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1	1	Cog.Eng. K. J. McCracken	<i>[Signature]</i>	7/1/96		P. A. Scott	<i>[Signature]</i>	7/1/96		1	1
1	1	Cog. Mgr. J. E. Filip	<i>[Signature]</i>	7/1/96		D. G. Panther	<i>[Signature]</i>	7/1/96	L6-39	1	1
1	1	QA B. R. Fillion	<i>[Signature]</i>	7/1/96		J. R. Thielges	<i>[Signature]</i>	7/1/96	L6-38	1	1
1	1	Safety T. D. Merklings	<i>[Signature]</i>	7/1/96		D. M. Ogden	<i>[Signature]</i>	7/1/96		1	1
		Env.				J. R. Frederickson	<i>[Signature]</i>	7/1/96		1	1
1	1	J. J. Irwin	<i>[Signature]</i>	7/1/96		E. S. Ruff	<i>[Signature]</i>	7/1/96	45-70.	1	1
1	1	J. B. Truitt	<i>[Signature]</i>	6/28/96		M. J. Schliebe	<i>[Signature]</i>	7/1/96	L6-13	1	1
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Hanford Spent Nuclear Fuel Cold Vacuum Drying Test Specifacaton and Test Plan

K. J. McCracken

ICF Kaiser Hanford, Richland, WA 99352

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Abstract: This document provides the test plan and test specification for SNF cold vacuum drying proof of concept, CVD process equipment validation, and proof of performance testing.

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HANFORD SPENT NUCLEAR FUEL COLD VACUUM DRYING TEST SPECIFICATION AND TEST PLAN

Spent Nuclear Fuel Project (F6A6D4)

Prepared by

Kurt J. McCracken, Advanced Engineer
Spent Nuclear Fuel, ICF Kaiser Hanford Company

Technical Contributors

J. I. Irwin, Design Authority
Cold Vacuum Facility, Westinghouse Hanford Company

for
Westinghouse Hanford Company
P.O. Box 1970
Richland, WA 99352

Hanford Operations and Engineering Contractor for the
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ENGINEERING REPORT

HANFORD SPENT NUCLEAR FUEL COLD VACUUM DRYING TEST SPECIFICATION AND TEST PLAN

Spent Nuclear Fuel Project (F6A6D4)

Prepared by

ICF Kaiser Hanford Company
Richland, Washington

for

Westinghouse Hanford Company
Richland, Washington

Compiled by: *K. J. McCracken*
K. J. McCracken, Advanced Engineer
Spent Nuclear Fuel Engineering

6-28-96
Date

Reviewed by: *Kevin M. Jones*
K. M. Jones, Advanced Engineer
Spent Nuclear Fuel Engineering

6-28-96
Date

Approved by: *J. B. Truitt*
J. B. Truitt, Deputy Manager
Spent Nuclear Fuel Engineering

6-28-96
Date

Westinghouse Hanford Company

Approved by: *John F. Brown*

7-1-96
Date

INDEPENDENT REVIEW

Document Reviewed Hanford Spent Nuclear Fuel Cold Vacuum Drying Test Plan

Author K. J. McCracken Report No. WHC-SD-SNF-TP-018 EDT No. 600538

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

- Engineering Specification
- Design Input
- Basic Assumption
- Approach/Design Methodology
- Related Information
- Conclusion/Result Interpretation

Kevin M. Jones
Reviewer

6-28-96
Date

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1.0 INTRODUCTION

1.1 BACKGROUND

Spent nuclear reactor fuel 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 (SNF) 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 Multi-Canister Overpacks (MCOs) and sent to the Cold Vacuum Drying (CVD) facility for bulk water removal and content vacuum drying. Conceptually, CVD is done by elevating the temperature of the MCO up to 75 °C under decreased pressure (0.5 torr min.) to further remove water vapor and other gases from the fuel surfaces. The MCO is then sealed and transported to the Canister Storage Building (CSB) approximately 8 miles from the CVD facility. The loaded MCO will be vented and temporarily stored until a Hot Conditioning (HC) process could be performed. Conceptually, HC is done by elevating the temperature of the MCO to 300 °C under decreased pressure (0.5 torr min.) to further remove gases and oxidants from the fuel. The MCO is then cooled to 150 to 200 °C and the fuel is exposed to a limited source of oxygen to pacify chemically reactive sites on the fuel. MCOs would then go into interim storage, unvented, to await final disposition. The combined processes significantly diminish the reactivity of the fuel when exposed to air, mitigating accident potential and allowing dry storage for long periods in a stable condition.

A safety assessment has indicated that the water content of the MCO must be demonstrated to be below 1.68 kg (Cowan 1996). SNF Projects has adopted a pressure rise of less than 3 torr in 1 hr as an acceptance criteria for dryness based on commercial practices for intact fuel. After pumping to a base pressure of 0.5 torr and not observing a pressure rise of more than 3 torr, the water content will be controlled by bound water existing primarily in the sludge, by knowing the amount of water that dissipates without sludge present. The amount of sludge that is in a MCO can be based on the total water removed from a MCO. Sludge is estimated to be 10% water. The total water in the MCO shipment can be estimated based on characterization data for the bound water associated with sludge. The different characteristic drying curves for sludge, trapped water, and good fuel are desired to be able to recognize and to gain confidence that MCOs being transported are not exceeding the safe water content. A key component in this is the use of a model to simulate the drying, to adjust the drying profiles seen in the test set-up, and to adjust the model for differences such as the fuel heat generation, the different fuel heat capacity, etc. The model then can be used to interpret results from the full scale testing by running test cases to test hypothesis for unusual drying curves. By using the reported results from these tests and the models, a quantifiable acceptance criteria for N Reactor fuel dryness and process parameters should be used for CVD acceptance testing and start-up.

1.2 SCOPE

The proposed SNF vacuum drying and hot conditioning processes require proof of concept and proof of performance. Process models currently being constructed must be validated. This test plan will assist in the validation by first testing the proof of concept vacuum process on single MCO prototypes. Congruently proposed vacuum system components shall be tested during equipment performance testing. Component testing includes vacuum pump longevity, residual gas analyzer (RGA) sensitivity, bulk water

removal and totalization, in-line dewpoint sensitivity, MCO internal HEPA filter performance, data collection, instrumentation, and control system robustness. Finally, the system proof of performance shall be tested when full size prototype MCOs and vacuum drying modules (VDM) are received. If the testing schedule permits, it would be beneficial to test each system (MCO and VDM) separately prior to the full system test to facilitate quicker diagnostics.

