

10/12/2000 Sta#15 ID#22

S

# ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT

601073

2. To: (Receiving Organization) Distribution		3. From: (Originating Organization) Engineering Laboratories		4. Related EDT No.: None	
5. Proj./Prog./Dept./Div.: PFP		6. Design Authority/Design Agent/Cog. Engr.: Don M. Squier HFFV0011 1107401AJ60		7. Purchase Order No.: N/A	
8. Originator Remarks: Modified storage cubical test plan for reveiw, comment and release				9. Equip./Component No.:	
				10. System/Bldg./Facility:	
				12. Major Assm. Dwg. No.:	
11. Receiver Remarks: 11A. Design Baseline Document? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No				13. Permit/Permit Application No.: N/A	
				14. Required Response Date: 8/15/00	

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	HNF-6737		0	Test Plan to Determine the Maximum Surface Temperatures For a Plutonium Storage Cubicle with Horizontal 3013 Storage Canisters	N/A	1	1	

16. KEY		
Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)
E, S, Q, D OR N/A (See WHC-CM-3-5, Sec. 12.7)	1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)											
(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
1	2	Principal Engineer Design Authority D.W. Nelson	<i>[Signature]</i>	10/10/00	R3-56	1	1	T.H. Larkin	<i>[Signature]</i>	9/20/00	T4-20
1	2	Design Agent Authority R.W. Semperey	<i>[Signature]</i>	9/20/00	TS-55	1	1	B.W. Holstein	<i>[Signature]</i>	9/20/00	R3-56
1	1	Cog. Eng. D. M. Squier	<i>[Signature]</i>	8-5-00	L6-13	1	1	B.A. Crea	<i>[Signature]</i>	8/5/00	L6-35
1	1	Cog. Mgr. M. J. Schliebe	<i>[Signature]</i>	8/16/00	L6-13	1	1	F.J. Heard	<i>[Signature]</i>	8/3/00	L6-35
		QA									
		Safety									
		Env.									

18. Signature of EDT Originator <i>[Signature]</i> Date 8-30		19. Authorized Representative for Receiving Organization <i>[Signature]</i> Date 9/20/00		20. Design Authority/Cognizant Manager <i>[Signature]</i> Date 8/16/00		21. DOE APPROVAL (if required) Ctrl No. _____ <input type="checkbox"/> Approved <input type="checkbox"/> Approved w/comments <input type="checkbox"/> Disapproved w/comments	
--	--	--	--	--	--	--	--

[illegible]

# **Test Plan to Determine the Maximum Surface Temperatures for A Plutonium Storage Cubicle with Horizontal 3013 Canisters**

Prepared for the U.S. Department of Energy  
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the  
U.S. Department of Energy under Contract DE-AC06-96RL13200

**Fluor Hanford**

P.O. Box 1000  
Richland, Washington

# Test Plan to Determine the Maximum Surface Temperatures for A Plutonium Storage Cubicle with Horizontal 3013 Canisters

Document Type: TR

Division: PFP

F.J. Heard  
Fluor Hanford

B.A. Crea  
D.M. Squier  
Fluor Hanford

Date Published  
October 2000

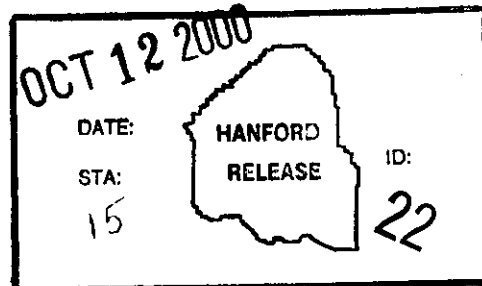
Prepared for the U.S. Department of Energy  
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the  
U.S. Department of Energy under Contract DE-AC06-96RL13200

**Fluor Hanford**  
P.O. Box 1000  
Richland, Washington

*Christine Stillingham*  
Release Approval

10/12/00  
Date



Release Stamp

#### **LEGAL DISCLAIMER**

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

This report has been reproduced from the best available copy.

