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Title: Special Analysis: 2017-001 Disposal of Drums Containing Enriched Uranium in Pit 38 at Technical Area 54, Area G

Author(s): Birdsell, Kay Hanson
Stauffer, Philip H.
French, Sean B.

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Special Analysis: 2017-001
Disposal of Drums Containing Enriched Uranium in Pit 38 at Technical Area 54, Area G

Author:
Kay Birdsell, Philip Stauffer, and Sean French

Prepared for:
Los Alamos National Laboratory

Date:
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Acronyms and Abbreviations

D&D	Decontamination and decommissioning
DOE	Department of Energy
ER	Environmental restoration
FSV	Fort Saint Vrain
LANL	Los Alamos National Laboratory
LLW	Low-level radioactive waste
PA	Performance Assessment
PA/CA	Performance Assessment and Composite Analysis
TA-54	Technical Area 54
WAC	Waste acceptance criteria

1.0 Introduction

Los Alamos National Laboratory (LANL) generates radioactive waste as a result of various activities. Operational waste is generated from a wide variety of research and development activities including nuclear weapons development, energy production, and medical research. Environmental restoration (ER), and decontamination and decommissioning (D&D) waste is generated as contaminated sites and facilities at LANL undergo cleanup or remediation. The majority of this waste is low-level radioactive waste (LLW) and is disposed of at the Technical Area 54 (TA-54), Area G disposal facility.

U.S. Department of Energy (DOE) Order 435.1 (DOE, 2001a) requires that radioactive waste be managed in a manner that protects public health and safety, and the environment. To comply with this order, DOE field sites must prepare site-specific radiological performance assessments for LLW disposal facilities that accept waste after September 26, 1988. Furthermore, sites are required to conduct composite analyses that account for the cumulative impacts of all waste that has been (or will be) disposed of at the facilities and other sources of radioactive material that may interact with the facilities.

Revision 4 of the Area G performance assessment and composite analysis (PA/CA) was issued in 2008 (LANL, 2008). These analyses estimate rates of radionuclide release from the waste disposed of at the facility, simulate the movement of radionuclides through the environment, and project potential radiation doses to humans for several on-site and off-site exposure scenarios. The assessments are based on existing site and disposal facility data, and assumptions about future rates and methods of waste disposal.

Permission is being sought to dispose of three drums of waste generated at the Fort Saint Vrain (FSV) Generating Station; radionuclides found in the waste include U-235, U-238, and Th-232. The waste consists of three carbon fuel blocks. Enriched uranium oxide fuel pellets are stored in penetrations in the carbon blocks. Each fuel block is packed into a 55-gallon inner drum that is, in turn, packed into an 85-gallon drum. The U-235 contents of two of the drums exceed the fissile material limits found in the LANL Waste Acceptance Criteria (WAC). Carbon (graphite), a moderator, is present in all three of the drums in quantities that are greater than those permitted by the WAC (LANL, 2014). Both of these requirements are related to criticality limits rather than to the performance assessment (PA). In addition, the void space within the waste drums likely exceeds 10%, which is a WAC requirement related to long-term site performance. Excess void space can lead to long-term subsidence of a disposal site, which in turn can enhance radionuclide transport through processes such as increased infiltration, bioturbation, and cover failure. These exceptions are documented in the Waste Acceptance Criterion Exemption Form (Appendix D).

An Unreviewed Disposal Question Evaluation (UDQE 1701, presented in Appendix A) determined that these WAC exceptions constitute a positive unreviewed disposal question, and a special analysis is required prior to implementing the activity. This special analysis, SA 2017-001, evaluates the potential impacts of disposing of this waste in Pit 38 at Area G based on the assumptions that form the basis of the Area G PA/CA. Section 2 describes the methods used to conduct the analysis; the results of the evaluation are provided in Section 3; and conclusions and recommendations are provided in Section 4.

2.0 Methods

The potential for the disposal of the three drums of waste generated at the FSV Generating Station to impact the PA/CA was evaluated based on a review of pertinent assumptions made in those analyses. These assumptions address the manner in which the characteristics of the waste influence radionuclide release rates from the disposal unit. In addition, waste drum concentrations are compared to radionuclide concentration limits for pits specified in Table 3-1 of the WAC (LANL, 2014). Waste activities are also compared to those assumed in the inventory model used for the most current PA/CA dose projections (LANL, 2017). Finally, container void space is compared to the WAC requirement that void space within the waste or the waste package not exceed 10% (LANL, 2014).

3.0 Results

3.1 Inventory and Concentration

The Area G PA/CA adopts a simple approach for estimating radionuclide release rates from the waste disposed of in pits and shafts. All radionuclides are assumed to partition between the solid waste and water in the pore spaces in proportion to their distribution coefficient; radionuclides present in the liquid phase are leached from the waste as water percolates through the disposal units, unaffected by the presence of waste packages. A small number of vapor- and gas-phase radionuclides may enter into the air-filled pore spaces as well.

The manner in which radionuclide releases are modeled is unaffected by the fissile nature of the waste or the presence of carbon. On this basis, then, the unique characteristics of the enriched uranium waste will not impact the modeled releases and, subsequently, the projected doses. Radionuclide concentrations in the three drums of waste, obtained from the Waste Compliance and Tracking System (WCATS), are less than the radionuclide concentration limits established using the Area G performance assessment and specified in the WAC (LANL, 2014). Table 3-1 shows this comparison; concentrations range between 2% and 20% of those allowed by the WAC, providing further evidence of no negative impact to the long-term performance projections developed for the disposal facility based on waste concentrations. The carbon (graphite) fuel blocks are not radionuclide sources, and transport related to the fuel blocks is not a factor for the PA.

The inventory estimates for Pit 38 assumed in the most current PA inventory model are based on waste projections for the time period between October 2014 and the assumed closure of Pit 38, rather than on actual waste disposed (LANL, 2017). The model assumes that Pit 38 was filled and closed in December 2015. However, Pit 38 is still open. Only one container of waste has been disposed in Pit 38 since October 2014, causing the actual disposed inventory to be significantly less than the inventory assumed for the most current dose projections for the site.

Table 3-1

Radionuclide Concentrations in Three FSV Waste Drums in Comparison to Radionuclide Concentration Limits given in the WAC, Table 3-1 (LANL, 2014)

Container ID	Radionuclide	Activity (Ci)	Container Concentration (Ci/m^3)	Concentration Limit (Ci/m^3) from WAC Table 3-1	Ratio $C_{Container}/C_{Limit}$
W727464	Th-232	8.80E-04	2.73E-03	2.00E-02	1.37E-01
	U-235	4.83E-04	1.50E-03	1.80E-01	8.34E-03
	U-238	3.50E-05	1.09E-04	5.30E-01	2.05E-04
W727467	Th-232	1.10E-03	3.42E-03	2.00E-02	1.71E-01
	U-235	7.15E-04	2.22E-03	1.80E-01	1.23E-02
	U-238	5.20E-05	1.62E-04	5.30E-01	3.05E-04
W727468	Th-232	1.32E-03	4.10E-03	2.00E-02	2.05E-01
	U-235	1.39E-03	4.32E-03	1.80E-01	2.40E-02

In Table 3-2, the activities for the radionuclides Th-232, U-235 and U-238 present in the FSV waste are compared to activities consistent with the PA model as waste that is assumed (in the model) to require disposal in Pit 38. Although the model and associated dose projections assume this waste will require disposal, no such waste is identified currently as requiring disposal. The last column of Table 3-2 gives the ratio of the activity in the FSV drums, proposed for disposal in this special analysis, to the remaining waste activity assumed to require disposal. The FSV waste for these three radionuclides would only make up between 0.033% and 15% of what is assumed in the current model. Therefore, the proposed waste would not impact the doses currently projected for the site.

