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TEST CELL A INDOCTRINATION COURSE

NUCLEAR ROCKET DEVELOPMENT STATION
NEVADA

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TEST CELL "A" INDOCTRINATION COURSE

STUDY GUIDE-SECTION I

GENERAL INTRODUCTION

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TEST CELL "A" INDOCTRINATION COURSE

STUDY GUIDE-SECTION I

GENERAL INTRODUCTION

A. REMARKS OF WELCOME

(By appropriate officials of NRDS)

B. ROVER PROJECT

1. Purposes

The Rover program is the development of nuclear propulsion systems for rockets. Nuclear rockets are expected to perform space missions beyond the capabilities of vehicles propelled by chemical systems.

The most important advantage of nuclear rockets lies in the fact that they can use hydrogen as propellant. Hydrogen is more than a dozen times lighter, per particle, than the combustion products used to propel chemical rockets. Because of its lower inertia, hydrogen can be accelerated to higher exhaust velocities at attainable temperatures than are possible for combustion product gases. Higher exhaust velocities result in better performance because they create higher "specific impulse" (pounds of thrust per pound-per-second of propellant expelled).

Where the force of gravity is great, high thrust is necessary to overcome it. Once a strong gravitational field has been left behind, high specific impulse becomes more important than high thrust, because effective performance of a mission then depends on the economical use of propellant.

It will be possible to build nuclear rockets capable of taking off from the earth, but their greatest advantages will appear in outer space. Nuclear engines now being planned or developed are thought of for use in weak gravitational fields, leaving earth on chemical boosters.

2. Problems

While the use of hydrogen propellant makes high exhaust velocities possible, these velocities still vary with the temperature of the propellant just before it expands. To take full advantage of the lighter propellant, nuclear engines must operate at temperatures approximately equal to those attained by chemical rocket engines. Such temperatures were unprecedented for nuclear reactors when the Rover program began, and the temperature problem is still formidable. It absorbs the energies of about one out of every three people working on the Rover project at Los Alamos. Fuel elements and certain structural components of rocket reactors must operate at temperatures similar to those in an incandescent light bulb. Since uranium melts at a much lower temperature, it cannot be used in its pure metallic form.

A rocket reactor should be capable of starting "cold" and rising to full power within a short time. This requirement poses problems of control engineering as well as additional problems of thermal stress.

A third requirement, arising from the fact that a flying reactor must not weigh too much, is that Rover reactors must generate great power in small volume. To create the rather modest thrust of 50,000 pounds, for example, a reactor must produce about one million BTU per second, or enough energy to boil away a ton of water every two seconds. In electrical terms, this power level is equal to 1000 megawatts - a megawatt being a million watts. The electrical power production rate of Hoover Dam is 1250 megawatts. The core of Kiwi-B-4A is hardly larger than a kitchen range.

To keep this extremely compact power generator from getting too hot (and to meet the obvious requirement that it must eject a large flow of propellant), arrangements must be made for the hydrogen coolant-propellant to flow through fast, still picking up a great deal of heat as it flows.

Because the presence of this hydrogen among the fuel elements has marked effects on the behavior of the neutrons, the gas flow becomes a complicating factor affecting the rate of power generation.

Since high pressures are necessary to the rapid flow, the whole reactor must be contained in a strong pressure shell.

Fuel elements must be able to resist not only the high temperatures and rapid temperature changes but the corrosive and erosive effects of the moving hydrogen.

These are merely samples of the many problems to which improved solutions are constantly being sought and found. In comparing the development of rocket reactors with that of conventional reactors, the chief of the Rover program at Los Alamos once said, "I think you have the right impression if you believe that nearly everything is somewhat harder to do."

3. Accomplishments

Project Rover began in 1955 at Los Alamos. Not even the problems it was facing were very well known. To say that Rover has since uncovered a great many problems is to record a significant and essential achievement.

The uncovering of solutions has gone very well too. Perhaps the most ingenious solutions have related to the chemistry, metallurgy, and fabrication of fuel, or to the handling of hydrogen as it changes from liquid to gas within the system. One of the most stubborn problems, and possibly the one most demanding of improved solutions in late 1962, has been core support. A host of other problems have been solved. The Kiwi reactors tested since 1959 have embodied steadily improving technology. They have entirely removed the very considerable doubts of 1955 concerning the feasibility of developing nuclear rocket propulsion at all.

The test operations on Kiwi reactors begin at Los Alamos. Each reactor was assembled in the LASL Critical Assemblies Laboratory and checked out at very low power, then taken apart and shipped to the Nuclear Rocket Development Station in Nevada. In the assembly bay of the MAD building (Maintenance, Assembly, Disassembly), the reactor is put together again on a special railroad car. A locomotive moves the reactor to a test cell. Still on its railroad car, the reactor is "plugged in" to propellant, instrumentation, and control lines in the outside face of the test cell wall.

When all personnel have withdrawn to the control point or other safe stations, control mechanisms increase the reactivity of the reactor core by withdrawing neutron-absorbent substances, and hydrogen flow begins. (All three reactors in the Kiwi-A series and the first Kiwi-B reactor were designed to use gaseous hydrogen as coolant-propellant. All testing since then has used liquid hydrogen, since gas would be too bulky to store in an actual rocket.) Reactor power is raised in a selected pattern to a predetermined level, held there for a predetermined number of minutes, and then lowered again. Performance data are continuously transmitted to the control point, almost two miles away, using hundreds of electronic channels.

After the power has dropped, it may be raised again for the purpose of measuring any reactivity loss of the system. Then the reactor is shut down. After a brief cooling-off period, the reactor and its car are moved by the remotely controlled locomotive to the disassembly bay. Examination and analysis of the reactor parts is carried out in the MAD building and, later, at Los Alamos.

An important function of the first test, in 1959, was the discovery of new problems. Since that time the testing program has become more and more a proof of new solutions.

4. Rover Project Organization - An accompanying chart, Figure I-1, shows this organization.

5. Future Rover Activity

A graphic presentation of the Rover Project, showing principal activities from the 1955 beginning through planned developments in years just ahead, as shown in Figure I-2, ROVER DEVELOPEMENT.

C. NUCLEAR ROCKET DEVELOPMENT STATION

An overall description of the facilities located at NRDS is provided in a handout booklet distributed to enrollees of this course, titled "Space Nuclear Propulsion Office (Nevada Extension) and the Nuclear Rocket Development Station." These facilities, both present and planned, include:

TEST CELL "A"

TEST CELL "C"

R-MAD BUILDING (Reactor Maintenance, Assembly, and Disassembly Building)

CONTROL POINT

ETS-1 (Engine Test Stand 1)

ETS-2 (Engine Test Stand 2)

E-MAD BUILDING (Engine Maintenance, Assembly, and Disassembly Building)

SAM BUILDING (Stage Assembly and Maintenance Building)

E/VTS-3, VTS-4, VTS-5 (Engine/Vehicle Test Stands 3, 4, and 5)

DEMATING FACILITY

D. ORGANIZATIONAL DESCRIPTIONS

Separate handout booklets and write-ups covering the general scope of activities of the principal industrial, educational, and governmental organizations connected with the Rover Project (particularly the NERVA Program) will be distributed following a short lecture coverage of this material. These organizations include: Atomic Energy Commission, National Aeronautics and Space Administration, Space Nuclear Propulsion Office, Aerojet-General Corporation, Westinghouse Astronuclear Laboratory, Los Alamos Scientific Laboratory, Pan American Airways, American Machine and Foundry - Atomics, Bendix Corp., Lawrence Radiation Laboratory, Reynolds Electrical and Engineering Co., American Car and Foundry Industries, Federal Services, Inc., Edgerton, Germeshausen, and Grier, Inc., Catalytic Construction Co., and others.

E. SELECTED MOTION PICTURE FILMS

As available, films appropriate to the introduction of the Rover Project, including the NERVA Program, Kiwi Tests, etc., will be shown in this section of the course.

ROVER PROJECT ORGANIZATION

ROVER DEVELOPMENT

THE NERVA CONTRACT WAS SIGNED IN 1961 AND THE RIFT CONTRACT IN 1962. IN ADDITION TO PROVIDING TECHNICAL ASSISTANCE TO THE NERVA AND RIFT CONTRACTORS, LASL IS DEVELOPING REACTORS FOR MORE ADVANCED ENGINES TO SUCCEED NERVA

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FIGURE I-2
03-0716-U-19

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STUDY GUIDE - SECTION II

TEST CELL FUNCTIONS AND OPERATIONS

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TEST CELL "A" INDOCTRINATION COURSE

STUDY GUIDE - SECTION II

TEST CELL FUNCTIONS AND OPERATIONSA. GENERAL

The objective at Test Cell A (TCA) is to develop a satisfactory nuclear reactor for the NERVA program. The reactor is essentially a controllable heat source for converting liquid hydrogen (LH_2) into hot gaseous hydrogen (GH_2), which serves as the rocket propelling force. When a proven reactor is demonstrated at TCA, it will then be installed and tested in an engine configuration at the Engine Test Stand No. 1 facility (ETS-1). All activities at TCA then, are directed towards the reactor development, specifically the NERVA Reactor Experiment series (NRX).

B. ORGANIZATION

The personnel organization at TCA is shown in figure II-1.

1. Facilities Operations Manager and Assistant Manager. The Facilities Operation Manager and his assistant are responsible to the Manager of NERVA Test Operations for operation, maintenance, and modifications to the various systems assigned to the facilities operations group. They are responsible for the coordination of all work performed at TCA, including the reactor pad - regardless of who authorizes the work or exercises prime responsibility. They are also concerned with the safety of all personnel at the test cell, and any request for action which would appear to affect adversely the operational integrity or safety of any system shall be referred to the Manager of NERVA Test Operations for resolution.

2. System Engineer. The system engineer is responsible for the operation, maintenance, safety, and quality control activities for his system. He supervises the work performed by technicians and various crafts in his area, and maintains log book records of all work done or conditions affecting his system.

a. Operations. The system engineer prepares a checklist to determine that his system shall fulfill test requirements prior to reactor test runs. He also sees that the checklist is accurately executed, or reports deviations to the control point. (CP).

b. Maintenance. In order to have a high degree of reliability in his equipment, the system engineer prepares checklists for routine inspection and maintenance of his system. He coordinates his activities with other systems engineers where they are affected. And he maintains a stock of tools and spare parts in conjunction with other related system requirement.

c. Safety. The direct responsibility for the safety of every person in his area rests with the system engineer. He has the authority to control access to his area, over-riding when necessary any prior access approval by the Facilities Operations Manager. The system engineer sees that safety practices are followed and that there is no compromise between expediency and safety.

d. Quality Control. The system engineer is responsible for the accuracy and quality of work done on his system, regardless of who performs the work. Insofar as practical he supervises all work on his system.

3. Rocket Test Technicians. All maintenance work, operational activities and checklist functions are performed by the rocket test technicians, under the direction of the system engineer. They operate and maintain the piping and mechanical components of the system. They check and prepare the system for specific reactor test requirements. At all times they are observant of conditions that may adversely affect system operation, and it is their responsibility to alert the system engineer of any deficiencies.

C. TEST PROGRAMS

Test cell A has, up to the present, been used to test the Kiwi reactor series. The facility will now be used to develop the NRX reactor for the NERVA engine program.

1. Kiwi Series. Development of the Kiwi reactor began back in 1955 under direction of Los Alamos Scientific Laboratory (LASL). The first reactor was tested at TCA in 1959. Here is a brief history of the Kiwi test program at NRDS:

Gas Flow (GH₂)

Kiwi - A	1 July 1959
Kiwi - A1	8 July 1960
Kiwi - A3	19 October 1960
Kiwi - B1A	7 December 1961

Liquid Flow (LH₂)

Kiwi - B - 1B	1 September 1962
Kiwi - B4 - A	30 November 1962

Cold Flow (Reactor not critical)

Kiwi - B-4A CF	April-May 1963
----------------	----------------

2. NRX Series. The NRX program is now in the process of being initiated at TCA. The LASL group is phasing out and training the NERVA team in TCA operation. There has been a series of cold flow tests using a Kiwi reactor pressure vessel and a mixing chamber. The responsibilities for operation of TCA is being transferred to NERVA and will be completed by the time the NRX reactor is ready for test.

D. TEST CELL LAYOUT

Test Cell A is located two miles from the control point (CP). The functions of the various buildings and structures will be discussed in

detail later in this course, as they are related to the numerous test systems. From the overall view, however, there are four major areas of interest. (See figure III-2)

1. Gas Tank Farm and Fill Station. The three major gases used in the process flow are delivered to the fill station and transferred to the storage banks. These gases are hydrogen, helium, and nitrogen. The compressor station is for gas transfer as required. The tank farm control room (TFC) houses the instrument racks and switches for monitoring the storage banks and controlling the remotely operated valves in the tank farm.

2. LH₂ Fill Station and Dewar Area. Liquid hydrogen is delivered to the fill station in a dewar trailer, and is transferred into the storage dewars by pressurizing the trailer. No pumping is required. This area also contains the piping and valves for controlling flow of LH₂ into the test cell building.

3. Test Cell Building. The heart of test facility is in the flow control room (FCR) in the test cell building. All lines serving the reactor flow through the FCR, and it is here that flow is monitored and controlled before the lines penetrate the concrete wall for connection to the reactor. Adjacent to the FCR is the electronic equipment room (ELR). The purpose of this equipment is to condition the signals for transmission to the CP, two miles away. In the mechanical equipment room (MER) are air compressors, hydraulic pump, and air conditioning equipment for various support systems.

4. Distribution Building Control Room (DBC). The controls for remote operation of TCA terminate in racks located in the DBC. Here the various systems may be monitored and controlled in preparation for a test. On the day of a test run, the master control switches in the racks are set to transfer control of the various systems from TCA over to CP.

E. TEST CELL SYSTEMS

Test Cell A is capable of testing a reactor under a variety of flow conditions. The reactor may or may not be critical during these tests. Initially a reactor is tested with a straight gas flow using nitrogen or

hydrogen. In subsequent tests liquid hydrogen may be used, or a mixture of LH_2/GH_2 . To achieve proper flow conditions, the facility at Test Cell A has various systems for gas and liquid flow, and support functions. The instrumentation and electronic control activities are not included in this phase of the indoctrination course, but are covered in a separate CP training program. Presented here is a brief introduction to these systems, with a more detailed study of them to be covered later in this course.

1. Cryogenic System. The cryogenic system comprises all equipment and piping through which LH_2 flows. This includes the LH_2 fill station, storage dewars, flow loops, and piping in the FCR. The LH_2 system supplies the major flow of propellant/coolant to the reactor. This system is one of the most critical at TCA because LH_2 has an extremely low temperature (-423°F), has a high expansion ratio from liquid to gas, and is extremely flammable in a wide range of gas-to-air mixtures.

2. Turbopump System. The turbopump is a very specialized piece of rotary equipment and is considered as a separate system. It is, however, the prime mover in the cryogenic system for pumping LH_2 to the reactor, and the turbine drive is the major consumer in the gas system.

3. Cryogenic Vacuum System. The storage and transfer of LH_2 requires vacuum-jacketed components for low temperature operation. The vacuum pumps in the LH_2 dewar area maintain a vacuum in the cryogenic vacuum-jacketed lines and equipment.

4. Gas Systems. The three gases: hydrogen, nitrogen, and helium are used for various purposes in process flow and support systems. In general, GH_2 is used as propellant/coolant flow through the reactor, and for pressurizing the LH_2 dewars during runs. Also, as previously mentioned, a large quantity of GH_2 drives the LH_2 turbopump. Helium and nitrogen are inert gases, and are used for cooldown and purging the reactor. These two inert gases have further uses in some of the support systems.

5. Reactor Cart Cooling System. The reactor cart has a water shield which is located between the reactor pressure vessel and the top of the privy.

This shield is essentially a large rectangular water box through which water is circulated during a hot reactor run. The water shield affords cooling and radiation protection for instrumentation and equipment in the privy below. As a safety measure this shield water is in a closed system, complete with its own pumps and a ground level storage tank of 100,000 gallon capacity. This system is totally isolated from other water systems.

6. Deluge Systems. There are two deluge systems for protecting hydrogen storage areas: (1) above LH_2 dewars A & B, (2) above GH_2 banks 6, 7, 8, and 9 at the tank farm. The deluge systems have spray nozzles capable of discharging a large volume of water to protect the storage vessels from the heat of fire. Each system is operated independently by heat actuated devices located above the LH_2 dewars and above the GH_2 storage banks. The water for the deluge systems flows from the elevated water tank.

7. Flare Systems. The two flare systems are used to burn off large releases of GH_2 to atmosphere. The main flare system disposes of all GH_2 released from the dewar area and FCR. The biggest contributor to this system is the GH_2 discharge of the turbopump drive. The other flare is located above the reactor discharge nozzle.

8. Utility Water System. The utility water system covers the distribution of water to washrooms, hose bibbs, safety showers, equipment cooling jackets and heat exchangers. An elevated water tank of 50,000 gallon capacity supplies this system as well as the fire water deluge system and make-up water to the reactor cart cooling system.

9. Hydraulic Systems. There are five independent hydraulic systems. One system at the gas tank farm operates the valves in this area. The second system is in the FCR and operates the valves in this room and in the dewar area. The third system is in the MER and actuates the coupling units at the reactor connection through the wall of the FCR. A fourth unit, also in the FCR, actuates the reactor control rods. The fifth and last independent system is the ram neutronic system and is located in the penthouse above the ELR. This system actuates the movement of the neutron detectors in a water tank in the adjacent room.

10. Electrical System. Electrical power is furnished to the test cell by the Nevada Power Company via a line from Mercury to the Jackass Flats substation. Distribution is then to the CP substation and TCA. The diesel generator at CP assumes the electrical load in conjunction with utility power for critical periods during test runs. In the event of utility power failure, non-essential circuits at the test cell and CP are dropped out and the diesel generator assumes the critical circuit load.

11. Compressed Air System. The main air compressor and auxiliary compressor are located in the MER. The main air compressor supplies air directly to the utility air header, and through an air dryer to the instrument air system. The auxiliary air compressor furnishes air to the gas detector analyzers.

12. Room Inerting System. Prior to a reactor test run, the FCR and reactor privy are inerted with GN_2 . This is a safety precaution. In the event of a hydrogen leak during the run, the GN_2 atmosphere in these two enclosed areas prevents air (oxygen) from forming an explosive mixture with hydrogen.

F. REFERENCE DATA

Numerous publications and drawings are available on the activities at NRDS and TCA. The following material is valuable for a more complete understanding of the systems and operations covered in this indoctrination course.

<u>TITLE</u>	<u>DWG. OR REFERENCE NUMBER</u>
Test Cell A Familiarization Manual	RN-FM-0001
Flow Diagram Test Cell A	56Y-117000
Cryogenic Vacuum System	56Y-117035
Flow Control Room Main Hydraulic System	56Y-117036
MER Hydraulic System	56Y-117037
Compressed Air System	56Y-117038
Flare System	56Y-117039

<u>TITLE</u>	<u>DWG. OR REFERENCE NUMBER</u>
Tank Farm Hydraulics	56Y-117040
N-4 Hydraulic System	56Y-117061
H ₂ & O ₂ Analyzing Systems	56Y-117066
Utility Water System	56Y-117072

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STUDY GUIDE - SECTION III

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STUDY GUIDE - SECTION III

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SYSTEM COMPONENTS

A. GENERAL

In the various systems at Test Cell A, there are valves, instruments, and equipment that are common to more than one system. Before going into a detailed study of each system it is well to have a good understanding of these components. The types and functions of the more important components in this category will now be discussed. And later, when specific systems are presented, the specialized components will be covered. Table III-1 lists the various groups of components at the test cell.

B. VALVE CLASSIFICATIONS

1. Types

There are six general types of valves used in the various systems. Each type is suitable for a particular service.

<u>TYPE</u>	<u>SERVICE</u>
Globe	Control, or throttling
Gate	Open or closed, full flow
Ball	Gas tight, full flow and throttling
Plug	Small valves in gas tight service, (propane, acetylene)
Needle	Throttling, small flow, instrument shut-off
Check	Prevent back flow

2. Groups

The valves fall into different groups according to their operation or purpose.

<u>GROUP</u>	<u>IDENTIFICATION</u>
Hand operated	Plain no number
	000-H hydraulic
	000-V vacuum
	VV vent
Remotely operated	OBV, OFV, OVV (open-closed)
	JBV (open, close, in between)
Control	ACV, AVV, PCV, FCV

GROUP

IDENTIFICATION

Miscellaneous

Check valve, safety valve (SV), spring loaded relief (SLR), solenoid (OEV), line blind (BV), rupture disc (RD).

C. VALVE OPERATION

The operation of several kinds of valves warrant further study. These are the valves that have special top works, control systems, or other unique features.

1. Remotely Operated Valves (OBV, OFV, OVV, JBV)

The remotely operated valves are those that may be positioned by personnel who are located at some distance from the valve. These valves can be operated from such points as the tank farm control room (TFC), distribution building control room (DBC), or two miles away at the control point (CP). Table III-2 shows the location and master control switches of the various control racks from which these valves may be operated. The valves themselves are actuated either pneumatically, hydraulically, or electrically.

a. Open/close valves (OBV, OFV, OVV)

The flow requirement for remotely operated valves is for them to be in the full open or closed position. This is true of all block (OBV), fill (OFV) and vent (OVV) operations. Most valves of this group are hydraulically actuated, and less than a dozen are pneumatic. The OBV, OFV and OVV are controlled by push buttons that light up to show open or closed position. See Figure III-1 for typical push button station in control racks.

b. Jog Blocking Valves (JBV)

Another type of remotely operated valves is one that can be jogged to any position between open and closed and remain there. The jog blocking valves are used in this manner to establish a certain flow rate for a given valve position. However, in actual operation at TCA the JBV's are generally set in the full open or closed position. The JBV's are controlled by a three-position, spring-centered toggle switch: in the up position the valve moves open, down position the valve moves closed, and in spring centered position the valve stem does not move. The JBV's are positioned by a reversible electric motor and gear box drive.

N U C L E A R T R A I N I N G O F F I C E

2. Control Valves (ACV, AVV, PCV, FCV)

During a test run some valves are necessary to control flow for a programmed variable, or automatically hold a given rate. These are the analog valves (ACV, AVV) and more conventional control valves (PCV, FCV).

a. Analog Valves (ACV, AVV)

The analog valve is a highly specialized component in a flow control loop. Often during a reactor run the important variables change too rapidly for an operator to observe them and then alter the position of controlling valves. Also there may be a required relationship between variables that must be maintained which would be difficult for an operator to do. The analog valve is capable of quick responsive in such a critical control loop. Movement of this type of valve from open to close is governed by the magnitude of a DC signal between -15 milliamps and +15 milliamps. A source of the electrical signal may be generated by a transducer that converts a measured system variable (flow, pressure, temperature, power, etc) into an electrical differential that is proportional to the system change. Another source for the electrical signal to the analog valve may be a variable potentiometer, where the number of turns (pot setting) corresponds to a certain position of the valve. See Figure III-2 for a typical analog valve control station.

b. Pressure and Flow Control Valves (PCV, FCV)

The more common control valves are those where the control pressure or rate is set at the valve, either by spring loading or pneumatic loading. There is normally no control loop or feed back for correction.

