Report of the Technical Advisory Panel: Options for Processing of Remediated Nitrate Salt (RNS) and Unremediated Nitrate Salt (UNS) Waste at the Los Alamos National Laboratory

April 2016

1. INTRODUCTION

Investigations by the Department of Energy's Accident Investigation Board (AIB) and Technical Assessment Team (TAT) determined that the February 14, 2014, release of radioactive material from the Waste Isolation Pilot Plant (WIPP) underground repository was caused by the breach of Drum 68660 containing transuranic (TRU) waste from the Los Alamos National Laboratory (LANL) nitrate salt waste stream.

The inadvertent mixing of an organic pet litter (sWheat™Scoop, a fuel) with nitrate salts (oxidizers) has been determined to be a key failure that lead to the incompatibility, and ultimately, the breach of the LANL TRU waste drum within the repository at WIPP. Sixty drums, stored at Los Alamos, were processed in the same manner (56 with sWheat and 4 with Wastelock 770) and require treatment to remove the hazardous waste characteristic of ignitability that the processed waste carries, thereby eliminating the specific hazard this waste represents. During 2015, a series of technical evaluations by LANL, with peer review by the Savannah River National Laboratory (SRNL), resulted in an Option Assessment Report recommending a potential remedy utilizing a RCRA stabilization process by the adding zeolite to the waste mixture. The evaluation also discussed facility availability for material treatment, including LANL on-site capabilities.

Later in the investigatory process, an Engineering Options Analysis provided an evaluation of methods for conducting the treatment, including batch- and drum-scale mixing. The original Option 1: Stabilization Using Zeolite (derived from the Option Assessment Report) was modified and refined through bench-scale engineering studies, leading to a process that involves water addition followed by zeolite addition. This option has several benefits such as the dissolution of the nitrates and the capture of salt laden liquid within the pores of the zeolite, isolating the oxidizer from the fuel.

To assist in the development of the drum remediation plan for the nitrate salt drums, LANL Deputy Associate Director for Environmental Management (DADEM) requested an independent technical review of the modified preferred and refined option(s), the planning effort, and the potential facilities for remediation which include a greenfield location housed at Area G using modular structures as treatment facilities, and other potential solutions brought forward by the committee. The purpose of the Technical Advisory Panel (TAP) is to provide a focused and dedicated set of expertise to evaluate LANL's review of treatment and remediation of the nitrate salt drums waste, ensuring that a *diversity of thought* has occurred.

The TAP convened at LANL for the on-site portion of the review on February 24-25, 2016. For subsequent evaluation the TAP was divided into two sub-teams to further review documentation and draft sections of this report: (1) the Process Chemistry Sub-team led by John Bowers and (2) the Engineering/Facilities & Safety Basis Sub-team led by Chip Lagdon. In mid-March, LANL management requested a preliminary summary of TAP observations, the TAP Chairperson, Steve Krahn, reviewed a short summary with the sub-team leads and provided it to LANL on March 16, 2016 (this summary can be found in Appendix A). The charter for this review is in Appendix B, brief resumes of the team members can be found in

Appendix C. Finally, the primary documentation that the TAP used for its deliberations is listed in Appendix D.

2. PROCESS CHEMISTRY

2.1 Process Chemistry Sub-Team Member Charge

Much work has transpired since February 14, 2014 and a summary was presented to the TAP members at the workshop. The workshop was hosted by the DADEM at LANL, with involvement from their customers (EM and NA field offices), under a newly formed integrated project team; the meeting was well attended by a variety of technical experts.

Los Alamos National Nuclear Security (LANS), NNSA and EM Field Offices are integrated to successfully complete the treatment of remediated nitrate salt (RNS) transuranic waste (TRU). The team members are to evaluate the most expeditious means of treatment using integrated risk management as a guiding principle, ensure the diversity of thought in evaluating the possible set of solutions, and provide recommendations to:

- Strengthen the basis for decisions
- Identify gaps and recommend a means to close those gaps
- Validate and if needed, alter the currently chosen course of action

2.2 Background

Team members reviewed a variety of materials related to facility and process-related issues and were presented with more current thoughts on direction at the two-day workshop. Specifically, the workshop served to summarize materials that had been provided as "read-ahead" material, provided more up-to-date information, and discussed the currently planned path forward for completing the treatment of all TRU waste both remediated (RNS) and unremediated (UNS). The emphasis has been on the remediated waste, as it is understood that the oxidizer/organic mixture in those drums provided for the energetic release of radionuclides from WIPP storage on February 14, 2104 (discussed in Section 1, above).

On the basis of the scientific understanding gained from their study in 2015, LANL provided an initial technical recommendation for rendering the RNS waste safe for subsequent treatment. Their recommended two-step process was: 1) Cool the RNS waste drums, and 2) Mix the RNS waste into an inorganic matrix of natural mineral zeolite. Their recommendation evolved with the attainment of new data.

The reviewed information related specifically to process chemistry included event analysis, interim safe configuration of inventory, and preventative measures in subsequent processing. These were all established as fundamental tenets for determining a path forward for safe and effective treatment.

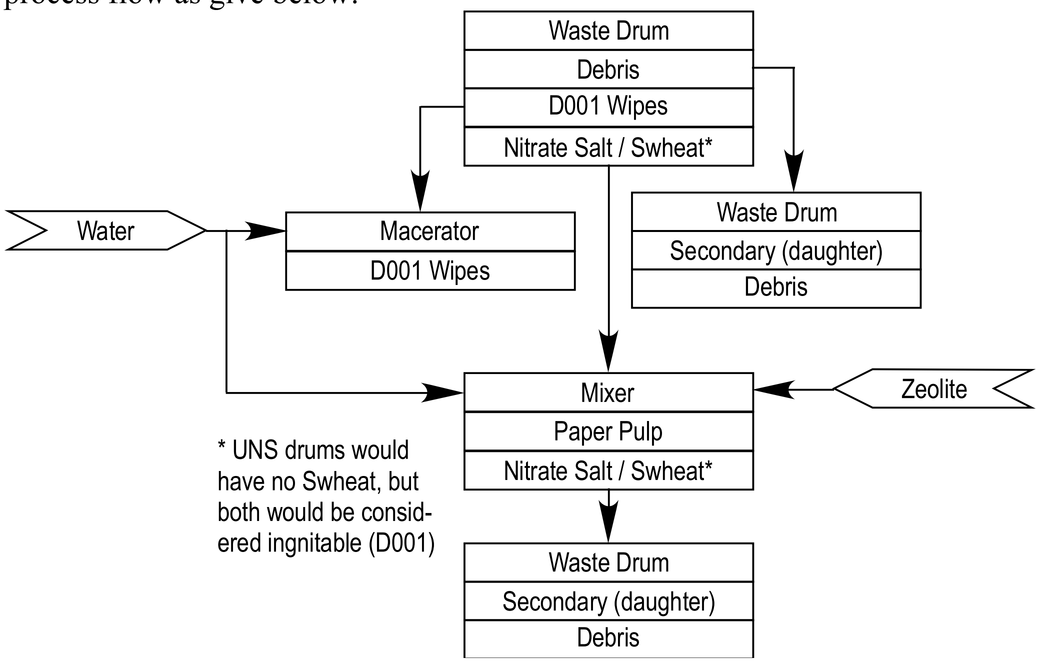
The event analysis features of the presented materials included a technical and scientific approach to determining plausible and conservative (default to higher reaction sensitivity) constituents present in the waste using historical records, simulation/modeling, limited sampling and analysis of parent waste residue (solids from two UNS drums, four empty parents and the parent of drum 68660), gas sampling and analysis, and real-time-radiography records. After plausible constituent species and "bounding" concentrations were determined, small sample simulants were developed. These were subjected to initiating event experiments to determine the reaction sensitivity of these simulants. Samples were subjected to impact, friction, and spark tests similar to those used for explosive sensitivity determinations. In addition, traditional reactivity assessments were made using differential scanning calorimetry (DSC) and automated pressure tracking adiabatic calorimetry (APTAC). Once these smaller samples were analyzed for reactivity, and at the request of the Accident Investigation Board, four 55 gallon drum mock-ups were made (vented and un-vented and each heated to 25^0C and 60^0C). Drum pressure, various temperatures (at specified drum and contents locations), and environmental conditions were measured over time in an effort to further analyze the event on the larger scale.