1.3 OBJECTIVE

This test plan summarizes developmental, validation, and acceptance tests required for the Hanford SNF CVD facility and systems. The test plan objectives are stated below.

- 1.3.1 Pre-test parameter establishment and equipment set-ups** section validates the process with several measurements which will have to be determined before any tests are performed. Some of these measurements and set-ups include:

- Water retention amounts and sites on MCO fuel baskets, mock fuel, debris, sludge, and combinations of each
- Bulk water removal and totalization measurements
- All test apparatus' system geometric measurements
- Internal viewing vacuum chamber
- Vacuum process instrumentation and monitoring.

- 1.3.2 The CVD proof of concept testing** provides valuable information for the definitive process design, provides CVD process model validation, and establishes a process cycle time baseline. Proof of concept testing is:

- Developing system baselines
- Determining heating cycles
- Conducting mock fuel, sludge, and debris drying tests
- Pursuing other process enhancing techniques that may be developed during testing.

- 1.3.3 The CVD equipment performance testing** verifies the process instrumentation and equipment meet the manufacture's performance specifications and verifies the equipment operation in the type of atmosphere conducive to the CVD process. The instruments and equipment that will be tested are:

- The process vacuum pump
- The internal MCO HEPA filtration manifold
- The Residual Gas Analyzer (RGA)/Quadrupole mass spectrometer
- The vacuum pump throttling techniques to prevent freezing
- The quick disconnect
- The MCO shield plug
- Other components that may be required in the CVD process.

- 1.3.4 The CVD proof of performance testing** will take place when process prototypes are shipped to the Hanford site and after or in parallel with other SNF sub-project component testing. These tests may be performed individually or as a complete system as determined by the design authority and scheduled component delivery dates. Component performance testing shall include:

Full scale MCO prototype vacuum drying tests
Vacuum drying module (VDM) performance tests
VDM upset condition tests
VDM/MCO complete prototypic system tests
Other performance tests on yet to be determined CVD process modules.

The test plan also establishes responsibilities, test requirements, documentation requirements, and, by enumerating the overall tests to be performed, the parts and materials required for the tests.

2.0 APPLICABLE/REQUIRED DOCUMENTS

- WHC-SD-SNF-SP-005, 1996, Integrated Process Strategy for K Basin Spent Nuclear Fuel, E. W. Gerber, Westinghouse Hanford Company.
- WHC-SD-SNF-TP-015, 1996 MCO Integrated Test Plan, E. S. Ruff, Westinghouse Hanford Company.

3.0 DEFINITIONS

BULK or FREE WATER	Water that is easily removed from the MCO or test apparatus by pumping or system pressurization
CLEAN AND DRY	Visually clean and dry to the touch
CVD (Cold Vacuum Drying)	The initial process of removing water from the MCO and drying of the fuel.
DRY	The final goal for the tests. Dry is essentially less than a 3 torr pressure rise in the system. Refer to Section 4.2.3 for acceptance criteria.
MCO (Multi-Canister Overpack)	The unit that will hold the fuel assemblies during the interim storage process.
MOCK FUEL	Unpainted carbon steel tubing that simulates the N Reactor fuel, Consisting of an inner and outer fuel element with nearly the same outside and inside diameter and wall thickness. The mock fuel will closely approximate the surface area of the real fuel. All the mock fuel elements will be allowed to rust throughout the testing and some elements will be initially damaged to provide water retention sites and debris as seen on the K Basin fuel and debris.
SLUDGE SIMULANT	The simulation of K Basin and N Reactor fuel sludge to be applied to the mock fuel element in a manner conducive to what is expected at K Basins. Information from SNF characterization will provide approximate sludge simulant ingredients and application techniques.
RETAINED WATER	Water remaining on articles after free water has been removed.

TEST LOGBOOK	A logbook for recording all data and observations by the test performer which are not included in a test procedure.
TEST PROCEDURE	A test procedure determines the steps for each test and provides documentation for process parameters that will be established during the testing.
VDM (Vacuum Drying Module)	The apparatus that contains process instruments and equipment for CVD

4.0 HANFORD AUTHORITY, ADMINISTRATION, AND ORGANIZATION RESPONSIBILITIES

Specific testing responsibilities are defined in the following sections.

4.1 AUTHORITY

4.1.1 Project Design Authority

The project design authority has final say in the conduction, repetition, or cancellation of any or all CVD tests. The design authority directs the test director and may consult the technical engineer and test director for test input.

4.1.2 Test Director

The test director is responsible for the overall performance of the test procedure and personnel safety. The test director is also responsible for all test material and personnel resource coordination. The test director directs the test engineer and reports to the design authority. The test director can act as both the test director and test engineer.

4.1.3 Technical Engineer

The technical engineer, currently from John Marvin Inc., will provide test design information and test data reduction as required during the course of these tests. The technical engineer may request a repeat test with concurrence from the design authority and test director.

4.1.4 SNF 306E/305 Facility Test Integrator

The facility integrator is responsible to coordinate all activities in the respective facilities and provide an interface with building management and personnel to establish priorities and requirements.

4.1.5 Test Engineer

The test engineer is responsible for directing performance of the test procedure and for personnel and plant safety as related to the performance of the test procedure. The test engineer directs personnel assigned to the test procedure. The test engineer reports to the test director.

4.1.6 Test Performers/Operators

The test performers are directed by the test engineer. The test performers are directly responsible for test procedure performance. The test performers report to the testing director.

4.2 ADMINISTRATION

4.2.1 Tagouts

Tagouts shall be conducted per WHC CM 1-10, "Safety Manual" Section WKS 8.1 and zero energy checks, mechanical or electrical, shall be performed on the affected system.

4.2.2 Changes

Test procedure changes required during testing may be made immediately in the field copy, provided that the changes cannot affect operating facility safety, function, or performance and will not compromise or influence test data. Any such change must be recorded in the change log as a change exception. Test parameters may be changed with concurrence of the design authority, test director, SNF 306E/305 facility integrator, and the technical engineer.

Test changes that affect operating facility safety, function, or performance or will compromise or influence test data are made via engineering change notice to the test procedure and approved by, at a minimum, the design authority, test director, SNF 306E/305 facility integrator, and the technical engineer.