D. INSTRUMENTS

Most of the instrumentation is for measuring flow, pressure, and temperature. Generally there is a local direct reading indicator, and also a transducer for converting the reading to an electrical signal. The electrical signal is conditioned in the ELR for two-mile transmission to the CP.

VALVES

1. Analog Valves	6. Solenoid Valves = OEV
ACV = Analog Control Valves	7. Safety Valves - SV
AVV = Analog Vent Valve	8. Spring Loaded Relief Valves = SLR
2. Open/closed Valves	9. Hand Valves
OBV = Open/closed Blocking Valve	10. Vent Valves = VV
OFV = Open/closed Fill Valve	11. Cryogenic Vacuum Valves = V
OVV = Open/closed Vent Valve	12. Hydraulic Valves = H
3. Job Blocking Valves = JBV	13. Blocking Valves = BV
4. Flow Control Valves = FCR	i.e. Figure 8 Line Blind
5. Pressure Control Valve = PCV	14. Rupture Diaphragms = RD

INSTRUMENTS

1. Flow Indicators = FI
2. Flow Elements = FE
3. Flow Transmitters = FT
4. Pressure Switches = PS
5. Pressure Indicators = PI
6. Level Indicators = LI
7. Temperature Indicators = TI
8. Temperature Elements = TE
9. Temperature Switches = TS
10. Restriction Orifice = RO

EQUIPMENT

1. Filters = F
2. Flex Hoses = FH
3. Operating Units = OU
Fans, Pumps
Compressors
4. Special Equipment = SE
Analyzers, Detectors
Sniffers, Air Packs
Portable Vacuum Pumps
Explosimeters, Blowers
Helium Tubetrailers (5)

Table III-1 Valves, Instruments, Equipment at TCA

1. Flow (FE, FT, FI)

The flow element (FE) in use at TCA is a venturi section in the main flow stream. Figure III-4 shows a typical flow measurement system with a flow transmitter.

The flow indicator (FI) is a direct reading tapered glass tube of the Brooks rotameter type.

2. Pressure (PI, PT)

The pressure indicator (PI) is a direct reading dial face. Pressure transmitter (PT) are transducer type for electrical readout at control racks in the TFC, DBC, or CP as required.

3. Temperature (TI, TE)

There are a few direct reading temperature indicators (TI) at the gas tank farm. Most of the temperature measurements, however, are with temperature elements (TE). The transducer element is a thermocouple, and here again the signal is conditioned at the ELR for transmission to the CP.

E. EQUIPMENT

There is a wide assortment of operating units (OU) and special equipment (SE) at the test cell. Most of the pumps and compressors will be discussed in subsequent study periods as they apply to the various systems. Safety equipment such as analyzers, detectors, sniffers, explosimeters and air packs are part of the industrial safety presentation. Air conditioning equipment and miscellaneous support items are only of incidental interest and are the responsibility of the support services contractor.

MCS NO. 1 GH₂ PROPELLANT SYSTEM - DBC

JBV-10
JBV-11
OBV-8
OBV-46
OBV-83
PCV-39 (Actually PCV-42)

MCS NO. 2 DEWAR PRESSURIZATION SYS. - DBC

OBV-10 OVV-40
OBV-16 PCV-33
OBV-36 PCV-49
OBV-37
OBV-74

MCS NO. 3 DEWAR VENT SYSTEM - DBC

JBV-5 OBV-38
JBV-6 OBV-39
JBV-13 OBV-71

MCS NO. 4 GAS STORAGE SYSTEM - TFC

OVV-3 OBV-28
OVV-4 OBV-35
OBV-6 OVV-47
OBV-7 OVV-48
OBV-9 OBV-49
OBV-11 OBV-50
OBV-14 OBV-53
OBV-15 OBV-54
OBV-23 OBV-57
OBV-24 OBV-58
OBV-25 OBV-61
OBV-26 OBV-62
OBV-27

MCS NO. 5 TURBINE DRIVE, LH₂ PUMP & LH₂**FLO SYSTEMS - DBC**

JBV-1	OBV-21	AVV-11
JBV-2	OBV-41	AVV-12
JBV-3	OBV-42	AVV-13
JBV-4	OBV-84	AVV-14
JBV-7	OBV-85	AVV-15
JBV-8	OBV-86	AVV-16
JBV-9	OEV-105	AVV-17
JBV-12	OEV-111	OVV-47
JBV-16	Pump Brake	ACV-3

MCS NO. 6 ROOM INERTING SYSTEM - DBC

OBV-78
OBV-79
OBV-20

Intake Fan
Exhaust Louvre
Intake Louvre
Exhaust Fan

MCS NO. 7 FLARE SYSTEMS - DBC

All Reactor Flare Valves
All Turbine Flare Valves
Main Flare Actylene

MCS NO. 8 CART COOLING WATER - DBC

FCV-17
OBV-100
OBV-101

MCS NO. 12 MISCELLANEOUS SYSTEMS - DBC

OBV-102	OBV-154
OBV-150	OBV-157
OBV-151	OEV-116
OBV-152	OEV-122
OBV-153	

NOTE: Valves shown are only those that transfer control to CP, per Figure III-3

Table III-2 Master Control Switch Valve Transfer

N E R V A T R A I N I N G O F F I C E

CONTROL PANEL SWITCH MODULES
FOR TRAINING USE ONLY

FIGURE III-1

03-0716-U-40

BORDER COLOR CODE:

BLACK - COMMAND SWITCH

GRAY -- INDICATOR - NO SWITCH

RED --- ALARM INDICATOR

FLASHING LIGHT: ALARM ATTENTION!

STEADY LIGHT: ALARM ACKNOWLEDGED
(BUT NOT REMEDIED)

DBC & TFC MASTER CONTROL SWITCH OPERATION

HAND SELECTOR SWITCH FUNCTION:

- OFF POSITION: POWER OFF TO MCS PANEL.
- MON POSITION: MONITOR LIGHTS ON AT ALL SWITCHES AND INDICATORS, BUT NO POWER FOR SWITCH ACTUATION.
- FWD POSITION: FORWARD AREA (TCA) NOW IN CONTROL OF ALL PANEL OPERATIONS.
- CP POSITION: CONTROL POINT (CPA) NOW IN CONTROL OF ALL PANEL OPERATIONS.

WHITE INDICATOR LIGHT FUNCTION:

- FWD LIGHT: THE FORWARD LIGHT IS ON WHEN THE HAND SELECTOR SWITCH IS IN FWD POSITION AND CONTROL IS AT TCA.
- CP LIGHT: THE CONTROL POINT LIGHT IS ON WHEN THE HAND SELECTOR SWITCH IS IN CP POSITION AND CONTROL IS AT THE CONTROL POINT (CPA).
- MON LIGHT: THE MONITOR LIGHT IS ON WHEN THE HAND SELECTOR SWITCH IS AT CP AND CPA IS MONITORING ALL PANEL OPERATIONS - NO VALVE CAN BE ACTUATED.
- CONT LIGHT: THE CONTROL LIGHT IS ON WHEN THE HAND SELECTOR SWITCH IS AT CP AND CPA HAS CONTROL OF ALL PANEL OPERATIONS.

FLOW ELEMENT (FE)

TYPICAL FE-4 6"
 FE-7 8"
 FE-10 8"

SECTION A: HIGH PRESSURE/LOW VELOCITY
 SECTION B: LOW PRESSURE/HIGH VELOCITY

TEST CELL "A" INDOCTRINATION COURSE

STUDY GUIDE-SECTION IV

CRYOGENICS SYSTEM

NERVA TRAINING OFFICE
N.R.D.S., NEVADA

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STUDY GUIDE-SECTION IV

CRYOGENICS SYSTEM

A. GENERAL

1. Definition. The word cryogenics is derived from the Greek words kyros, meaning icy cold, and genics, meaning science. Therefore, the term cryogenics might be defined as the science and technology of the production and utilization of ultra-low temperature processes and techniques.

As the term applies to the processes of Test Cell A, a better definition might be the handling of those liquefied gases whose critical temperatures are below the natural temperatures existing on earth.

Common usage of the term cryogenic temperatures usually refers to those temperatures from -150°C to absolute zero, or in Fahrenheit, from -238°F to -460°F .

2. Cryogenic Temperature Measurement. Several scales are used to measure cryogenic temperatures. The most common are the following:

a. Degrees Fahrenheit ($^{\circ}\text{F}$), which are used to measure temperature on the Fahrenheit and Rankine scales. Where absolute zero is -460°F on the Fahrenheit scale, it is 0°R on the Rankine scale. Zero degrees on the Fahrenheit scale is $+460^{\circ}\text{R}$. Degrees Rankine ($^{\circ}\text{R}$) are always positive.

b. Degrees centigrade ($^{\circ}\text{C}$), which are used to measure temperature on the centigrade and Kelvin scales. Where absolute zero is -273°C on

LH₂ CRYOGENIC SYSTEM
FOR TRAINING USE ONLY

the centigrade scale, it is 0°K on the Kelvin scale. Zero degrees on the centigrade scale is $+273^{\circ}\text{K}$. Degrees Kelvin ($^{\circ}\text{K}$) are always positive.

c. The Fahrenheit/Rankine scales are used at TCA with preference being given to the Rankine scale.

d. Normal mercury type thermometers cannot be used to measure cryogenic temperatures. Cryogenic temperatures are usually measured by thermocouples and other resistance-type sensors and probes.

3. Characteristics of Cryogenic Liquids. The physical properties of materials at cryogenic temperatures differ greatly from that of ambient temperatures.

a. The heats of vaporization of low boiling liquids are quite small. Therefore such liquids can be preserved only in well-insulated storage vessels, usually high-vacuum type. High-vacuum techniques are of great importance in maintaining cryogenic temperatures. Nearly all heat transfer occurs by means of thermal radiation across the insulating vacuum. (The heat of vaporization is that amount of heat required to change the state of a unit mass of a liquid to a gas at constant pressure and temperature.)

b. The specific heats of all liquids decrease with decreasing temperatures and become extremely small at cryogenic temperatures. (Specific heat is the ratio of that quantity of heat required to raise the temperature of a body one degree, to that required to raise an equal mass of water one degree.)

4. Characteristics of Liquid Hydrogen (LH_2).

a. LH_2 Relationships. The cryogenic liquid used at TCA is LH_2 . To best understand the processes and techniques at TCA it is necessary to consider the relative properties of other gases at the temperature of LH_2 . The content of air (21% oxygen and 79% nitrogen) and helium gas are of particular importance. The following table shows the relative condensing and freezing points of these gases under standard pressure. (1 atmosphere = 14.7 psia.)

Table IV-1

<u>Gas</u>	<u>Boiling/Condensing Points</u>	<u>Melting/Freezing Points</u>
Oxygen	-297°F/163°R	-362°F/98°R
Nitrogen	-320°F/140°R	-346°F/114°R
Hydrogen	-423°F/34°R	-434°F/26°R
Helium	-452°F/8°R	-458°F/2°R
Absolute zero	-460°F/0°R	

(1) LH_2 -air. From the above table it can be determined that, at the temperature of LH_2 , both oxygen and nitrogen will not only become liquid but will also freeze. This actually occurs when LH_2 is exposed to air. Oxygen and nitrogen balls are formed in the LH_2 , and these balls create several potential hazards: they can physically interfere with the proper functioning of valves, vents, and filters; an impact explosion hazard may be caused by the sudden closing of valves, etc.

(2) GH_2 -air. An additional hazard exists when LH_2 is converted to GH_2 and the temperature rises above the boiling point of LOX. GH_2 , in combination with air or oxygen, creates combustion and explosive hazards. The difference between the combustion and explosive hazard is primarily the degree of confinement of the combination of gases. The greater the confinement, the greater the explosive hazard. The combustion limits of GH_2 in oxygen are from 4% to 94% by volume. The combustion limits of GH_2 in air are from 4% to 74% by volume.

(3) LH_2 -He. The above table indicates that helium gas is not effected at the temperature of LH_2 . For this reason helium gas is used both as an LH_2 purge and block and bleed system at TCA. In either of these uses helium is vented as a gas with no adverse effects to the LH_2 .

b. LH_2 as a propellant. The problems of handling and storing LH_2 are more than outweighed by its advantages as a propellant. These advantages include:

(1) Low liquid density. Low liquid density means low weight per volume. This is of particular importance in rocketry where highest payloads are desired. LH_2 weighs 4.43 lbs/cu ft compared with LOX which weighs 71.1 lbs/cu ft.

(2) Relatively high heat of vaporization. LH_2 at 193 btu/lb compared with LOX at 91 btu/lb. This makes LH_2 extremely useful as a heat exchanger to cool the reactor nozzle where the exit temperatures are in the thousands of degrees. Using LH_2 to cool the nozzle also helps to ensure that by the time it reaches the thrust chamber it is completely converted to GH_2 .

(3) High expansion factor. LH_2 has an expansion factor of up to 840 to 1 when converted to GH_2 . This is extremely useful where GH_2 is being converted from LH_2 for thrust purposes. A gallon of LH_2 equals about 105 cu ft of GH_2 at standard temperature and pressure (STP). The density of GH_2 is .005 lb/cu ft.

c. Hydrogen problems. The use of hydrogen either as a liquid or as a gas presents many problems for both personnel and equipment. Although these problems have been adequately solved at TCA, there is always the possibility that they might recur. Problems when working with hydrogen include the following:

(1) As a liquid - LH_2 .

(a) Extremely low temperature which requires special handling and corresponding precautions regarding exposure to personnel and materials. Perhaps the handiest and best remedy for personal exposure to LH_2 is the immediate use of plenty of water to the exposed body part. Water is also a rapid means of dissipating spilled LH_2 into GH_2 . The safety showers and water hoses are for that purpose.

(b) Low viscosity or viscous flow. The leakage rate of LH_2 is about 100 times that of JP-4 fuel, 50 times that of water, and 10 times that of LN_2 . This contributes greatly to porosity and connection problems when making repairs or modifications. Hydrogen leak checks are made regularly with a special detection device to ensure that leakage is kept to a minimum.

(c) High expansion factor. When LH_2 is exposed to ambient temperatures, a change of well over 500 degrees, it converts to GH_2 very rapidly. If this conversion takes place in a confined area there is great danger of both explosion and combustion. Precautions are taken throughout the cryogenic system to ensure adequate venting in the event it is needed.

(2) As a gas - GH_2 :

(a) Not humanly detectable. GH_2 is colorless, odorless, tasteless, and non-toxic at ambient temperature and pressure. This indicates that although it is not poisonous it still requires that extreme caution be used particularly in confined areas to prevent explosions or suffocation. GH_2 can only be detected with special detection devices.

(b) Highly flammable. GH_2 requires very low energy for ignition, roughly about one-tenth the energy required to ignite gasoline-air mixtures. Sufficient ignition energy can be produced by combing the hair, stroking a cat, or rubbing nylon or other synthetic materials on poor conductors. Extreme care must be exercised when using tools near GH_2 . Many precautions are taken during an exercise run to remove spark hazards from areas where GH_2 might become present. Special inerting with GN_2 is accomplished in the FCR with constant GH_2 monitoring during an exercise run. "No Smoking" regulations are rigidly enforced at TCA.

(c) Low viscosity. The leakage rate of GH_2 is about twice that of air. This contributes to porosity and connection problems particularly when making repairs or modifications. Hydrogen leak checks are made regularly with a special detection device to ensure that leakage is eliminated.

d. Source. Hydrogen is manufactured from petroleum products since only .0005% is contained in the atmosphere. The processes employed utilize the Joule - Thompson effect. LH_2 is received from Long Beach, Ontario, or Fontana, California by tank truck.

B. PHYSICAL DESCRIPTION

1. Dewar Fill Area. The dewar area is located at the east end of TCA. It includes the following:

a. Parking area. An area with outside access through two large gates in the perimeter fence. The fence-enclosed parking area contains:

(1) Lighting. Sufficient flood lights are available for night operation.

(2) Fire hydrants. Two fire hydrants are located on either side of the fill area. The hydrant on the east side is the one normally manned by the fire department standby crew during LH_2 fill operations.

(3) Safety shower. A safety shower is located between the east fire hydrant and the dewar fill station.

(4) Hydrogen alarm. A manually-operated, red-colored hydrogen alarm is located on a light pole on the southeast side of the parking area. This alarm is for use in the event of a hydrogen emergency. The alarm actuates the siren, sends the voice tape over the PA system, and rings an alarm in the fire station.

(5) Desert drain line. Pipe rollers are located along the north side of the parking area for use in the event a desert drain hookup is needed to empty the LH_2 dewars into the desert.

b. Dewar Fill Station. The dewar fill station is located at the north end of the dewar fill area. It is a concrete shed-like structure with the south end completely open to the parking area. The open end will accommodate two tankers, side by side, for simultaneous unloading. However, standard practice is to unload only one at a time. The dewar fill station contains:

(1) Dewar fill lines to dewars A & B, 1-1/2 inch diameter.

(a) Hand valves 133 and 134. Used to control the filling of either dewar A or B.

(b) LH_2 filter, F-1, with PI-35 to measure the ΔP across the filter.

(c) Helium lines. Used to maintain block and bleed in the fill lines through PCV 85, from valves 133 and 134 to OFV 33 and OFV 34. They are also used to purge the fill lines of LH_2 before and after loading.

(d) Vacuum and diffusion pump No. 6. Used to maintain vacuum in the vacuum-jacketed LH_2 lines from valves 133 and 134 to OFV 33 and OFV 34.

(e) Flexible fill line. Used to connect the truck tanker to valve 133 or 134. The ten foot flexible line has a sealed vacuum jacket and requires no vacuum pump connection.

(f) Instruments

1 Dewar level indicators. Indicate the LH_2 level in each dewar by percentage.

2 Dewar pressure indicators. Indicate the pressure in each of the dewars in psig.

(g) Fill valves OFV 33 and OFV 34 remote control box. Used to enable local control of these fill valves which can also be controlled from the Distribution Control Room (DBC).

(h) Vent lines and vent stack. Used to vent GH_2 and He to atmosphere during fill operations.

(2) Safety devices

(a) Fire extinguisher. For use in extinguishing electrical fires.

(b) Water hoses. The two hoses are used to flush the fill station area as required. Also used to dissipate small amounts of spilled LH_2 or the liquid air released by the truck tanker ambient vaporizer during fill operation.

(c) Heat Actuated Devices - HADs. Two HADs are located near the ceiling of the fill station to detect any sudden rise in temperature which would actuate the dewar deluge system.

(d) Sprinklers. The six sprinklers located near the ceiling are fusible plugged and require above ambient heat to melt. The sprinkler system is a dry system unless the dewar deluge system is operating. Therefore, in the event of a fire in the fill station the heat generator would necessarily have to actuate the HADs as well as melt the fusible plugs before the sprinklers would be effective.

(e) Grounding cable reels. Two reels one located on each side of the fill station are used to provide extended connection of ground buss to truck tankers during fill operation by means of clamps on the ends of the reel lines.

(f) Communications. There are three head phone jacks in the fill station and a PA speaker on the ceiling for communication purposes.

(g) Lighting. There are sufficient lighting facilities in the fill station to accomodate night time fill operations.

(h) Safety shower and fireman standby crew. Safety shower is located just outside the fill station.

(i) Hydrogen alarm box. (See paragraph 1a(4) above) For use in the event an LH_2 spill or leak gets beyond local control.

c. Dewar Storage Area. The dewar storage area includes the area around the dewars from the rear wall of the dewar fill station on the south, to the FCR wall on the north and from the reactor pad protection wall on the east, to the end of the concrete pad on the west. The inclusion of dewar C, presently being installed, will extend the western boundaries accordingly.

d. FCR. The flow control room might be considered as the focal point of the various systems required to perform the reactor test runs at TCA. The reactor cart interface is on the east wall. The reactor cart is attached and held to the interface by hydraulically operated bars.

2. LH₂ Flow System. The LH₂ flow system (refer to Fig. IV-1) extends from the dewars through the FCR to the reactor cart interface during non-operational periods, and through the interface into the reactor during reactor test run operations.

a. Dewars A and B. The two dewar systems may be considered to be identical. They are located in the dewar storage area. To increase the fuel capability at TCA, dewar C with a capacity of 100,000 gallons, is presently being constructed and will be located just west of the present dewars.

(1) Design.

The dewars were designed and constructed by the Southwest Welding and Manufacturing Division of Yuba Consolidated Industries, Incorporated. The dewars are cylindrically shaped although usually, for economic reasons, dewars of over 25,000 gallon capacity are spherically shaped. The spherically-shaped dewars provide less surface area exposure to heat radiation through the vacuum annular space.

(2) Capacity. Although the dewars have a total volume of 32,000 gallons each, the 100% full level of each is 28,000 gallons.

(3) Dimensions.

(a) Outer shell.

1 Length 58 feet - diameter 12-1/2 feet

2 Material - 7/16 inch and 3/8 inch head

(ASTM-SA-285C) carbon steel

3 Stiffeners at five foot intervals.

(b) Inner shell

1 Length 55-1/3 feet - diameter 10 feet

2 Material - 5/8 inch (ASTM-SA-240-S, Type 304, 0.5% carbon minimum) stainless steel

3 Design pressure is 116 psi from +100°F to -425°F

4 Supports within outer shell consists of one fixed and one sliding to compensate for differential thermal expansion.

(c) Vacuum annular space is 1-1/2 feet thick.

(4) Vacuum annular space. The dewar annular space is tightly packed with a finely ground volcanic ash called Perlite. A 51 foot filter is attached to the vacuum pump lines to retain the Perlite. The Perlite is an effective insulating substance. The dewar annular vacuum is normally maintained between 5 and 10 microns which gives a boil-off rate of .66% per 24 hours. Without Perlite the vacuum would have to be maintained at less than one micron to achieve the same boil-off rate. The vacuum annular spaces are protected against over-pressurization by three 6-inch spring-loaded relief valves atop each dewar.

(5) Inner space. The dewar inner space contains:

(a) A twelve point rake LH_2 level measure. The rake measures the level by capacitance between the points. Readouts are located in the dewar fill station, DBC and CP.

(b) Manhole and ladder. Used for personnel access into the inner space.

(c) Vortex eliminator. Used to prevent the LH_2 from eddying as it leaves the dewar. Eddying causes surface GH_2 to be drawn into the outlet line thereby creating a flow hazard through the turbopump.

b. LH_2 lines

(1) Main flow system

(a) Turbopump inlet lines. The eight-inch turbopump inlet lines may begin at either dewar A or dewar B depending upon which dewar is being used. LH_2 flow from the dewars is accomplished one dewar at a time due to the turbulence which would be created by differences in dewar levels and pressures. The turbopump inlet lines begin at either dewar A or B, run through either JBV-1 or JBV-2, through the junction to JBV-3, through JBV-3 to flow element FE -4, to the turbopump.

1 JBV-1 and JBV-2 are used to retain LH_2 in dewars.

2 JBV-3 is one of the major valves in the cryogenic system. Its primary purpose is to maintain He block and bleed downstream of JBV-1 and JBV-2. JBV-3 is located between the dewars and the FCR wall.

3 FE -4 is a venturi-type restrictor used to measure the LH_2 flow rate into the turbopump. The flow rate is determined by the ΔP across the element by means of PT-125. The element is located in the FCR just upstream of the turbopump.