Table 3-2

Comparison of Modeled Inventory for Pit 38 for the time period since October 2014 to Actual Plus Proposed Inventory

Radionuclide	Assumed Remaining Pit 38 Inventory based on PA Model (Ci)	Activity of 3 FSV Drums (Ci)	Ratio of Proposed Additional FSV Waste to Assumed Remaining Pit 38 Waste
Th-232	6.31E-02	3.30E-03	5.2E-02
U-235	1.72E-02	2.59E-03	1.5E-01
U-238	2.65E-01[a]	8.70E-05	3.3E-04

[a]For U-238, the "Assumed Remaining Pit 38 Inventory based on the PA Model" is equivalent to that assumed in the PA Inventory Model minus the U-238 inventory contained in the single waste package disposed of in Pit 38 since October 2014 (see LANL, 2017).

3.2 Void Space

The waste stream profile obtained from WCATS for the three waste drums describes the waste as "three carbon (graphite) fuel blocks, each bagged and packed into separate 85-gallon drums." Each fuel block has a regular hexagonal cross-section with 8.182 inch sides, a width of 14.172 inches, and a height of 31.22 inches (DOE, 2001b; Cobb 1976). WCATS information also states that, "the inner containers are stabilized within the drum using vermiculite." Information from the Criticality Safety Evaluation for this waste (LANL, 2013) states the "the blocks are stabilized in the drums using standard packing materials such as bags, low-density foam material, Celotex, Vermiculate etc."

Follow up questions were asked of LANL scientist, William Crooks, who inspected the drums to determine how much vermiculite (or other) fill was added. In summary, Mr. Crooks inspected the drums at some point between 2004 and 2008 when material was being moved out of TA-18 for closure of the technical area. Each hexagonal fuel block is contained in an inner 55-gallon drum, which in turn is in an 85-gallon drums. Mr. Crooks took photographs of the contents of the drums, which are shown in Figure 3-1(a-c). The photographs show some additional packing material along with the fuel blocks inside the inner 55-gallon drums. However, the void space appears to be much greater than 10% in these photos. Figure 3-1(d) shows a typical Fort St. Vrain fuel block, like those is the waste drums. Figure 3-1(e) shows the 85-gallon outer drums.

For this special analysis, real time radiography (RTR) was performed to estimate the void volume within the drums and to determine the possible impacts on ground subsidence. Images from the RTR scans of the drums are included in Appendix B. Maximum void space for the drums was estimated to be 21.1% based on the radiographic analysis (Appendix C). In addition, void space at the top of the drums indicates that each drum could compact a maximum of approximately 6 inches vertically; the drums appear to have little to no void space radially.

Assuming the drums are not collocated or stacked, which is in line with the Criticality Safety Evaluation (LANL 2013), maximum linear compaction of 6 inches per drum could occur based on the RTR results presented in Appendix B. The Pit 38 extension has a total depth of 36 to 38 feet, and the final cover will add another 8 to 10 feet of additional overall thickness to the overall waste disposal region. Therefore, the maximum linear compaction is small compared to the overall waste/cover thickness. According to a subsidence study done for the Radioactive Waste Management Sites at the Nevada National Security Site, 60% to 80% of the long-term expected compaction of steel drums should occur over the first 100 years after disposal (DOE, Nevada Operations Office, 1998), and any subsidence observed could be remedied during the 100-year institutional control period. In addition, the final cover has a monolithic design constructed of crushed tuff mixed with bentonite. This type of cover is designed to be self-healing if subsidence occurs meaning that no breaks in internal cover layers will occur and the cover surface is self-leveling. It is highly unlikely that drum compaction at depth would result in a commensurate amount of subsidence at the surface because of the cover design, and the drums will be buried relatively deep, an estimated depth of between 18 and 21 ft below grade, within the pit. In addition, the significant overburden (18 ft of waste/fill and approximately 10 ft of cover) that will be present on top of the drums will hasten subsidence during the institutional control period, when maintenance activities can alleviate the problem.

According to a subsidence study done for the Radioactive Waste Management Sites at the Nevada National Security Site, long-term subsidence is thought to occur until the bulk density of the waste approaches the bulk density of the surrounding native rock (DOE, Nevada Operations Office, 1998). This general concept applies for waste with a lower overall density that the native rock, which is not the case with this waste. The graphite fuel blocks have an approximate density of 1.75 g/cm^3 (Cobb, 1976). The native rock at Area G, Unit 2 of the Tshirege Member of the Bandelier Tuff (Qbt2) is less dense that the fuel block with an approximate bulk density of about 1.32 g/cm^3 (Krier et al., 1997). It is highly unlikely that the fuel element itself will be compressed with time because of its high density, although the two outer drums and the void space within the drums may compress.

In a final comparison, the void space in the FSV drums is compared to the WAC allowable void space estimated for the Pit 38 extension. Void space of 21.1% applied to the three 85-gallon drums yields 54 gallons of void space. The Pit 38 extension has an approximate volume of greater than 400,000 ft^3, which is equivalent to approximately 3 million gallons. If we assume that half the volume of the pit is available for waste (1.5 million gallons), and that the waste has void space of 10% (maximum acceptable from the WAC), the acceptable void space according to the WAC for Pit 38 extension is 150,000 gallons. Thus, an exception to the WAC for these three drums results in a fraction of only 0.04% (54/150000) change in the total void space in this pit. This tiny fraction is likely to have no impact on the overall performance of the pit with respect to subsidence. Thus, this line of reasoning provides the strongest justification for the current analysis and leads us to the conclusion that disposal of these drums, though technically exceeding the void-space requirement in the WAC, does not lead to a measureable exceedance of the void space when the total volume of Pit 38 extension is considered.