Printed in the United States of America

Total Pages:

14

## ABSTRACT

*A simulated full-scale plutonium storage cubicle with 22 horizontally positioned and heated 3013 canisters is proposed to confirm the effectiveness of natural circulation. Temperature and airflow measurements will be made for different heat generation and cubicle door configurations. Comparisons will be made to computer based thermal Hydraulic models.*

## **CONTENTS**

1.0	Introduction.....	1
2.0	Objectives and Scope .....	1
2.1	Description of Storage Cubicle and 3013 Canisters .....	2
2.2	Description of Thermal-Hydraulic Models .....	3
3.0	Test System.....	4
3.1	Simulated Plutonium Storage Cubicle .....	4
3.2	Simulated Plutonium Storage Canister .....	4
3.3	Instrumentation.....	5
4.0	Test Methods.....	6
4.1	Thermal Emissivity Measurements .....	6
4.2	Storage Cubical Temperature and Air Flow Rate Measurements .....	7
5.0	Equipment and Facilities .....	7
6.0	Safety .....	7
7.0	Quality Assurance .....	8
8.0	Report .....	8
9.0	References.....	8

**List of Figures**

1.	Modified Storage Cubicle.....	2
2.	Canister Cross Section.....	2
3.	Simulated Storage Cubicle .....	4
4.	Canister and Wall Thermocouple Locations .....	5



## **TEST PLAN TO DETERMINE THE MAXIMUM SURFACE TEMPERATURES FOR A PLUTONIUM STORAGE CUBICLE WITH HORIZONTAL 3013 STORAGE CANISTERS**

### **1.0 INTRODUCTION**

A change to the current plutonium storage vault-packaging configuration has been initiated based on the Department of Energy standard: DOE-STD-3013-99. The new standard permits a “new” storage container for the packaging and long term storage of Special Nuclear Material (SNM), such as plutonium oxide ( $\text{PuO}_2$ ) powder. The “new” plutonium storage containers are commonly referred to as either 3013 containers or 3013 canisters.

Current plans call for Hanford’s plutonium inventory to be repackaged and stored in 3013 containers. The existing storage vaults must be modified to accept and safely store the 3013 canisters. The Plutonium Finishing Plant (PFP) has proposed to modify the existing plutonium storage cubicles to store the individual 3013 canisters in a horizontal rather than the vertical position presently used. Forced ventilation through the storage cubicle is not planned. Natural convection cooling will occur. However, it is not known if natural convection will provide sufficient cooling to limit the maximum concrete surface temperature to less than 150 °F.

A simulated full-scale plutonium storage cubicle with 22 horizontally positioned and heated 3013 canisters is proposed to confirm the effectiveness of natural circulation. Temperature and airflow measurements will be made for different heat generation and cubicle door configurations. Comparisons will be made to computer based thermal-hydraulic models.

### **2.0 OBJECTIVES AND SCOPE**

The primary objectives of the proposed tests are: 1) substantiate the effectiveness of natural convection cooling in modified plutonium storage cubicles containing horizontal 3013 canisters, 2) support the definitive design, 3) provide design recommendations, and 4) support the safety analysis report.

Another objective is to obtain data for validating the computer based thermal-hydraulic models and refining the models for future use. Once the computer models have been confirmed and “benchmarked” against experimental results, the affect of perturbations and additional modifications can be investigated analytically. (Section 2.2 provides additional discussion of the computer models.) Specifically, both the tests and analyses will focus on maximum concrete temperatures to ensure the design temperature limit of less than 150 °F is met.

The scope of the proposed tests will be for two simulated decay heat loading arrangements and two door configurations. One decay heat loading will be based on uniform maximum values.

The second will be based on a more realistic range of decay heats and a random loading. The range of decay heat values will be based on operating experience and customer input. Some cubicles have two overlapping moveable doors, while others have a one fixed and one moveable door with an eight-inch gap between. The two simulated decay heats will be repeated for two different door configurations.

Additional configurations can be accommodated through a separate test series.