(b) Turbopump. The present turbopump, located in the FCR, is a GH_2 turbine driven pump designed by Rocketdyne and referred to as the NFS-1, Nuclear Feed System - 1. The turbopump is electronically programmed and controlled to both meet the reactor flow requirements and to maintain the pump operation within its design limitations. The proper functioning of the turbopump is a key factor in the success of experimental reactor test runs and is covered in a separate section.

(c) Turbopump outlet line. The turbopump outlet line leads from the pump to a Y-duct where one line, a by-pass line, leads to the LH_2 by-pass valve, ACV-6, into a four inch non-jacketed line to the main flare stack. The other line leads to FE-7, to ACV-3, to mixing chamber OU-84, to F-39, through OBV-86 to the reactor.

1 ACV-6. The LH_2 by-pass valve is primarily to control the downstream impedance of the turbopump so that it appears as a constant value to the pump.

2 FE-7. A venturi-type restrictor used to measure the LH_2 flow rate out of the turbopump. The flow rate is determined by the ΔP across the element by means of PT-126. The element is located just upstream of ACV-3.

3 ACV-3. The turbopump output control is another of the turbopump control valves controlled at the CP during reactor test runs. Simultaneous control of valves ACV-3 and ACV-6 ensure the proper

functioning of the turbopump. Control of these valves is computed and programmed on a pump map which effectively controls the pump during operation.

4 Mixing chamber, OU-84. The mixing chamber is used for mixing LH_2 and GH_2 to provide GH_2 to the reactor at a higher temperature than LH_2 . The GH_2 used for the mixture is fed from the tank farm at ambient temperatures through PCV-41. The chamber is approximately nine feet high and five feet in diameter. It is not vacuum jacketed but is covered with fiberglass and foil. It contains two "rashig" rings which retain small aluminum pieces which are used to create turbulence and provide additional surface area for heat transfer to the LH_2 . At the bottom of the chamber there is a doughnut shaped ring approximately eight inches in sectional diameter and two feet in overall diameter with several spokelike connections into an eight inch pipe which comes up through the center into the main chamber. The LH_2 enters the doughnut shaped ring and flows through the spokelike ducts into the eight inch pipe which contains the GH_2 from the tank farm. The LH_2 and GH_2 enter the main chamber at approximately 800 to 900 psig. The GH_2 at ambient temperature (540°R) and the LH_2 at approximately 40°R , a differential of approximately 500°R . Control of valves ACV-3 and PCV-41 determine the temperature of the GH_2 leaving the chamber.

5 F-39. This filter is presently removed from the line due to excessive pressure drop across the filter during testing.

6 OBV-86 is the final valve in the LH_2 line upstream from the reactor. LH_2 line chill extends to this valve, prior to test run, by venting through AVV-11.

(2) Recycle system. The recycle system, presently not in use, affords a recirculation system to test the turbopump or any other portion of the flow system without the loss of LH_2 . The LH_2 may be pumped from one dewar to another by attaching the connecting spool to the main flow line downstream of ACV-3. The recycle system lines begin at the top of each dewar to JBV-7 and JBV-8, through junction to ACV-4 to the flange at the connection end of the line.

(a) JBV-7 and JBV-8 retain GH_2 at top of dewars A and B.

(b) ACV-4 is the pump output control valve during recycle system operation. During non-operational periods ACV-4 remains open.

3. Helium Block and Bleed System. The empty LH_2 lines which, during static conditions, could be filled with LH_2 or GH_2 from leaking valves are protected by a helium block and bleed system which is pressurized from 20 to 30 psig. The helium is supplied from tank farm bank No. 2A with a water volume of 690 cu ft and a helium volume of 157,000 SCF at 3500 psig. The helium is fed through the three-inch He process gas head to the FCR, dewar storage area, and dewar fill area. The helium is also used to purge LH_2 , GH_2 , or air from the LH_2 system as required.

a. Helium to FCR:

(1) Reactor shroud purge through PCV-40

(2) Reactor purge through PCV-39

b. Helium to dewar storage area: (through PCV-54 and PCV-33)

(1) Recycle system lines through PCV-34

(2) JBV-3 to JBV-1 and JBV-2 through PCV-35

c. Helium to dewar fill station through PCV-85

4. Vacuum system. The vacuum system of the cryogenics system is divided into two major areas, the dewar annular spaces and the LH_2 vacuum jacketed lines. It has no direct operational role in the cryogenic system operations during reactor test runs. Its primary function is to maintain the necessary vacuum to ensure minimum heat transfer to the LH_2 storage areas and lines. Vacuum is maintained in the dewar annular spaces and LH_2 line vacuum jackets at all times. The vacuum system is covered in a separate section.

5. Controls. Controls of the cryogenic system are operated locally, in the DBC and at the CP.

a. Local. The local controls at TCA are primarily to validate valve and component readiness prior to switching to REMOTE-FWD control. The validity of valve and component operation is a very important pre-run requirement. Operational checking is usually made with the assistance of a checklist to ensure complete coverage of components.

b. DBC. The DBC control panels are primarily to enable remote checkouts of the remotely controlled valves and functions prior to switching to REMOTE. The DBC is located at the south end of TCA just inside and to the right of the main gate. The remote checkouts can be made in the TCA area without reference to the CP controls. All of the FWD controls at the DBC are also controlled at the CP. After all checkouts have been completed at the DBC the key switches are moved from FWD to REMOTE which transfers control to the CP.

c. CP. The Control Point is the central control station for all reactor test operations at TCA and TCC. It is located approximately two miles south of TCA. Control at the CP is not effected until all LOCAL and FWD checklists have been completed and key switches moved to REMOTE. Upon completion of the reactor test run and the necessary post run safety requirements, control is switched back to FWD at the DBC.

C. FUNCTIONAL DESCRIPTION

1. System Engineer. The effectiveness of a system is directly dependent upon the ability of the system engineer. He is directly responsible for the operational, maintenance, safety, and quality control processes required by his system. He is also responsible for the proper utilization of all personnel required to assist him in these responsibilities. These duties are described in detail in the TCA Functions and Operations Section.

2. Static Condition. During non-operational periods, the cryogenic system requires very little daily attention except to check the vacuum readings, block and bleed pressures, dewar pressures and venting, and to ensure that valve positions are maintained.

a. Vacuum.

(1) Vacuum jackets. The vacuum pumps to the vacuum jackets are run continuously to maintain the vacuum below one micron.

(2) Dewar annular spaces. The vacuum pumps to the dewar annular spaces are run as necessary to maintain the vacuum between 5 and 10 microns.

b. Block and bleed. The helium block and bleed pressure of 20 to 30 psig, is used primarily to prevent LH_2 and GH_2 from leaking into the empty LH_2 lines. During static conditions, the LH_2 in the dewars is contained within valves OFV-33, OFV-34, JBV-1, and JBV-2 at a pressure of 5 to 7 psig. GH_2 at the top of the dewars is contained within valves JBV-7 and JBV-8. Should any of these valves develop a leak, the helium pressure being greater than the dewar pressure would cause the helium pressure to override the dewar pressure, thereby retaining LH_2 or GH_2 within the dewars. The helium which would leak into the dewars would be vented through the dewar vents. Leakage is monitored by observing the helium block and bleed pressures. The block and bleed also keeps air out of the empty LH_2 lines. The block and bleed is contained in the following lines from valves:

- (1) 133 and 134 to OFV-33 and OFV-34.
- (2) JBV-1 and JBV-2 and JBV-3.
- (3) JBV-7 and JBV-8 to flange at end of line.

c. Dewar pressure and venting. Dewar pressure is monitored by readouts in the dewar fill station and DBC. The venting is through clapper valves on top of the dewars.

d. Valve positions. All valves are closed except:

- (1) OBV-38 and OBV-39, the dewar vent valves.
- (2) AVV-2 to allow venting to main flare stack in event of JBV-3 leakage.

3. Dewar Filling. The dewars are filled from truck tankers at the dewar fill station. The LH_2 is shipped from Long Beach, Ontario, or Fontana, California. Government specification requires LH_2 purity of 92 percent. The vendor's specification is 99.9998 percent or 2 parts per million.

a. Truck tankers. The truck tankers are 8,000 and 12,000 gallons capacities with self contained vacuum systems. The tanker is maintained at approximately five psig during transit to keep air from the LH_2 . The truck tankers usually have the following:

(1) Ambient vaporizer. A manually operated unit which is used to pressurize the tanker by flowing LH_2 through ambient temperature coils thereby causing LH_2 to vaporize.

(2) Pressure gage. The readout of the tanker pressure in psig.

(3) LH_2 level gage. The readout of the level of LH_2 in gallons.

(4) Tanker vent valves. Used to maintain the desired pressure within the tanker.

(5) Tanker discharge valve. Used to manually control the LH_2 from the tanker.

(6) Discharge vent valve. Used to manually control venting downstream of the discharge valve during purge of the fill line.

b. Dewar fill operation. The dewar fill operation is normally performed by the cryogenic technicians. Firemen crews are on standby with fire hoses.

(1) Hookup. The truck tanker is backed up to the fill station in proper position. The ground cable is clipped to the truck chassis. The flexible fill line is secured to the tanker discharge connection and dewar fill line valve 133 or 134.

(2) Fill line purge. Valve 133 or 134 is opened allowing the helium block and bleed to purge the flexible fill line through the tanker discharge vent valve.

(3) Tanker pressurization. The tanker is pressurized to 20 psig, by means of the ambient vaporizer.

(4) LH_2 transfer. The LH_2 is forced from the tanker into the dewar being filled through either OFV-33 or OFV-34 which is opened remotely from the dewar fill station. Dewars vent through normal vents OBV-38 and OBV-39.

(5) Post fill. The tanker discharge valve and OFV-33 or OFV-34 are closed. The fill line and the flexible line are helium purged through the tanker discharge vent valve. Valve 133 or 134 is closed and the flexible line disconnected. The tanker is secured, the ground cable removed, and the tanker moved away and vented down to transit pressure. The LH_2 fill line from 133 or 134 to OFV-33 or OFV-34 is vented again through the fill station vent to atmosphere. The line is then pressurized with block and bleed.

4. Filling a Warm Dewar. This procedure required for initial fill or after repairs have been made. The dewar must be thoroughly cleaned before being filled. Filling a warm dewar requires 8 hours or more.

a. Dewar purge. The dewar is purged of all air with GN_2 until 100 percent GH_2 is attained. This is determined by sampling with a Hoke-bottle which is taken to the ETL for analysis. The dewar is then purged of GN_2 with GH_2 until 100 percent GH_2 is attained. The Hoke-bottle is also used for sampling this purge.

b. Dewar chilldown. The dewar must be chilled down to LH_2 temperature. This is done by a normal fill operation requiring approximately 4,000 gallons of LH_2 and several hours. Boil off venting is to atmosphere through OBV-38 or OBV-39.

c. Dewar fill. Normal fill operations are continued until dewar is at desired level. The normal post fill securing is required.

5. Dewar Emptying and Warmup. This procedure is required when it is necessary to remove contamination or to make repairs within the dewar. In the event of suspected LH_2 contamination with O_2 , continuous sampling is required during warmup due to explosive hazard. The warmup requires several days.

a. Dewar emptying. Transfer of LH_2 from the dewar can be accomplished by either of several methods.

(1) Dewar to dewar. This type of transfer can be accomplished by pressurizing the dewar to be emptied with GH_2 through PCV-33, through OBV-36 or OBV-37. JBV-1 and JBV-2 are opened and LH_2 transferred. Venting is through JBV-5 or JBV-6 to the main flare stack.

(2) Dewar to tanker. This can be accomplished by reversing the dewar fill operation. Filter, F-1, is not bypassed in this operation. Any matter in the filter would be transferred to the tanker.

(3) Dewar to desert. The dumping of LH_2 into the desert is done only when the LH_2 is sufficiently contaminated to be of no further use. It is accomplished by attaching an 1-1/2-inch copper line from the dewar fill valve to the desert drain pipe across the road, south of the tanker parking area. Filter F-1 is removed for this operation.

b. Breaking dewar vacuum. Breaking the vacuum in the dewar annular space hastens the warmup process of the dewar inner space. The annular space is pressurized to an absolute maximum of 15 psia with GN_2 . The GN_2 condenses on the inner wall giving up heat in the process.

c. Dewar warmup. Warmup of the empty dewar space is a slow process and may take as long as two days. A temperature rise is on the order of over 500°F .

(1) Helium purge. The empty dewar is first purged with helium until the temperature readout in the DBC rises above -320°F , the condensing point of GN_2 . If conservation of helium is desired it can be removed with a vacuum pump. In this instance the dewar annular vacuum space is not broken and GN_2 pressurized due to a possible explosion hazard to the dewar. Otherwise the helium is vented.

(2) GN_2 purge. The inner space is then purged with GN_2 until the content is 100 percent GN_2 and the temperature is above -297°F , the condensing point of oxygen.

(3) Ambient air. After the temperature has risen above -297°F , usually to -200°F , the dewar manhole cover is removed to allow ambient air to enter. Sometimes a portable fan is used to assist in the entry of air and warmup process. The warmup and airing process is continued until the dewar reaches ambient temperature and the oxygen content within the dewar is above 18 percent.

d. Personnel entry. Personnel entering the dewar are required to wear Scott air packs, special clothing, and other safety gear including an attached rope with the other end kept outside the dewar. A fireman standby crew is present while personnel are in the dewar. After the necessary work has been completed the dewar is returned to service by the warm dewar fill operation.

6. Test Run Preparation. Routine maintenance and necessary modifications are accomplished during non-operation periods. Each test run usually requires specific modifications and preparations which must be accomplished before Run Day. Desired supply of gases and LH_2 for the test run must also be obtained. Final pre-test run systems checkout usually begins two days prior to Run Day in the sequence of R-2, R-1, and Run Day.

a. Checklists. Checklists are detailed lists of specific components and functions to be individually checked in the preparation and execution of a reactor test run. Each reactor test run has specific checklists prepared for that run. Those checklists must be prepared, verified,

and approved prior to R-2 Day. Once approval has been made, any changes to the checklist must also be approved. A very large portion of the activities during reactor test run preparations and execution is controlled directly by checklists. The cryogenic system reactor test run checklists are prepared by the cryogenic system engineer at such time to complete preparation, verification, and approval before R-2 Day. The engineer will also ensure that his system is safe and free from component failures and ready to perform its function by R-2 Day. This requires individual inspection of any replacements, repairs, or modifications performed since the last reactor test run. A typical system checklist contains 13 sections. CP permission must be requested and received before each section of the checklist can be executed. The CP must also be notified upon the completion of each checklist section.

b. R-2 Day. Beginning on R-2 Day, and continuing throughout Run Day, access to TCA is restricted to only those persons having need to be there and these individuals are listed and monitored by a gate guard. During the actual test run the guards are restationed at a safe distance from TCA until the run has been completed at which time they return as gate guards until TCA has been returned to normal status.

Beginning very early on R-2 Day until the system has been secured on Run Day, the system engineer is available on immediate call status. R-2 Day activities are normally confined to the execution of the following sections of the cryogenic system checklist:

(1) Section 1, Dewar Area Safety Check - A check of the dewar area to verify the status of:

- (a) Valve positions.
- (b) He block and bleed pressures and content.
- (c) Main flare stack content.
- (d) Block valve installations.
- (e) PCV settings

(f) K-bottle pressures

(2) Section 2, DBV Valve Operation and Safety Check - A check of the DBC to verify the status of:

- (a) MCS functioning.
- (b) Remotely operated valve functioning.
- (c) Oxygen analyzer at main flare stack.
- (d) Hydrogen analyzer.
- (e) He block and bleed pressure.
- (f) Dewar pressurization.

c. R-1 Day. The cryogenic system activity on R-1 could include the correction of any deficiencies found on R-2 or R-1 in addition to the execution of the following sections of the cryogenic system checklists:

(1) Section 3, DBC Safety Check - A check of the DBC to verify the status of:

- (a) Remotely operated valve positions and power
- (b) MCS positions
- (c) Weigh system
- (d) Oxygen analyzer at main flare stack
- (e) Hydrogen analyzer
- (f) He block and bleed pressures

(2) Section 4, Dewar Area Safety Check and Set-up - A check to verify the status of:

- (a) Valve positions
- (b) He block and bleed pressures and content
- (c) Main flare stack content
- (d) Block valve installations

- (e) PCV settings
- (f) Power to remotely controlled valves

(3) Section 5, FCR Safety Check and Low Pressure Helium Shutdown - A check to verify the status of:

- (a) Valve positions
- (b) Fan switch settings
- (c) PCV setting

(4) Section 6, Switch Control to REMOTE - A check in the DBC to verify the status of:

- (a) MCS positions
- (b) Other switch positions

(5) Section 7, Switch Control to Local and Secure - A check to verify the status of:

- (a) MCS positions
- (b) Other switch positions
- (c) Main flare stack content
- (d) Valve positions
- (e) Helium supply to dewar area
- (f) Helium block and bleed pressures and content

d. Run Day. The cryogenic system activity on Run Day could include the correction of any deficiencies found on R-1 or Run Day in addition to the execution of the following sections of the cryogenic system checklist:

(1) Section 8, DBC Safety Check - A check to verify the status of:

- (a) Valve switch positions
- (b) MCS positions and key removals

- (c) Weigh system
- (d) Oxygen analyzer at main flare stack
- (e) Hydrogen analyzer

(2) Section 9, Dewar Area Safety Check and Set-up - A check to verify the status of:

- (a) Cryogenic line content
- (b) Valve positions
- (c) Helium block and bleed pressures
- (d) Main flare stack content
- (e) Block valve installations
- (f) PCV settings
- (g) Oxygen analyzer at main flare stack
- (h) Remotely controlled valve positions and power
- (i) Acetylene supply to main flare stack
- (j) Vent valve functions

(3) Section 10, Cryogenic Line and Mixing Chamber Purge - A check to verify the status of:

- (a) Helium purge pressure at TF
- (b) Valve positions
- (c) BV removals
- (d) Helium purge of lines
- (e) Helium purged line contents
- (f) Oxygen and helium content of main flare stack
- (g) Helium block and bleed of LH_2 fill line

(4) Section 11, FCR Set-up and Low Pressure Helium Shutdown - A check to verify the status of:

- (a) Securing of vacuum pumps and valves
- (b) Closing of helium system to dewar area
- (c) Closing of GN_2 header in TF
- (d) Opening of acetylene header to 50 percent flow rate
- (e) Opening of He header in TF
- (f) K-bottle pressure to PCV's on GN_2 header
- (g) GN_2 inerting PCV's adjusted
- (h) Air pressure PCV adjusted
- (i) Fan switches properly positioned
- (j) Louver air pressure set
- (k) Reactor He purge line readied
- (l) Reactor shroud purge line opened
- (m) Doors to FCR, ELR, and penthouse sealed

(5) Section 12, Switch Control to REMOTE - A check to verify the status of:

- (a) MCS positions
- (b) Other switch positions

(6) Reactor Test Run Operation. Each reactor test run is designed to develop data pertinent to eventual completion of a successful nuclear rocket propulsion system. Therefore, no two reactor test runs are exactly alike. However, there are standardized processes that are required regardless of the test run objectives. When all TCA system checklists have been completed, the remoting team moves to the CP for standby duty during the actual test run. The remainder of the test run preparations, the test run itself and the initial post operational shutdown processes are controlled from the CP. The generalized processes include:

(a) Pre-operational phase - During this phase the control valves and control system are switched to CP control. The control room communications net is checked. The gas hand valves are opened and the bleeds closed. The FCR and privy are inerted. All valves which will be used in the test run are exercised except those which would release high pressure gas or LH_2 . The propellant flare is checked and the reactor coolant water system started. The manual control rod pins are unlocked and the rods switched to CP control.

(b) Flow shutdown and scram check phase - During this phase, flow shutdown and scram circuits are checked.

(c) Header pressurization, line chilldown, and neutronic calibration phase - During this phase the headers will be pressurized, the LH_2 lines chilled, and the neutronic calibration checked.

(d) Reactor power run phase - During this phase the reactor test run objectives are attempted. Additional phases may be used to accomplish the objectives. Reactor shutdown and a voltage calibration are included in this phase.

(e) LH_2 removal and header depressurization phase - During this phase LH_2 is removed from the LH_2 lines and the headers and lines are bled down.

(f) Shutdown phase - During this phase rod locking is performed and the systems switched to FORWARD control.

(7) Section 13. Switch Control to LOCAL and Secure - Performed after the remoting team has returned to TCA - A check to verify that:

- (a) Fans running and louvers opened in DBC
- (b) DBC MCS's switched from REMOTE
- (c) Other switches transferred from CP control
- (d) FCR doors opened and oxygen content 21 percent
- (e) Vacuum pumps and valves turned on

stack

(f) Oxygen analyzer operating in FCR and main flare

(g) TF process gas system is at low pressure

(h) FCR GN₂ inerting valves closed

(i) Instrument air line valves closed

(j) Helium purge line valves closed

(k) Helium header valves opened to dewar area

dewar area

(l) Helium block and bleed system re-established to

(m) LH₂ line venting valves closed

(n) LH₂ line valves returned to static positions

(o) GH₂ line to mixing chamber closed

(p) Power is removed from remotely controlled valves

(q) Dewar venting valves returned to static positions

(r) Main flare stack purged of oxygen and hydrogen

(s) Main flare stack purge valves closed

LH₂ CRYOGENIC SYSTEM
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FIGURE IV 1
03 0716-U 20

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STUDY GUIDE - SECTION V

TURBOPUMP

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STUDY GUIDE - SECTION V

TURBOPUMPA. GENERAL

1. Introduction. In order to achieve a general familiarization of the turbopump at Test Cell "A" (TCA) and its relationship to the system, the material presented here will cover only the major facets of the turbopump. In the NERVA engine, the present design concept utilizes a turbopump as a major component in the propellant feed system to transfer liquid hydrogen from the tankage to the reactor section. At TCA, one of the most important parts of the cryogenic system is the Rocketdyne turbopump, designated as "Nuclear Feed System No. 1 (NFS-1)".

The term "Turbopump" is a combination of "turbine" and "pump", meaning that a pump is coupled directly to a driving turbine.

The present configuration of NFS-1 is a result of a seven year development program, and is very similar in operation to the more advanced systems forthcoming at NRDS.

The history of the development, the names and the relationships of the Nuclear Feed Systems are shown in figure V-1.

The basic principles of this turbopump apply also to the operations of any similar system, especially the actual flight hardware.

2. Terms.

a. Specific speed may be defined as an expression for the relationship between important parameters of both pumps and turbines; this

discussion concerns the LH_2 pump.

The parameters are as follows:

- (1) Volumetric flow rate (Q) in gallons per minute.
- (2) Head (H) in feet.
- (3) Rotational speed (N) in revolutions per minute.

The expression "Specific Speed" (N_s) is $N_s = \frac{N \sqrt{Q}}{H^{3/4}}$ (Dimensionless)

When head (H) is compared to the flow rate (Q) graphically at various rotational speeds, the points where the similar fluid flow conditions exist describe a parabolic curve, which is a line of constant pump efficiency. A typical family of curves is shown in Figure V-2 which is called a pump map.

H is proportional to the pump discharge pressure and Q is proportional to the mass flow rate (W). Therefore, pressure (psi) and mass flow rate (lbs. per sec) are shown on the axes of the pump map.