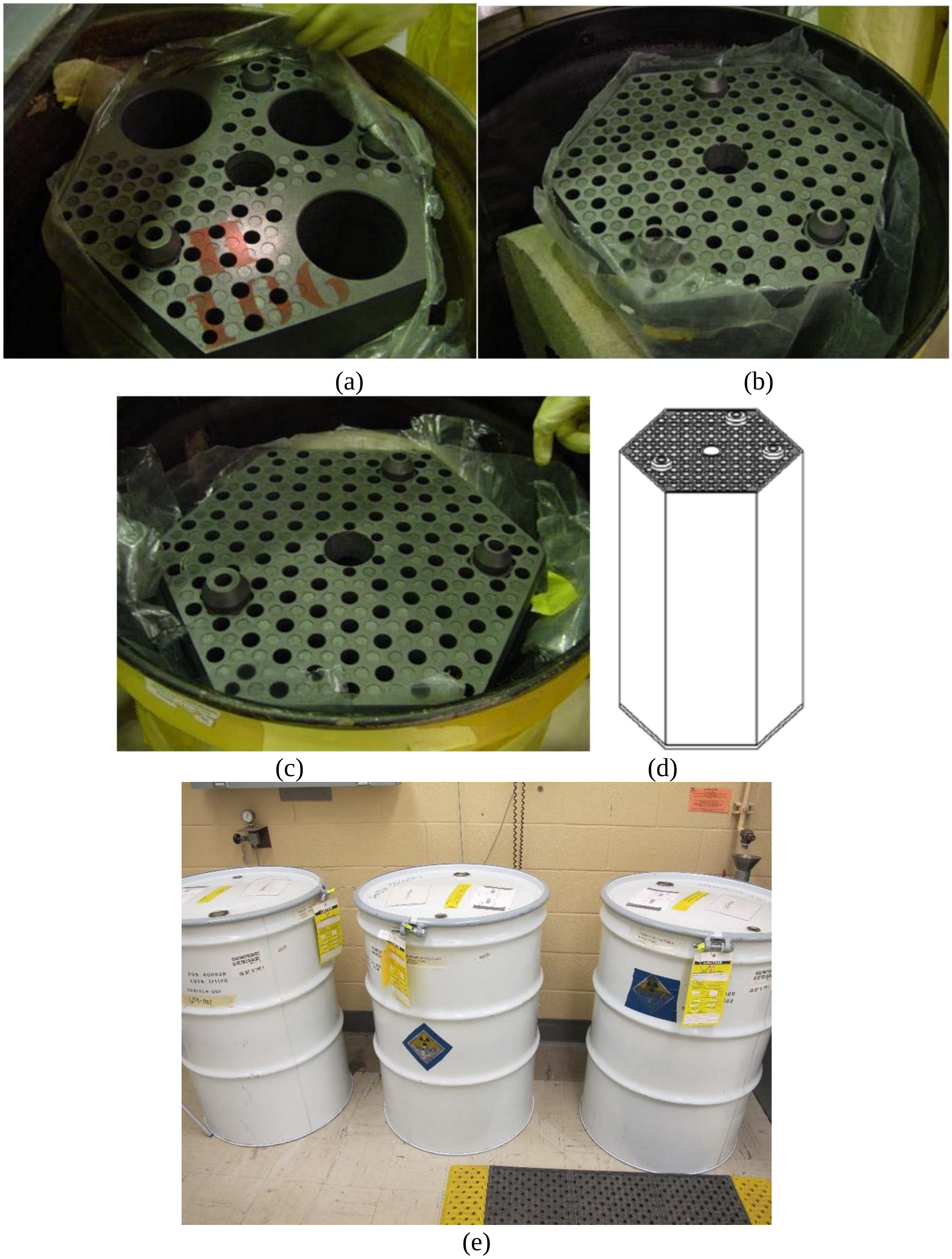

Figure 3-1. Photographs related to the Fort St. Vrain Waste Drums: (a-c) carbon fuel blocks inside 55-gallon inner disposal drums, (d) typical fuel block, (e) 85-gallon outer disposal drums.

4.0 Conclusions

The disposal of the three drums containing enriched uranium fuel pellets from the FSV Generating Station does not violate any of the assumptions upon which the Area G PA/CA are based. The criticality characteristics of the waste that cause it to violate the LANL WAC do not play a role in the performance modeling, and radionuclide concentrations in the waste fall within radionuclide concentration limits for the disposal pits. Radionuclide inventories that include the waste of the three drums fall within radionuclide inventory values included in the most recent inventory model for the performance assessment. It will be necessary to dispose of the waste in a manner that is consistent with the fissile nature of the waste, as recommended in the Criticality Safety Evaluation for the waste (LANL, 2013).

Container void space in the three drums exceeds the WAC recommendation of <10% void space. Excess void space can lead to long-term subsidence of a disposal site, which in turn can enhance radionuclide transport through processes such as increased infiltration, bioturbation, and cover failure. RTR scans indicate that the containers have a maximum void volume of 21.1%. Based on the dense nature of the waste, the relatively low maximum linear compaction per drum (approximately 6 inches), and the self-healing nature of the proposed cover, potential future subsidence from the three drums is thought to be acceptable in terms of overall site performance. Any subsidence that occurs during the institutional control period can be remedied. In addition, though technically exceeding the void-space requirement in the WAC, the void volume of these three drums does not lead to a measureable exceedance of the void space, particularly when the total volume of Pit 38 extension is considered. Therefore, future subsidence occurring specifically due to these drums is likely to have no measurable impact on site performance. This special analysis, SA 2017-001, concludes that the three FSV drums are acceptable with respect to the PA/CA assumptions for disposal in Pit 38 at Area G. The SA recommends that the drums be placed vertically in the pits and that there be adequate backfill around the drums to minimize potential future subsidence.

5.0 References

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DOE, Nevada Operations Office, 1998, *Consequences of Subsidence for the Area 3 and Area 5 Radioactive Waste Management Sites, Nevada Test Site*, DOE/NV--502, March.

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LANL, 2017, *Annual Report for Los Alamos National Laboratory Technical Area 54, Area G Disposal Facility – Fiscal Year 2016,* Los Alamos National Laboratory Report LA-UR-17-22215, March.

Appendix A

Unreviewed Disposal Question Evaluation 1701

ATTACHMENT 1
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UNREVIEWED DISPOSAL QUESTION EVALUATION WORKSHEET

Unreviewed Disposal Question Evaluation Worksheet			
8.1[1] UDQE Number:UDQE 1701	8.1[2] Date:4/3/2017		
Section 1: Proposed Activity			
8.1[3] Disposal of 3 drums of enriched uranium from Fort St. Vrain in pit 38 at Area G			
8.1[4]Section 1.1: Summary description of activity/change The disposal of the drums of enriched uranium oxide fuel pellets stored in carbon fuel blocks require a variance to the Area G WAC because they (1) exceed the fissile material limits and (2) have more that 10% void space.			
8.1 [6] Section 1.2: Reference LANL, 2014, *LANL Waste Acceptance Criteria,* Los Alamos National Laboratory Procedure P930-1, March.			
8.1[7] Section 1.3: Is the activity/change addressed by a previous UDQE or the LLW authorization basis documents?		☐ YES	☒ NO
8.1[8][A][a] UDQE No.:UDQE 1701	Date of UDQE:4/3/2017		
8.1[8][A][b] Justification for not requiring a UDQE			