After the full-scale drum study, the collection of results clearly identified the role of vessel temperature and pressure in sustaining and accelerating the reaction. To mitigate the hazard associated with temperature, the waste is to be placed in refrigerated storage prior to processing. Cooling the waste was 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.

To mitigate pressure, a filter apparatus with a burst disk has been developed to ensure that and reaction product gases can vent, thus reducing the likelihood of runaway reactions. Allowing reaction product gases to escape, to quench the reaction, was determined to be a critical mitigation control. This interim safe configuration of inventory (larger vents on RNS drums) stemmed from results of the event analysis—particularly related to pressure build up. What LANL learned from the event analysis and what was emphasized was that temperature and pressure contribute to the runaway reaction and in the materials presented for full scale mock-up there was a definite "quenching" of reaction when reaction product gases were allowed to escape. The large drum tests also allowed for first principles assessment of gas flow rate and it was determined that near or after initiation of runaway (and/or when the drum breaches) a flow rate of 2.75 liters per minute can occur (e.g., at 30.9 psig and 146^0F) which by far exceeds an NFT filter flow rate (well beyond choked flow) and without venting allows pressure build up and retention of hot gas causing runaway reaction. It was concluded that pressurization was required for the runaway reaction. Thus limiting the potential for pressurization is a primary strategy for the interim measures to put the drums into safe configuration.

To provide for subsequent measures in processing (treatment), LANL has developed several options and these options were still evolving, since documentation in September and November of 2015, when presented to the TAP. These options include locations (e.g., Area G, WCRRF), infrastructure/facility (e.g. mobile platform glove box, WCRRF glove box), and process/process equipment (zeolite, cementation, full container, small batches, etc.). This section focuses on the processing method and the process equipment (locations for processing are discussed in Section 3, below). The population of containerized waste is, in many respects, typical radioactive glove box waste for isotope purification processes. However, there are some differences for the UNS, there are containers (and/or bags) of salt (perhaps with water), a lead liner, multiple plastic bag liners, and debris. Some are still below ground, but most are in Dome 230 at Area G. For the remediated salt waste there is a vented bag liner, a fiberboard insert and bulk salt with sWheat (added in a 3:1 volume), some with neutralizers (e.g., triethanolamine that could have become TEAN), in some cases a folded-up lead liner, and debris (usually at or near the bottom of the drum). Both sets of waste could have paper towels that are determined to be ignitable when soaked with nitrate salts (Southwest Research Institute, EPA certified laboratory results in progress), as well as the sWheat/Nitrate salt mixtures (Energetic Materials Research and Testing Center already made similar determinations for Nitrate salt mixtures when mixed with cellulose).

Even though the process is evolving, there appears to be a general consensus on the preliminary process flow as give below:



Several pieces of equipment have been proposed for the processing. A device (termed macerator) would be used to pulp the wipes with water, and a mixer would be used to combine water waste and zeolite. These devices would be housed in the glove box and small batches would be created rather than mixing in a drum mixer (a recent revision to the LANL strategy, when the TAP was briefed). LANL also personnel presented the possibility of mixing the waste in cement with adjustment of pH and pumping from the glovebox to a drum where a drum tumbler or a drum rotator would be used (perhaps with baffles). They had also evaluated using an enclosed mixer available in TA-55. Regardless of batch or full drum mixing, these secondary waste drums will have to cease exhibiting the characteristic of ignitability and must they meet the rest of WIPP-WAC for eventual disposal.

2.3 Assessment Event Analysis Characterization

LANL personnel performed due diligence in their efforts to determine the fundamental cause, and to the extent possible, understand the mechanisms of the incident to move forward with preventive and/or mitigative methods. There has been a general discussion regarding predictions with organic/oxidizer mixtures and specifically with nitrate salts/nitric acid and cellulose. TAP members concluded that significant and valuable information was gained in an attempt to reproduce the incident. It is understood that LANL's use of surrogates is a necessity due limited testing equipment available for radioactive materials, worker protection regarding radiological controls and knowing that waste has inherent variability. Understanding the generation processes, use of limited records, analysis of parent drum residue, headspace gas sampling and analysis of numerous RNS waste drums, and use of real time radiography from drum 68660 provided a starting point to hone in on sensitive constituent concentrations that could have contributed to activation energy catalysis for plausibly optimized cellulose/nitrate ratios.

2.4 Reaction Testing through to Full Scale

For complex mixtures, reaction mechanisms can seldom be definitively determined. Furthermore, taking the appropriate steps to mitigate deleterious reactions in the RNS drums is more prudent if done sooner rather than later. Testing seemed to clearly favor installation of the larger drum vents. One team member provided an analysis of energy density through the reaction of sodium nitrate salt and nitric acid using standard heats of formation and compared it to measured data supplied at the workshop. There was also evidence of sWheat nitration occurring that was as high as 7% (again, supplied at the workshop). Other reactions that have been postulated show formation of CO_2/N_2O molar ratios in acid environments that agree very well with the gas measurements of the RNS waste in storage and are categorized by the American Institute of Chemical Engineers (AIChE) to have a high degree of hazard (i.e., greater than 3 kJ/g)[1]

Based on the material reviewed by the TAP, it seems as though the technical approach was an effective and comprehensive approach. LANL varied the waste within a plausible range and then performed numerous initiation tests to determine the lowest reaction activation. They first used tests typical of explosive sensitivity, then methods of differential thermal analysis, prior to moving to full scale tests with likely candidates; these tests demonstrated an ability to understand the complex nature of this incident and informed development of preventative measures. However, the LANL team did not discuss an overall strategy for simulant development and use; such a strategy would have been useful to the TAP to evaluate chosen simulants, experimental methods, and conclusions. The TAP suggests that a documented, overall simulant strategy would add value to the technical rationale and conclusions of the process chemistry performed.

2.5 Waste Treatment Preferred Option

The LANL team proposed that the current preferred option is to batch process waste within the glovebox. First, the waste would be segregated into debris, nitrate salt/sWheat, and ignitable paper pulp. The debris would be placed into a waste drum. Next, the ignitable paper pulp would be macerated with a mixer and water. Last, the macerated paper and the nitrate salt/sWheat would be remediated by mixing (perhaps a change-can mixer) with water and zeolite.

Generally the team concurs with this approach and has suggested including a neutralizing or buffering agent (such as calcium oxide) with the zeolite to yield an alternative that provides additional advantage. The team understands that the addition of water to dissolve and/or rinse the nitrate salts from the organic absorbent will allow nitric acid to adsorb onto the zeolite and

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[1] Evaluation of Exothermic Reactions from Bulk-Vitrification Melter Feeds Containing Cellulose, PNNL, R. D. Scheele, et al., April 2007.

dewater the mixture adding inert material to lower the energy density and reduce pathways for runaway reactions. The use of a buffering agent will further neutralize the corrosive nature of the evaporator bottom's hydronium ion rich salts. This buffer is not proposed as a removal of the characteristic of corrosively, but rather as acid reaction mitigation and prevention of container degradation during interim storage. One TAP member commented that, due to the possibility of CO_2 formation from carbonates, buffer should not necessarily be added in the same step as the water to ensure that all CO_2 is allowed to escape from the acid environment first if possible.

Cementation was offered as an alternative for remediation of the drums, but the LANL team believed that this option is more complex with pH adjustment, mixing complications, and dewatering issues. There was some discussion of worker safety and worker fatigue in a process set to generate hundreds of daughter drums. The issue is relevant to either zeolite blending or cementation. The mixing and maceration mechanism should be developed and designed with a high degree of worker involvement.

2.6 Summary of SRNL Independent Reviews

In the LANL Nitrate Salt Waste Remediation Peer Review Team Report, SRNL summarized the work done to date and essentially provided 19 recommendations. There were several that may be categorized as surrogate related; these five recommendations (along with the numbers from the report) are listed below:

(1) Surrogate process selection
(2) Justification to not address the neutralization agent and possible formation of TEAN
(10) Surrogate testing for characteristics
(13) Confirm Zeolites will not adversely react with acid
(14) Surrogate testing for D003 and Paint filter tests

These should be documented as addressed not necessarily through additional testing but with justification. The TAP team did believe that the rational for surrogate selection required documentation and there was the possibility that more surrogate testing may be needed; this aspect is addressed in the Team Observations and Comments Section (Section 4.7) below.

