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Hanford Spent Nuclear Fuel Hot Conditioning System Test Procedure

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Abstract: This document provides the test procedures for cold testing of the prototype Hot Conditioning System (HCS) at the 306E Facility. The primary objective of this testing is to confirm design choices and provide data for the detailed design package prior to procurement of the process equipment. The current scope of testing in this document includes a fabricability study of the HCS, equipment performance testing of the HCS components, heat-up and cool-down cycle simulation, and robotic arm testing.

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HANFORD SPENT NUCLEAR FUEL HOT CONDITIONING SYSTEM TEST PROCEDURE

Spent Nuclear Fuel Project (W484/LH018)

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HANFORD SPENT NUCLEAR FUEL HOT CONDITIONING SYSTEM TEST PROCEDURE

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INDEPENDENT REVIEW

Document Reviewed Hanford Spent Nuclear Hot Conditioning System Test Procedure

Author K. J. Cleveland Report No. HNF-SD-SNF-TP-010 EDT No. 606760

The subject document has been reviewed by the undersigned. The following items were verified as applicable [EP.4.1].

- Engineering Specification
- Basic Assumptions
- Approach/Test Methodology
- Conclusion/Result Interpretation

K.A. McCracken
Reviewer

9/12/97
Date

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1.0 INTRODUCTION

1.1 OBJECTIVE

The main objective of the Hot Conditioning System (HCS) cold testing described in this test procedure is to confirm design choices and provide data that will help complete an adequate 100% detailed design package prior to procurement of the process equipment. This testing will evaluate whether or not the HCS design meets the requirements specified in HNF-S-0460, *Performance Specification for the Spent Nuclear Fuel Hot Conditioning System Equipment*. Recommendations will be provided to improve the design in order to avoid major design changes during construction or start-up activities, which could result in substantial costs and schedule delays.

The cold testing needs, which are described below, address five main areas.

- Hardware tests - This testing evaluates sizing of equipment, longevity/suitability of the equipment for the operating conditions, equipment maintenance/accessibility, and equipment performance (both standard and "one of a kind" or custom equipment). This testing also includes 3-over-1 safety qualification of the robotic arm.

- Measurement of parameters not possible in production equipment - Measurements that can not be obtained in the production equipment such as temperature and gas flow rate/flow distribution inside a Multi-Canister Overpack (MCO) will be obtained in these tests. Analysis of these measurements can lead to design modification for optimization of the internal structure of the MCO, and optimal basket placement.

- Process performance - These tests will simulate the HCS process using prototypic processing equipment and an MCO loaded with mock fuel, scrap, and sludge. The data obtained from these tests will be used to help optimize the process parameters for the control system.

- Qualifications of models - The HCS process tests described above will also provide valuable data that can be used to validate computer models, which are used extensively in safety demonstration and for the evaluation of MCO throughput.

- Safety - Upset conditions such as over temperature, loss of power, loss of helium, air ingress, etc. can be simulated to demonstrate the capability of the safety class helium purge system to isolate the MCO and establish a safe configuration.

1.2 SCOPE

The current testing scope is based primarily on testing needs identified in WHC-SD-SNF-TP-019, *Hanford Spent Nuclear Fuel Hot Conditioning Proof of Concept Test Plan* (McCracken 1996). The following tests will be conducted in accordance with this test procedure:

- Fabricability study of HCS skid and oven components by building a full scale prototype
- Equipment performance testing of the following components
  - Process vacuum pump
  - Internal MCO HEPA filtration manifold
  - MCO process connectors

- HCS oven
- Process heaters
- Process blowers
- Process enclosure manipulator arm and end effectors
- Heat-up and cool-down cycle of a full size MCO including
  - MCO internal heat distribution using mock fuel elements and mock scrap
  - MCO and shield plug external heat distribution
  - Oven external temperature during loss of combined ventilation system at HCS
  - Oven external temperature during loss of oven dewar vacuum
  - Limited control system functionality and full data logging
- Process enclosure testing encompassing
  - Process enclosure mock-up for Operations design review
  - Process enclosure component placement for robotic arm
  - Process enclosure and trench accessibility with open trench covers
- Robotic arm testing entailing
  - Process connector installation and actuation
  - Miscellaneous process operations/manipulations
  - Shield plug heat cover installation
  - Software programming for repetitive manipulations
  - Robotic arm 3 over 1 safety qualification.

The original test plan was based primarily on the 30% conceptual design, and since that time additional testing requirements have been identified. These tests include the following:

- HCS process optimization using simulated sludge (hydrates)
- Helium regeneration system testing
- Water totalization system testing
- Upset conditions and response of the safety class equipment
- Additional instrumentation testing such as H_2/O_2 monitors and moisture sensor performance
- Process connector leak testing, seal longevity, and sludge build-up
- Cesium trap fabrication and functional testing
- Robotic arm 3 over 1 safety qualification
- Trench filter and cesium trap change out using the robotic arm
- Robotic arm end effectors or special tool requirements

The 3 over 1 safety qualification test procedure is provided in this document (Section 11.0) for information only; this test is not part of the current testing scope. The additional tests identified above will be included in a future revision of this test procedure and performed at a later date. The test plan, WHC-SD-SNF-TP-019, will also be revised to reflect the additional testing requirements.

1.3 BACKGROUND

Spent nuclear fuel (SNF) has been stored in water from the beginning of operations at the Hanford Site. Approximately 2100 metric tons or 80% of the U. S. Department of Energy's (DOE) total inventory of spent fuel is currently stored in water at 105 K East and West Basins. These basins were built in the 1950's and are nearing the end of their useful lives. There is a great deal of concern over continued storage of the fuel in the K Basins because of the age of the facilities, the close proximity to the Columbia River, and because the 105 K East Basin is known to have leaked in the past.

The Spent Nuclear Fuel Project (SNFP) has recommended a process to the DOE for removal of materials from the K Basins. The process includes removal of the K Basin Fuel from their existing canisters, de-sludging, and re-racking in the K Basins. The re-racked fuel is loaded into MCOs and sent to the Cold Vacuum Drying (CVD) facility at the 100 K Area for bulk water removal and content vacuum drying. Conceptually, CVD is done by elevating the temperature of the MCO up to 50 °C under decreased pressure (0.5 Torr minimum) to remove water vapor and other gases from the fuel surfaces. The MCO is then filled with inert gas, sealed, and transported to the Canister Storage Building (CSB) approximately 8 miles from the CVD facility. The loaded MCO will be temporarily stored in the CSB with active pressure relief until a Hot Conditioning (HC) process can be performed. Conceptually, HC is done by elevating the temperature of the MCO to 300 °C to further remove water and hydrates from the fuel. MCOs would then go into sealed interim storage with active pressure relief to await final disposition. The combined processes are intended to allow dry storage for long periods in a stable condition. The following section provides more detail on the HCS process.

1.4 HCS PROCESS SUMMARY

The HCS equipment is designed to receive MCOs after completion of CVD and to further process the SNF contained within these MCOs. Processing is done at more rigorous conditions than CVD, with the SNF heated to over 300 °C and held under vacuum for a sustained period of time. As the MCO is heated, residual free water is first removed, followed by the breakdown of chemical bonds at various temperatures of uranium oxide hydrates. Depending on the temperature, the released water vapor may react with unoxidized uranium fuel to produce hydrogen and uranium oxide. After the temperature reaches 300 °C and the hydrogen released from the uranium hydride decomposition and the fuel-water reaction decreases, a vacuum is applied to the SNF and further hydrogen is released from the decomposition of uranium hydrides. The MCO is then cooled, back filled with an inert gas, sealed, and removed from the HCS process oven and placed into interim storage in the CSB.

Six process trains are each equipped with a process oven, for heating and cooling the MCO, and a Process Module (PM), which contains equipment (blowers, heaters, vacuum pump) to support the process heating system (PHS) and vacuum pumping system (VPS). A central Service Module (SM) provides common services to each of the process trains. These services include vacuum supply for the vacuum insulated ovens and gas handling for the VPS on each PM. The PE is essentially a portable shielded hot cell, which is used for connecting/disconnecting process piping to the MCO. The PE provides radiation protection to an operator who conducts robotic arm remote handling operations using direct observation, a television monitor, and a control panel. All process actions are actuated using a Process Control System (PCS). Operators direct the PCS when to initiate a sequence, but the sequencing and control, such as valve state changes and process temperature, are accomplished solely through the PCS.

The following steps, summarize the HCS process for normal operating conditions.

1) The MCO Handling Machine (MHM) delivers the MCO and installs it in the process oven.
2) The PE is moved into position and VPS process piping are connected to the MCO using the robotic arm.
3) The safety class helium system is verified to be ready and the process connections are leak checked.
4) MCO valves are opened using the robotic arm after containment integrity is verified.
5) The insulation cover is installed on top of the shield plug.
6) The PE closes the process pit cover and moves to the next processing location.
7) The Helium Recycle System (HRS) begins circulating helium through MCO via the SM and PM.

8) Heating of the MCO begins under the control of the PCS. The heating cycle is estimated to take approximately 25 hours.
9) A vacuum and a slow argon purge are applied to the MCO after the SNF reaches 300°C and a low hydrogen concentrations has been achieved.
10) After a total drying time of 48 hours under vacuum, and a pressure of 5 torr has been reached, the MCO is backfilled with helium and cooled to 122 °C.
11) The gas within the MCO is displaced by high purity helium.
12) The PE then moves into position, opens the process pit covers, removes the insulation cover, closes the MCO valves, and disconnects the VPS process lines.
13) The MCO head cover is set in place and welded to the MCO using the welding machine inside the PE.
14) After welding and inspection are completed, the PE closes the pit covers and moves to the next location.
15) The MHM moves into position and removes the MCO from the process oven and takes it to interim storage within the CSB.
16) If the cesium/iodine trap or HEPA filter requires changeout, the PE moves back into position to complete the changeout and perform any other required maintenance.
17) Following trap/filter changeout the pit cover is closed and the PE moves to its next location.

2.0 REFERENCES

CM-1-10, *Safety Manual*, latest revision, Fluor Daniel Hanford Company, Richland, Washington.

DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual*, Department of Energy, Richland, Washington.

McCracken, K. J., 1996, *Hanford Spent Nuclear Fuel Hot Conditioning Proof of Concept Test Plan*, WHC-SD-SNF-TP-019, Rev. 0, Fluor Daniel Northwest, Richland, Washington.

HNF-S-0460, Rev. 1, 1997, *Performance Specification for the Spent Nuclear Fuel Hot Conditioning System Equipment*, Numatec Hanford Company, Richland, Washington.

WHC-IP-0883, *306E Facility Administration Manual*, Cowan 1996.

3.0 DEFINITIONS

HC (Hot Conditioning)	The process of removing chemically bonded water from the SNF within the MCO at temperatures in excess of 300 °C.
HPU (Hydraulic Power Unit)	A 3000 psi, 4 gpm pump with 7.5 hp motor used to supply hydraulic power to the manipulator arm.
MCO (Multi-Canister Overpack)	The vessel that will contain the fuel assemblies during the drying and interim storage process. For the purpose of proof of concept testing, MCO refers to a full size MCO with a prototypic bottom and mechanical seal shield plug.

