensor heads of the General Monitors gas detection system and eight sniffers of the Davis gas detection system (shown in Figure 3) were located as follows:

General Monitors

- Point No. 1 - East cryostat, back side
- 2 - East cryostat, reactor side at rod seals
- 3 - North cryostat, back side
- 4 - North cryostat, reactor side at rod seals
- 5 - West cryostat, back side

- 6 - West cryostat, reactor side at rod seals
- 7 - Senior-pool vent stack
- 8 - GTR rod-drive platform
- 9 - North wall of pool between east escalator
- 10 - Vacuum-pump exhaust on north ramp.

Davis

- Point No. 1 - Top of facility shield, northwest corner
- 2 - Hydrogen exhaust manifold
- 3 - In the west walkway by senior-pool
- 4 - Liquid-hydrogen fill manifold
- 5 - Top of facility shield, east side
- 6 - Vacuum pump on north ramp (same as GM No. 10)
- 7 - TV camera mount at northwest corner of senior pool
- 8 - Reactor control room

1.4 Responsibilities

As prime contractor, Aerojet-General Corporation carries the prime responsibilities of the program with the exception of facility safety. Certain of these responsibilities were delegated to GD/FW in order to carry out the program efficiently. The distribution of operating responsibilities are indicated in the following tabulation.

Experimental equipment design	AGC
Experimental equipment fabrication	GD/FW
Cryogenic supply and vent-piping systems	GD/FW
Design and fabrication of test specimens	AGC

Establishment of nuclear and nonnuclear test environments	AGC
Safety	GD/FW
Data-system design and fabrication	GD/FW
Preirradiation tests	GD/FW
Reactor irradiation tests	GD/FW
Reactor space and time scheduling	
Utilities and removal of experimental assemblies	
Reactor and facility operation	
Data accumulation	
Nuclear measurements	
Postirradiation tests	GD/FW
Data reduction	GD/FW
Disposition of equipment	GD/FW at the direction of AGC
Reporting	GD/FW

During actual testing operations, both control and irradiation, an AGC representative is present to observe the test operations and to ensure compliance with test procedures. This AGC representative also exercises final judgement and authority for substitutions in test plans in the event that unforeseen developments necessitate any changes.

BLANK

II. DESCRIPTION OF EVENTS

This section presents a compilation and description of events preceding, during, and subsequent to the fire which are considered pertinent in a determination of the cause.

The cryogenic tensile-test assemblies, including all feed and exhaust lines, are referred to with respect to the position each occupies at the reactor. Thus, since the three reactor positions are identified as the "west," "north," and "east" positions, the test assemblies are identified as the "west," "north," and "east" cryogenic test assemblies, respectively.

The equipment for this experiment was moved into the nuclear reactor area on 22 March 1963. Setup and sample-loading operations were complete at beginning of the second shift on Wednesday, 27 March 1963, at which time the initial leak-check operation began.

Following is a chronological summary of events, by shift, for the duration of operation in the nuclear reactor area.

Second Shift: 27 March 1963

Leak checks of the three experimental tensile-test assemblies began. The main pull-rod seals and extensometer seals were checked with portable MSA hydrogen sniffers. No leaks were detected at any of the pull-rod seals. A small leak was noted on the east pulling assembly at extensometer

seal No. 4. This leak disappeared before any significant cool-down had occurred.

The liquid-hydrogen flow was increased. The east dewar filled normally, and level was stabilized at point 3 (liquid-level indicator position). The north dewar was slower in filling but was also stabilized at point 3. The west dewar would not fill. The east and north dewar fill lines were valved off and, with a 36-40-lb pressure on the liquid-hydrogen tank, the west dewar filled to point 2.

A kink was detected in the west hydrogen fill line; the liquid-hydrogen flow was terminated and all three assemblies purged with gaseous helium. A vacuum check was made on the three dewars (inner and outer chambers of each dewar were manifolded and valved off) and the following readings were noted:

East Dewar	35 microns
North Dewar	225 microns
West Dewar	> 2000 microns

A vacuum pump was connected to the dewars and all were evacuated to 35 microns.

The 3/4-inch hydrogen fill lines were installed and, after the systems were purged with gaseous helium, hydrogen was introduced into the system as follows: (1) the three 3/4-inch pneumatic valves were opened approximately half-way; (2) the 2-inch hand-operated hydrogen-tank valve was cracked 1/8 turn.

In about two minutes, the pressure relief valve on the west dewar released. The liquid-hydrogen flow from the tank was decreased. Approximately two minutes later, the pressure relief valve on the north dewar released and flow from the hydrogen tank was again decreased.

Approximately one minute later, the level of liquid-hydrogen was above point 4 in all three dewars, and at this time flow was completely stopped. A loud noise was heard in the north ramp area. It was found that the severe thermal shock induced by rapid filling had broken the 4-inch vent line at a location on the north ramp where the line penetrated the facility concrete shield. The hydrogen was allowed to boil out of the three dewars. The vacuum chambers in the west dewar were checked during this period. Hydrogen gas was detected in the vacuum-pump exhaust. It was determined that the thermal shock given to the system had cracked the inner wall of the west dewar.

Third Shift: 28 March 1963

The entire system was purged with helium, and the west dewar was removed from the pulling assembly and sent to the shop for repair.

The broken 4-inch exhaust line was replaced during this time. A sleeve was installed through the facility shield to permit freedom of expansion of the vent line.

Liquid-hydrogen fill procedures were modified to reduce the dewar fill rate so as to preclude dewar overfill and to reduce the severity of thermal shock resulting from

the maximum fill rate attainable with the 3/4-inch fill lines.

First Shift: 28 March 1963

The west dewar was repaired and rechecked for leaks. None was found. A leak was found, however, in the inner nitrogen chamber wall. It was decided to manifold the inner vacuum and nitrogen chambers and evacuate them so that a vacuum would be maintained in all outer chambers. The chambers were evacuated to approximately 15 microns.

Second Shift: 28 March 1963

1700 The west dewar was reassembled to the west tensile pulling assembly.

2011 The liquid-nitrogen chambers on the north and east dewars were filled with helium gas. He_2 gas was used in lieu of LN_2 for LH_2 leak check only to expedite warm-up of the systems and subsequent refill.

Liquid hydrogen was introduced into the three systems. The dewars were filled normally. No difficulties were encountered.

Entire systems were leak-checked and found to be satisfactory; so hydrogen flow was cut off and the systems purged.

All the vacuum chambers, except the west outer chamber (which was evacuated and valved off), were manifolded and connected to a vacuum pump to permit continuous evacuation.

Third Shift: 29 March 1963

- 0115 The three systems were rechecked and prepared for movement into position for the irradiation.
- 0200 The General Monitor sensor No. 10 was placed on the vacuum-pump exhaust, and an indication of hydrogen gas was detected. At this time, there was no hydrogen in the area. This meter remained in the alarm condition for some time. It was concluded that either vacuum-pump oil or fumes from a large BUDA diesel generator located adjacent to the north ramp area had contaminated the sensor, causing it to give spurious alarms.
- 0400 The installation of all equipment was completed and checked out, and the check lists were signed off.
- 0500 Liquid-hydrogen flow was begun. During fill operations, leak checks were made of all fill lines. A small leak was detected between the east tracks in the facility handling area. The leak disappeared after cool-down and could not be detected again.
- 0537 The three dewars were filled and level control maintained. No leaks were detectable from any of the detector systems.
- 0600 The GTR was brought to 3-Mw power level in the fully retracted (south) position.
- 0632 The reactor was moved into the closet at the 2-inch position, thus officially beginning the experiment.

Note: The reactor was gradually moved into position to reduce thermal shock as well as to permit control of liquid levels.

First Shift: 29 March 1963

- 0944 The GTR was retracted and power reduced. A demineralizer pump had ceased to operate, necessitating a pump change before continuation of the experiment.
- 1030 An intermittent hydrogen alarm was observed on the Davis explosion meter point 6. There was no indication of any hydrogen from the GM No. 10 meter. (Both sniffers were located at the vacuum pump exhaust on the north ramp)
- 1125 The GTR demineralizer pump was reinstalled. The reactor was not moved into position, because of possible trouble with the west dewar.
- 1250 The calibration was checked on both the Davis No. 6 and GM No. 10. The calibrations were confirmed.
- 1437 The north hydrogen fill valve was opened too rapidly and GM Nos. 5, 6, and 10 alarmed. A cloud of vapor was also noticed in the reactor pool. At the same time a pressure rise was noted in the north dewar. It is known that this rise in pressure is a typical condition when dewars are filled too rapidly.
- 1445 The liquid level in the north dewar decreased below point 1, and it was not possible to refill without over-pressuring. The hydrogen storage-tank pressure was raised from 9 to 15 lb/in², with refill of the dewar being accomplished normally.