4.2.3 Acceptance Criteria

The majority of these tests are mainly research and developmental (R&D) tests--such as the proof of concept testing and equipment performance testing. These R&D tests collect data to establish the acceptance criteria for the proof of performance and acceptance tests. For any step in the test procedure that has an associated acceptance criteria, the value will be designated in that step. The governing acceptance criteria, based on commercial practices, is an internal vacuum chamber pressure rebound of less than 3 torr within 1 hr. If the pressure rebounds above this limit, the drying specimens (mock fuel, sludge, or debris) are not completely dry. The pressure rebound starts after the vacuum vessel is pumped down to a base pressure and the vacuum pump is isolated.

4.2.4 Test Failure

Equipment operation or data verification must maintain their function or readings during the tests (i.e. vacuum pump maintains vacuum over assorted time intervals up to a year, thermocouples provide accurate readings, pressure gauges maintain accurate pressure indication, etc.). Failures must be recorded in an

exception log, in a test log, and on an exception page. The test engineer will decide whether to continue with the test procedure in the event of a test step or equipment failure.

4.2.5 Test Log

A narrative log of testing activities is to be maintained by the test engineer. Page numbers and date shall be entered as new pages are added. Each added page will be stamped "CONTROL COPY". Dark, reproducible ink shall be used for all entries.

4.2.6 Exceptions

The test procedure shall not be closed with open exceptions. All exceptions shall be recorded in the exception log unless it is immediately correctable and retested. Prior to the close of the test procedure, each exception is dispositioned. When all exceptions are dispositioned then the test procedure may be closed. The test procedure does not have to be changed due to the existence of an exception, however a change may be warranted if the exception causes a significant impact to the performance of the test procedure.

4.2.7 Exception Dispositioning and Closing

Dispositioning of exceptions can be accomplished in one of two ways, clear the exception or change the requirement/procedure (refer to Section 4.2.2). Exceptions are then closed when they have been dispositioned and signed by the test director.

4.2.8 Signatures

All personnel entering signatures or initials in the test procedure must print their name and provide their signature and initials in the test procedure signature identification log.

4.2.9 Repeat Testing

If a repeat test is required, additional copies of applicable procedure sections or data sheets of this test procedure may be used. The addition of procedure sections to be used for repeat testing shall be added as Repeat Testing, noted in the test log, and concurred with by the test director and SNF 306E/305 test facility integrator.

4.3 HANFORD ORGANIZATION RESPONSIBILITIES

4.3.1 Engineering Testing and Technology Projects (ETTP)

306E Equipment Design personnel and 305 Engineering Testing Laboratory personnel shall be responsible for preparing the vacuum cylinder test stand and test articles. Test laboratory personnel shall be responsible to prepare mock MCO baskets, mock fuel, sludge, and debris, to conduct retained water location tests, and to assist in test article and test apparatus fabrication as required.

4.3.2 Engineering Analysis

Support from Engineering Analysis, currently John Marvin Inc. and ICF Kaiser SNF Engineering, will be required to assist, as needed, in the test requirements, test article and test equipment design, and to perform compilation of testing results and test report preparation.

4.3.3 Quality Assurance

Quality Assurance (QA) will provide review of the test plan, test procedure, and test report. SNF Project QA will provide support for the dimensional measurement of test components and independent verification of test apparatus set-ups and will provide independent verification of selected hold and/or witness points in the test procedure. SNF project QA will provide certified personnel to support measurements or verification activities required by the test procedure..

4.3.4 Fabrication

WHC Cold Vacuum Drying Project shall supply the design of mock N Reactor fuel assemblies; prototype MCO baskets; piping interface details for the current vacuum system to accept a prototypic scroll pump and RGA; and the chemical composition, preparation specifications, application procedure for simulated sludge, and fuel rubble/debris specifications. It shall be the responsibility of ETTP to fabricate the necessary mock fuel assemblies and MCO baskets (if necessary) from commercially available steel. ETTP shall also construct the pump and RGA interfaces to the current glove box vacuum testing apparatus with commercially available vacuum components.

5.0 VACUUM DRYING TESTS

The outline of the vacuum drying tests include pre-test parameter establishment and equipment set-up, proof of concept testing, component performance testing, and proof of performance testing. Each of the testing categories are further broken into testing subsets. Due to equipment fabrication timing, component delivery dates, material and equipment procurement, and other unforeseen obstacles, it may become necessary to postpone, combine, repeat, or renumber the subset vacuum drying. The testing may also take place in multiple apparatuses. Planned test apparatus depictions are shown in Appendix A.

5.1 PRE-TEST PARAMETER ESTABLISHMENT AND EQUIPMENT SET-UP

This section describes pre-test parameters and test apparatus set-ups. The pre-test parameter establishment consists of a series of measurements for water retention, bulk water removal and totalization, and vacuum system(s) geometries. The equipment set-ups consist of vacuum vessel internal viewing and instrumentation monitoring. The vacuum chambers used in vacuum testing shall be initially pressure tested by evacuating and observing any indications of leakage such as pressure rise. With the completion of this section during testing, the proof of concept testing will begin.

5.1.1 Water Retention Testing

This series of tests examines the amount and location of water retained on a prototypic, single MCO fuel basket, mock fuel in a variety of conditions ranging from good to very poor, simulated sludge, and simulated

conducted with the basket and clean, pristine mock fuel; and finally, the third stage, and most complex, could be performed with a basket of simulated sludge, with debris, and/or with a variety of fuel assembly conditions. When each test article is removed from the water, a close video camera inspection with editorial comments will indicate where the remaining water is located. The test article shall be monitored during the drain time, up to 30 minutes after removal from water. Averaging techniques will need to be employed for these tests due to the uncertainty involved in qualifying and quantifying retained water. Equipment required for MCO water retention tests is:

- water retention measuring device;
- prototypic MCO fuel basket;
- mock N Reactor fuel (good and very poor condition); and
- simulated debris and sludge.

The water retention tests may be performed by bulk water differential measurements, load cell weight differential measurements, volumetric removal, or other means, as required to obtain acceptable results. Currently, we believe the volumetric removal process to be the most accurate. If this method proves to be too inaccurate, other water retention measurements shall be investigated and tested.

5.1.2 Bulk Water Removal and Totalization

Bulk water removal may be accomplished by pumping the free water from the vacuum vessel utilizing the prototype bulk water removal pump, by pressurizing the vacuum chamber with compressed air or inert gas, or a combination of methods. For bulk water totalization, the water may be pumped into an empty weighing vessel to obtain a rough estimate of water removed. For testing purposes, bulk water removal and totalization is currently planning to utilize the vacuum vessel pressurization with air and the volumetric method of water retention described above in the water retention testing. The increased air pressure in the sealed vacuum chamber will force the water out of the dip tube and into the water retention apparatus. This will alleviate water in additional equipment and lines. After a drying test is completed, the bulk water totalization can be combined with the RGA residual water detection (mass spectrometry) to determine total water removed from the system. This process will be repeated several times to determine totalization accuracy.