MOCK FUEL	Unpainted carbon steel heavy wall tubing that simulates N Reactor fuel, consisting of an inner and outer fuel element with nearly the same outside and inside diameter and wall thickness as N Reactor fuel. The mock fuel will closely approximate the surface area of actual fuel. All the mock fuel elements will be allowed to rust throughout the testing and some elements will be initially damaged to provide water/sludge retention sites and scrap as seen on the K Basin fuel and scrap.
PCS (Process Control System)	The computer system developed for automatically controlling the HC process. All process steps are actuated through the PCS.
PE (Process Enclosure)	A portable shielded hot cell that moves into position over the MCO and process oven for connecting/disconnecting process lines to the MCO and/or for performing maintenance activities in the process trench.
PM (Process Module)	A steel constructed skid that contains equipment (blowers, heaters, vacuum pump, instrumentation) to support the process heating system and vacuum pumping system. Each process oven has an associated PM at the HC Facility.
SLUDGE SIMULANT	A simulant of K Basin and N Reactor fuel sludge with similar particle size, shape, and hydrated properties. Information from SNF characterization and Battelle PNNL will provide approximate sludge simulant ingredients and application techniques.
SM (Service Module)	The SM provides common services to each PM, such as vacuum supply for the vacuum insulated oven, and gas handling (helium & argon) for the vacuum pumping system.
TEST LOGBOOK	A hard bound notebook for the test performer to record all data and observations not included in the test procedure. The logbook number used for this procedure is WHC-N-944. The test logbook will be archived in central files following testing.
TEST PROCEDURE	A test procedure lists the steps for each test and provides instructions for documentation of the process parameters that will be established during the testing.

4.0 TEST EQUIPMENT AND TEST METHOD

4.1 GENERAL TEST APPARATUS DESCRIPTION

A general description of the HCS was presented in Section 1.4. This section describes the HCS sub-systems/components that will be tested as part of this procedure and identifies the differences between the test components and the design specified components.

4.1.1 Helium Recirculation System (HRS)

The HRS is used to supply helium at approximately 0.0047 m^3/s (10 scfm) to the MCO through the PM process piping. In the HCS design, a central service module supplies helium and other gases to all six process trains. For testing, however, a central service module was not needed, and therefore the required utilities that would normally be supplied from the service module were mocked up on a smaller scale. An auxiliary skid was fabricated for testing that consists of a gas compressor, Corken model D291, and a 3 kW Watlow heater. The HCS service module has two Corken model D691 gas compressors, which are the same type of compressor that is being used for testing, except that the D691 has three times the flow capacity.

The heater is used to preheat the helium prior to the MCO, which would normally be heated by the heat exchanger on the PM. The 90% design specified heat exchanger is a helium-helium exchanger, i.e., the hot helium leaving the MCO is used to preheat the cold helium entering the MCO. With this process, the hot helium leaving the MCO is also cooled to the operating temperature of the process vacuum pump and gas compressor. For testing, a heat exchanger based on the 60% design was procured that uses air for cooling the helium. The gases entering the MCO will be heated to a temperature of approximately 5.6 °C (10 °F) below the temperature of the gas entering the cooling heat exchanger (returning from the MCO) to simulate the 90% design heat exchanger operation.

4.1.2 Instrumentation

The test apparatus is equipped with several different types of instrumentation. Most of the instrumentation is design specified and is part of the PM. However, auxiliary instruments, such as thermocouples for the MCO/oven and a cold cathode gauge for the oven vacuum, were acquired to support testing. Figures 1 through 3 are piping and instrumentation diagrams (P&IDs) that show the location of the instruments on the test apparatus. A detailed description of the test instrumentation is provided in Appendix A.

4.1.3 Manipulator Arm

The manipulator arm is a Schilling Titan III model and will be used to perform a variety of different tasks within the PE. After the PE is moved into position over the trench, the arm attaches lifting hooks to the trench covers. Next, the process port cover is removed and the valve plug actuator is installed using the arm. Then the pressure relief valve is replaced with a rupture disk. The arm is then used to help guide the insulation cover over the flexible process hoses. After hot conditioning is complete, the arm is used to remove the insulation cover, remove the valve plug actuator, change out HEPA filters and cesium traps as needed, perform swipes for contamination monitoring, aid with the final closure of the MCO, and unhook the trench covers.

The arm purchased for testing is the actual arm to be used in the facility. Most of the arm functions will be tested during this phase of testing. Different tools and end effectors will be developed to accomplish the required tasks. The arm will be qualified as a 3 over 1 safety class item. Qualification testing will include load testing the arm, failure mode analysis, and suspect bolt inspection.

4.1.4 MCO Assembly

An MCO that was fabricated to the 90% design specifications is being used for testing, which is the only mechanical closure MCO currently available. This MCO was modified slightly for inserting a larger dip tube made of 1 inch XXS pipe as specified in the 100% design, instead of ½ inch SCH 40 pipe, which was specified in the 90% design. MCO process connectors are not currently available for testing, and therefore temporary connectors consisting of welded 1 inch pipe were installed on the MCO ports. Also, a hole was bored through a pressure relief port and out the bottom of the shield plug for insertion of thermocouples inside the MCO.

The MCO will be loaded with four prototype MK IV fuel baskets and one MK IV scrap basket, both constructed of carbon steel. Carbon steel mock fuel elements, which approximate the dimensions of actual SNF, will be loaded in each of the four fuel baskets. The scrap basket will be filled with pieces of carbon steel mock fuel elements that are 0.6 cm (1/4 in.) to 7.6 cm (3 in.) long to simulate scrap SNF. The MCO contents may vary from test to test depending on testing needs.

4.1.5 MCO Process Oven

The function of the MCO process oven is to slowly and uniformly heat the MCO and its contents. Heated air from the PM flows through the process trench piping to the oven and heat cover, around the outside of the MCO and shield plug, and then back through the trench to the PM.

The stainless steel constructed oven consists of a 0.7 m (26 in.) diameter inner shell and a 1.0 m (39 in.) diameter outer shell, with a multilayer insulation blanket hanging between the two shells. The insulated space between the shells is vacuum pumped to a pressure of 10^{-2} Pa (10^{-4} Torr) to obtain the maximum performance of the insulation. Hot air supply and return lines from the trench, which are constructed of 6 inch SCH 10 pipe, are attached to a manifold located on the outside of the inner shell near the top of the oven. The supply air flows through the manifold, down four vertical pipes to another manifold at the bottom of the inner shell, up around the outside of the MCO, out the top manifold, and back through the return line. Smaller 2-1/2 inch process heating lines from the trench flow through the heat cover inlet, around the outside of the MCO shield plug, and back out the heat cover outlet to the trench and PM.

The fabrication of the MCO oven and heat cover were based on the 60% design. The primary difference between the test oven and the 60% design specified oven is that the test oven does not have the index drive assembly and support weldment for rotating the MCO. Instead, a sheet metal insulating ring was fabricating to fill in the space between the oven and heat cover where the index drive assembly would normally be located.

4.1.6 Process Control System (PCS)

The PCS consists of field instrumentation (local and remote indication/actuation), a programmable logic controller (PLC), and a computer control station (see Figure 4). The field instrumentation (described in Appendix A) consists of temperature, pressure, flow transmitters, and air operated valves. The PLC provides the interface between the instrumentation and the computer. The PLC central processing unit (CPU) is connected to a 486 or pentium computer control station through one of the computer's communications port. The computer control station provides the data collection and control activities through Man Machine Interface (MMI) software.

The PLC is Modicon Quantum[1] series, distributed I/O, "hot" card replacement PLC. The PLC has input cards to convert the voltage signals from the type K thermocouples and RTDs, and amperage signals from the pressure and flow indicators to signals which are readable by the PLC CPU. The PLC also has output cards to provide remote setpoint and/or control signals to the heater controllers, flow controllers, temperature control valves, and air operated valves.

The process is controlled and monitored through the computer control station utilizing Intellution FIX MMI[2] software. The software provides system operation, process component control (blowers, pumps, heaters, and valves), data collection, and data storage. The data can be viewed during real time system operation and/or archived for future data analysis.

4.1.7 Process Enclosure (PE)

The PE is a mobile shielded hot cell primarily used for connecting/disconnecting process lines to the MCO. An operator remotely controls the manipulator inside the PE to perform the required handling operations. The manipulator is also used to change out the cesium trap and HEPA filters located in the process trench. A welding machine inside the PE performs the final seal weld on the MCO cap.

A mock up PE was constructed using unistrut for the frame and plywood for the walls to simulate the size and arrangement of the actual PE. This mock up gives the Operations group a hands-on opportunity to review a critical component of the HCS and recommend design improvements. The mock up PE was built according to dimensions specified on draft drawing H-2-827977, which was part of the 90% design package. The plywood on the front of the enclosure has cut-outs corresponding to the location of the leaded glass windows. A set of sliding shelves were also fabricated using unistrut and plywood to mock up the shelves inside the actual PE. These shelves will hold tools and equipment for the manipulator testing.

4.1.8 Process Module (PM)

The PM contains the equipment, piping, and instrumentation for the PHS and VPS along with some piping for the combined ventilation system (CVS). There are two separate heating systems on the skid to supply heated air to the MCO oven and the MCO shield plug heat cover. The main oven heating system consists of a 75 kW, 480V, 3PH Watlow circulation heater wired in a wye configuration to produce 25 kW of power and a Robinson Industries blower to flow 0.35 m^3/s (750 cfm) of air at 2500 Pa (10 inches water gauge). The shield plug heating system includes a 12 kW, 480V, 3PH Watlow circulation heater wired wye to produce 4 kW of power and an Illinois Blower, Inc. to flow 0.071 m^3/s

[1]Modicon and Quantum are registered trademarks of the Square D Corporation.

[2]Intellution and FIX MMI are registered trademarks of Intellution software.

(150 cfm) of air at 2500 Pa (10 inches water gauge). The heaters are controlled using a Chromalox[3] 4239-20504 Mini SCR temperature control system.

A Varian[4] model 600DS vacuum pump is used for the VPS. The Varian pump is a scroll type vacuum pump which requires no oil. It utilizes Teflon to obtain the seal between the internal scrolls. The Varian 600DS pump has a ultimate pressure of 10^{-3} Torr and a base pressure of 10^{-2} Torr.

The prototype PM was fabricated based primarily on the 90% design specifications. The primary difference between the prototype PM and the design specified PM, is that the piping for the CVS and process vent lines were not fabricated. Another difference is that a unistrut frame was used instead of a structural steel frame to reduce the cost of fabrication. As mentioned in Section 4.1.1, the heat exchanger used in the VPS and HRS, is based on the 60% design, rather than the 90% design.

4.1.9 Oven Vacuum System

The oven vacuum system evacuates the process oven insulated space to a pressure of 10^{-2} Pa (10^{-4} Torr) for maximum oven insulation performance. The vacuum system used for testing is not based on the HCS design; it was acquired for this testing only. The roughing pump being used is a Pfeiffer DS050 roots vacuum pump, which is the CVD design specified pump. The Pfeiffer pump has a base pressure of 10 Pa (10^{-1} Torr) with an ultimate of 1 Pa (10^{-2} Torr). A Leybold Heraus turbo vacuum pump model 450 will be used to bring the final vacuum pressure of the oven insulated space to a pressure of 10^{-2} Pa (10^{-4} Torr) or better.

4.2 FABRICABILITY STUDY

As the prototype HCS components/sub-systems are being fabricated at the 306E facility, design review comments are being supplied to the design agent prior to issuance of the 100% definitive design package. These comments are typically related to design changes to improve the ease of fabrication along with identifying interferences and other potential problems related to fabrication. Additional comments following the release of the 100% design package will be logged in the test logbook, documented at the end of testing, and transmitted to the HCS project manager, design authority, equipment designers, and project files.

4.3 EQUIPMENT PERFORMANCE TESTING

Performance of the HCS design specified equipment is typically evaluated as part of the process testing, e.g., the blowers and heaters on the PM will be evaluated as part of the heating cycle tests to verify that they can produce the required process flows and temperatures. Other than initial functional checkouts and verifying that the design satisfies the requirements of the equipment operating manuals, there are no plans to test these components separately. However, certain components require unique individual testing to evaluate their performance as described in the following sections. Other HCS component tests identified in Section 1.2 will be performed at a later date.