1500 The vacuum pump located on the north ramp and connected to the three dewars was observed to be laboring excessively. The Davis No. 6 alarmed. The west vacuum line was valved off with no apparent relief to the pump. This line was reopened and the north vacuum line disconnected. The vacuum pump returned to normal operation almost immediately and no further hydrogen indication was noted on the Davis No. 6. It was also noted that gas was being discharged from the north dewar vacuum line under a slight positive pressure. Checks were made immediately with the Davis and GM sensors and with a portable MSA sniffer. No indication of hydrogen was observed. It was decided that the vacuum-pump oil vapor had been causing spurious alarms.

Note: Sensitivity of these sensors to oil vapor was later confirmed by experiment.

1530 It was concluded that a small leak had developed in either the inner or outer nitrogen chamber walls and that, as long as gas under positive pressure was being discharged from the line, the experiment would continue. The experimental crew chief was instructed to check this line regularly both as to evidence of positive pressure and as to hydrogen indications.

Second Shift: 29 March 1963

- 1656 The GTR was raised to a 3-Mw power level and started into the irradiation position.
- 1719 The GTR was in the 2-inch position and the experiment again underway.
- 1800 The liquid-hydrogen consumption rate was calculated and found to be approximately 470 gal/hr. This was only slightly in excess of the predicted consumption rate.
- 2000 The liquid-nitrogen exhaust line showed no nitrogen-gas exhaust from the north dewar. GM Nos. 3, 4, and 6 were alarming intermittently. This alarm condition occurred in each case where the hydrogen liquid level exceeded point 5.
- 2150 A second hydrogen storage tank was put on the line.
- 2155 The experiment crew chief noted an indication of hydrogen from the north dewar vacuum line.
- 2210 The first (or empty) liquid-hydrogen tank was removed from the area.
- 2400 A small liquid-nitrogen vapor plume was observed from the north dewar.

Third Shift: 30 March 1963

- 0045 A fire was observed in the vicinity of the north dewar assembly. The Radiation Effects crew chief fired the CO₂ system, and the GTR was scrammed and retracted. All three pneumatic hydrogen-control valves were closed.

Simultaneously with the fire, all the GM sensors, except No. 10, gave a full-scale reading, and the pressure-recorder trace located on the north dewar oscillated from band edge to band edge (Fig. 4). The east and west dewar traces drifted erratically, and then stabilized after several minutes. As the CO₂ filled the pool, the hydrogen was evidently displaced upward, since one by one the GM sensors at the pool vent duct, GTR frame, and north wall gave an alarm. None of the Davis sensors was located in the pool and none gave an alarm. Thermocouple records indicated a steady temperature in the dewar for several minutes following the incident (Fig. 5).

The east and west hydrogen fill-line valves were cracked to see if liquid could be maintained in the east or west dewars. Upon introduction of hydrogen flow, GM point No. 6 alarmed and the valves were closed.

0100 A smoke plume was noticed at the north upper pulling assembly and, as a result, a second bank of CO₂ was fired into the pool. This action completely extinguished any residual fire.

The facility shield was removed and the pool shield dollies retracted. During this period, the north dewar pressure transducer indicated a rapidly rising pressure. To avoid the consequence of overpressure due to gas trappage, the north fill line and the tank

NPC 17,708

Figure 4. Pressure-Recorder Traces at Time of Incident

Figure 5. Dewar Temperatures at Time of Incident

by-pass valve were opened. This action had no effect on the transducer trace; and, since the pressure had passed the point where the pressure relief valve on the dewar would have opened, it was concluded that the fire had damaged the wiring and that any readings were erroneous.

0200 The test was terminated and the entire system was purged with gaseous helium.

After the fire and during the period that the facility shield was being opened, the west dewar lost vacuum. A few minutes later, a loud report was heard and debris was expelled from the reactor pool area. This could have been either ice or CO₂ vapor. Approximately 30 minutes later, the east dewar lost vacuum. The hydrogen storage tank was removed from the area.

After helium purging was completed, GM Nos. 2 and 4 still showed an alarm. These channels were checked and found to have damaged filament circuits. All channels were then checked and GM No. 3 was also found to be damaged.

The north assembly had extensive fire damage to all wiring. The east assembly suffered some fire damage to wiring on the corner nearest the north position. No fire damage was observed on the west assembly.

After the north assembly was lifted approximately two feet, the reactor closet was examined with binoculars, and no damage was apparent other than a buckling of the north boron shroud.

First Shift: 1 April 1963

The test assemblies were removed from the pool. Still photographs and color movies were made of this operation. The outer wall on the north dewar was broken, and the west dewar outer wall and outer nitrogen wall had ruptured. All visible ruptures had occurred at welded seams. There was no visible damage to the east dewar.

BLANK

III. DAMAGE SUMMARY AND ANALYSIS

3.1 Present Condition

One dewar failed during the control tests, sustaining heavy damage. Two dewars were heavily damaged and one was slightly damaged during irradiation. The fire resulted in considerable damage to one pulling assembly and slight damage to the other two pulling assemblies. Inspection of the dewars yielded the following information:

Control Dewar. The outer two walls were ruptured and buckled outward (Figs. 6 and 7). The inner vacuum and the hydrogen compartments were intact.

West Dewar. The outer two walls were ruptured and buckled outward (Figs. 8 and 9). The inner vacuum compartment was open; however, the hydrogen compartment was intact - which means the inner nitrogen wall was broken. The location of the leak could not be determined.

East Dewar. The inner vacuum compartment was intact. The outer wall was intact. There was a leak between the outer vacuum compartment and the nitrogen compartment. The location of this leak has not been determined.

North Dewar. Every wall was broken. The outer wall was buckled outward slightly at the flange (Fig. 10) and broken open at a lower corner (Figs. 11 and 12). The next two inner walls were split along a lower edge (Fig. 13). The inner wall had the lower surface upward, thus splitting both lower edges (Fig. 14).

Of the eight pull-rod seals on the pulling assembly, four leaked very badly on inspection after the test was terminated. Two of the remaining seals leaked slightly and two were leak-tight. Inspection of the Teflon sealing material revealed that it was slightly brittle. Although brittle, it did not exhibit a tendency to crumble as is often encountered with irradiated Teflon. The extensometer-mechanism seals exhibited no leaks.

NPC 17,710
31-6891

Figure 6. Control Dewar after Failure

HPG 17,711
31-6955

Figure 7. Control Dewar after Failure Showing Tear
in Parent Material

NPC 17,712
31-6926

Figure 8. West Dewar Upper Surface Reactor Side

NPC 17,713
31-6921

Figure 9. West Dewar Reactor Side Close-Up

NPC 17,7 14
31-6925

Figure 10. North Dewar Upper Surface Reactor Side

NPC 17,715
31-6924

Figure II. North Dewar Lower Corner Reactor Side : Front View

NPC 17,716
31-6923

Figure 12. North Dewar Lower Corner Reactor Side : Side View

NPC 17,717
31-6952

Figure 13. North Dewar Section Thru Bottom

NPC 17,718
31-6950

Figure 14. North Dewar into Lower Corner

Fire damage to the pulling assemblies has not been fully assessed at this point; however, the equipment known or suspected to be damaged includes:

1. Rod movement indicator mechanisms on the north assembly,
2. Pressure transducer on the north assembly,
3. Extensometer actuator microswitches on the north assembly,
4. Four hydraulic cylinders on the north assembly,
5. All the instrumentation harnesses on all three assemblies,
6. Rod load cells on the north assembly.

3.2 Dewar History

Three dewar configurations have been utilized in materials test programs by GD/FW at the GTR. All of these have been flat-sided because of the requirement to get the test specimens as close as possible to the reactor, with a minimum of hydrogen or other material in the intervening space.

3.2.1 First Dewar Configuration

The dewars of the first configuration were designed and built by GD/Astronautics; they were the smallest. These dewars had rounded ends with flat sides and bottom and utilized a vacuum chamber, a nitrogen shield, and an outer fiberglass insulation wrapped and taped on. These were used with no difficulty in one 100-hour run, with a subsequent pulling period of about 50 hours, and in the associated control tests.

3.2.2 Second Dewar Configuration

The dewars of the second configuration were designed and built by GD/FW. These dewars were rectangular, 17.0 x 28.75 x 27.6 inches OD; they contained an inner vacuum wall, a nitrogen shield, and an outer polyurethane foam insulation protected by a thin outer aluminum wall. These dewars were built for use in a program being carried out for NASA-MSFC. As described below, difficulties encountered by the third set of dewars (which were placed in service before the second set) led to a change to Refrasil insulating material for the first use of these dewars. They were used in a liquid-nitrogen run in October 1962 and in a liquid-hydrogen run in November 1962. One of the dewars suffered a split outer nitrogen wall during the irradiation, apparently as a result of a blocked nitrogen exhaust line. This line was made of wire-reinforced cloth and was not used on any other tests. The damaged dewar was repaired, and a liquid-nitrogen control run was performed in April 1963.