There were several recommendations that may be categorized as defense-in-depth and flowsheet related. The recommendations (along with the numbers from the report) are paraphrased below:

(4) Visual drum inspection
(5) Borescope of Standard Waste Boxes (SWBs)
(6) Refrigerator at WCRRF
(7) 20^0C as opposed to 5^0C
(15) Correct recipe
(16) How to handle debris

A flowsheet was supplied to the TAP with a date of 3/7/2016. This flow sheet is a good start in developing the overall process; however the flowsheet did not include the temporary mitigation step of vent installation and it should. There were some questions that came to mind. There was a discussion in the SRNL report to not bring containers down to below 5^0C. The flowsheet still has this as a criterion. There are also a few “container acceptable yes/no” tests that are not further developed/discussed . These could include things like visual examination for bulging containers and borescope examinations of SWBs, if venting is included in the flowsheet. Also some material balance/recipe information is traditionally found on flowsheets and these should be included. The items in SRNL report could also be considered as defense in depth. Recommendation 3 and Recommendation 12 are related to venting. There was no discussion of the need for venting after treatment; that is, whether additional venting (perhaps beyond 1 NFT filter) is needed and if it is acceptable in the WIPP-WAC after processing.

There were three recommendations that may be categorized as permit application related. The recommendations (along with the numbers from the report) are listed below:
(8) Containers left open
(9) Demonstrate to NMED
(17) Good operation logs

These should be addressed in the development of stakeholder involvement and the permit application/operations plan for treatment.

There were three recommendations that may be categorized as best management practice. The recommendations (along with the numbers from the report) are listed below:
(11) Update current plans within the option document
(18) Time and Motion Study
(19) Refining Process

It would be prudent to continue to document current thought processes and the "options" document appears to be a good place for it. Again worker involvement and continuous improvement are paramount and make up important tenets of integrated safety management. It is apparent that LANL is developing plans to conduct practice sessions (mock-up glove box fabricated). These sessions will be fruitful when implemented.

2.7 Sub-team Observations and Comments

Process Chemistry Sub-team members are in a general consensus regarding solving the nitrated salts issue from a process chemistry perspective. Of the options given during the TAP review, zeolite mixing is the preferred option to treat the drums containing RNS/UNS waste, and Process Chemistry team members would like to see additional and more representative surrogate testing for increased certainty with treatment strategy development.

Wet zeolite blending was determined by TAP team members to be the simplest and safest path forward to treating RNS and UNS containing drums. Zeolite is preferred to cementing the mixture due to concerns regarding cementing such as: dewatering and the inability for further processing once set. Zeolite blending will dilute the energy density; help separate the nitrates (oxidizer) from the sWheat (fuel); and when wet will increase the thermal conductivity to help disperse heat pockets that were found in surrogate drums. TAP team members recommended the addition of a neutralizing or buffering agent to address concerns over corrosivity and drum integrity during interim storage. It was also found that blending through the use of a small mixer, as presently preferred by LANL, can be an adequate solution although there should be clear process controls to ensure proper ratios and uniform blending.

Some concerns were raised over unknowns regarding the composition of drum wastes and surrogates that preclude absolute confidence in picking a process solution; however, it was noted that time plays an important factor and may not allow for creating exact replications for all potential testing purposes. TAP team members would prefer to have a more representative sample on which to base a sound process. Although there was agreement that the surrogate drums were a good start and provided valuable insight, it was felt that they may not be truly representative and more testing should be done especially in regards to the treatment process safety—as opposed to storage conditions. In a similar line of thought, TAP team members would like to see a clearer and encompassing rationale for the simulant testing strategy. Testing conducted with venting devices and in an SWB to would better assess WCS options.

TAP members found that risk mitigation is a key component of successfully treating the wastes containing nitrate salts. It was noted that the drums at Area G pose a risk to the public in a worst-case scenario, and need to be treated in a timely manner (safety basis considerations are further addressed in Section 4, below). There was agreement that temporarily mitigating drum reactivity through cooling was an acceptable strategy, and cooling should be considered during treatment. Because the RNS wastes are subject to energized reactions under specific conditions, some members suggest that the treatment process be designed to handle unexpected pressure surges; for example, glovebox contingency measures such as a quenching system. It was noted that issues may arise due to variable compositions between drums. A desire for conclusively representative samples and surrogates also found its way into member's thoughts regarding safety, as more information can help determine the appropriate safety needs for the process setup.

The TAP believes that a chemical process hazard analysis of the whole remediation operation would be a key part of process development to avoid the oversights that occurred during evaluation of the original operation—when nitrates were mixed with an organic absorbent without consideration of chemical hazards. Overall the Process Chemistry Sub-team recommends pursuing the wet zeolite blending option with neutralization. The team also recommends additional surrogate testing rationale documentation, and testing indicated by that review—to create bounding parameters; a chemical hazard analysis to identify process chemical risks; and a process that ensures specifications will be met. This hazard's analysis should include total reaction enthalpies as well as temperature controls and should avoid the chemical drying of nitric acid and production of N_2O_5.

3. ENGINEERING/FACILITY OPTIONS

LANL completed an options report in November 2015, "Engineering Options Assessment Report: Nitrate Salt Waste Stream Processing" which is a study of the options available to conduct remediation activities on RNS and UNS waste containers at LANL. The assessment included a review of the waste streams consisting of 60 RNS, 29 aboveground UNS, and additional candidate below-ground UNS containers that may need treatment. In this section of the report the waste steam characteristics were also examined by the TAP, along with the proposed treatment options.

3.1 Facility Analysis

Six processing/repackaging systems were examined and assessed by LANL for their applicability to support zeolite blending and/or cementation of RNS and UNS waste streams. These systems include:

1. Waste Characterization Reduction and Repackaging Facility (WCRRF) glovebox
2. Mobile Visual Examination and Repackaging (MOVER) trailer
3. Mobile Repackaging (MORK) system
4. Modification of available on-site gloveboxes for placement in a Perma-Con
5. Fabrication of a new glovebox
6. Relocation of the WCRRF glovebox

The LANL used expert input to rate these options across several criteria. Based on this qualitative evaluation, the LANL assessment report identified that the preferred processing-repackaging system is the WCRRF glovebox because it is the most accessible to support operations with the least anticipated delays for design, construction, and authorization basis development. The drawbacks to the use of WCRRF include drum transportation and difficulties in adding the capability for incorporating cementation (should it be needed). The TAP reviewed the LANL report and conducted technical discussion to assess the viability of each option.

3.2 Additional Facility Considerations

The TAP was also briefed by VJ Technologies, a company that historically specialized in the design and manufacture of advanced x-ray systems, inspection services and some waste characterization and remediation systems at Hanford. They presented a conceptual design for a Mobile Modular Treatment and Repackaging Unit; however, it lacked sufficient detail for the TAP to fully evaluate its viability. To develop this modular unit from design through operation could take 3-5 years, based on the presentation and dialogue among the TAP and with personnel familiar with nuclear facility design. Cost and schedule details were not presented. Some TAP members with experience at LANL, indicated that there tends to be a push to design and build purpose-specific equipment, such as that proposed by VJ Technologies. It is thought by some TAP members that this would not be a good idea, as adequate facilities already exist.

On the other hand, the TAP was briefed on two existing mobile facilities, MORK and MOVER, which have been used in the DOE complex in the past to repackage low-level waste. Neither of these facilities has been used for many years, and both would require refurbishment and updating of safety bases to be utilized for the RNS and UNS missions. Detailed cost and schedule estimates for reconditioning these facilities were not presented, although potential challenges in restarting them was qualitatively reviewed in the LANL Engineering Options Assessment.

The TAP believes that continued pursuit of a least one of these three design options would provide a viable backup strategy for LANL, if problems are encountered in the restart of WCRFF or revision of its safety basis. Such design work also has the potential to inform WCRFF process development.

3.3 Small Batch versus Drum Mixing

The LANL Engineering Options Assessment presents a discussion involving the benefits and challenges to batch and drum blending methods for treating the waste. Batch blending includes combining the salt or salt/sWheat mixture and free liquids with zeolite. Drum mixing involves using the existing drum fitted with an insert to accomplish mixing. The TAP concluded that the biggest differences between the two, considering all of the benefits and challenges, are: (1) the ability to verify the product quality of the drum contents and (2) potential worker exposures due to the amount of work in close proximity to the waste in the glovebox.