5.1.3 System Geometric Measurements

This portion of the testing establishes geometric measurements using standard physical measuring devices of the test apparatuses. A basic vacuum drying system will include a vacuum roughing pump, vacuum vessel, RGA system; purge gas system; vacuum vessel heating system, and basic temperature and pressure data acquisition. Simple piping and equipment schematics shall include measurements of: wall thickness, internal volume, and surface area of the vacuum vessel, components, and piping; system piping lengths and location of tees, elbows, valves, and other piping components; pump specification data of model and flow rates during drying; throttle valve flow conductances (if applicable vendor specifications); and location and operating specifications of system instrumentation and vessel heating system.

5.1.4 Vacuum Vessel Internal Visualization

The proof of concept vacuum drying tests are currently planned to be conducted in a one-fifth size MCO (1 basket) with a transparent top plate and the equipment performance testing is currently planned for a glove box with a viewing port. The transparent plate and viewing port will allow visual correlation between instrument readings and vessel internal characteristics. The transparent plate on the MCO will have

allowances for several thermocouple pass throughways, a center dip tube simulation, and a short tube vacuum port (see Appendix A).

5.1.5 Vessel Instrumentation and Monitoring

The vacuum systems will be fully instrumented for vacuum vessel pressure, temperature, dew point indications, residual gas analysis, and any additional instrumentation that may provide better indication or quick response times. Instrument data logging of pressure, temperature, dew point and others will be provided for data analysis during the model validation process.

5.2 PROOF OF CONCEPT TESTING (DESIGN MODEL VERIFICATION)

The information gathered in the baseline tests, heating cycle determination, and mock fuel, sludge, and debris drying tests is essential for the CVD model validation. During each test, a heating system surrounding the vacuum vessel will maintain an initial base temperature ranging from ambient to 75°C. It is currently planned to utilize a heated water bath as the vessel heating system. The test apparatus shall have the same configuration or the equivalent pipe length (from the MCO outlet to the vacuum pump) that will be prototypic of the CVD vacuum process line design. This is required to remove uncertainties of the system configuration parameters for model validation. Each test may be repeated at different base temperatures and with assorted prototypic baskets as specified by the test director. Pressure at the pump inlet and vacuum vessel outlet and temperature of the vessel exterior wall, vessel internal gas, representative mock fuel assemblies, and vessel heating system shall be monitored. Additional equipment required for these tests is:

- leak tight vacuum vessel;
- 54 mock N Reactor fuel assemblies; and
- vacuum vessel heating system.

5.2.1 Vacuum System Baseline Tests

These tests establish system baseline operating characteristics such as pressures, temperatures, and evacuation times for a vacuum chamber that is first, empty; second, with a empty fuel basket; third, with a fuel basket loaded with mock fuel assemblies; and finally, additional baselines may be established for dry sludge, debris, and other test articles as required. The baseline tests will utilize components that are visually clean and dry.

5.2.2 Heating Cycle Determination

During the baseline tests and the vacuum drying tests, heat cycle is an important parameter that needs to be determined for the CVD process. Using mock fuel elements that do not possess radiolytic heat will provide a high bound for the expected heating cycle inside the MCO. The baseline tests will commence when the inner wall is established at the water heating system base temperature. The vacuum drying tests (includes bulk water removal and totalization) will commence when the inner row of mock fuel in basket reaches the bath base temperature.

5.2.3 Vacuum Drying Concept Tests

The vacuum drying concept tests consists of: evacuating various amounts of free water in the vacuum vessel and evacuating the retained water on the fuel baskets, mock fuel assemblies, simulated sludge, and/or debris. Drying techniques and drying system operation will begin during these tests. Two drying techniques that will be tested are straight drying and cyclic drying. Straight drying pumps down the vacuum chamber until the articles are dry. Cyclic drying involves: first, evacuating the vacuum chamber; second, back purging the chamber; and then evacuating the vacuum chamber again. This process is repeated until the articles are dry. The drying tests will initially utilize clean and sludge free fuel assemblies and progress to applying sludge to a number of assemblies. Additional testing may be necessary to dry sludge, debris, and other test articles separately. The test articles may be wetted several different ways for these tests. A wetting approach prototypic of the Hanford CVD process would be filling the vessel with a known amount of water then drain the vessel just prior to evacuations noting the amount of bulk water removed.

5.3 VACUUM DRYING EQUIPMENT PERFORMANCE

This section examines the pump performance over a prolonged testing period including; RGA responses to air-in leakage of Krypton, Xenon, Hydrogen and other off-gases; residual water detection by mass spectrometry; pump throttling techniques; prototype MCO internal HEPA filter testing; MCO quick disconnect testing; and MCO shield plug flow testing. These tests are currently planned to utilize the modified glove box/vacuum chamber located in the 306E facility (see Appendix A). Equipment required for the equipment performance tests are:

- prototypic scroll pump;
- prototypic off gas monitoring system;
- prototypic MCO internal HEPA filter;
- prototypic MCO shield plug;
- vacuum vessel or piping heating system; and
- bottled Xenon, Krypton, and Hydrogen sources.

The following outlined tests may be performed using the same test apparatus by isolating the scroll pump inlet with the throttle/isolation valve to provide access to the vacuum chamber internal while the pump is operating during the scroll pump longevity test.

5.3.1 Vacuum System Baseline Tests

These tests establish system baseline operating characteristics such as pressures, temperatures, and evacuation times for a vacuum chamber and process lines that are empty. The baseline tests will utilize components that are visually clean and dry.

5.3.2 RGA Off-Gas Monitoring and Testing

The RGA Quadrupole/mass spectrometer will be used in the CVD process to indicated retained water, system air-in leakage, and lower gas detectability limits at various operating temperatures, pressures, and vessel internal gas atmospheres. The RGA subsystem shall be prototypic of the CVD process with heat tracing applied to prevent water condensation in the sample line. Use of the RGA in the Faraday Cup mode is mandatory and use of the electron multiplier mode is optional. The CVD project may purchase and furnish an RGA Quadrupole/mass spectrometer in addition to using several available on the Hanford site to determine the required accuracy and performance needed for the CVD process.