3.2.3 Third Dewar Configuration

Design. The dewars of the third configuration were patterned after those of the second set, with a change in dimensions to 12.43 x 41.25 x 34 inches. This set was built at approximately the same time as the second set, but was used before the second set. A radiation test run utilizing liquid hydrogen and liquid nitrogen was made with these dewars in September 1963. The control tests associated with this test were carried out in November, as was the

pulling of some of the irradiated specimens. Due to difficulties associated with the polyurethane insulation, this material was removed and replaced by a vacuum jacket prior to initiation of the 1963 test program. The outer wall was replaced in this process, and the vacuum line to the inner vacuum chamber was relocated and enlarged to permit more efficient pumping.

Test. The nitrogen and hydrogen chambers were pressure-tested to 5.0 psi with helium before and after a cycle to liquid-nitrogen temperature during fabrication. The nitrogen chamber was again pressure checked to 5.0 psi, and the hydrogen chamber to 8.0 psi prior to the control tests of March 1963.

Histories. Individual histories of each of the dewars are outlined below.

Control Dewar. This dewar was one of those used with liquid hydrogen in the previous test series. There was no damage found to the inner walls during rework.

East Dewar. This dewar was also used with liquid hydrogen previously. During rework, the outer nitrogen wall was found to be split in the weld seam along the lower edge on the reactor side. This was repaired and checked before the outer wall was installed.

North Dewar. This dewar was used in the previous test for the test involving liquid nitrogen. The outer compartment was not damaged in the previous test, and no damage to the inner walls was found during rework.

West Dewar. This dewar had not previously been used in any test.

3.3 Post-Test Analyses

3.3.1 Weld Metallography

A metallurgical investigation of the north and west dewars was performed by GD/FW to determine the quality of the welds. The results of this investigation follow.

Discussion. The subject dewar flask was a part of a cryostat used by the Nuclear Research and Development Department for irradiation tests. It was fabricated from several thicknesses of 6061-T6 aluminum plates which were welded together with 4043 aluminum filler rod. Because of the relatively deep and narrow cavities, the walls were successively placed and welded, starting with the inner wall. Therefore, each wall (to cap T-joint) was only welded on the outside of the joint. The completed flask was not heat-treated after welding.

Metallurgically the two broken welds (Fig. 15) exhibited very poor quality on the two sections of the flask examined. Near the suspected origin of failure, the welds contained oxide folds which were three-fourths the depth of the bead. Gas holds and porosity were almost continuous along the root of the weld. At several places, where the base metal had been overheated, craze cracks formed when insufficient filler metal was applied to fuse the joint (Fig. 16).

The most serious deficiency was a decided lack of fusion and penetration in the weld root. Figure 17 shows that:

Poor penetration at the weld root is indicated by the arrows. Oxide skins and porosity were evident in the fractures.

Figure 15. Photomicrograph (1.3x) of Weld Failure

Craze cracks caused by overheating the base metal and applying insufficient filler rod to fuse the joint.

Figure 16. Photomicrograph (9x) of Weld Failure

These two sections show the lack of penetration, particularly at the weld root. What appears to be a root crack was actually an oxide skin. The inner flash wall is on the left.

Figure 17. Photomicrograph (4x) of Weld Penetration (Keller's Etch)

1. The weld bead on the inner wall joint was completely filled, but penetration of the base metal was very shallow.
2. The two middle wall joints had some base metal penetration, but not in the weld root.
3. The outer wall joint was chamfered to form a V-groove, but there was no root penetration at any point along the two sections examined.

Secondary fatigue cracks caused by pressure-flexing of the flask wall were not found by a metallographic examination of the weld roots, nor was fatigue damage evident in the fracture. The fracture did indicate that the loads on the joint were basically tensile, coupled with some bending. At final separation, the two outer walls were pushed outward in a secondary action which produced a small smear along the edge of the fracture.

The aluminum alloys in this flask were a good selection for low-temperature service, but the joint design and weld quality were poor. A "U" or "V" groove design would have permitted full penetration at the weld root, making stronger joints with less chance of vacuum leaks.

Conclusion. The joint design and weld quality are poor.

3.3.2 Hydrotest of Dewars

The hydrogen compartment of the control dewar failed at a pressure of 54.5 psig. A leak from the hydrogen compartment to the inner vacuum compartment, as evidenced by a flow of water from the inner vacuum line, developed at a pressure of approximately 25 psig.

The outer compartment of the east dewar burst at 19.7 psig. Figure 18 shows the dewar prior to pressurization; Figure 19 shows the dewar just prior to failure; and Figures 20 and 21 show the condition just after failure. The inner vacuum compartment was open to the atmosphere during this pressure cycle. The hydrogen compartment had been pressurized to 8 psig and valved off prior to pressurization of the outer walls. The ultimate pressure reached in this compartment was 13.1 psig during pressurization of the outer walls.

The inner vacuum compartment of the east dewar was evacuated prior to pressurizing the hydrogen compartment. A vacuum of 15 microns was reached after approximately three hours of pumping. At this point, the pumping speed had dropped to 1-2 microns/hour. The resident AGC engineer was consulted, and it was agreed to proceed with the test at this vacuum. The pressure was approximately 14 microns at the time the chamber was valved off and the pump removed. The hydrogen compartment failed at 40 psig. A leak from the hydrogen compartment to the inner vacuum compartment, as evidenced by a sudden pressure drop in the hydrogen compartment, developed at 32.2 psig. A report was heard in the vicinity of the dewar at approximately the same time as the drop in pressure was recorded.

All failures occurred in both dewars at weld seams:

NPC 17,722
31-7043

Figure 18. East Dewar Hydrotest, Prior to Pressurization

NPC 17,723
31-7022

Figure 19. East Dewar Hydrotest, Just Prior to Failure

NPC 17,724
31-7021

Figure 20. East Dewar Hydrotest, Just After Failure

NPC 17,725
31-7020

Figure 21. East Dewar Hydrotest, After Failure

Control Dewar. Failure occurred in the hydrogen compartment at the lower horizontal seam on the back, away from the inlet tubes.

East Dewar. The first failure occurred in the outside wall on the back side along the upper horizontal seam and in a vertical seam. When pressure was applied to the hydrogen chamber, the following failures were noted: (1) at the lower horizontal seam, i.e., the same as in the control dewar; (2) in both LN_2 walls at the same vertical corner as the outside wall that had previously failed.

Notes:

1. In hydrotest, the control dewar (which had a leak in the inner nitrogen wall) was pressurized with water, pressure being applied by helium gas. The hydrogen chamber developed a leak at 25 psig and failed between 54 and 55 psig. Pressurization rates were 1.0 psi/min.
2. The east dewar had a leak in the outer nitrogen wall. With the LH_2 chamber initially at 8 psig, the outer vacuum chamber and the nitrogen chamber were manifolded together and pressurized as above. The outer wall failed at 19.7 psig. At this time, the LH_2 chamber (which had been capped off) was reading 13.1 psig. The inner vacuum chamber of this dewar was then evacuated to 15 microns and the LH_2 compartment was pressurized as in paragraph 1, above. The vacuum was lost at 32.2 psig (49.6 psia on the inner wall), and the walls failed at 40 psig.

IV. CAUSE OF DEWAR FAILURES

4.1 Control Dewar

During the period that liquid hydrogen was being maintained in the inner dewar compartment, radiative heat transfer across the inner vacuum chamber and conductive heat transfer through the upper dewar flange reduced the temperature of the inner nitrogen wall. A partial vacuum was created in the nitrogen chamber as a result of cryopumping. Air then leaked through the inlet and outlet fittings to the nitrogen chamber. The nitrogen chamber then filled to an unknown level with liquid air. At the conclusion of the control experiment, as the liquid hydrogen was boiled out of the dewar, boil-off of the entrapped liquified air created sufficient pressure to rupture the dewar.

4.2 West Dewar

The west dewar ruptured as a result of high pressure in the nitrogen chamber. The pressure source was entrapped liquid air which boiled off during the post-experimental temperature rise.

This dewar had been subjected to repeated thermal cycling during setup and leak-check operation; this probably cracked or weakened the welds in the joint between the upper flange and the vessel walls. In addition, the severe temperature gradient existing between the various chambers and walls of the dewar introduced stresses which opened

cracks in the already-weakened welds. Air that was then cryopumped into the nitrogen compartment liquified and provided the source of overpressure necessary to rupture the dewar walls.

