SAND2018-10010R

APPENDIX E

FCT DOCUMENT COVER SHEET [1]

Name/Title of Deliverable/Milestone/Revision No.	Engineering Cost Analysis Support - Scoping (Milestone M5SF-18SN010305054)
Work Package Title and Number	Technical and Programmatic Solutions for Direct Disposal of DPCs – SNL / SF-18SN01030505
Work Package WBS Number	WBS 1.08.01.03.05
Responsible Work Package Manager	Ernest Hardin (Name/Signature)
Date Submitted	

Quality Rigor Level for Deliverable/Milestone[2]	☐ QRL-1 ☐ Nuclear Data	☐ QRL-2	☐ QRL-3	☒ QRL-4 Lab- Specific

This deliverable was prepared in accordance with Sandia National Laboratories
(Participant/National Laboratory Name)

QA program which meets the requirements of

☒ DOE Order 414.1 ☐ NQA-1-2000 ☐ Other

This Deliverable was subjected to:

☒ Technical Review ☐ Peer Review

Technical Review (TR)
Review Documentation Provided

☐ Signed TR Report or,
☐ Signed TR Concurrence Sheet or,
☒ Signature of TR Reviewer(s) below

Peer Review (PR)
Review Documentation Provided

☐ Signed PR Report or,
☐ Signed PR Concurrence Sheet or,
☐ Signature of PR Reviewer(s) below

Name and Signature of Reviewers

John Kessler/SNL subcontractor

NOTE 1: *Appendix E should be filled out and submitted with the deliverable. Or, if the PICS:NE system permits, completely enter all applicable information in the PICS:NE Deliverable Form. The requirement is to ensure that all applicable information is entered either in the PICS:NE system or by using the FCT Document Cover Sheet.*

- *In some cases there may be a milestone where an item is being fabricated, maintenance is being performed on a facility, or a document is being issued through a formal document control process where it specifically calls out a formal review of the document. In these cases, documentation (e.g., inspection report, maintenance request, work planning package documentation or the documented review of the issued document through the document control process) of the completion of the activity, along with the Document Cover Sheet, is sufficient to demonstrate achieving the milestone.*

NOTE 2: *If QRL 1, 2, or 3 is not assigned, then the QRL 4 box must be checked, and the work is understood to be performed using laboratory specific QA requirements. This includes any deliverable developed in conformance with the respective National Laboratory / Participant, DOE or NNSA-approved QA Program.*

Technical & Programmatic Solutions for DPC Direct Disposal: Engineering Cost Analysis Support – Scoping

Spent Fuel and Waste Disposition

Prepared for
U.S. Department of Energy
Spent Fuel and Waste Science and Technology
by
Ernest Hardin
Sandia National Laboratories

September 6, 2018
Deliverable: M5SF-18SN010305054

Revision History

Version	Description
Technical & Programmatic Solutions for DPC Direct Disposal: Engineering Cost Analysis Support - Scoping Deliverable: M5SF-18SN010305054 WBS 1.08.01.03.05 Work Package: SF-18SN01030505 Sandia R&A Tracking #854545	Prepared by Sandia National Laboratories and its subcontractor NRSS, LLC. Submitted to the U.S. Department of Energy, Office of Spent Fuel and Waste Science and Technology.

Disclaimer: This is a technical presentation that does not take into account the contractual limitations under the Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste (Standard Contract) (10 CFR Part 961). Under the provisions of the Standard Contract, DOE does not consider spent nuclear fuel in canisters to be an acceptable waste form, absent a mutually agreed-to contract amendment. To the extent discussions or recommendations in this presentation conflict with the provisions of the Standard Contract, the Standard Contract provisions prevail.

