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Options Assessment Report: Treatment of Nitrate Salt Waste at Los Alamos National Laboratory

Rev. 1

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Executive Summary

This report documents the methodology used to select a method of treatment for the remediated nitrate salt (RNS) and unremediated nitrate salt (UNS) waste containers at Los Alamos National Laboratory (LANL). The method selected should treat the containerized waste in a manner that renders the waste safe and suitable for transport and final disposal in the Waste Isolation Pilot Plant (WIPP) repository, under specifications listed in the WIPP Waste Acceptance Criteria (DOE/CBFO, 2013). LANL recognizes that the results must be thoroughly vetted with the New Mexico Environment Department (NMED) and that a modification to the LANL Hazardous Waste Facility Permit is a necessary step before implementation of this or any treatment option. Likewise, facility readiness and safety basis approvals must be received from the Department of Energy (DOE). This report presents LANL's preferred option, and the documentation of the process for reaching the recommended treatment option for RNS and UNS waste, and is presented for consideration by NMED and DOE.

After the release of radioactivity from the WIPP on February 14, 2014 and the subsequent recognition that the breached drum was a RNS waste drum processed at LANL (Drum 68660), LANL took a number of precautionary steps to protect workers, the public, and the environment. Drums stored at LANL continue to be maintained in isolated storage. Monitoring results are reported to the NMED under the LANL Nitrate Salt Bearing Waste Container Isolation Plan (Isolation Plan: LANL, 2014). Drums are currently stored under a High Efficiency Particulate Air filtration system and the temperature controls provided by the building, with active fire suppression systems. Monitoring of the drums consists of hourly visual inspections, daily temperature measurements of the standard waste boxes (SWBs) containing the RNS waste drums, and periodic sampling and analysis of the headspace gases within these SWBs. This configuration of the RNS and UNS wastes at LANL represents the "initial state" for subsequent treatment options being considered in this Options Assessment report. The report describes the methods used to evaluate a wide range of potential treatment options to permanently treat the waste, and presents the results of that evaluation.

The scientific underpinning for this assessment is the work of Clark and Funk (2015), which reports the comprehensive set of studies undertaken by LANL to gain an understanding of the chemical reactivity that led to the exothermic reactions and breech of the drum in WIPP. Experimental and modeling studies performed at LANL indicate that mixtures of metal nitrate salts (oxidizer) with Swheat™ organic kitty litter (fuel) create the potential for exothermic chemical reactions. The use of Swheat™ absorbent in the processing of nitrate salt wastes can be pinpointed as the critical processing decision that led to the failure of Drum 68660 in the WIPP repository. Based on their studies, Clark and Funk (2015) proposed a remediation strategy consisting of two steps: 1) cooling of the waste drums during handling to lower the rates of reactions that may be occurring; and 2) stabilizing the waste by mixing the RNS waste into an inorganic matrix of natural mineral zeolite like clinoptilolite to deactivate RCRA characteristics (D001/D002).

To evaluate this recommendation as well as other potential treatment options, LANL assembled a team (the "Core Remediation Team" or "Core Team") consisting of subject matter experts across a wide range of disciplines including scientific, operational, safety and regulatory specialists. The team's goal was to increase the number and diversity of options beyond that considered by Clark and Funk (2015), and to subject those options to an evaluation process that considers a broad set of evaluation criteria, thereby ensuring a more robust, defensible treatment recommendation. Four treatment options previously considered by LANL staff were originally included. These involved zeolite addition, cementation, or both. An additional LANL option was later evaluated including dissolution of the nitrate salts, filtration of the mixture, and final cementation. As part of this study, the Core Team expanded the list of treatment options beyond RCRA stabilization to include nine other general or industry-practice-based technologies recommended in the Resource Conservation and Recovery Act (RCRA) treatment standards (40 CFR Part 268). The full list of treatment options considered is shown in Table ES-1.

A diverse set of eleven criteria was defined to ensure that a broad set of factors was considered in evaluating these options. A twelfth criterion, cost, was also considered for information purposes but not explicitly used in the evaluation. The evaluation process consisted of two steps. First, a pre-screening process was conducted to cull the list on the basis of a decision of infeasibility of certain potential options with respect to one or more of the criteria. Then, the remaining potential options were evaluated and ranked against each of the criteria in a relative fashion, and numerical scores were established by consensus of the review Core Team (with a range of 1 to 5, with higher scores being more favorable). After the ranking process was completed for all criteria and a matrix of scores was determined, the final results were tabulated and the discussion and rationale for the scores was documented. The main report provides definitions of the treatment options and criteria, and narratives explaining the Core Team's rationale for the pre-screening decisions and the justification for the scores awarded for each options against each criteria.

The final results of the evaluation are summarized in Table ES-2. In the pre-screening step, a total of fourteen options were considered. Four RCRA stabilization options were identified using zeolite, zeolite with cementation, and dry-process or wet-process cementation (Options 1 through 4). A fifth stabilization option of combined technologies, filtration and dissolution with cementation of the nitrate salt waste (Option 14), was evaluated as a treatment option, after the initial meeting of the remediation team. All other options were eliminated in this step and screened out. After the determination of the screening, the eliminated options were not ranked. Clearly, this result applies only for the particular nitrate salt waste streams at LANL, and is not a general conclusion. Difficulties in permitting, safety basis, and short-term or long-term effectiveness of the final waste form were typical criteria that led to the elimination of these options. In the subsequent full evaluation of the five stabilization options, Option 1 (Stabilization Using Zeolite) ranked the highest based on the criteria used in the evaluation. Its score is significantly higher than any cementation option; for most of the eleven criteria applied to the evaluation, this option scored equal to or higher than any of the cementation options. Therefore, even if one were to apply unequal weightings to the various criteria, the conclusion that zeolite addition is the preferred option will not change. Therefore, the recommendation to pursue Option 1 is very robust. The results of the cost criterion, though not used in the analysis, reinforces the results of the evaluation in that the treatment option recommended based on non-monetary criteria is also judged to be the most cost effective option.

Finally, recommendations were developed based on current information and understanding of the scientific, technical, and regulatory situation at the time of writing of this document. Any significant changes to the state of knowledge in any of these areas should be followed up with a qualitative re-evaluation, or a more thorough quantitative evaluation, as appropriate.

Table ES- 1. Summary of potential treatment options considered

Option	Description	Applicability		EPA Technology Code*
		RNS	UNS	
RCRA Stabilization Options				
1. Stabilization Using Zeolite	Mix waste into inorganic natural mineral to eliminate ignitability potential of the waste	X	X	STABL /RHETL
2. Stabilization Using Zeolite With Cementation	Option 1 followed by production of cement waste form	X	X	STABL /RHETL
3. Stabilization Using Dry-Process Cementation	Production of cement waste form with water added only at the time of cementation	X	X	STABL
4. Stabilization Using Wet-Process Cementation	Initial water addition to eliminate potential thermal runaway reactions, followed by production of cement waste form	X		STABL/WTTRx
14. Salt Dissolution With Cementation/ Stabilization	Water addition followed by filtration and cementation process of Swheat™ cake and nitrate salt solution	X		WTRRx/STABL/ RHETL
Other RCRA Recommended Options				
5. Incineration	Burning of waste in a radiological incinerator	X		INCIN
6. Thermal Oxidation of Organics	Treatment of waste in air to oxidize without flame	X		RTHRM
7. Biodegradation	Biological breakdown of organics or non-metallic inorganics under aerobic or anaerobic conditions	X		BIODG
8. Chemical or Electrolytic Oxidation	Breakdown of organics through the addition of oxidation reagents	X		CHOxD
9. Chemical Reduction	Breakdown of nitrate constituents through the addition of reducing reagents	X	X	CHRED
10. Vitrification	Incorporation of waste into a glass waste form	X	X	HLVIT
11. Alternate Macro-Encapsulation	Coating of the waste with an organic polymer to reduce surface exposure	X	X	MACRO
12. Neutralization	Reagent addition to neutralize the pH	X	X	NEUTR
13. Controlled Reaction or Leaching	Removal of soluble salts by leaching with water	X	X	

* EPA Technology Code derived from 40 CFR 268.42.

Table ES-2. Summary of results of the evaluation of treatment options

EVALUATION CRITERIA

	POTENTIAL TREATMENT OPTIONS	Robust to waste stream variability	Ease of permitting (permitting difficulties)	Safety basis challenges	Extent of testing required	Reduction of toxicity and mobility	Reduction in volume	Short-term and long-term effectiveness	WCS implications	Scalability and complexity	Facilities challenges	Schedule	Cost (not a primary evaluation criterion) *	SCORE
1	Stabilization Using Zeolite (remediated)	5	3	4	5	4	2	4	2	4	4	4	4	41
	Stabilization Using Zeolite (unremediated)	5	3	4	5	4	2	5	N/A	5	5	5	5	43
2	Stabilization Using Zeolite With Cementation (remediated)	5	2	3	3	4	1	4	1	2	2	1	1	28
	Stabilization Using Zeolite With Cementation (unremediated)	5	2	3	3	4	1	5	N/A	3	3	2	1	31
3	Stabilization Using Dry-Process Cementation (remediated)	5	2	2	3	4	3	4	1	3	2	2	2	31
	Stabilization Using Dry-Process Cementation (unremediated)	5	3	2	3	4	3	5	N/A	4	3	3	3	35
4	Stabilization Using Wet-Process Cementation (remediated)	3	4	1	3	4	2	4	1	1	1	1	2	25
14	Salt Dissolution With Cementation/Stabilization (remediated)	3	3	1	3	4	2	4	1	2	1	2	2	26
5	Incineration		■	■										
6	Thermal Oxidation of Organics		■	■										
7	Biodegradation			■										
8	Chemical or Electrolytic Oxidation			■										
9	Chemical Reduction			■				■						
10	Vitrification									■		■		
11	Alternate Macro-Encapsulation							■						
12	Neutralization					■								
13	Controlled Reaction or Leaching of Reactive Inorganic Chemicals With Water							■						

Note: Stabilization Options 1-4 and 14 are discussed in Section 4.1 RCRA Stabilization Options. Options developed from RCRA treatment standards are the gray-shaded rows. Red cells denote the screening out of an option based on a high degree of infeasibility with respect to that criterion. Because of the initial screened-out determination, Options 5-13 were not ranked. Discussion of Options 5-13 is found in Section 4.2 Additional RCRA Treatment Options.

*Cost not included in final score.

1 Introduction

On February 14, 2014, a release of radioactivity occurred at the Waste Isolation Pilot Plant (WIPP), resulting in distribution via airborne transport of radioactivity within the repository and to the surrounding environment in the vicinity of the facility. Subsequently, WIPP personnel gained access to the underground and determined that a waste drum or drums had breached in Panel 7, Room 7 of WIPP. After WIPP declared a potentially inadequate safety analysis (PISA) on the possibility of inadequately remediated nitrate salt-bearing waste contained in waste packages at WIPP (May 1, 2014), LANL took precautionary measures to move all remediated nitrate salt (RNS) waste drums to TA-54, Area G, Dome 375 and began daily temperature measurements.

When definitive photographic evidence became available (May 15, 2014) that the breeched drum was indeed an RNS waste drum processed at LANL (Drum 68660), LANL implemented additional precautions and controls, including overpacking of the 55-gallon RNS waste drums into Standard Waste Boxes (SWBs)[1], as well as moving all unremediated nitrate salt (UNS) containers[2] to a Permacon at TA-54, Area G, in Dome 375. As of August 2015, the UNS waste drums were moved to the general population located in Dome 230. RNS waste drums similar to those at LANL had previously been shipped to WIPP (515 drums,[3] emplaced in the WIPP underground), and to the low level radioactive waste facility in Andrews, Texas managed by Waste Control Specialists, LLC (WCS) (115 drums, subsequently placed in shallow underground storage with temperature monitoring). Thus, LANL, WIPP, and WCS have taken precautions to protect workers, the public, and the environment from further reactions.

In a series of subsequent actions, LANL took the following steps associated with the UNS and RNS waste drums:

- Environmental Protection Agency (EPA) Hazardous Waste Number D002 (corrosivity) was conservatively applied to 26 of the UNS containers due to the presence of free liquids,[4]

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[1] On May 18, 2014, there were 57 RNS waste containers at LANL, overpacked into a total of 55 SWBs. Four additional containers were pipe overpack containers. The resulting final number of RNS containers was 61 as of June 30, 2015. An August 27, 2015 update reflected 56 RNS waste containers remained in 54 SWBs. The remaining four pipe overpack containers were each stored in an 85-gallon overpack.

[2] At the time that LANL suspended further processing of UNS waste on May 2, 2014, there were a total of 29 UNS waste drums that had not yet been processed. The movement of these drums to Dome 375 was completed on June 3, 2014. These drums were moved to Dome 230 with the general waste population in August 2015.

[3] Nitrate Salt Bearing Waste Container Inventory March 27, 2015 (ADESH-15-052) and April 24, 2015 (ADESH-15-071).

[4] The waste drums are lined with epoxy to minimize corrosion. LANL took the conservative approach and designated the drums as D002 in July 2014.

- EPA Hazardous Waste Number D001 (ignitability) was applied to all UNS waste containers based on the presence of nitrate salt compounds,

- EPA Hazardous Waste Number D001 (ignitability) was applied to all RNS waste containers. This step was taken based on independent testing using surrogate samples comprised of mixtures of the organic absorbent (Swheat™ kitty litter) and sodium nitrate indicating that the remediated nitrate salts are considered to be oxidizers under Department of Transportation rules; and

- EPA Hazardous Waste Number D003 (reactivity) was not initially applied to the RNS waste containers. The oxidizer basis for applying the D001 EPA Hazardous Waste Number (ignitability) was deemed sufficient to characterize the waste because it was the primary constituent and regulatory basis for the characterization (40 CFR §261.21(a)(4)); a thermal reaction would be the most probable source for a reactivity determination; there were relevant and applicable testing procedures available; the oxidizer characterization was rebuttable by testing under DOT regulations at 49 CFR §173.127; and the waste would be managed with all special requirements for both ignitable and reactive waste.

Drums at LANL continue to be managed and monitoring results are reported to the NMED under the requirements of the LANL Nitrate Salt Bearing Waste Container Isolation Plan (Isolation Plan: LANL, 2014). Drums are currently stored under HEPA filtration and the temperature controls provided by the buildings, with active fire suppression systems. Monitoring of the drums consists of hourly visual inspections, daily temperature measurements of the SWBs containing the RNS waste drums, and periodic sampling and analysis of the headspace gases within these SWBs. This configuration of the RNS and UNS wastes at LANL, and the hazardous waste designators applied to the drums represent the "initial state" for subsequent treatment options being considered in this Options Assessment Report.

This report documents the methodology used to select a method to treat the RNS and UNS waste in a manner that renders them safe and suitable for transport and final disposal in the WIPP repository, under specifications listed in the WIPP Waste Acceptance Criteria (WAC) (DOE/CBFO, 2013). Furthermore, on December 6, 2014, the NMED issued an Administrative Compliance Order (ACO: NMED, 2014) to DOE and LANS[5] for violations to LANL's Hazardous Waste Facility Permit (Permit) connected to the management of nitrate salt wastes. The pertinent portions of the ACO relevant to

[5] As of the writing of this report, negotiations are ongoing and the ACO has not been finalized.

this report are the following compliance actions pending NMED issuance of the ACO actions.[6]

> *130. No later than 60 days after this order becomes final, Respondents shall submit to NMED for review and approval a plan to remediate and/or treat the 57 remediated daughter containers pursuant to all applicable HWMR and Permit requirements.*
>
> *131. No later than 60 days after this order becomes final, Respondents shall submit to NMED for review and approval a plan to remediate and/or treat the 29 un-remediated parent containers pursuant to all applicable HWMR and Permit requirements.*

To comply with these actions, documents are being provided to the NMED to provide the technical and other justification for the proposed treatment plans that LANL proposes. Figure 1-1 is a schematic diagram representing the feeds and information content of the various documents comprising the overall plans. Documentation of LANL's scientific work consists of a series of scientific investigations feeding the summary report of Clark and Funk (2015). This collection of reports provides the technical underpinning for the remaining documents. The Options Assessment Report (this document) provides the rationale for LANL's recommendation of the treatment options for RNS and UNS wastes, including a description of the process used to arrive at the recommendation. Finally, the Remediation Plans for RNS and UNS wastes will establish the recommended path forward for final treatment of the waste streams. These plans translate the Options Assessment Report recommendation and the LANL facility-based requirements to resume safe operations (the Resumption Plan) into an actionable plan for treatment to render the nitrate salt wastes safe for transportation and final disposal in the WIPP repository. The scientific studies, the Options Assessment Report, and the Remediation Plans collectively serve to satisfy the ACO deliverables previously cited.