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[3]Chromalox is a registered trademark of Emerson Electric Co.

[4]Varian is a registered trademark of Varian Associates.

4.3.1 MCO Process Connector Leak Testing and Seal Longevity

The MCO process connectors are custom designed components that connect the process lines from the PM to the valve ports on the MCO shield plug. These connectors must maintain a vacuum tight seal under hot and cold operating conditions, and after several cycles of installation/removal and heat up/cool down. For these tests, the process connector will be installed in a test assembly that mocks up a valve port on the MCO. Helium leak tests will be performed by qualified NDE personnel at room temperature and at 300 °C, leak tests will be repeated after several cycles of installation/removal from the test assembly. The leak rate shall be verified to be less than 1×10^{-4} std. cm^3/s.

4.3.2 Vacuum Pump Back Flow Tests

The capability of the vacuum pump to prevent back flow into the HCS system and MCO will be verified in these tests. Back flow prevention is required to ensure that air is not entrained in the MCO. The vacuum pump inlet will be isolated from the system and pumped down to the pump's base pressure. Pump operation will then be stopped and the pressure rise on the inlet piping will be measured. The approximate amount of air back flow will be calculated from this pressure rise.

4.4 PROCESS HEATING AND COOLING SYSTEM TESTING

The primary objective of these tests is to verify that the PHS equipment satisfies the performance requirements. These tests will provide equipment and instrumentation performance along with optimum sensor placements for system and MCO internal pressures, temperatures, and flow rates. These tests will provide valuable information to determine the heating cycle parameters (set points, ramp rates, etc.) and help validate HCS thermal computer models. The following performance requirements from HNF-S-0460 will be verified:

- Heat the MCO to 300 °C (+50 °C, -0 °C), but at a rate not to exceed 100 °C/hr.
- Heat the fuel at approximately 20 °C/hr.
- Maintain the MCO wall temperature below 350 °C to prevent exceeding the MCO temperature design limit.
- Maintain a temperature differential between any two points on the MCO of less than 100 °C.
- Provide sufficient insulation to minimize power required to heat the MCO and protect personnel where appropriate.
- Cool the MCO at a rate not to exceed 100 °C/hr.

The heating and cooling cycles will be simulated using a full size MCO filled with a basket of simulated scrap, and four baskets of mock fuel (damaged and pristine). One of the primary objectives of testing is to obtain measurements that cannot be obtained in the production equipment. Temperature measurements of the MCO and its contents are required to verify the performance requirements. Therefore, thermocouples will be installed inside the MCO, in the shield plug, and on the outside of the MCO shell. Thermocouples will also be installed on the outside of the oven to measure external oven temperatures when simulating upset conditions, such as loss of vacuum in the oven insulated space. The following list shows the thermocouple arrangement that will typically be used, but may be subject to change depending on testing needs. Note that temperature elements on the PM are not listed. Figures 5 and 6 show these approximate thermocouple locations on the MCO and oven. Figure 6 also shows the overall layout of the test apparatus in the 306E Facility.

MCO Thermocouples

TE1	MCO outlet port (filter)
TE2	shield plug port bolt hole
TE3	shield plug center, inserted in hole 12.7 cm (6 in.) deep from top of shield plug
TE4	center of shield plug top
TE5	MCO inlet port (dip tube)
TE6	outer shell 7.6 cm (3 in.) above shield plug bottom
TE7	outer shell 7.6 cm (3 in.) below shield plug bottom
TE8	outer shell 3.0 m (10 ft) from bottom
TE9	outer shell 1.5 m (5 ft) from bottom
TE10	center of bottom plate
TE11	midsection of fuel element located nearest the outside of basket 1 (bottom)
TE12	midsection of fuel element located midway between center and outside of basket 1
TE13	midsection of center column of basket 1
TE14	midsection of center column of basket 2
TE15	midsection of fuel element located nearest the outside of basket 3
TE16	midsection of fuel element located midway between center and outside of basket 3
TE17	midsection of center column of basket 3
TE18	midsection of center column of basket 4
TE19	midsection of scrap element located nearest the outside of basket 5 (top)
TE20	midsection of scrap element located midway between center and outside of basket 5
TE21	midsection of center column of basket 5
TE22	MCO filter pleat
TE23	spare
TE24	spare

Oven External RTDs

TT01	top center of shield plug insulation cover
TT02	bottom side of shield plug insulation cover
TT03	outer shell 3.6 m (12 ft) from bottom
TT04	outer shell 2.4 m (8 ft) from bottom
TT05	outer shell 1.2 m (4 ft) from bottom
TT06	center of oven bottom plate

The thermocouples and RTDs that are located on the PM and auxiliary HRS skid are listed in Appendix A. Of particular interest is the auxiliary helium heater outlet temperature (pre-heat temperature of helium flowing to the MCO). The effect of this helium temperature on the heat up cycle will be evaluated as part of this testing.

4.5 PROCESS ENCLOSURE TESTING

The PE mock-up provided the SNFP Operations group with valuable information on enclosure window placement and sizing, component placement for robotic arm and crane access, and process trench accessibility when the trench covers are open. The only testing planned for the PE is to support robotic arm testing described in Section 4.6.

4.6 ROBOTIC ARM TESTING

This testing will evaluate the arm's ability to perform required manipulations such as removing the MCO shield plug port covers, installing the process connectors, and assisting with the shield plug heating cover installation. Some of the arm's repeatability, learning, and programming functions will also be tested. The arm must be programmed to operate in the process enclosure envelope efficiently and safely without damaging the enclosure, the arm, the process piping, or the MCO. SNFP operators will perform much of this testing, which will provide significant hands-on training.

5.0 RESPONSIBILITIES, TEST ADMINISTRATION, AND CONTROLS

5.1 RESPONSIBILITIES

5.1.1 306E Facility Management

D. G. Panther, J. R. Thielges

- Approves the test procedure and the Job Hazards Analysis (JHA).
- Provides personnel and equipment for fabrication of the PM, PE, process oven, and related test articles including mock fuel, scrap, and sludge.
- Provides space and personnel in the 306E Facility for performing testing.

5.1.2 HCS Design Authority

C. R. Miska

- Identifies requirements for HCS testing.
- Approves the test plan, test procedure, and test report.
- Provides technical expertise and guidance during testing of the HCS.
- Approves acceptability of test activities and test results and provides final authorization for significant test procedure changes, repeat tests, or cancellation of tests.

5.1.3 Test Director

K. J. McCracken

- Responsible for the overall performance of the test procedure.

- Approves the test plan, test procedure, and test report.
- Manages testing activities, such as coordinating facility and personnel resources.
- Acts as a liaison with the quality assurance (QA) representative and other test participants, as required.
- Directs the test engineer on test performance activities and reports to the design authority and 306E Facility management.
- The test director may act as a test engineer.

5.1.4 Technical Engineer

M. Throurgood

- Provides test design information and test data analysis as required throughout testing.
- May request a repeat test or test procedure change with concurrence from the test director.

5.1.5 Test Engineer

G. A. Ritter, K. J. Cleveland

- Prepares the test plan, test procedure, and test report.
- Ensures JHA is complete prior to testing.
- Ensures informal testing and inspection is complete.
- Conducts prejob safety briefings as required prior to initiating tests.
- Directs the test performers during test preparation and test performance and reports to the test director.
- Maintains and controls testing and documentation to ensure compliance with the test procedure.
- Approves minor field changes to the test procedure and coordinates the resolution of test exceptions.
- The test engineer may act as a test performer.

5.1.6 Test Performers/Operators

M. E. Dahl, M. L. Casto, F. L. Bolson

- Performs testing in accordance with the test procedure as directed by the test engineer.

- Records test data and observations as specified in the test procedure.

5.1.7 Industrial Safety

J. A. Charboneau

- Approves the JHA checklist.
- Approves the test procedure.
- Provides testing oversight to ensure compliance with applicable safety standards.

5.1.8 Quality Assurance

- Approves the test plan, test procedure, and test report.
- Ensures that quality requirements are defined and satisfied for the tests.
- Witnesses conductance of acceptance testing as identified in the test procedure steps. Testing may proceed in accordance with the test procedure without a QA representative present.
- Provides independent verification of the test apparatus configuration and instrumentation calibration as required.

5.1.9 Nondestructive Examination (NDE)

- Performs component or system leak testing during fabrication and testing as required.

5.2 TEST ADMINISTRATION AND PROCEDURE CONTROLS

5.2.1 Test Procedure Package

A controlled test procedure package shall be used for testing and shall include, as a minimum, single copies of the following:

- This test procedure.
- Instrument calibration sheets.
- Pre-job briefing records.
- Engineering calculations supporting testing activities.
- Additional documents required to perform, document, or validate a test.

All the above documents shall be marked "Controlled Copy" in red ink. The test procedure package shall be published as an appendix to the test report.

5.2.2 Test Data and Test Log

All test data, pertinent observations, off-normal events, sketches, and photographs, etc., shall be recorded in test data sheets provided in the appendices or in the test logbook, WHC-N-944, and maintained by the test engineer. All logbook entries shall be signed and dated in dark reproducible ink and adequately referenced to the appropriate section of this procedure. The test data sheet and test logbook entries shall be published in the test report.

5.2.3 Test Procedure Changes

Changes to the test procedure are permitted. Minor procedure changes such as editorial changes to a step, clarification of a step, elimination or addition of a step, or limited sequential changes of steps shall be noted in the controlled procedure by redline entries. Approvals of all redline changes shall be documented by the test engineer's initials and date next to the redlined item. Changes other than those just described must be recorded in the exception log (Appendix E), and a test exception form must be completed (Appendix F).

5.2.4 Test Procedure Exceptions

All exceptions to the procedure shall be documented in accordance with the instructions provided in Appendix D. The test procedure does not have to be changed if there is an exception, however, a change may be warranted if the exception causes a significant impact to the performance of the test procedure or influences data quality. Failure of instrumentation during a test, unless immediately correctable, must be recorded as an exception. The approval designator, a description of the exception, and a description of the disposition shall be entered on an exception form (Appendix F). Typical test exceptions are as follows:

- Test approved with exception (i.e., repeat of the test is unnecessary).
- Test procedure steps affected to be repeated after the discrepancy has been resolved.
- Entire test procedure to be repeated after the discrepancy has been resolved.

Test exceptions must be approved by a minimum of the test director and the appropriate test engineer. The test director and test engineer will decide whether to continue with the test procedure in the event of test instrumentation or equipment failure. Each exception shall be dispositioned prior to the close of the test procedure.

5.2.5 Repeat Testing

If a repeat test is required, additional copies of applicable procedure sections or data sheets may be used. The addition of procedure sections or data sheets to be used for retesting shall be added to the test procedure package and marked "Controlled Copy" in red ink.

5.2.6 Test Performance

Only the test director, test engineers, and approved test performers shall operate the HCS test equipment. Each test procedure section is performed sequentially. If two consecutive tests produce similar and reliable results, the third test can be waived with the agreement of the test engineer, test director, and technical engineer. The test engineer has authority to perform major sections out of sequence or concurrently (without a test procedure change) provided:

1. The "Special Prerequisites" in that section are completed.
2. Performing the section out of sequence will not adversely affect any unfinished (previous or subsequent) sections or adversely affect the test procedure performance schedule.
3. The section does not bypass basic equipment control and interlock tests (related to that section) that are being performed in previous sections.
4. Concurrence from the test director is obtained and entered into the test log.
5. **NO HOLD POINTS**, indicated by **(HP)** in the left hand margin, shall be by-passed.