4.3 East Dewar

The only damage sustained by the east dewar during the experiment was a broken outer nitrogen chamber wall. Thermal cycling and the resultant thermal stresses caused by post-test warm-up initiated a crack in one of the weld joints of this wall. That the leak was minor, at least before the incident, is evidenced by the fact that no difficulty was encountered in maintaining a vacuum in the dewar during irradiation.

4.4 North Dewar

The north dewar suffered heavy internal damage, with only slight damage to the outer vacuum chamber wall. The bottom of the hydrogen chamber was pushed inward, and the inner and outer nitrogen chamber walls at a lower weld seam were pushed outward. The outer vacuum chamber wall was pushed outward slightly at the upper weld joint (the joint which mates the dewar flange to the vessel wall).

Repeated thermal cycling and the resultant thermal stress imposed on the dewar during irradiation cracked a weld in either the inner or outer nitrogen chamber wall. This was evidenced by loss of vacuum in this dewar and the

emission, under positive pressure, of gas from the north dewar vacuum line. Some of the nitrogen collected on the hydrogen chamber walls and froze. Over a period of several hours this frozen nitrogen partially filled the inner vacuum chamber of the dewar. The resulting thermal conduction path froze the liquid nitrogen in the nitrogen chamber, as evidenced by a cessation of the plume from the nitrogen exhaust line. Later, the combination of gas pressure and the thermal stresses initiated a crack in a weld in the hydrogen chamber wall. This accounts for the hydrogen-gas indications picked up at the north dewar vacuum line. Sufficient stress was induced to rupture the outer vacuum-wall weld.

A severe thermal gradient in this dewar was evidenced by the fact that a small plume of nitrogen gas was seen at the nitrogen-chamber exhaust line several hours after apparent cessation of nitrogen flow.

The hydrogen gas emitted from this ruptured weld ignited immediately upon leaving the dewar. This follows from the fact that no hydrogen was detected in the pool just prior to the fire.

Simultaneously with the fire, liquid-hydrogen flow was terminated and the hydrogen remaining in the dewar allowed to boil off. The resulting temperature increase gave rise to a rapid boil-off of the solidified and liquid nitrogen present in the inner vacuum chamber. The gas formed could not escape through the vent line (either as a result of impedance or partial blockage by solid nitrogen) to prevent a pressure rise sufficient to rupture the internal walls of the dewar.

BLANK

V. EXPERIMENTAL EQUIPMENT AND PROCEDURAL MODIFICATION

The experience gained during the past two hydrogen experiments have made evident a number of modifications which should be performed, both to the experimental equipment and to the experimental operating procedures and philosophy. Following is a brief description of the proposed modifications.

5.1 Experimental Equipment

5.1.1 Dewars

New dewars will be designed and fabricated. These dewars will incorporate as many optimum design features as possible for weld strength and thermal contraction and expansion. Expanded quality control procedures will be initiated and followed to assure reliable fabrication.

5.1.2 Tensile-Test Assemblies

An aluminum can or shroud will be designed and installed over the entire pulling assembly to allow nitrogen purging or inerting. This shroud will include ports and fittings for all leads and tubing and will include a nitrogen-gas supply and vent system.

The pull-rod seal mechanism will be redesigned and fabricated to eliminate leaks.

The liquid-level probes will be modified to include two additional resistors for each probe.

An automatic liquid-hydrogen-level control system will be designed, fabricated, and checked out so that a constant hydrogen level can be maintained. This system will utilize

presently available hydrogen manifolds and, where possible, existing control instrumentation.

The hydrogen vent system will be redesigned and installed to include separate vents from each dewar and will be tied into the ASTR burn stack.

5.2 Operating Philosophy and Procedures

Complete experimental assemblies will be set up outside the nuclear area (without test specimens), and the experimental equipment will be operated and monitored for 30-40 hours at liquid-hydrogen temperatures to demonstrate the safety and adequacy of the system.

Schedules will be eliminated from consideration in the event of any malfunction of equipment, and no compromised go-ahead will be permitted.

VI. BACKGROUND OF TEST PERSONNEL

Brief resumes of GD/FW personnel who were responsible for the setup and operation of the test are presented in the following paragraphs, together with their duties with respect to this test. The organization of the Nuclear-Radiation Effects Research Group for this contract is shown below.

*PROJECT ENGINEER FOR AGC MATERIALS PROGRAM

SUPPORT PERSONNEL

- 3 - REACTOR OPERATORS/SHIFT
- 2 - HEALTH PHYSICISTS/SHIFT
- 3 - MECHANICS
- 1 - HYDROGEN TRUCK OPERATOR
(LINDE)/SHIFT

E. W. BRADFORD

Education

University of Colorado, Engineering Physics, BS, 1954

Experience

Mr. Bradford joined GD/FW in 1954 after graduation from CU. His first assignment was in the Nuclear Instrumentation Group, where he was involved in the design, fabrication, calibration, and installation of nuclear detection systems for shielding tests. After approximately 1-1/2 years, he was transferred to the Radiation Effects Research Group. His assignments have included evolving design criteria for a proposed Radiation Effects Facility, investigating the effects of radiation on transducers, and coordinating radiation-effects tests performed by GD/FW for outside agencies. He participated in a cryogenic irradiation test performed at GD/FW as a joint GD/FW and GD/Astronautics project. He contributed to the initial design effort of a cryogenic irradiation test program being conducted for NASA-MSFC. Mr. Bradford has been the responsible engineer from the AGC materials cryogenic irradiation tests performed at GD/FW

R. D. CRABTREE

Education

Mississippi State University, E.E., BS, 1957

Experience

Upon joining GD/FW, Mr. Crabtree was assigned to the Flight Test Department. He was responsible for designing a telemetry ground station, including the writing of

justifications and specifications for equipment. He designed and developed Flight Test Instrumentation. He is co-author of a manual for maintenance and operation of the Sylvania Conversion Package, used to convert radar signals to permit their recordation for instrumentation purposes. He was in charge of instrumentation systems on B-58's and pods.

He transferred to the Radiation Effects Research Group in August 1962, where he has been responsible for the design, development, and use of the instrumentation system for an AGC/WANL cryogenic irradiation test program, (employing LN_2 as a cryogen) and for the data reduction and analyses. He has performed similar work in conjunction with two AGC materials tests and one NASA-MSFC materials test, all of which used LN_2 as a coolant. He is presently responsible for the first AGC test utilizing the ASTR facility and the high-pressure LH_2 system.

G. E. IRBY

Education

San Houston State College, Physics, BS, 1956

Experience

Mr. Irby spent his first 2-1/2 years with GD/FW in the Nuclear Analysis Unit of the Radiation Effects Research Group, where he determined neutron spectra for the ASTR and GTR. He also conducted studies and calculations on various neutron- and gamma-detection devices, including fission foils. He spent 6 months of this time on active duty with the Army Reserve.

Since August 1959 he has worked with the support equipment required for the performance of all experiments conducted at the reactor site. His primary responsibility is the operation of the Environmental System and Shuttle System which are used in conjunction with all experiments.

During experiments it is his responsibility to assist in setup procedures, and to ascertain that all safety requirements are met prior to reactor start-up. Mr. Irby has participated at this facility in all experiments in which cryogenic fluids were employed.

W. M. LANEY

Education

Tyler Junior College, 1947 - 1948

Kilgore Junior College, 1949

Texas Christian University, 1956 - 1959

Arlington State College, 1959 - Present. (Will receive a BS degree in ME upon completion of remaining 15 hours)

Experience

Mr. Laney was a member of the USAF from 1951 to 1955, where he worked as a jet-engine mechanic.

Upon joining GD/FW in 1955, Mr. Laney was assigned to the Radiation Effects Research Group, where he coordinated and assisted in the testing of turbojet-engine fuel and oil-system components and assemblies and aircraft cabin environmental control systems. He has designed, constructed, and operated several dynamic-test loops for the evaluation of candidate high-temperature lubricants in a radiation environment. Mr. Laney has participated in the testing of materials

in a combined cryogenic (LH₂) and nuclear-radiation environment in connection with both the NASA-MSFC and AGC irradiation tests programs. During the LH₂ testing phases, it was his responsibility to assist in the setup, leak checks, and installation of the test assemblies in the test cell. During the irradiation, he assisted in data-taking and monitoring of safety equipment.

J. B. McGOODWIN

Education

Oklahoma State University, M.E. (Aero), B.S., 1957

Experience

While with Douglas Aircraft Corporation, Tulsa Division, Mr. McGoodwin worked as a design engineer on the XC-132.

Upon joining GD/FW, Mr. McGoodwin was assigned to the Radiation Effects Research Group and conducted experiments on the combined effects of temperature and radiation on all classes of materials. Since November 1957, he has been responsible for the operation of all support equipment required for performance of all radiation-effects experiments conducted at the reactor site. He designed special test equipment and coordinated design efforts on facility modifications and additions.