The remainder of this Options Assessment Report consists of a brief summary of the scientific findings relevant to the future treatment of UNS and RNS waste and a discussion of assumptions. The report describes the potential treatment options that were considered for RNS and UNS wastes including the methodology used to arrive at the recommended treatment options. The methodology was an expert-based process in which a cross-disciplinary team of LANL professionals established a set of evaluation criteria and ranked the various proposed options. Finally, the results of this process are presented, and specific recommendations for remediation of RNS and UNS wastes are summarized.

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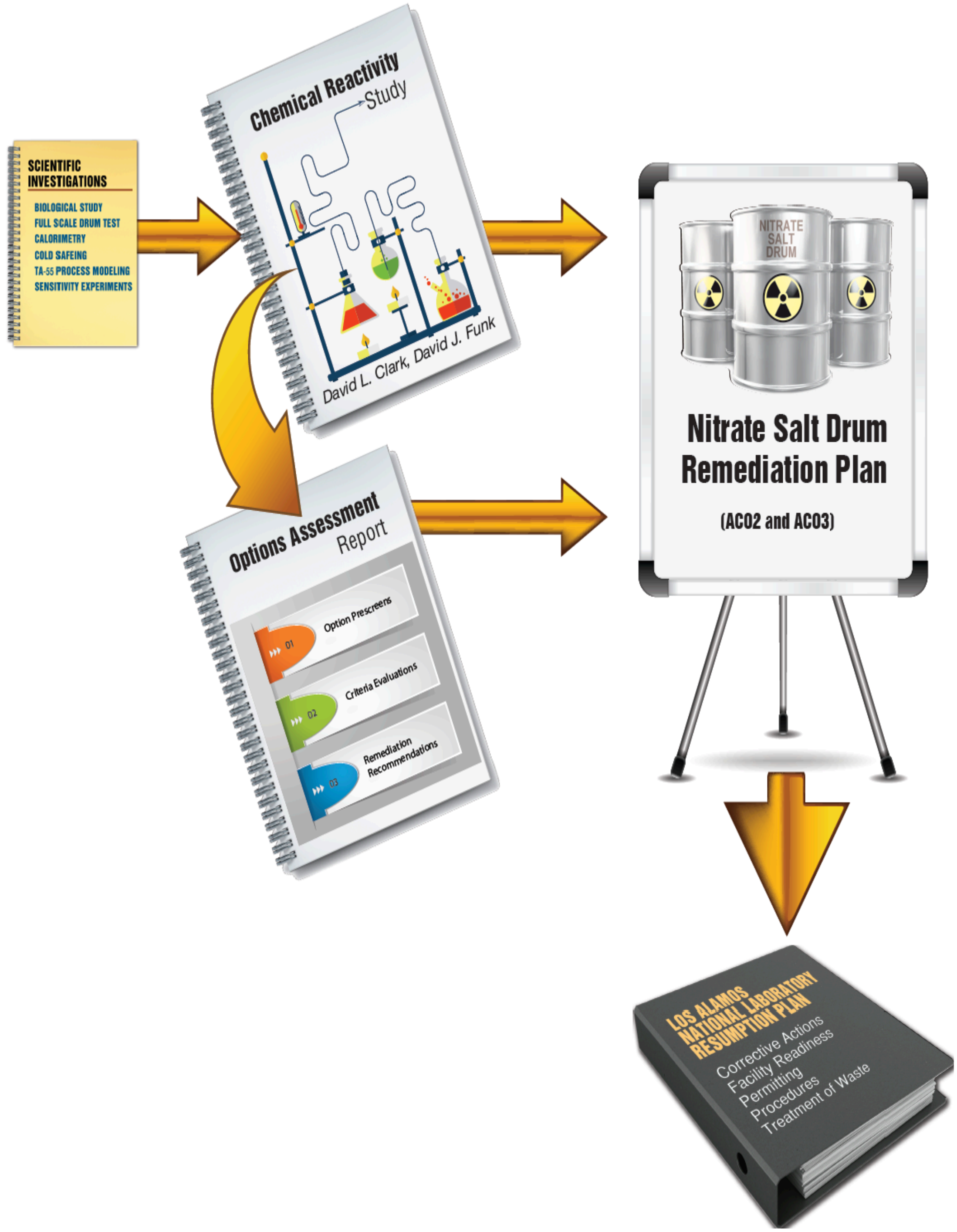
[6] From NMED, 2014. HWMR refers to the Hazardous Waste Management Regulations, 20.4.1 NMAC, and "Permit" refers to the LANL Treatment, Storage, and Disposal Facility (TSDF) Permit, EPA I.D. Number NM0890010515-TSDF.

Figure 1-1 Schematic diagram describes the documentation elements associated with the Administrative Compliance Order deliverables for treatment of nitrate salt waste



2 Summary of Scientific Findings on RNS Waste

This section provides a brief summary of the findings of LANL scientists with respect to the energetic reaction that occurred in RNS waste drum 68660 in the WIPP repository, leading to the breach of that drum. It is provided to set the stage for subsequent evaluation of treatment options. This description is derived from the report of Clark and Funk (2015): refer to that report for details.

This section is divided into two parts, a summary of the technical understanding of the chemical reactivity in the RNS waste drums, followed by the remediation strategy recommended in the Clark and Funk study on the basis of this understanding.

2.1 Chemical Reactivity of RNS Waste

Experimental and modeling studies performed at LANL indicate that mixtures of metal nitrate salts (oxidizer) with Swheat™ organic kitty litter (fuel) create the potential for exothermic chemical reactions. The use of Swheat™ absorbent in the processing of nitrate salt wastes can be pinpointed as the critical processing decision that led to the failure of Drum 68660 in the WIPP repository, regardless of the details of the thermal processes that enabled the drum to achieve temperatures sufficient to initiate the chemical reactions. Evaluation of the characteristics of the failed drum, coupled with extensive chemical testing indicate that, in addition to the nitrate salt/Swheat™ organic kitty litter mixture, an additional trigger mechanism (or mechanisms) is likely required to raise the internal drum temperature high enough to initiate the nitrate salt/Swheat™ organic kitty litter reaction.

A combination of chemical conditions were identified that may lower the temperature for reaction, including initial high acid concentration of free liquids; significant quantities (> 1 gal) of neutralized, absorbed free liquids; the presence of reactive or catalytic metals like magnesium, iron, or lead; the presence of bismuth containing glovebox gloves; and the presence of natural biological activity. Complex surrogate nitrate salt mixtures prepared to simulate wastes, particularly those containing iron and magnesium, can generate NO_x gases that partially nitrate the organic Swheat™ kitty litter and form a more energetic fuel, i.e., triethylaminenitrate (TEAN). These complex surrogate salt mixtures display exothermic behavior at temperatures *as low* as 60 °C (140 °F) which is still well above the ambient temperature conditions experienced by a drum.[7]

Neutralization of free liquids and sorption onto Swheat™ establishes conditions (moisture with near-neutral pH) that will support natural biological activity. Spontaneous self-heating generated by low-level chemical reactions and/or the

[7] The lower bound is dependent upon total mass. The lower bound is a complicated thermal transfer problem and dependent upon volume and configuration.

respiration of bacteria, molds, and microorganisms is potentially important in the early stages and may be sufficient to raise the temperature as high as 60 °C (140 °F), where the other exothermic chemical reactions can take place. Additional studies are being conducted to evaluate the role biological activity may have played in initiating the event. Planning for these studies is ongoing, and is anticipated to require long-duration experiments due to the nature of the evolution of biological processes under these conditions.

From the combined results of literature studies, modeling, and experiments amassed to date, one can arrive at a plausible scenario in which a production of heat, either from low-level chemical reactions or the growth of natural microbes, in concert with mixed metal nitrate salts, bismuth lined glovebox gloves and/or lead nitrates when combined with the Swheat™ organic kitty litter, generated a stepwise series of exothermic reactions that heated and pressurized the drum resulting in the venting of high-temperature gases and radioactive material into the room.

It is likely that a specific set of conditions is required to trigger the suite of reactions that has to date led to thermal runaway in just one drum, to the best of the technical experts' knowledge. However, the complexity of the mixtures, ambiguity in procedures such as those used for neutralization, the heterogeneity of the drum contents, and the difficulty of sampling leads to an irreducible level of uncertainty that mandates the exercise of caution in managing RNS wastes. Even though drums being monitored at LANL have not exhibited any observable thermal excursions, analyses of samples of the headspace gases within the SWBs containing RNS waste are consistent with the presence of oxidation reactions or microbial activity (Leibman et al., 2015). There is evidence that the UNS drums are outgassing H_2. For the RNS drums, the headspace gases are being monitored and sampled. Thus, the organic-oxidizer combination is inherently a thermally sensitive mixture actively exhibiting the RCRA characteristic of ignitability (D001). Finally, recent studies with the most reactive surrogates developed to study the hazards indicate some sensitivity to electrostatic discharge (ESD), which mandates additional study to ensure that waste handling and processing procedures appropriately account for this possibility.

This situation requires that the RNS waste stream continue to be monitored and that safety precautions be taken during continued storage and ultimately during treatment. By contrast, the UNS waste stream does not possess these same hazards (Funk, 2014), but the fact that the waste is a RCRA characteristic ignitable (D001) due to it being an oxidizer requires that the UNS waste will undergo normal WIPP certification process which includes treatment prior to transportation and disposal at WIPP.

2.2 Clark and Funk Recommendations on Cooling and Treatment of RNS Waste

On the basis of the scientific understanding gained from their study, Clark and Funk (2015) provided a technical recommendation for rendering the RNS waste safe for subsequent treatment. Their recommended two-step process is:

1. *Cool the RNS waste drums.* Cooling the waste is a safety measure to be performed in advance of removing the waste from its current configuration in order to sample and subsequently process the solids. Cooling drums to -10 °C or lower will slow down both chemical and biological reactions. Drums can then be warmed back to +10 °C, a value that is 50 °C below the onset temperature of exothermic reactions, consistent with chemical industry safety guidelines for process operating conditions for exothermic reactions. [8,9]

The UNS sampling must appropriately bound the waste in the RNS drums. Currently planned strategies for the RNS waste treatment plans indicate that the treatment success demonstration will involve testing the "treated" surrogate waste rather than the RNS waste to avoid the Safety Basis complication (i.e., difficult or unsafe to sample radioactive waste on-site). This includes chemical constituents and physical properties (e.g. particle size and surface area, which would have strong effects on ignitability and burn rate) and to ensure the mixture is not ignitable or corrosive after treatment without affecting the Safety Basis. The treatment plan demonstrates that the physical properties impacting D001/D002 characteristics are modified by stabilization process – such that measuring and testing UNS waste is sufficient to define the characterization and treatment testing. The treatment plan ensures species, characteristics and/or properties are measured during and after processing to ensure stabilization of the waste and debris prior to WIPP certification and disposal. If the validation sample comes back with a negative result, then further remediation is necessary.

2. *Mix the RNS waste into an inorganic matrix of natural mineral zeolite like clinoptilolite.* Adding zeolite to the RNS and UNS waste containers is a potential process to remove the RCRA hazardous waste characteristic (D001, ignitability) from the waste in the containers that prevents them from meeting the WIPP WAC. Determining the capability of the zeolite to meet this condition and the quantity of zeolite used will need to be determined through treatment studies which will subject surrogate waste samples to a variety of EPA-specified tests for ignitability and oxidizer potential (SW-846, EPA, 2007). If for some reason, natural zeolites are found to be undesirable, then grout is an acceptable alternative with the important caveat that following water addition to make grout, the wetted nitrate salt/Swheat™ organic kitty litter mixture should be processed directly into concrete.[10]

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[8] Center for Chemical Process Safety "Guidelines for Chemical Reactivity Evaluation and Application to Process Design," AIChE, New York, NY, 1995.

[9] Pressure is very important to achieving thermal runaway. A filter block may occur due to ice particle buildup. If the filter is moist at the time of cooling, ice can block the filter decreasing the amount of gas flow capacity. This safety measure must also be investigated.

[10] Results of oxidizing solids testing EMRTC Report FR 10-13 conclusively demonstrates that either zeolites (36 wt.%) or grout (55 wt.%) in proper ratios deactivate D001 characteristics per EPA SW-846, Method 1040.

3 Assessment Assumptions

This section establishes the underpinning assumptions that the team formed to perform the evaluation used in its deliberations on treatment options for the RNS and UNS waste streams. These are the “boundary conditions” that are important to consider when assessing the viability of different options.

All options require continued management of waste in its current configuration or in a configuration that ensures safety during storage. Studies continue to be conducted to understand the factors that led to the breach of drum 68660 in the WIPP repository. Continued safe management of the waste will consist of control of the environmental conditions around the drums, such as temperature, and the continued application of engineering controls under an approved Container Isolation Plan. Temperature control is also a necessary precursor to denesting[11] and handling of the waste (Clark and Funk, 2015). Processing of the waste under an approved Permit modification will enable it to be removed from the Isolation Plan. This assumption applies equally to all proposed treatment options, and impacts all treatment options equally.

Surrogate wastes developed from UNS sampling will be representative of the RNS waste stream. Development of an effective treatment option for the unique RNS waste stream requires that surrogates of the waste be used for product testing to ensure that the ignitibility characteristic has been mitigated in the final waste form.

Only the RNS waste contains a combination of fuel and oxidizer such that a significant energetic reaction can occur. While latent chemical reactions may exist in the UNS, they are not sufficient to cause a large release of heat. Some of the drums that have a decomposition of the salts are endothermic and release gas but not heat. Due to the obstacles in sampling the contents of the RNS drums at the present time, surrogate mixture compositions and samples of Swheat™/salt mixtures starting with UNS waste will be developed that are bounding and represent samples of the actual RNS drum compositions. Surrogate wastes developed from UNS sampling will be representative of the RNS waste stream.

To ensure that estimates of the contents of the drums are appropriately bounded by these mixtures and to demonstrate RCRA treatment success, confirmatory sampling and analysis of UNS and RNS wastes must be performed during the treatment process. This assumption applies equally to all proposed treatment options, and impacts all treatment options equally.

The selected treatment option will be conducted only after re-establishment of facility readiness, implementation of required corrective actions, and regulatory approval of modifications to the LANL Permit. This assumption applies equally to all proposed treatment options, but some options may make it easier or more difficult to fulfill the

[11] Denesting is the removal of the waste drums from the overpack for sampling and then stabilization.

requirements. Several criteria used to evaluate options allow for discrimination between options on the basis of relative ease to obtain these approvals.

Waste will be treated in a manner that leads to safe onsite storage of the treated waste, followed by shipment to and disposal in the WIPP repository. This assumption applies equally to all proposed treatment options, but some options may be technically straightforward, technically challenging, or even infeasible.

Several criteria used to evaluate options allow for discrimination between options or screening out of some options on the basis of the ease or difficulty of producing a waste form that meets the WIPP WAC (DOE/CBFO, 2013).

To ensure the remediation plan is adequate and to address the similarity between the RCRA characteristic of ignitability (D001) and reactivity (D003)[12] for the RNS waste, LANL will demonstrate that neither the ignitability nor the reactivity characteristic are present after the selected treatment process for UNS and RNS waste.

A modification of the LANL Hazardous Waste Facility Permit would be required in order to commence with treatment of the nitrate salt wastes. The options being considered must result in deactivation to remove the EPA Hazardous Waste Numbers of D001, ignitability, and D002, corrosivity, for the nitrate salt waste. This will need to be demonstrated, with a technical basis and data, in the permit modification request (application to NMED) for the process to ensure the remediation plan is adequate. LANL will also conservatively demonstrate that the reactivity characteristic is removed with the selected treatment process for UNS and RNS waste as discussed above.

The permit modifications will also take into account the definition of related waste streams and their corresponding characteristics to ensure the permit properly describes the wastes generated, stored, and treated at LANL.

[12] The UNS waste must meet 40 CFR 261.23 criterion for evaluation of the characteristic of reactivity to ensure remediation plan is adequate: *(6) It is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement.*

4 Treatment Methods Evaluated

This section describes the full suite of potential treatment options considered for both the RNS and UNS wastes. After the breeched drum in WIPP was revealed to be a RNS waste drum generated at LANL, staff began a process to develop a series of options based on current waste management practices and considering the availability of LANL facilities to conduct the work. From this initial work, four RCRA stabilization options were identified involving zeolite addition, zeolite addition with cementation, and wet or dry cementation. Later, when the Core Remediation Team was established (see Section 5.1), the team decided to expand the list and subject the options to a screening process to ensure the broadest possible consideration of options. To do this, a range of general or industry-practice-based technologies recommended in the RCRA treatment standards (40 CFR Part 268) were included that appeared to be applicable. Nine additional options were added as a result. A fifth stabilization option of combined technologies, filtration and dissolution with cementation of the nitrate salt waste (Option 14), was evaluated as a treatment option after the initial meeting of the remediation team.