At the Test Cell A control room, the specific speeds are recorded on a chart which is the pump map for that particular pump in use at TCA. The recorder is called an X-Y plotter. The plotter provides a visual indication and a record of the range in which the pump is operating.

Notice the regions on the pump map at low and high specific speeds. Pump operation in these areas is not practical because the phenomena that occur would damage the pump.

b. Cavitation exists above a maximum specific speed for the pump. It exists at low discharge pressure and high flow rates, when the pressure of the liquid in the pump drops below the vapor pressure of the liquid. Vapor pressure is that pressure exerted by vapor molecules (gas) at that particular temperature. If the pressure of the liquid in the pump is maintained above the vapor pressure of liquid hydrogen, the formation of vapor bubbles is prevented. This pressure relationship between the pressure is referred to as

- (1) Net Positive Suction Head (NPSH), or

(2) Net Inlet Head (H_{sv}), or $H_{sv} = (\text{inlet head} + \text{velocity head}) - (\text{vapor pressure})$, and in order to prevent cavitation, this value of H_{sv} must remain positive.

Cavitation of a pump can be compared to a "vapor lock", which is a partial or complete interruption of fuel flow for an internal combustion engine caused by the formation of bubbles of vapor or gas in the fuel feed system.

Liquid hydrogen boils at 37°R at 1 atmosphere pressure (14.7 psia).

Raising the pressure raises its boiling point and thereby helps prevent cavitation. This is accomplished in two ways.

(1) The Dewars are pressurized to approximately 60 psig, thus subcooling the liquid.

(2) As the LH_2 passes through the pump, there is an increase in head.

As the liquid flashes to a vapor it is said to "unload". Operating under cavitating conditions (low pressure, high flow rate), the pump unloads one stage at a time, and its acceleration is relatively low. However, continued operation in the cavitation region could result in damage to both the turbine and pump. Prevention of cavitation under run conditions is accomplished, by increasing the pressure on the fluid in the pump by slightly closing ACV-3, which causes an increase in back pressure.

c. Stall exists below a minimum specific speed. It exists at low flow rates and high outlet pressures where the energy imparted to the liquid hydrogen by the impeller blades cannot be utilized in the form of motion (Kinetic energy), but instead is converted to heat energy by fluid friction.

A possible misconception of "pump stall" might be that the pump slows down, as does an automobile engine when it "stalls" or stops from overloading. This is not the case for pump stall. As the liquid hydrogen

absorbs more energy, the temperature rises.

If the pump is operated in the stall region too long, the pump is then in "deep stall", where the liquid temperature rises to the critical point and it is transformed to vapor or gas - then the pump unloads; and in this case all stages unload at once, permitting the impeller speed to increase rapidly. This overspeed occurs during stall conditions at a rate of 100 rpm per millisecond (1/1000 sec.). The destruction speed of the pump is 40,000 rpm. Therefore, it would take only 160 milliseconds to reach destruction if the pump had been operating at design speed (24,000 rpm).

To prevent stall, the discharge output impedance (outlet pressure) is changed by opening slightly ACV-6. This allows LH₂ to flow to the flare stack, thereby reducing the impedance of the pump output.

The stall region is not sharply defined as a line, but rather is a narrow band that exists when the foregoing conditions are met. The main requisite for operation is to not remain in the stall region for very long.

B. PHYSICAL DESCRIPTION

1. System Function. The purpose of the turbopump at TCA is to transfer the propellant liquid hydrogen from the Dewars to the reactor through the cryogenic system. (Refer to Fig. V-3 and Fig. V-4.)

The turbopump consists of three major sub-assemblies. These are the Turbine Assembly (Mark III), the pump (Mark IX-A) and the torquemeter assembly.

2. System Components.

a. Pump. The pump is an axial-flow type, with six stages and one inducer stage. The inducer blading resembles an auger. Each pumping stage has a rotor and a stator. A "balance piston" performs as a spring to counter-balance the axial thrust developed by the rotor while pumping.

This "spring" action is accomplished because balance piston functions as a differential area piston, controlling two variable orifice areas located in the front and rear faces of the piston.

The pressure head rise across each stage of the pump is the same, but the rise across the inducer stage is somewhat greater than that of any stage.

The pump bearings are lubricated with liquid hydrogen; the front one by LH_2 circulated through due to the pressure differential between the inducer and the first stage. The rear bearing is lubricated by bleeding off LH_2 and then venting it to the atmosphere.

The LH_2 enters the pump at approximately 60 psig (This pressure is obtained by the pressurization of the dewars with gaseous hydrogen). The output pressure and flow rate are parameters determined for each experiment and vary with the power level requirement for the reactor during the test. The pump is capable of NERVA design requirements.

The pump is operated at essentially constant rpm, and the adjustments in the flow rate and pressure are made by varying the specific speed (N_s). This is done primarily by ACV-6 which changes the downstream impedance.

b. Turbine. A turbine is basically a pump that is being driven backwards. The NFS-1 turbine originally was designed for a hot gas drive, but was re-designed for use at TCA using gaseous hydrogen at ambient temperature from the tank farm.

The turbine is a two-stage impulse type. Its design points are these:

Torque	=	12,000 in-lbs.
Power	=	4,000 HP
GH_2 Flow	=	6.3 lbs/sec
Speed	=	23,400 rpm

The gaseous hydrogen enters the turbine at approximately 500 psig at ambient temperature and is expanded through the turbine to 45 or 50 psig at -100°F , then exhausted to the flare stack.

The rotational speed of the turbine is controlled by the use of PCV-50.

c. Torque Meter. The torque meter is an assembly used for the transmission of power from the turbine to the pump. It performs two additional functions; one is to provide a tachometer and the other is to measure the angle of twist of the torque shaft, which in turn is related to horsepower. A 60 tooth counting gear is located at each end of the shaft; three magnetic pick-up heads are positioned around one gear and one head over the other gear at the other end. Two of the three-head cluster are used for speed pickup, while the other pick-up head is used in conjunction with the single one at the other end for the determination of twist angle.

One other important feature of the torque meter assembly is that it provides a signal to the overspeed trip device. When the pump speed reaches a pre-set limit, this device actuates the heavy-duty hydraulic actuator of PCV-50 and shuts off the GH_2 flow in 25 to 30 milliseconds.

d. Oil Lubrication System. The oil lubrication provision for the turbopump is a self-contained, recirculating system. This lubricates only the torque meter assembly and the turbine. The oil is circulated by a small vane-type pump, and the storage tank is located on the floor at the west end of the turbopump.

e. Pump Latch. (Electrical Solenoid-operated brake) The pump latch is located on the torque meter assembly and is basically a pin device to provide the CP with a positive indication regarding the rotation of the pump. This latch is not meant to stop the pump once it has begun to rotate. The pin device is held disengaged by spring pressure while the pump is rotating. A solenoid engages the pin device between adjacent gear teeth in the torque meter assembly and requires power to remain engaged, thus

indicating position to the CP. Therefore, between runs, when the latch is not actuated and to prevent accidental rotation of the turbine or pump, a mechanical brake is used to lock the turbopump in a stationary condition. This brake is merely a long bar clamped around the splined shaft perpendicular to its centerline between the torque meter and the pump. The two ends of the bar extend over the turbopump frame, and act as a fixed crank arm to prevent the shaft from turning.

On run day, the mechanical brake is removed and the pump latch actuated. The pump latch remains engaged until released remotely from the CP to proceed with the operation.

After a run, and after the pump has been determined to be no longer rotating, the pump latch is again engaged to prevent rotation of the pump while it is being purged.

f. Valves

(1) ACV-6. The primary purpose of this valve is to cause the downstream impedance of the discharge line to appear as a constant value to the pump. This is important in preventing stall.

(2) ACV-3. The primary purpose of this valve is to control the flow rate. This may be programmed slightly closed to increase the back pressure and preventing cavitation. This valve is hydraulically operated by a Moog servo valve and was designed by Rocketdyne.

(3) PCV-50. This is gaseous hydrogen control valve for the turbine. It is a 3-inch Annin valve with a linear characteristic plug. PCV-50 is actuated by either of two servo valves. One servo is used for normal operation and the other is the heavy-duty servo valve used for fast turbine shutdown on a signal from the overspeed trip device.

(4) Valve 585. This is the pump bearing vent valve which is hand operated. This valve closes the bearing vent to maintain cryogenic line purge. It is important that this valve be opened before the pump is operated in order to provide the rear bearing with LH_2 for lubrication and cooling.

3. Instrumentation.

The turbopump and related components are highly instrumented to assure the proper control over its operation, since the turbopump is one of the most important components at Test Cell A.

The following is a list of pressure instrumentation.

- a. Pump inlet
- b. Pump outlet
- c. Stator discharge (pump)
- d. Balance piston sump
- e. Shaft seal drain
- f. Lube oil
- g. Hydraulic actuator inlet (PCV-50)
- h. Pressure drop, hydraulic actuator (PCV-50)
- i. Hydraulic actuator inlet (ACV-6)
- j. Pressure drop, hydraulic actuator (ACV-6)
- k. Turbine inlet.
- l. Turbine outlet.

The temperatures are monitored at these probe locations:

- a. Pump inlet
- b. Pump discharge.
- c. Turbine inlet.
- d. Turbine discharge.
- e. Balance piston return.
- f. Lube oil.
- g. ACV-6 flare line (2).
- h. Turbine bearings.
- i. Pump bearing.

C. FUNCTIONAL DESCRIPTION

1. Duties and Responsibilities of the System Engineer.

These duties have been outlined previously in the TCA Functions and Operations Section. The responsibility for the turbopump belongs to the cryogenic system engineer.

2. Operational Methods

a. Static Condition. During static conditions the turbopump is not disturbed, the pump latch is disengaged and the mechanical brake prevents it from rotation. The pump side has been vented and exists at atmospheric conditions. The turbine side is also vented to atmosphere.

b. Operations. For operation, the pump side is purged with helium and the turbine side purged with nitrogen. Then the cryogenic line is opened to allow pressurized LH_2 to flow and chill down the line. The pump latch is energized until a "soft" chill is obtained; then it is released. During hard chill, the pump is free to rotate and windmills at 4000 rpm with about 12 lbs/sec flow. The pump programmed from the CP for the particular test run requirements by the application of power from the turbine.

c. Test run preparation. Routine maintenance and necessary activities are carried out during the non-operational periods. Final pre-test run checkout usually begins two days prior to Run Day. Various operations are carried out for R-2, R-1 and Run Day. These operations are performed in accordance with a check list prepared by the cryogenic systems engineer and approved by the Test Cell Manager.

A Safety and Operational check list specifically for the turbopump is issued for each run, depending on the requirements. However, the check lists for the turbopump do not vary to any great degree from run to run.

The check list consists usually of six sections, and contains these items:

- (1) Section 1. Safety and Operational Check, R-2.
 - (a) Check pump latch
 - (b) Check oil level
 - (c) Check oil pressure
- (2) Section 2. Safety and Operational Check R-1.

Same as above
- (3) Section 3. Safety and Operational Check Run Day

Same as above
- (4) Remove Mechanical Brake - Run Day
 - (a) Check that pump latch engaged
 - (b) Remove mechanical brake
- (5) Local to Remote - Run Day
 - (a) Change lube oil pump switch from remote - local to CP control.
 - (b) Open valve 585
 - (c) Check that pump latch is engaged
- (6) Secure - Run Day
 - (a) Check that pump latch is engaged and install mechanical brake.
 - (b) Release pump latch
 - (c) Close bearing drain vent (585)
 - (d) Change lube oil pump switch from CP to local control.

HISTORY TURBOPUMP DEVELOPMENT
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FIGURE V -1
03-0716-U-24

TYPICAL PUMP MAP CONFIGURATION
FOR TRAINING USE ONLY

FIGURE V-2

03-0716-U-25

LH₂ PUMP MK IX-A
(FOR TRAINING USE ONLY)

FIGURE V-4
03-0716-U-27

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CRYOGENIC VACUUM SYSTEM

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CRYOGENIC VACUUM SYSTEMA. GENERAL

1. Purpose. The purpose of the vacuum system is to protect the cryogenic system from ambient temperature thermal radiation. This is accomplished by means of vacuum jackets around the LH_2 lines and annular spaces around the dewars. The thermal radiation is minimized through vacuum because of the small amount of matter present in the vacuum. The less matter, the less media for thermal radiation transfer.

2. Vacuum Measurement. Vacuum, or partial vacuum, is considered to be a space containing less matter, gas molecules, than are present in the atmosphere. Like atmospheric pressure, vacuum is measured with mercury. Atmospheric pressure at sea level will cause mercury to rise 29.92 inches in a tube which has been filled with, and inverted in, mercury. Vacuum is normally measured by the metric system. One atmosphere, 29.92 inches, equals 760 mm. (One meter equals 39.37 inches). The metric measurement of vacuum as it nears an absolute vacuum, 0.000 mm of mercury, necessitates a smaller unit of measure which is microns, 10^{-3} mm, of mercury. One pound pressure equals 50,000 microns. Vacuum measurement instrumentation is usually accomplished electronically. Vacuum measurement at TCA is indicated on gages in ranges of 10^{-3} , 10^{-4} , 10^{-5} , etc.

B. PHYSICAL DESCRIPTION

1. General. The vacuum system consists of six vacuum pumps, inter-connecting lines, valves, instrumentation, LH_2 line vacuum jackets, and LH_2 dewar annular spaces.

2. Vacuum Pumps. Each vacuum pump includes a vacuum gage, vacuum shutoff valves, and connecting lines.

a. Pump No. 1. Evacuates the vacuum jackets of the LH_2 line downstream from the turbopump to the end of the vacuum jacket.

b. Pump No. 2. Evacuates the vacuum jackets of the LH_2 line downstream from JBV-3 to the turbopump.

c. Pump No. 3. Evacuates the vacuum jackets of the LH_2 line downstream from the dewars to JBV-3 and the recycle lines from the dewars to the flange at the end of the line.

d. Manifolding. Pumps No. 1, No. 2, and No. 3 can be manifolded together to evacuate all vacuum jackets of the LH_2 lines downstream from the dewars simultaneously.

e. Pump No. 4. Evacuates dewar A annular space.

f. Pump No. 5. Evacuates dewar B annular space.

g. Pump No. 6. Evacuates the vacuum jackets of the LH_2 lines from hand fill valves 133 and 134 to fill valves OFV-33 and OFV-34.

3. Vacuum Jackets. The vacuum jackets are irregularly sectionalized due to construction requirements. The lines connecting vacuum pumps with vacuum jackets are flexible lines. Each vacuum jacket pump consists of a roughing pump and a diffusion pump which are necessary to maintain the vacuum in the vacuum jackets below one micron of mercury.

4. Dewar Annular Spaces. The dewar annular spaces are tightly packed with a finely ground volcanic ash called Perlite. A 51 foot filter is attached to each vacuum pump line to retain the Perlite. The Perlite is an effective insulating substance. The dewar annular vacuum is normally maintained

between 5 and 10 microns which gives a boil-off rate of .66% per 24 hours. Without Perlite the vacuum would have to be maintained at less than one micron to achieve the same boil-off rate. The annular spaces are protected against over pressurization by three 6-inch spring-loaded relief valves atop each dewar.

5. Roughing Pumps. The vacuum roughing pumps, Welsh Duo-Seal Pumps, Mod. 1403 D, consist of a stationary stator containing an eccentric rotor with vanes which compress the molecules and force them to vent to atmosphere. The roughing pumps rotate at 375 rpm with a pump rate of 100 liters, (3 cu. ft.) per minute at atmospheric pressure. The seal between the rotor and the stator is 0.0001-inch and requires a special oil for lubrication.

6. Diffusion Pumps. The vacuum diffusion pumps contain no moving parts except for a fan which is for cooling purposes only. The diffusion pumps function by shoving molecules into a mass and feeding them into roughing pump. This is accomplished by means of hot oil vapor being forced through jets to the bottom of the chamber, pushing the molecules ahead of it. The diffusion pump is used in conjunction with a roughing pump and capable of pumping vacuum down to .01 microns.

7. Dewar Annular Space Pumps. The vacuum pumps used to maintain vacuum in the dewar annular spaces are regular Kinney KC - 15 pumps. They are rotary piston, two stage, 525 rpm, 15 cu. ft./min, pumps capable of 2 micron pressure.

C. FUNCTIONAL DESCRIPTION

1. System Engineer. The vacuum system is the responsibility of the cryogenic systems engineer.

2. Initial Vacuum Pumping. Before vacuum spaces are initially evacuated, the inner spaces and the lines must be cleaned per specifications. This minimized wall out-gas caused by moisture, oil, and other foreign matter which will vaporize at hard vacuum pressures.

3. Static Conditions. During non-operational periods the vacuum system is maintained in the following status:

a. Vacuum jackets. Pumps No. 1, No. 2, No. 3, and No. 6 run continuously to maintain vacuum below one micron.

b. Dewar annular spaces. Pumps No. 4 and No. 5 are operated as necessary to maintain vacuum between 5 and 10 microns. This is accomplished by daily monitoring of vacuum gages.

4. Test Run Preparations. Since the vacuum pumps are run continuously for the cryogenic vacuum lines, there are no checklists specifically for this system. The operations for the pumps are included as part of the cryogenic system operational checklist.

Before a run, the valves to the cryogenic vacuum lines and pumps No. 1, 2, and 3 are shut off. Pump No. 6 runs continuously; the valves to the vacuum jackets for the LH_2 fill lines are merely closed while LH_2 flows during fill operations.

Procedures followed in the event of having to reactivate a system after a shutdown are contained in seldom-used checklists, and will not be included in this section. For this information, refer to Vacuum System Procedure - Publication Number RN-FOP-0006.

NOTE

VACUUM SYSTEM IS A THERMAL VACUUM JACKET OVER THE CRYOGENIC SYSTEM. THIS INCLUDES FILL LINES, DEWAR VESSELS AND LINES TO REACTOR. (SEE LH₂ TURBOPUMP SYSTEM.)

PUMP #

- 1 } VACUUM SYSTEM FOR CRYOGENIC LINES
- 2 }
- 3 }
- 4 } VACUUM SYSTEM FOR DEWAR VESSELS
- 5 }
- 6 } VACUUM SYSTEM FOR CRYOGENIC FILL LINES

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STUDY GUIDE - SECTION VII

GAS FLOW SYSTEM

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STUDY GUIDE - SECTION VII

GAS FLOW SYSTEM

A. GENERAL

1. Background of TCA Gas System

The gas flow system at TCA consists of the hydrogen (GH_2), nitrogen (GN_2), and helium (He) subsystems, together with the facilities used in fill, storage, and run operations which require these gases. The coverage of this study guide includes information covering gases used, details of the gas system facilities, operational uses and requirements of the gases, and the duties of personnel assigned to the operation and maintenance of the gas flow system.

Since the test cell support operational configuration depends upon the objective of a particular test or series of tests, the gas system will have many modifications in hardware and equipment before the completion of the NRX reactor test series. This study of the gas flow system reflects the gas system configuration existent in the fall of 1963.

2. Gases

Test Cell "A" operations require gases for propellant, pressurization, valve operation, and purging applications. The gases used or stored at TCA in the tank farm or in bottles are: hydrogen (GH_2), nitrogen (GN_2), helium (He), propane (C_3H_8), and acetylene (C_2H_2). The gas systems discussion covers only the GH_2 , GN_2 , and He. Propane and acetylene are covered in discussions of the flare system.

a. Hydrogen (GH_2)

Hydrogen is a colorless, odorless gas and is the lightest of the elements. Liquid hydrogen is the primary propellant for the NRX reactor series. Gaseous hydrogen is employed in propellant low power runs and in some phases of liquid hydrogen runs. GH_2 is also used at TCA for LH_2 dewar pressurization and for the turbo-pump drive.

In addition to its use in low power runs, GH_2 is used in the propellant header to the reactor for purging (to prevent freezing solid of air or nitrogen in the header) prior to the introduction of LH_2 through OBV-86 on the reactor cart. GH_2 is also run through the propellant header as a gaseous coolant to the reactor after reactor power operations.

In the turbine header, GH_2 flows through to the FCR where it supplies the drive power for turbo-pump operation, which supplies LH_2 to the reactor.

GH_2 is used to pressurize the LH_2 dewars (nominal 60 psig) prior to LH_2 runs, in order to provide a positive suction head to the LH_2 portions of the turbo-pump.

Hydrogen is highly flammable and burns with a flame which is not normally visible. It is not toxic, but can be an asphyxiant by displacing breathing air. Hydrogen requires low flash energy to cause detonations in confined areas. It is stored and used at TCA at high pressures. The handling and safety requirements established for LH_2 also apply to GH_2 .

b. Nitrogen (GN_2)

Nitrogen is an inert gas (will not burn or support combustion) which comprises approximately 79 percent of atmospheric air. GN_2 is used at TCA in some low power reactor runs, for purge applications, pressurization valve operation, and room inerting. GN_2 is stored in pressure vessels at the tank farm area and in pressure bottles at various locations.

GN_2 , as used in the inerting of the FCR and the privy section of the reactor test cart, will be covered in the room inerting portion of this course. GN_2 is used in the propellant header for purging and for some low power run functions. GN_2 is also used for extensive purge applications in the tank farm and FCR areas. GN_2 is used to operate valves and to provide pressurization of hydraulic accumulators. Nitrogen is stored and used at high pressures. It is not toxic but it can become an asphyxiant by displacing breathing air.

c. Helium (He)

Helium is a light, inert, colorless and odorless gas. Helium is used for purging, emergency reactor cooling, system block and bleed, system

pressurization, and valve operation. Helium is very useful in purge application where nitrogen cannot be used. It is stored at the tank farm and in storage vessels located at various locations in the test cell area. Helium is non-toxic but can be an asphyxiant.

B. PHYSICAL LAYOUT AND MAJOR COMPONENTS OF THE GAS SYSTEM (TCA)

NOTE: Refer to the TCA layout diagram for the location of the equipment described in the following text.

1. Fill Station Area

The fill station comprises a group of structures, buildings, and equipment used for handling the transfer of various gases to the storage banks. Refer to the three schematic drawings, figures 1, 2, and 3, for methods of unloading helium, hydrogen, and nitrogen from the trailers into the storage banks.

a. Fill Station Piping Manifold

The helium and nitrogen trailers are parked and connected by high pressure flex hoses behind a protective parapet wall. Flex lines are secured with sand bags and chains to prevent whipping in the event of failure. The piping manifold is adaptable to handle gases from various trailer positions. With proper valving, gas may be routed either through the compressor station or to bypass it directly into the storage banks. Nitrogen is delivered to the fill station area in the liquid condition and is vaporized and pumped from the trailer.

b. Fill Lines and Valves

There are three one-inch fill lines in the main pipeway between the fill station and storage banks. These lines normally handle one particular gas, i.e. one for helium, one for hydrogen, and one for nitrogen. Prior to filling a storage bank, all hand and remotely operated valves in the fill header are positioned opened or closed as required. The technician walks the lines and checks or positions each hand valve. At the TFC, he sets or verifies the

position of all remotely operated OBV's and OFV's. Detailed step-by-step operations are outlined in the respective fill procedures.

c. LH_2 Pump-Vaporizer Unit

The LH_2 dewar delivery trailer is positioned west of the parapet wall near the pump-vaporizer unit. This unit converts LH_2 to GH_2 for transfer into the hydrogen banks.