5.2.7 Test Personnel Signatures/Signoffs

All personnel entering signatures or initials in the test procedure must print their name, responsibility, and provide their signature and initials in the test procedure signature verification sheet (Appendix B).

The test engineer shall sign off test steps where indicated in the test procedure to certify that direct observation or inspection has been performed, or that notification was received from test personnel signifying that the step was performed.

5.2.8 Measurement Accuracy

Dimensional measurements shall be taken to the nearest millimeter. Temperature measurements shall be taken to the nearest 2 °C. Pressure measurements shall be taken to the nearest 10 Pa (0.1 Torr). Time measurements will be to the nearest 5 minutes unless specified otherwise. Data logging shall be to the nearest 10 seconds.

5.2.9 Video Recording

If visual observations are to be performed as specified in a procedure section, then at least one test in that section shall be video recorded to document the observations.

6.0 SAFETY

Safety information and standards are contained in CM-1-10, *Safety Manual*. The following sections specify safety requirements and precautions applicable to this testing.

6.1 PERSONNEL PRECAUTIONS

6.1.1 Injury Notification

The 306E building administrator and industrial safety representative shall be immediately notified if any personnel injury occurs. If the injury also warrants the need for outside assistance, medical aid shall be obtained by phoning 911. The emergency points-of-contacts and their phone numbers will be identified on applicable pre-job planning documents.

6.1.2 Job Hazard Analysis

A JHA checklist shall be prepared prior to testing and approved by the industrial safety representative and 306E facility management. All personnel performing this test procedure and related work shall read and sign the JHA for this job. The on-shift test engineer shall be responsible for ensuring that this requirement is met.

6.1.3 Lock and Tag

Lock and tag shall be conducted in accordance with HNF-PRO-081, *Hazardous Energy Control Program* as applicable, and zero energy checks, mechanical or electrical, shall be performed on the affected system.

6.1.4 Lifting

All manual lifting shall be performed in accordance with CM-1-10, and all mechanical lifts shall be performed in accordance with DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual*.

6.1.5 Test Equipment Operation

Only the test director, test engineers, and approved test performers shall operate the HCS test equipment.

6.2 EQUIPMENT PRECAUTIONS

6.2.1 Energizing Equipment

Supply power to a component must be off when connecting or disconnecting any electrical cables to that component.

6.2.2 Equipment Operating Manuals

The operating manuals for the blowers, heaters, vacuum pumps, etc., shall be read and understood prior to testing to prevent damage to the equipment. Personnel safety and equipment precautions specified in the operating manuals shall be identified on the JHA and complied with throughout testing.

7.0 PREREQUISITES

The following sections specify prerequisites that must be completed prior to the start of the entire test procedure. In addition, some sections of the test procedure have special prerequisites that must be completed prior to starting that particular section only.

7.1 INSTRUMENTATION CALIBRATION

The test engineer and QA representative shall verify that test instrumentation, items 2 through 7 in Appendix A, are within their current calibration cycle. Place all calibration records in Appendix H and sign below to confirm that test instrumentation are calibrated.

_______________________ / __________
Test Engineer Date

_______________________ / __________
QA Date

7.2 NDE LEAK TEST

A helium leak test shall be performed by qualified NDE personnel on all VPS and HRS process lines prior to testing. Also, a helium leak test shall be performed on the oven annular space (insulated space), and on the assembled MCO. The leak rate of the process system, which includes the VPS, HRS, and MCO, shall be less than 1×10^{-5} std. cm^3/s. The leak rate of the oven annular space shall be less than 1×10^{-6} std. cm^3/s. If there is excess leakage in the system, perform diagnostics, and contact test engineer to assist in system repair. After repairs are complete, recheck leak rate.

Record equipment calibration information in Appendix H and leak test results in Appendix I. Sign below to indicate initial system leak tests have been satisfactorily completed.

_______________________ / __________
Test Engineer Date

_______________________ / __________
NDE Date

7.3 PRE-JOB SAFETY BRIEFING

Prior to the start of any work performed under this test procedure, a pre-job safety briefing shall be conducted. Additional pre-job briefings will be performed throughout testing as required by the test director. The briefing shall be chaired by the test director or his designee. For each pre-job briefing, the form provided in Appendix C shall be completed. As applicable, the following topics will be discussed:

- Expected testing to occur on shift
- Test procedure status including changes in test procedure or scope
- Special safety concerns, including lifting precautions and high temperature gas safety
- General facility status
- Review of applicable MSDS's
- Employee concerns
- Lessons learned
- Review of the JHA.

Place all pre-job briefing forms in Appendix C.

8.0 EQUIPMENT PERFORMANCE TEST PROCEDURE

8.1 PROCESS CONNECTOR LEAK TESTING AND SEAL LONGEVITY

8.1.1 Special Prerequisites/Instructions

8.1.1.1 Mount MCO process connector in the test assembly (Figure 7) and torque bolts to the test engineer's direction. Record torque value in the test logbook along with a sketch of the test assembly.

8.1.1.2 Perform helium leak check with calibrated leak detection equipment and qualified NDE personnel. Verify that the leak rate is less than 1 x 10^{-4} std. cm^3/s. Record initial baseline leak rate below.

______________	______________ / ______	______________
Baseline leak rate	NDE Date	Report number

8.1.1.3 Record leak rate results obtained in the following section in Appendix J.

8.1.1.4 Contact the test engineer when failure occurs.

8.1.2 Instructions

8.1.2.1 Mount process connector in test assembly if not already done and actuate the mock MCO valve two times. Place test assembly in the furnace and heat the test assembly to 300°C (-0, +50°C).

8.1.2.2 Evacuate the system and perform leak test per step 8.1.1.2 if directed by the test engineer.

8.1.2.3 Allow the system to cool to ambient temperature and repeat leak test if directed by test engineer.

8.1.2.4 Remove the test assembly from the furnace and remove the process connector from the test assembly.

8.1.2.5 Repeat steps 8.1.2.1 through 8.1.2.4 up to 50 times. Perform leak tests periodically as directed by the test engineer. Typically, leak tests will be performed for the first cycle, and then after 5, 10, 20, 30, 40, and 50 cycles. The test is complete when the system leak rate is unacceptable or if 50 cycles have been achieved while maintaining a satisfactory seal. Record final leak rate and number of cycles below.

________________	________________	/ ________	________________
Final leak rate	NDE	Date	Report number

8.2 VACUUM PUMP BACKFLOW

8.2.1 Special Prerequisites/Instructions

8.2.1.1 Record results in Appendix K.

8.2.1.2 Verify inlet piping between pump inlet and pump isolation valve are leak tight.

8.2.2 Instructions

8.2.2.1 Isolate the vacuum pump from system by closing the pump isolation valve and evacuate the pump inlet piping to pump base pressure ($10^{-2} < P < 10^{-1}$ Torr). Record the pump inlet pressure.

8.2.2.2 Stop any ballast gas or seal gas into the pump and shut off power to the pump.

8.2.2.3 Record the pressure rise on the inlet piping for a 1 hour period and note observations in the test logbook.

8.2.2.4 Repeat steps 8.2.2.1 through 8.2.2.3 two additional times.

9.0 PROCESS HEATING AND COOLING SYSTEM TEST PROCEDURE

9.1 HEATING CYCLE

9.1.1 Special Prerequisites/Instructions

9.1.1.1 Verify that thermocouples have been installed on the process oven, MCO exterior, and MCO interior per Section 4.4 and Figures 5 and 6. Note any changes to thermocouple locations in the test logbook. Verify that the thermocouples have been connected to the PCS for data acquisition and that the PCS if functioning correctly.

9.1.1.2 Verify that the MCO has been loaded with 1 scrap basket and 4 fuel baskets. Record description of the MCO contents in the test logbook.

9.1.1.3 Verify that the shield plug heat cover is installed and that the insulated space between the oven shells has been evacuated to less than 10^{-2} Pa (10^{-4} Torr).

9.1.1.4 Verify that the PHS and associated equipment are ready for testing.

_______________________ / __________
Test engineer Date

9.1.1.5 Refer to the P&ID drawing, Figures 1 through 3, for equipment, valves, and instrumentation numbers.

9.1.1.6 Use PCS to record MCO and oven temperatures at a minimum of every 10 minutes.

CAUTION: **PERSONNEL** are **NOT** allowed **INSIDE** the barricaded area when heating/cooling tests are in progress.

9.1.2 HRS/VPS Start-up Instructions

9.1.2.1 Evacuate the MCO and VPS/HRS lines to remove air by turning on vacuum pump VPS-P-2P02 and setting valves to the following positions:

1. Close GOV-2P20 and GOV-2P22.
2. Open GOV-2P03, GOV-2P09, GOV-2P16, GOV-2P17, HRS-V-P55, HE-V-P46.

9.1.2.2 After a vacuum of less than 133 Pa (1 Torr) has been achieved as indicated on PI-2P05, set valves in the following positions for establishing a helium purge through the MCO:

1. Close GOV-2P03, GOV-2P16, GOV-2P20, and GOV-2P22.
2. Open GOV-2P09, GOV-2P17, HRS-V-P55, and HE-V-P46.

NOTE: If a vacuum of 133 Pa (1 Torr) cannot be achieved, there is a large leak in the system. Fix leak before continuing with this start-up procedure.

9.1.2.3 Start building air flow through heat exchanger VPS-CLR-2P01 by opening GOV-2P22. Record pressure regulator setting and flow rate in the test logbook.

9.1.2.4 Start compressor HRS-P-4002 to establish a helium purge through the MCO. Verify that a flow rate of at least 0.0047 m^3/s (10 scfm) is indicated on FIC-2P23.

CAUTION: Closely monitor TI-2P02 throughout the heating cycle to prevent damage to the compressor. If the temperature exceeds 38°C (100°F), immediately close GOV-2P09 and stop compressor.

9.1.2.5 Start heater PHS-HTR-4003 with TIC-4005 set to initial temperature according to the test engineer's direction. This heater is used to preheat helium flow to the MCO and the set point temperature should be adjusted according to the test engineer's direction. Typically, it is set approximately 5 °C (10 °F) less than the temperature of the heat exchanger inlet as indicated on TI-2P01. Monitor the helium temperature on TI-4005.

9.1.3 PHS Equipment Start-up Instructions

9.1.3.1 Start blower PHS-BLO-3P03 with TV-3P09 closed and verify that at least 0.19 m^3/s (400 cfm) flow is indicated on FI-3P12. If the flow rate is less than 0.19 m^3/s, then stop blower and troubleshoot system before proceeding.

NOTE: Operation of the blowers and heaters shall be in accordance with the manufacturer's operating manuals. Specifically, the following requirements apply to operating blower PHS-BLO-3P03:

- The blower shall not be heated/cooled at a rate in excess of 56 °C/h (100 °F/h)

- In the event of power failure or interruption of fan operation at high temperatures, it is imperative that the fan be rotated by hand or other means until the gas temperature decreases below 93 °C (200 °F).

9.1.3.2 Start heater PHS-HTR-3P04 with TIC-3P09 set to initial temperature according to the test engineer's direction. Record temperature set points and ramp rates in the test logbook.

9.1.3.3 Start blower PHS-BLO-3P05 with TV-3P15 closed and verify that at least 0.035 m^3/s (75 cfm) flow is indicated on FI-3P18. If the flow rate is less than 0.035 m^3/s then stop blower and troubleshoot system before proceeding.

9.1.3.4 Start heater PHS-HTR-3P06 with TIC-3P15 set to initial temperature according to the test engineer's direction. Record temperature set points and ramp rates in the test logbook.