By nature of the way these options were developed, the five RCRA stabilization options are more developed than the other nine RCRA treatment standards. The five stabilization options are presented in summary form in Section 4.1 (and in greater detail in Appendix 1), after which the nine other treatment options are described in Section 4.2. Table 4-1 is a summary of all of the treatment options considered, and indicates whether the option is applicable to the RNS waste, the UNS waste, debris, or any combination. It should be noted that the "best" option for each stream might be different.

4.1 RCRA Stabilization Options

The five RCRA stabilization options are described in summary form below, and a more complete presentation is provided in Appendix 1. Four of the RCRA stabilization options were proposed by LANL staff in the initial months after the WIPP release, and took into account scientific and technical considerations as well as facility and waste specific issues, given that the work is to be performed at LANL. Salt Dissolution With Cementation/ Stabilization was later added to the option investigation process. Once the preliminary studies of surrogate samples conclude, the five RCRA stabilization options will be revisited to ensure each option is viable. Note that if one of these processes is implemented, additional optimization would take place, and the details might change. However, the descriptions represent the basis that the Core Team used in its evaluation.

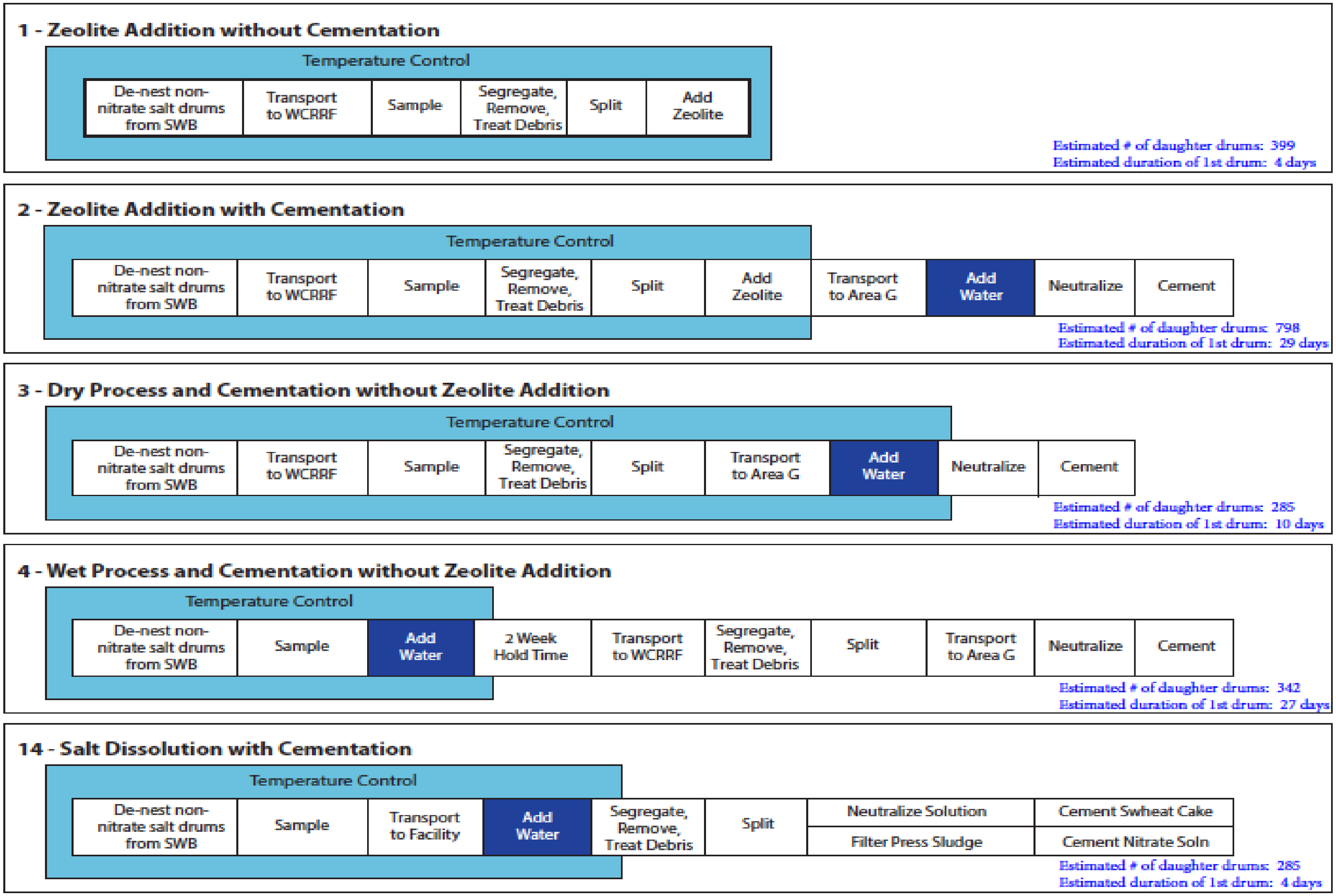
A comparison of the process steps for the five stabilization options is presented schematically in Figure 4-1. As stated in the assumptions section (Section 3) and as pointed out by Clark and Funk (2015), the RNS waste must be under temperature control during handling until steps are taken to mitigate the potential for reaction. This is indicated in the figure with the light blue frame labeled "Temperature Control." These controls can be removed once the possibility of runaway reactions is eliminated. Also indicated on Figure 4-1 are the estimated number of daughter drums and the estimated duration required to generate the first drum (an indication of complexity and duration of the process). For details, see Appendix 1.

Table 4-1. Summary of potential treatment options considered

Option	Description	Applicability		EPA Technology Code*
		RNS	UNS	
RCRA Stabilization Options				
1. Stabilization Using Zeolite	Mix waste into inorganic natural mineral to eliminate ignitability potential of the waste	X	X	STABL /RHETL
2. Stabilization Using Zeolite With Cementation	Option 1, followed by production of cement waste form	X	X	STABL /RHETL
3. Stabilization Using Dry-Process Cementation	Production of cement waste form with water added only at the time of cementation	X	X	STABL
4. Stabilization Using Wet-Process Cementation	Initial water addition to eliminate potential thermal runaway reactions, followed by production of cement waste form	X		STABL/WTTRx
14. Salt Dissolution With Cementation/ Stabilization	Water addition followed by filtration and cementation process of Swheat™ cake and nitrate salt solution	X		WTRRx/STABL/ RHETL
Other RCRA Recommended Options				
5. Incineration	Burning of waste in a radiological incinerator	X		INCIN
6. Thermal Oxidation of Organics	Treatment of waste in air to oxidize without flame	X		RTHRM
7. Biodegradation	Biological breakdown of organics or non-metallic inorganics under aerobic or anaerobic conditions	X		BIODG
8. Chemical or Electrolytic Oxidation	Breakdown of organics through the addition of oxidation reagents	X		CHOxD
9. Chemical Reduction	Breakdown of nitrate constituents through the addition of reducing reagents	X	X	CHRED
10. Vitrification	Incorporation of waste into a glass waste form	X	X	HLVIT
11. Alternate Macro-Encapsulation	Coating of the waste with an organic polymer to reduce surface exposure	X	X	MACRO
12. Neutralization	Reagent addition to neutralize the pH	X	X	NEUTR
13. Controlled Reaction or Leaching	Removal of soluble salts by leaching with water	X	X	

* EPA Technology Code derived from 40 CFR 268.42.

Figure 4-1. Summary of stabilization treatment options



Note for Option 14: The number of daughter drums is dependent upon the repulp options chosen. The no repulp option would produce 4 daughter drums of cemented waste and another partial drum of debris (plastic bags and liner material) from the orignal drum. If the repulp option is chosen, 6 drums per waste would be generated, resulting in 342 drums.

Option 1. Stabilization Using Zeolite

Waste is processed by removing debris and processing it separately. Following removal of the debris, an inorganic matrix of natural mineral zeolite such as clinoptilolite is added to the RNS. The resulting mixture will not be corrosive, ignitable, self-heating, or an oxidizer. The quantity of zeolite used would be determined through treatability studies using surrogate mixtures of waste, and confirmed once the waste is sampled. To do this, surrogates of the waste would be used for product testing to ensure that the corrosivity and ignitibility characteristics have been mitigated in the final waste form by subjecting treated waste samples to a variety of EPA-specified tests for corrosivity, ignitability, and oxidizer potential. Surrogate samples of Swheat™/salt mixtures would be prepared based on the analysis of the UNS waste representative of the actual RNS drum compositions. Corrosivity will be addressed through absorption of the liquid medium by the zeolite addition. The zeolite will also reduce the potential for thermal runaway and render the mixture safe by creating a thermal barrier. Zeolite, being a desiccant, separates the waste components, reduces the potential for chemical kinetics and acts as a physical and thermal barrier against reactions.[13] The debris separated from the original RNS waste stream is not expected to have the D001 designation because the percent of residual reactive material is small and will be confirmed by visual inspection used to determine the degree of contamination of the debris.

For RNS waste, the drums will be processed at temperatures below ambient in order to reduce chemical reaction risk during denesting and slow chemical kinetics potential, and to allow for safe and efficient denesting and handling. Denesting would occur at Area G, and the waste would be transported to the Waste Characterization, Reduction and Repackaging Facility (WCRRF) for processing. For UNS waste, similar processing would be conducted, but temperature control is not required because the nitrate salts without organic absorbent do not pose a safety hazard from oxidation reactions involving contents within the drum (Funk, 2014). The zeolite remains in the mixture and ultimately reaches physical and chemical equilibrium. Cooling does not affect the amount of water the zeolite absorbs.

Option 2. Stabilization Using Zeolite With Cementation

Waste is processed identically to Option 1 up to and including zeolite addition, at which point the ignitability and corrosivity characteristics of the waste is mitigated. The material is then further treated through a process that includes water addition, additional neutralization as needed, and cementation to produce monoliths that would be suitable for transportation and disposal. Waste transport occurs from Area G to WCRRF for zeolite addition, and, in the process evaluated here, back to Area G for cementation. UNS waste, similar processing will be conducted, but without temperature control. As with Option 1,

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[13] Semisolids must pass the paint filter test to be considered non-wastewater and solid. Under environmental temperatures, LANL experimentalists attempted to inflame a zeolite added surrogate mixture with a 1000 °F torch and were unable to ignite the mixture.

surrogate testing would be performed to ensure that the corrosivity and ignitability characteristics are mitigated for the final waste form.

Option 3. Stabilization Using Dry-Process Cementation

Waste is moved to WCRRF and processed by removing debris from the RNS waste and processed separately in smaller quantities suitable for subsequent treatment. Following the removal of the debris, the RNS waste is split into smaller quantities suitable for subsequent treatment. The waste is transported as a dry material to a cementation unit (assumed to be a new facility at Area G) where it is processed through the addition of water, neutralization, and cementation to produce monoliths that would be suitable for transportation and disposal. The addition of water to nitrate salts is an endothermic reaction. Additional cooling will not be necessary to prevent uncontrolled reactions. Thus, the temperature controls are removed at the point at which water is added. As with Option 1, surrogate testing would be performed to ensure that the corrosivity and ignitability characteristics are mitigated for the final waste form.

Option 4. Stabilization Using Wet-Process Cementation

Waste is processed by cementation at Area G, but with water addition early in the process, minimizing the flammability risk for the waste and eliminating the immediate hazard. During the full-scale drum test, it was verified that the wetted Swheat did not ignite. At that point, temperature control is removed. The waste is then transported wet to WCRRF for segregation and splitting followed by transportation of daughter drums back to Area G to a new cementation unit where it is processed by neutralization and cementation to produce monoliths that would be suitable for transportation and disposal. Because the early addition of water is a safeing[14] strategy designed specifically for the RNS waste and thus is unnecessary for UNS waste, this option is only applicable for RNS waste. As with Option 1, surrogate testing would be performed to ensure that the corrosivity and ignitability characteristics are mitigated for the final waste form.

Option 14. Salt Dissolution with Cementation/Stabilization

The salt dissolution with cementation process for RNS waste consists of waste repulped in water. Repulp is the size reduction of a slurry to decrease viscosity. The nitrates (potassium and sodium) are highly soluble. For RNS waste, the drums will be processed at temperatures below ambient in order to reduce chemical reaction risk during denesting and slow chemical kinetics potential, and to allow for safe and efficient denesting and handling. Denesting would occur at Area G. The organic Swheat™ is separated from the mixture by a filtration process. A Swheat™ filter cake product and a salt solution product are recovered in separate drums. The fraction of organics that travel with the dissolved nitrate salts is the fraction of organics that can be dissolved in the water. At this stage of dissolution, TEAN is not found in the filtered cake, but rather in the liquid. Organics once dissolved in water are not combustible. Repulping and filtration of the Swheat™ stream can

[14] Safeing is defined as reducing the probability of a deleterious event to an acceptable level.

achieve improved efficiencies in separation of Swheat™/salt if desired. The Swheat™ is then dissolved using caustic digestion and cemented for final preparation prior to transporting for disposal. The salt solution stream is cemented separately then transported for disposal.

UNS waste can be processed by salt dissolution without Swheat™ processing. Testing would be performed to ensure corrosivity and ignitability characteristics are mitigated for the final waste form. Addition of a base to TEAN will result in triethylamine (TEA) and the nitrate salt of the base. This reduces the chemical reactivity of the system overall. However, the pH of the dissolved nitrate salt must be monitored to ensure a good cement monolith is produced.

4.2 Additional RCRA Treatment Options

These nine recommended RCRA treatment options (40 CFR 268 Appendix 1) are numbered 5-13 since they follow the four RCRA stabilization options. The nine options are described generically below. Some of the options are only applicable to either the RNS or UNS waste, the RNS or UNS waste, but not for all categories of waste. The descriptions below identify those instances.

Option 5. Incineration

The waste is intentionally forced to burn in a radiological incinerator. Treatment is performed in units operated in accordance with the technical operating requirements of 40 CFR Part 264 subpart O, which is, using maximum achievable control technology. Furthermore, this option is not applicable for UNS waste since no organic absorbents are present to oxidize.

Option 6. Thermal Oxidation of Organics

Waste is treated in air under high heat to oxidize fuels without flame. A heating process other than flame incineration is used to treat organic constituents of the waste stream or, secondarily, treat residues from a primary treatment process. This option is not applicable for UNS waste since no organic absorbents are present to oxidize.

Option 7. Biodegradation

Waste is treated via biologic breakdown of organics or non-metallic inorganics (i.e., degradable inorganics that contain the elements of phosphorus, nitrogen, and sulfur) in units operated under either aerobic or anaerobic conditions such that a surrogate compound or indicator parameter has been substantially reduced in concentration in the residuals. Salt tolerant bacteria may be cultivated to eat the organic material. But facilities for this treatment would need to be built. This option is not applicable for UNS waste since no organic absorbents are present to biodegrade.

Option 8. Chemical or Electrolytic Oxidation

The waste is treated to eliminate the organics via chemical or electrolytic oxidation utilizing the following oxidation reagents (or waste reagents) or combinations of reagents: 1) hypochlorite (e.g., bleach), 2) chlorine, 3) chlorine dioxide, 4) ozone or UV light assisted ozone, 5) peroxides, 6) persulfates, 7) perchlorates, 8) permanganates; and/or (9) other oxidizing reagents of equivalent efficiency. Chemical oxidation specifically includes what is commonly referred to as alkaline chlorination. This option is not applicable for UNS waste since no organic absorbents are present to oxidize.

Option 9. Chemical Reduction

The waste is treated to chemically reduce the nitrate constituents utilizing the following reducing reagents (or waste reagents) or combinations of reagents: 1) sulfur dioxide, 2) sodium, potassium, or alkali salts or sulfites, bisulfites, metabisulfites, and polyethylene glycols (e.g., NaPEG and KPEG), 3) sodium hydrosulfide, 4) ferrous salts; and/or 5) other reducing reagents. Nitrates are reduced to N_2 by contacting nitrates with metal to convert nitrates to nitrites. Nitrites are reacted with amide to produce N_2 and $C0_2$. This would be performed in small controlled batches and may concentrate TRU waste. The waste could be effectively reduced.

Option 10. Vitrification

Waste is incorporated into a glass waste form by mixing the waste into molten glass in a melter, after which the mixture is poured and allowed to solidify and cool.