The Linde LH_2 vaporizer is composed of a pump, surge cylinder, vaporizer, fans, controls and purging lines necessary for the changing of LH_2 to GH_2 . The GH_2 flows from the vaporizer to the storage vessels in the tank farm. The hydrogen flow path in the LH_2 vaporizer is shown in the flow diagram, figure 4. The details of the fill operation will be discussed later.

2. Compressor Station Area

The compressor station, located north of the gas fill parapet, houses two high pressure Corblin gas compressors (OU-102 and OV-103) and two Kinney vacuum pumps (OU-104 and OU-105). The Corblin compressors pump helium from the trailer to storage bank pressure of approximately 3300 psig. The Kinney vacuum pumps evacuate the fill lines, run lines, and storage tanks. Space is provided in the compressor station for some light maintenance of tank farm components.

a. Corblin Compressors

Figure 5 shows the cross section of the compressor operation. The gas is drawn through the compressor inlet and check valve by the action of the diaphragm, which is drawn by the piston acting on the oil. As the piston forces the oil against the diaphragm from below, the gas is pumped through the fill header to the storage vessels.

b. Kinney Vacuum Pumps, Model (KDH-130)

(1) Description

The two Kinney vacuum pumps are alike and are rated as follows:

Pressure	10 microns or lower
Free air displacement	131 cfm

Type	Rotary-cam piston
Speed (pump)	535 rpm
Horsepower of electric motor	5 hp
Cooling	Water jacket
Lubricant-sealant capacity	6 gal/hr.

(2) Operation

The Kinney pump uses a rotary-cam piston to draw the air or other gases through the inlet port, forcing the lubricant-sealant ahead of the tangent point of the cam to the discharge port. As the cam rotates, the air is drawn into the cylinder following the tangent point (intake cycle) to the exhaust port where it discharges (exhaust cycle) as shown in figure 6. Controls for the vacuum pump are located outside the north end of the compressor station.

c. Work Area

The compressor station also has a work area for minor maintenance of gas system components.

3. Gas Storage Area

The gas storage system consists of nine banks of storage vessels, of which five banks (1, 2, 3, 4, and 5) are underground. This system also includes the associated valves and instruments necessary for the fill, storage, and run operations required for the support of the TCA test operations. The tank farm storage vessels have a combined water volume of 15,300 cu. ft. and a total rated gas storage capacity of 3,412,000 SCF at 3500 psi.

Figure 7 gives detailed data on the gas storage area and covers the gas flow from the fill headers through the run headers for the individual banks of storage vessels. The separation of banks 2A and 2B is also illustrated.

Figure 8 illustrates arrangement for the fill, run-bypass, and venting (including block and bleed) and safety valves for a typical gas farm storage vessel.

A 3,000 gallon propane storage tank is also located in the gas storage area. This system will be covered in the discussions of the flare systems. The PRV shed is located at the north end of tank farm area. The PRV

shed houses the JBV's and the vent system and valves associated with the GH_2 turbine and propellant run headers. The tank farm hydraulic system is located in the PRV shed.

4. Tank Farm Control Room

The tank farm control room (TFC), located at the east end of the compressor station, houses controls for the remote operation of the fill and run valves located in the tank farm area. The main control panel in the TFC is illustrated in the TCA Familiarization Manual (p. 1-11).

5. Gas Flow Headers

The gas flow headers deliver the gas from the storage vessels to the points of use in the FCR, reactor pad area, and the LH_2 dewar areas. Headers vary in size according to the usage. The flow diagram, Dwg. No. 117000, shows the routing of the headers through the various functions.

C. FUNCTIONAL DESCRIPTION OF THE GAS FLOW SYSTEM

1. Duties of Gas Systems Personnel

System engineering and other assigned personnel duties have been described, in general, in the Test Cell "A" Function section of the course. Specific duties of the gas system support personnel are as follows:

- a. Checklist preparation and verification for each run in accordance with the test plan and objectives.
- b. Inspection, maintenance, and replacement of valves, regulators, and instruments. This includes preparation of routine and scheduled maintenance procedures and the responsibility for adequate spares. Logs must be kept for system history.
- c. System and component safety including the establishment of operating and inspection safety procedures.

2. Gas System Operational Methods

- a. Fill and Storage Operations
 - (1) Helium Fill Operations

(a) Delivery

Helium is delivered as a gas in high pressure tube trailers to the fill station. Trailer capacities vary from 60,000 to 90,000 SCF at 3500 psig. Several tube trailers may be unloaded simultaneously through the six flex hose connections on the south side of the fill station parapet wall.

(b) General Fill Procedures

Figure 1 is a simplified schematic of the helium fill station basic operation. This shows the vacuum pumps which serve to evacuate the fill lines of contaminants before introducing helium. The vacuum in the lines is replaced with helium from the tube trailer. The pressure is allowed to equalize between the tube trailer and helium bank 2A through the compressor bypass line. When the pressure is equalized, the bypass line is closed and the compressors started up. Helium is pumped from the tube trailer into the helium bank to a pressure of approximately 3300 psig, depending upon ambient temperature.

(c) Detail Fill Procedures

Step-by-step operations at the helium fill station are included in publication RN-FOP-0003, which is intended for personnel directly associated with checking the system and positioning each valve for helium fill operations.

(2) Hydrogen Fill Operations

(a) Delivery

Hydrogen is delivered as a liquid in LH_2 dewar trailers. The trailer size varies from 8,000 to 12,000 gallons. For safety reasons and because of the time that is required to unload, only one dewar trailer is connected to the LH_2 pump-vaporizer unit at the fill station. It requires about 20 hours to pump and vaporize 8,000 gallons of LH_2 .

(b) General Fill Procedures

Figure 2 is a simplified schematic of the GH_2 fill station basic operation. This shows the vacuum pumps which serve to evacuate the fill lines of contaminants before introducing GH_2 . The LH_2

pump-vaporizer unit is purged with low pressure helium from bank 2A to remove air. After the unit is purged, the valve on the LH_2 trailer is opened. The flow of LH_2 begins to cool down the pump-vaporizer unit. During the time for chill-down of the LH_2 pump, the GH_2 is vented locally. When the pump becomes sufficiently cooled down, the pump and vaporizer fan are turned on. There is a noticeable gear loading sound on the pump when it begins to pump the LH_2 . The LH_2 pump-vaporizer unit is now in operation, vent valves are closed, and the discharge valve is opened to allow GH_2 to flow from the fill lines to the storage banks. The hydrogen bank pressure is approximately 3300 psig, depending upon ambient temperature. The pump has a maximum output pressure of 3500 psig.

(c) Detail Fill Procedures

Step-by-step operations at the GH_2 fill station are included in publication RN-FOP-0002 which is intended for personnel directly associated with checking the system and positioning each valve for GH_2 fill operations.

(3) Nitrogen Fill Operations

(a) Delivery

Nitrogen is delivered as a liquid in LN_2 dewar trailers. On the back end of the trailer are LN_2 pump, vaporizer coils, and valve manifold to deliver GN_2 to the high pressure flex hose connection at the fill station.

(b) General Fill Procedure

Figure 3 is a simplified schematic of the GH_2 fill station basic operation. The fill lines are purged with GN_2 from bank 2B and/or 4 back to the fill station. The driver of the LN_2 dewar trailer starts the LN_2 pump and vaporizer and opens the GN_2 discharge valve. Nitrogen flows through the flex hose connection at the fill station, then into the lines to the nitrogen banks. This is a straight-forward operation. The pressure, at which the GN_2 is pumped into the storage banks, is established by the LN_2 pump on the trailer, which has a maximum rating of 3500 psig. The GN_2 bank pressure is approximately 3300 psig, depending upon ambient temperature.

(c) Detail Fill Procedure

Step-by-step operations of the GN_2 fill station are included in publication RN-FOP-0004 which is intended for personnel directly associated with checking the system and positioning each valve for GN_2 fill operations.

3. Gas Flow Operations For Test Cell Runs

The extent of use of the gases stored at TCA depends upon the plans and objectives of the scheduled test operation. The gases have been discussed in general in an earlier section of this study guide. These gases (GH_2 , GN_2 , and He) together with the flow paths, most of the key valves, and regulators in the flow systems are illustrated in figures 9 through 12. These diagrams will be helpful in understanding the use of the gases as used in TCA operations. The flow diagram, Test Cell A, Dwg. No. 56Y-117000, is for use by personnel requiring an understanding of the specific flow path and controls used in an operation. Personnel assigned to the operation or maintenance of the gas flow system must be familiar with the flow diagram, specific location of all operating components (headers, valves and controls), and detailed procedures covering each gas system.

4. Typical Gas Systems Operation In Support of a TCA Run Operation

The following discussion covers the operation of the gas flow systems in support of a typical TCA operation for Run day minus two (R-2), Run day minus one (R-1), Run day, and systems securing. Static situations (between runs) are discussed also. Check sheets prepared for each operational day prior to the actual run are to be followed by all assigned personnel. The established gas system and safety procedures are to be followed by all personnel. A typical run operation is discussed in the following breakdown. The student should become familiar with the more detailed check-sheets covering the operations at his earliest opportunity. Permission to perform any check-sheet activity together with the reporting of all team activities is required and is accomplished through communication with the CP.

a. R-2 Day

The R-2 day activities are divided into four areas:

(1) Tank Farm and Test Cell Safety Set-Up

This operation consists of following the check-sheet to determine that the hand valves and block valves are in the proper position to perform the subsequent operational checks. Valves are checked throughout the gas flows from the fill area through the areas of use including the GH_2 dewar area, the reactor cart area and the FCR area. The team performing this set-up operation must also check the gas system areas for any condition which might affect the safety of the system. The CP, and other cognizant TCA personnel, must be informed immediately of any unsafe condition or error in the check-sheet.

(2) TFC Safety Check

The tank farm control room (TFC) activities using MCS-4 consist of:

(a) Exercising some of the hydraulically operated OVV's, JBS's, PCV's, and OBV's in the tank farm area and the FCR.

(b) Inerting tank farm headers 1A and 2A with low pressure nitrogen.

(c) Checking the correct position for all of the OFV's and the OBV's used for fill, run and by-pass.

(d) Recording the pressure indication on the check sheet for each of the storage banks for each gas.

(3) DBC Safety Check

The distribution control building (DBC) activities consist of:

(a) Opening and closing (exercise) the room inerting OBV's using MCS-6.

(b) Exercising the JBV's in the turbine and propellant header (PRV) using MCS-5.

(c) Exercising the OVV and OBV in the turbine area using MCS-5.

(d) Exercising the OBV in the GN_2 purge header system using MCS-12.

(e) Exercising OBV-16 in GH_2 dewar pressurization header with OBV-10 in the He system closed using MCS-2.

(f) Exercising JBV's in GH_2 propellant header (PRV) using MCS-1.

(g) Exercising OBV's in He propellant purge (FCR) using MCS-1.

(4) Additional DBC control functions consists of:

(a) Closing the He PCV in the FCR.

(b) Closing the OBV controlling the He purge header.

(c) Shutting down the TFC hydraulic system.

(d) Sampling header 1A at valve 391 (PI-10).

b. R-1 Day

Run minus one day procedure includes five activities as follows:

(1) TFC and Test Cell Set-Up PRV Shed Activities

(a) Start the TFC hydraulics system in the TFC.

(b) Turn on circuit breakers for the JBV's in the PCV area.

(c) L. P. helium shutdown - After cryogenics team shuts down the He low pressure block and bleed, close hand valves controlling the He flow (PRV).

(2) TFC Transfer of Control Local to Remote

Place MCS-4 and TFC hydraulic system in CP position (TFC).

(3) Remote to Local Control and Secure

(a) Place MCS-4 in "monitor" and tank farm hydraulics in "Fwd." Stop tank farm hydraulics.

(b) Place He block and bleed pressure by closing H. V. 32, venting VV-15 to 75 psig and open H. V. 299.

(c) Turn off JBV circuit breakers.

(4) Sample Tank Farm Headers

H₂ and O₂ sampling of header 1A at Valve 391. Purge with GN₂ if necessary.

(5) Swing BV-9 and Purge Dewar Press Header

This operation consists of opening the proper valves between storage bank No. 5, including BV-9 and PCV-33 (dewar area) and purging with helium to 200 psi. The header is then vented to 50 psi at VV-9. Take a gas sample and analyze.

c. Run Day Activities.

Run day activities consist of six operations which cover the placing of the gas system in a position for support of the test operation and the return to local control and securing the system.

(1) Open BV-17

This operation consists of checking for H₂ at VV-17 opening BV-17 and closing VV-17.

(2) Open BV-16 (Room Inerting)

This operation consists of opening VV-16, opening BV-16, and then closing VV-16.

(3) Open BV-1 and BV-2.

This operation consists of swinging BV-1 (GH₂ turbine header) and BV-2 (GH₂ propellant header) after first opening the associated vent valves and checking for GH₂.

(4) L. P. Helium Shutdown and Arming GH₂ and GH₂ Banks

This operation consists of opening hand valves to the run headers and closing off the block and bleed systems for the storage banks. The low pressure helium dewar block and bleed system is closed down also.

(5) Local to Remote

This run day operation is conducted from the TFC and consists of transferring MCS-4 to the TF hydraulic system to CP. The complete gas flow system is then ready for remote operation in support of the run activity. The gas system team leaves the TCA area.

(6) Remote to Local and Secure

This operation completely secures the gas system, sets up the proper vents, and establishes the low pressure helium block and bleed system for the dewars. Lines are cleaned and purged.

5. Non-Run Operations

During non-run operations, the tank farm is maintained and preparations are made for the next run. Maintenance of the gas system has been described, in general, in section III-A of this study guide.

D. SAFETY

1. Personnel assigned to the gas systems or personnel operating within the gas systems areas are required to follow all of the established safety regulations for TCA and for the specific areas. Operating procedures are to be followed and all unsafe conditions are to be reported to the test cell manager and to the systems engineer. In general, the following safety practices always apply to personnel operating within the gas systems area.

- a. Perform all operations with two or more persons.
- b. Always wear the required personal protection equipment for the task; i.e., ear plugs, face shield, hard hat, etc.
- c. Use equipment and tools designed for safe performance of a task.
- d. Follow established procedures for all operations.

2. The ROVER Test Site Safety Manual and the NERVA Operations Health and Safety Instructions cover the safety regulations and equipment required for specific operational environments. Information on safety procedures or equipment can be obtained from the NERVA safety organization.

E. REFERENCES AND SUGGESTED STUDY IDEAS1. Reference Documents

Flow Diagram, Test Cell A	56Y-117000
Test Cell A Familiarization Manual	RN-FM-0001
Vacuum Systems Operations	RN-FOP-0006
GH ₂ Fill Station, Test Cell A	RN-FOP-0002
Helium Fill Station, Test Cell A	RN-FOP-0003
GN ₂ Fill Station, Test Cell A	RN-FOP-0004

2. Study Ideas

The student should supplement the gas flow system classroom and study guide course information with independent study in order to function as an adequate member of the TCA operations team. The following independent study plans are suggested:

a. Using the flow diagram and colored pencils, trace out each of the gas systems from storage through the point of use.

b. Identify major components shown on the Flow Diagram through visits to the specific area.

GH₂ FILL STATION FUNCTIONAL SCHEMATIC
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FIGURE VII-2
03-0716-U-31

GN_2 FILL STATION FUNCTIONAL SCHEMATIC
FOR TRAINING USE ONLY

FIGURE VII-3

03-0716-U-32

LINDE LH₂ VAPORIZER
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FIGURE VII-4
03-0716-U-33

LEGEND

- 1 RETURN VALVE
- 2 ADJUSTING SCREW
- 3 GAS PLATE
- 4 GASKET
- 5 PERFORATED PLATE
- 6 RETAINING VALVE
- 7 PACKING
- 8 PISTON
- 9 OIL HOUSING
- 10 PISTON HEAD
- 11 PISTON STOP ADJUSTING SCREW
- 12 CONNECTING ROD
- 13 COUNTERBALANCE
- 14 CRANKSHAFT
- 15 CAM
- 16 COMPENSATOR CHECK VALVE
- 17 COMPENSATOR RINGS
- 18 COMPENSATOR
- 19 FILTER
- 20 INTAKE VALVE
- 21 RETAINING SCREW
- 22 PRESSURE REGULATING VALVE
- 23 PRESSURE GAUGE
- 24 PISTON SLEEVE
- 25 PISTON RINGS
- 26 GUIDE SLEEVE
- 27 BEARING
- 28 FLYWHEEL

CORBLIN COMPRESSOR
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FIGURE VII-5

03-0716-U-34

SIMPLEX PUMP
SHOWING EXHAUST STROKE
WITH UNCOMPRESSED GASES
IN CHAMBER.

DUPLEX PUMP
SHOWING TANDEM DESIGN
WITH PISTONS
BALANCED AT 180°.

FIGURE VII-9

03-0716-U-37

NITROGEN (GN₂) PURGE
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FIGURE VII-10
03-0716-U-38

HELIUM (He) PURGE SYSTEM
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FIGURE VII-11

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STUDY GUIDE-SECTION VIII

REACTOR CART COOLING WATER SYSTEM

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STUDY GUIDE-SECTION VIII

REACTOR CART COOLING WATER SYSTEM

A. GENERAL

1. Purpose. The purpose of the reactor cart cooling water system is to protect the electronic instrumentation in the reactor cart privy from radiation and heat damage.

2. Design. The reactor cart cooling water system is a modification of an earlier system designed to provide moderator water cooling for D20 reactors. The D20 reactors were plugged into the ELR and required a much greater amount of water than presently needed. The earlier system also required a cooling tower located just east of the pumphouse, which is no longer needed or used. The modified system in its present use as the reactor cart cooling water system, could be considered an overly designed system. The earlier system required three pumps and twelve inch piping whereas the present system requires one pump and four inch piping.

3. Use. The reactor cart cooling water system is required for reactor test operations using "hot" reactors.

B. PHYSICAL DESCRIPTION

1. Water Storage Tank. The reactor cart cooling water system is supplied from a 100,000 gallon tank located west of the pumphouse at ground level. The gilsonite coated steel tank is 25 feet high and 27 feet in

diameter. It has an inverted type level readout which is fed from a float and reads in percentage. The tank is filled by connecting a fire hose from the tank overflow pipe to valve 456 just outside the pumphouse, as necessary. The system recirculates in a closed loop and is isolated from other water systems. The water contains a rust inhibitor, Komtrol X-8, which is added at the ETL.

2. Pumphouse. The water is circulated by means of three 200 hp pumps located in the pumphouse. The pumps are manifolded together for single or or combined operation. Each of the three pumps currently in use have an output of approximately 1000 gpm at 300 psig through the system. The system requires 500 gpm which can be furnished satisfactorily with only one pump operating. Pumps No. 1 and No. 2 are on the utility power buss. Pump No. 3 is on the critical power buss. During reactor test runs, either pump No. 1 or No. 2 is operated with pump No. 3 on standby.

3. System Piping. The piping, beginning at the water storage tank, is a 14 inch pipe through valve 196 to the 10-inch inlet header to the pumps; through the pumps to the 8-inch outlet header; through the 12-inch main to ELR roof, where it is reduced to 4-inches. The 4-inch pipe runs to the reactor interface, with the return pipe dividing into a desert drain pipe and the return to the storage tank. The return pipe is expanded to 12 inches on the ELR roof and returns to the water storage tank. The 4-inch line on the ELR roof contains a pressure indicator, pressure transducer, and a restricted orifice with a bypass flow element and pressure indicator. A bypass pipe with remote controlled valve, OBV-101, connects between the reactor inlet pipe and outlet pipe in the FCR. This valve allows for water circulation through the system without a reactor cart hookup. Remote controlled valve, OBV-100, allows flow of system water to the desert drain.

4. Reactor Cart Privy Shield. The reactor cart privy shield, the roof of the privy, is an aluminum tank 10 feet square and 16-inches deep. It is filled with cadmium plated steel balls which assist in heat dissipation and radiation absorption. The steel balls are held in place by baffles.

C. FUNCTIONAL DESCRIPTION

1. System Engineer. The duties and responsibilities for the reactor cart cooling system belong to the Miscellaneous Systems Engineer. These have been outlined in Section II.

2. Operational Methods.

a. Static Condition. During non-operational periods, the reactor interface connections are blocked with blank valves which require physical reversal to open the system.

b. Test Run Preparations. The checklists are exercised. These include activities and operations for R-2, R-1, and Run Day. A typical checklist would consist of nine sections. The checklists pertain only to that particular Run; however, the steps would not vary much from the following:

- (1) Section 1. DBC Safety Check, R-2
 - (a) FCV-17 closed
 - (b) OBV-100 open
 - (c) OBV-101 open
- (2) Section 2. Pumphouse Safety Check, R-2 (57 actual items)
 - (a) Record water level
 - (b) Check all line valves (supply, drain, return, etc.)
 - (c) Check circuit breakers for main pump
 - (d) Check pump valves
 - (e) Open circuit breakers
- (3) Section 3. FCR Safety Check, R-2
 - (a) Circuit breakers OFF (FCV-17, OBV-100, OBV-101)
 - (b) Check FCV OBV's
 - (c) Check BV's
 - (d) Check valves for PI's, gages, drain

- (4) Section 4. Pump Checkout, R-2
 - (a) MCS-8 to LOCAL
 - (b) Open valve 196
 - (c) Exercise pumps (2 at a time)
 - (d) MCS-8 to MONITOR
 - (e) Close valve 196
- (5) Section 5. Valve checkout, R-2
 - (a) Unlock circuit breakers (FCV-17, OBV-100, OBV-101)
 - (b) Operate above valves
 - (c) DBC operate same valves
 - (d) Circuit breakers OFF
 - (e) MCS-8 to MONITOR
- (6) Section 6. Set-up for CP Control, R-1
 - (a) MCS-8 to LOCAL
 - (b) Unlock circuit breakers for FCV and OBV's
 - (c) Close valve 426
 - (d) Open MV-1G
 - (e) Open valve 196
 - (f) Pump circuit breakers to ON
 - (g) Open all doors and windows of pump house
 - (h) MCS-8 from LOCAL to REMOTE
- (7) Section 7. Secure, R-1
 - (a) MCS-8 REMOTE to LOCAL
 - (b) Close FCV-17, open OBV's 100 and 101
 - (c) MCS-8 to MONITOR

VIII-5

- (d) Pump circuit breakers to OFF
- (e) MV-1G closed
- (f) Valve 196 closed
- (8) Section 8. Set-up for CP Control, Run Day
Same as Section 6.
- (9) Section 9. Secure, Run Day
Same as Section 7.

REACTOR CART COOLING WATER
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FIGURE VIII-1

03-0716-U-23

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STUDY GUIDE-SECTION IX

DELUGE SYSTEMS - DEWAR AND TANK FARM

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STUDY GUIDE-SECTION IX

DELUGE SYSTEMS - DEWAR AND TANK FARM

A. GENERAL

1. Purpose. The primary purpose of the deluge systems is to provide a rapid means of cooling the two dewars and the four above ground gaseous hydrogen tanks at the tank farm in the event of fire.