9.1.4 Operating Instructions

9.1.4.1 Monitor MCO temperatures and adjust temperature set points/ramp rates to heat the MCO and its contents to 300 °C. Record adjustments and any other observations in the test logbook. The objective is to minimize heat up time while ensuring that the following criteria, as specified in Section 4.4, are being satisfied:

1) Heat the MCO to 300 °C (+50 °C, -0 °C), but at a rate not to exceed 100 °C/hr.
2) Maintain the MCO wall temperature below 350 °C to prevent exceeding the MCO temperature design limit of 375 °C.
3) Maintain a temperature differential between any two points on the MCO of less than 100 °C.

If, for example, temperature variations between the MCO and shield plug approach 100 °C, reduce the heater output to the section with the highest temperature (i.e., if the MCO temperature is almost 100 °C greater than the shield plug, reduce PHS-HTR-3P04 output).

9.1.4.2 Maintain helium flow through the MCO at greater than or equal to 0.0047 m^3/s (10 scfm) during the heat up cycle.

9.1.4.3 Simulate a high hydrogen concentration event if directed by the test engineer. This type of event would normally interrupt the heating process and the set points of TIC-3P09 and TIC-3P15 would be held or decreased as required. If temporary cooling is desired, start blower CVS-BLO-5001 and open TV-3P09 and TV-3P15 to accelerate cooling.

9.1.4.4 Monitor the fuel element temperatures and record time for each fuel element to reach 300 °C.

9.1.4.5 Test is complete when all fuel element temperatures reach at least 300 °C. Record final temperatures of all MCO and oven thermocouples when the test is complete.

9.1.4.6 Continue on to the cooling cycle as directed by the test engineer. Repeat heating cycle test in accordance with the test engineer's instructions.

9.2 COOLING CYCLE

9.2.1 Special Prerequisites/Instructions

9.2.1.1 The temperatures of the MCO and fuel are at least 300 °C.

9.2.1.2 Use PCS to record MCO and oven temperatures at a minimum of every 10 minutes.

9.2.2 Instructions

9.2.2.1 Verify the building air supply fan to TV-3P09, CVS-BLO-5001, is operating per the test engineer's direction.

9.2.2.2 Verify blower PHS-BLO-3P03 is operating with at least 0.19 m^3/s (400 cfm) flow as indicated on FI-3P12. Shut off power to heater PHS-HTR-3P04 and adjust set point of TIC-3P09 per the test engineer's direction. TIC-3P09 manipulates temperature control valve TV-3P09 to control the cooling process. Record set points and observations in the test logbook.

9.2.2.3 Verify blower PHS-BLO-3P05 is operating with at least 0.035 m^3/s (75 cfm) flow as indicated on FI-3P18. Shut off power to heater PHS-HTR-3P06 and adjust set point of TIC-3P15 per the test engineer's direction. TIC-3P15 controls TV-3P15. Record set points and observations in the test logbook.

9.2.2.4 Verify that helium flow through the MCO is maintained at greater than or equal to 0.0047 m^3/s (10 scfm) during the cooling cycle.

9.2.2.5 Monitor the cooling rate along with the MCO and oven temperatures to verify that the following criteria, as specified in Section 4.4, are satisfied.

1) Cool the MCO to the specified temperature at a rate not to exceed 100 °C/hr.
2) Maintain a temperature differential between any two points on the MCO of less than 100 °C.

Adjust temperature set points according to the test engineer's directions and note any adjustments in the test logbook.

9.2.2.6 Record the time in the logbook when all the mock fuel elements have reached the specified final temperature and the MCO wall temperature has decreased to below 122 °C.

9.2.2.7 Repeat heating and cooling cycles, Section 9.1 and 9.2 respectively, as directed by the test engineer.

9.3 LOSS OF VACUUM IN OVEN INSULATED SPACE

9.3.1 Special Prerequisites/Instructions

9.3.1.1 The objective of this test is to verify that the temperature on the outside of the oven will not exceed 66°C (150°F) if the vacuum system for the oven insulated space fails. This temperature corresponds to the concrete design specified temperature limit for the HCS facility.

9.3.1.2 Use PCS to record MCO and oven temperatures at a minimum of every 10 minutes.

9.3.2 Instructions

9.3.2.1 Start heat-up cycle in accordance with Section 9.1 and allow MCO mock fuel temperatures to reach a set point as specified by the test engineer.

9.3.2.2 Stop the vacuum system to the oven insulated space and allow oven annulus to reach atmospheric pressure.

9.3.2.3 Continue heating and logging temperatures at least every 10 minutes as directed by the test engineer. Closely monitor thermocouple temperatures on the outside of the process oven and note temperatures in excess of 66°C (150°F) along with pertinent observations in the test logbook.

9.3.2.4 Cool the system to ambient temperature following the cooling cycle specified in Section 9.2.

9.3.2.5 Repeat steps 9.3.2.1 through 9.3.2.4 as directed by the test engineer.

10.0 MANIPULATOR ARM TEST PROCEDURE

10.1 PREREQUISITES

10.1.1 Special Setup Instructions

10.1.1.1 Perform suspect bolt inspection on the manipulator.

____
QA

10.1.1.2 Mount manipulator arm on stand in test process enclosure.

10.1.1.3 Set enclosure on platform 0.77 m (30.5 inches) off the floor.

10.1.1.4 Place mock shield plug on the floor using cribbing in the designated trench area in enclosure.

10.1.1.5 Build platform for operator on the front of the enclosure at enclosure floor level.

10.1.1.6 Set limits on manipulator to ensure arm will not contact process enclosure.

10.1.2 Manipulator Startup Instructions

NOTE: ONLY PROPERLY TRAINED PERSONNEL ARE ALLOWED TO START AND OPERATE THE MANIPULATOR ARM.

10.1.2.1 Ensure Section 10.1.1 is complete.

10.1.2.2 Ensure no personnel are inside the process enclosure.

10.1.2.3 Turn on the junction box switch.

10.1.2.4 Start power to the master controller. If error messages appear on display screen refer to Titan III technical manual.

10.1.2.5 Start HPU.

10.1.2.6 Enable arm hydraulics. Immediately turn hydraulics off if the slave arm moves from its current position.

10.1.2.7 Ensure that no objects are inside the arm deployment path (called the "stow out" path).

10.1.2.8 Stow out the slave arm.

WARNING: Monitor the hydraulic fluid temperature and return pressure during manipulator operations. If the temperature exceeds 49°C (120°F) or the return pressure exceeds 2.76 MPa (400 psi) shut the system down.

10.1.3 Manipulator Shutdown Instructions

10.1.3.1 Select SHUTDOWN from the MAIN menu.

10.1.3.2 Move slave arm to a position that approximates the STOW OUT position.

10.1.3.3 Begin the stow-in sequence.

10.1.3.4 When arm has reached the STOW IN position disable hydraulics to the arm.

10.1.3.5 Turn off the HPU.

10.1.3.6 Turn off power to the master controller.

10.1.3.7 Turn off power to the junction box.

10.2 VALVE PLUG ACTUATOR

10.2.1 Special Prerequisites/Instructions

10.2.1.1 Record results, observations, and recommendations in the test logbook.

10.2.1.2 Record manipulator operations using the video camera in the process enclosure.

10.2.1.3 Develop different tools and strategies to perform the required tasks inside the process enclosure.

10.2.2 Installation Instructions

10.2.2.1 Perform manipulator startup instructions in Section 10.1.2.

10.2.2.2 Loosen bolts on process port cover plate and remove process port cover plate and store it out of the way.

10.2.2.3 Pick up the valve plug actuator and install in the shield plug port.

CAUTION: Do not grab flexible process hose with robotic arm.

10.2.2.4 Torque valve plug actuator bolts per test engineer specified torque value and record value in test logbook.

10.2.2.5 Loosen bolts on pressure relief valve, remove, and store out of the way.

10.2.2.6 Install rupture disks and torque bolts.

10.2.2.7 Operate valve actuator.

10.2.2.8 If process hoses are not on pipe support, use hook tool to align the process hoses on the support.

10.2.2.9 Perform arm shutdown sequence Section 10.1.3.

10.2.2.10 Use calibrated torque wrench to verify bolt torque values and note comparison in logbook.

10.2.3 Removal Instructions

10.2.3.1 Perform manipulator startup instructions in Section 10.1.2.

10.2.3.2 Use valve actuator to close shield plug valve and torque to test engineer specified value. Record torque value in test logbook.

10.2.3.3 Loosen bolts on valve plug actuator and place actuator back in its resting place in the trench.

10.2.3.4 Ensure process hoses are clear of the MCO.

10.2.3.5 Perform arm shutdown instructions in Section 10.1.3.

10.2.3.6 Use calibrated torque wrench to verify bolt torque values and note comparison in logbook.

10.3 SHIELD PLUG INSULATION COVER

10.3.1 Special Prerequisites/Instructions

10.3.1.1 Record results, observations, and recommendations in the test logbook.

10.3.1.2 Record manipulator operations using the video camera in the process enclosure.

10.3.1.3 Develop different tools and strategies to perform the required tasks inside the process enclosure.

10.3.1.4 Install shield plug valve actuator.

10.3.2 Installation Instructions

10.3.2.1 Perform manipulator startup instructions in Section 10.1.2.

10.3.2.2 Position overhead crane above shield plug insulation cover.

10.3.2.3 Attach crane hook to insulation cover.

10.3.2.4 Raise insulation cover and position over shield plug.

10.3.2.5 Slowly lower insulation cover onto shield plug using manipulator to guide insulation cover over flexible process hoses.

10.3.2.6 When cover is in place unhook crane from insulation cover.

10.3.2.7 Perform arm shutdown instructions in Section 10.1.3.

10.3.3 Removal Instructions

10.3.3.1 Perform manipulator startup instructions in Section 10.1.2.

10.3.3.2 Position overhead crane over insulation cover and lower hook.

10.3.3.3 Use arm to attach hook to insulation cover.

10.3.3.4 Remove insulation cover and place on top shelf.

10.3.3.5 Use arm to disconnect hook from insulation cover.

10.3.3.6 Perform arm shutdown instructions in Section 10.1.3.

11.0 MANIPULATOR ARM SAFETY QUALIFICATION TEST PROCEDURE

(NOTE: SECTION 11.0 IS FOR INFORMATION ONLY!!!)

11.1 LOAD TEST

11.1.1 Special Prerequisites/Instructions

11.1.1.1 Record results, observations, and recommendations in the test logbook.

11.1.1.2 Record manipulator operations using the video camera in the process enclosure.

11.1.2 Manufacturer Rated Load Test

11.1.2.1 Perform arm startup instructions Section 10.2.

11.1.2.2 Place 1112 N (250 lb) load 2 m (76 in.) from the base with lifting strap long enough to reach arm in horizontal position.

11.1.2.3 Grasp shackle on end of strap with jaw.

11.1.2.4 Lift load with arm.

11.1.2.5 Perform arm shutdown instructions Section 10.3.

11.1.2.6 Record observations.

11.1.3 150% Rated Load Test

11.1.3.1 Perform arm startup instructions Section 10.2.

11.1.3.2 Place 1668 N (375 lb) load 2 m (76 inches) from the base with lifting strap long enough to reach arm in horizontal position.