Option 11. Alternate Macro-encapsulation

The surface of the waste is coated with an organic polymer (e.g., resins and plastics) or an inert inorganic matrix to substantially reduce surface exposure to potential leaching media.

Option 12. Neutralization

The waste is neutralized to a pH between 2 and 12.5 by adding acids, bases, or water. Such a treatment is likely to be part of a cementation primary treatment process or if free liquids are encountered during treatment.

Option 13. Controlled Reaction or Leaching of Reactive Inorganic Chemicals with Water

Controlled reactions are conducted with water for highly reactive inorganic or organic chemicals with precautionary controls for protection of workers from potential violent reactions as well as precautionary controls for potential emissions of toxic/ignitable levels of gases released during the reaction. Soluble salts are removed by these reactions. This technology is similar to Option 14, but lacks the subsequent stabilization/solidification steps, which deactivate characteristics D001 and D002.

5 Assessment Methodology

This section outlines the methodology employed to assess the various treatment options for the UNS waste and RNS previously developed in Section 4. First, the scope and makeup of the evaluation team are presented, followed by a general overview of the methodology and the definition of the criteria used for evaluating the options.

5.1 Core Remediation Team

This section describes the scope, activities, and composition of the Nitrate Salt TRU Waste Remediation Team, referred to as the "Core Team" in this document. The Core Team is responsible for developing and executing plans to ensure the safety of the RNS and UNS wastes.

This includes a series of high-level steps.

- Conduct an options analysis (Options Assessment Report) leading to a recommended path or paths to remediation of the nitrate salt TRU containers.

- Ensure that the selected remediation option(s) are comprehensively reviewed, vetted, and documented, including development of a regulatory permitting strategy and schedule to begin nitrate salt remediation.

- Ensure that the approved remediation plan is properly reflected in process flow sheets and operating procedures that account for all regulatory, safety basis, permitting, and waste acceptability issues (future activities and work products of the Core Team).

To ensure that the appropriate expertise was engaged in the process, the Core Team was comprised of staff from many relevant disciplines/organizations.

- Energetic chemistry
- Actinide chemistry
- Waste form expertise
- ADEP operations expertise
- TA-55 waste expertise
- Facility Operations Directorate representative
- Regulatory compliance
- ES&H
- Safety basis
- Representative(s) from LANL Carlsbad Office's Difficult Waste Team

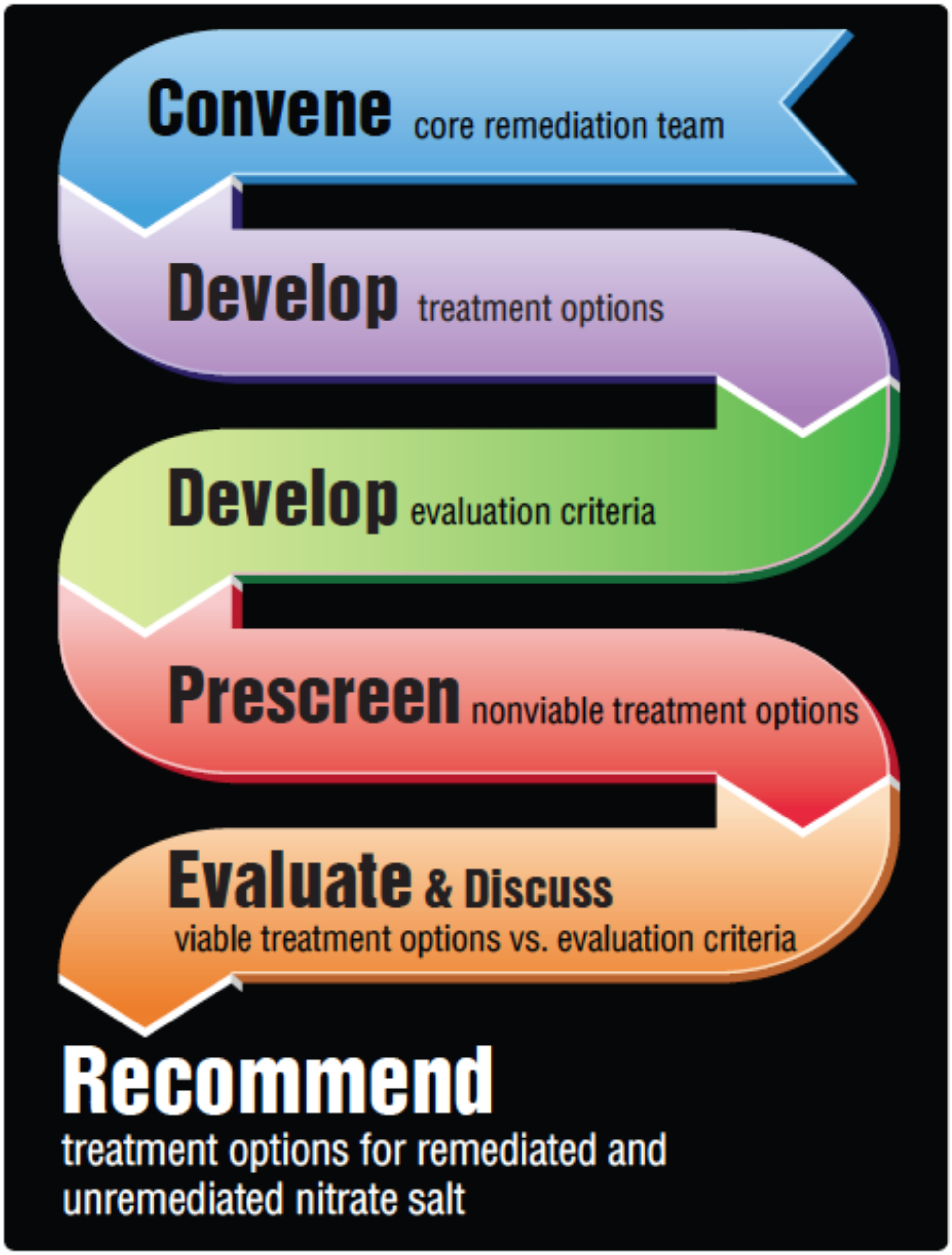
A list of participants in the Core Team as part of this Options Assessment activity is provided in Appendix 2.

5.2 Evaluation Process

The Clark and Funk (2015) report provided a recommendation for a remediation strategy based on the scientific studies and accompanying safety considerations. While from the perspective of science, LANL believes this recommendation to be valid, it was decided to form and engage the Core Team to factor in a broader set of considerations. The Core Team held a series of meetings and performed offline work to develop and run an expert-based process for evaluating and selecting preferred treatment options for the UNS and RNS waste streams and debris streams. An overall map of activities is diagrammed in Figure 5-1, and additional details are provided below.

The first step was to develop a comprehensive list of potential treatment options for consideration. These options were described previously in Section 4. Next, a list of evaluation criteria (see Section 5.3 below) was developed collectively by the Core Team to comprehensively evaluate options against a diverse set of criteria. Then, an initial pre-screening meeting was conducted to cull the list on the basis of a decision of infeasibility of certain potential options with respect to one or more of the criteria. The Core Team discussion was documented to provide the rationale for the screening decisions. The remaining potential options were then evaluated in another meeting of the Core Team. At that meeting, an appropriate member of the Core Team was selected to lead a group discussion for a given criterion. Each option still under consideration was ranked against the criterion in a relative fashion, and numerical scores were then established by consensus. After ranking all criteria, a complete matrix of scores was determined. The final results were tabulated and the discussion and rationale for the scores was documented.

Figure 5-1. Schematic of the process steps used by the Core Team



5.3 Evaluation Criteria

This section provides a list of the criteria that were applied to assess the various treatment options. These criteria were applied in separate evaluations to the February 2014 original number of containers: 57 RNS daughter containers and the 29 UNS parent containers. Since the process required a numerical score to be applied for each treatment option against each criterion, the basis for awarding a particular integer score from 1 to 5 was also defined. A summary of these criteria and scoring range is provided in Table 5-1; full definitions used by the Core Team in its deliberations are provided in Appendix 3.

Table 5-1 List of criteria used to evaluate the potential treatment options

Criterion	**Definition of Minimum Score of 1***	**Definition of Maximum Score of 5**
Robust to Waste Stream Variability	Extremely difficult to develop a robust process	Highly likely to be a robust process
Ease of Permitting (Permitting Difficulties)**	Extremely difficult to permit	Simple permitting process
Safety Basis Challenges	Extremely complex safety basis challenges	Straightforward safety basis approval process
Extent of Testing Required	Very onerous testing required	Straightforward testing required
Reduction of Toxicity, Mobility, Corrosivity, and Ignitability	Marginally effective waste form and/or difficult to package	Highly effective waste form and straightforward to package
Reduction of Volume	Large volume and/or large number of daughters generated	Low volume with low numbers of daughters generated
Short Term and Long Term Effectiveness	Effectiveness of the final waste form is questionable or indeterminate	Highly effective final waste form
WCS Implications	Extremely difficult to implement for WCS drums	Straightforward to implement for WCS drums
Scalability and Complexity	Extremely difficult to implement for drum remediation	Straightforward to implement for drum remediation
Facilities Challenges	Extremely difficult to implement due to Authorization Basis scope	Highly likely to implement under current LANL Authorization Basis status.
Schedule	Extremely time consuming	Expedited schedule is achievable
Cost***	Extremely expensive	Cost-effective option

*If a treatment option was judged by the Core Team to be infeasible based on any of the criteria, it was eliminated in the initial screening and not considered further. A minimum score of 1 applied to an option that is not screened out is a very unfavorable score, but by definition is not a score that on its own rules the option out.

** A more precise definition of the scores for ease of permitting is provided in the text description of this criterion (see Appendix 3).

*** Cost was not a primary evaluation criterion used to evaluate potential options; it is provided for information purposes and could have been used as a final discriminator in the event of ties. The evaluation process did not lead to any ties: therefore, the cost scores are for information only and did not factor into the final recommendations.

6 Assessment Results

This section presents the results of the evaluation of the Core Team of the fourteen potential treatment options against the evaluation criteria, leading to the recommendation of treatment options for the RNS and UNS waste streams. As discussed in Section 5.2, the evaluation occurred in two steps: a prescreening step and a full evaluation of options not screened out in the first step. The results of the evaluation, including a narrative capturing the discussions within the Core Team, are provided in the next two subsections, and discussed in Section 6.3.

6.1 Screening Results

The results of the screening exercise indicate that each of the five stabilization treatment options (Options 1 through 4, and Option 14) were determined to be suitable for full evaluation, whereas the other RCRA treatment options were screened out in the initial evaluation. This section provides the rationale for the elimination of options 5 through 13, capturing the discussion of the Core Team leading to the screening decision.

Option 5. Incineration

In theory, this method is attractive from a volume standpoint in the sense that it minimizes the mass and volume of the final waste product by destroying both the nitrate and starch components in a system with engineered controls for deflagration. The result should be highly radioactive metal oxide wastes, assuming that all of the nitrates that do not react with the cellulose decompose to a non-oxidizing solid. Experience suggests that this operation would be very difficult to permit and is complicated by the presence of transuranics. The incineration of the RNS drums may concentrate the TRU waste and the heating of TEAN may have dangerous consequences. Previously, a radiological incinerator at LANL was constructed but proved to be very difficult to permit, and DOE decided not to go forward with the incinerator after approximately a year of experimental testing. Thus, the Core Team believed that the risk of failure to achieve the necessary safety basis and regulatory approvals is unacceptably high.

Based on Safety Basis Challenges and Ease of Permitting, this treatment option is removed from further consideration for RNS waste and debris, and, as discussed in Section 4.2, is not applicable for UNS waste.

Option 6. Thermal Oxidation of Organics

In the context of the current RNS waste stream, lab experiments conducted by LANL prove that heating would unavoidably result in the onset of thermal runaway and further work needs to be done to ensure 60 °C is the bounding condition. However, this option may therefore be considered “inadvertent incineration,” which is not acceptable from either a safety or regulatory basis.[15] Removal of organic materials may concentrate TRU waste and the heating of TEAN may have dangerous consequences. Both dry and wet thermal oxidation techniques were considered. Current wet thermal oxidation techniques involve the use of superheated steam that would require complex additional facilities and procedures.

Based on Safety Basis Challenges and Ease of Permitting, this treatment option is removed from further consideration for RNS waste and RNS debris, and is not applicable for UNS waste (see Section 4.2).

Option 7. Biodegradation

One hypothesis concerning the initial heating of the waste drums holds that biological metabolism of the organic kitty litter is heating the drums, and that for drum 68660, this heat generation was sufficient to trigger other exothermic reactions leading to thermal runaway. According to this hypothesis, adding competent biological organisms, including salt resistant bacteria, to the dry waste could precipitate thermal runaway. Alternatively, wetting the waste sufficiently to afford a heat sink for the biological activity and adequately reduce the high ionic strength of the medium would only be a preliminary step, as the waste would need to be further treated to make it acceptable under the WIPP WAC. This would require extensive drying and dilution after a long incubation period. Finally, any nitrated starch in the barrels would likely be untouched, effectively concentrating a compound of greater hazard than the original organic absorbent. This option is not acceptable due to complicated accretion of risk and is time and cost prohibitive.

Based on Safety Basis Challenges this treatment option is removed from further consideration for RNS waste, and is not applicable for UNS waste or debris (see Section 4.2).

Option 8. Chemical or Electrolytic Oxidation

The fundamental instability of the remediated nitrate salt waste stems from the mixture of fuel with oxidants. One redeeming outcome of the method used is the fact that the average drum is probably fuel rich, although knowledge of the exact contents of the drums is limited. Addition of oxidizing compounds will bring the material closer to oxidative stoichiometry, increasing the potential hazard. Electrochemical oxidation suffers from the low solubility of starch in aqueous solution and the necessary dilution of the waste into a large volume of aqueous solvent. This treatment process could result in thermal runaway. Also, the waste stream already contains oxidizing material. The goal of this treatment is to remove the oxidative properties, not to enhance the waste.

Based on Safety Basis Challenges this treatment option is removed from further consideration for RNS waste, and is not applicable for UNS waste (see Section 4.2).

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[15] UNS waste drums do not require the same remediation as the RNS waste drums. Reactions may occur between the salts but heat is not generated to cause an additional reaction.

Option 9. Chemical Reduction

For RNS waste, the fundamental instability stems from the mixture of fuel with oxidants. It is not clear that adding more fuel will improve the situation; moreover, it is likely to evolve heat and thermally traumatize the material. None of the reducing agents listed are effective against nitroesters. Thus the expected result for RNS waste is a radiological contaminated energetic fuel with no disposal path. This treatment process could result in thermal runaway. For UNS waste, chemical processing of this sort would present severe safety basis challenges associated with the act of deliberately adding fuel to the nitrates. Heating the UNS waste would create an oxidizing environment. This operation falls outside of existing facility safety basis (engineered operation to control the chemical reduction in an efficient and safe manner). This reaction is highly exothermic and could result in uncontrolled release of material. Containment of reaction requires special facilities. Facilities for this treatment would need to be built. This option would be time and cost prohibitive.

Thus, based on Safety Basis Challenges and Short Term and Long Term Effectiveness this treatment option is removed from further consideration for both RNS and UNS.

Option 10. Vitrification

Vitrified waste forms are highly durable and of uniform consistency. If the process is well controlled, all organic constituents in the RNS waste will be destroyed. However, this treatment process is equivalent to, if not more violent than, incineration. The level of process control required is intensive, and thus vitrification is generally applied only to large waste streams in facilities resembling a chemical plant. Furthermore, for disposal in salt at WIPP, a waste form with the durability of glass is not required. Vitrification technology may not be locally available. Mobile units could be relocated but could be cost prohibitive to permit efficiently.

Based on Scalability and Complexity and Schedule this treatment option is removed from further consideration for both RNS and UNS waste.

Option 11. Alternate Macro-Encapsulation

The fundamental instability of the RNS waste stems from the mixture of fuel with oxidants. Coating the oxidizing nitrate salt particles in an organic polymer would improve intimate mixing between fuel and oxidizer, potentially sensitizing the waste. Furthermore, for either RNS or UNS waste, the virtue of reduced susceptibility to leaching is of minimal benefit in the WIPP repository, a dry repository in bedded salt, with no groundwater intrusion and minimal natural fluids. Per EPA stabilization/solidification documents, this is not recommended for TRU waste.

Based on Short Term and Long Term Effectiveness, this treatment option is removed from further consideration for both RNS and UNS waste.