2. Limitations.

a. Design. The deluge systems were not designed to be capable of extinguishing gas fires. However, they would probably be somewhat effective in extinguishing ground fires under the dewars or tanks or along the flow path of the deluge water. The deluge water would also be of value in dispersing LH_2 in the flow path of the deluge water in the event of dewar rupture or system leaks.

b. Time. The deluge systems water supply from the elevated water tank is sufficient for approximately 17 minutes if both systems are actuated simultaneously. The duration of water flow through any one system has not been determined, but it would probably be less than 30 minutes.

3. Fire Water Protection System.

a. Fire hydrants. The fire water protection system at TCA consists of six fire hydrants also supplied from the elevated water tank.

b. Fire department. The fire department, located approximately three miles south of TCA, is responsible for all controls and fire fighting processes and equipment at TCA. The fire department also provides standby crews and emergency rescue crews as necessary. In the event a deluge system is actuated at TCA, a signal light and alarm are actuated at the fire station and a water tanker is immediately requested from Mercury. A crew from the fire station is dispatched to TCA to ensure that all personnel have been evacuated and treated as required. Firemen are not required to fight gas fires, but are required to first take whatever action is necessary to protect personnel, and secondly, to do whatever possible to protect equipment and facilities until the fire has burned itself out.

4. Utility Water System. The TCA utility water system is also supplied from the elevated water tank and is covered in a separate section.

B. PHYSICAL DESCRIPTION.

1. Deluge Systems. The two deluge systems are the same except that the dewar deluge system contains a remotely operated deluge supply valve, OBV-102, which enables shutoff from the DBC and CP. The tank farm deluge system will have a similar valve, OBV-151, in the near future.

2. Elevated Water Tank. The deluge systems are supplied from a 50,000 gallon elevated water tank, the bottom of which is 148 feet above ground. The water level in the tank is maintained between 15 and 19 feet. When the level falls below 15 feet a 200 gpm pump, located in the CP area, is actuated until the level reaches 19 feet.

3. Deluge Water Piping.

a. Elevated water tank pit contains the 10-inch leadout pipes to the two deluge systems and the main supply valve, 207.

b. Tank farm deluge system. The 10-inch pipe from the tank pit runs underground to deluge valve pit No. 2, located just north of the tank farm PRV shed, to valve 210, and reduced to 6-inches. The pipe then runs underground to the sprinkler system at the above-ground gaseous hydrogen tanks.

c. Dewar deluge system. The 10-inch pipe from the tank pit runs underground to valve 208 located in a pit southeast of the tank pit. The pipe then runs underground to deluge valve pit No. 1, located west of the dewar storage area. There are two 6 inch leadoffs prior to deluge pit No. 1 which connect to fire hydrants No. 1 and No. 2, the two dewar area safety showers, and the two water outlets on the reactor pad shielding wall. The flow path in deluge valve pit No. 1 is to valve 211, through a 10 to 6-inch reducer, through valves 03V-102 and 482, through the deluge valve, to an 8-inch line to the dewar deluge sprinkler system. Antifreeze has been added to the underground water pipe from deluge valve pit No. 1 to the dewar deluge sprinkler system.

4. Sprinklers The deluge systems sprinklers are considered as a dry sprinkler system. The sprinkler heads are sized according to water requirements at their locations. The sprinklers located on the dewars and tanks are unplugged. The remaining sprinklers are fusible plugged even though in a dry system. This is to ensure maximum water to the dewars and hydrogen tanks unless the heat is sufficient at other points to melt the fusible plugs. The fusible plugged sprinklers are located over the east end of the dewar storage area, on the ceiling of the dewar fill station and over the valve area between the dewars and the FCR. The unplugged sprinklers are located along the top, sides, and bottom of the dewars and tanks.

5. Thermo-pneumatic Detection System A thermo-pneumatic detection is a method of detecting fire by means of units which are sensitive to abnormal heat rises, thereby creating an air pressure impulse which triggers a fire fighting system. Thermo-pneumatic detection system at TCA consists of the following:

a. HAD's - Heat Actuated Devices The HAD's are ellipsoidal shaped hollow shells approximately 5-inches in diameter and constantly pressurized to 16 - 24 oz through 1/8-inch copper tubes from the supervisory air pump in the deluge valve pit. The supervisory air maintains a constant pressure in the HAD's regardless of normal changes of ambient temperature. The HAD's are located near or under the 4 hydrogen tanks, and the two dewars.

They are located overhead in the dewar fill station and between the dewars and FCR wall. The gaseous hydrogen tanks require 21 HAD's and the dewar area requires 25.

b. HAD header bar. The HAD's are grouped on 1/8-inch copper lines which lead to a header board in each of the two deluge valve pits. The header bars, or terminal boards, afford ease of inspection and testing of the thermo-pneumatic system.

c. Mercury check valves. Each copper tube line on the header bar is connected to a mercury check valve. The mercury check valve will allow the passage of an air pressure impulse from any HAD in its group, but will prevent the impulse from being absorbed by other HAD groups. Each tube line is also connected to a compensating vent just prior to where it enters the mercury check valve. The compensating vent bleeds off normal pressure rises due to normal ambient temperature rises.

d. Supervisory air. The thermo-pneumatic system is supervised with 16 to 24 oz pressured air. Should this pressure fall below 8 oz, alarms and lights are actuated on panels in the DBC and at the outer east wall of the ELR. The alarm and light must be reset in the DBC.

e. Electric air pump. An automatically controlled electric air pump maintains the supervisory air. The pump is actuated when the pressure falls below 16 oz and stops when the pressure reaches 24 oz.

6. Deluge or "Clapper" Valve. The purpose of the deluge system is to provide an immediate supply of water. This supply is provided by the deluge valve located in the deluge pit. The deluge valve is actuated by an air operated diaphragm connected to a clapper latch which releases the deluge valve. The deluge valve opens completely and immediately. The actuation of the deluge valve can also be triggered manually by a pull handle located on the enclosing box. Once triggered, the deluge valve can only be reset manually. Reset requires removing a plate held by 8 bolts and physically resetting the clapper and clapper latch. Care must be taken to ensure the seat is free from debris so that the valve will seat properly.

7. Remotely Controlled Valve, OBV-102. OBV-102 is located immediately upstream of the deluge valve in the deluge pit and is controlled from the DBC or CP. Its purpose is to provide a remote shutoff to conserve water in the elevated tank in the event the deluge system becomes unnecessary before the elevated tank runs dry, or in the event the deluge system is accidentally actuated. OBV-102 is always OPEN.

8. Alarm System. When the deluge system is actuated, panel indicators glow in the DBC and on the outer wall of the MER. An alarm light and signal are actuated at the fire station which sends the fire department into action.

C. FUNCTIONAL DESCRIPTION.

1. System Engineer. The responsibility for the deluge systems belongs to the Miscellaneous Systems Engineer. These duties have been detailed in Section II.

2. Static Condition. The static condition of the deluge systems is that of readiness for immediate action. This ready condition is maintained at all times and includes these requirements:

- a. Elevated water tank at minimum level of 15 feet
- b. Deluge systems feed lines to deluge pits No. 1 and No. 2 open.
- c. Valves in deluge pits closed except remote controlled valve OBV-102, and valves 210 and 211 in pits adjacent to deluge pits.
- d. Thermo-pneumatic detection system functioning properly.
- e. Fusible plugs properly installed in proper sprinkler heads.

3. Test Run Operations.

- a. Section I - Safety Check. Check that:
 - (1) Dewar deluge sprinkler drain valve is closed.
 - (2) Valves to fire hydrants are open.
 - (3) Valves 210 and 211 in adjacent pits are open.
 - (4) Supervisory air pressures are at minimum of 16 oz.

- (5) Deluge trip weights are in UP position.
- (6) Drain valves are closed.
- (7) Vent valves are closed.
- (8) System fill supply valves in pits are closed.
- (9) Pressure indicator block valves are open.
- (10) System test valves in pits are closed.
- (11) Deluge control valves are open and microswitch actuator position compares with DBC indications.
- (12) Strainer blowdown valves are closed.
- (13) Supply header drain valves are closed.
- (14) Test block valves are closed and capped.
- (15) Remote control valve circuit breaker is in ON position.

- (16) Remote control valve and light are functioning.
- (17) Remote control valve is open.
- (18) Elevated water tank level is above minimum.
- (19) Dewar areas supply valves are open.
- (20) Utility water supply valve is open.

b. Section II - Local to Remote. Check that:

- (1) Remote control valve is switched to LOCAL position.
- (2) Remote control valve is open.

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STUDY GUIDE - SECTION X

FLARE SYSTEMS

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STUDY GUIDE - SECTION X

FLARE SYSTEMSA. GENERAL

1. Flare Systems. Hydrogen gas exhaust, which can be an extreme hazard, is disposed of efficiently and safely through burning by flares.

The flare system at TCA is operated as part of the Miscellaneous Systems Operations and is made up of two flares: the reactor flare and the main flare. The main flare system vents and burns the exhaust from the GH_2 turbopump propellant system and the exhaust hydrogen emitted from the reactor under test. The operation flare systems, together with most of the components, are similar. The controlled routing and burning of the hydrogen exhaust helps to eliminate the potential hazard of hydrogen air mixtures. However, burning in the presence of explosive gases can be dangerous if the operations and equipment are not functioning properly. Thus built-in safety features are required which will be discussed in this study guide. A schematic of the flare system is shown in figure 1.

The flares are ignited by a propane-air mixture which lights the flare pilots (three on main flare - one on reactor flare). The pilots then fire the flares to burn the hydrogen exhaust. Flare pilots use propane gas. Acetylene gas can be pulsed into the flares to produce smoke since the flame from propane and hydrogen is not normally visible. Television cameras are used to monitor the flare burning areas during test operations. Three temperature

indicators on the main flare stack give readout indications as to the burning of the flares.

2. Gases. Propane (C_3H_8), acetylene (C_2H_2), nitrogen (N_2) and instrument air are used in the flare system. Liquid propane is stored in a 3,000 gallon tank located in the tank farm area. Propane is non-toxic but must be handled and used with care. Nitrogen (GN_2) is used to purge the propane system, the acetylene system, and the flare headers. The constant purge from the dewar area forms a molecular seal in the main flare stack. The molecular seal prevents flame from flashing back through the main flare stack to the 30 inch flare header. Nitrogen is purged continually through the 12 inch flare headers in the Dewar area to the stack.

Instrument air is used in each flare system to provide the proper air-propane mixture in the flame generator. Instrument air is covered in the Compressed Air Section of this course.

B. PHYSICAL DESCRIPTION OF THE FLARE SYSTEM AND COMPONENTS

NOTE

Refer to the TCA Layout Diagram for locations of the systems and components.

1. Equipment Locations.

a. Propane Storage. A 3,000 gallon propane storage tank (OU-110) is located in the tank farm area. This tank is filled from a tank truck parked adjacent to the fence along the east part of the tank farm. The tank has pressure and temperature indicators, safety valve, fill level indicator and the necessary valves for fill and flow control. The propane tank is maintained at a minimum of 80 percent of capacity for runs with a nominal pressure of 109 psi.

b. Acetylene System. The acetylene used in the flare systems is stored in bottles closed to the point of use in the systems. Acetylene

for the main flare system is stored in a shed located about halfway between the north wall of the ELR and the main flare stack. The acetylene bottles (nominal 250 psi) for the Reactor Flare System are located on the north outside wall of the FCR. The banks of bottles are provided with hand control valves and local pressure indicators. Minimum pressure for run operations is 150 psi. The acetylene systems have flash arrestors (OU-41 and OU-42) to prevent flashback to the storage bottles. Acetylene pulsing is accomplished from the Services Console.

c. Flame Generators. The John Zink flame generators (Main Flare, OU-45 and Reactor Flare, OU-42) are used to ignite an air-propane mixture which ignites the hydrogen gas (exhaust) in the flare. The flame travels from the flame generator to the flares in each system. The flame generator for the main flare system is located near the acetylene shed while the flame generator for the reactor flare is located on the north wall of the penthouse. The main flare flame generator is ignited from a push button through local control only while the reactor flare flame generator is usually ignited from the Services Console or by local control. The ignition is provided by a special spark plug supplied from a 115 to 10,000 volt transformer.

d. Main Flare Stack. The main flare stack is located north of the ELR at the end of the thirty inch main flare stack header. The main flare is provided with three pilot lights. A thermocouple located in each pilot flame is connected to a meter relay which activates warning lights at the control consoles if the flame goes out. The nitrogen purge of the flare stack also serves to form the molecular seal which helps to prevent the flame from returning back through the header. The molecular seal and the main flare stack are illustrated in figure 3.

e. Reactor Flare Boom. The reactor flare boom is located on the east wall of the FCR above the reactor pad. The flare is mounted on a swinging boom which has two positions. The flare boom is operated manually at the present time. The reactor flare is checked out in a position where it is not directly over the reactor or the nozzle (30° from wall) and is moved to a position over the nozzle only after it has been proven to operate correctly.

C. FUNCTIONAL DESCRIPTION OF THE SYSTEM

1. Duties of the System Personnel. The duties of the system personnel have been described, in general, in another section of this course. Specifically, the flare systems are the responsibility of the Hydraulic and Miscellaneous Engineer team. Since this system is dependent upon other systems in operation, there is an overlapping of duties with the other systems. The operational check sheets will reflect all of the checks and operations that are required to insure that the flare systems operate properly when required.

2. Operational Methods. The following discussion covers the typical operation of the team prior to a test cell run operation and the securing of the system. The Hydraulic and Miscellaneous Systems team is also responsible for the general systems maintenance between run operations. All of the established operational safety procedures are to be followed while operating with this system. Permission to perform any operation must come from the J-5 CP. The check sheets prepared for each operational phase (R-2 through securing) are to be followed step-by-step with all required information recorded and all unusual conditions reported immediately. In all phases of operation the flare operations personnel are to maintain contact with the J-5 CP continuously. The following outline of typical operations for the set-up and checkout of the flare systems includes the following:

a. Run Day Minus 2 (R-2) Activities. R-2 day activities for the miscellaneous systems team includes the systems safety check of the compressed air system, flare operations, and flare securing. These activities are based on the check sheet prepared specifically for these particular support activities. The R-2 day activities include:

(1) Safety Check

(a) Check of the air compressor (instrument air) system to determine proper functioning and an adequate supply of air (90 to 120 psi)

(b) Check of both acetylene supplies, valve settings, and tank pressures

(c) Check of the N_2 supply and valve setting

(d) Check of the propane supply from the storage tank through to the flare system

(e) Check from the DBC (MCS-7 and MCS-12) of the OEV's which control the propane, acetylene, and GN_2 for use in the flare systems

(f) Check of the flare system components

(2) Flare Operations

(a) Manually setting up all of the reactor and main flare valves and controls including purging lines if necessary

(b) The set-up of the propane and acetylene systems

(c) Ignition of the flares (main flare locally and reactor flare from the DBC)

(3) Securing - Flare Systems

(a) DBC control through MCS-7 and MCS-12 includes closing down the propane and acetylene pulser controls, setting up the L.P. N_2 purge, and purging the propane systems.

(b) Propane system securing includes the closing of the hand valves in that system.

(c) Main Flare system securing includes the closing of the hand valves for the gas supply and the venting of pressure through MCS-7.

(d) Reactor flare securing includes system pressure relief, swinging the BV's, and shutdown of the gas supply.

b. Run Day Minus 1 (R-1) Activities. Flare system operations for R-1 consist of flare operations and securing.

(1) Flare Operation - The R-1 flare operations consist of the same operations or procedures used for both flare systems on R-2 except that the flow pressures of the support gases are set-up.

(2) Securing - The flare systems securing is done in the same manner as the securing for R-2.

c. Run Day Flare System Activities. The flare system run day activities include the checkout and set-up of both flare systems for remote operations during the reactor test activities and, upon completion of the test operations, securing the system.

(1) Flare Operation and Set-Up - This activity by the systems personnel includes the manual and DBC control set up of the gases used in the flare systems, and the checkout and ignition of each of the flare systems. The main flare system remains operating while the reactor flare system is left ready for remote operation.

(2) System Securing - Upon completion of the test operation and when the systems team is allowed back into the area, the flare systems are secured in the same manner as accomplished on R-2 and R-1 days.

3. Non-Operation. During periods between operations the flare systems are inspected and maintained according to the procedures established to keep both systems in the ready condition.

D. SAFETY

1. Personnel assigned to the miscellaneous systems for flare operations are required to follow all of the established safety regulations for TCA and are required to follow the operating procedures and check-sheet instructions. All unsafe conditions are to be reported to the test cell manager and to the systems engineer.

2. The ROVER Test Site Safety Manual and the NERVA program Health and Safety Instructions cover the safety regulations and the equipment required for specific operational environments. Information on safety procedures or equipment can be obtained from the NERVA safety team.

E. REFERENCES AND SUGGESTED STUDY IDEAS1. Reference Documents.

Flow Diagram, Test Cell A	56Y-117000
Test Cell A Familiarization Manual	RN-FM-0001
Flare Systems Operations	RN-FM-0008
Flare Systems (Operator Plan Dwg)	117039

2. Study Ideas. The student should supplement the Flare Systems classroom and study guide information with independent study in order to function as an adequate member of the TCA operations team. The following independent study plans are suggested:

a. Use the TCA Flow Diagram and trace the path of flow and control of the GN_2 , acetylene, and propane.

b. Become familiar with the layout and operation of MCS-7 and MCS-12 (DBC).

c. Become familiar with the components of the flare system through inspection and research of available data on these units.

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STUDY GUIDE - SECTION XI

UTILITY WATER SYSTEM

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STUDY GUIDE - SECTION XI

UTILITY WATER SYSTEM

A. GENERAL

1. Purpose. The utility water system provides the water necessary for equipment cooling, safety, and sanitation purposes at TCA. It is also the water supply for the ETL building located immediately west of TCA.

2. Source. The water is supplied from the 50,000 gallon elevated tank at TCA which is also the supply source for the dewar and tank farm deluge systems. The six fire hydrants at TCA are considered as part of the deluge systems. If deemed necessary, the utility water system could be supplied directly from the CP pump inlet/elevated tank line by means of a lead-off line into the pump house which is presently disconnected at valve 457. This line was previously used to fill the reactor cart cooling water tank.

B. PHYSICAL DESCRIPTION

1. Elevated Water Tank Pit. The pit at the base of the elevated tank contains the control valves and pressure indicator for the six inch supply line to the elevated tank from the CP pump, and the main system shutoff valve on the one inch line to the tank farm hydraulic pump. Dewar deluge shutoff valve 208 and utility water valve 209 are located in two manhole-covered pits near the elevated water tank pit.

2. Tank Farm Hydraulic Pump One Inch Oil Cooler Line. This line leads from the elevated water tank pit to valves 205 and 228 and to valves 678 and OEV-119 located at the hydraulic pump. Valve OEV-119 is open only while the hydraulic pump is operating. During pump operation the cooling water empties into a drain.

3. MER Refrigerating Unit Compressor Pump and Ten Ton Heat Pump Lines.

a. This is a recirculating system made up of three inch lines recirculated by pump OU-50 in the pump house. Makeup water is supplied to the system from a line between valves 891 and 892 toward the cooling tower in the northeast corner of the pump house.

b. The pump house portion of the system includes the return line to valves 889 and OEV - 93, through the cooling coils and pump, through valves 888 and 887 to the outlet line to the MER.

c. The MER refrigerating unit compressor pump inlet line enters the MER to valve 908 through the refrigeration unit, OU-12, through valve 909 to the return line.

d. The MER ten ton heat pump inlet line enters the MER to valves 883 and 885 through the heat pump, OU-48, through valve 886 to the return line.

4. FCR and MER Hydraulic Pump Cooling Lines. These lines are fed through valve 894 in the pump house through a two inch line to:

a. Valve 475 in the ELR to:

(1) FCR valves 562 and 563 to OEV-110 and bypass valve 564 through the hydraulic pump oil cooler to the drain. OEV-110 opens only while the hydraulic pump is running.

(2) FCR valve 508 through FCR hydraulic pump oil cooler coils to valve 671 to drain. These valves are operated manually as required.

b. A reducer to a one inch line to valve 673 outside near the north wall of the MER to:

(1) MER valve 522 to the air compressor oil cooler to drain. Valve 522 is operated manually as required.

(2) MER valves 677 and OEV-92 to hydraulic pump oil cooler to drain. OEV-92 opens only while hydraulic pump is running.

c. Valve 691 outside near the north wall of the women's restroom to the women's and men's restrooms facilities.

5. Pump House Lines.

a. NERVA trailer water lines are fed from valves 891 and 893 near the cooling tower.

b. Pump house restroom facilities line is fed directly from the main inlet line reduced from two inches to one and one half inches.

c. Surge chamber line is fed from takeoff of restroom line to valve 896 to surge chamber to valve 897 to drain. The surge chamber is designed to absorb any sudden surges within the water system.

6. Compressor Station Pump Cooling Lines. These lines are fed through valve 895 in the pump house to the following:

a. Vacuum pumps No. 1 and No. 2 through valves 901 and 900 to drain. These valves are operated manually as required.

b. Compressor pumps No. 1 and No. 2 through valves 903 and 902 to drain. These valves are operated manually as required.

c. Operator's trailer through valve 898 in compressor station.

d. Compressor station swamp cooler through valve 899 in compressor station.

e. Safety shower and safety hose connection (valve taps 905, 906 and 907) through valve 904 in compressor station. The safety shower and the three safety hose connections are located outside near the southwest corner of the compressor station.

C. FUNCTIONAL DESCRIPTION. The utility water system functions on an "as required" basis and has no direct relationship to Run Day preparations or requirements except to function satisfactorily.

D. MAINTENANCE. The maintenance of the utility water system is performed under the supervision of the Miscellaneous Systems Engineer as a part of his systems responsibility.

TEST CELL "A" INDOCTRINATION COURSE

STUDY GUIDE - SECTION XII

HYDRAULICS SYSTEMS

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A. GENERAL

1. Background of TCA Hydraulics Systems. Four independent hydraulic systems supply approximately 95% of the total actuation power required by Test Cell A. The remaining 5% of actuation power is supplied in either pneumatic or electrical form. Of the five systems the tank farm hydraulic system is the most extensive, for it supplies hydraulic pressure for the actuation of OBV, OFV, and OVV valves in the tank farm area. The second system, the FCR (Flow Control Room) hydraulic system, provides hydraulic pressure for the actuation of OBV, OFV, OVV, and Servo valves in the FCR and dewar areas. The third system is the MER (Mechanical Equipment Room) hydraulic system. This system supplies hydraulic pressure for the actuation of reactor cart locking devices, reactor cart servos, and the electrical connector positioning device in the FCR. The fourth system, the Reactor Control Rod Actuation system, provides hydraulic pressure for the control rods.

2. Hydraulic System Characteristics.

- a. Typical Flow Loop. Figure (XII-1) illustrates a typical hydraulic flow system. An adequate supply of fluid is maintained in a reservoir (A). Fluid is withdrawn from the reservoir by the pump (C), which receives motive power from the electric motor (B), and is pumped through a maximum pressure relief valve (D), which returns fluid to the reservoir when it reaches excessive pressure, to a four-way valve (E). The four-way valve controls the demand and supply of fluid to the cylinder (H). All fluid passed by the four-way valve must go through the flow control valve (F) which meters the flow rate to the cylinder. A check valve (G) is in parallel across the flow control valve to allow fluid on the piston return cycle to by-pass the flow-control valve which passes fluid in one direction only, and return to the four-way valve.
- b. Gear Type Pump. In a gear type pump, as illustrated in Figure (XII-2), two closely meshing gears, one driver and one idler, are used to produce fluid flow. As the gears rotate, fluid is trapped between the teeth and the housing and carried around from the inlet (A) to the outlet (B). Fluid return to the inlet is prevented by the close meshing of the gears. Gear type pumps are normally used for lower pressure service, up to approximately 1000 psi.