11.1.3.3 Grasp shackle on end of strap with jaw.

11.1.3.4 Attempt to lift load with arm.

11.1.3.5 Record any error messages on the master controller.

11.1.3.6 Perform arm shutdown instructions Section 10.3.

11.1.3.7 Record observations and examine arm for damage.

11.1.3.8 If no damage is observed repeat Section 11.1.2.

11.2 FAILURE MODE TESTING

11.2.1 Special Prerequisites/Instructions

11.2.1.1 Record results, observations, and recommendations in the test logbook.

11.2.1.2 Record manipulator operations using the video camera in the process enclosure.

11.2.1.3 Remove flexible hose from valve actuator.

11.2.2 Power Failure

11.2.2.1 Perform arm startup instructions Section 10.2.

11.2.2.2 Lift simulated valve actuator and position arm in a horizontal orientation.

11.2.2.3 Turn power off to junction box.

11.2.2.4 Observe arm for one hour.

11.2.2.5 Record observations every 5 minutes.

11.2.2.6 Develop recovery techniques for arm in its final resting position.

11.2.2.7 Repeat steps 11.2.2.1 through 11.2.2.6 with arm holding the valve actuator at trench level.

11.2.2.8 Perform arm shut down instructions Section 10.3.

11.2.3 Hydraulic Failure

11.2.3.1 Perform arm startup instructions Section 10.2.

11.2.3.2 Lift simulated valve actuator and position arm in a horizontal orientation.

11.2.3.3 Turn power off to hydraulic power unit.

11.2.3.4 Observe arm for one hour.

11.2.3.5 Record observations every 5 minutes.

11.2.3.6 Develop recovery techniques for arm in its final resting position.

11.2.3.7 Repeat steps 11.2.3.1 through 11.2.3.6 with arm holding the valve actuator at trench level.

11.2.3.8 Perform arm shut down instructions per Section 10.3.

Figure 1. MCO and Trench P&ID

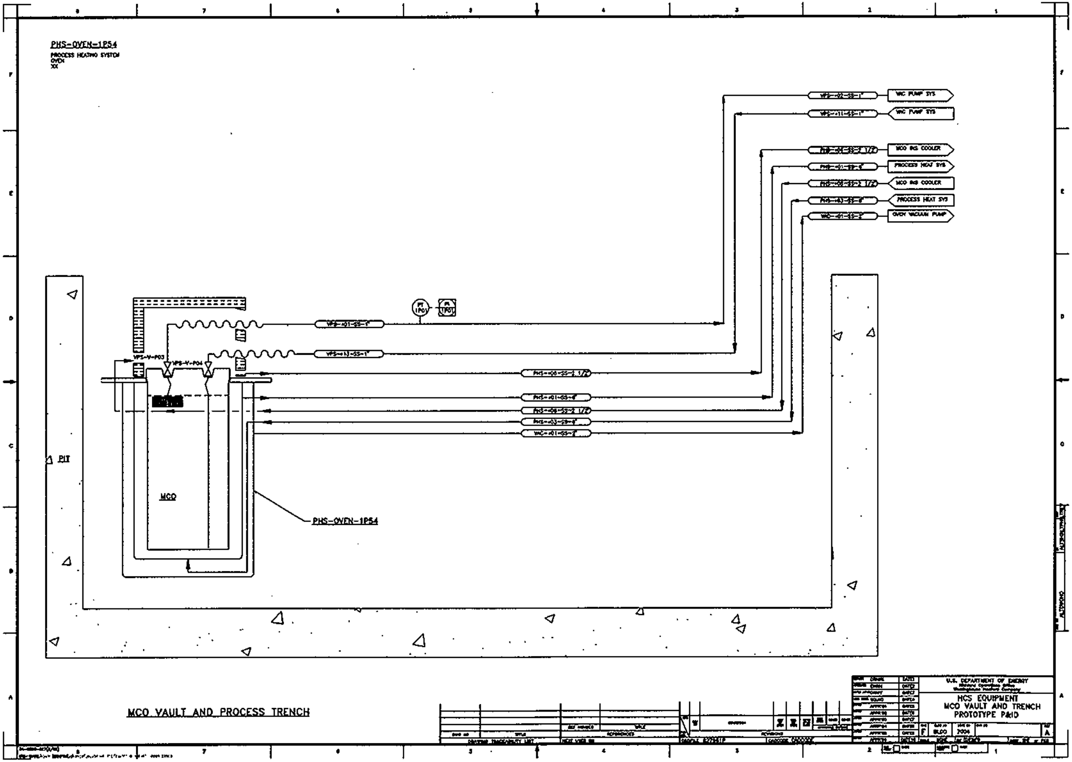


Figure 2. Vacuum Pumping System P&ID

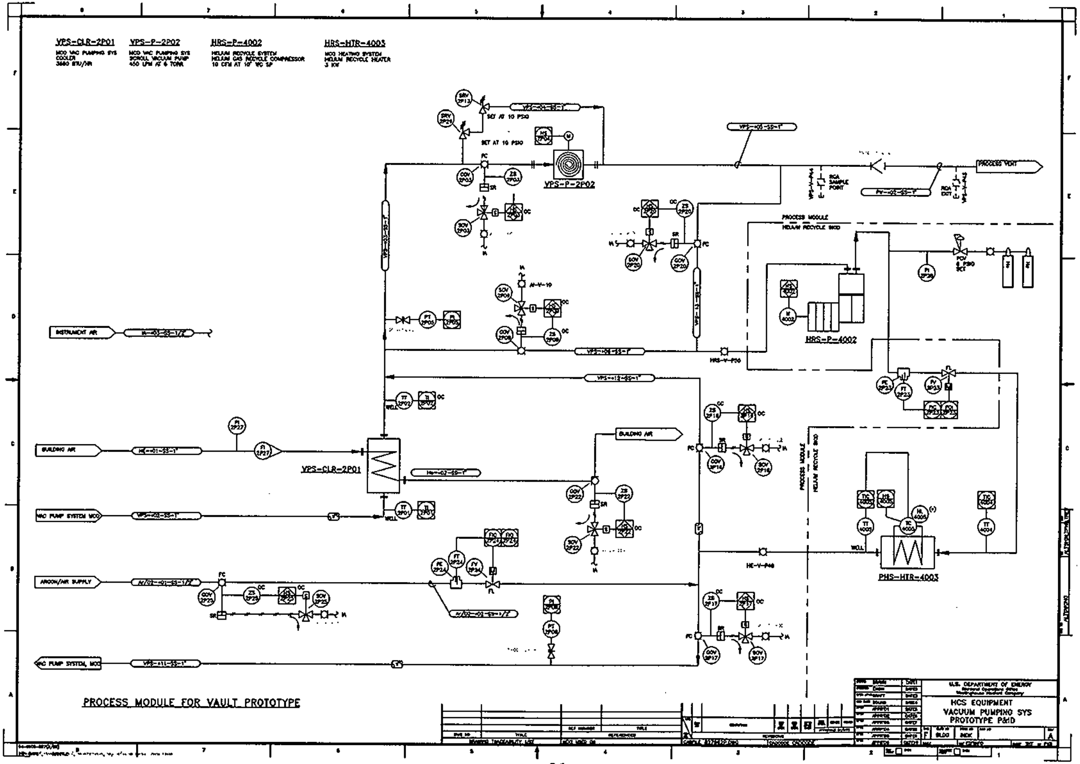


Figure 3. Process Heating System and Oven Vacuum P&ID

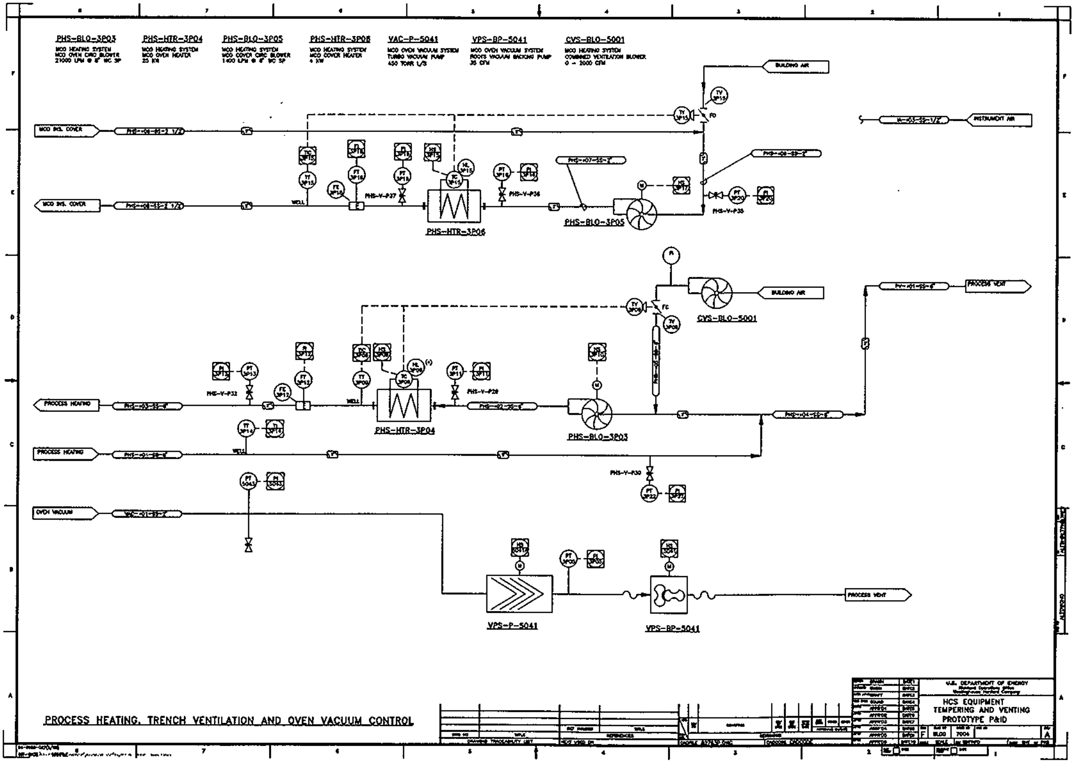


Figure 4. Control System Layout

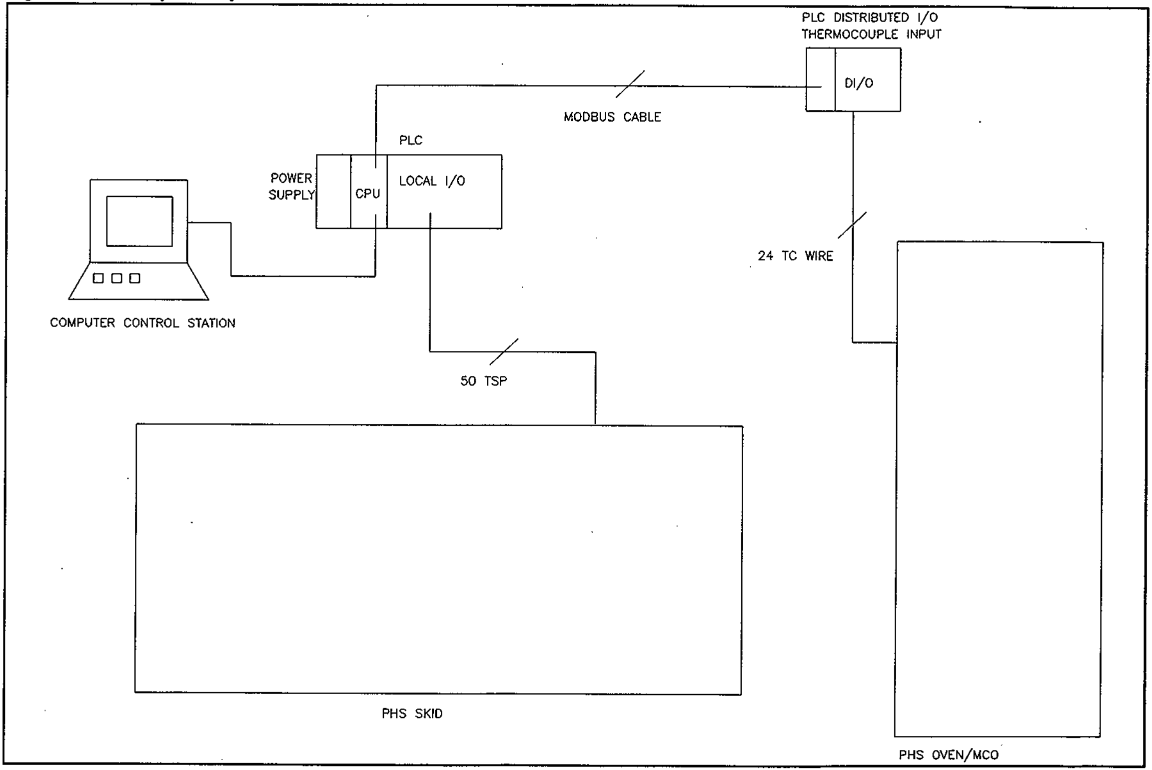
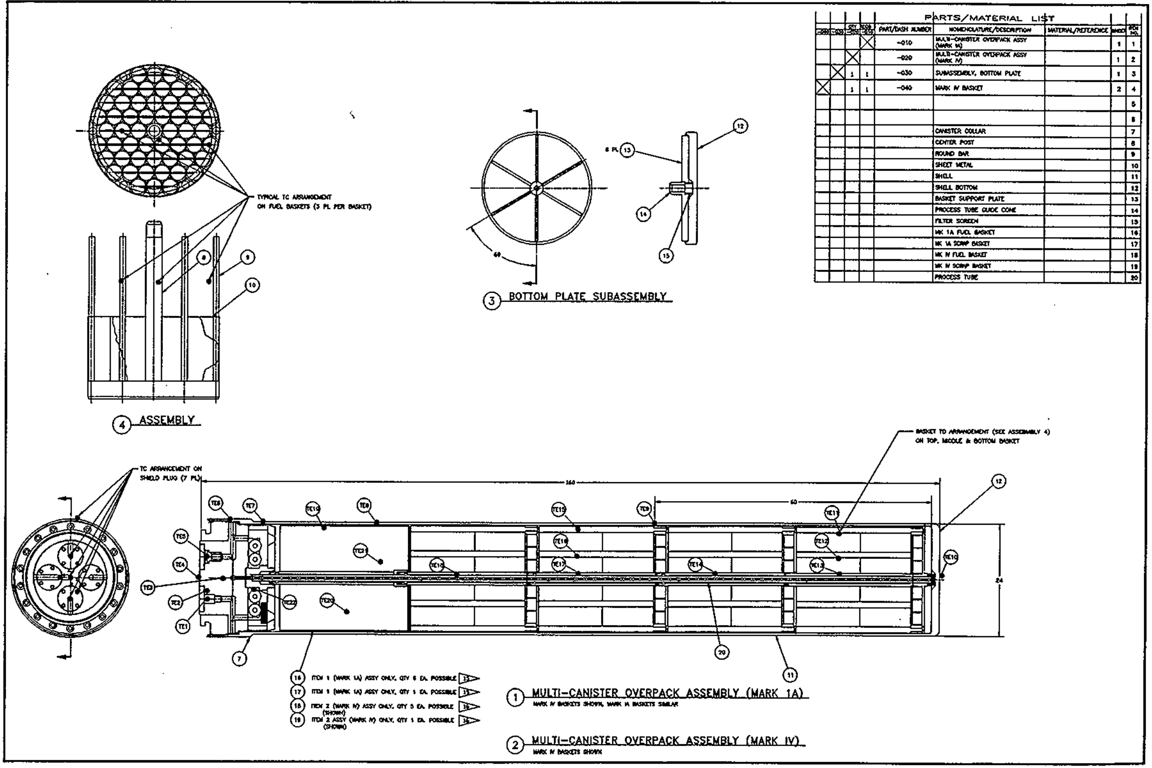