At this facility, there have been four experiments employing LH₂ as a cryogen: a joint effort between GD/Astronautics and GD/FW 1961; AGC materials, 1962; AGC materials, 1963; and NASA materials, 1962. Mr. McGoodwin has participated in all of these experiments in the planning, preparation, design, and testing phases. During

the irradiation he assisted in data-taking and monitoring of safety equipment.

As a member of the Nuclear Safety Council he has been engaged in the safety analysis of all of these experiments prior to their being conducted.

L. P. STUART

Education

University of Tennessee, E.E., BS, 1958

Experience

Mr. Stuart joined GD/FW in June 1958. He was assigned to Flight Test Instrumentation Section, where he was responsible for design and operation of the Electronic Data Acquisition System on the B-58 Flight Test Program.

In January 1963, Mr. Stuart served as instrumentation coordinator between GD/FW and GD/Astronautics for a test concerning the Centaur Space Vehicle. This test was being conducted by GD/FW under contract to GD/Astronautics.

He transferred to the Radiation Effects Research Group in May 1962. Since that time he has designed the instrumentation for two LH₂ tests and worked on another. During these tests he was engaged in setup and check-out of all test equipment, and was responsible for obtaining data from these tests.

G. W. THIEBAUD

Education

Texas Christian University, 3 years work toward BS in
Physics

Experience

Mr. Theibaud joined GD/FW December 1955, and was assigned to the Structures Department.

He transferred to the Radiation Effects Research Group in 1957, where he worked for two years in the Nuclear Analysis Unit. His primary duties were reduction of dosimetry data and plotting curves to correlate the calculated data with the dosimetry data. He transferred to the Radiation Effects Control Unit in 1959, and since that time has worked with the support system required for the performance of experiments. He is responsible for the operation and safety of this equipment. He was assigned as Coordinator of the Irradiated Materials Laboratory (IML) in 1961. In this assignment he was responsible for the proper usage of the IML as well as the proper handling, storage, and disposal of activated or contaminated materials.

At the present time, he is a crew chief responsible for the setup and operation of experiments at the reactor site while on duty. He operates the equipment required for support of any experiment and is responsible for the safety of the facility during his shift. He has been crew chief at this facility on all tests which used a cryogen fluid as a coolant.

H. G. THORNTON

Education

University of Illinois, M.E., BS, 1957

Experience

Mr. Thornton served with the USAF as a jet pilot during the Korean conflict.

Upon joining GD/FW, Mr. Thornton was assigned to the Flight Test Department as a control engineer. His duties were to coordinate the work on certain flight tests of B-58 aircraft. He controlled and approved all work on this aircraft and assisted in the scheduling of the work loads.

He transferred to the Radiation Effects Research Group in August 1962 and, since that time, has assisted in the design, modification, and check-out of hardware associated with experiments involving LH₂. He assisted in the planning, setup, and operation of these experiments, and was in charge of one shift during the performance of these experiments.

J. R. TUCKER

Education

Texas A and M, M.E., BS, 1956

Experience

Upon joining GD/FW, Mr. Tucker was assigned to the Nuclear Design Group. While in this position, he designed special test equipment and support equipment required for facility modification or for specific tests.

He transferred to the Nuclear Operations Group in 1960 and assisted in the maintenance and modification of all equipment associated with the reactor. He operated the reactor during the performance of experiments. Upon returning from one year military leave of absence, he was assigned to the Radiation Effects Research Group and assumed the duties of crew chief over the support equipment required for the performance of experiments. He is still responsible for this equipment.

Mr. Tucker was crew chief over one shift of operation during the two AGC cryogenic-irradiation tests and the NASA-MSFC test, which employed LH_2 as a coolant. His responsibility during these tests was to assist in the setup, to place test assemblies in the irradiation cells, and to monitor all safety equipment continuously.

BLANK

APPENDIX A

NUCLEAR SAFETY COUNCIL REVIEW

The following paragraphs are verbatim excerpts from the minutes of General Dynamics/Fort Worth Nuclear Safety Council meetings covering all discussions dealing with the materials test program (Contract NP-5).

BLANK

29 November 1962

1. The council continued the discussion of the fire in Area No. 1 on 2 November. (Ref.: Item 2, NSC minutes of 11/8/62.) An additional memo relating to the emergency was received and reviewed (J. B. McGoodwin to R. E. Fields, "Incident in Nuclear Area No. 1 Related to Fires During AGC and NASA LH₂ Irradiations," 11/29/62). The council intends to issue a final report on the subject in the near future which will include a discussion of the events which occurred, conclusions concerning actions taken and safety measures available, and explanations of the following council recommendations:

Rec. No. 62-23: In any hydrogen experiment, a prior complete test should be performed using every item to be involved in the experiment connected and working in the same configuration as in the experiment, and operated long enough to constitute a reasonable proof-testing (lacking only the nuclear environment) of all phases of the installation, including cycling of any mechanical equipment involved.

Rec. No. 62-24: The design of any system involving LH₂ should be such as to preclude the formation of LOX anywhere in the system.

Rec. No. 62-25: (a) The explosive mixture detection system should encompass the entire experimental area and should have the capability of continuous recording for all sampling points. Readout from any selected sampling point should be available in less than one minute.

(b) Television coverage should be adequate to permit viewing the entire experimental area, as much simultaneously as is practical.

(c) A fire detection system backup should be provided in those parts of experimental areas where television monitoring is not possible.

Rec. No. 62-26: The use of only six-cylinder CO₂ banks, determined to be inadequate and discontinued should not be reinstituted.

- Rec. No. 62-27: A single-action device should be provided which will immediately cut all power to all electrical distribution panels and outlets providing power to the experimental test setup areas of the GTR. A similar single action device should also be provided for the ASTR.
- Rec. No. 62-28: Sufficient people in the Fire Department should be well informed of the type of experiment and of the configuration of potentially hazardous elements prior to each experimental operation that all three shifts will be adequately aware of the situation.
- Rec. No. 62-29: A study should be performed to optimize communications in Nuclear Area No. 1 in the event of an emergency.

31 January 1963

5. The council reviewed a memo from H. G. Thornton to J. W. Allen, 1/24/63, "Overpressure Protection for LH₂ Dewars." The council agrees that the step proposed alleviates the conditions of overpressure in the dewar caused by difficulties in the exhaust line, but is not demonstrated to relieve the situation where an overpressure is caused by complications internal to the dewar, and in that respect falls short of the original recommendation. (Ref.: Item 6, NSC minutes of 10/18/62, Rec. No. 62-20.

"To comply with this reservation in recommendation, we put a He purge in the exhaust system to prevent any stoppage from internal dewar pressure, pressure checked the dewar to 8 psi, and then set the relief valve at 7-1/2 psi."

21 February 1963

3. The council began review of the "Planning Document, Aerojet General Materials Irradiation Test, Contract NP-5, Appendix B." Because of the length of the document, review will continue for at least one more week. The council had two preliminary comments. (a) Criteria for explosive mixture detection have been previously recommended (Ref.: NSC minutes of 11/29/62. Rec. No. 62-25a). The council notes that the use of the Davis system, as proposed in paragraph 4.5 of the planning document, is not acceptable for this purpose. (b) The use of a television system which is not in explosion-proof housings (paragraph 4.4) is not in accordance with good practice.

28 February 1963

2. The council continued review of the planning document for the AGC irradiation (Ref.: Item 3, NSC minutes of 2/21/63). Review will be extended for one more week. An observation evolved concerning the incompleteness of provisions for the emergency removal of power from disconnect panels in the pool area. A previous recommendation on this subject (Ref.: Item 1, NSC minutes of 11/29/62, Rec. No. 62-27) was based on the experience firemen had on 11/2/62 with live wires which were thought to be electrically inactive. Fortunately the potentially tragic consequences did not develop on that occasion. To avoid giving fate a second change, NSC recommendation No. 62-27 should be implemented!

7 March 1963

2. The council deferred review on Aerojet-General Materials Irradiation Test planning document until next week, at which time McGoodwin will present some changes in the document.

4. The council saw two movies, "Experimental Investigation of Liquid Hydrogen," Part I and II.

14 March 1963

1. The council continued review of the AGC irradiation planning document. McGoodwin presented "Radiation Effects Operating Procedures, Nuclear Area No. 1," 3/13/63, which specifies additional procedures as an administrative interlock in response to a previous council observation concerning the emergency removal of electric power from disconnect boxes in the pool area. (Ref.: Item 2, NSC minutes of 2/28/63.) The council approved the procedures as a temporary palliative, noting that they do not constitute a final solution. (Ref.: Item 1, NSC minutes of 11/29/62, Rec. No. 62-27.) Following extensive discussion and noting that a revised version of the document will be available for final action at the next meeting, the council disapproved the experiment because the explosive mixture detection system is not extensive enough to provide adequate coverage. Except for this deficiency, the proposed experiment is acceptable. (Ref.: Item 1, NSC minutes of 11/29/62, Rec. No. 62-25a.)