ATTACHMENT 1

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UNREVIEWED DISPOSAL QUESTION EVALUATION WORKSHEET

8.1[1] UDQE Number: 1701		8.1[2] Date: 4/3/2017	
8.1[10]	**Section 2: UDQE– Screening**		
2.1	Waste Characteristics ☐	Not Applicable	
a.	Does the requested variance to the Area G WAC involve a technical issue (including radionuclide content, container specifications, amount of void space in containers, waste form, etc.)?	☒ YES	☐ NO
b.	Does disposal of radioactive waste within Area G which requires a variance to the LANL WAC, P 930-1?	☒ YES	☐ NO
c.	Does the proposed activity involve the retrieval of below ground waste?	☐ YES	☒ NO
2.2	Disposal Practices ☐	Not Applicable	
a.	Does the depth of waste placement exceed the depth of placement modeled in the PA/CA?	☐ YES	☒ NO
b.	Will the distance between the top of the disposed waste and the ground surface be less than the distance specified in the PA/CA?	☐ YES	☒ NO
2.3	Procedures /Documents/Systems ☒	Not Applicable	
a.	Does the procedure or process changes define, control or administer LLW characterization and/or disposal activities?	☐ YES	☐ NO
b.	Does the activity invoke changes to DAS?	☐ YES	☐ NO
c.	Does the activity change the Chem/LL database information that impacts LLW volume, activity, and or mass information, or the methods for calculating database quantities?	☐ YES	☐ NO
2.4	Site/Facility Construction ☒	Not Applicable	
a.	Does the proposed activity involve the addition/modification of structures, affect water runoff configurations, or impact the characterization/monitoring wells and/or equipment which are currently located at Area G?	☐ YES	☐ NO
b.	Does the proposed activity bring the facility/site back into compliance with current assumptions regarding site configurations and operations as defined within PA/CA and applicable Area G disposal authorization basis documents?	☐ YES	☐ NO
c.	Does the proposed activity involve the drilling of new boreholes or monitoring wells?	☐ YES	☐ NO
d.	Will the proposed activity require changes in site grading or storm waste runoff control provisions?	☐ YES	☐ NO
2.5	New Disposal Unit Construction ☒	Not Applicable	
a.	Do any design parameters differ from the PA/CA and applicable Area G disposal authorization basis documents? These parameters include, but are <u>not</u> limited to, disposal unit dimensions, distance of units from the mesa edge, and depth of disposal units.	☐ YES	☐ NO
b.	Is there construction of new site structures or facilities?	☐ YES	☐ NO
c.	Is there contruction activities for removal of existing site structures or features?	☐ YES	☐ NO
d.	Is there construction activities for creation of new disposal units (pits and shafts)?	☐ YES	☐ NO
2.6	Interim/ Final Disposal Unit Closure ☒	Not Applicable	
a.	Will the minimum depth of cover between the top of the waste and the ground surface be less than that specified in the PA/CA and applicable DAB documents?	☐ YES	☐ NO
b.	Do any design parameters of the cover differ from the PA/CA and applicable Area G disposal authorization basis documents? These parameters include, but are <u>not</u> limited to, slope, material properties, performance characteristics, and depth.	☐ YES	☐ NO
c.	Does the proposed activity affect the closure of active disposal pits and shafts or installation of operational or final covers?	☐ YES	☐ NO

ATTACHMENT 1 Page 3 of 3		
8.1[1] UDQE Number:1701	8.1[2] Date:4/3/2017	
If the answers to all applicable questions in Section 2 are "No", the activity/change does constitute a UDQ; proceed to Section 3: UDQ Evaluation Summary and Approval.		
Section 3: UDQ Evaluation Summary and Approval		
UDQ Number:1701	Date:4/3/2017	
8.1[11] ☐	This activity/change does not (all responses are "No") constitute a UDQ	
☒	This activity/change does (at least one response is "YES") constitute a UDQ and a Special Analysis is required prior to implementing the activity/change	
The quantities of uranium in 2 of the 3 drums from Fort St. Vrain exceed the fissile gram equivalent inventories permitted by the LANL WAC for the 85-gal drums in which the waste has been placed; the amount of carbon in all 3 drums also exceeds permissible limits. In addition, the contents of the drums exceed the recommended < 10% void space requirement. Therefore, the disposal of the drums in pits at Area G constitutes a UDQ, and a special analysis of the potential impacts must be prepared.		
8.1[12] UDQ Evaluator		
Name (Print)Kay Birdsell	Signature: [signature]	Date: 4/5/17
8.1[13] UDQE Reviewer		
Name (Print)Philip Stauffer	Signature: [signature]	Date: 4/6/17
ADC: ☒ Unclassified ☐ OUO ☐ UCNI ☐ Classified		
Derivative Classifier		
Name (Print) Kay Birdsell	Signature: [signature]	Date: 4/5/17
Section 4 FINAL APPROVAL		
8.1[19]/9.[7] LLW Operations Manager:		
Name (Print) LESLIE SONNENBERG	Signature: [signature]	Date: 5/26/2017

Appendix B

Real-Time Radiography of Fort St Vrain Drums

Real-time Radiography (RTR) of the Fort St Vrain Drums was conducted in April 2017 to estimate the void space within each of the three drums. Photos and three-dimensional video scans were performed. RTR allowed for interrogation of the void space in the drums without opening them in order to avoid worker exposure and to avoid jeopardizing the authorization to discard and the criticality safety evaluation which have already been completed.

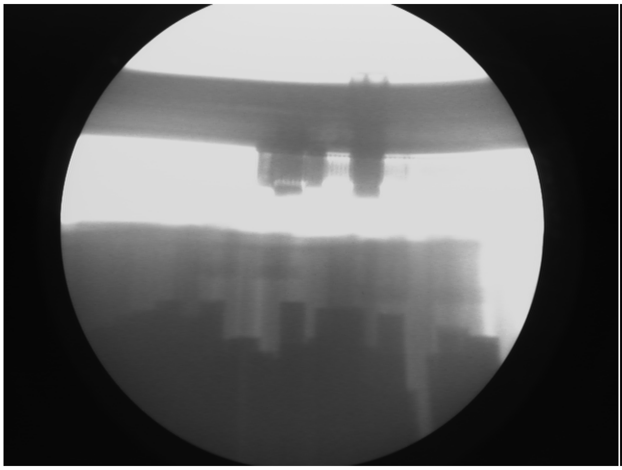
Figures B-1, B-2, and B-3 show typical RTR scans for the tops, middles and bottoms of the three drums. The orientation of each scan is a side view. According to the radiographers, the light portions of these scans show void space. The top view for each container shows void space at the top between the 85-gallon and 55-gallon drums, and also between the 55-gallon drum and the fuel element. The middle and bottom views show void space within the fuel element for those penetrations that were left empty. The scans indicate much less void space than observed in the photographs shown in Figures 3-1 (a-c). Decreased void space is thought to be because vermiculite was added around the fuel elements inside the 55-gallon drum and between the 55- and 85-gallon drums. The addition of vermiculite was noted in WCATS for these containers.

The radiographers estimated the maximum void space as 21.1%, as documented in Appendix C.

Drums have both a local drum number (e.g. 57, 61) and a corresponding WCATS identification number. The following table provides the mapping between these two systems of identification.