- c. **Vane Type Pump.** A vane type pump consists mainly of a slotted rotor in which vanes are mounted freely. The rotor is driven and revolves on a shaft that is eccentric in relation to the center of the casing. See Figure (XII-3). The centrifugal force of the rotor causes the vanes to slide to the inner periphery of the casing and maintain intimate contact with it during 360° of rotor travel. The eccentric mounting of the rotor and the reaction of the vanes to centrifugal force result in one side of the pump chamber, the fluid inlet, having an area which is increasing in size and the opposite side, the fluid outlet, having an area which is decreasing in size. As the pump rotor rotates, fluid enters the inlet, is trapped by the action of the vane, and carried around the chamber to the outlet side where the reduction of area forces it out in to the line. Vane type pumps are generally used for low pressure service, approximately 1000 psi. Their efficiencies range above 80%.
- d. **Variable displacement type pump.** A simplified version of an axial piston pump is illustrated in figures (XII-4). Basically, this pump consists of a drive shaft to rotate the pistons, a cylinder block to house the pistons and a stationary valving surface facing the cylinder block bores which ports the inlet and outlet flow. The drive shaft axis is angular in relation to the axis of the cylinder block. Rotation of the drive shaft causes rotation of the pistons and the cylinder block. Since the pistons plane of rotation is at an angle to the plane of the valving surface, the distance between any one of the pistons and the valving surface is continually changing during rotation. Close examination of figure (XII-5), A, B, and C will reveal how an incremental change in the angular relationship between the drive shaft and the cylinder block will increase or decrease the piston displacement. The valving surface is ported in a manner which allows its inlet passage to open to the cylinder bores in that portion of the revolution where the piston travel is towards the valving surface. Rotation of the pump causes the pistons to draw fluid into their respective cylinders through the inlet chamber and forces it out through the outlet chamber.

- e. Accumulators. A typical bladder-type accumulator is illustrated in figure (XII-6). The chief function of an accumulator is to store fluid under pressure. Air or nitrogen is pumped into the bladder which expands within the accumulator chamber and exerts a pressure on the fluid. When fluid is pumped into the chamber, the gas in the bladder is compressed, and the fluid is retained under pressure and available when there is a reduction of pressure in the main system. Accumulators are generally used to compensate for leakage, reduce shocks by absorbing line transients, to compensate for change in volume due to temperature and pressure and to reduce the size of pumps where the use of hydraulic pressure is intermittent.
- f. Filters. Included in the realm of fluid filters are strainers. Strainers are constructed of fine wire mesh screens or of screening elements wrapped around metal frames. As a rule, strainers do not offer as fine a screening action as filters, but they do offer less resistance to flow. Quite often they are used in pump inlet flow lines where pressure drop must be kept at a minimum. Fluid filters can be classified as either proportional or as full flow type. In a full flow type, all of the system fluid is passed through the filter element, while in the proportional type, only an incremental portion passes through the element. Figure (XII-7) illustrates a typical full flow filter which has incorporated a bypass valve. This type of filter is designed for use in tank return lines and provides continuous full flow filtration at low flow rates or partial filtration at high flow rates. Fluid flows around the cartridge, passes through the filtering element and through the center of the cartridge to the outlet port. When loading requirements dictate the need for greater flow, the poppet valve unseats and allows some of the fluid flow to bypass the element. The filtering element, in this case, consists of two layers of paper filter material which absorb contaminants and filter out particles above the 10 micron range.

Illustrated in Figure (XII-8) is a proportional type filter which operates on the venturi principle. When fluid passes through the venturi throat, a pressure drop is created at the narrowest point. This pressure drop creates a siphoning action which draws some of the fluid flow down around the cartridge, through the filter element and up into the throat of the venturi. Fluid flowing in either direction is proportionally filtered and constant recirculation through the system will eventually pass all of the fluid through the filter element. Figure XII - 9 serves to illustrate the relative size of micronic particles.

To assure that the filtering system is operating efficiently and that no particles of damaging size are present in the system, 100 millimeter samples of hydraulic fluid are withdrawn from the tank farm hydraulic system and the FCR hydraulic system prior to operation. Specifically, an analysis of this sample must reveal no more than 10,000 particles, 5 to 10 microns; 5,000 particles, 11 to 25 microns; 1,000 particles, 26 to 50 microns; 20 particles, 51 to 100 microns; and 5 fibers present (a fiber is defined as a particle having a length 10 times its width).

- g. Fluids. A hydraulic fluid must be chemically stable, flow easily and be a good lubricant. As a rule, petroleum base oils are used, but, in cases of viscosity - temperature importance, silicone oils are used. Silicones, however, do not adequately lubricate ferrous to ferrous surfaces, and must be restricted to applications where surface relationships such as bronze and steel are predominant. In Test Cell A, a petroleum based oil, which complies with MIL-H-5606A is used. This particular oil is supplied by the Texaco Oil Corporation and the Bray Oil Company. It has a cost of approximately \$10.00 per gallon.

B. SPECIFIC TCA HYDRAULIC SYSTEMS

1. Tank Farm Hydraulic System. The tank farm hydraulic system receives its actuating power from a Denison variable displacement pump which is driven by a 40 hp 220/440 V, 3 phase motor at 1200 rpm. The pump has a flow capacity of 20 gpm at an operating pressure of 3000 psig. The system reservoir has a capacity of

100 gallons of fluid and is vented to the atmosphere. Fluid within the reservoir is cooled by water tubes which flow water at system pressure, approximately 90 psi. Pressurized hydraulic fluid, prior to being used as actuation power, is circulated through a bank of 12 Bendix full flow filters. These filters employ a filter media composed of sintered stainless steel and have a filtration capability of removing particles as small as 10 microns. A differential pressure reading is maintained across the filter bank and when the pressure drop exceeds 50 lbs., the filter elements are changed. Teed off of the filter output line are two Greer accumulators which are pressurized to 1800 psi each with dry nitrogen gas. These accumulators have a capacity of 10 gallons and serve to absorb line transients, maintain line pressure, and offer reserve emergency pressure for the actuation of any of the 43 OEV's which control tank farm gas flow, in the tank farm hydraulic system. The tank farm hydraulic system may be controlled from the PRV (Pressure Reducing Valve) shed, which is located in the northern section of the tank farm, or from the CP (Control Point) where a pressure readout of the system is monitored. Typical tank farm hydraulic system operations and procedures are thoroughly outlined in Publication No. RN-FOP-0010.

2. Flow Control Room Hydraulic System. The main FCR hydraulic system receives its actuating power from a Denison variable displacement pump which is driven by a 40 hp, 220/440 V, 3 phase motor at 1200 rpm. The pump has a flow rating of 20 gpm at an operating pressure of 3000 psig. The system reservoir has a capacity of 100 gallons of fluid and is vented to the atmosphere to allow pressure equalization. Hydraulic fluid within the reservoir is cooled by water tubes which flow water at system pressure, approximately 90 psig. Separate and apart from the main FCR hydraulic system is the FCR recirculation system. This system withdraws fluid from the FCR reservoir, passes it through a bank of 4 Luber-Finer filters, which employ a filter medium of Microcell-Pac, and returns the fluid to the reservoir. However, the return of this recirculating system can be fed directly into the main actuation line. The recirculating system is pumped by a Mayhew pump which is driven by a 3 hp, 208/226V 3 phase motor at 1800 rpm, and develops approximately 50 psi. The main FCR hydraulic line has 6 Greer accumulators which are pressurized to 1800 psi with dry nitrogen gas. Five of these have a 10 gallon capacity and one, (HA-6), has a 2-1/2 gallon capacity. Filtration for the main FCR hydraulic lines is accomplished by 36 Bendix full flow type filters. These filters employ a sintered

stainless steel element which is capable of filtering out particles down to 10 microns in size.

The main FCR hydraulic system supplies actuation power for 15 OEV's and 6 Servo actuated valves in the flow control room and dewar areas.

The FCR recirculating system is controlled from the FCR, and the pump motor control is located outside the north wall of the FCR and is labeled HYDRAULIC FILTER PUMP. The main FCR hydraulic system can be controlled from the FCR and remotely controlled, from the DBC (distribution building control room). This hydraulic system is the only one which has remote control facility in the DBC. Monitoring of the system can be performed either in the CP or the DBC by means of a system pressure readout and a reservoir volume readout which is calibrated in gallons.

Typical FCR hydraulic system operations and specifications are outlined in publication NO. RN-FOP-0010.

3. Mechanical Equipment Room Hydraulic System. The MER (Mechanical Equipment Room) hydraulic system receives its actuation power from a Vickers vane type pump which delivers a flow rate of 10 gpm at an operating pressure of 1000 psig when driven by a 7.5 hp, 220/440V, 3 phase motor at 1200 rpm. The MER reservoir has a fluid capacity of 40 gallons and is vented to the atmosphere, through a filter, to allow for pressure equalization. Hydraulic fluid is cooled by circulation through a radiator type oil cooler. The radiator is a water-tube type which is capable of exchanging approximately 250 BTU per min. Filtration of fluid in the MER hydraulic system is accomplished by 3 Bendix full-flow type filters which employ a filter element of sintered - stainless steel. This type of filter has the capability of removing particles and fibers as small as 10 microns in size. The MER hydraulic system supplies actuation power to 4 OEV's; OEV 123 which controls OV 37 and OV 38, the cart locking pins, OEV 124 which controls the hydraulic jack motor, OEV 125 which controls the plug coupling motor, and OEV 126 which controls the cart holding mechanism.

Control of any of these valves may be accomplished only from the ELR and C. P.

Pump motor controls are accessible only in the MER. There are no remote control features for the pump motor incorporated into this system.

Additional and more specific operational procedures are documented in publication No. RN-FOP-0100.

4. Rod Actuation Hydraulic System. The Rod Actuation hydraulic system receives power from a Racine vane type pump which develops a flow rate of 10 gpm at an operating pressure of 700 psig when driven by a 7.5 hp, 220/440V, 3 phase motor at 1200 rpm. The reservoir has a fluid capacity of 40 gallons. The system hydraulic fluid is cooled by passing the system return line through a water tube heat exchanger which flows water at system pressure, approximately 90 psig. Filtration of the system hydraulic fluid is performed by 12 Bendix full-flow type filters. This type of filter employs a sintered stainless steel element and is capable of removing all particles and fibers over 10 microns in size. Two ten gallon, Greer accumulators supply emergency pressure for the system. Each accumulator is pressurized to 750 psig with dry nitrogen gas. The principal function of the Rod Actuation hydraulic system is to supply hydraulic power for the reactor control rod system which is located in the reactor cart. The system may be controlled from the FCR or remotely controlled from the CP where there is an on-off switch, a system pressure indicator and a reservoir volume indicator calibrated in percentage. Specific operational procedures concerning the rod actuation system are documented in the publication No. - RN-FOP-0010.

C. SAFETY

1. Personnel assigned to the hydraulic systems are required to follow all of the established safety regulations for TCA.

2. Hydraulic oil (MIL-H-5606A) is flammable. Any oil which may be spilled during filling operations or as a result of line leakage must be promptly and thoroughly mopped up.

3. Operator safety demands that any modifications to the hydraulic system be fully completed prior to line pressurization. Verification of the system integrity must be obtained from the cognizant engineer.

4. Avoid contact with any of the hydraulic components, especially the flex lines, after the system has been pressurized.

5. Publication No. RN-FOP-0100 recommends specified safety checklists for each hydraulic system. It is advisable to review these suggestions.

6. The ROVER Test Site safety manual and the NERVA Operations Health and Safety Instructions cover the safety regulations and equipment required for specific operational environments. Information on safety procedures or equipment can be obtained from the NERVA safety organization.

D REFERENCES AND SUGGESTED STUDY IDEAS.

1. Reference Documents

Test Cell A

Flow Control Room - Main Hydraulic System - 56Y-117036-J5

Test Cell A

Tank Farm Hydraulics - 56Y-117040-J5

Test Cell A MER

Hydraulic System - 56Y - 117037-J5

N-4 Hydraulic

System Flow Diagram - 56Y-117061-J5

Test Cell A Familiarization Document - RN-FM-0001

Test Cell A Checklist

Hydraulic Systems - Kiwi-B4A - EPV & VI

Test Cell A

Hydraulic Systems Operation - RN-FOP-0010

2. Study Ideas

- a. Review a systems engineers' check sheets for all hydraulic system operations occurring from R-2 to system securing.
- b. Using the flow diagram, identify the major components of each specific hydraulic system and its physical location by visits to TCA and visual verification.

LIST OF COMPONENTS

- A - RESERVOIR
- B - ELECTRIC MOTOR
- C - PUMP
- D - MAXIMUM PRESSURE (RELIEF) VALVE
- E - DIRECTIONAL VALVE
- F - FLOW CONTROL VALVE
- G - RIGHT ANGLE CHECK VALVE
- H - CYLINDER

(COURTESY OF VICKERS INCORPORATED)

GEAR TYPE PUMP

FIGURE XII-2

VANE TYPE PUMP

FIGURE XII-3

VARIABLE DISPLACEMENT TYPE PUMP

(COURTESY OF VICKERS INCORPORATED)

FIGURE XII-4

DRIVE SHAFT-CYLINDER BLOCK ANGULAR RELATIONSHIP

FIGURE XII-5

BLADDER-TYPE ACCUMULATOR

FIGURE XII-6

FULL-FLOW FILTER

FIGURE XII-7

PROPORTIONAL-FLOW TYPE FILTER

FIGURE XII-8

(COURTESY OF VICKERS INCORPORATED)

MAGNIFICATION 500 TIMES

RELATIVE SIZES

LOWER LIMIT OF VISIBILITY (NAKED EYE)	40 MICRONS
WHITE BLOOD CELLS	25 MICRONS
RED BLOOD CELLS	8 MICRONS
BACTERIA (COCCI)	2 MICRONS

LINEAR EQUIVALENTS

1 INCH	25.4 MILLIMETERS	25,400 MICRONS
1 MILLIMETER	.0394 INCHES	1,000 MICRONS
1 MICRON	25,400 OF AN INCH	.001 MILLIMETERS
1 MICRON	3.94×10^{-5}	.000039 INCHES

SCREEN SIZES

MESHES PER LINEAR INCH	U.S. SIEVE NO.	OPENING IN INCHES	OPENING IN MICRONS
52.36	50	.0117	297
72.45	70	.0083	210
101.01	100	.0059	149
142.86	140	.0041	105
200.00	200	.0029	74
270.26	270	.0021	53
323.00	325	.0017	44
		.00039	10
		.000019	.5

(COURTESY OF VICKERS INCORPORATED)

TCA HYDRAULIC SYSTEMS
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FIGURE XII-10
 03-0716-U-51

TEST CELL "A" INDOCTRINATION COURSE

STUDY GUIDE - SECTION XIII

ELECTRICAL SYSTEM

NEEDHAM FIELD OFFICE
N.H.S., NEVADA

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ELECTRICAL SYSTEMA. GENERAL

The electrical power for the operation of NRDS is supplied by two outside public utilities. The original source of power is from Southern Nevada Power Company, and a second source is currently being installed to obtain power from the Amargosa Valley Cooperative (REA). The substation at Jackass Flats distributes power to the CP area and Test Cell A.

B. DISTRIBUTION

Electrical energy is transmitted at 138,000 volts (138KV) to the Jackass Flats substation. This substation is located southeast of the highway near the bottom of Skull Mountain grade. Power is distributed to Areas 400 and 401 from this substation. See Figure XIII-1 for electric power distribution diagram.

1. Southern Nevada Power Company (SNPC). The present source of power is from SNPC. This public utility services an area encompassing Clark and Nye Counties. SNPC generates about 80 percent of its power at a steam generator plant located ten miles outside of Las Vegas. The remaining 20 percent they purchase from Hoover Dam. Power is transmitted at 138 KV by overhead lines from Las Vegas to the base camp at Mercury. A branch from there carries power to the Jackass Flats substation.

2. Amargosa Valley Cooperative (AVC). A secondary source of power from AVC is now nearing completion. AVC is located in Henderson and distributes power up through Pahrump to serve the Amargosa Valley and NRDS. The 138 KV transmission line from AVC enters the Jackass Flats substation from the west side. This feeder is connected to the substation, but the air break switches are open, and no power can be used from this source until further modifications are made at the substation.

3. Jackass Flats Substation. The 138,000 volt feeder at the Jackass Flats Substation is reduced by means of a transformer to 69,000 volts. This, in turn, is split into (1) a second bank of transformers to reduce the power to 12,470 volts for transmission to the CP No. 2 substation and the critical bus feeding Test Cell A, and (2) a 69,000 volt line to the CP No. 1 substation where it is transformed down to 12,470 volts for feeding the CP and utility bus to Test Cell A.

4. Test Cell A. Two parallel overhead transmission lines feed Test Cell A complex from the CP area. These are the utility bus and the critical bus. Two pole mounted air break switches can be observed just south of the access road at Test Cell A. The switches are used to transfer all of TCA to the utility bus, or during a run to switch part of TCA to the critical bus.

The utility bus feeds from a 5,000 KVA transformer in the CP area substation to the R-MAD building, and also to a 1,000 KVA transformer located in the TCA substation. The utility bus normally feeds the Equipment Test Laboratory, the gas tank farm compressor station, and two cart cooling water pump motors in the pumphouse.

The critical bus feeds from a 5,000 KVA transformer located at the Jackass Flats substation to the CP area, Test Cell C, R-MAD building and TCA. At Test Cell A this bus feeds a 1,000 KVA transformer located in the substation, and three 37-1/2 KVA pole mounted instrument transformers. Most of the remaining power requirements are fulfilled by this critical bus.

C. DIESEL GENERATOR.

A diesel-driven, 750 KW generator is located at the CP area. This serves as a back-up during test runs, and supplies power to the critical bus. A step-up transformer boosts the output voltage from 2300 to 12,470 for transmission to the test cell.

The diesel generator has the following nameplate rating:

Diesel Engine (G-M)

Horsepower	900 (at 690± 10 RPM)
Cylinders	12

Generator (Crocker-Wheeler)

Special rating for AEC:

937.5 KVA

750 KV

Volts 2300/4000

Amps 230/135

Type

Alternator

Capacity

1250 KVA 80% P.F.

Volts

2300/4000

Amps

314/180

RPM at full load

720

3-phase, 60-cycle

D. PANEL NOMENCLATURE

There are several systems now in use at the test cell for identifying electrical panels. In order to standardize on panel nomenclature, a new nine-block system will be used.

1. Electrical Panel Nomenclature

The electrical panels will be marked according to the following system:

Identification position: 1-2-3-4-5-6-7-8-9

Positions 1-2-3: Panel name

Position 1 and 2 tells the panel location.

Position 3 names the panel with a letter designation.

Example: ELA = panel A in the electronic equipment room (ELR).

Positions 4-5-6: Panel size rating

Position 4 gives the power phase

Example: 1 = single phase

3 = three phase

Position 5 is voltage rating

Example: 11 = single phase, 120 V

12 = single phase, 120/240 V

14 = single phase, 480 V

32 = three phase, 120/208 V

34 = three phase, 480 V

Position 6 is ampere rating

Example: M = 30A N = 200A
 L = 50A Q = 225A
 J = 60A R = 400A
 W = 100A G = 600A
 T = 125A

positions 7-8-9: Source of power

Example: FCB = Panel B in the flow control room (FCR)

2. Use of Panel Nomenclature. With this system of panel identification it would be possible to look at a panel and determine the source. Also it would be easier when looking at a drawing to determine where the panel is physically located. The full description of a panel would read ELA-34W-FCB. This identifies it as electrical panel A in the electronic equipment room, with a power rating of 3-phase 480 volts, and source of power is from panel B in the flow control room.

E. PRE-RUN ELECTRICAL CHECK

Various steps are taken preceding a test run to insure uninterrupted power supply to TCA. In general these activities are:

1. At some convenient time before R-2, Test Cell "C" is isolated from the critical bus in order that TCA only will be fed from this bus.
2. The Southern Nevada Power Company, the Lawrence Radiation Laboratory, and REEC Co at Mercury are requested to do nothing which may endanger the power distribution to the Jackass Flats Substation.
3. An inspection is made at the Jackass Flats Substation, and the reclosing circuits on various breakers are de-engaged and tagged. This prevents reclosing in the event of outside power failure.
4. Depending upon the circumstances, the diesel generator is put in operation during R-1 and R-2 days and is paralleled with the critical bus. After paralleling, the generator is adjusted to deliver a load of 400 KW at a power factor of .84 lag to the systems. The .84 lag figure has been obtained as a general system value.
5. On the morning of R-Day, the circuit breakers at the CP No. 2 substation are adjusted so that adequate isolation will occur if the commercial power fails.

ELECTRICAL POWER DISTRIBUTION

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Figure XIII-1

03-0716-U-53

TEST CELL "A" INDOCTRINATION COURSE

STUDY GUIDE XIV

COMPRESSED AIR SYSTEM

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COMPRESSED AIR SYSTEM

A. GENERAL

1. TCA Compressed Air System

The compressed air system in TCA is composed of three subsystems; the utility air subsystem, the instrument air subsystem, and the J-W subsystem. The system is normally in constant operation and maintains a line pressure that ranges between 90 and 120 psig.

2. Compressed Air System Components

a. Compressors.

There are two compressors within the compressed air system at TCA. The main air compressor is an Ingersoll-Rand Model 71TE, 10 HP, rated at 28 SCFM, with a pressure setting of 90 to 120 psig. Driving power is supplied to the compressor by a Louis Allis 10 HP, 3 phase motor which develops 1760 rpm. The compressor is a two stage type and is classed as fully automatic. In a two-stage compressor, such as this unit, air at atmospheric pressure enters the first stage cylinder through the inlet muffler and valves located in the head. (See Figure XIV-2). On the compression stroke on the first stage piston, the air is compressed to an intermediate pressure and discharged through the valves into a common manifold. From the manifold, the air passes through the inter-cooler tubes, where the heat of first stage compression is removed by the action of the belt wheel fan passing cool air over the intercooler tubes. On the suction stroke of the second-stage piston, this cooled air enters the second-stage cylinder through the inlet valve. The compression stroke of the second-stage piston compresses the air to the final discharge pressure and forces it out through the valve, thence through a water jacketed after cooler, which cools the air, and thence into a receiver, which, in this case, maintains about 140 SCF of air at line pressure. Cool air within the receiver condenses somewhat,

and as a result, about 1 pint of water is drained from the receiver every day. As a preventive maintenance procedure, the compressor air intake filter is cleaned monthly and changed every 6 months when the cylinder valves are inspected and cleaned. The main air compressor and its electrical controls are located in the MER.