22 March 1963

1. The council renewed discussion of the explosive mixture detection system (for) the AGC irradiation test next week. (Ref.: NSC Minutes of 3/14/63, Item 1.) (In) attempt to delineate what is considered adequate coverage of the experimental (area) the council judged the following requirements to be the minimum for facility (safety).

- Rec. No. 63-2:
- (a) Each cryostat should have two sensors located on it which are continuously monitored.
 - (b) There should be one sensor located above the GTR which is continuously monitored.
 - (c) There should be one sensor in the pool vent stack which is continuously monitored.
 - (d) There should be four sensors beneath the facility shield which are monitored either continuously or at frequent intervals.
 - (e) If a sequential sampling system be used, one sensor in the sequence should be located in the control room for periodic recalibration and checking.

With the incorporation of these requirements, the council judges the proposed experiment acceptable and approves it on this basis.

APPENDIX B

SYSTEM ENGINEERS LOG RECORD

The following pages are verbatim copies of the systems engineers log record for the period 27 March 1963 through 30 March 1963. Included are memoranda and check lists that have been inserted in and made part of the log record.

BLANK

SYSTEMS ENGINEERS LOG

SHIFT 1stDATE 27 March 1963

PERSONNEL DOSE INFORMATION

NAME	DEPT	QTRTRY DOSE TO DATE	DOSE THIS SHIFT	TOTAL DOSE	TIME
Irby	64	1748			
Bradford	64				
Stuart	64				
Miller	94	1008			
Estell	94	2505			
Stutt	94				

1. Joe - Jiggs req'd _____ bolts. They only have 35 -- C 34's but the rest will be ordered by shortage.
2. Checked our power control circuits to all stations. O. K.
- 0900 3. Baggett has a fix in work for LH₂ lines.
4. Called phone company about console phone.
5. ~~Has anyone seen Jack Pugh's small screwdriver?~~
- 12:45 6. All 3 cryostats have passed the He leak check.
7. I got a better connection on the Davis Alarm Pot, so maybe it will calm down.
8. Hasn't anyone noticed the new logbook?
9. CO₂ fire extension is armed.
10. I started the check list.
- 1300 12. Located remaining Davis sniffers (see meter panel).
13. To calibrate Davis meter from control room:
 - A. Put 3/16 sampling tube inside calibration box.
 - B. When instrument steps to point 8, turn power switch off.
 - C. Inject 550 cc H₂ in box and stir.
 - D. Depress "Valve Stop" (purge) button (Davis).

E. Turn Davis power switch on.

F. Keep purge button depressed and wait ~ 1 min. to pull sample into analyzer head. Meter should read .46 (see calib. curve).

14. Everything is wired to our power control switch except Phil Mace's Instrumentation. His signal is only 1 mil.

SHIFT 2nd

DATE 27 March 1963

PERSONNEL DOSE INFORMATION

NAME	DEPT	QRTRLY DOSE TO DATE	DOSE THIS SHIFT	TOTAL DOSE	TIME
Thiebaud	64				
Stuart					
Thornton					
Bradford					
Mace	AEC				
Stevens	98				
Winton	94				

1. Telephone fixed.
2. Pt. No. 2 on Davis sometimes goes off as it charges from No. 1 to No. 2.
3. Pt. No. 8 shows some H_2 in control room. It reads about .04.
4. Tucker, if LN_2 truck comes or calls, call R. W. Lanford E-D-6-0791. Hold truck at guard and change house.
5. Leak checked. Got some indication. About 10% of L.E.L.
6. Started filling. West cryo would not fill. Probably 1/4" fill line is kinked.
7. Will change to big fill lines and start again.
8. Gerry, is full scale readout on Bristol recorder 100% of L.E.L.?
9. Just started flowing. LH_2 filled dewars so fast pop valves on dewars went off and H_2 exhaust cracked in concrete block. Try to get plumbers to put in three 2-in lines in parallel and tap back into 3-inch exhaust. Went to pt. 4 on liquid level indicator in 5.5 minutes.

10. There is indication of a crack in vacuum seal on the west dewar.

Procedure for filling with LH_2 :

1. Close all pneumatic valves.
 2. Barely open them one at a time. The reason for this being that the large fill lines fill too rapidly.
 3. Open truck valve slightly.
 4. Continue to fill as per Item 5 of planning document.
11. The way valves from truck to manifold are installed liquid could be trapped.

N. O. P. D6.0033

Date 20 March 1963

Approved J. B. McGoodwin

RADIATION EFFECTS
NUCLEAR OPERATING PROCEDURES

SUBJECT: Master Electrical Safety Switch

SCOPE:

The purpose of this procedure is to provide an administrative interlock which will control all power to any test setup.

RESPONSIBILITY:

The responsibility for implementation of this interlock is delegated to the Radiation Effects Crew Chief.

PROCEDURE:

The Crew Chief on duty prior to start-up of any experiment will check the entire test setup to ascertain that all power cables from the control room to the test setup are connected to the electrical receptacles which are controlled by the master safety switch. The safety switch will be de-energized and the test setup checked to see that all power has been eliminated. Power, other than 115 VAC, will be routed thru appropriate relays and these relays will be energized by 115 VAC from the controlled receptacles.

The Crew Chief on duty prior to start-up will record on the attached check list any necessary deviation from the above procedure. This deviation, if any, will be explained to each succeeding Crew Chief and the correct action to be taken in the event of any incident.

Each Crew Chief will complete the attached check list at the beginning of each shift and file it in the logbook. Any changes made in the test setup after the start of an experiment will be approved by the Crew Chief. This change will be noted on the appropriate check list and other Crew Chiefs informed of such changes at the start of each shift.

ELECTRICAL DISTRIBUTION SYSTEM

CHECK LIST

Panel A

Enter Yes or No and Initial

	Day	1	2	3	4	5	6
1. All power to test setup connected to controlled receptacle.		NO					
				POWER			
2. All power to test setup not connected to controlled receptacle is routed thru appropriate relays which are connected to controlled receptacle. .					TO		
						TEST	
3. Uncontrolled power to test setup.							SETUP

Explain:

GE GE GE

Emergency Actions:

Panel B

Enter Yes or No and Initial

	Day	1	2	3	4	5	6
1. All power to test setup connected to controlled receptacle.		NO					
			POWER				
2. All power to test setup not connected to controlled receptacle is routed thru appropriate relays which are connected to controlled receptacle.				TO			
					TEST		
3. Uncontrolled power to test setup.							SETUP

Explain:

GE GE GE

Emergency Actions:

Panel C

Enter Yes or No and Initial

	Day	1	2	3	4	5	6
1. All power to test setup connected to controlled receptacle.		YES GE	YES GE	YES GE			
2. All power to test setup not connected to controlled receptacle is routed thru appropriate relays which are connected to controlled receptacle.							
3. Uncontrolled power to test setup							

Explain:

Emergency Actions:

Panel D

Enter Yes or No and Initial

	Day	1	2	3	4	5	6
1. All power to test setup connected to controlled receptacle.							
2. All power to test setup not connected to controlled receptacle is routed thru appropriate relays which are connected to controlled receptacle.				YES GE	YES GE	YES GE	
3. Uncontrolled power to test setup.				YES GE	YES GE	YES GE	

Explain:

Phil Mace has:

1-4 Cond. Cable
Carrying 1 Mil
(Instrumentation)

Emergency Actions:

Unplug 3 115 VAC Cords from STA D.

Panel E

Enter Yes or No and Initial

	Day	1	2	3	4	5	6
1. All power to test setup connected to controlled receptacle.		NO					
				POWER			
2. All power to test setup not connected to controlled receptacle is routed thru appropriate relays which are connected to controlled receptacle.					TO		
						TEST	
3. Uncontrolled power to test setup.							SETUP

Explain: GE GE GE

Emergency Actions:

SHIFT 3rd

DATE 28 March 1963

PERSONNEL DOSE INFORMATION

NAME	DEPT	QRTRLY DOSE TO DATE	DOSE THIS SHIFT	TOTAL DOSE	TIME
Tucker	64	940	5	945	
Laney	64	847	5	852	
Evans	94	1910	5	1915	
Shoemaker	94	2460	5	2465	

1. Moved west dewar to shop.
2. Maintenance repaired vent pipe thru concrete block. First shift is supposed to re-pour the concrete.
3. LH₂ truck pressure should not exceed 10-15 psi when beginning LH₂ filling.