Table B.1

WCATS	Local Drum Number
W727646	Drum 057
W727647	Drum 061
W727648	Drum 063



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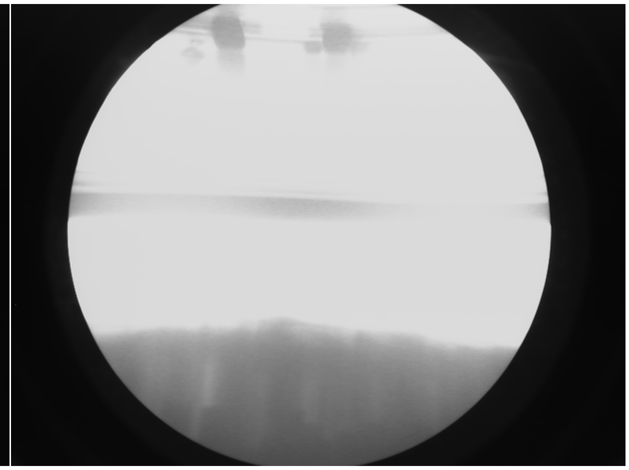
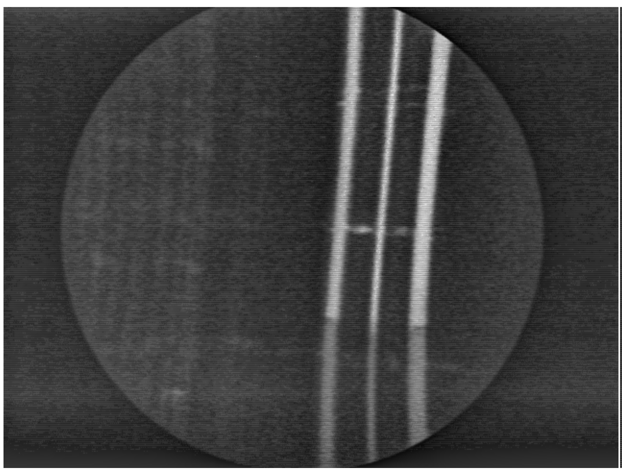
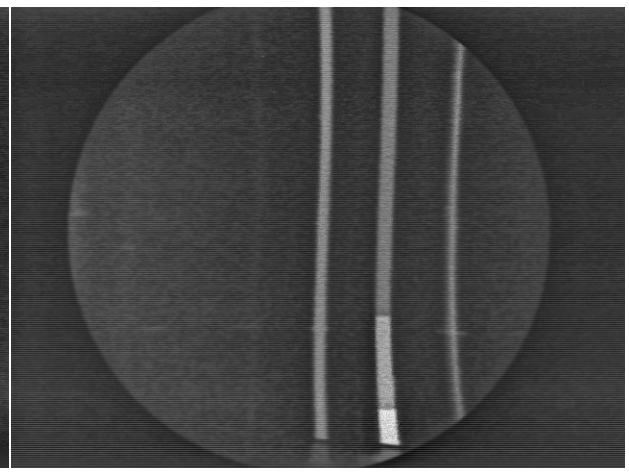


(b)

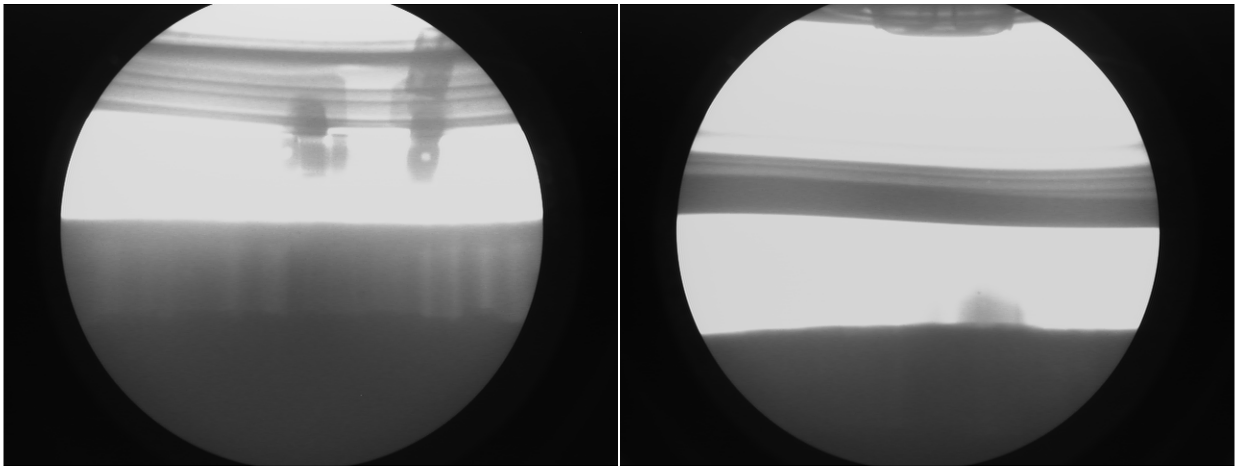


(c)

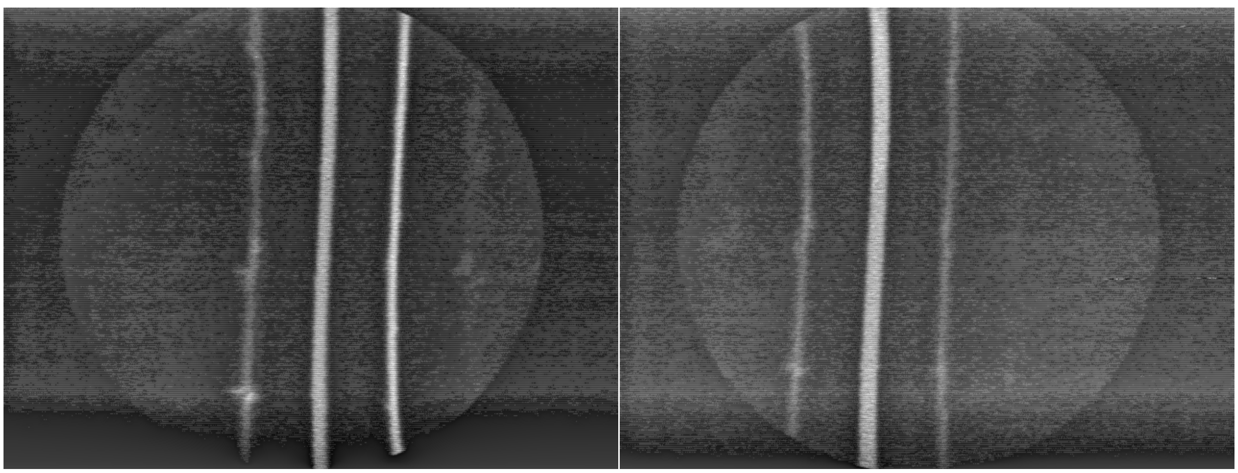


(d)

Figure B-1. Real Time Radiography of Drum 57, (a) top, (b) top (2nd view), (c) middle, and (d) bottom