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Engineering Cost Analysis Support - Scoping

Deliverable: M5SF-18SN010305054
WBS 1.08.01.03.05
Work Package: SF-18SN01030505
(Technical and Programmatic Solutions for Direct Disposal of DPCs – SNL)

Purpose and Scope: This memo describes the engineering technical and costing analysis support needed for identifying and evaluating technical and programmatic solutions for spent nuclear fuel (SNF) in dual-purpose canisters (DPCs), and the resources planned to provide that support.

The Technical and Programmatic Solutions (T&PS) work scope is intended to identify and evaluate the range of feasible options available for DPC direct disposal, considering the range of DPC designs in the existing fleet and a range of generic geologic disposal concepts. It will also identify changes to the way DPCs are loaded, and/or additional hardware that could be installed in DPCs as they are loaded, to improve disposability (chiefly, postclosure criticality control). These two thrusts are the focus of engineering support to the work package.

Constraints: The engineering analysis will be generic (non-site specific), and costing will be rough-order-of-magnitude (ROM) only, as appropriate for concepts that support decision-making but are essentially undeveloped (e.g., engineering design has not begun). It is anticipated that if additional detailed engineering description or costing analysis is needed, that further work on specific alternatives would be done in the future.

Costing will use present value, without discount analysis that distorts comparisons among nuclear fuel management options that may start many years hence and have durations of decades.

In identifying or developing engineering alternatives, it is important that to be viable, alternatives must be described with aspects that reduce overall cost relative to re-packaging of the same SNF. Further, alternatives to re-packaging should not increase worker dose or public health risk, although if dose or risk is low this may not be a strict constraint. Worker dose from loading DPCs (and by analogy, re-packaging) were estimated by Weck (2013).

On the other hand, where reduction of dose or risk could be seen as a benefit, the levels of dose or risk are likely to be low so that reduction would not be a strong selling point.

Consideration of public health risk in developing engineering alternatives should include postclosure criticality, although actual screening analysis is beyond the scope of engineering support (or the T&PS work package).

1. Evaluation of Disposition Alternatives for Current DPCs

Evaluations will consist of descriptions (e.g., high-level concept of operations), durations of SNF disposition (especially where significantly different from other alternatives and re-packaging), and ROM costs.

The scope of alternatives to be evaluated by the T&PS activity is suggested in Table 1. Selection from among these alternatives and identification of additional ones, along with engineering support needs, will be developed when the T&PS activity is underway. Engineering input will be sought in the selection process.

If DPC fillers are included among alternatives to be evaluated, the recent review of technical and regulatory requirements will be considered (Alsaed 2018a).

A statement of work (SOW) for engineering support that includes this activity is presented in the appendix. Additional resources may be provided once the T&PS activity is underway.

2. Identification of Modifications to DPCs Loaded in the Future

Possible DPC modifications include "criticality control enhancements" (EPRI 2008a,b) that could be added at the time of SNF loading. Information on duration of fuel pool operations, safety, worker dose, hardware costs, and operational and licensing issues are particularly important because utilities and DPC vendors would become more directly involved in DPC configuration for direct disposal.

Such measures as adding disposal control rods can also be implemented for existing DPCs by cutting DPC lids off, then re-sealing. This may be an option for consideration by the T&PS activity, but for planning purposes engineering support will be limited to implementation for new DPCs of existing designs, prior to initial sealing.

A statement of work (SOW) for engineering support that includes this activity is presented in the appendix. Additional resources may be provided once the T&PS activity is underway.

References

Alsaed, A. 2018a. *Technical and Regulatory Considerations for Use of Fillers in DPCs*. SFWD-SFWST-2018-000495 Rev. 0. U.S. Department of Energy, Office of Spent Fuel and Waste Science and Technology. July 31, 2018.

Alsaed, A. 2018b. *Review of Criticality Evaluations for Direct Disposal of DPCs and Recommendations*. SFWD-SFWST-2018-000491 Rev. 0. U.S. Department of Energy, Office of Spent Fuel and Waste Science and Technology. April 20, 2018.