SHIFT 1st

DATE 28 March 1963

PERSONNEL DOSE INFORMATION

NAME	DEPT	QRTRLY DOSE TO DATE	DOSE THIS SHIFT	TOTAL DOSE	TIME
Irby	64				

0700 1. Ref. Item No. 8 2nd Shift: GM meter is linear up to present alarm point. After alarm level is reached, amplifier saturates and becomes non-linear.

So, since Bristol follows meter reading, recorder printout is valid only up to channel alarm level. % LEL on Bristol depends on which channel has been selected for recording.

0725 2. NOTE: When (and if) GM sensors are mounted on cryostats, make sure they are put where ice cannot form on them like it did on tygon sniffer tube last time.

3. Wayne, will you get our ~~big-patchet, breakover-~~ and 2 sockets (N 1" and 1-1/8") from Steve?

0820 4. Called phone co. back.

5. Wayne, where are the 5 thermoswitches we took off the ASTR to have calibrated?

6. ~~Replaced-batterys-in-one-portable-sniffer, switch has-been-left-"on"-the-past-2-nights.~~

7. Was a check list filled out for LH₂ flow?

0930 8. C. Kelley is welding up leaks in the dewar.

1315 9. Leak checking east and north cryos w/He.

10. A He bottle rack and manifold are being rigged up at the Demin. House to circumvent doodle-bugging bottles down the stairs. Our old inert gas manifold is being used.

11. Inert gas regulator suggests 125 lb supply. Do not exceed 150 lb. The regulator referred to is the one on the floor behind rack 3.

SHIFT 2nd

DATE 28 March 1963

PERSONNEL DOSE INFORMATION

NAME	DEPT	QRTRLY DOSE TO DATE	DOSE THIS SHIFT	TOTAL DOSE	TIME
Thiebaud					

-
1. Phone is fixed.
 2. Inert gas switch fixed. Haven't checked to see if solenoid works yet.
 - 1700 3. Brought west dewar down to start leak check.
 4. Batteries for portable sniffers are in the bottom (like on the floor) of our shelf space between racks 4 and 5.
 - 2011 5. Filled LN₂ jackets with He. Starting leak check at 2030.
 6. North pneumatic valve starts opening at 12 lbs.
East pneumatic valve starts opening at 11-1/2 lbs.
West pneumatic valve starts opening at 11 lbs.
Takes 16 lbs to close North.
 7. Purged and H₂ gassed off at 2249/not sure if it was 49 or 99 - sp
 8. Pt. No. 10 of GM Sensor will be placed on vacuum pump (small leak suspected on dewar) and Pt. No. 6 of Davis will be placed on west pool wall. This was done because of small amount of H₂ is expected to be pumped through a dewar but the leak could get worse. When and if the leak becomes a hazard a tygon tube section is in the vacuum line and it will be clamped off to eliminate this hazard.
 9. It has been suggested slightly that a yard compressor be used so as to supply 90 lbs of air to pneumatic valves. I am against this due to the refueling problems, etc.

SHIFT 3rd

DATE 29 March 1963

PERSONNEL DOSE INFORMATION

NAME	DEPT	QRTLY DOSE TO DATE	DOSE THIS SHIFT	TOTAL DOSE	TIME
Tucker	64				
Laney	64				
Evans	94				
Shoemaker	94				

1. 11-1/2 psi is 1/16" open on north valve.
- 0115 2. Started putting cryostats in the hole.
3. 11 psi is 1/16" open on east valve.
- 0400 4. Cryostats in the hole, checklist complete
- 0500 5. LH₂ flow started.
6. There is a small hydrogen leak somewhere between the east tracks in the handling area.
7. 10-1/2 psi is about 1/32" open on west valve.
- 0537 8. All dewars full, reactor about to start up.
9. By the way, the east and west dewars, as they are mounted on the dollies, actually scrape the tracks as they start down. So be extra cautious coming up with them after the experiment is over.
- 0600 10. There are now no detectable leaks in the handling area. Reactor is on the way to 3 Mw.
11. Where are some more copies of check list?
12. GM point ten alarmed when I placed it near the vacuum pump exhaust. At that time there was no hydrogen in the area. This was about 0200. The meter has not moved at all since then, even when I moved it away and tried to ventilate it. I don't know whether it is saturated with oil or what, but it is useless as a hydrogen detector as long as it is in the alarm condition. So, Davis Meter point 6 is on the vacuum pump exhaust. Point nine has also been high for about the same length of time. I think they both may have been sensing diesel fumes from the BUDA.

13. 0611 3 MW at 30 inches
- 0614 3 MW at 24 inches
- 0617 3 MW at 20 inches
- 0618 3 MW at 16 inches
- 0620 3 MW at 12 inches
- 0621 3 MW at 8 inches
- 0624 3 MW at 6 inches
- 0625 3 MW at 4 inches
- 0629 3 MW at 3 inches
- 0632 3 MW at 2 inches

14. GM Meter Positions

1. East cryostat (back)
2. East cryostat (reactor face)
3. North cryostat (back)
4. North cryostat (reactor face)
5. West cryostat (back)
6. West cryostat (reactor face)
7. Vent stack (pool)
8. Reactor Frame
9. North Pool Wall
10. Vac. pump exhaust

Davis Meter Locations:

1. Fac. shld. N-W
2. H₂ exhaust manifold
3. West Walkway
4. LH₂ fill manifold
5. HA East Side
6. Vac. pump exhaust
7. T. V. Camera 1
8. Control Room

RADIATION EFFECTS

CHECK LIST

Date 29 March 1963

Time _____

A. Prior to Startup

1. Experimental installation complete.	<u>JRT</u>
2. Water window closed and filled.	<u>GE</u>
3. Turn off power to escalator system	<u>JRT</u>
a. Throw the three 440 vac switches in the hoist house.	<u>JRT</u>
b. Disconnect cannon plugs to all limit switches at the south end of the Fairlead Assy.	<u>JRT</u>
c. Place "do not operate" signs on both escalator control panels.	<u>JRT</u>
d. Turn key lock to "off" position.	<u>JRT</u>
4. Disconnect power to all of the environmental units.	<u>GE</u>
a. Disconnect the four 440 vac plugs on the east wall of the handling area just below the catwalk and the one 440 vac plug on the north wall of the handling area.	<u>GE</u>
b. Disconnect the cannon plugs from the junction box on the west wall of the handling area.	<u>GE</u>
c. Turn breakers, located in rack No. 1 Radiation Effects Console, off to racks No. 1 and No. 3, and No. 2.	<u>GE</u>
d. Place "do not operate" sign on low temperature control panel in rack No. 4 and on spray system control panel in rack No. 2. BRKRS. OFF	<u>GE</u>

5. Miscellaneous Items

a. Place remote intercom boxes in normal talk position and leave it in this position for the duration of this test.	<u>T-BO</u>
b. Turn cooling water switch to "off" position and place "do not operate" sign on this switch in rack No. 4.	<u>GE</u>
c. Turn cooling tower, on east ramp, off and place a "do not operate" sign on its control box.	<u>GE</u>
d. Turn cooling water pump, in handling area, for regrigeration units off and place a "do not operate" sign on its control door.	<u>GE</u>
e. Turn all lights off in the hoist house.	<u>JRT</u>
f. Explosion meter on and purged and wired to emergency power and calibration checked.	<u>GE</u>
g. Sniffer tubes in the correct places	<u>JRT</u>
h. Fire extinguisher system armed and wire to emergency power. Verify 12 bottles per rack. CHECK LCO ₂ BACK-UP.	<u>GE</u>
i. Television system operational	<u>JRT</u>
j. Disconnect solenoid valve on fill line to harness access opening.	Cannot be done
<u>JBM</u>
k. Mercury vapor lamps and incandescent lamps in pool on.	<u>JRT</u>
l. Pool vent system on.	<u>JRT</u>
m. Verify status of NPO D6.0033 check lists (Wire to pwr. cont. SW)	<u>GE</u>

B. Start of Hydrogen Flow

1. Remove non-operating personnel from exclusion area and verify Operations Check List through Item D.2, C.2, or both. T-B0
2. Hydrogen truck grounded. T-B0
3. Fire extinguishers by truck. T-B0
4. Fire hoses spotted and hydrant valve open. T-B0
5. Initiate hydrogen flow per Item 5.0 of Planning Document. T-B0
6. Leak check assemblies after operating liquid level is attained. T-B0
between liquid levels 2 and 3

SYSTEMS ENGINEERS LOG

SHIFT 1st

DATE 29 March 1963

PERSONNEL DOSE INFORMATION

NAME	DEPT	QRTRLY DOSE TO DATE	DOSE THIS SHIFT	TOTAL DOSE	TIME
Irby	64				
Stuart	64				
Miller	64				
Bradford	64				

1. When sending people outside, send 2 at a time. (EJB)
- 0800 2. LH₂ level at 5500 Gal. was 7000 gal at 0500.
- 0830 3. LH₂ level 5000 gal.
- 0930 4. LH₂ level 4500 gal.
- 0944 5. GTR retracted. Pump (GTR) trouble in east tuning.
(rod seals)
- 1000 6. Hooked up He purge to east and west/cryos. (in HA).
- 1010 7. GTR Demin. Pump has burned up motor. Replacing with
one from ASTR.
8. We need a way to isolate the FM filaments so that
we can check meter zero.
- 1030 9. LH₂ level is 4100 gal.
- 1025 10. Davis alarm on Vac. pump Exh./Meter read ~ 0.65.
Nothing on GM No. 10.
- 1034 11. Ditto Item No. 10.
12. We have been requested to take data once per hour
for Phil Mace. See yellow pad on table.
13. Camera 4 is at northeast corner of reel shack looking
at H₂ exh. stack. Don't focus No. 4.
14. The way our GM meter gain is adjusted, along with
recorder space adjust, reacorder reads ~ 8 when meter
is at zero.