The following paragraphs and sections describe the plutonium storage cubicle, storage canister, and measurement methods needed to obtain the data necessary to confirm and refine the computer models of a plutonium storage cubicle and canisters.

## 2.1 Description of Storage Cubicle and 3013 Canisters

Sixty-eight storage cubicles are located in each of three storage vaults. The plutonium storage cubicles are constructed with eight-inch thick concrete walls. Common side and back walls are shared by adjacent cubicles. The interior storage volume of each cubicle is approximately 24-inches wide by 12-inches deep by 96-inches high. Each plutonium storage cubicle has two concrete doors. Some cubicles have two overlapping moveable doors, while others have a one fixed and one moveable door with an eight-inch gap between. (See reference drawing H-2-829374).

Each modified storage cubicle will receive twenty-two new 3013 canisters. The cubicle will contain storage racks to accommodate the horizontal storage of the 3013 canisters in two vertical columns of eleven as shown in Figure 1. The racks will position the canisters with a center-to-center vertical and horizontal spacing of  $8\frac{1}{4}$  inches.

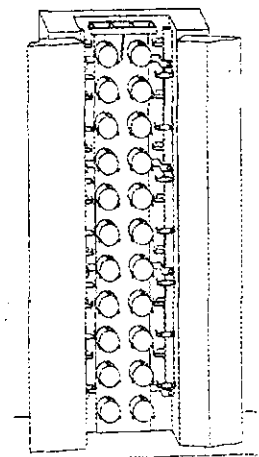


Figure 1 Modified Storage Cubicle

Each 3013 canister consists of an assemblage of three containers. One container is placed within another and then another canister, as shown in Figure 2.

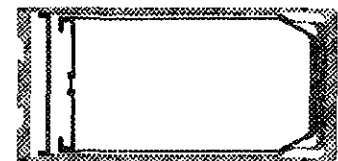


Figure 2 3013 Canister Cross Section

The plutonium oxide powder decay heat is variable from canister-to-canister, but could be as much as 19 watts per canister. Openings under the door(s) and at the top of each cubicle encourage natural convection airflow to remove decay heat from the 3013 canisters and internal cubicle surfaces. It is not known if natural convection will provide enough cooling to maintain the maximum concrete surface temperatures less than 150 °F. The cubicle door configuration's influence on the natural convection airflow and cooling is also unknown.

## 2.2 Description of Thermal-Hydraulic Models

Two separate thermal models will be developed for the thermal assessment of the modified plutonium storage cubicle with horizontal 3013 canisters. This is necessary to handle the

computational limitations imposed by the change in dimensional scale from the full-height storage cubicle to the relatively thin walls and small separation distances between the three nested containers. These models are expected to be similar to models previously developed (Heard 1999) for a series of analyses for a ducted ventilation storage cubicle.

The first model will be a full-scale three-dimensional, half-symmetric representation of a plutonium storage cubicle with horizontal 3013 canisters. The cubicle model will be used to complete a series of steady-state analyses to determine the distribution of the natural convection flow within the cubicle and around the canisters. This model will also determine the temperature distributions within the storage cubicle and 3013 canisters. Only the outermost container will be included in this model. The two inner canisters, gaps, and plutonium oxide will be modeled as a smeared mass with a given volumetric heat generation rate. The cubicle model will provide a realistic estimate of the outer canister surface temperatures, but does not provide a realistic estimate of the internal or maximum canister temperatures.

A second three-dimensional, full-symmetry thermal model will be developed of a 3013 storage canister lying on its side (i.e. horizontal). Each of the three nested containers will be modeled as a separate component. The flow field surrounding the outermost container will not be calculated but accounted for by applying a heat transfer coefficient and ambient temperature or applying a fixed temperature to the outermost surface as a boundary condition. The canister surface temperatures from the full-scale storage cubicle model will be used as the boundary conditions for the detailed canister model. The canister model will determine the temperature distribution and maximum temperature within a given 3013 canister for a known environment within a storage cubicle.