Option 12. Neutralization

Both the starch and nitrostarch in RNS waste could be destroyed by adequate addition of alkaline media (e.g. sodium hydroxide solution). Experiments with these protocols were conducted by LANL as a pre-treatment for cementation. The relative merits of these protocols are relevant in regard to cementation. However, while acid- or base-catalyzed hydrolysis could be used to degrade the nitrostarch component of the RNS waste, it would be difficult to monitor the progress and ensure complete destruction. Furthermore, this treatment would do nothing to address the oxidizer characteristic associated with the nitrate salts in either the RNS or UNS waste. Thus, neutralization on its own will be insufficient to treat the waste, and must be combined with solidification or absorbent addition to be considered an adequate treatment process to remove the D001 characteristic. Neutralization will not remove the highly soluble nitrate salts.

Neutralization treatment option, as a stand-alone treatment, is not considered for either RNS or UNS waste or debris. This discussion was based on reduction of toxicity and mobility. However, neutralization may be a step within another treatment option such as cementation.

Option 13. Controlled Reaction or Leaching of Reactive Inorganic Chemicals with Water

None of the ingredients in the RNS waste are water reactive. Nitrate salts in either the RNS or UNS waste could be removed by liquid/solid extraction. However, for the RNS waste, this would have no effect on nitrated starch material, and the resulting waste would potentially be a radiological contaminated energetic fuel with no disposal path. For UNS waste, the leaching on its own would result in an aqueous waste stream that would need to be combined with a solidification option such as cementation to be considered an adequate treatment process.

Based on Short Term and Long Term Effectiveness, this treatment option is removed from further consideration for RNS waste, and on its own is not considered further for UNS waste, but may be a step within another treatment option such as cementation.

The results of the screening exercise are presented in summary form in the bottom portion of Table 6-1.

Table 6-1. Summary of results of the evaluation of treatment options

EVALUATION CRITERIA

	POTENTIAL TREATMENT OPTIONS	Robust to waste stream variability	Ease of permitting (permitting difficulties)	Safety basis challenges	Extent of testing required	Reduction of toxicity and mobility	Reduction in volume	Short-term and long-term effectiveness	WCS implications	Scalability and complexity	Facilities challenges	Schedule	Cost (not a primary evaluation criterion) *	SCORE
1	Stabilization Using Zeolite (remediated)	5	3	4	5	4	2	4	2	4	4	4	4	41
	Stabilization Using Zeolite (unremediated)	5	3	4	5	4	2	5	N/A	5	5	5	5	43
2	Stabilization Using Zeolite With Cementation (remediated)	5	2	3	3	4	1	4	1	2	2	1	1	28
	Stabilization Using Zeolite With Cementation (unremediated)	5	2	3	3	4	1	5	N/A	3	3	2	1	31
3	Stabilization Using Dry-Process Cementation (remediated)	5	2	2	3	4	3	4	1	3	2	2	2	31
	Stabilization Using Dry-Process Cementation (unremediated)	5	3	2	3	4	3	5	N/A	4	3	3	3	35
4	Stabilization Using Wet-Process Cementation (remediated)	3	4	1	3	4	2	4	1	1	1	1	2	25
14	Salt Dissolution With Cementation/Stabilization (remediated)	3	3	1	3	4	2	4	1	2	1	2	2	26
5	Incineration													
6	Thermal Oxidation of Organics													
7	Biodegradation													
8	Chemical or Electrolytic Oxidation													
9	Chemical Reduction													
10	Vitrification													
11	Alternate Macro-Encapsulation													
12	Neutralization													
13	Controlled Reaction or Leaching of Reactive Inorganic Chemicals With Water													

Note: Stabilization Options 1-4 and 14 are discussed in Section 4.1 RCRA Stabilization Options. Options developed from RCRA treatment standards are the gray-shaded rows. Red cells denote the screening out of an option based on a high degree of infeasibility with respect to that criterion. Because of the initial screened-out determination, Options 5-13 were not ranked. Discussion of Options 5-13 is found in Section 4.2 Additional RCRA Treatment Options.
*Cost not included in final score.

6.2 Full Evaluation of Remaining Options

Based on the screening out of options 5 through 13 and the judgment that Options 1 through 4 and 14 were feasible, the Core Team performed a full evaluation of the latter group, which are the five RCRA stabilization options described in Section 4.1. The most effective way to compare the options was to discuss the relative merits of each option for each criterion, and then present the results by criterion. Typically, the group discussion focused on the more problematic RNS waste stream including debris, and after scores were established, the UNS scores were determined by reference to the RNS score. For example, for Scalability and Complexity, the UNS score is one point higher than the corresponding RNS score because temperature control is not required for UNS waste). This logic is also captured in the discussion below.

Criterion 1: Robust to Waste Stream Variability

The committee carefully examined the initial five options and compared the testing results and input from an explosives and reactive material Subject Matter Expert (SME) on the stability of the zeolite waste form produced from Option 1 (Stabilization Using Zeolite). Further discussion examined the data obtained from testing completed by a cementation SME for the cement waste form produced by the options employing cementation. In addition, there was discussion of the equipment and training requirements to correctly execute and consistently produce the waste forms from all options. The variability of the waste from drum to drum, and within a drum, was also assessed to evaluate the applicability of the treatment strategy suitable across the expected range of compositions.

After consideration of the test data, the procedural steps required, the equipment complexity, and waste stream variability, it was the consensus of the committee that the first three options were highly likely to develop a robust process (score of 5) for both the RNS and UNS. All options involve deactivating D001/D002 for waste and debris, and for these options there was little doubt that a robust formulation could be devised to accomplish this objective of rendering the waste unreactive. Option 4 (Stabilization Using Wet-Process Cementation) was ranked a 3 for RNS waste due to the additional complexity of the two-week hold time after water addition, opening the possibility that low-level reactivity could vary across the drum population and complicate the process. Option 14 (Salt Dissolution With Cementation/Stabilization) also ranked a 3 due to the resulting two end streams and the requirement that the dissolved solids must meet the pH requirement for waste and steel corrosion.

Criterion 2: Ease of Permitting (Permitting Difficulty)

Under the assumption that a modification of the LANL Hazardous Waste Facility Permit would be required (see Section 3), the evaluation approach of the Core Team was to examine the degree of complexity for each stabilization treatment option required by standard RCRA permitting factors. Option 4 produces a score of 4 while the other options produce a score of 3. The basis for the higher score was that the permitting difficulty for simpler cementation based processes would be easier due to the common use of the cementation process in the waste management industry.

Upon discussion by the review committee, the RCRA permitting process and schedule, including the NMED's review and approval, would be similar for each treatment option. The original documentation proposing the five treatment options (Appendix 1) captured this by suggesting that a possible permitting mechanism for all the options would be a Temporary Authorization by the NMED with a follow-up Class 2 or 3 Permit Modification Request. Therefore, the potential extent and complexity of the technical discussion needed to be included in each permit modification submittal was estimated for each treatment option and focused on as the determining evaluation criterion rather than simply the permit modification class as originally proposed in the definition of the Ease of Permitting criterion.

Option 1 (Stabilization Using Zeolite) has the advantage of being similar to the process that was previously used to prepare TRU waste containers for WIPP certification. Additionally, the treatment option would be limited to a single permitted treatment storage and disposal facility (WCRRF) at LANL. However, a permit submittal would need to present a strong technical discussion regarding the use of zeolite to inert the ignitable waste including the determination of appropriate types of zeolite, final volumetric ratios with the waste, sampling results, and any other factors determined to be relevant. Based on these complications and technical requirements, the zeolite treatment option was assigned a score of 3 for the Ease of Permitting evaluation criteria. The process required for both RNS and UNS waste appeared similar and the evaluation score of 3 was applied to both types of waste and includes debris.

Option 2 (Stabilization Using Zeolite With Cementation) combines the zeolite process with a second cementation step. Cementation adds the complication of water addition and treatment by neutralization to prepare the waste for solidification with the cement. However, cementation is also a commonly employed treatment procedure for these types of waste and is similar to the treatment process at TA-55 which is already approved in the LANL permit (this is also true of Options 3 and 4). The combined steps for two processes will require a larger amount of technical description in the permit modification request involving both the WCRRF permitted unit and a new location for cementation at TA-54 Area G. The two sites and additional operational changes will also influence other parts of the LANL permit for the two facilities, including potential changes to operational factors such as inspections, training, waste management operations, and emergency procedures. Therefore, the treatment option was assigned a lower score of 2 due to the increased potential for complexity in the permit modification request. The value was applied for both RNS and UNS waste.

Option 3 (Stabilization Using Dry-Process Cementation) uses the same two waste management sites but limits waste processing at WCRRF to segregation to prepare the waste for subsequent remediation at a new TA-54 Area G cementation location that would require a permit modification. However, many of the same potential operational factors that would need to be described for changes to the permit would be similar. Therefore, the treatment option for the remediated waste stream was assigned the same score of 2 for the potential permitting complexity. However, the absence of the organic component in the UNS waste was considered to be a less complex technical process, and the Ease of Permitting score was raised to 3 for that waste stream.

Option 4 (Stabilization Using Wet-Process Cementation) and Option 14 (Salt Dissolution With Cementation/Stabilization) would also use the same two waste management sites and potential operational factors, implying increased operational changes associated with the permit. However, as stated above, cementation treatment alone in Option 4 is a simpler process and has been previously approved. Option 14 is slightly more complex than Option 4 due to the generation and treatment of two discrete waste streams with associated facilities but similar in the cementation processes. The early addition of water would minimize the worker safety concerns and waste management procedures related to the oxidizer capability in the early stages of the process, a beneficial factor for permitting by potentially mitigating the degree of operational change descriptions needed to modify the permit. The need for temperature control of the waste is limited to the earliest stages of the waste treatment process, making potential permit conditions at WCRRF less complex. As a result, options 4 and 14 were assigned evaluation criteria values of 4 and 3, respectively, for the remediated waste stream regarding permitting difficulty.

Criterion 3: Safety Basis Challenges

This criterion includes the facility features needed for radiation protection, as well as the degree of procedure development needed to ensure that requirements for worker safety are met. If a treatment option can use or build from the existing safety basis analysis, the challenges will be reduced. Conversely, if facilities not previously used to treat waste are envisioned, or if different processes are developed that are complex or require new controls, safety basis challenges are more severe.[16] On that basis, Option 1 (Stabilization Using Zeolite) was judged to be the option with the simplest safety basis path forward because the operations (transport, processing at WCRRF) are those that were already used to process nitrate salts at LANL.

Comparing the remaining cementation options, Option 2 (Stabilization Using Zeolite With Cementation) and 3 (Stabilization Using Dry-Process Cementation) are identical up to the point at which zeolite is added. After that point, wastes are transported to TA-54 Permacon

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[16] There is no impact to the safety basis when the drums are cooled, unless cooling is considered a treatment. The controls considered are temperature and handling.

231 for cementation. Because the mixing with zeolite removes the ignitability and corrosivity hazards, the subsequent movement to TA-54 presents fewer safety basis challenges, making Option 2 (Stabilization Using Zeolite With Cementation) somewhat less onerous (from a safety basis perspective) than Option 3 (Stabilization Using Dry-Process Cementation). It is believed that there is also a clear separation between these options and Option 4 (Stabilization Using Wet-Process Cementation) and Option 14 (Salt Dissolution With Cementation/Stabilization), which has the challenges of the other two cementation options, but also includes movements and handling of waste to which water has been added. These new additional steps led to the determination that Option 4 (Stabilization Using Wet-process Cementation) and Option 14 (Salt Dissolution With Cementation/ Stabilization) present the most difficult safety basis challenges of the five options and were given a score of 1.

In summary, for RNS waste, the team perceives a distinct difference in the five options, resulting in the assignment of scores of 4, 3, 2, 1, and 1 to Options 1, 2, 3, 4, and 14 respectively, for the safety basis criterion. For UNS waste, the team believed that essentially the same challenges exist, so the same scores were assigned for the first three options. Option 4 is not applicable for UNS waste or debris.

Criterion 4: Extent of Testing

Extent of testing refers to the amount and complexity of sampling and analysis required to implement the treatment process. The new characterization of the TRU nitrate salt bearing waste stream with the D001 EPA hazardous waste number for ignitability (based on the presence of oxidizers) requires that the final treated product or appropriate surrogates must demonstrate that the oxidizer capability has been negated by testing to SW-846 Test Method 1030, Ignitability of Solids, Test Method 1040, Oxidizing Solids, Test method 1050 Test Methods to Determine Substances Likely to Spontaneously Combust and DOT methods. Since any treatment strategy would require such testing, there are no scoping differences that would contribute to the overall score. Likewise, gas and solids sampling of the barrels was not included as it is common to all processes. The evaluation specifically compared the amount of testing that would be required during the remediation operation, and post-processing.

For any cementation operation (all Options except Option 1, Stabilization Using Zeolite), achieving the proper pH for the mixture is critical to making a viable grout, making pH testing mandatory during remediation to ensure proper pH. In addition, cemented mixtures are known to dewater during storage, which adds an additional requirement[17] for tests to ensure that the solid matrix was stable and did not lose water. By comparison, the Core Team believes that no pH testing was necessary or beneficial in the case of Option 1 (Stabilization Using Zeolite), and that post-treatment dewatering may not be necessary when the prescribed selection of the appropriate zeolite ratio is used.

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[17] The WIPP WAC (DOE/CBFO, 2013) requires that, due to corrosivity concerns, the waste packages contain no free liquids.

Based on these considerations, Option 1 (Stabilization Using Zeolite) received a score of 5 for both RNS and UNS waste since they require no tests other than those requisite for waste acceptance. All of the remaining options involve cementation, requiring pH testing during the remediation operation followed by surveillance for dewatering after they had set. For this reason, these options all received a score of 3 for both RNS and UNS waste.

Criterion 5: Reduction of Toxicity, Mobility, Corrosivity, and Ignitability

The design and operating permit for the WIPP facility is the primary consideration for the applicability of the criteria for mobility of contaminants.[18] In a bedded salt repository, the waste form is of secondary importance to the long-term performance of the repository. The waste form for all options is a solid waste confined by the waste containers. Even if the waste form dewaters over time, the amount of liquid liberated would be insufficient to facilitate transport of radionuclides through the salt bed to the accessible environment. The self-sealing of the salt will limit the availability and transport of water into and through the repository, and correspondingly minimize the potential release of TRU nuclides from the repository. In the undisturbed repository scenarios considered by the WIPP repository program, no significant release of actinides from the WIPP is predicted.[19] The nature of the WIPP salt bed would prevent mobility of contaminants. All five options meet the WIPP WAC, are an effective waste form and fairly straightforward to package as long as the corrosivity and ignitability characteristics of the content are removed to mitigate the safety hazard. Therefore, this criterion was determined to not be a discriminator among treatment options, so a uniform score of 4 was applied to each option.

Criterion 6: Reduction of Volume

The number of daughter drums generated by each option was the primary criterion used for ranking each option with respect to this criterion. The estimated number of drums generated for the five options are 399, 798, 285, 342, and 285 respectively (Table 6-2). Based on the fact that all five options increase the number of drums of waste to be disposed, the maximum number for these options was capped at 3: Option 3 (Stabilization Using Dry-process Cementation) received this score. Scaling the remaining scores to the relative number of drums generated, Option 1 (Stabilization Using Zeolite) received a score of 2, Option 2 (Stabilization Using Zeolite With Cementation) scored a 1, Option 4 (Stabilization Using Wet-Process Cementation) scored a 2, and Option 14 (Salt Dissolution With Cementation/Stabilization) scored a 2. The corresponding scores for UNS waste, where applicable, were assigned the same values.

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[18] WIP WAC prohibits free liquid. Therefore, WIPP is not permitted to accept wastes with observable liquid that is more than 1 percent by volume of the outermost container at the time of radiography or visual examination.

[19] Title 40 CFR Part 191 Subparts B and C Compliance Recertification Application 2014 for the Waste Isolation Pilot Plant Appendix SOTERM-2014 Actinide Chemistry Source Term, Appendix PA-2014, Section 7.

Criterion 7: Short Term and Long Term Effectiveness

Regarding the effectiveness of the examined remediation options to produce an acceptable final waste form, RNS and UNS mixed with zeolite or in a concrete monolith are equally acceptable if a sufficiently robust cemented waste form is developed that will not dewater. The scoring of Criterion 4, Extent of Testing Required, covers the development and testing of a cement waste form containing RNS or UNS. Should testing fail to reveal a cemented monolith waste form that will not undergo dewatering then Option 1 (Stabilization Using Zeolite) is the superior remediation option. However, assuming that testing confirms the suitability of either type of waste form, there is no reason to favor one over the other with respect to effectiveness.