EPRI (Electric Power Research Institute) 2006. *Criticality Risks During Transportation of Spent Nuclear Fuel*. 1013449. EPRI, Palo Alto, CA.

EPRI (Electric Power Research Institute) 2007. *Fuel Relocation Effects for Transportation Packages*. 1015050. EPRI, Palo Alto, CA.

EPRI (Electric Power Research Institute) 2008a. *Feasibility of Direct Disposal of Dual-Purpose Canisters: Options for Assuring Criticality Control, 1016629*. EPRI, Palo Alto, CA.

EPRI (Electric Power Research Institute) 2008b. *Feasibility of Direct Disposal of Dual-Purpose Canisters in a High-Level Waste Repository, 1018051*. EPRI, Palo Alto, CA.

Hardin, E., L. Price, E. Kalinina, T. Hadgu, A. Ilgen, C. Bryan, J. Scaglione, K. Banerjee, J. Clarity, R. Jubin, V. Sobes, R. Howard, J. Carter and T. Severynse 2015. *Summary of Investigations on Technical Feasibility of Direct Disposal of Dual-Purpose Canisters.* FCRD-UFD-2015-000129 Rev. 0. U.S. Department of Energy, Used Fuel Disposition R&D Campaign. May, 2015.

Weck, P. 2013. “Worker Exposure for At-Reactor Management of Spent Nuclear Fuel.” *Radiation Protection Dosimetry*. 156(3), pp. 386–393.

Table 1. Preliminary list of disposition pathways for commercial SNF in DPCs (fresh-water geologic settings except salt repositories, as noted).

Disposal parameter*	Fraction of DPCs*	Confidence*	Comment*
Deterministic analysis for low-probability screening, with misloads. Limit probabilistic inputs to manufacturing defects and early overpack failure.	<50%	Medium	(Current approach) A significant number of DPCs would likely not be demonstrated subcritical in fresh-water settings, with misloads, especially if the analysis includes loading of higher reactivity assemblies. See EPRI reports on misloads (EPRI 2006, 2007).
Probability-weighted consequence screening of criticality FEPs from repository performance.	100%	High	Criticality events would be screened from PA based on a combination of: a) low-probability screening of *consequential* criticality events, and b) low-consequence screening of *inconsequential* criticality events (i.e., that would not significantly impact dose, but for which the aggregated probability may exceed the 10^{-4} threshold).
Risk-based analysis with criticality included in repository performance assessment.	100%	Medium	Including criticality in the PA could be done using the same models used to exclude inconsequential events as noted above. Including criticality would likely present challenges with data quality, validation, etc.
Use fillers pumped into DPCs, that solidify and exclude moderator (also may absorb neutrons) after overpack breach in the repository.	100%	Medium-Low	An effective fillers strategy could ensure that criticality is excluded on the basis of low probability. A major R&D effort would likely be needed to develop this approach using new filler technologies, for a range of DPC basket designs and SNF types.
Control the SNF loading arrangement for *future* DPCs to minimize reactivity for disposal configurations, in conjunction with a tool for confirming SNF burnup.	75%	Medium	Many DPCs have been loaded without this guidance and without criticality control measures such as disposal control rods. Some sites may not have enough high- or low-reactivity assemblies to meet all thermal, shielding, and disposal criticality needs. Also, reactivity margin demonstrated using this approach may be insufficient for regulatory purposes.
Salt repository	100%	High	Analysis has demonstrated that chlorine concentration in salt brine would be sufficient to ensure subcriticality with readily demonstrated burnup credit (see Hardin et al. 2015).
Screening that relies on low probability as noted above, but with a more fully probabilistic approach to quantifying neutron multiplication factor (k_{eff}).	90%+	Medium	Low-probability screening with uncertainty distributions implemented for inputs to and outputs from heretofore deterministic k_{eff} calculations. Given the variability in basket designs, SNF characteristics and loading, misload probabilities, and site-specific information, it is likely that only a subset of DPCs could be demonstrated acceptable for disposal.
Use an overpack with sufficiently low failure probability to exclude post-closure criticality on low probability.	100%	Medium-Low	Recent analysis has shown that improved reliability of corrosion resistant overpacks could be important in a low-probability criticality screening approach. However, some early failure will be predicted so that criticality is more likely. Also, failures associated with disruptive events (e.g., seismic) cannot be excluded.
Re-packaging of some or all DPCs into disposal specific canisters	100%	High	While confidence is high, cost would also be higher. Estimation for re-packaging is needed for comparison.