The second air compressor in the TCA compressed air system is the Bell and Gossett air compressor which is a carbon ring, oil free type of compressor that delivers 80 to 90 psig of compressed air when driven by a 3/4 HP motor at 1725 rpm. This unit is housed in the NE corner of the MER.

b. Air Dryer

Air, which is designated for use in the Instrument Air System of TCA, is forced through a Kemp, two-stage, air dryer to assure that the moisture level is kept at a minimum. The Kemp Oriad dryer, located in the MER, is a dual tower, fully automatic dryer that reduces the moisture content of compressed air by means of a solid granular desiccant. Each tower is charged with enough desiccant, in this case, 60 lbs. of silica gel, to remove moisture from air at a rated capacity of 50 SCFM. Figure XIV-3 illustrates a typical air drying flow diagram.

The compressed air enters the drying tower, after passing through a pre-filter, through a 4-way lubricated plug valve. The air is dried during its passage through the desiccant bed and discharges through the after-filter. The operation of each tower is cyclic in that reactivation is required after each 8 hour absorption cycle. After 8 hours of service, the saturated tower is reactivated by heating the desiccant bed by means of an electric heating element. A small amount of predried air is bled through the tower to purge moisture liberated during a reactivation. The reactivation heating period continues for 4 hours. At the end of this period, the desiccant bed temperature is between 250 and 500 degrees f. The desiccant bed is then allowed to cool for 4 hours before it is put into another

adsorption cycle. A typical drying tower is shown in Figure XIV-4.

c. Filters

Filters are used in the instrument air system to remove oil, vapors, scale, and foreign particles from the system. The prefilter, used in conjunction with the Kemp air dryer, is charged with 25 lbs. of Vapoilsorb which serves to remove oil vapors that may be passed by the main compressor. Oil or hydrocarbons passed by this filter would contaminate the silica gel desiccant and lower the drying efficiency of the desiccant bed.

A brief coverage of the specifications of the air drying system is presented in Figure XIV-5.

B. SPECIFIC COMPRESSED AIR SYSTEMS

1. Utility Air System

Pressure for the utility air system is supplied by the main air compressor, operating Unit No. 4. All of the pressurized air required by this system is untreated, it is neither filtered nor dried, it is withdrawn for activation directly from the reserve tank. Actuation pressure is supplied to operate:

- a. The reactor cart jack locking pins in the cart holding mechanism. (Reference Drawing No. 56Y-1107037).
- b. OBV-155, the ETL Header Pressurization Valve, and OBV-150, the Nitrogen Flare Purge Line valve. Both of these valves are located in the Tank farms area.
- c. Numerous utility air stations, either plugged taps or quick disconnect fittings, which are located throughout the FCR, Tank farm and Fill Station areas. Reference Drwg. No. 56Y-117038-J5.

2. Instrument Air System

Operating pressure for the instrument air system is supplied by the main air compressor, operating unit No. 4. Prior to being available for use in the instrument air system, pressurized air is passed through filter F-32, the

Kemp air dryer, and filter F-33. At this point of the cycle, pressurized air has sufficient conditioning to be utilized in the instrument air system for:

- a. Actuation for AVV-10, cool-down vent downstream of ACV-4; AVV-11, cool-down vent upstream of OBV-86, OBV-84, purge to JBV-3 downstream; OBV-152, remote block and bleed shutoff; OBV-153, PCV-34 shutoff; OBV-154, PCV-35 shutoff; OFV-33, fill to dewar A; OFV-34, fill to dewar B; OBV-55, vacuum pump No. 1 suction; OBV-59, vacuum pump No. 2 suction; OBV-63, vacuum pump No. 3 suction; and OBV-51 vacuum pump No. 6 suction.
- b. Flame generator, -main flare.
- c. Flame generator - reactor flare.
- d. Reactor control rod locking pins.
- e. The two temperature control systems in the FCR.
- f. The fresh air and return air damper motors in the FCR.
- g. Instrument air stations located throughout the FCR, Penthouse, ELR, and fill station areas. Reference Drawing No. 56Y-117038-J5.

3. J-W Compressed Air System

The J-W compressed air system may be classed as a Independent system. It is the sole function of this system to provide unfiltered and un-dried air to the J-W analyzer system, in the FCR. A hand valve is provided to use Inst air in case of failure of the J-W compressor stage. The J-W compressor maintains 80 to 90 psig of air to the J-W analyzers. Air pressure in this system is reduced to 5 psig at a flow rate of 5 SCFM at each of the 9 J-W analyzers.

4. Compressed Air System Operating Procedures

The compressed air systems in TCA are in continual operation. Initiation of the system may be achieved by turning ON breaker No. 5 in the MER, which supplies electrical power to the main compressor unit. The existence of water pressure at the solenoid valve inlet, OFV-91, should be verified. This valve will allow cooling water to flow during compressor operation. The compressor control switch on the compressor unit will maintain the air pressure between 90 and 120 psig. Figure XIV-1 presents a system flow diagram.

C. SAFETY

1. Personnel assigned to the compressed air system in TCA are required to follow all of the established safety regulations of TCA. In general, all operating procedures, as designated by the Test Cell Manager are to be followed. It is the moral duty and job responsibility of every individual within the scope of TCA operations to report any and all unsafe conditions to the Test Cell Manager or cognizant systems engineer.

2 The Rover Test Site Safety Manual and the NERVA Operations Health and Safety Instructions cover the safety regulations and equipment required for specific operational environments. Information on safety procedures or equipment can be obtained from the NERVA safety organizations.

D. REFERENCES AND STUDY IDEAS

1. Reference Documents

Test Cell "A" - Compressed Air System - 56Y-117038 - LASL

Flow Diagram - Test Cell "A" - 56Y-117000 - LASL

Test Cell "A" - Checklist, Reactor and Main Flare System - Experimental Plan V - LASL

Test Cell "A" - Familiarization Manual - RN-FM-0001 - AGC

Test Cell "A" - Compressed Air System - RN-FOF-0011 - AGC

2. Study Ideas

Classroom lectures should be supplemented by independent study to gain a functional knowledge of the TCA Compressed Air Systems.

- a. Physically identify the system components and controls during visits to the specific area.
- b. Review the systems engineers checksheets which outline the pertinent compressed air operations from R-2 through secure.
- c. Using the flow diagram and colored pencils, trace out each of the compressed air systems from compressor stage to points of usage.

Operating Conditions:

Capacity: 50 SCFM of Air
 Entering Pressure: 90 PSIG
 Entering Temperature: 105 °F. saturated
 Effluent Dewpoint: -40 °F.
 Reversal Cycle: 8 Hours
 Heating Period: 4 Hours

Design Data:

Method of Operation: Full Automatic
 Electrical Components: NEMA I Construction
 Control circuit: 115 v 1 ph 60 cy
 Power circuit: 460 v 3 ph 60 cy
 Electric Heater: Part No. X-50-OR-60-C
 KW. 1.95
 Pressure vessels fabricated in accordance with Section VIII
 ASME code, for design pressure of 150 PSIG
 Pop-safety Valve Setting: 150 PSIG
 Dryer Desiccant: 60 lbs. Silica Gel per tower
 lbs. per tower
 Prefilter Adsorbent: 25 lbs. Vapoilsorb per charge
 Stick Lubricant for Plug Valves: Walworth No. 603 Size B

Utility Requirements for Reactivation:

Purge gas: 2.0 SCFM
 Control Circuit: 50 Watts
 Power Circuit: 1.95 KW

FIGURE XIII-5

FIGURE XIV-1

03-0716-U-17

TEST CELL "A" INDOCTRINATION COURSE

STUDY GUIDE - SECTION XV

ROOM INERTING

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STUDY GUIDE - SECTION XV

ROOM INERTINGA. GENERAL

The inerting portion of this course is intended to familiarize the student with the requirements and processes involved in the inerting of part of the reactor test cart and the FCR from the dangers of flashing (fire) and detonations during hydrogen (H_2) run operations. General descriptions of equipment and system functions of the inerting process will be included, as will the activities of cognizant personnel responsible for inerting activities prior to, during, and after the test run operations.

B. SYSTEM DESCRIPTION

1. Inerted Facilities and Equipment at TCA - Confined areas which are involved with the use of H_2 (both GH_2 and LH_2) during test runs, are inerted at TCA. These include the following:

a. Privy (instrument room) of the Reactor Test Cart. (Refer to the Familiarization Manual, page 1-3, for the photo of the reactor cart).

b. Flow Control Room (FCR). (Refer to the test cell layout for location of the FCR).

2. Reasons For Inerting - In confined areas, H_2 mixed with air or oxygen at certain concentrations, will result in conditions which can cause fire or detonation. In the Privy and FCR there is a possibility of H_2 and air forming an explosive mixture. The hydrogen to air concentration within the range of 4.1 percent to 74.2 percent together with certain circumstances

(confined areas and sparks, etc.) can be flammable. For example, a 29 percent concentration of H_2 in air requires $580^{\circ}C$ (20-30 microjoule in energy) to be set off in a confined area. It is the O_2 in air combining with the H_2 which forms the dangerous mixture. (About 20 percent of air is O_2).

3. Inerting Gas - Nitrogen (GN_2)

a. Nitrogen (GN_2) is a relatively inexpensive inert gas which is available at the test cell at the necessary pressures and quantities for room inerting. The properties of N_2 are covered in the Gas Flow Systems of this course.

b. Nitrogen is stored at the tank farm in banks 2B and 4 and runs through the room inerting 1-1/2 inch header U-174-Z; to the room and privy inerting OBV's and PCV's located on the north outside wall of the FCR. Nitrogen pressure for the FCR inerting is regulated at 120 psi. and for the privy inerting at 130 psi.

4. Monitoring and Monitoring Equipment. Since the function of the inerting system is to keep the explosive concentrations within a safe range, monitoring equipment for concentrations of both O_2 and H_2 gases is required throughout the run operations. Monitoring of H_2 is also done during non-run conditions at the test cell. For room inerting only the O_2 concentration is used to control the amount of nitrogen.

a. Oxygen (O_2) monitoring in TCA is accomplished through a Beckman Model F3 Oxygen Analyzer (OU-13) with a range of 0-25 percent O_2 . This analyzer is located in the northwest part of the FCR just inside the west door. The three O_2 sample locations in the FCR are:

- (1) Over the turbopump assembly
- (2) Over the north door
- (3) Adjacent to the plug area

Also, a sample line runs from the O_2 analyzer through the reactor cart plug in the FCR to monitor the O_2 concentration in the privy. Another line runs to the main flare stack to monitor the O_2 concentration in that area.

b. The Beckman analyzer, at present, is calibrated just prior to run operations by the instrument maintenance personnel (EG&G) and for the purpose of this course, it is classified as "black box" type of equipment. In operation, the analyzer samples the atmosphere and measures its paramagnetic properties as an indication of its oxygen content. The analyzer then produces an analog signal, where one mv equals one percent concentration for readout purposes.

c. Oxygen Readouts - Oxygen concentration readouts are displayed:

- (1) On the Beckman analyzer
- (2) Recorded on charts in the DBC (Panel A₂-RD11.)
- (3) On the Services Console at the CP on meters and warning lights

d. Hydrogen (H₂) Monitoring. Hydrogen analysis is not part of the room inerting, nitrogen inerting control. However, a description of the hydrogen analysis is included in this course. Hydrogen sampling in the FCR is accomplished through five Johnson and Williams (J&W) Model EX-SM Hydrogen Analyzers with a range of 0-10 percent H₂ and are enclosed in explosion proof cases. The J&W Analyzer locations in the FCR are:

- (1) Over the reactor plug
- (2) In the vicinity of PCV-41
- (3) Over the turbopump
- (4) In the vicinity of the hydraulic pump
- (5) In the northeast end of the FCR where the mixing chamber is now located

The J&W Analyzers are calibrated once a week. Four calibration gas bottles containing various percentages of gases are used for calibration of the individual J&W units.

J&W Analyzers are also located in four other locations outside of the FCR. One of these additional J&W units is located along the outside

north wall of the FCR for flare stack monitoring and the other three are located in the penthouse area. The sensor element location for three penthouse J&W units is as follows:

- (1) A sensor in the penthouse
- (2) A sensor located along the wall of the ELR
- (3) A sensor line to the reactor shed

The J&W Analyzers are used to monitor H_2 presence at all times. A compressed air (instrument air) source from the Bell & Gossett compressor runs to each of the nine J&W units. The compressed air system of this course covers the Bell & Gossett compressor operation.

The J&W unit functions in the following manner:

- (1) Sampled gas is passed over a hot platinum wire filament constituting one leg of a wheatstone bridge. The heat released by the reaction of the combustible hydrogen with the catalytic surface of the filament raises the temperature of the filament and, therefore, its resistance. Instrument air is fed to the J&W units as a comparison to the combustible gas.

- (2) The resistance change causes an imbalance in the wheatstone bridge proportional to the amount of combustible gas present in the sample. A second platinum coil is connected on an adjacent leg of the bridge to compensate for variations of ambient temperature and voltage, and for changes in resistance due to filament aging. Any H_2 concentration of 2 percent to air will actuate the H_2 alarm.

e. Hydrogen Readouts. Each J&W unit has a local readout on the instrument. Also, there is an H_2 chart and alarm in the DBC (panels A₂-R010 and A₂-ROLL) and readouts appear on instruments and warnings on the CP Services Console. Hydrogen alarm signals are displayed in the DDA, Fire Station and at the R-MAD Building. The H_2 alarm also actuates sirens, road warning lights and audio tape instructions on the loud speakers.

5. Miscellaneous Room Inerting Equipment and Facilities. See the System Components section of the TCA course for a more detailed description of this equipment.

a. Intake and Exhaust Louvers and Fans. The FCR air intake is controlled through the use of louvered openings and fans. The FCR exhaust has a "butterfly" type of closure. The opening and closing of the louvers is controlled through actuators OU-9, -10 and -11, which are operated by instrument air. During inerting operations the intake air louvers are closed and a second set of louvers located outside the FCR in the intake system open to allow the complete circulation of the N_2 inerting gas throughout the FCR through a duct system and the intake air fan. The exhaust louvers are closed during room inerting.

b. Privy. The privy uses a blower-exhaust system.

c. Room Pressure Indicators. During the inerting process the room air pressure (in inches of water) is measured through a Sostman Pressure Transducer has gauge readouts on instruments located:

- (1) On the west wall of the FCR
- (2) In the DBC
- (3) On the Service Panel in the CP

d. Doors and Other Openings. The doors and other openings are sealed through the use of rubber weather stripping. Pipes have rubber boots covering potential leak areas. A complete seal in the FCR is purposely not maintained to allow for the displacement of air with the nitrogen inerting gas. The privy section of the reactor test cart is sealed in a similar manner.

e. Valves and Controls. The inerting valves and controls are located on the north outside wall of the FCR under the exhaust fan. Valve functions during inerting are covered in another section.

f. Relief Valves. Two relief valves with large stacks are located on the west end of the FCR and are set to vent at one ounce overpressure caused by inerting. Future plans call for these vents to be used in the event of the release of high pressure H_2 resulting from a massive leak or rupture in the hydrogen lines.

g. Temperature Control System. An FCR temperature control system is operated with inerting functions.

C. INERTING PROCESSES

1. Control Modes. There are two modes of inerting operation; manual and automatic. The manual mode of operation is controlled by the SER while the automatic system automatically closes the OBV's and the N_2 flow when the O_2 concentration reaches 3 percent and opens the OBV's when the O_2 concentration reaches 5 percent. One or the other mode must be selected for both systems during operations.

2. Procedures and Inerting Operations. The procedures outlined herein approximate the procedures followed by the team responsible for the set-up of the facilities for inerting from R-2 Day thru Run securing and will go into some detail of the actual gas operations during the inerting procedure. Additional inerting procedures are found in NRDS-071609 - Room Inerting Procedure and the check lists which are prepared by the system engineers for the detailed inerting operations. Figure 1 is a flow diagram of the inerting system showing the major components used. The nitrogen flow for the privy and FCR inerting can be followed on Figure 1 with the following description:

a. R-2 Day. Two checks are made in the room inertions on R-2 day:

(1) Pressure test the room sealing for major leaks in the FCR by closing the exhaust louvers, sealing the doors and turning on the circulation fan. The running of the intake fan builds enough pressure for the detection of major leaks around the plug, the doors and other room outlets which should be sealed.

NOTE

The privy of the test cart is normally checked for leaks prior to run day. Inerting leaks are located, reported and repaired at this time.

(2) The checkout of all the inerting valve operations and the operation of the fans and louvers from the DBC plus a checkout of the fans and louvers from the SER console in the CP.

b. R-1 Day. Checkout of the valves in the inerting system from the SER Console.

c. Run Day Inerting Activities. The Room Inerting Check List indicates the procedures followed for room inerting. The nitrogen (N_2) flow for Privy and FCR inerting can be followed on Figure 1.

(1) Tank Farm. The tank farm setup consists of swinging blind flange BV-16 to open position arming the N_2 storage banks 2B and 4. The N_2 room inerting flow system is checked through to the OBV's at the FCR.

(2) FCR. The N_2 flow system is checked at the FCR. The nitrogen valve loading bottle, PI-158, should indicate in excess of 1000 psi. OBV's in the room inerting system are opened and closed. PCV's -46, -47 and -45 are adjusted to load PCV's -95, -96 and -38, which control the N_2 pressure for inerting the FCR and the privy. The fans are checked and control is turned to the DBC. The louvers are inspected for foreign objects which could affect proper operation. The exhaust fan speed is set to HIGH.

When the cryogenic team has completed its checkout functions inside the FCR and after careful inspection has verified that no personnel are inside, the three sets of double doors are closed and sealed.

The exhaust louvers are closed from the DBC and the intake air fan is started to pressurize the room to a reading of 1-1/2 inches of H_2O on PI-198. The pressure should build up to a reading of 1-inch of H_2O in about 20 minutes. If a leak is indicated, the ELR area, the plug area, and the FCR roof should be inspected for leaks from the outside of the FCR. If no leaks are indicated, the team moves out of the area upon completion of the final safety check.

(3) DBC. The DBC sets the exhaust fan to OFF, opens the exhaust louvers, and sets the MCS-6 switch to Monitor so that inerting can be accomplished from the CP.

(4) CP. The SER console monitors the H_2 and O_2 concentrations and the room pressure indications. The N_2 inerting is controlled as part of the gas flow system in either the manual or automatic modes of control. Usually the operator uses the automatic mode up to the time of actual run operations and then moves to manual mode for a finer control of the inerting conditions. The CP has control of OBV's-78,-79, and-20 which control the N_2 flow through the PCV's into the FCR and privy. The FCR pressure can be controlled by allowing more N_2 through the inerting system. Unless large GH_2 or LH_2 leaks develop, the inerting system can keep the room within allowable limits. Figure 1 indicates the N_2 inerting flow and control. The room inerting activity is not a systems operation itself but part of the overall run operations.

d. Securing From Remote Operations.

(1) The GH_2 and LH_2 lines in the FCR are purged according to the gas purging procedures and the intake and exhaust louvers of the FCR are opened from the CP.

(2) The DBC on command from the CP resumes local control of the room inerting systems. The DBC verifies that OBV's-78,-79 and-20 are closed and that there is no GH_2 contained in the room.

(3) The securing team opens the double doors but does not enter until the O_2 content is about 20 percent.

(4) BV-16 and hand valve 222 are closed at the tank farm and PCV's 47,-46 and-45 are adjusted for zero loading of PCV's-96,-95 and -38 at the FCR.

(5) The DBC shuts down the system.

D. SAFETY

1. General. The established safety regulations for TCA operating personnel hold true for all of the room inerting operations. Only authorized personnel should be in the inerting operations areas. Communications are to be maintained with the designated control points and warning signals are to be followed at all times. Individuals should not work in or around dangerous areas alone. The hazards in the inerting system involve high pressure gases,

and the normal hazards of a nuclear test environment. Overall safety provisions are covered in the safety portion of this course.

2. Entering Inerted Areas. If it becomes necessary for personnel to enter inerted environments, the following minimum procedures must be followed:

a. Safety Equipment. SCOTT air packs and portable gas monitoring equipment are to be used. Additional protective clothing may also be required by the safety regulations.

b. Communications with the test director must be maintained and an adequate number of qualified personnel should form the team entering and supporting the activity.

c. Hazardous conditions are to be reported at once.

E. ADDITIONAL STUDY SUGGESTIONS

1. Review Procedure RN-FOP-0009 for step by step operations of the inerting check.

2. Trace out the N_2 flow through the FCR on the FCR Flow Diagram, Drawing No. 56Y11700. Check the physical location of all the equipment (valves, intake and exhaust louvers) used in privy and FCR inerting.

3. Run through a systems engineer's check sheet for all actual room inerting operations from R-2 Day to system securing.

TEST CELL "A" INDOCTRINATION COURSE

STUDY GUIDE - SECTION XVI

SUPPORT SERVICES

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STUDY GUIDE - SECTION XVI

SUPPORT SERVICES

A. GENERAL

The activities at NRDS are directed primarily towards test operations. These test programs are conducted by various operating contractors under the direction of SNPO-C. In conjunction with the test operations are several support contractors under SNPO-N, who provide the maintenance and other support effort not specifically connected with test operations. The support activities which are available to the operating contractors are generally furnished by Pan American (Pan Am) or Catalytic Construction Company (Catco). Pan Am is the support services contractor (SSC). Catco is the management construction contractor (MCC).

B. SUPPORT CATEGORIES

The support contractors have the responsibility for performing work that falls into a number of broad areas.

1. Normal Operation, Maintenance, and Repair (Pan Am). The everyday operation, maintenance and repair work is performed without specific requests. These services are shops, station services, stores, warehousing support equipment, etc.

2. Preventive Maintenance (Pan Am). A preventive maintenance program is conducted without specific requests. This work includes air conditioning equipment, water pumps, etc.

3. Major Breakdown and Repair (Pan Am). In the event of a major breakdown or repair of test operation equipment, the operating contractor will issue a work request to the support services contractor. The SSC will make the repair under the technical supervision of the operating contractor.

4. Technical Support (Pan Am). On various occasions the operating contractor will require special technical support. The support services contractor will provide radiation monitoring during reactor runs, computer operations, calibration and standards labs.

5. Major Operational Modification (Catco). A test facility is continually undergoing changes and improvements. Major alterations, construction changes, or additions to a test facility is done by the MCC. Work of this scope requires drawings, estimates and bids.

C. SUPPORT SERVICES

The SSC operates various shops and provides numerous support services.

1. Shop Services. The majority of shops are located at the CP area. These include:

a. Machine Shop	f. Plumbing
b. Electrical Shop	g. Air Conditioning
c. Carpenter Shop	h. Stores and Supplies
d. Sheetmetal	i. Warehousing
e. Welding	

2. Office Services.

- a. Blue Printing
- b. Drafting - Design
- c. Reproduction Facilities
- d. Housing

3. Technical Support

- a. Radiation Monitoring (RADSAFE)
- b. Computer Operation
- c. Calibration Standards Lab.

D. REFERENCE DOCUMENTS

There are several documents that give a more complete definition and understanding of the support services contractor's responsibilities. These are recommended for further reading:

1. "Memorandum of Understanding Governing the Conduct of Testing at NRDS", issued by SNPO-N, 1 July 1963.

2. "NERVA Test Operations and Support Services Contractor Responsibilities at NRDS", issued by Aerojet-General Corporation.