Further, it is recognized that treatment to an acceptable final waste form for the UNS waste can be accomplished with greater certainty than for the RNS waste. Mixing of the UNS with either zeolite or grout to remove the ignitability characteristic assigned to oxidizers is straightforward and has already been thoroughly examined by Walsh (2010). The conservative zeolite or grout treatment ratios will be sufficient to account for future liquid production and will, therefore, remove the potential for the corrosivity characteristic. If enough zeolite is used, dewatering will not occur. Therefore, on the basis of this increased certainty for UNS waste, scores are assigned one point higher for UNS waste than for RNS waste. Thus, all five options received a score of 4 for RNS waste, and the three options applicable to UNS waste received a score of 5.

Criterion 8: WCS Implications

This criterion, which addresses the relative ease with which a treatment process could be implemented for nitrate salt waste in storage at WCS, applies only to the RNS waste. The Core Team discussed two general approaches to treatment of WCS waste: On-site treatment at WCS, and transport of waste to LANL where treatment would be conducted using LANL facilities. The team did not discuss burying the drums at WCS. If the waste were to be treated at LANL, the untreated waste residing at WCS does not meet certification of compliance for transport. The RNS waste is considered ignitable; therefore, transporting the RNS waste without treatment requires an exception by NRC. The team evaluated the options under the assumption of the need for WCS to construct and operate an on-site capability to process the waste due to the difficulty in transporting ignitable waste. There was agreement that this would be a difficult process and that relatively low scores should be given to any of the options. Comparing Option 1 (Stabilization Using Zeolite) to the three cementation options, deploying a glove box for the single step of zeolite addition was judged to be easier than deploying equipment for multiple steps of a cementation process. On that basis, Option 1 (Stabilization Using Zeolite) was given a score of 2, and each of the cementation options was given a score of 1.

Criterion 9: Scalability and Complexity

In the evaluation of this criterion, issues that were considered were the ability to treat RNS and UNS with the current available facilities at LANL, consideration of whether similar operations have been performed at LANL or elsewhere in the DOE complex, and the number and complexity of steps required to complete the operation. The availability of engineering controls to meet ALARA in accordance with LANL and DOE requirements were also considered.

Table 6-2, constructed from the descriptions developed in Appendix 1, allows the options to be compared with respect to the number of facilities used, the total number of operational steps, the number of transport movements between facilities, and the complexity in procedure and/or facility changes. This table contains information relevant to this criterion, as well as the next (Facility Challenges).

In summary, Option 1 (Stabilization Using Zeolite) is the most straightforward option to implement due to the smaller number of operational steps, the use of only WCRRF for treatment, and the precedent of having performed these operations in WCRRF in the past (albeit with an inappropriate use of an organic absorbent, non-permitted neutralization and in violation of the BIO). It was given a score of 4 for RNS waste as a result. All of the cementation options involve many more operational steps and drum transport steps. On a relative basis, Option 3 (Stabilization Using Dry-Process Cementation) is the most straightforward of the cementation options and has the lower number of daughter drums generated. Next is Option 2 (Stabilization Using Wet-Process Cementation) has one fewer step than Option 3 (but many more than Option 1) but suffers in this evaluation from the generation of many more daughter drums. One of the most complex, least scalable choices is Option 4 (Stabilization Using Wet-Process Cementation), which involves a large number of operations and transport steps, water addition at TA-54 Permacon 375 (which presents new challenges), and the transport of drums which have had significant water added. Option 14 (Salt Dissolution With Cementation/Stabilization) consists of a filtration process followed by two separate streams, nitrate solution and Swheat™ cake, both requiring cementation. For these reasons, the scores issued to these four options for RNS waste were 4, 2, 3, 1, and 2 respectively.

For UNS waste, the scores applied to the three options are one point higher than the corresponding RNS waste score for that option due to the absence of required temperature control, which makes the operations less complex.

Table 6-2. Statistics and features of the five stabilization treatment options

Option	# of Daughter Drums[1]	Drum Duration (days)[2]	# of Operational Steps[3]	# of Facilities[4]	# of Drum Movements[5]	Other Considerations[6]
1. Stabilization Using Zeolite	399	4	6 w/ debris removal	2	2	• Precedent has been established for this option • Personnel are familiar with this option • Readiness activities should be straightforward compared to cementation operations stood up at TA-54 • WCRRF is authorized for TRU waste treatment
2. Stabilization Using Zeolite With Cementation	798	29	10	3	3	• Additional procedures and training for cementation process (also applies to Options 3 and 4) • New glove box and related utilities and permit modification (also applies to Options 3 and 4)
3. Stabilization Using Dry-Process Cementation	285	10	9	3	3	• Fewer number of daughter drums makes this a more scalable option than the other cementation options
4. Stabilization Using Wet-Process Cementation	342	27	10	3	3	• Water addition would be an additional new operation • Drum movements after water addition is a new operation
14. Salt Dissolution With Cementation/ Stabilization	285	4	10	2[6]	2	• Water addition, filtration with water, and filter press of sludge, and drum movements after water addition are new operations.

[1] Values are for treatment of the RNS drums. Corresponding values for the UNS waste scale by a factor of 29/57, or 0.51. (The number of steps and transportation between facilities accounts for the increase in option time.) The number of daughter drums includes grouted parent and debris drums.

[2] Drum duration refers to the "cycle time" starting from initial handling to a completed waste drum ready for shipment.

[3] Operational steps are represented schematically in Figure 4-1. Values do not include temperature control steps, which apply to all options for RNS waste.

[4] Facilities include WCRRF at TA-50 (all options), TA-54 Permacon 375 (current storage location of RNS waste), and TA-54 Permacon 231 (assumed to be used for cementation operations, if applicable).

[5] Movements include transport from current location to WCRRF, transport to cementation location (applicable for cementation options), and transport of treated daughter drums to final storage location.

[6] Facility location has not been determined.

Criterion 10: Facility Challenges

In the evaluation of this criterion, the issue that was considered was the ability to use available sites and facilities that are currently operating under the LANL approved Authorization Basis (AB) to treat RNS and UNS waste. Evaluation of options consisted of comparing the number of facilities used in each option, the current operational configuration of each facility and what operation(s) are currently authorized to occur in each facility.

In summary, Option 1 (Stabilization Using Zeolite) was judged to present the easiest path from a facility readiness and AB perspective. WCRRF could be used for Option 1 without modification, and is already authorized for TRU waste treatment. In contrast, the three cementation options all employ one additional facility, and require the installation of a glove box in TA-54 Permacon 231, with accompanying new evaluations to obtain AB approval. Thus, the cementation options are all ranked significantly below Option 1 (Stabilization Using Zeolite) for this criterion. Of the four, Option 4 (Wet-Process Cementation) and Option 14 are considered to be the most challenging with respect to facilities because the additional complication of the water addition step in TA-54 Permacon 375 requires introduction of additional new equipment (beyond that of the other cementation options) that would need to be evaluated prior to operations. For these reasons, the four options received scores for RNS waste of 4, 2, 2, 1, and 1 respectively for the facilities challenges criterion.

For UNS waste, the scores applied to the three options are one point higher than the corresponding RNS waste score for that option due to the absence of required temperature control, which makes the facilities challenges somewhat less onerous.

Criterion 11: Schedule

Schedule factors considered in the Core Team deliberations included compliance schedules, staffing requirements, and project and procedure development. Some factors influencing the schedule, such as the time required for permitting approvals, and treatment-process facility design complexity, were not included here because it was agreed that those are covered in other criteria. Additionally, during discussion it was recognized that dominant factors influencing schedule (discounting the preliminary steps before treatment operations) were the number of drums created, and the "cycle time" associated with a drum, from first handling to completion of all steps to make the drum ready for shipment. A lower cycle time results in a decrease in the number of drums generated which require less storage space, potential movement, and processing time. These measures are provided for the four potions in 6-2.

Option 1 (Stabilization Using Zeolite) was determined to rank the highest among the four options due to the modest number of daughter drums created[20] and the short

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[20] The value of 399 daughter drums is thought to be an upper-bound estimate because it is based on a 3:1 zeolite/waste ratio, which very likely overestimates the amount of zeolite required to inert the RNS waste.

drum duration. In contrast, all of the cementation options have significantly longer drum durations. Options 2 (Stabilization Using Zeolite With Cementation) and 4 (Stabilization Using Wet-Process cementation) have particularly long drum durations due to the large number of steps required. Option 4 has the unique requirement of a hold time on the drums after initial water addition. Option 14 (Salt Dissolution With Cementation/Stabilization) consists of a two-part process; nitrate solution collected in one drum and Swheat™ cake collected in a second drum. Both drums require cementation processing. With regard to the number of daughter drums generated, the cementation process envisioned requires leaving enough room in the drum for cement addition and mixing after splitting the RNS waste, resulting in a lengthy process of cementation being applied to a large number of daughter drums. Option 2 (Stabilization Using Zeolite With Cementation) would generate a particularly large number of daughter drums, which lowers this option's rating with respect to schedule. Option 3 (Stabilization Using Dry-Process Cementation) and Option 14 (Salt Dissolution With Cementation/Stabilization) are the best of cementation options with respect to schedule due to the relatively small number of daughter drums generated, but it is not as time-efficient as Option 1. In summary, based on these considerations, the four options for RNS wastes received scores of 4, 1, 2, 1, and 2 respectively for the schedule criterion.

For UNS waste, the scores applied to the three options are one point higher than the corresponding RNS waste (and debris) score for that option due to the absence of required temperature control, which should shorten the times required to complete the processing of a waste drum.

Criterion 12: Cost

Cost was not used as a criterion for discriminating between treatment options, and was not included in the summation of scores used to rank the options. The scores and this description are included for information purposes, capturing the discussion conducted at the ranking meeting.

For RNS waste, judgments on the relative costs of the options were based on: 1) the number of facilities employed, and the required changes to these facilities in order to conduct the work, 2) the estimated number of daughter drums generated, which correlates to materials and labor costs; and 3) the cycle time required to remediate a drum, which includes additional costs for operations for items such as surveillance while a drum is being remediated. On these bases, Option 1 (Stabilization Using Zeolite) ranks as the most cost efficient option based on the use of existing facilities at WCRRF and Area G, the need for only a single movement of waste after cold safeing, the relative efficiency in terms of number of daughter drums generated, and the relatively fast cycle time to complete the remediation of each drum. A relatively high score of 4 was assigned for these reasons. On the other end of the spectrum, Option 2 (Stabilization Using Zeolite With Cementation) received a low score of 1 based on the far greater number of labor hours per drum, the large number of daughter drums generated, the more involved facility change process required, and greater shipment costs between facilities. Option 4 (Stabilization Using Wet-Process Cementation) similarly received a low score of 1 because the lower number of daughter drums compared to Option 2 was judged to be offset by the slow cycle time and corresponding larger labor and surveillance costs. Option 4 (Stabilization Using Dry-Process Cementation) and Option 14 (Salt Dissolution With Cementation/Stabilization) was judged to be intermediate to Options 1 and 4 in these aspects, and thus received a relatively low but intermediate score of 2. Option 14 (Salt Dissolution With Cementation/Stabilization) scored a 2 because of the need for a new nuclear facility and gloveboxes.

Operations for UNS waste are the same as for RNS waste except that temperature control operations are not included. Accordingly, the scores for UNS wastes were set one point higher than the corresponding RNS waste score for Options 1 and 3. (Options 1 and 4 received scores of 5 and 3, respectively). The elimination of temperature control steps for Option 2 was deemed to be inconsequential compared to the costliness of the other operations, so Option 2 received a score of 1 for UNS waste, as it did for RNS waste.

6.3 Discussion of Results

The overall results presented earlier in Table 6-1 indicate that for both RNS and UNS waste, Option 1 (Stabilization Using Zeolite) ranked the highest based on the criteria used in the evaluation. This is seen from the total obtained by adding all of its scores except cost, which was not included in the summation. The four cementation options were significantly lower in total score, and were ranked in the following order for RNS waste: the second-ranked option was Option 3 (Stabilization Using Dry-Process Cementation); the third-ranked option was Option 2 (Stabilization Using Zeolite With Cementation); fourth-ranked option was Option 14 (Salt Dissolution with Cementation/ Stabilization); and the fifth-ranked option was Option 4 (Stabilization Using Wet-Process Cementation). For UNS waste, the order of the rankings was the same: Option 1, Option 3, Option 2, and Option 14 (Option 4 is not applicable for UNS waste). Generally, the positive or negative attributes leading to a higher or lower score for a given criterion held true for either RNS or UNS waste. Therefore, the remainder of this discussion will focus on the RNS waste and RNS debris.

The score for Option 1 (Stabilization Using Zeolite) exceeded that for any cementation option by 10 points or more; for virtually all of the 11 criteria applied to the evaluation, this option scored equal to or higher than any of the cementation options. Exceptions to this conclusion are: 1) for the Ease of Permitting criterion, Option 4 (Stabilization Using Wet-Process Cementation) was deemed to pose fewer obstacles to permitting than simple zeolite addition and 2) for the Reduction in Volume criterion, Option 3 (Stabilization Using Dry-Process Cementation) ranked higher than zeolite addition because of the smaller number of daughter drums generated. These are very isolated instances of a higher score for an option other than Option 1. Therefore, even if one were to apply unequal weightings to the various criteria, the conclusion that Option 1 (Stabilization Using Zeolite) is the preferred option will not change. Therefore, the recommendation to pursue Option 1 is very robust.

The results of the cost criterion, though not used in the analysis, reinforce the results of the overall evaluation in that the treatment option recommended based on non-monetary criteria is also judged to be the most cost effective option. Had cost been included in the evaluation, rather than given a zero weight, the recommendation of Option 1 would have been even stronger.

An important aspect of the analysis was the inclusion of a variety of non-stabilization RCRA standards based treatment options in the pre-screening phase of the evaluation. In effect, each of these options received a failing score on one or more criteria, and thus was screened out. Clearly, this result applies only for the particular nitrate salt waste streams at LANL, and is not a general conclusion. Difficulties in permitting, safety basis, and short-term or long-term effectiveness of the final waste form were typical criteria that led to the elimination of most of these options.

Finally, most of the criteria applied to these treatment options had value in discriminating among options. The exception is Reduction of Toxicity and Mobility, which was found to be an ineffective criterion for this application because those attributes are relatively unimportant for waste disposed at WIPP. Typically, such a criterion would be important for low-level waste disposal or situations in which credit will be taken for a durable waste form resistant to leaching of contaminants. This is not the case for disposal of TRU waste at WIPP: Therefore, this criterion should be eliminated from use for any future analyses of this sort.

7 Conclusion

The evaluation of various processes to judge their suitability for treating the nitrate salt wastes at Los Alamos led to a definitive recommendation that Option 1 Stabilization Using Zeolite be pursued for both the RNS and UNS waste streams and associated debris. This result confirms the previous recommendation of Clark and Funk (2015) to mix the waste with zeolite to mitigate the corrosivity and ignitability characteristics. The Clark and Funk recommendation was based primarily on scientific and technical considerations. The evaluation process reported herein was designed to be comprehensive, in terms of the variety of treatment options considered, and robust, in terms of the use of a diverse set of criteria in the evaluation. The Core Team conducting the evaluation consisted of subject matter experts across a wide range of disciplines, thereby ensuring that appropriate experts in the scientific, operational, safety and regulatory arenas informed the evaluation of the options. These factors, plus the decided advantage of zeolite addition revealed by the evaluation, provide confidence in the recommendation.

The results of the Options Assessment Report were externally peer-reviewed. LANL recognizes that the results of the analysis will be vetted with NMED and that a modification to the LANL operating permit is a necessary step before implementation of this or any treatment option. Likewise, facility readiness and safety basis approvals must be received from the DOE. This report represents LANL's documentation of our process for arriving at the recommended treatment option for RNS and UNS waste for consideration by NMED and DOE.

Finally, these recommendations have been developed based on current information and understanding of the scientific, technical, and regulatory situation at the time of writing of this report. Any significant changes to the state of knowledge in any of these areas should be followed up with a qualitative re-evaluation, or a more thorough quantitative evaluation, as appropriate.

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Appendix 1 Description of Stabilization Treatment Options

This Appendix provides additional details on the four stabilization and salt dissolution treatment options developed in the summer of 2014 in response to the recognition that a nitrate salt waste drum generated at LANL had breached in the WIPP underground (Drum 68660). The team was charged with the goal of developing potential treatment options for RNS and UNS waste using LANL facilities, taking into consideration the current state of the waste and facility readiness. Technical requirements that the team considered included the need to store and handle the waste safely before and during treatment, and the development of treatment options that would yield an acceptable final waste form for disposal at WIPP, with recognition that any proposed option will require acceptance by the regulator in the form of an approved modification of the LANL operating permit.