Retained water detection and totalization may be performed utilizing the RGA/mass spectrometer and using a tracer gas at a known flowrate. This is performed by utilizing basic functions of the RGA/mass spectrometer. Air-in leakage analysis may also be performed with the RGA. Nitrogen, Oxygen, and Argon detected in certain relative percentages is an indication of air-in leakage. If the vacuum vessel is air-tight, air can be introduced into the system at the inert gas bottle station to observe RGA responses in a controlled situation. Lower gas detectability limits will be accomplished by utilizing Hydrogen, Krypton, or Xenon gases. The use of these gases simulates the fission gases given off prior to a pyrophoric event inside the MCO. The lower gas detectability limits are performed by varying gas flow rates of Hydrogen, Krypton, or Xenon and observing the RGA's responses.

5.3.3 Pump Throttling and Purge Gas Testing

Vacuum pump throttling is necessary to control the pressure inside the vacuum vessel, to insure system pressures, and to avoid freezing. Throttling may be accomplished a number of ways two of which will be used in the CVD process. One method is to throttle a valve at the pump inlet. By closing the pumping inlet valve, the gas mass flow is restricted keeping the vacuum vessel at a constant pressure. The throttle valve positions (if applicable) shall be recorded in all tests. Another method of pump throttling is by introducing a purge gas into the vacuum chamber. The purge gas (dry air in these tests and commercially available Helium premixed with 2% Oxygen during the full scale prototype tests) acts as a make-up for the gas that is being evacuated from the vacuum chamber. If the purge gas flow rate equals the pump evacuation rate, a steady-state pressure can be maintained. Pressure and temperature shall be monitored inside the vacuum chamber during throttling tests. The purge gas will be introduced at various pressures not to exceed 5 torr operation parameters.

5.3.4 Prototype MCO Internal HEPA Filter Testing

The MCO internal HEPA filter will provide a primary layer of protection against internal system contamination and worker exposure limits in the CVD. The HEPA filter tests performed are to establish the filter operational characteristics (flow and differential pressure) while in both dry and wetted states at flow rates ranging from 10 to 60 cfm and at pressures ranging from 5 to 100 torr. Testing shall include analysis of the HEPA filter conductances, the ability of the vacuum pump to overcome the filter blanking caused by the water film held by capillary action during MCO draining, and the possibility of HEPA ice over during evacuation. Purge gas pressurization may be employed to clear some of the filter retained water prior to evacuation. The HEPA filter assembly may be installed as shown in Appendix A. The filter shall be tested initially dry to establish new system baseline characteristics. The new baseline will be compared to the process baseline (without filter) and the differences will provide the performance characteristics of the filters. The tests will progress to wet tests with varying filter soak times and the wetted filter characteristics will be quantified. These tests would be best performed in a test apparatus that the filter characteristics could be viewed for indications of ice-over. Additional dry and wet tests may be conducted to establish other HEPA filter parameters with particles and other stimulants sized between 3 and 10 micron.

5.3.5 Prototype MCO Quick Disconnect Testing

The parameters for the MCO quick disconnect that must be tested by Helium leak checking are: operation leakage and life cycle testing. Parameters such as: thermal cycling, fouling and cleaning may be tested. Leak tests will be performed using certified leak testing equipment. Life cycle testing will be performed by connecting and disconnecting the quick disconnects a minimum of 10 evolutions and leak testing. The quick disconnect may be installed as part of any or all of the test apparatuses shown in Appendix A.

5.3.6 Prototype MCO Shield Plug Flow Testing

Flow parameters must be established through the shield plug to investigate the rigorous flow path's effect on the vacuum drying system. Parameters such as flow conductance and flow resistances will be investigated using differential pressure and flow indication. This test may be conducted with the prototype MCO mechanical shield plug testing apparatus. The testing may be combined with the MCO internal HEPA filter testing and the quick disconnect testing, if required.

5.3.7 Scroll Pump Longevity Testing

When the testing of the CVD equipment performance is completed, in the proposed glovebox vacuum chamber, the scroll pump will be energized and allowed to run for up to a calendar year barring building power failure or accidental shutdown. Periodic monitoring of the pump temperature and inlet and outlet pressures may indicate eminent failure. A water mist injected into the vacuum chamber would provide a prototypic atmosphere expected inside the MCO during the drying process. This will also provide information regarding the planned operation of the cold vacuum facility.

5.4 PROOF OF PERFORMANCE TESTING (FULL SCALE DESIGN TESTING)

The proof of performance testing is the final laboratory testing and one of the final chances for design improvements to the system prototypes before facility installation, acceptance testing, and operational startup of the CVD. Parameters of the drying effectiveness such as temperature, pressure, heating, drying, and cooling cycles, and total cycle duration will be examined closely during this testing. The full scale MCO drying tests will be a repeat of the proof of concept testing. The proof of performance tests include: full scale MCO baseline testing; full scale MCO drying testing; prototype vacuum module testing; and complete prototypic CVD system testing. These tests shall be conducted at the discretion of the design authority and are currently slated for completion in the 305 Cold Test Facility. The 305 facility houses a 107 cm (42in.) diameter riser which will provide the water bath and mock cask around the full scale MCO. These tests will utilize the CVD proof of concept testing apparatuses and equipment wherever applicable. Equipment required, additional to the proof of concept testing, for the full scale MCO tests are:

- 5 MCO prototypic fuel baskets;
- 270 mock N Reactor fuel assemblies;
- 4-7 m (12-20 ft) deep, 66 cm (26 in.) minimum diameter heated water bath of 75°C; and
- commercial grade Helium premixed with 2% Oxygen.

5.4.1 Full Scale MCO Baseline Testing

System baselines must be established similar to the proof of concept testing using a clean, dry, and empty MCO. The process will then fill the MCO with clean, dry baskets and mock fuel assemblies. These tests will be conducted at water bath system design operating temperatures. Other temperatures may be selected ranging from ambient to 75°C.

5.4.2 Full Scale MCO Drying Testing

Full scale MCO drying testing determines the process effectiveness on a full scale MCO prototype fully loaded with mock fuel (good and bad condition). Twenty-four hour cycle time will determine system parameters over a typical design drying cycle. Cyclic and straight drying tests, described in proof of concept testing, will be conducted. RGA responses to retained water will be investigated. Also, pump throttling and

purge gas throttling effectiveness will be investigated. Purge gas introduction into the MCO during the CVD process could mitigate instability inside the MCO. Purge gas testing will be conducted initially with dry air, then with commercially available Helium premixed with 2% Oxygen (2% Oxygen mitigates Hydrogen/Uranium oxide reactions), and possibly with other gases. Additional tests may be necessary to complete the MCO drying tests.