*Based on Alsaed (2018b, Table 5.1). TBD = to be determined

Appendix – Subcontractor Scope of Work for Engineering Support to Technical & Programmatic Solutions Work Package

1. Deliverable: Design options, analysis recommendations, and ROM cost for changes to future DPCs to control postclosure criticality (22Feb19)

About 200 dual-purpose canisters (DPCs) of existing designs are being added to the fleet each year, for dry storage of spent fuel at nuclear power plants across the U.S. These systems are licensed (or licensable) for dry storage and transportation, but not disposal. One disposition for these DPCs is to cut them open and re-package the spent nuclear fuel in canisters designed and licensed specifically for disposal. Another disposition option could be to implement simple measures so that DPCs of existing design, could be directly disposable without re-packaging. Previous studies have shown that the main technical challenge for direct disposal strategies is control of postclosure criticality. Strategies for managing postclosure criticality include low probability and low consequence screening, following applicable regulations.

This task will identify and briefly describe possible options for rendering existing DPC designs disposable, for example, by adding long-lived neutron absorbing components, and/or by managing how fuel assemblies are loaded in canister baskets according to how reactive they are (burnup). It will also identify any associated technical or regulatory challenges. Rough-order-of-magnitude comparative cost analysis will be provided so that DPC direct disposal options can be compared with re-packaging on a relative basis.

The deliverable will be a letter report to Sandia, which will be submitted to the Sandia Designated Representative for acceptance review on/before 22Feb19. This letter report will support M4SF-18SN010305055 – *Engineering and Cost Analysis for DPC Disposal Solutions*. Note that planning input for this effort will be included in M5SF-18SN010305054 – *Engineering Cost Analysis Support - Scoping*.

Resource estimate: Hours TBD plus travel

2. Deliverable: Costing support for DPC disposition options including the existing fleet (12Apr19)

This task will work with other researchers in Sandia's Technical and Programmatic Solutions for Direct Disposal of DPCs work package (SF-18SN01030505) to identify a list of disposition pathways for existing DPCs (that do not involve removing the fuel but may involve fillers), and to provide rough-order-of-magnitude cost analysis for those options.

The deliverable will be a letter report to Sandia, which will be submitted to the Sandia Designated Representative for acceptance review on/before 12Apr19. This letter report will support M4SF-18SN010305055 – *Engineering and Cost Analysis for DPC Disposal Solutions*.

Resource estimate: Hours TBD plus travel

3. Planning and scoping of probabilistic model for consequence screening, and technical reviews for deliverables resulting from the consequence screening. Assist Sandia in following up on recommendations from SFWD-SFWST-2018-000491 – *Review of Criticality Evaluations for Direct Disposal of DPCs and Recommendations* (issued 20Apr18). Planning and scoping input will be provided by the subcontractor in meetings and other interactions with Sandia's consequence screening team. Additional time is included for background research and review aimed at making these team interactions successful. Note: this scope is listed here to show one

way the integration between the T&PS effort and consequence screening activities will be achieved, by sharing staff resources.

The term of this effort will run from initiation until completion of the Sandia deliverable M2SF-18SN010305062 – *Preliminary Probabilistic/Regulatory Analysis of Postclosure DPC Criticality Consequences*. Travel at the direction of the Sandia Designated Representative is funded up to the amount indicated below.`

Resource estimate: Hours TBD plus travel