Below are the assumptions that the team made in order to develop the options.

1. All 60 RNS drums will be processed.
2. All 29 UNS drums will be processed.
3. Existing drums are 75% full on average.
4. Zeolite will be mixed at a ratio of 3:1 (zeolite:nitrate salt/kitty litter) by volume. (Testing most likely will change this assumption).[21]
5. Non-cemented product drums will be filled to 50% to allow for mixing.
6. Cemented drums will contain approximately 25% waste material (absorbed or otherwise), which is estimated to produce approximately 80% cemented material.
7. For RNS waste, the drums will be processed at temperatures below ambient in order to reduce chemical reaction risk during denesting and slow chemical kinetics potential, and to allow for safe and efficient denesting and handling.
8. Final forms will be tested to validate that the D001 EPA Hazardous Waste Number is no longer applicable.
9. Final forms meeting WIPP acceptance criteria will have less than 1% liquid and will not have D002 hazardous waste labeling (corrosivity) because of the

[21] A 3:1 ratio was originally selected as a way to mitigate dose because packaging of waste would have been in a pipe overpack container (POC), which is limited by dose and amount of salt that can be transported. The remediated material is significantly different than the original nitrate salts because it is an efficient mix of oxidizer and fuel. Small-scale testing will be performed to determine the appropriate ratio used to eliminate the hazards.

removal of all liquids and neutralization depending upon the treatment option chosen.

10. Temperature control would be applied to the RNS drums until treatment enables removal of the D001 hazardous waste labeling.

11. A container may be removed from the Isolation Plan upon removal of the D001 hazardous waste labeling.

12. The SWB may be considered secondary containment for corrosive liquids during transportation of a container controlled through the Isolation Plan.

13. The SWB will be considered a regulatory control during loading and shipping while a container is controlled through the Isolation Plan.

14. Remediated nitrate salt drum processing (debris segregation, splits and zeolite addition) may be performed at WCRRF.

15. Visual examination will be conducted at WCRRF for debris drum loading with controls to ensure no additional waste is added prior to cementation.

16. Cementation (neutralization, cement addition and mixing) will be performed in a new facility in Area G.

The following is a description of each stabilization option, and accompanying diagrams that were provided to the Core Team to define the options.

Option 1. Stabilization Using Zeolite

Figure A1-1 is a schematic of this option. Waste is processed by removing debris and mixing it into an inorganic matrix of natural mineral zeolite such as clinoptilolite. The resulting mixture removes the characteristics of ignitability, corrosivity, and the oxidizer potential of the nitrate salts is eliminated. The quantity of zeolite used would be determined through reactivity studies using surrogate mixtures of waste, and confirmed once the waste is sampled. For RNS waste, the drums will be cooled to allow for safe and efficient denesting and handling. Denesting would occur at Area G, and the waste would be transported to the WCRRF for processing. For UNS waste, similar processing will be conducted, but temperature control is not required because the nitrate salts without organic absorbent do not pose a safety hazard for oxidation reactions involving contents within the drum (Funk, 2014). The figure is annotated with markers denoting the operational and regulatory steps that would be performed at various stages of the process.

For RNS waste, based on the assumptions of a 3:1 ratio of zeolite to waste, an assumed average volume in each drum, and 50% fill of the new daughter drums, this option is calculated to produce 399 daughter drums including the original empty drums.

Option 2. Stabilization Using Zeolite

Figure A1-2 is a schematic of this option. Waste is processed identically to Option 1 up to and including zeolite addition, ensuring ignitability and corrosivity characteristics are removed. The waste is now considered non-oxidizing, and removed from temperature control. The material is then further treated through a process that includes water addition, neutralization, and cementation to produce monoliths that would be suitable for transportation and disposal when the D001/D002 characteristics are removed. Waste transport occurs from Area G to WCRRF for zeolite addition, and, in the process evaluated at WCRRF. Then, the containers are transported back to Area G for cementation in a new facility. For UNS waste, similar processing will be conducted, but without temperature control. The figure is annotated with markers denoting the operational and regulatory steps that would be performed at various stages of the process. For UNS waste, a similar process would be conducted, but without temperature control.

For RNS waste, based on the assumptions of a 3:1 ratio of zeolite to waste, and an assumed average volume in each drum before and after cement addition, this option is calculated to produce 798 daughter drums, including the original empty drums and debris drums. The 3:1 ratio was based on possible dose. The actual ratio will be determined by the treatment studies.

Option 3. Stabilization Using Dry-Process Cementation

Figure A1-3 is a schematic of this option. Waste is moved to WCRRF and processed by removing debris and splitting it into smaller quantities suitable for subsequent treatment. The waste is transported as a dry material to a new cementation unit (assumed to be at Area G) where it is processed through the addition of water, neutralization, and cementation to produce monoliths that would be suitable for transportation and disposal. Temperature controls are removed at the point at which water is added. The figure is annotated with markers denoting the operational and regulatory steps that would be performed at various stages of the process. For UNS waste, a similar process would be conducted, but without temperature control.

For RNS waste, based on the assumptions of the average volume in each drum before and after cement addition, this option is calculated to produce 285 daughter drums, including the original empty drums and debris drums.

Option 4. Stabilization Using Wet-Process Cementation

Figure A1-4 is a schematic of this option. Waste is processed by cementation as in Option 3, but with water addition early in the process, rendering the mixture absent of ignitability characteristics. At that point, temperature control is removed. The waste is then transported wet to WCRRF for segregation and splitting followed by transportation of daughter drums back to Area G to a new cementation unit where it is processed by neutralization and cementation to produce monoliths that would be suitable for transportation and disposal. The figure is annotated with markers denoting the operational and regulatory steps that would be performed at various stages of the process. Because the early addition of water is a safeing strategy designed specifically for the RNS waste and thus is unnecessary for UNS waste, this option is only applicable for RNS waste.

For RNS waste, based on the assumptions of the average volume in each drum before and after cement addition, this option is calculated to produce 342 daughter drums, including the original empty drums and debris drums.

Option 14. Salt Dissolution with Cementation/Stabilization

Figure A1-5 is a schematic of this option. Waste is processed by removing debris, filtering the nitrate salt with water and separately capturing the Swheat™ during the filtration process. Temperature control is removed when the early addition of water occurs. The nitrate solution is neutralized and cemented to produce monoliths that would be suitable for transportation and disposal. The Swheat™ cake is pressed to remove excess water and also cemented for transportation and disposal.

For RNS waste, based on the assumptions of the average volume in each drum before and after cement addition, this option is calculated to produce 285 daughter drums, including the original empty drums and debris drums.

The number of daughter drums is dependent upon the repulp options chosen. The no repulp option would produce 4 daughter drums of cemented waste and another partial drum of debris (plastic bags and liner material) from the original drum. If the repulp option is chosen, 6 drums per waste would be generated, resulting in 342 drums.

Figure A1-1. Schematic of Option 1 (Stabilization Using Zeolite)

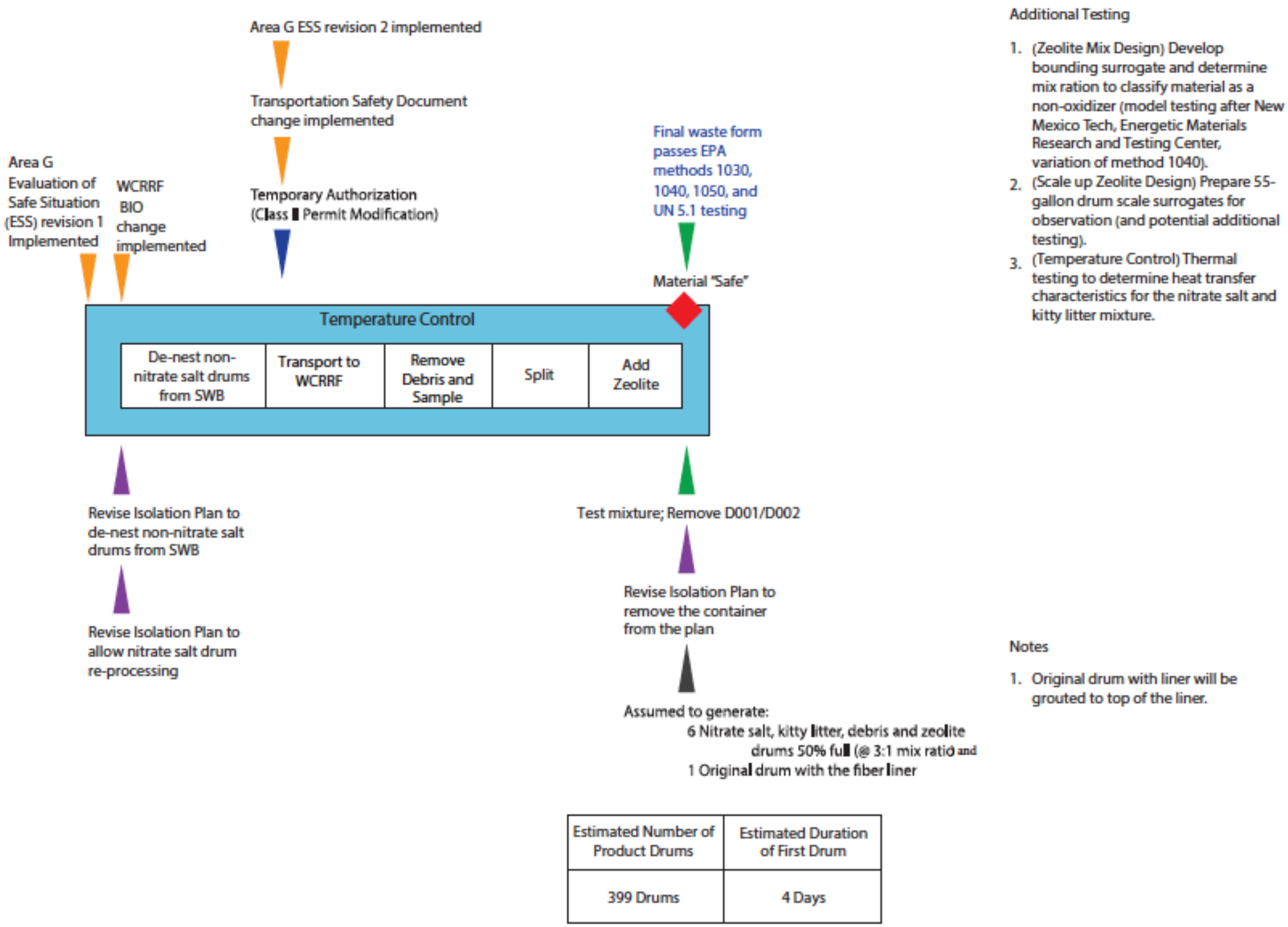
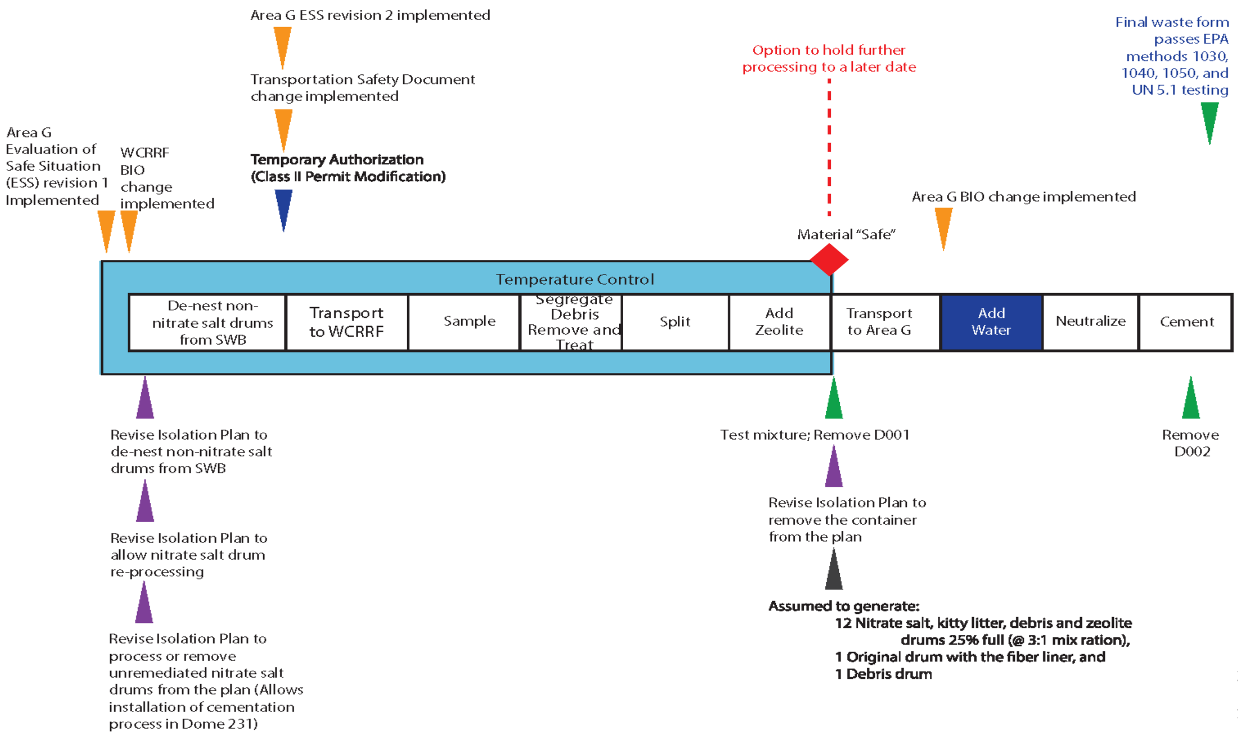


Figure A1-2. Schematic of Option 2 (Stabilization Using Zeolite With Cementation)



Additional Testing

1. (Zeolite Mix Design) Develop bounding surrogate and determine mix ration to classify material as a non-oxidizer (model testing after New Mexico Tech, Energetic Materials Research and Testing Center, variation of method 1040).
2. (Scale up Zeolite Design) Prepare 55-gallon drum scale surrogates for observation (and potential additional testing).
3. (Cement Mix Design) Conduct cementation bench scale testing to determine mix design.
4. (Scale up) Scale cemented form up to 55-gallon drum and determine setting and dewatering characteristics.
5. (Temperature Control) Thermal testing to determine heat transfer characteristics for the nitrate salt and kitty litter mixture.