The computer models will be judged adequate and valid when close agreement is obtained with the experimental results. The computer models will be used to predict the areas of maximum temperatures. This will help when installing instrumentation in the simulated cubicle and 3013 canisters. The simulated cubicle and canisters will not be identical to the field units in every respect. However, it is possible to adjust the computer model parameters to account for differences between the simulated and actual cubicles. The changes in flow rates and temperatures resulting from model adjustments will indicate which parameters are important or insignificant. This ability to adjust parameters is critical to explore alternatives should the initial cubicle configuration not provide adequate natural convection cooling. Alternative cubicle configurations would be examined under a separate scope of work if necessary.

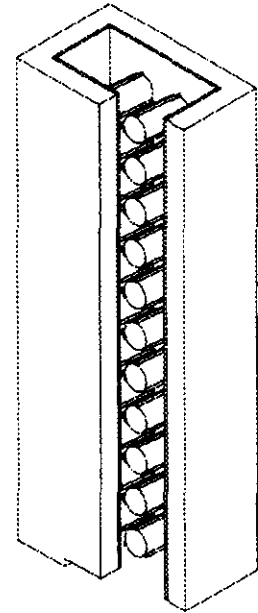
### 3.0 TEST SYSTEM

Valid computer model development is dependent on knowing system characteristics. The most important system characteristics are: a geometry similar to the field components, known energy input and energy losses, known mass flow rate through the system, known thermo-physical properties of the test and field system components, and proven instrumentation.

#### 3.1 Simulated Plutonium Storage Cubicle

Geometry has a first order effect on the convective flow patterns and energy transport by thermal radiation. Geometry can be broken down into the following factors: canister diameter and length, canister spacing (pitch) and array (square), and cubicle layout and internal dimensions. A simulated plutonium storage cubicle will be constructed with internal finished dimensions of 24-inches wide by 12-inches deep by 96-inches high to match the field units (See reference drawing H-2-829374).

Figure 3 is a representative sketch of the simulated storage cubicle with one door partially removed to show the interior canister stacks. The internal surfaces shall be faced with a sheet concrete product to approximate the field unit's poured concrete surface thermophysical properties. The outside shall be insulated with foam board.



**Figure 3 Simulated Storage Cubicle**

Two cubicle doors shall be constructed in a similar manner with a concrete sheet interior face and foam board insulation on the outside. These doors will be set in place rather than hinged to simplify the construction. One door is butted against the other to simulate the gapless door design or spaced eight inches from the other to emulate the gapped door configuration. Each door configuration will have an inlet vent cut at floor level that matches the location and dimensions of the field units.

Two other methods of construction still under discussion are: 1) a storage cubicle constructed from a series of cast concrete slabs banded together and, 2) solid concrete blocks mortared together. These two methods of construction could approximate the thermal mass of an actual storage cubicle and would allow transient tests to be performed once the steady-state tests have been completed. The chosen method of construction will be based on customer input and schedule requirements.

The cubicle interior shall be fitted with a rack to hold horizontal storage canisters in two vertical columns of 11 each. This rack shall space the canisters on a pitch of  $8\frac{1}{4}$  inches in both the horizontal and vertical planes. It is possible that upcoming criticality analyses will dictate a change to this geometry. Large deviations from this geometry can be accommodated through a separate test series and some modification to the computer models.

### 3.2 Simulated Plutonium Storage Canister

Twenty-two simulated plutonium storage canisters will be constructed with internal variable heaters. The test canisters represent a simplified single container construction rather than the triple container arrangement used in the plutonium storage facility. The interior volume shall be filled with sand to provide a conduction path to the canister walls.

Each test canister heater will be powered by a DC power supply. A precision shunt resistor is installed in a power lead so that the heater current flow can be derived by dividing the voltage drop across the resistor by the resistance. This current multiplied by the voltage drop across the heater gives the power delivered to the heater. The heat produced by each canister will be controlled by adjusting the power applied to the heater. The heaters will be capable of 30 watts, but will not exceed the current maximum expected decay heat of 19 Watts.