5.4.3 Prototype Vacuum Module Tests

These tests will validate the performance of the VDM during non-routine (upset) activities such as a power loss or a power surge and a uninterruptable power supply (UPS) backup, emergency shutdowns of the system control system, and functions during the upset conditions including sudden system exposure to atmospheric pressure.

5.4.4 Complete Prototypic System Tests

These tests shall utilize a full scale MCO prototype and VDM prototype to identify any final design modifications prior to field installation. This test shall provide insight and training for operators and engineers on the CVD project. The testing shall start with a clean, dry MCO/VDM system baseline testing and progress to the higher functions of determining drying and cycling times of mock fuel, sludge and debris. All system parameters will be tested starting with bulk water removal and totalization, progress through vacuum pump, RGA, additional instrumentation, and system performances, and end with final pressure rebound observations for drying effectiveness. The results will be compared to the modeling techniques for model validation. A model that has comparable results to these tests will then be valid to establish drying characteristics of real fuel and real sludge.

6.0 TESTING REQUIREMENTS

Specific test documentation requirements, in addition to the general test documentation requirements defined in WHC-CM-6-1 and WHC-IP-1026, Appendix K, are defined in the following sections.

6.1 GENERAL CONSIDERATIONS FOR TESTING

6.1.1 Test Articles and Apparatuses

For test article and apparatuses fabrication, as identified in this test plan, quality assurance and safety requirements shall be applied commensurate for non-safety system (previously Safety Class 4) except as otherwise directed in this plan.

6.1.2 Test Article Identification

Each completed assembly shall be permanently marked with an identification number (e.g. a metal stamp, vibrating pencil, electro-etching, or laser engraver, as appropriate). The identification number shall provide traceability to the origin and preparation history of the test article. Any other identification that may be helpful in identifying the condition and treatment history of each test article shall be considered for inclusion in the identification. This information shall be included on the follower data file for each test article.

6.1.3 Test Article Verification

QA/QC verification of 10% of the mock fuel elements for sizing tolerances specified in sketches SK-2-300395, SK-2-300396, and SK-2-300397. QA/QC shall verify and document test article welding surface finish and other test article attributes that could present moisture traps.

6.1.4 Test Article Disposition

Storage of test articles shall be adequate to prevent physical damage or loss. All test articles shall be kept at least until the completion of the K Basin Spent Nuclear Fuel project in a Hanford facility (preferable the CSB) at the discretion of this project task manager.. The test articles may be archived/stored beyond that time at the discretion of the task manager. Conceivably, some test articles might be stored from 40 to 200 years, depending on the length of stay of the MCO's in the CSB. After testing, components will be packaged, labeled, and maintained in a designated dry storage location.

6.1.5 Attachment of Thermocouples to Test Articles

If thermocouples are to be directly attached by spot welding, the surfaces of the test article will be dry and cleaned to remove any film from machining or welding processes. Surface cleaning is to be performed on the same day that thermocouples are attached.

6.1.6 Test Environment

Tests shall be conducted at the Hanford 305 Engineering Test Laboratory or at 306E Engineering Design and Fabrication High Bay. The location of each individual test location shall have concurrence between the test director and 306E/305 facility test integrator. The decision shall be documented in the test log.

6.1.7 Equipment and Facilities

306E vacuum drying system including but not limited to:

- Vacuum vessel (glove box);
- Vacuum vessel heating system or comparable;
- Flow and temperature measurement systems;
- Offgas content analysis system (RGA sampler);, and
- Bottled gases (Air, Helium, Argon, and a mixture of Kr83, Kr84, and Kr86).

305 equipment includes but not limited to:

- 107 cm (42 in.) Riser for water bath.

A more complete listing of material and equipment required is shown in Appendix B on a test by test basis.

6.2 TEST PROCEDURE

The test procedure(s) document shall be prepared and approved for functional and acceptance testing of the Vacuum Drying System. The test procedure(s) will be prepared in accordance with WHC-CM-6-1, EP 4-2, Testing Requirements and shall include the following generic provisions:

- Performance criteria
- Signature identification page
- Description of test set-up
- Test procedure steps with required signature verification spaces, as required.

Cognizant managers (e.g. facility managers and SNF task managers) will be notified (by the test engineer or test technician) prior to performing actual tests.

6.3 TEST DATA DOCUMENTATION REQUIREMENTS

All written data and associated calculations will be entered into bound numbered laboratory notebooks with numbered pages, loose leaf notebooks, or project files. Each entry or series of related entries will be dated and initialed by the test engineer.

Each laboratory record book entry shall be signed and dated by the author (test performer). Periodically, the test director or test engineer will review, sign, and date pages. Non-data entries such as notes on meetings, telephone contacts, and acknowledgments of activities shall not require reviews. Files may consist of folders, loose-leaf binders, notebooks, and other methods which result in organization and permit quick retrieval. The files must be clearly marked as to what is contained within them. An index records list will be maintained to provide the locations of these files. Testing records shall be stored in a manner to preclude loss or damage.

Original computer data graph plots shall be signed and dated by the test performer. Data analysis will be performed by manual or computer-assisted methods or combinations of the two. Calculations (whether by hand or computer) that are important in establishing reported conclusions shall be verified by qualified persons other than those who performed the original calculations. Computer software used for data collection and analysis shall be verified and validated in accordance with WHC-CM-4-2, QR 19 *Software Quality Assurance Requirements* and WHC-CM-3-10, *Software Practices*. Verifications shall be done by a qualified WHC staff member. At the minimum for the IETs, verification shall consist of signatures and dates on the record indicating who performed the calculations and who verified them. A statement about how verification was performed shall be made.

Following submittal of the final report, the notebooks or copies of relevant pages from these notebooks along with all suitably identified strip charts, computer disks, magnetic tape, and/or Data Acquisition System (DAS) printouts will be submitted for retrievable storage in accordance with the Records Inventory and Disposition System (RIDS). After completion of the test, the data acquisition system (if used) will be stopped, and backup files of the test data immediately made. Hard copy output of computer generated test data will be attached to the test record for each test performed. All test data will be recorded on the test data sheets or bound notebook. The test performer will sign (legibly) the data pages.