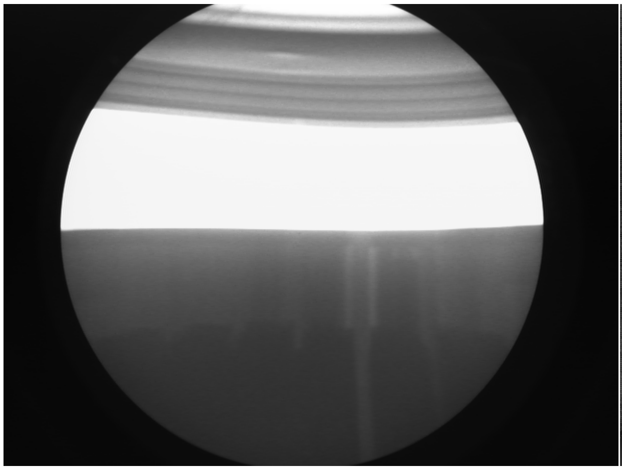


(a) (b)

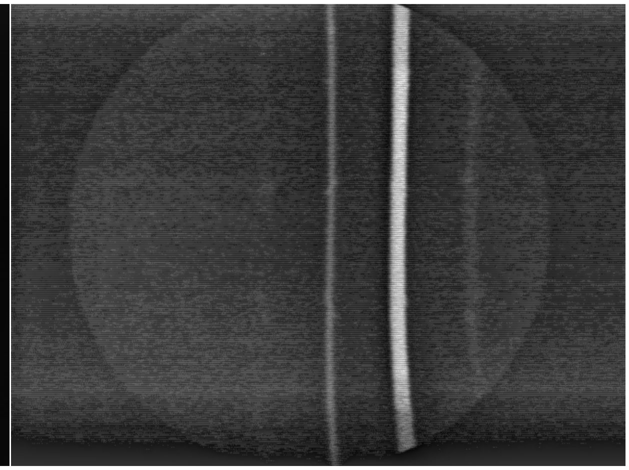


(c) (d)

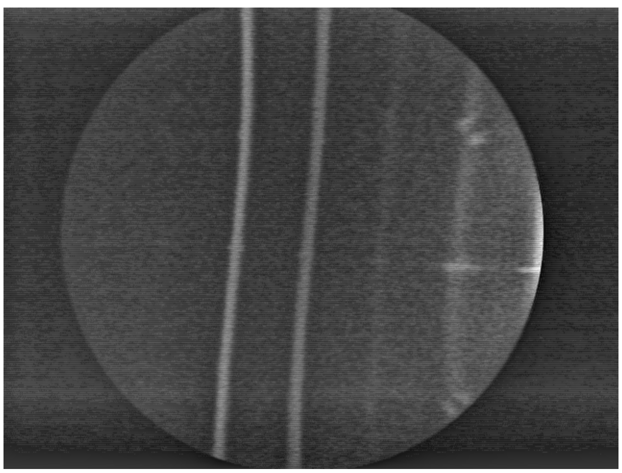
Figure B-2. Real Time Radiography of Drum 61, (a) top, (b) top (2nd view), (c) middle, and (d) bottom



(a)



(b)



(c)

Figure B-3. Real Time Radiography of Drum 63, (a) top, (b) middle, and (c) bottom

Appendix C

Calculation of Void in the Fort St Vrain Material pby

David. C. Potter (C-IIAC),
Craig M. Taylor (C-IIAC),
and James E. Coons (C-CDE)

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Philip Stauffer

LA-UR-17-23872

2 May 2017

1.1 Executive Summary

The percent void of the Fort Saint Vrain (FSV) material is estimated to be 21.1% based on the volume of the gap at the top of the drums, the volume of the coolant channels in the FSV fuel element, and the volume of the fuel handling channel in the FSV fuel element.

1.2 Assumptions

The assumptions used in calculating the percent void of the Fort Saint Vrain (FSV) materials are listed as follows:

1. The fuel chambers do not contribute void. All 210 fuel holes are capped with graphite plugs and filled with a blend of TRISO particles and coke filler[1].
2. The fuel handling pickup hole is located at the center of the hexagonal fuel element, is 1.62” in diameter, and 15.6” deep. These approximate dimensions are taken from Figure C-1.
3. The inside volume of the 55 gallon drum containing the FSV fuel element is filled to the top surface of the fuel element or 31.2” from the bottom of the drum.
4. The inside volume of the 85 gallon drum surrounding the 55 gallon drum is also filled to the level of the top surface of the fuel element or 31.2” from the bottom of the drum.
5. Void in the FSV material originates from three sources; (i) the unfilled gap at the top of the internal and external drums, (ii) the 108 coolant holes, and (iii) the fuel pickup channel.

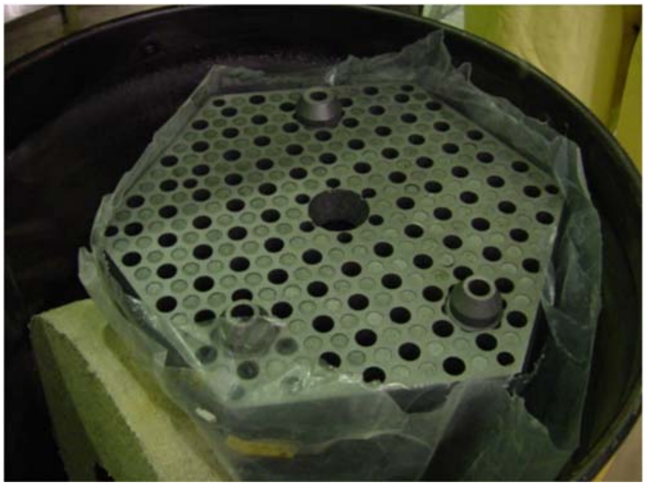

Figure C-1. Fort Saint Vrain fuel element in a 55 gallon drum .

The FSV fuel elements are standard fuel elements and specifically do not contain control poison channels[1]. A photograph of the FSV fuel element is provided in Figure 1, and fuel elements with and without control poison channels are shown in the lower left of Figure C-2.

[1] Dahlberg, R.C., R.F. Turner, and W.V. Goeddel, *Core design characteristics*, Nuclear Engineering International **14** (1969) 1073-1077.

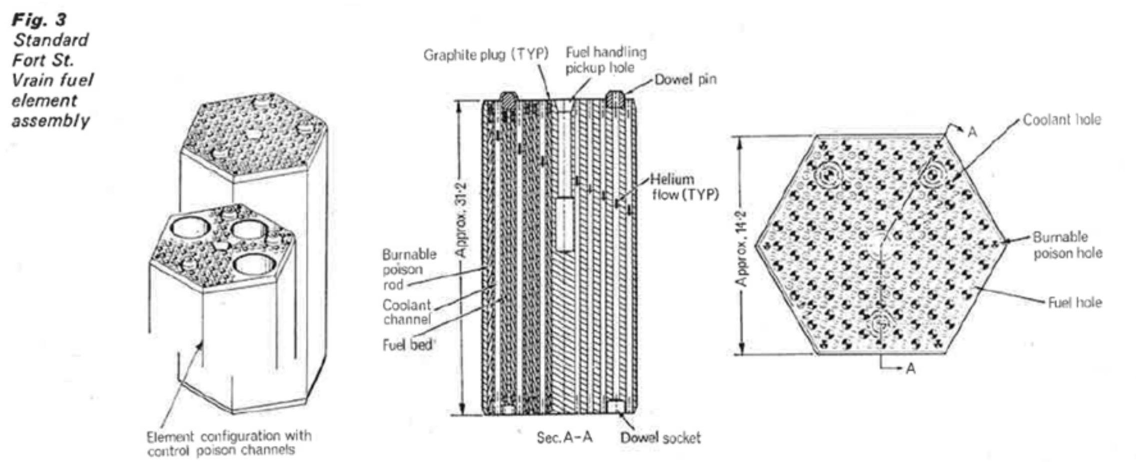

Figure C-2. Standard FSV fuel element[1].