Figure 5. MCO Thermocouple Layout



PARTS/MATERIAL LIST

		QTY REQ'D		PART/DASH NUMBER	NOMENCLATURE/DESCRIPTION	MATERIAL/REFERENCE	SHEET	ITEM NO.
			X	-010	MULTI-CANISTER OVERPACK ASSY (MARK 1A)		1	1
		X		-020	MULTI-CANISTER OVERPACK ASSY (MARK IV)		1	2
	X	1	1	-030	SUBASSEMBLY, BOTTOM PLATE		1	3
X		1	1	-040	MARK IV BASKET		2	4
								5
								6
					CANISTER COLLAR			7
					CENTER POST			8
					ROUND BAR			9
					SHEET METAL			10
					SHELL			11
					SHELL BOTTOM			12
					BASKET SUPPORT PLATE			13
					PROCESS TUBE GUIDE CONE			14
					FILTER SCREEN			15
					MK 1A FUEL BASKET			16
					MK 1A SCRAP BASKET			17
					MK IV FUEL BASKET			18
					MK IV SCRAP BASKET			19
					PROCESS TUBE			20

Figure 6. Prototype HCS Equipment Layout

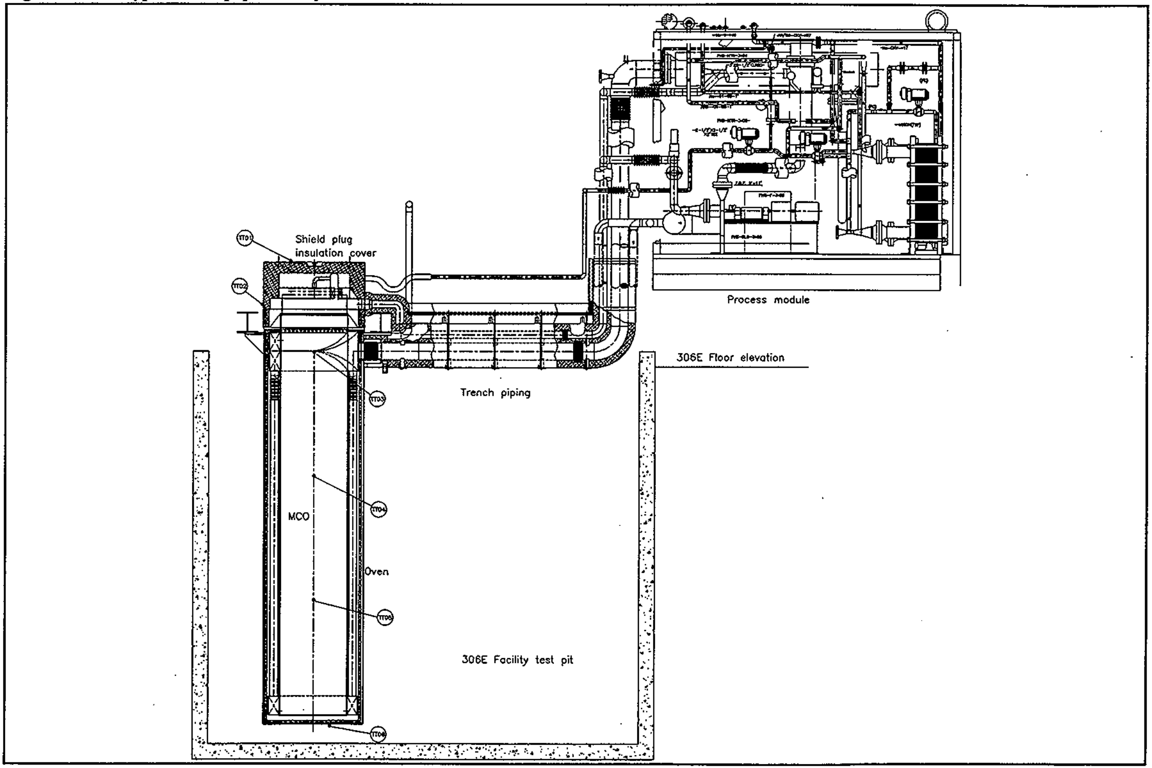
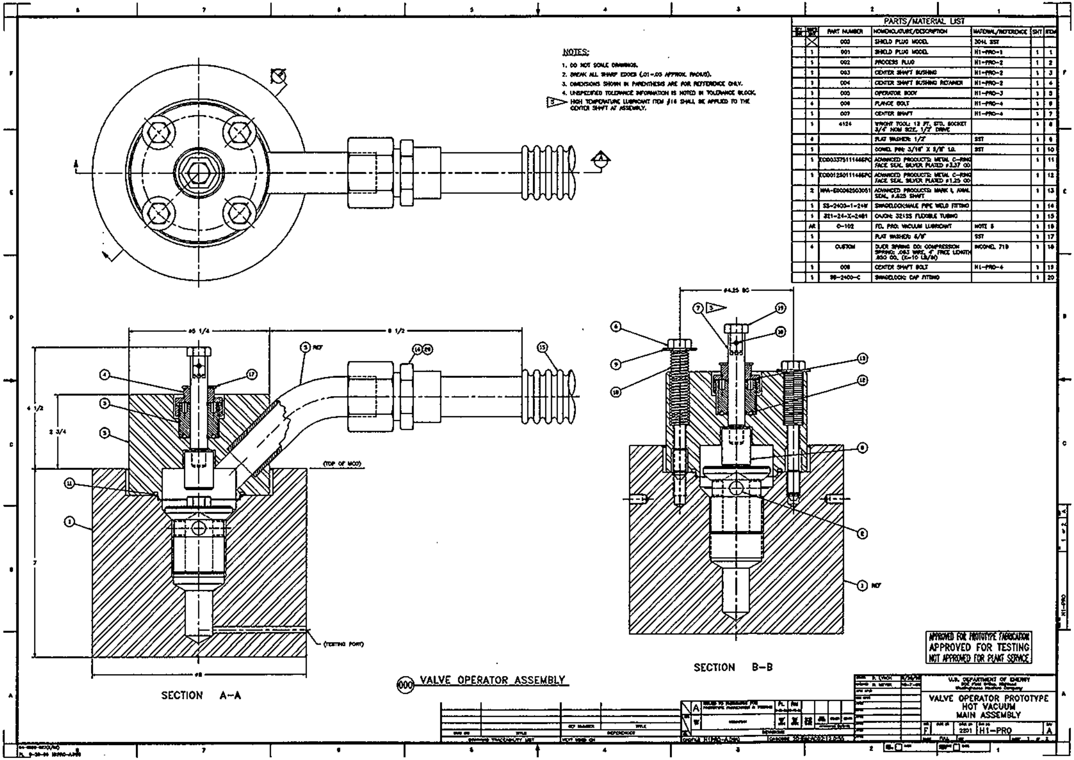


Figure 7. Prototype Valve Operator



APPENDIX A
INSTRUMENTATION

Item No.	Qty	Description	Specs.	Cert. Required
1	16	PLC cards	Modicon or approved equal	N/A
2	2	Vacuum pressure indicators - Capacitance manometer type capable of ranges 10^{-3} to 10^{+3} Torr with 0-10 VDC or 4-20 mA DC analog output, Pirani and cold cathode capable of 10^{-4} Torr accuracy.	MKS-100 or 200 series or approved equal	NIST and/or QA compare
3	24	Thermocouples - Type K (chromel/alumel).	Omega TJ36-CASS-116G-12 or approved equal	NIST and/or QA compare
4	13	RTDs - Platinum.	Omega PR-13-2-100-0.25"-12-E or approved equal	NIST and/or QA compare
5	2	Mass Flow Meter and Control System - Capable of 0 to 10 cfm Helium and Argon with an analog 4-20 mA or voltage output.	Kurz series or approved equal	NIST
5	2	Flow Meter - Capable of 0 to 750 cfm with an analog 4-20mA or voltage output.	Deterich Standard or approved equal	N/A
7	7	Pressure sensors - Pressure ranges 0 to 30" WC absolute 316 SS.	Rosemount Measurement 1151	NIST
8	1	Rotometers	Dwyer or approved equal	N/A
9	5	Gas Operated valves	Worcester or approved equal	N/A
10	2	Temperature Control Valves 4-20 mA, fully closed to fully open	Centerline or approved equal	N/A