Test records shall include, but not limited to, follower cards, original data printouts, calculations, procedures, instructions, verifications, M&TE calibration records, and reviews of test reports, as applicable.

6.3.1 Guideline Criteria for Measurement Data

The instrument serial number and calibration date for key measuring devices shall be recorded in the test record.

The precise acceptance criteria or measurement accuracy for measurement data shall be specified in each test procedure document. However, the following general guidelines may be useful:

- The acceptance criteria for temperature measurement from 0 to 100 °C (32 to 212 °F) is: ± 2.2 °C (5.0 °F), or better.
- The acceptance criteria for temperature measurement from 100 to 425 °C (212 to 800 °F) is: ± 3.1 °C (6.0 °F), or better.
- The acceptance criteria for dew point temperature measurement from -40 to 60 °C (-40 to 140 °F) is: ± 2.2 °C (5.0 °F) or better.
- The acceptance criteria for pressure measurement above vacuum from 0 to 170 kPa (0 to 25 psig) is: ± 6.8 kPa (1 psig), or better.
- The acceptance criteria for measurement of vacuum conditions is: ± 0.1 torr, down to vacuum levels of 0.5 torr.
- The acceptance criteria for water weight and water volume is: ± 0.5 kg (0.1 lbs) and ± 0.04 l (0.01 gal) respectively.
- The resolution for the RGA/mass spectrometer range from 0-100 or 0-200 AMU is 0.5 AMU or better.

6.4 TEST REPORTS

6.4.1 Final Report Preparation

At the conclusion of testing and analyses, a final report(s) describing the test article designs, test equipment preparation and setup, test data, and post-test examination results will be prepared and issued. The report shall present photographs of equipment and test article components as well as graphical descriptions of trends in the data. This task includes the following activities:

- Prepare the final report
- Provide photographic documentation of test articles and test equipment used
- Label all photographs and photomicrographs with the negative number for traceability
- Mark all photomicrographs with a metric calibration scale.

This report will include the following information:

- Description of the test apparatus
- Typical photographs or as built drawings

- Experimental results
- Analysis and interpretation of the results
- Conclusions.

Final report submitted to the test managers shall meet normal standards for publication in professional journals. Among these are:

- Graphs and tables shall be legible and understandable by a person skilled in the subject matter
- Reference material shall be well-identified, and its selection justified (Explain why other data may not have been included)
- The test engineer shall arrange for independent, documented reviews of reports.

7.0 SCHEDULE

In order to transport the MCOs to the CSB and to stage the MCOs at the CSB, they must first undergo the CVD process. This puts the design, construction, and start-up of the CVD facility on the critical path of the K Basin fuel removal schedule. This schedule is driven by a DNFSB milestone requiring all of the spent nuclear fuel to be removed from the K Basins by December, 1999. The proposed testing is an integral part of the CVD and HC design process and must be completed expeditiously in order to stay on track for meeting the milestone.

The schedule for the proof of concept initial baseline and initial vacuum drying testing is to be completed by July 15, 1996 to meet design input dates. The remaining tests shall be performed as system components are delivered to the Hanford Site and completed before December 31, 1996 with the exception of the scroll pump longevity test. A tentative, itemized schedule is shown in Appendix C.

8.0 SAFETY

8.1 GENERAL SAFETY CONSIDERATIONS

All work completed shall be performed in accordance WHC-CM-1-10, *Safety Manual*; WHC-CM-1-11, *Industrial Hygiene Manual*; WHC-CM-4-40, *Industrial Hygiene Manual*; and WHC-CM-6-1, *Standard Engineering Practices* and shall have the following considerations.

A pre-job meeting will be required before work begins (per WHC-CM-1-10, WKS-6) to discuss personnel protective equipment needs (WKS-10), lock and tag requirements (WKS-8.1), subcontractor Safety and Health Management (WKS-5), and other relevant issues.

Safety review analyses or a Hanford Job Hazard Analysis (JHA) checklist and a 305/306E Specific JHA checklist shall be prepared and approved prior to testing in accordance with appropriate WHC procedures.

There is no radiation work associated with the test activities described in this test plan.

9.0 QUALITY ASSURANCE

Testing activities shall be performed and controlled to comply with the applicable requirements of WHC-CM-4-2, *Quality Assurance Manual*.

Testing activities may also have to comply with the applicable requirements of DOE/RW/0333P, *Quality Assurance Requirements and Description (QARD)*. The applicability of the QARD to CVD testing and design activities is uncertain at this time. If all SNF will be hot vacuum conditioned, then compliance with the QARD may not be necessary. The applicability of the QARD to CVD systems, structures, components, and activities will be identified in the Spent Nuclear Fuel Project "Q-List," to be issued in the near future and documented in WHC-SD-SNF-RPT-007, "APPLICATION OF THE OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT QUALITY ASSURANCE REQUIREMENTS TO THE HANFORD SPENT NUCLEAR FUEL PROJECT."

For this test plan, the QARD requirements will be considered applicable to CVD testing activities. If the decision is made that the QARD requirements are not applicable to CVD testing activities, that decision will be documented in WHC-SD-SNF-RPT-007.

9.1 MEASURING AND TEST EQUIPMENT (M&TE)

M&TE shall be checked and verified, prior to testing, to ensure calibrations are current and are traceable to nationally recognized standards (e.g., National Institute of Standards and Technology [NIST]) or accepted values of natural physical constants. M&TE calibrations will be performed and maintained by the Site Physical and Electrical Calibration Services (SPECS) in accordance with WHC-CM-8-7, *Operations Support Services*, Section 803, Control of Portable Measuring and Test Equipment and Nondata Test Equipment.

Calibration and control measures for rulers, tape measures, levels, or other such devices will not be required unless the accuracy specified in the test procedures is beyond that available from standard commercial measurement equipment.

M&TE shall be post-test calibrated to ensure calibrations remained constant throughout the test procedure. Post-test calibration shall be performed immediately following completion of the test procedure, or as directed in the test procedure.

9.2 RECORDS

Test records shall be maintained as quality assurance records in accordance with WHC-CM-3-5, *Document Control and Records Management Manual*.

9.3 INSPECTIONS

SNF Project QA personnel shall provide inspections of testing equipment/instrumentation to verify test readiness.

QA hold, witness, and verification points will be provided in the test procedure.

QA/QC personnel may choose to exercise or waive the right to witness any tests. The waiver shall be documented in test procedure or other appropriate test documentation.