The preferred nitrate waste process option, identified in the LANL Engineering Options Assessment, was drum blending with zeolite. Blending using a drum tumbler would be the simplest operationally, take the least amount of time and minimize exposures to the operators. This option creates approximately 178 RNS blended daughter drums and 99 UNS blended daughter drums because the drums are filled to 60% for blending optimization. Testing to demonstrate the final mixing capability will need to be conducted to ensure acceptability of the final waste form.

The second option, batch blending zeolite extends the amount of time operators must spend processing waste thereby increasing potential radiation exposures. The process is simple requiring only blending. All the gloveboxes reviewed would be capable of supporting this approach without modification. Zeolite addition into the glovebox could be accomplished using the daughter drum although an augur type delivery system could be used by making modifications to existing glovebox or designed into a new glovebox. The blended product is verified by visual examination and requires little testing. This process is expected to produce about 132 RNS blended daughter drums and 73 UNS blended daughter drums.

Two approaches were analyzed by LANL to evaluate the feasibility of implementing cementation for nitrated salt waste streams: cementing inside the glovebox using a sacrificial agitator and cementing outside the glovebox using a drum tumbler. Cementation using a drum tumbler was determined to be the preferred cementation option; however, issues with product verification, complexity and the cementation equipment make this less desirable than zeolite. Cementation in the glovebox is the least desirable due the limitations of the available gloveboxes.

The review team considered cementation as the least favorable option; it adds process and chemical complexity, introduces new risks associated with process time limitations and potential void spaces, and limits future options—due to its irreversible nature. Throughout the DOE complex, TAP members shared, that operations have experienced problems with cemented TRU waste streams. The TAP team clearly favors drum blending with zeolite because it has none of these disadvantages.

The RNS and UNS waste drums contain debris waste that is comingled with, and it is assumed to be contaminated with the salt (UNS) or the salt/sWheat (RNS). It is unclear during the TAP review if the debris stream would be considered D001 and requires treatment. Adding organic debris waste to the daughter drums with the UNS or RNS is not allowed. It is planned that the debris waste will be washed/wiped and placed back into the parent drums. Determinations will then be made as to whether the debris waste is categorized as TRU or LLW and dispositioned accordingly.

3.4 Startup and Commissioning

LANL has developed an initial process flowsheet and a sequence for the order of processing drums (discussed in more detail in Section 2.2, above). These documents provide the foundation for developing a Readiness Plan of Action that would enable the project team to develop cost and schedule estimates. The details necessary to treat the waste at WCRRF, prerequisites, permitting and other activities can be identified in this plan.

The TAP viewed the development of the processing order of drums to be a significant factor in improving safety of potential treatment options. Because a thermal runaway depends on the quantity of material and configuration, the identification of the drum treatment sequence by starting with lower inventory drums improves the treatment process and minimizes the probability of a runaway reaction. This approach will allow operations to progress while monitoring drum conditions and develop enhanced procedures for handling higher content drums, if appropriate.

In addition to the drum treatment sequence, LANL has developed a process flow sheet that would provide the steps necessary for operations. Operating procedures can be developed from this process flow sheet. It can also facilitate assembly of operations and support personnel into teams and performance of dry runs to provide proof of process for readiness assessment preparations. A hold point could be established to identify when the higher MAR drums would be processed and any additional necessary process steps identified.

LANL should prepare a Readiness Plan of Action that addresses the elements for operation in WCCRF. The plan of action would complement the draft Project Execution Plan and begin to identify the prerequisites and other necessary actions needed to begin waste treatment. The following elements should be considered in developing the plan (this is not all inclusive of the DOE 425.1D minimum core requirements) and gives a general framework for operation.

1. Scope of the Readiness Assessment (RA) to include an initial number of drums that contain lower amounts of MAR (a reasonable subset of the 60). Evaluation criteria can be built in the process to determine what actions would be necessary for proceeding to the next subset of drums to process.
2. Identification of the core operations team, to include operations, health physics, chemists, waste specialists, transportation specialists, and others who will be responsible for the day-to-day execution of the drum remediation.
3. Establishing the conditions of WCRRF to verify the safety envelop to process wastes. This includes the necessary Basis for Interim Operation (BIO) updates to reflect current

plant conditions. Resolution of any PISAs, maintenance, TSRs status, etc. should be included as prerequisites.

4. Develop procedures for movement of the waste to WCRRF building upon the process flowsheet already developed. Include appropriate prerequisites to ensure actions related to waste safety have occurred (venting and temperature control). Establish transportation requirements (including responses to events) to relocate the drum to WCRRF.
5. Begin trial runs with operators, draft procedures, and complete movement runs to test the operation. Develop transit times that support reasonable operational capability while maintaining margins to established safety limits.
6. Establish abnormal and emergency response procedures to address different AB scenarios and conduct drills to ensure capability during trial runs.
7. NDA drums prior to treatment, as required, and conduct surveys during processing to develop a range of accuracy of the NDA measurements for use later with the movement of the higher MAR materials. This is an attempt to reduce TMU that can add unnecessary conservatism.

In parallel with the development of the Contractor Readiness Plan-of-Action, DOE-LASO EM will need to determine the level of the readiness assessment, the AB requirements and the degree of oversight for conducting the evolution. DOE LANL will need to prepare for their three minimum core requirements commensurate with the level of restart review required by DOE O 425.1D.

3.5 Sub-team Observations and Comments

The proposed treatment techniques and location (WCRRF) are appropriate based on the analysis presented by LANL to the TAP. It appears that these options will provide the quickest avenue toward treatment of the waste and reduce the risk of continued storage. The results of the process developed for WCRRF can then inform what will be needed to treat the waste at WCS as appropriate.

The team notes that LANL prefers the drum blending option instead of batch blending due to exposure concerns. However, the doses have not been calculated. Batch blending in a glovebox is the simplest approach and provides a verifiable result. The specific analysis to support the approach to be utilized needs to be conducted and could be factored into a phased readiness assessment activity where a combination of methods is deployed based on the conditions. The TAP notes that towards the end of our review LANL's thoughts were evolving towards a batch process.

The team noted, however, that LANL did not discuss performing the work inside a tented structure, rather than a glovebox. A tent or Permacon structure has the potential to simplify the batching process by allowing additional space and larger batches. LANL has such a facility, as it was used to process boxed transuranic waste. Other DOE locations, particularly Idaho, but including Hanford, use such systems for higher-hazard work. The TAP understands that such a process would involve radiation and contamination control challenges; however, several TAP members provided their experience that it provides significantly more flexibility and room to perform this type of activity. The TAP Team consensus remains in favor of glovebox processing.

The WCCRF was placed in Cold Standby after the nitrate salt incident and a PISA exists because of a damaged roof. The schedule and necessary actions to repair the roof and get WCCRF operational, along with required BIO upgrades should be identified and documented in the Plan of Action and for continued path forward decision-making.

Detailed cost and schedule estimates for reconditioning the two available mobile repackaging facilities (known as MORK and MOVER) were not presented, nor has such information been developed for the modular approach presented by VJ Technologies. Continued pursuit of a least one of these three design options would provide a viable backup strategy, if problems are encountered in the restart of WCRFF or safety basis revision and also have the potential to inform WCRFF process development WCS decision-making.

The risks of a thermal runaway have not been quantified; however, the research and analysis completed to date suggest that the temperature and pressure controls should be implemented to reduce uncertainties. Since pressurization is required for a runaway, larger drum vents being developed by LANL should be installed expeditiously. This will also help provide time for drum movement for treatment. Similarly, venting is one of the key variables in preventing similar reactions in other processes. These preparations will also reduce risks during drum movement. These risks are also further minimized by the drum treatment sequence LANL has developed.

The work presented by LANL about the investigative work performed to date was compelling, particularly with respect to the four simulated waste containers. The mechanism of failure appears well understood, and as a result, appropriate temperature and pressure controls will be adequate to safely control further treatment operations. The testing provides general information to establish criteria for drum movement, abnormal response, and necessary controls. External heating appears likely to be the most significant risk contributor (fire). Therefore, appropriate time constraints and limits can be built into the processing schedule and also establish conditions for abnormal conditions or disruptions in treatment.

Discussions with personnel that had actually processed waste in the WCRRF glovebox, indicated that previous "events" that had occurred in the glovebox during prior repackaging operations and that procedures had not adequately provided steps on dealing with off normal events. Operational experience in handling the wastes is a benefit for WCRRF; however, incorporation of past experience in procedures for RNS and UNS remediation will be important.