Thermal radiation will transport a significant fraction of the energy from the canister outer surface to the cubicle interior walls. Both geometry and surface emissivity are important factors affecting thermal radiation. The test canisters shall be constructed using the same general dimensions, material, and exterior surface finish as the actual canisters to duplicate thermal emissivity characteristics. The test canister shall be a simple cylinder with a welded closure; this will require a vent to allow the interior volume to achieve ambient air pressure during and after the welding operation. This vent may only be several small holes drilled into the lid. These deviations from the field canisters will reduce the cost of constructing these test fixtures.

Selected canisters shall be instrumented for temperature measurements of the end plates and/or at four equal intervals round the circumference in the center of the axial length. These temperature measurements will indicate the energy losses from the top, bottom, sides and ends of the test canisters.

### 3.3 Instrumentation

The outer canister and concrete surface temperatures shall be measured by thermocouples. The thermocouples will be connected to a computer controlled data acquisition system that will collect the temperature data at intervals and display a plot of the temperature trends. This plot will be used to determine when the test system has achieved temperature equilibrium as indicated by flat temperature traces.

The data acquisition system will also measure the voltage and current delivered to the heaters. This will consume 44 input channels, leaving 53 channels available for thermocouple inputs. Canister levels 7, 8, and 9, as numbered from bottom to top, will be instrumented. (Previous analyses indicate that levels 7, 8, or 9 will sustain maximum canister and concrete temperatures.) Figure 4 shows a

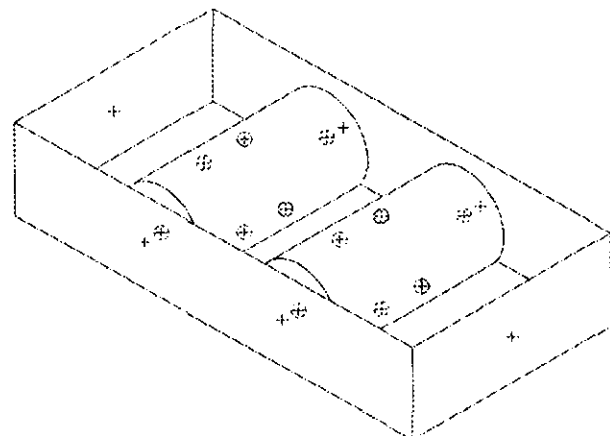


Figure 4 Canister and Wall Thermocouple Locations

single or unit canister level and the surrounding cubicle walls with thermocouple locations. The thermocouple locations on the canisters are circled. Thermocouples will be installed on the cubicle floor, air entrance, and air exit points. Additional thermocouples may be added as necessary once experience is gained with the test system and computer models.

A hot wire anemometer will measure the airflow entrance and exit velocities. This handheld probe measures the flow velocity at a single point. A single point flow measurement does not provide an accurate measurement of the flow rate through the system. Airflow velocity measurements will be made at six or more intervals across the cubicle opening's faces. The measured airflow rate, cubicle opening dimensions, barometric pressure (obtained from the Hanford weather station), relative humidity and temperature will yield the mass flow rate through the system.

## **4.0 TEST METHODS**

All measurements will be recorded with the test system operating under steady state conditions. The test system heaters will be energized while the data acquisition system is configured to display the power delivered to the heater(s). Adjustments are made to the heat power to obtain the required heat input. The data acquisition system will be configured to display a plot of the temperatures over time so that it is possible to observe when steady state temperatures are achieved.

### **4.1 Thermal Emissivity Measurements**

Thermal radiation will transport a significant fraction of the energy from the canister to the cubicle interior walls. Surface emissivity can be thought of as a surface resistance to radiant heat flow, it is very dependent on the material and surface finish. Surface emissivities are usually quoted as a single significant figure for a given material. This critical parameter must be measured to develop an accurate computer model.