- 1130 15. LH₂ level 4000 gal.
16. Be sure to move GM No. 9 before pulling east.
17. Ref. Item No. 14. This applies to each channel so zero meter reading will print out differently from channel to channel, 1.
18. NOTE: If LH₂ flow is ever shut off at trailer, call Maint. to check oil in air comp.
- 1230 19. LH₂ level at 3800 gal.
- 1250 20. Checked calibration of Davis No. 6 and GM No. 10 with 10% H₂. Both alarmed properly.
- 1328 21. GTR pump has been fixed since ~1125. Still at 300 KW full south. They are waiting on us. West cryo still alarms Davis No. 6.
- 1400 22. LH₂ level 3500 gal; press 9 psi
- 1430 23. LH₂ level 3200 gal.
- 1437 24. GM No.'s 5, 6, and 10 alarmed. Also saw cloud of vapor in pool. Severe overpressure on north cryo. All cleared in ~20 sec.
25. Caution -- when adjusting north valve, do so very gingerly.
- 1445 26. Lost all LH₂ in north cryo. Can't refill without a severe pressure spike.
- 1500 27. LH₂ level 3200 gal.
28. Wayne - Get someone to cover camera No. 4 with polyethylene. Short and Stutt have been "manifolding."
- 1530 29. GM No.'s 4 and 6 alarmed.
- 1530 30. LH₂ level 3100 gal. Press 9 psi

SHIFT 2nd

DATE 29 March 1963

PERSONNEL DOSE INFORMATION

NAME	DEPT	QTRTRY DOSE TO DATE	DOSE THIS SHIFT	TOTAL DOSE	TIME
Thiebaud					

16:34 11 psi 2900 gal LH₂ level

16:56 at 30" at 3 Mw

17:00 at 24" at 3 Mw

17:01 at 20" at 3 Mw

17:06 at 16" at 3 Mw

17:09 at 12" at 3 Mw

17:10 at 9"

17:12 at 6"

17:12 at 4"

17:18 at 3"

17:19 at 2"

LH₂ level 12-1/2 psi 2500 gal at 17:21

LH₂ level 11-1/2 psi 2100 gal at 18:03

LH₂ level 14 psi 1950 gal at 18:38

LH₂ level 11-1/2 psi 1800 gal at 19:16

Plotted consumption curve seems to be using 470 gal/hr.

When truck pressure dropped to nine pounds we seemed to lose
LH₂ flow.

20:00 Noticed no nitrogen exhaust on North Which One?

GM Pt. 4 remains at 12%. Pt. 6 and 3 ring intermittently.

Pool vent fan (Pt. 7) will rise and fall, but so far has not reached alarm level.

LH₂ level (15 psi) is 750 gal at 21:30

Both trucks are on manifold at 21:00

Holding truck pressure constant at 15 psi

Put both trucks on manifold when:

(old truck)

600 gal at 21:50

7500 gal (new truck)

switched over

Called Strode (LN₂ man at St. Louis). He will call back and give time of arrival. Here we are supposed to give 48 hours notice for LN₂. The LN₂ tank gauge gives amount in inches. Take a reading every hour and arrive at some kind of conclusion as to when we will be out.

Gerry, Jiggs said to call him at 07:00, 3-30-63 (Sat.) tomorrow.

Gerry, E.T.A. for LN₂ is 08:00 tomorrow. If it looks like we will need it earlier inform Jiggs, etc.

2400 - 13"

Littleton, Colo. 303-794-4248

Air Products Co.
Norbert Hochreiter
Chief Operator

Linde Co. Fontana, California

714-YU4-2766 (No Answer)

714-822-2295

Jim Findley (Night Foreman)

Air Products Long Beach, Calif.

213-835-0106

G. L. Richards (Shift Supervisor)

SHIFT 3rd

DATE 30 March 1963

PERSONNEL DOSE INFORMATION

NAME	DEPT	QRTRLY DOSE TO DATE	DOSE THIS SHIFT	TOTAL DOSE	TIME
Tucker	64		40 Week	970	
Evans	94	1875	90	1965	
Laney	64				
Shoemaker	94		125 Week	2565	
Thornton	64				

1. Large fire on North Assy at 0045.
2. Severe pressure spike on North simultaneously with fire.
3. Fired second bank of CO₂. The north cryostat appeared to break out in a second fire on the closet side. All we could see was flickering light and smoke, not the fire itself, but Pancoast and I agreed that we should shoot the second bank.
4. CO₂ displaced the hydrogen to other points in the pool. All points on GM meter alarmed except point 10. Several points went off scale intermittently. Not before fire.
5. Before the second bank of CO₂ was fired, McQueen was attempting to maintain LH₂ in the east and (0100) west, but now all LH₂ is shutoff and the Pool is being opened.
6. The cable to G-M explosion meter No. 3 is apparently burned in two. The channel is dead-press to test gets no meter movement.
7. Operations burned up the motor on the pool shield dolly.
8. 0200 - Purging is in process.
9. McQueen and JWA agree the test is Kaput.
10. Not once did the Davis explosion meter alarm or give any noticeable indications.
11. Just finished looking at North Assy. with binoculars. The explosion meter conduit was evidently in the hottest part of the fire. The wire is burned back for a couple of feet, the conduit is black, the rubber stopper is just a mass of charcoal, and the sintered flame arrester, surprisingly enough, looks almost normal.

12. G-M pts 2 and 4 appear to have burned out filaments -- alarm condition, and cannot zero the meters.

13. There is considerable general damage visible on the North, mostly instrumentation burned up. There was not any damage that I noticed on the West in the brief look I took. I did not look at the East. The closet apparently was not damaged.

14. The limit switch cables for the escalator are plugged back in at the edge of the fairlead. The North Assy is up about 2 feet on the escalator tracks. We're leaving it there for the weekend.

15. The tag line (1/8") cable on the West is tangled pretty badly on the cable drum.

16. The fire initially flared up about 6 or 8 ft high, then immediately reduced to about the top of the pulling assy, and burned generally all over the North face until it was put out. It took longer than usual to put it out because the pool vent system coasted so long. The CO₂ did not fill the pool at all on bank one, in fact, the fog did not even obscure the view of the cryostat, but it did put out the fire. The second fire broke out almost immediately, but it took us a few seconds to make up our minds that it really was a fire.

17. Gene Thornton made a set of notes. I haven't read them, but we should do so Monday.

18. The hand valves on the CO₂ tank on the roof are closed.

19. I called Linde and Air Products and canceled the LN₂ and LH₂ that had been ordered. See 2nd shift note last page.

20. Shortly after the fire, and as Operations was uncovering the facility, the West dewar lost its vacuum. Shortly thereafter, there was a loud report, (according to Thornton, I didn't hear it) and debris(?) was noticed flying up out of the pool. But when I looked outside, I didn't see any evidence of there having been an explosion? Anyway, sometime later, the East dewar also lost its vacuum. After this the LH₂ truck was disconnected and the drivers released.

21. I have probably forgotten a few details, but I'm sure I've covered the main points.

22. Brunner is making a tape recording of some of the pertinent facts.

23. Opinion is pretty general (me, too) that hydrogen was getting out through the nitrogen vent, and that this is how we got enough to create the large flame that was seen. Because earlier in the evening, the wall between the nitrogen and the vacuum cracked and N_2 started coming out the vacuum line. Later, H_2 started coming out the vacuum line. This means (to me, at least) that there could have been hydrogen in the nitrogen space.

24. Turned off Mace's instrumentation and all our power.

25. When the CO_2 bottles are pulled Monday, check bank 1 for mis-fires. We sure didn't have much CO_2 on that first shot.