Notes

1. **Original drum with liner will be grouted to top of the liner.**
2. **Debris drum will be filled with grout to an 80% level and rolled for mixing.**
3. **Allows for an option to "safe" the drums, return to storage, and cement at a later date.**

Estimated Number of Product Drums	Estimated Duration of First Drum
798 Drums	29 Days

Figure A1-3. Schematic of Option 3 (Stabilization Using Dry-Process Cementation)

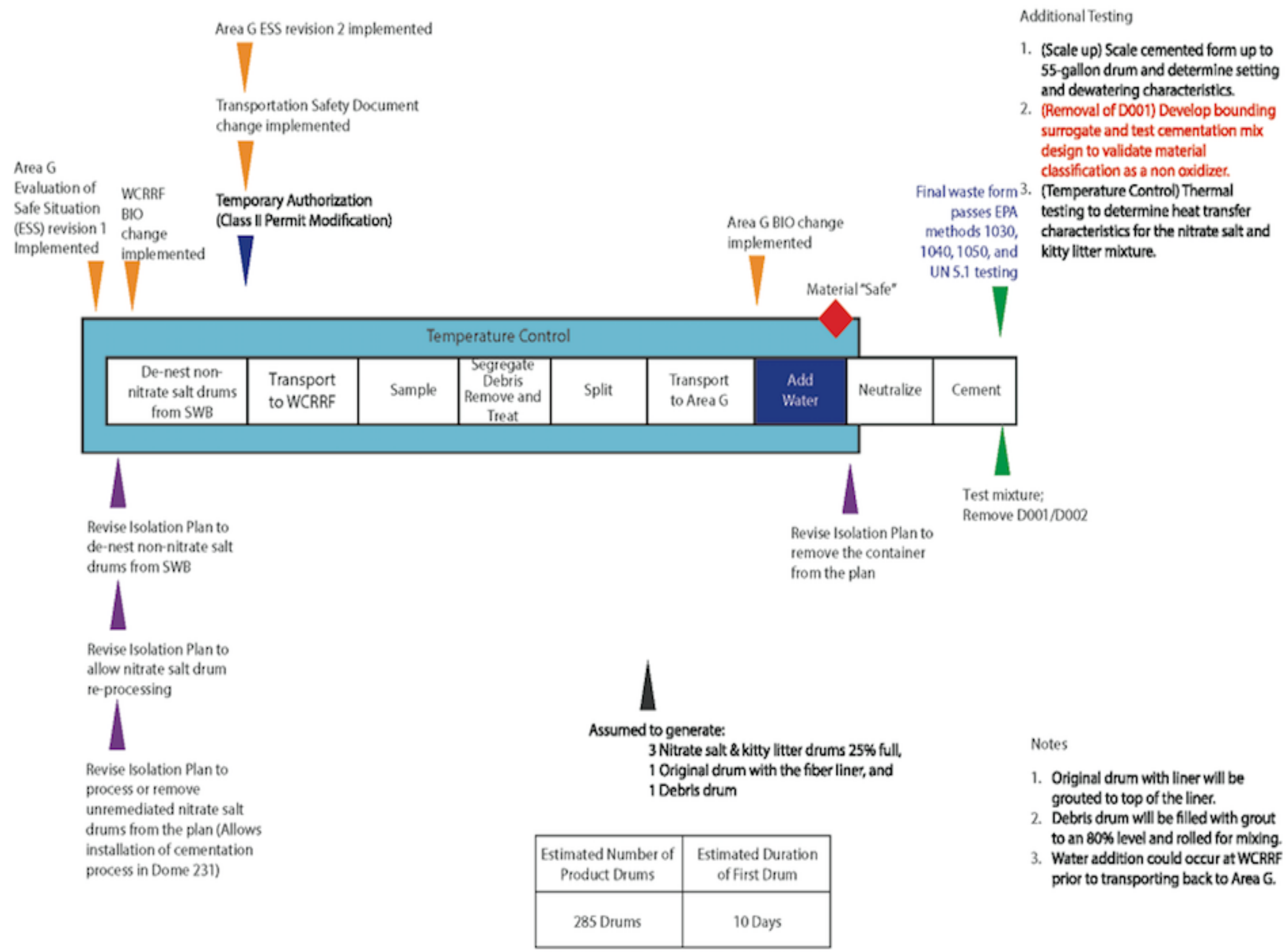
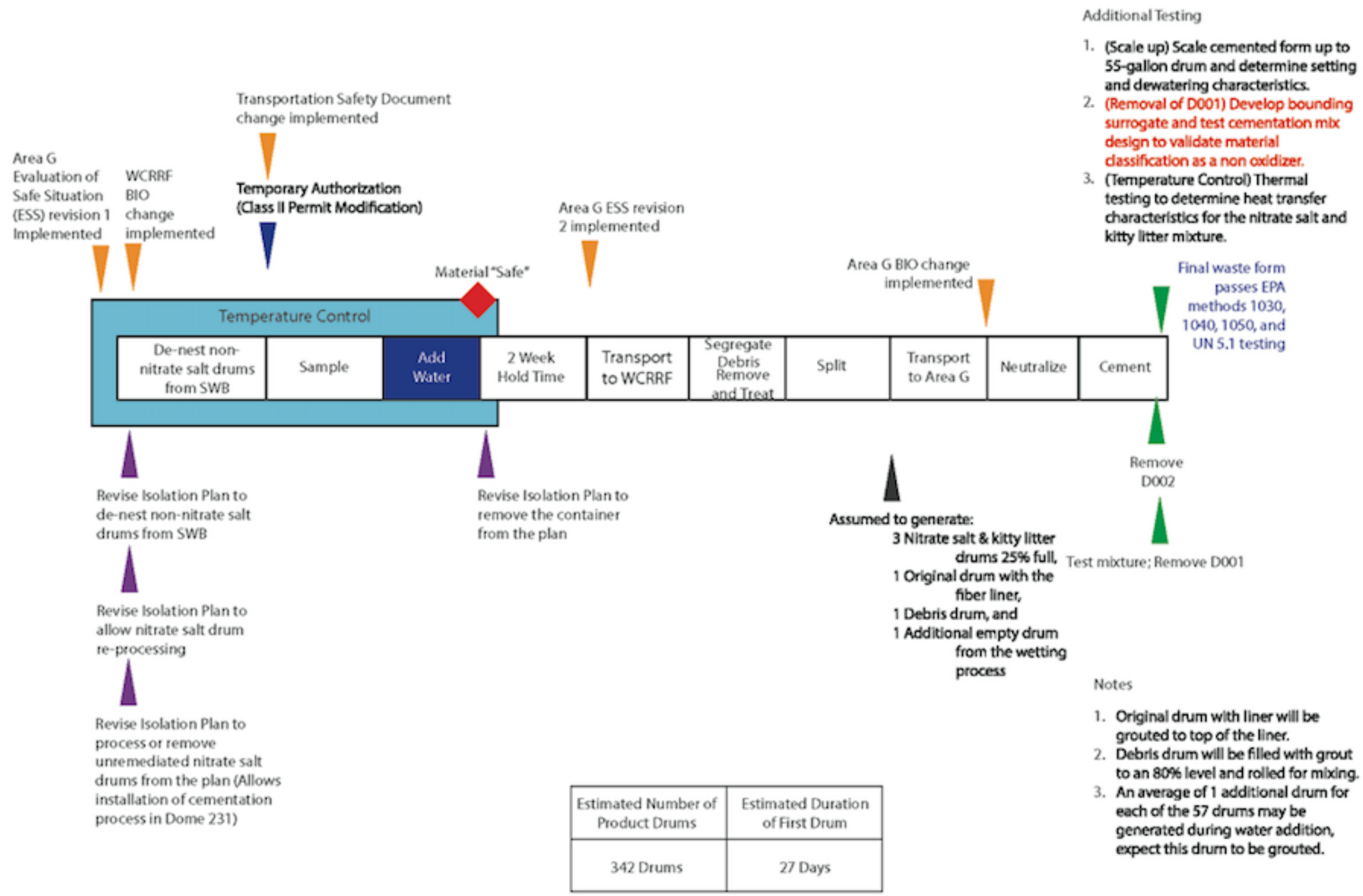
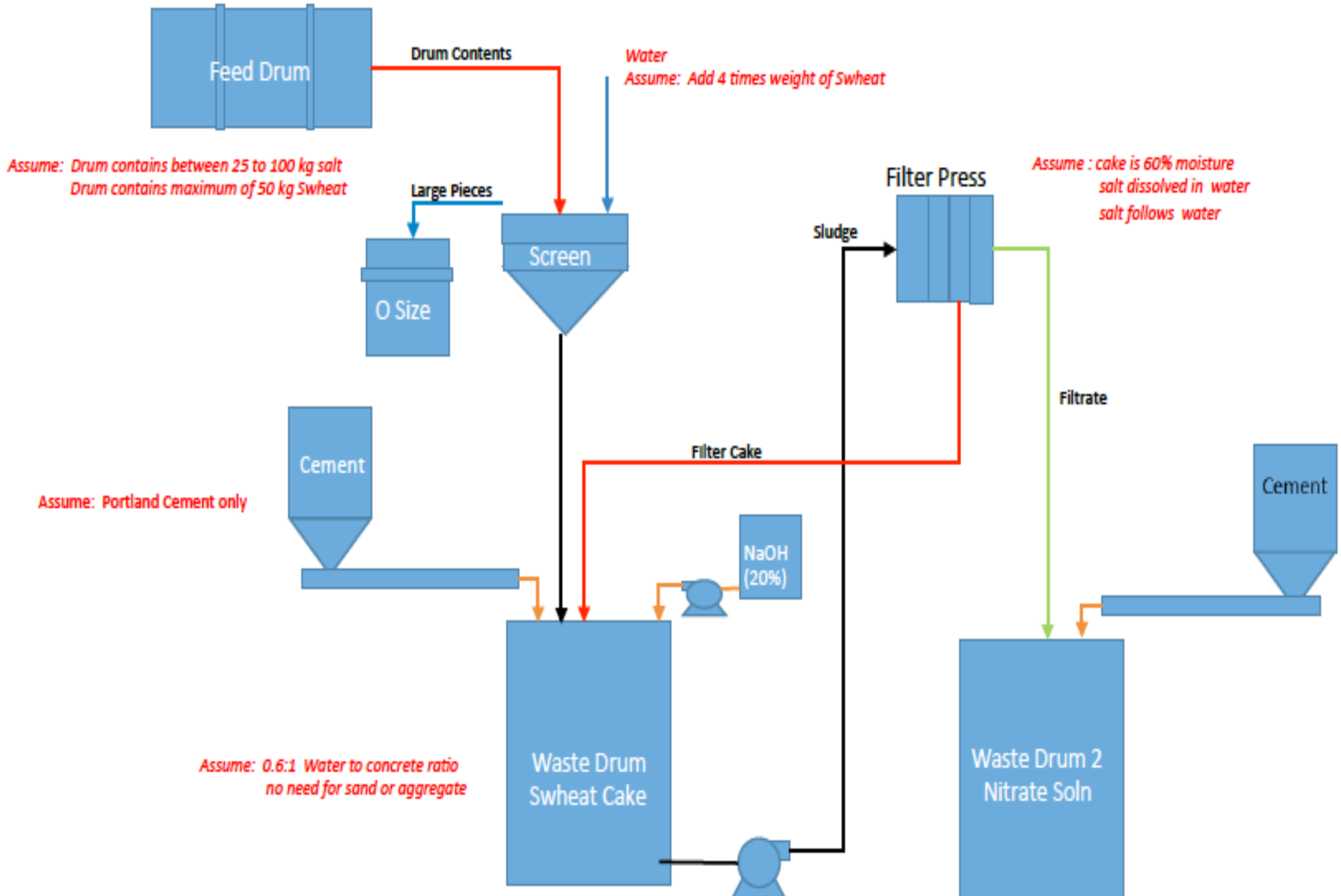


Figure A1-4. Schematic of Option 4 (Stabilization Using Wet-Process Cementation)



Estimated Number of Product Drums	Estimated Duration of First Drum
342 Drums	27 Days

Figure A1-5. Schematic of Option 14 (Salt Dissolution With Cementation/Stabilization)



Appendix 2. List of Core Team Members and Others Participants in the Options Assessment Activity

Remediation Integrated Team Members

ADEP Management	**Randall Erickson**
Lead	**Bruce A. Robinson**
Technical Input	
Energetic Chemistry	Philip Leonard
Actinide Chemistry	Stephen L. Yarbro
Cementation	Robert M. Wingo
Technical Advisors	David L. Clark
	David J. Funk
Operations	Scotty A. Miller
	James (Steve) S. Clemmons
	Kurt R. Anast
TA-55 Waste Expert	Kapil Goyal
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Regulatory	Gian A. Bacigalupa
	John K. Hopkins
ES&H	Robert (Bob) C. Stokes
Safety Basis	Ronald D. Selvage
Quality Assurance	Faris M. Badwan
Carlsbad DWT	Timothy P. Burns
	Christopher J. Chancellor
	Timothy A. Hayes
Benchmarking	Enrique (Kiki) Torres
Project Management	Patrice A. Stevens

Remediation Team Reviewers

High Explosives Science and Technology	Philip Leonard
Explosive Science and Shock Physics	Gary R. Parker
Environmental Compliance	Paul B. Schumann
Actinide Science and Engineering	D. Kirk Veirs
Environmental Compliance	Luciana Vigil-Holterman

Appendix 3. Evaluation Criteria Descriptions

The following set of definitions of the evaluation criteria presented in Table 5-1 was developed by the Core Team and used in its deliberations on potential treatment options. Instances in which criteria were adjusted or interpreted differently during the evaluation meeting are described in the evaluation write up (Section 6.2).

Criterion 1. Robust to Waste Stream Variability

A ranking of the ability to effectively treat all items potentially in the waste stream. This would include the need for separation, pretreatment or chemical compatibility with each of the items in the waste stream, accounting for potential differences in chemical composition from drum to drum. A procedure must be written that is robust enough to meet all potential waste streams. Note: if a process can be easily adapted to treat both the RNS and UNS waste streams, that benefit should also be factored into this criterion. Range: 1 – extremely difficult to develop a robust process, 5 – highly likely to be a robust process.

Criterion 2. Ease of Permitting (Permitting Difficulties)

The relative ease of obtaining permit approval from NMED, evaluating factors such as the regulator's familiarity with the treatment process, whether the process is used elsewhere at the facility, the overall technical complexity and maturation of the process, the need for associated risk assessments, degree of associated changes to the RCRA permit, and potential for stakeholder opinion. Range: 1 – extremely difficult to permit, 5 – simple permitting process.

A more precise definition of the scoring system used for this criterion was provided to the Core Team.

1 – Class 3 permit modification request with public hearing (Approval process with NMED could take three years or longer because of perceived technical complexity, significant public opposition, and need for extensive negotiations with stakeholders).

2 – Class 3 permit modification request without public hearing (Approval process could take two years).

3 – Class 2 permit modification request (Approval process one year if treatment process is common or less technically significant).

4 – Class 1 permit modification request with NMED approval (Short approval time by NMED without public input if treatment process is relatively simple, similar to previously approved processes, and/or previously coordinated with NMED).

5 – Class 1 permit modification notification without NMED approval or the treatment process can be included in an NMED compliance order without permitting.

NOTE: This range is based on the availability of distinguishing permit mod types in 40 CFR 270.42, Table I. NMED has the option to make any permit modification a higher class based on technical complexity or public interest.

Criterion 3. Safety Basis Challenges

The relative ease of obtaining Safety Basis approval. Factors include facility constraints such as facility features needed for protection from radioactivity. Another factor would be the degree of procedure development needed to ensure that requirements for worker safety are met. Range: 1 – extremely complex safety basis challenges, 5 – straightforward safety basis approval process.

Criterion 4. Extent of Testing Required

A review of the amount and complexity of sampling and analysis required to implement the treatment process. Significant factors will include the need for testing the waste prior to treatment, testing associated with developing operational parameters for the treatment process, operational testing during treatment, and final testing to assure the treatment process is effective. Testing must be sufficient to prove the technical viability of the treatment process. If a process is judged to be technically infeasible, then it will be screened out during the pre-screening phase. 1 – very onerous testing required, Range: 5 – straightforward testing required.

Criterion 5. Reduction of Toxicity, Mobility, Corrosivity, and Ignitability

The ability of the treatment process to provide reductions in toxicity, ignitability, corrosivity, and mobility of the final waste form. This would include factors such as level of ignitability of the final waste form, its ability to prevent releases, and the ability to package the final waste form. Range: 1 – marginally effective waste form and/or difficult to package 5 – highly effective waste form and straightforward to package.

Criterion 6. Reduction of Volume

Reductions in the volume of the final waste form due to the treatment process. This would include the ability to minimize volume of the final waste form including the number of daughter drums generated from the treatment. Range: 1 – large volume and/or large number of daughters generated 5 – low volume with low numbers of daughters generated.

Criterion 7. Short Term And Long Term Effectiveness

A review of the treatment process to evaluate whether the treated waste stream can meet the WIPP WAC, including prevention of future dewatering. Another factor will be the potential for the treated final waste stream to develop future biological/chemical problems such as degradation of entrained items or chemical compatibility. Range: 1 – effectiveness is questionable or indeterminate, 5 – highly effective.

Criterion 8. WCS Implications

A review of the difficulty of implementing the treatment option for the nitrate salt waste drums at Waste Control Specialists at Andrews, Texas. Evaluation includes the need for transportation of drums to Los Alamos to treat, versus implementing the treatment process on site. Range: 1 – extremely difficult to implement for WCS drums, 5 – straightforward to implement for WCS drums.

Criterion 9. Scalability and Complexity

The ability to treat RNS and UNS waste drums using the available sites and facilities at LANL, including the complexity of the remediation process for either type of drum. This includes the complexity and number of steps required to treat the waste, and whether engineering controls are available to meet ALARA in accordance with DOE and LANL requirements. Range: 1 – extremely difficult to implement for drum remediation 5 – straightforward to implement for drum remediation.

Criterion 10. Facilities Challenges

Ability to use available site and facilities that are currently operating under the LANL approved Authorization Basis (AB) scope. Range: 1 – extremely difficult to implement due to AB scope 5 – highly likely to implement under current LANL AB status.

Criterion 11. Schedule

A review of time constraints, evaluating schedule factors such as treatment process facility design complexity, staffing requirements, project and procedure development, permitting approvals, and compliance schedules. Range: 1 – extremely time consuming, 5 –expedited schedule is achievable.

Criterion 12. Cost (not a primary Evaluation Criterion; can be used as a final discriminator)

A review of financial constraints, evaluating cost factors such as treatment process facility design complexity, required facility modifications, and staffing requirements. Range: 1 – extremely expensive, 5 – cost-effective option.