PLC Cards

The PLC cards for the local I/O addresses are as follows:

Slot	Module	Input Ref Address	Output Ref Address	Description	Amps
1	CPS 114 xx			AC PS 115/230V 8A	--
2	CPU x13 0x			CPU 1xMB+	0.78
3	AVI 030 00	300001-300010		AN IN 8CH BIPOLAR	0.28

Slot	Module	Input Ref Address	Output Ref Address	Description	Amps
4	AVI 030 00	300011-300020		AN IN 8CH BIPOLAR	0.28
5	AVI 030 00	300021-300030		AN IN 8CH BIPOLAR	0.28
6	ARI 030 10	300031-300039		RTD IN 8CH	0.20
7	ARI 030 10	300040-300048		RTD IN 8CH	0.20
8	ACO 020 00		400001-400004	AN OUT 4CH CURR	0.48
9	ACO 020 00		400005-400016	AN OUT 4CH CURR	0.48
10	DAI 540 00	100001-100016		AC IN 115V 16x1	0.18
11	DAO 840 00		000001-000016	AC OUT 24-230V 16x1	0.35
12	DRC 830 00		000017-000024	RELAY OUT 8x1 NO/NC	0.56
13	SPARE				--
14	SPARE				--
15	SPARE				--
16	SPARE				--
				Total Amps	4.07

The distributed I/O addresses are as follows:

Slot	Module	Input Ref Address	Output Ref Address	Description	Amps
A	CRA 21x x0			DIO DROP MB+	--
B	ATI 030 00	300049-300057		TC IN 8CH	0.28
C	ATI 030 00	300058-300066		TC IN 8CH	0.28
D	ATI 030 00	300067-300075		TC IN 8CH	0.28
				Total Amps	0.84

Thermocouples

The thermocouple (designated as TE**) arrangement consists of the following:

TE1 MCO inlet port (filter)
TE2 shield plug port bolt hole
TE3 shield plug center, inserted in hole 12.7 cm (5 in.) deep from top of shield plug
TE4 center of shield plug top

TE5	MCO outlet port (dip tube)
TE6	outer shell 7.6 cm (3 in.) above shield plug bottom
TE7	outer shell 7.6 cm (3 in.) below shield plug bottom
TE8	outer shell 3.0 m (10 ft) from bottom
TE9	outer shell 1.5 m (5 ft) from bottom
TE10	center of bottom plate
TE11	midsection of fuel element located nearest the outside of basket 1 (bottom)
TE12	midsection of fuel element located midway between center and outside of basket 1
TE13	midsection of center column of basket 1
TE14	midsection of center column of basket 2
TE15	midsection of fuel element located nearest the outside of basket 3
TE16	midsection of fuel element located midway between center and outside of basket 3
TE17	midsection of center column of basket 3
TE18	midsection of center column of basket 4
TE19	midsection of scrap element located nearest the outside of basket 5 (top)
TE20	midsection of scrap element located midway between center and outside of basket 5
TE21	midsection of center column of basket 5
TE22	MCO filter pleat

Resistance Thermal Detectors (RTDs)

The RTDs are a 3 wire platinum, 100 Ohm, European alpha coefficient 0.00385 RTD and are designated as TT-****, for those located on the PM.

RTD Locations are as follows:

TT-2P01	inlet to system heat exchanger
TT-2P02	outlet of system heat exchanger
TT-4004	inlet to Helium heater
TT-4005	outlet to Helium heater
TT-3P14	inlet of oven blower
TT-3P09	outlet of oven heater
TT-3P15	outlet of shield plug heater
TT01	top of shield plug heating cover
TT02	bottom side of shield plug heating cover
TT03	outer shell 3.6 m (12 ft) from bottom
TT04	outer shell 2.4 m (8 ft) from bottom
TT05	outer shell 1.2 m (4 ft) from bottom
TT06	bottom of oven outer shell

Mass Flow Meter

The mass flow meters are used to determine and control the amount of helium and argon gas flow that is required in the HCS process. These flow elements are the Kurz model 755 hot wire anemometers, the flow valves are Kurz model 757 rotary ramp valves, and the flow controller is the Kurz model 750 Jr 24 VDC. This flow controller has up to two 4-20mA input from two flow elements and controls two flow control valves via 4-20mA output and has 4-20mA remote setpoint inputs for both control valves.

Rotameters

The rotameters are used to measure the flow of water and air during different testing activities. Various types of rotameters may be used during the course of testing. Each rotameter may have different scales or outputs.

Pressure Transducers

The pressure sensing is accomplished using Rosemount model 1151 and MKS model 230 absolute pressure loop powered transducers. These pressure transducers cannot withstand the HCS operating temperatures, so provisions were made in the sensing system to dissipate the heat before reaching the transducers.

Flow Transducers

The flow in the process heating system is measured by Dietrich Standard model DCR diamond annubars and Rosemount model 1151 DP loop powered differential pressure transducers. These pressure transducers cannot withstand the HCS operating temperatures, so provisions were made in the sensing system to dissipate the heat before reaching the transducers. As the flow increases, the differential pressure across the annubar increases.

Gas Operated Valves

The gas operated valves are spring return, fail closed valves with UHMWPE (ultra high molecular weight polyethylene seats and seals where applicable in the lower temperature range on the system (Worcester PN# 1" & ½" 5966UUBW4) and metal seats and seals where applicable in the higher temperature range on the system (Worcester PN# 1 1/4" 9466GGBW4). Each valve is fitted with a mounting kit (MK509 and MK506 for 1" and ½" valves respectively and specially made brackets for the 1 1/4" valves) and air operated spring return, fail closed, solenoid actuators with limit switches, 120 VAC power, spool valve, LED indication (15M39SWM2120APBC for 1" & ½" and 25M39SWM2120APBC for the 1 1/4").

Temperature Control Valves

The temperature control valves are air actuated butterfly valves with no seats or seals because of the high temperatures expected. Each valve has a Moore I/P valve positioner responding to 4-20 mA DC and is fully closed to fully open respectively.

Heater Temperature Controllers

The heater temperatures and ramp rates are controlled through a Chromolox heater control and SCR unit for each of the three system heaters (25 kW oven, 4 kW shield plug, and 3 kW helium recycle). This unit provides remote set point capabilities with RTD, TC, or 4-20mA inputs, and over temperature protection.

APPENDIX B
SIGNATURE VERIFICATION DATA SHEET

Instructions: Anyone entering their signature or initials in this test procedure must complete the information below.

NAME (PRINT)	RESPONSIBILITY	COMPANY	SIGNATURE	INITIALS	DATE

APPENDIX C
PRE-JOB BRIEFING RECORDS

PRE-JOB SAFETY MEETING FORM	Page 1 of 2
Job Description/Title	Date
Work Package No.: Person in Charge (PIC):	
First Aid Qualified Person:	

Check Items Discussed

- [] Procedures/Plans to be Used No.
- [] Applicable OSR's No.
- [] Radiation Work Permit No.
- [] Job Hazard Analysis No.
- [] Construction Permit (as needed) No.
- [] Additional Permits (i.e., confined space, excavation, etc.) No.
- [] Review All Applicable Safety Precautions and Prestart Conditions per Procedures/Plans to be used
- [] Employee Concerns
- [] Changes in Procedure or Scope
- [] Lessons Learned
- [] Components Locked and Tagged
- [] ALARA Considerations (applicable MSDS's)
- [] Respiratory Protection (fresh air, PAPR's, chemical filters, etc.)
- [] Radioactive Contamination Containment Device
- [] Emergency Response and Actions
- [] Summary of Job Sequence (or steps)
- [] Work Area Conditions (high/low temperatures, lighting, etc.)
- [] All Equipment Functionally Checked and at Work Site

Special Circumstances or COMMENTS:

Chairman Signature:

Operations ______________________________

Maintenance ______________________________

Other ______________________________

Pre-Job Safety Meeting Form **ATTENDANCE ROSTER**		Page 2 of 2
Name	Org. Code	Payroll No.

APPENDIX D
TEST PROCEDURE EXCEPTION INSTRUCTIONS

Instructions

1. The test procedure exception is documented per the following instructions using the exception log in Appendix E and the Test Procedure Exception form provided in Appendix F.

2. Record serial number and short description of the exception in the test procedure exception log provided in Appendix E.

3. Determine the approval designator for the exception per WHC-CM-3-5 section 12.7 "Approval Of Environmental, Safety, and Quality Affecting Documents" and enter approval designation on the test procedure exception form.

4. Enter the next test procedure exception serial number obtained from Appendix E. Make an entry in the test logbook. A redlined note in the appropriate procedure section shall be made so that the exception is easily identified and traceable.

5. Enter a detailed description of the exception including procedure section, page etc. or for procedure changes the exception form may be attached to the form that shows the "as is" conditions and the "should be" conditions (Appendix F).

6. For procedure changes, new type-written pages may be substituted. Pages being replaced must be saved in Appendix G. The test procedure exception number, date, and initials of the person making the change must appear on each page in the vicinity of the change. All replaced pages shall be marked "REPLACED" and retained in Appendix G of the controlled copy of the test procedure.

7. Enter the disposition to the exception.

8. Based on the approval designator and exception contents obtain the required test procedure exception approvals.

9. Insert the completed form in Appendix F.

APPENDIX E
TEST PROCEDURE EXCEPTION LOG

TEST PROCEDURE EXCEPTION LOG

Instructions: Enter the next sequential serial number, i.e. 001, and a short description of the exception. Fill out the exception form in Appendix F using the serial number obtained from this log.

Serial Number	Description

APPENDIX F
TEST PROCEDURE EXCEPTION

TEST PROCEDURE EXCEPTION FORM	DATE:		
Exception Title:			
Approval Designator:		NOTE: For Approval Designator see WHC-CM-3-5 section 12.7 "Approval Of Environmental, Safety, AND Quality Affecting Documents".	
Author:			
Exception #:			

EXCEPTION DESCRIPTION

EXCEPTION DISPOSITION

EXCEPTION APPROVALS		NOTE: The Test Engineer & Test Director are minimum required signatures.	
Safety Engineer		Test Director	
QA Engineer		Other	
Test Engineer		Other	
Technical Eng.		Other	

APPENDIX G
CHANGED PAGES

APPENDIX H
INSTRUMENT CALIBRATION RECORDS

Procedure section #	Equipment description	Equipment/ calibration #	Cal. due date	Test engineer signature & date	QC signature & date

APPENDIX I
LEAK TEST PROCEDURES AND TEST REPORTS

Test #	Test Engineer	Date	Section number	Leak Rate Results	NDE Technician

APPENDIX J
VALVE LEAK TEST

Section 8.1 Valve Actuator Assembly

Number of Cycles	Leak rate at room temp		Leak rate at 300°C	
	Temp	Leak rate	Temp	Leak rate
Initial				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				
________Cycles				

APPENDIX K
PUMP BACKFLOW TESTS

Section 8.2

Pump Backflow Test 1		
Starting pressure		Observations:
Final pressure		
Pressure rise for 1 hr		

Pump Backflow Test 2		
Starting pressure		Observations:
Final pressure		
Pressure rise for 1 hr		

Pump Backflow Test 3		
Starting pressure		Observations:
Final pressure		
Pressure rise for 1 hr		