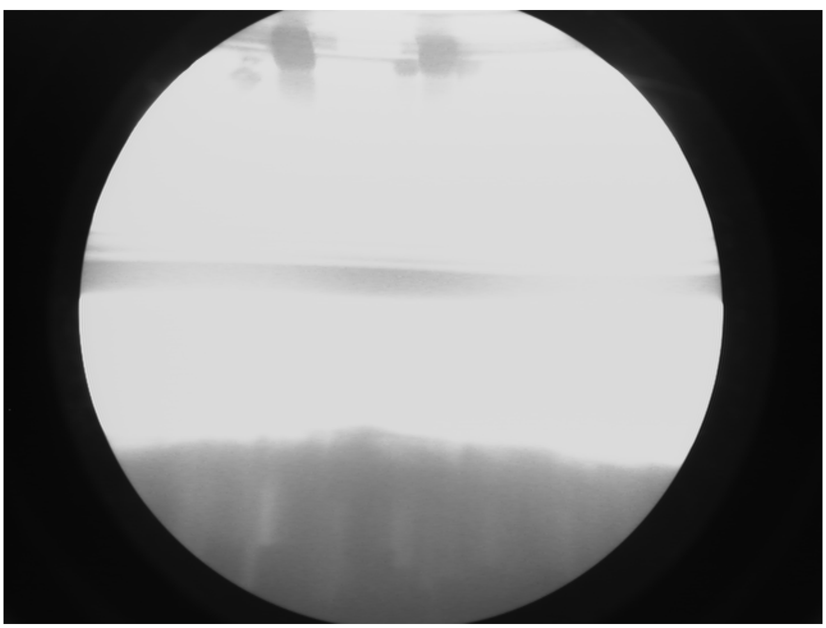

Figure C-3 A side view radiograph at the top of a FSV drum showing the fuel element filling the bottom of the image, the lid on the 55 gallon drum across the middle, and the lid on the 85 gallon drum at the top of the image

1.3 Volume of the Gap at the Top of the 85 Gallon Drum

The dimensions of the internal 55 gallon drum and external 85 gallon drum are provided in Table C-1.

Table C-1. Drum dimensions relevant to the void calculations[2].

Drum Capacity (Gallons)	Diameter (Inches)	Height (Inches)
55	22.5	33
85	26	37

Volume of the 85 gallon drum (V_{85}) is calculated from the information in Table 1.

$$\begin{aligned} V_{85} &= \pi D^2 h_{85}/4 \\ &= \pi(26 \text{ inches})^2 (37 \text{ inches})/4 \\ &= 19644 \text{ cubic inches} \end{aligned}$$

Volume of the gap at the top of the 85 gallon drum (V_{Gap}).

$$\begin{aligned} V_{Gap} &= \left[\left(h_{85} - h_{FE}\right)/h_{85}\right]V_{85} \\ &= \left[\left(37 \text{ inches} - 31.2 \text{ inches}\right)/37 \text{ inches}\right]\left(19644 \text{ cubic inches}\right) \\ &= 3079.3 \text{ cubic inches} \end{aligned}$$

No credit is taken for the volume of the 55 gallon drum extending into the unfilled space.

1.4 Volume of the Coolant Channels

There are 108 total coolant channels in the standard fuel element comprised of 106 large channels (0.630 inches or 16 mm diameter) and 6 small channels (0.512 inches or 13 mm diameter)[3]. The volume of the coolant channels ($V_{Coolant}$) is calculated from the sum of both types of channels.

$$\begin{aligned} V_{Coolant} &= \pi\left(n_{small} D_{small}^2 + n_{large} D_{large}^2\right) h_{FE}/4 \\ &= \pi\left[6\left(0.512 \text{ inches}\right)^2 + 102\left(0.63 \text{ inches}\right)^2\right]\left(31.2 \text{ inches}\right)/4 \\ &= 1030.6 \text{ cubic inches} \end{aligned}$$

[2] Skolnik Industries, Inc., downloaded from www.skolnik.com/container_measurements on May 2, 2017.
[3] Prismatic Modular High Temperature Gas Cooled Reactor, downloaded on 5/2/2017 from the International Atomic Energy Agency's Advanced Reactor Information (https://aris.iaea.org/sites/GCR.html).