10.0 REFERENCES

- Cowan, R. G., 1996, *Bounding Particulate Contents of a Multi-Canister Overpack*, WHC-SD-SNF-TI-023, Westinghouse Hanford Company, Richland, Washington.
- DOE, *Quality Assurance Requirements and Description*, DOE/RW/033P, Department of Energy-RL, Richland, Washington.
- WHC, *Quality Assurance Manual*, WHC-CM-4-2, Release 85, Westinghouse Hanford Company, Richland, Washington.
- WHC, *Document Control and Records Management*, WHC-CM-3-5, Section 12.7, Release 33, "Approval of Environmental, Safety, and Quality-Affecting Documents," Westinghouse Hanford Company, Richland, Washington.
- WHC, *Engineering Practice Guidelines*, WHC-IP-1026, Release 11, Appendix K, "Test Plans, Specifications, Procedures and Reports," Westinghouse Hanford Company, Richland, Washington.
- WHC, *Safety Manual*, WHC-CM-1-10, Westinghouse Hanford Company, Richland, Washington.
- WHC, *Standard Engineering Practices*, WHC-CM-6-1, Release 68, Westinghouse Hanford Company, Richland, Washington.
- WHC, *Uniform Publications System Manual*, WHC-CM-306, Release 23. Westinghouse Hanford Company, Richland, Washington.
- WHC, *Operation Support Services*, WHC-CM-8-7, Westinghouse Hanford Company, Richland, Washington.
- WHC, *Industrial Hygiene Manual* , WHC-CM-1-11, Westinghouse Hanford Company, Richland, Washington.
- WHC, *Industrial Hygiene Manual* , WHC-CM-4-40, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A
TEST CONFIGURATIONS CONCEPTUAL DRAWINGS

Figure A-1. Water Retention and Totalization Apparatus

Figure A-2. Proof of Concept Testing Apparatus

Figure A-3. Equipment Performance Testing Apparatus

Figure A-4. Proof of Performance Testing Apparatus

APPENDIX B
REQUIRED EQUIPMENT

WATER RETENTION TEST EQUIPMENT (Planned)

Vernier scale
Hook gauge
85 gallon overpack drum
Prototype MCO fuel basket
54 N Reactor mock fuel assemblies
4" x 4' clear pipe
Miscellaneous plumbing fittings

INSTRUMENTATION FOR PROOF AND EQUIPMENT TESTS (Planned)

Computer
Data logger
Thermocouples
Vacuum pressure transmitters
Dewpoint/hygrometer transmitters
Pressure transmitters
RGA Quadrapole mass spectrometers
Video Camera

PROOF OF CONCEPT TESTING (Planned)

Water bath (26 in. inside diameter and 40 in. tall)
Water heater (upto 75°C)
1/5 size MCO with prototypic bottom
Prototype MCO fuel basket
54 N Reactor mock fuel assemblies
Transparent MCO top cover and 13' simulated dip tube
Vacuum pump or scroll pump
Compressed air system
Miscellaneous vacuum valves and plumbing fittings

EQUIPMENT PERFORMANCE TESTS

Prototype MCO quick disconnect
Prototype MCO internal HEPA filter apparatus
Prototype MCO shield plug and 1/5 size MCO mechanical closure test fixture
Prototype scroll vacuum pump
Miscellaneous vacuum valves and plumbing fittings

PROOF OF PERFORMANCE TESTING EQUIPMENT

Water bath (26 in. inside diameter and 40 in. tall)
Water heater (upto 75°C)
Prototypic full size MCO
5 Prototypic MCO fuel baskets
270 N Reactor mock fuel assemblies
Prototypic vacuum drying module

MISCELLANEOUS EQUIPMENT

3 ton (minimum) overhead crane

forklift (optional)

fuel basket lifting fixture (2 ton capacity minimum)

APPENDIX C
TEST SCHEDULE

ID	Task Name	Duration	Start
1	COLD VACUUM DRYING TESTING	71d	6/17/96
2	Pre-Test Measurements & Set-up	40d	6/17/96
3	Water Retention Tests	6d	7/1/96
4	Bulk Water Removal/Calatization	6d	7/8/96
5	System Geometric Verify	22d	7/1/96
6	Proof of Concept	2d	7/1/96
7	Equipment Performance	2d	7/2/96
8	Proof of Performance	2d	7/29/96
9	System Set-ups	40d	6/17/96
10	Proof of Concept Testing	11d	7/8/96
11	Baseline Testing	3d	7/8/96
12	Heating Cycle Determination	8d	7/11/96
13	Mock Fuel Assembly Drying	8d	7/11/96
14	Vacuum Equipment Performance	144d	7/24/96
15	RGA Tests	4d	7/24/96
16	Pump Throttling Techniques	4d	7/30/96
17	Internal HEPA Tests	2d	8/5/96
18	Quick Disconnect Tests	2d	8/7/96
19	Shield Plug Flow Tests	2d	8/9/96
20	Scoil Pump Longevity	130d	8/13/96
21	Proof of Performance Testing	110d	7/31/96
22	Baseline	5d	7/31/96
23	Full Scale MCO Drying Tests	10d	8/7/96
24	Vacuum Module Tests	10d	11/15/96
25	Pilot-type Systems Test	23d	11/29/96

DISTRIBUTION SHEET

To	From	Page 1 of 1
J. J. Irwin	K. J. McCracken	Date 6/28/96
Project Title/Work Order		EDT No. 600538
Spent Nuclear Fuel Cold Vacuum Drying Test Specification and Test Plan / F6A6D4		ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
R. L. Brown (Bob-Startup)	B4-08	X			
W. P. Dana	G3-05	X			
J. I. Dearing	S0-04	X			
J. E. Filip	R3-85	X			
B. R. Fillion	E6-03	X			
J. R. Frederickson	R3-86	X			
J. J. Irwin	H0-34	X			
K. J. McCracken	X3-85	X			
T. D. Merkling	R3-09	X			
D. M. Ogden	H0-34	X			
D. G. Panther	L6-39	X			
E. S. Ruff	H5-70	X			
M. J. Schliebe	L6-13	X			
P. A. Scott	R3-87	X			
S. M. Short	S3-87	X			
J. R. Thielges	L6-38	X			
J. B. Truitt	S0-04	X			
G. A. Wyatt	P7-19	X			
J. L. Wise	X3-85	X			
M. E. Witherspoon	R3-85	X			
SNF Project Files	R3-11	X			
SNF/LB	S0-04	X			
Central Files	A3-88	X			