The TAP agreed that the use of zeolite as a chemical reagent to deactivate the D001 ignitable (oxidizer) characteristic associated with the RNS is appropriate. The testing that LANL has performed to date seems to demonstrate acceptable results, and utilizing this treatment approach appears to meet the intent of the Land Disposal Restriction (LDR) for a D001 oxidizer (i.e., "DEACT"). Process hazard analysis, recommended in Section 2.7 (above), will help inform revisions to the WCRFF safety basis and ensure that appropriate process and safety controls are incorporated.

The team believes that the idea of disassociating the nitrate from the sWheat by means of water addition prior to mixing in with the zeolite should improve remediation efforts. This would help achieve some neutralization of the acidic conditions associated with the waste (by means of dilution), it should help to sequester the nitrate in with the zeolite keeping it from interacting with the sWheat in the waste, and it should make blending in to the zeolite easier from uniformity and dusting perspectives.

The LANL team has performed a thorough review of the incident and the causes. The path forward as proposed to utilize the WCRRF facility to repackage the drums is supported by the analysis performed to-date.

The challenges remaining are in providing adequate oversight and demonstrating to the regulators and stakeholders that the efforts performed are adequate. LANL must also demonstrate to the regulators/stakeholders that they can safely repackage the waste, create no new adverse situations, and provide a package that can meet the WAC and safely stored long term at WIPP. The development of the Integrated Project Team, Project Execution plan and Contractor Plan of Action are essential to ensure safe processing and build confidence that LANL can conduct safe operations. These documents, if developed properly, will help establish the necessary details to develop appropriate cost and schedule estimates

4.0 SAFETY BASIS AND REGULATORY CONSIDERATIONS

4.1 Authorization Basis

For the options being considered, only WCRRF has a safety basis that is nearly suitable to support processing. Other options would need either authorization basis development or substantial modification, along with approval.

The existing WCRRF Technical Safety Requirements and administrative controls limit the consequences of normal operational events. However, NPH events (seismic, wildland fire, lightning strikes) can result in consequences to the public that challenge the Evaluation Guideline for the higher MAR drums. Precautions will be necessary during processing to minimize risks for limited period of time that these operations will be conducted.

For drums with higher MAR content, that challenge the evaluation guideline, administrative controls can be applied in Phase 2 of the operation; the proper set of controls should be based on what is learned from the initial set of drums processed. Prerequisites can be established for higher MAR drum movement and processing assuming a single drum per shift is processed (as discussed by LANL). For example, prior to moving a drum into the WCCRF facility, operators can verify conditions related to wildland fires and whether they exist in the area. If conditions change during operations, there should be immediate actions established to minimize the MAR and protect personnel as part of the operations plan.

4.2 Dependence on Process/facility Decision

The treatment process and facility that is ultimately selected to remediate the waste will drive the safety basis requirements. The TAP noted that the safety information presented did not include chemical process hazard analysis of the planned process operations; this type of analysis will be important to adequately identifying safety systems and process controls specific to the final flowsheet.

The current safety analyses for WCRRF have evaluated a number of accidents and the capability to contain these events within regulatory limits. Generally, internal events including operational fires, hydrogen deflagrations, and spill events are addressed by current analysis and technical safety requirement controls. NPH and aircraft crash events can challenge the Evaluation Guideline of 25 rem, for drums greater than 14 PE-Ci.

The risk from fires cannot be overlooked. The site has experienced a number of forest fires that encroached on the site boundaries. With respect to site boundary considerations, WCRRF is further from the site boundary than Area G. The accident consequence for an offsite release is a factor of 10 times higher for accidents at Area G.

4.3 Permitting

The use of an existing facility such as WCRRF with no major additions to equipment used for waste management could allow a Class 1 permit to be utilized, based on LANL's initial discussion with regulators. Class 1 permit modifications can be accomplished in a reasonably short time frame and should be done in parallel with startup preparations. Under LANL's worst case analysis, up to four months could be required to obtain approval.

4.4 Drum Process Sequence

There are only 12 drums in the RNS inventory that contain greater than 14 PE-Ci. If the proposed drum processing sequence is utilized, processing the higher activity drums last will help ensure that process efficiencies are developed and minimize the risks and exposure times for the remaining drums. The TAP agrees with initial plans presented by LANL—that focus on the first set of drums being of low risk, to demonstrate proof of process and adequacy of protection measures. Once this is complete, LANL will be able to better judge that the Unmitigated risks associated with Cases 1 and 2, that slightly exceed the EG for RNS, and determine the WCRRF TSR controls that are adequate for time at risk of a seismic event during processing of the ~ 12 high MAR drums. Similarly, the risks from an aircraft crash and lightning strikes can be dispositioned in a similar manner.

4.5 Drum Transportation

Although the installation of a HEPA filter and rupture disk to the individual RNS drums further decreases the probability of an already very low frequency, high consequence event, i.e. thermal runaway, it could increase the probability of a more conventional spill and release of radioactivity during handling and transportation of the individual RNS drums. The drum configured with a large HEPA/rupture disk device is an unusual configuration and would protrude from the drum making it prone to rigging and handling accidents; such accidents could break off the mechanism at the lid, or accidently fracture the rupture disk resulting in a release of contamination from the drum. From a transportation aspect, the drum is a weaker container with the venting rig in place, and the integrity of the container may not be as robust in the event of transportation accidents—when compared to a standard, tested 7A drum.

4.6 Sub-team Observations & Comments

Existing TSRs and administrative controls limit the consequences of normal operational events. However, NPH events (seismic, wildland fire, lightning strikes) can result in consequences to the public that challenge the Evaluation Guideline. For these events, administrative controls can be applied as prerequisites for drum movement and processing assuming a single drum per shift is processed (consistent with LANL plans). For example, prior to moving a drum into the WCCRF facility, operators can verify conditions related to wildland fires and whether they exist in the area. If conditions change during operations, there should be immediate actions established to minimize the MAR and protect personnel as part of the operations plan.

Initial plans discussed in operations should focus on the first set of drums believed to be of low risk to demonstrate proof of process and adequacy of protection measures. Once this is complete, LANL will be able to better judge that the risks of Cases 1 and 2, that slightly exceed the EG for RNS, and whether the WCRRF TSR controls are adequate for time at risk of a seismic event during process of the ~ 12 high MAR drums. The risks from an aircraft crash and lightning strikes can be addressed in a similar manner.

The treatment study needs to be completed to facilitate glove box process and safety control development for waste treatment. It should provide criteria for zeolite and cementation mixture ratios for procedure development for the initial set of drums with low MAR.

Transportation of the RNS and UNS to the selected area for treatment:

- More than likely the installation of the HEPA filter/Rupture disc unit onto the drums of RNS has now rendered them non-DOT certified 7A containers.
- If 7A certification is required for onsite transportation, the Porvair filter assembly should be removed prior to transport?
- Has removal of 7A certification, installation of the Porvair filter assembly, and the fact that the containers are no longer to be stored in SWBs been evaluated for the current storage location?

5.0 TAP TEAM CONCLUSIONS

The chemical analysis and experimentation done by LANL to-date provides significant additional understanding of the potential reactions in RNS waste drums that could have led to the incident that occurred at WIPP. Interim measures taken by LANL to cool the RNS drums and segregate them for special attention appear appropriate.

The wet zeolite blending option, a batch processing mode with neutralization, appears to be the best of the options evaluated to-date and presented to the TAP. The TAP also recommends that LANL document its surrogate testing strategy to ensure that bounding parameters for neutralization and zeolite addition for the treatment of wastes have been ascertained and the need for any further surrogate testing determined.

The processing-repackaging system that appears to be the best option is the WCRRF glovebox at LANL; it is accessible to support operations (although presently in cold standby) and LANL expert reviewers believed it presented the fewest design, modification and safety basis challenges. However, the TAP was not presented detailed design, schedule or cost information, therefore, due to the importance placed on RNS remediation, an option such as the development of a modular facility or refurbishment of mobile facilities such as MORK and MOVER should continue to be evaluated to provide a viable backup strategy, until detailed schedule and cost analysis demonstrates a clear advantage to one path.