A thermocouple-instrumented canister will be suspended in a horizontal position and heated at a low power level. Once thermal equilibrium is achieved, an infrared pyrometer will measure the canister temperature. The pyrometer's emissivity adjustment will be altered so that pyrometer reading agrees with the thermocouple reading. The pyrometer emissivity setting and the thermocouple reading will then be recorded. The heater's power level will then be incremented and the measurements repeated at least three times to obtain an average emissivity value throughout the 19-watt power range.

A similar measurement will be made for the sheet concrete material that lines the test cubicle. A thermocouple will be attached to one side of the sheet and an infrared heat lamp is directed at the opposite side to heat the sheet. The distance between the lamp and the sheet will control the sheet's temperature. The lamp will initially be located some distance from the sheet to produce a measurable increase in the temperature. A pyrometer is aimed at the sheet's thermocouple side and the emissivity adjustment is altered so that pyrometer reading agrees with the thermocouple reading. The pyrometer emissivity setting and the thermocouple reading will then be recorded.

The distance between the infrared lamp is reduced and the measurement sequence is repeated at least three times to obtain an average emissivity value.

#### **4.2 Storage Cubicle Temperature and Air Flow Rate Measurements.**

The gapless doors will be installed on the test cubicle and the canister heater power will be configured to deliver 19 Watts to every heater. This condition represents the maximum heat loading possible. Once the test system has achieved temperature equilibrium, the data acquisition system will be configured to record temperature and power values at five-minute intervals for a minimum period of one hour. Averaged values will be computed from the collected data. The entrance and exit airflow rates will then be measured as previously described. The barometric pressure and relative humidity will also be recorded. The gapped door will replace the gapless door and the maximum heat loading measurements will be repeated.

A random decay heat loading condition will be simulated by using a random number table to obtain eleven values that will be normalized to represent decay heat values ranging from 6 to 19 watts. (The final range of decay heat values will be based on customer input.) Each of the eleven values will be randomly assigned to two heated canisters at a common elevation in the storage cubicle. This heat loading arrangement will accommodate the computer model that is limited to one half of a cubicle split on a vertical plane. The model assumes a mirror image at the split plane so that the canisters at a common elevation will have identical heat loads. Data acquisition and door changes will proceed as described above.

The energy from the heaters must exit the test cubicle as sensible heat deposited within the exhaust air or through the walls. Measurements of air temperatures and flow rates entering and leaving the cubicle allow an energy balance calculation that will account for the energy lost through the test cubicle walls.

### **5.0 EQUIPMENT AND FACILITIES**

These tests will be conducted in the Engineering Laboratories using existing equipment. Suitable thermocouples and test fixture fabrication materials will be purchased.

### **6.0 SAFETY**

The heaters will be powered by a DC source of 50 Volts or less to remove the hazards associated with high voltages.

Estimated maximum temperatures of 250° F could be encountered on the heated surfaces. With the exception of the canister emissivity measurements, the heated components will be contained in the test cubicle and not exposed for inadvertent touching. The heated components will be barricaded and posted with warnings of the elevated temperatures.

## 7.0 QUALITY ASSURANCE

All instruments shall receive a documented calibration using standards traceable to NIST. The thermocouples will receive a two-point characterization at a temperature near ambient and a nominal 250° F. This should cover the range of temperatures encountered in the test cubicle. The accumulation of errors associated with the temperature measurements are estimated as  $\pm 2.4$  °C.

## 8.0 REPORT

The Engineering Laboratories will issue a supporting document describing this test effort. This report will document the instrument calibrations, test system configuration(s), observations and measured values. A computer model section will describe the agreement between the measured values and the model. This section will include predictions of the peak temperatures within the cubicle and plutonium oxide powder. These values will determine if natural convection cooling is effective for safe storage of the plutonium oxide powder using the described cubicle geometry.

## 9.0 REFERENCES

Department of Energy standard: DOE-STD-3013-99

Heard, F. J., "Thermal-Hydraulic Assessment of Concrete Storage Cubicles with Horizontal 3013 Canisters," HNF-3830, Numatec Hanford Company, released April 8, 1999.

Drawing H-2-829374, Rev A., "Canister Support Rack Sections, and Details", Fluor Daniel Northwest, Inc.