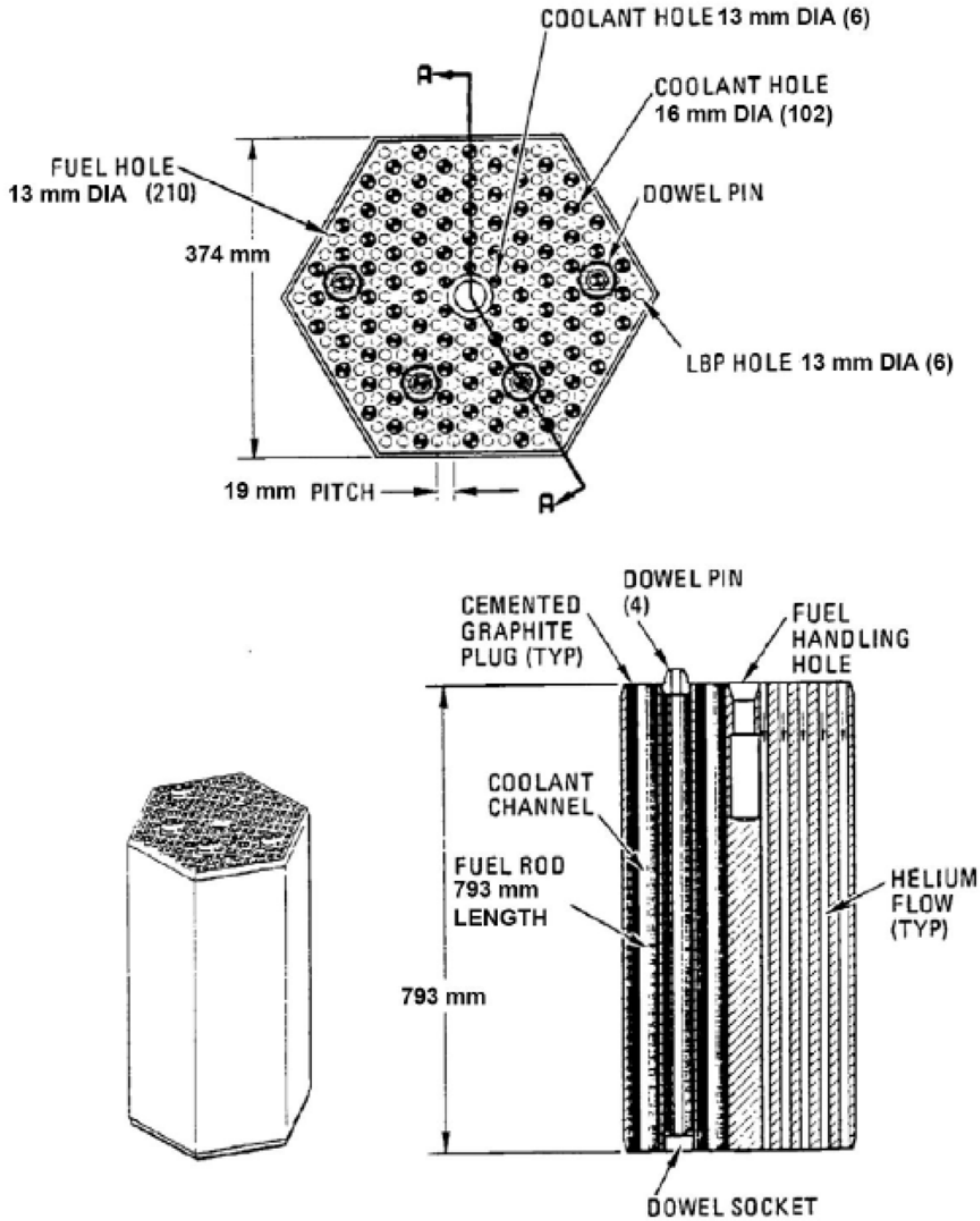

Figure C-4. Standard fuel element described by the IAEA[3].

1.5 Volume of the Fuel Handling Pickup Channel

The volume of the fuel handling pickup channel (V_{FHC}) is calculated from the information described in the assumptions section.

$$\begin{aligned} V_{FHC} &= \pi D_{FHC}^2 h_{FHC} \Big/ 4 \\ &= \pi \left(1.62 \text{ inches}\right)^2 \left(15.6 \text{ inches}\right) \Big/ 4 \\ &= 32.2 \text{ cubic inehes} \end{aligned}$$

1.6 Percent Void of the FSV Materials

The percent void is determined from the sum of the gap, coolant channels, and fuel handling pickup channel volumes.

$$\begin{aligned} \%\text{Void} &= \frac{\left(V_{Gap} + V_{Coolant} + V_{FHC}\right)}{V_{85}} \times 100\% \\ &= \frac{\left(3079.3 + 1030.6 + 32.2\right)}{19644} \times 100\% \\ &= 21.1\% \end{aligned}$$

1.7 Nomenclature

h_{85} is the inside height of the 85 gallon drum, inches.

h_{FE} is the height of the fuel element, inches.

h_{FHC} is the height of the fuel handling channel, inches.

$n_{l\arg e}$ is the number of large coolant channels.

n_{small} is the number of small coolant channels.

V_{85} is the volume of the 85 gallon drum, cubic inches.

$V_{Coolant}$ is the volume of coolant channels, cubic inches.

V_{FHC} is the volume of the fuel handling channel, cubic inches.

V_{Gap} is the volume of the gap at the top of the 85 gallon drum, cubic inches.

Appendix D

Waste Acceptance Criteria Exception Form

Los Alamos NATIONAL LABORATORY EST. 1943

Waste Acceptance Criteria Exception Form

WEF Number	WPF Number	CWDR/TWSR Number	Item Number
14-004	24319	1830864	W727646, W727647, W727648

Completed by Waste Generator

☐ On-going	☐ Hazardous/Chemical	☒ Low-level Waste	☐ Transuranic
☐ One-time	☐ Mixed Low-level Waste	☐ Radioactive Liquid Waste	☐ Other ______

Waste Acceptance Criteria:

See attachment A

Reason for Variance and Justification:

See attachment B

Requested by	Signature	Z Number	Date
David Potter	[signature]	241266	4/09/2014

Form 1973 (5/08)

Waste Management Review

1. Unreviewed Safety Questions Screen/Determination

Is a USQ Screen (USQS) required? ☐ Yes ☐ No ☐ N/A			
If required, USQ Screen was ☐ Positive ☐ Negative			
If the USQS was positive, note the USQ Determination Number (USQD Number): ___________			
Results of the USQD were: ☐ Positive ☐ Negative			
If the USQD was positive, DOE approval is required for this action.			
Any USQ issues were resolved. Qualified Person	Signature	Z Number	Date

2. Waste Management Approval

Special Instructions and Comments			
Basis for Exemption or Denial			
☐ Approved ☐ Rejected	Signature	Z Number	Date

Form 1973 (5/08)

Attachment A

Exemption 1.)

No: 930-1 LANL Waste Acceptance Criteria

3.2.4 Fissile Radionuclides

Table 3-5. Fissile Gram Equivalent (FGE) Content for Low-Level Waste (LLW) Packages

Drums are 55 gal. or larger, but are smaller than 90 ft3, then the total FGE must not exceed 275 g.

Exemption 2.)

No: 930-1 LANL Waste Acceptance Criteria

3.1.8 Beryllium and Carbon

The LLW matrix shall not contain beryllium and/or carbon in amounts greater than 20% by weight of the total waste in a package (criticality requirement).

Exemption 3.)

No: 930-1 LANL Waste Acceptance Criteria

3.3.1 General Requirements

Waste must be packages so that it does not present a hazard during handling or disposal operations. Packages used for waste must meet all of the following requirements (according to ABD-WFM-002, Appendix B):

- Be as full as possible with minimum void space. The void space within the waste or the waste package must not exceed 10%.

Attachment B

Exemption 1.)

Exceed U-235 and U-238 drum limits of LANL WAC.

The amount of U-235 and U-238 in the containers range from 370g to 672g.

Because there is only one item per package and the item is a structural monolith, the material cannot be size reduced or further divided to meet the LANL WAC.

Exemption 2.)

Exceed carbon drum limits of LANL WAC.

Each drum contains a single monolithic graphite (carbon) cylinder, 14' X 32", packed with enriched uranium oxide pellets coated with graphite. Because there is only one item per package and the item is a structural monolith, the material cannot be size reduced or further divided to meet the LANL WAC.

Exemption 3.)

The void space in the drum exceeds 10%.

Each drum contains a single carbon cylinder with the dimensions and density reported above. The cylinder is surrounded by packing material to stabilize its movement. The percent void of the Fort Saint Vrain (FSV) material is estimated to be 21.1% based on the volume of the gap at the top of the drums, the volume of the coolant channels in the FSV fuel element, and the volume of the fuel handling channel in the FSV fuel element.

After some consideration it was determined that the packaging is sufficient and fixed. Opening the drum for additional packing material is extremely hazardous from an ALARA perspective, and would provide minimal benefit as it would not address voids in the capped FSV element. In addition, opening the drum jeopardizes the existing Termination of Safeguards and Criticality Safety approval authorizations.