LANL has developed an initial process flow diagram to support treatment of the waste at WCRRF and they have also identified a sequence for drum treatment that begins with drums with less material-at-risk. These documents provide the foundation for planning the restart of WCRRF to treat the waste by developing a Plan-of-Action for readiness that would address issues that remain, including:

- Development of a process hazards analysis for the process flowsheet to support safety analysis and procedure development.
- Addressing on-site transportation safety analysis issues including and configuration changes to the drums (vents, filters) and the appropriate analysis to support movement to WCRRF.
- Limiting the number of initial drums treated to ensure safety basis limits are maintained and develop appropriate lessons learned that would inform processing higher risk drums.
- In summary, the analysis and experimentation completed to date provides a basis for the current controls on the drums. The proposed actions of installing additional venting and cooling of the drums can provide short-term mitigation; however, they could potentially impact the portability of the drums for treatment, and the hazards associated with installation and transportation should be assessed. The approach to treating the lower MAR drums initially is a solid approach to evaluate the process, validate the treatment methods, and validate predictions regarding drum content. The results from the initial drums can further inform the analysis for other options, if needed, for the higher risk drums at LANL and the WCS drums.

Appendix A – Team Leader Brief Notes (3/16/16)

In an e-mail dated 3/15/16, Randy Erickson requested a brief summary of the review team's findings, to date, for the purpose of a meeting with DOE-EM. After consultation with the sub-team leads, the following brief summary was provided:

LANL RNS Review—Team Leader Summary

The chemical analysis and experimentation done by LANL to-date provides significant additional understanding of the potential reactions in RNS waste drums that could have led to the incident that occurred at WIPP. Interim measures taken by LANL to cool the RNS drums and segregate them for special attention appear appropriate.

The wet zeolite blending option with neutralization appears to be the best of the options evaluated to-date and presented to the Team. The Team also recommends additional surrogate testing to create bounding parameters for neutralization and zeolite addition for the treatment of wastes.

The processing-repackaging system that appears to be the best option is the WCRRF glovebox at LANL; it is accessible to support operations (although presently in cold standby) and LANL expert reviewers believed it presented the fewest design, modification and safety basis challenges. However, the Team was not presented detailed design, schedule or cost information, therefore, due to the importance placed on RNS remediation, options such as the development of a modular facility and refurbishment of mobile facilities such as MORK and MOVER should continue to be evaluated until detailed schedule analysis demonstrates a clear advantage to one path.

LANL has developed an initial process flow diagram to support treatment of the waste at WCRRF and they have also identified a sequence for drum treatment that begins with drums with less material-at-risk. These documents provide the foundation for planning the restart of WCRRF to treat the waste by developing a Plan-of-Action for readiness that would address issues that remain, including:

a. Development of a process hazards analysis for the process flowsheet.
b. Addressing on-site transportation safety analysis issues including and configuration changes to the drums (vents, filters) and the appropriate analysis to support movement to WCRRF.
c. Limiting the number of initial drums treated to ensure safety basis limits are maintained and develop appropriate lessons learned that would inform processing higher risk drums.

In summary, the analysis and experimenting completed to date provides a basis for the current controls on the drums. The proposed actions of installing additional venting and cooling of the drums can provide short-term mitigation; however, they could potentially impact the portability of the drums for treatment and the hazards associated with installation should be assessed. The approach to treating the lower MAR drums initially is solid approach to evaluate the process, validate the treatment methods, and validate predictions regarding drum content. The results from the initial drums can further inform the analysis for other options if needed for the higher risk drums at LANL and the WCS drums.

Appendix B:

ENGINEERING OPTIONS TREATMENT SCIENCE ADVISORY PANEL CHARTER

INTRODUCTION

Investigations by the Department of Energy's Accident Investigation Board (AIB) and Technical Assessment Team (TAT) determined that the February 14, 2014, release of radioactive material from the Waste Isolation Pilot Plant (WIPP) underground repository was caused by the breach of Drum 68660 containing transuranic (TRU) waste from the Los Alamos National Laboratory (LANL) nitrate salt waste stream.

The inadvertent mixing of a an organic pet litter (sWheat™Scoop, a fuel) with nitrate salts (oxidizers) is the key failure that lead to the incompatibility, and ultimately, the breach of the LANL TRU waste drum within the mine at WIPP. Sixty drums, stored at Los Alamos, were processed in the same manner and require treatment to remove the hazardous waste characteristic of ignitability that the processed waste carries, eliminating the specific hazard that this waste represents prior to shipment for disposal.

During 2015, a technical series of evaluations resulted in an Option Assessment Report [1] recommending a potential remedy utilizing a RCRA stabilization process by the adding zeolite to the waste mixture. The evaluation also discussed facility availability for material treatment including LANL on-site capabilities.

Later in the investigatory process, an Engineering Options Analysis [2] provided an evaluation of methods for conducting the treatment, including batch and drum scale mixing. The original Option 1: Stabilization Using Zeolite (derived from the Option Assessment Report) was modified and refined through bench scale engineering studies, leading to a process that involves water addition followed by zeolite addition. This option has several benefits such as the dissolution of the nitrates and the capture of salt laden liquid within the pores of the zeolite, separating the oxidizer from the fuel.

DIVERSITY OF THOUGHT ACTION REQUESTED OF THE TECHNICAL ADVISORY

PANEL LANL is required to remediate the previously remediated nitrate salt (RNS) and

unremediated nitrate salt (UNS) drums that originated from the LANL nitrate salt waste stream. To assist in the development of the drum remediation plan for the nitrate salt drums, LANL Deputy Associate Director for Environmental Management (DADEM) is requesting an independent technical review of the modified preferred and refined option(s), the planning effort, and the potential facilities for remediation which include a greenfield location housed at Area G using modular structures as treatment facilities, and other potential solutions brought forward by the committee.

The purpose of the Technical Advisory Panel is to provide a focused and dedicated set of expertise to evaluate LANL's review of treatment and remediation of the nitrate salt drums waste, ensuring that a *diversity of thought* has occurred. Specifically, the Team will provide expertise to ADEM. The goal of

the panel is to ensure that a preventive and process-based solution to the treatment of the identified nitrate salt drums is properly identified and defined.

Technical advice and recommendations of the engineered option treatment of the RNS and UNS drums as well as opportunities for operational improvements and the feasibility of treatment facility availability are requested. This inclusion of expertise allows for additional *diversity of thought* regarding the evaluation of options available to LANL including the option of utilizing portable capabilities (e.g. MObile Visual Examination and Repackaging [MOVER] and/or MObile RepacKaging [MORK]) for
the treatment of these drum materials. Providing a *diversity of thought* ensures a more comprehensive analysis of the options, as well as the ability to provide other potential options for evaluation. An informed decision is needed that that will move LANL forward with a hazardous waste path of treatment for drum waste stored on-site and is expected to be relevant to the same waste that is currently staged within the Federal Cell at WCS (113 drums), in Andrews, TX.

MEMBERSHIP AND ROLES OF THE ENGINEERED OPTION TREATMENT TECHNICAL ADVISORY PANEL

The Technical Advisory Panel consists of a team of subject matter experts derived from pertinent scientific and technical disciplines and with specific operational and assessment experience. Represented on the Advisory Panel are experts in operational experience for TRU processing, environmental remediation, and environmental management within the DOE complex. This includes experts from Idaho National Laboratory (INL), Vanderbilt University, Columbia Energy and Environmental Systems, Carlsbad Field Office (CBFO), Department of Energy (DOE), and Savannah River National Laboratory (SRNL), and Lawrence Livermore National Laboratory (LLNL), AECOM, and Enercon. Members include:

Steven Krahn, Vanderbilt University, Chairperson
David Haar, AMWTP
Don Coffey, TRU Project
Wayne Hohs, Enercon Federal Services
Herb Cruikshank, CBFO
Robert Pierce, SRNL
Tim Hayes, LANL Carlsbad
John Bowers, LLNL
Eric M. Mihailovic, LLNL

Dean Nester, Hanford
Michael Waters, Hanford
Steve Agnew, Columbia Energy
Douglas Pruitt, Idaho
Daniel Weinacht, ARES Corp.
Chip Lagdon, AECOM

The Technical Advisory Panel will provide their observations and recommendations to the DADEM, Dr. David J. Funk.

REVIEW, SCOPE, AND DURATION FOR DIVERSITY OF THOUGHT

The Advisory Panel focus pertains to the technical aspects of the remediation plan development and will include an operationally focused review on the type of remediation process used for RNS and UNS waste. The evaluation of the surrogate data and methods (blending with zeolite, cementation) as well as a set of facility options including an expanded analysis of the Waste Characterization, Reduction and Repackaging Facility (WCRRF) and the safety basis will be carefully reviewed. A re-evaluation of all facility options including the evaluation of the criteria (augmenting and deleting as appropriate) and adding other facility options including possibilities such as greenfield construction within Area G at Los Alamos will be discussed. Such greenfield construction could potentially include a multipurpose, transportable facility for use at LANL and WCS.

REVIEW METHODS AND DELIVERABLES

During this review, LANL subject-matter experts will provide an extensive set of briefings on the nitrate salt waste stream, testing performed and data results, discussion on the drum isolation and *safing* efforts, regulatory and permit requirements, and engineered option treatment plans as well as a discussion of the preferred area and facilities at LANL for drum treatment and a broader look, beyond WCRRF to a potentially multipurpose, transportable facility that could be used at both LANL and WCS.

The Advisory Panel will review and provide advice on:

Technical assessment of preferred engineered treatment option, including a rescoring of the options to include the following criteria (subject to committee addition/deletion), factoring in integrated risk management:

- **Blending**
- **Cementation**
- **Debris Waste**
- **Remediated Nitrate Salt (RNS) and Unremediated Nitrate Salt (UNS) Drums**
- **Authorization Basis**
- **RCRA**
- **Installation**
- **Legacy Drums**
- **Fabrication**

- **Regulatory/Public Acceptance**
- **Operation**
- **Schedule**

Definitions of these criteria can be found on page 71 of Reference 2.

ENGINEERED OPTION TREATMENT TECHNICAL ADVISORY PANEL DELIVERABLE

The team will come to closure on the observations and recommendations and present to ADEM in a briefing within 30 days after the workshop. No later than 45 days from the date of the workshop closure, the Advisory Panel chair will provide their observations and recommendations in a written review as evidence of *due diligence* to meet the *diversity of thought* action.

Appendix C – Team Member Bios

Dr. Stephen F. Agnew is principal scientist and chief technology officer for Columbia Energy and Environmental Services, Inc. (CEES) and supports nuclear waste modeling and technology development and review for various clients including DOE EM-23, WRPS, CHPRC, Intera, and UOP. He has 32 years of experience in science and technology development in both the public and private sectors and is an internationally recognized nuclear waste scientist with over seventy publications and four patents. Prior to CEES, Dr. Agnew was a technical staff member and project leader in the Chemistry Division at LANL for 17 years and then principal chemist for a commercial start-up plasma chemistry process, Archimedes Technology, for seven years. He has been involved with Hanford and DOE complex defense nuclear waste chemistry and safety issues for a large number of projects. He authored a process based inventory of Hanford waste tanks called the HDW (Hanford Defined Wastes) model in 1996, which is still in use today at Hanford. Past projects include a variety of safety reviews that have involved several reactive chemical safety accident investigations such as the Russian Tomsk-7 TBP-nitrate and the French bitumen-nitrate accidents. Other safety reviews involve flammable and noxious tank vapors at Hanford as well as a tank waste criticality review. Among his many awards is a LANL Distinguished Performance in 1994 for his work on Hanford's safety issues. He received his undergraduate degree from Evergreen State College in 1976, was awarded a Ph.D. in Chemical Physics at Washington State University in 1981.

Mr. John S. Bowers received a BS degree in chemical engineering from the University of California, Berkeley in 1985. From 1985 to 1988 he worked in the hazardous waste management facility at Lawrence Livermore National Laboratory (LLNL) performing packaging, shipping, categorizing, and treatment of radioactive and hazardous wastes. From 1988 to 1989 he assumed a role as an experimenter in tritium research in the Chemistry and Material Science Division of LLNL where he designed and operated gas handling systems and inert atmosphere experimental equipment. In 1989 he joined the Hazardous Waste Management Division at LLNL as a major contributor to the first approved Part B permit application and was the lead process engineer for the 67 million dollar facility, Decontamination and Waste Treatment Facility (DWTF) commissioned in 2003. He is now the Waste Treatment Group Leader responsible for managing a 4+ million dollar program in hazardous and radioactive waste treatment where both conventional and innovative technologies are employed to treat radioactive and hazardous wastes.

Mr. Don Coffey, CHMM, currently serves as Chief Operating Officer (COO) for Waste Management Innovations, Inc. (WMI^2), a Woman-Owned, HUBZone Certified Small Business. He currently serves as the Acceptable Knowledge/ Process Knowledge Expert (AKPKE) and Waste Characterization Support Lead for the Transuranic Waste Processing Center (TWPC) at the Oak Ridge National Laboratory (ORNL). The TWPC is responsible for the processing, characterization and repackaging of the contact-handled (CH) and remote-handled (RH) Legacy Transuranic (TRU) Waste Inventory stored at the ORNL. The repackaged TRU waste is characterized and certified for disposal at the Waste Isolation Pilot Plant (WIPP) under the National Waste Partnership's (NWP) Central Characterization Program (CCP). Containers certified as low-level waste (LLW) or mixed low-level waste (MLLW) are disposed of at the Nevada National Security Site (NNSS). Prior to his current assignment, he served as a staff member of the ORNL for 33 years where his work included radiochemical analysis in the Transuranium Analytical Laboratory (TAL) at the Radiochemical Engineering and Development Center (REDC), Operation of the Waste Examination and Assay Facility (WEAF) and technical support for the Solid Waste Operations Department in the Waste Management and Remedial Actions Division. He was a member of the Generator Interface (GI) Pilot Program that evolved into the current ORNL Waste Services Representative (WSR) program providing primary characterization, documentation and disposal of the hazardous, mixed, transuranic and low-level waste generated from ORNL Operations.

Mr. Herbert H. Cruickshank is a TRU Waste Certification Manager for the Department of Energy – Carlsbad Field Office. Prior to joining DOE Mr. Cruickshank was a Senior Consultant at Magnox Ltd UK where he was responsible for developing the strategy for draining, desludging, decontaminating and sealing five Magnox spent fuel ponds for entry into Care and Maintenance. During his 10 year UK assignment Mr. Cruickshank stood up the Waste Program at Sizewell A Station and also opened the first metal melt routes from the UK to the USA and Germany that allowed the shipment and treatment of 1700 contaminated Magnox pond skips. He also sponsored the first use of robotically deployed industrial lasers to remotely size reduce ILW contaminated Pond Skips, and then piloted dry CNC Milling decontamination techniques to free release up to 80% of the mass of the skips for recycling without generating any secondary waste arisings other than the milling swarf. He has also worked with a major Japanese Industrial company to successfully perform an underwater laser cutting trial of highly contaminated metal components at 4 meters depth. In the USA he was project lead for PSE&G for the shipment of four 300 ton radioactive steam generators from New Jersey to the disposal site in Barnswell, SC and was Project Manager during the Westinghouse TR-2 test reactor removal project. Mr. Cruickshank served as a Health Physics Supervisor, Radiological Engineer and Health Physics Manager at Rocky Flats during the decommissioning of Bldg 771. Prior to decommissioning he spent 17 years in commercial nuclear power and performed INPO inspections at 12 nuclear power stations. He started his career in the US Navy Nuclear Power Program and earned a BS Degree in Nuclear Engineering Technology from Thomas Edison State College.

Mr. David Haar is currently the Waste Programs Manager at the Advanced Mixed Waste Treatment Plant (AMWTP), located at the Idaho National Laboratory. The AMWTP is the primary DOE facility for processing and treating legacy transuranic waste, in preparation for disposal at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, NM. Mr. Haar has significant experience with the characterization, treatment, packaging, certification, and shipment of transuranic waste materials. He worked 14 years at the WIPP, where he helped establish, and then managed, the Central Characterization Program, processing waste at several sites throughout the complex. The last 4 years have been at the AMWTP, where he is responsible for all waste processing operations. He has a bachelor's degree in Mechanical Engineering from the University of Nebraska, is a licensed Professional Engineer, and a certified Project Management Professional.

Mr. Wayne Hohs has over 32 years in the nuclear industry with 25 years supporting DOE contracts at 5 DOE sites. He started his career at the Perry Nuclear Power Plant where he was a Fire Protection Systems Engineer and went through the final stages of construction, startup and commissioning, first power cycle, and first refuel and maintenance outage. He then joined the

Babcock & Wilcox Company where he spent 23 years of his career. Mr. Hohs has held progressive leadership positions throughout his career and has managed Category I, II, and III Nuclear facilities as well as RCRA permitted TSDF's. He has served in leadership roles on several major DOE cleanup projects including Hanford, Rocky Flats, Mound, Idaho, and Portsmouth. While at the Idaho National Laboratory he served as the Deputy Site Area Director for the Test Reactor Area and later as the Plant Manager for the Advanced Mixed Waste Treatment Project where they retrieved, characterized, treated, and shipped over 50,000 m3 of TRU and MLLW waste out of the state of Idaho (2005-2010). He has participated in or led many nuclear facility startups and restarts, including through ORRs. He is a certified Project Management Professional and has managed line item and GPP capital improvement projects as well as environmental restoration and cleanup projects. His education includes: a BS in Fire Protection and Safety Engineering Technology (University of Cincinnati/Case Western Reserve University) and an MBA with focused studies in Operations Management, Labor Relations, and Finance (Case Western Reserve University - Weatherhead School of Management). He is also an active member of the EFCOG Project Delivery and Waste Management working groups. [Note: Mr. Hohs insights were valuable to initial drafts of the report; however, since he joined LANL in mid-March, he was not involved in the final drafting of the report.]

Dr. Steven L. Krahn (Chairperson) is Professor of the Practice of Nuclear Environmental Engineering at Vanderbilt University. His research focuses on the nuclear fuel cycle and insertion of technology into complex nuclear systems and he is a Board Certified Environmental Engineer. Immediately prior to joining Vanderbilt, he served in DOE-EM as: Deputy Assistant Secretary for Safety & Security and Office Director for Waste Processing Technology Development. He has participated in or led external technical reviews of nuclear facilities for the Department of Energy including a range of technology approaches to improved operations of nuclear fuel cycle and radioactive waste processes at: Hanford, Washington, the Savannah River Site, the Idaho National Laboratory, several sites at the Oak Ridge Reservation, the Los Alamos National Laboratory. Dr Krahn was selected to the American Academy of Environmental Engineers & Scientists in 2013. His education includes: a BS in Metallurgical Engineering (University of Wisconsin, 1978), MS in Materials Science (University of Virginia, 1994), PhD in Public Administration (University of Southern California, 2001).

Mr. Chip Lagdon joined AECOM in January as a Senior Project Director after retiring from the Department of Energy. Mr. Lagdon served as Chief of Nuclear Safety for Environmental Management for the past 10 years where he led Construction Project Reviews and managed a group of nuclear safety experts responsible for overseeing nuclear safety at the Department. He has also led Accident Investigations, Operational Readiness Reviews and conducted numerous technical evaluations across the complex. Prior to joining DOE, Mr. Lagdon served as the Senior Nuclear Licensing Engineer for the Turkey Point Nuclear Plant, Senior Reactor Operator at Georgia Power's Plant Hatch, and Reactor Shift Test Engineer for Newport News Shipbuilding and Drydock Company. He holds a Masters Degree in Engineering Administration from George Washington University, a Bachelor of Science Degree in Marine and Nuclear (minor) Engineering from the US Merchant Marine Academy, and attended the Senior Executive Fellows Program at Harvard University. After 30 years of service as an Engineering Duty Officer, he retired from the US Navy Reserve in 2012 holding the rank of Captain. He has been licensed on 3 reactor types and held US Coast Guard 3rd Assistant Engineer licenses for steam and diesel plants.

Mr. Eric M. Mihailovic is a process engineer for the Lawrence Livermore National Laboratory's Waste Treatment Group. His experience there includes developing treatment plans for hazardous, low-level, and mixed wastes, and optimizing facilities infrastructure and treatment processes. Previously he was an engineer for the Department of Veterans' Affairs in Palo Alto, CA, and Mather, CA, where he managed a diverse array of capital projects and worked with Central Office to implement a new engineering asset management system. He obtained a B.S. in chemical engineering from UC Santa Barbara in 2013.

Mr. Dean E. Nester is currently a Project Manager for Central Plateau Remediation Contractor (CHPRC) at the Hanford Site in Washington State. He has been working in the nuclear industry for his entire professional career which spans 30 years. Relevant experience includes 23 years in the radioactive waste management field, exclusively at the Hanford Site located in Washington State. Primary focus with the treatment and final disposition of low-level and mixed low-level waste (M/LLW), and transuranic and transuranic mixed waste (TRU/M). Developed the technical requirements and infrastructure for utilization of offsite commercial waste treatment facilities to aid the Hanford Site in the meeting multiple Tri-Party Agreement milestones for the disposition of these wastes. He is CHPRC's Subject Matter Expert (SME) for mixed waste disposition, and he has safely dispositioned over 30,000 containers of these radioactive wastes during his tenure at Hanford. Formally the design authority (DA) for multiple mechanical systems at the Plutonium Finishing Plant (PFP) located at the Hanford Site, including several safety significant systems and components. Performed in-situ metallurgical examinations on primary components associated with the N-Reactor (Hanford Site) and Fort Saint Vrain (Colorado). His education includes a BS in Metallurgical Engineering (Montana School of Mines, 1986), Engineer-In-Training (EIT), Project Manager Professional (PMP), and former Certified Welding Inspector.

Mr. Robert A. Pierce is a Senior Advisory Scientist at the Savannah River National Laboratory. Bob has spent 27 years supporting and developing processes for the Savannah River aqueous nitrate plutonium and uranium processing facilities. The Savannah River unit operations are primarily nitrate-based processes. He also has experience of laboratory R&D activities and the generation of TRU waste. He has participated in the evaluation of the Tomsk (Russia) nitrate evaporator explosion and with nitrate-based oxidation of organic waste. Mr. Pierce has a BChE from the University of Detroit (1988).

Mr. Douglas M. Pruitt serves as the Operations Activity Manager for the RH-TRU program in Environmental Management of the DOE-ID Field Office at the Idaho National Lab. His experience in program and project management includes CH-TRU retrieval from underground pits and trenches and compliant packaging of CH-TRU waste using glove boxes for disposal at WIPP; RCRA Closure of dozens of tank and tank systems; construction, commissioning, and operations of Category 2 Nuclear Facilities; and retrieval and repackaging of RH-TRU waste using hot-cells for disposal of waste at WIPP. He has performed multiple readiness reviews to start and restart nuclear operations in facilities on the Idaho clean-up Project and has performed several project reviews at Hanford and SPRU. His education includes a BS in BioChemistry from Idaho State University in 2008.

Mr. Michael S. Waters is currently the Manager, Waste Management Services for Central Plateau Remediation Contractor (CHPRC) at the Hanford Nuclear Reservation. His focus is on the safe and compliant packaging of transuranic (TRU) and mixed/low level radioactive waste generated as a result of facility operations and D&D activities across the Hanford Site. In addition he supports the Waste Treatment Program objectives for treatment of retrievably stored suspect TRU waste. His broad based experience includes 8 years active service in the Navy Nuclear Propulsion Program, 14 years in the commercial nuclear industry in chemistry and radiation protection instruction, and 22 years supporting various Department of Energy waste management activities. He has supporter status in the National Registry of Radiation Protection Technologists (NRRPT) and is a member of the Energy Facilities Contractors Group (EFCOG) Waste Management Group as the sitting Vice Chair of the Packaging and Transportation Subgroup.

Dr. Daniel J. Weinacht has over 30 years of diverse experience as a mechanical engineer and program/project manager. His areas of expertise include mechanical engineering design and analysis, fatigue and fracture analysis, materials behavior, computational mechanics, constitutive model development, project management, and risk management. Dr. Weinacht holds a Bachelor of Science degree in mechanical engineering from the South Dakota School of Mines and Technology as well as Master of Science and Ph.D. degrees in mechanical engineering from the University of Illinois at Urbana-Champaign. He was employed at Los Alamos National Laboratory from 1984 to 1998 serving in various technical and management roles. From 1995-1998, he served as the Project Leader for a $44M upgrade project at LANSCE. In 1998, he joined ARES Corporation, an engineering consulting firm, where he has served in various roles over the last 18 years. Dr. Weinacht provides professional services to ARES clients in a variety of technical areas. He has a broad spectrum of expertise in the areas of project management including project planning and definition of technical, cost, and schedule baselines, project management and controls; engineering analysis/design including specialty mechanical design, analysis, and fabrication; and risk management including Nuclear Weapon System Safety Assessments for the B-2A and F-15/F-16 Dual Capable Aircraft as well as blast effects modeling and testing. Within ARES, he has responsible charge for over 160 personnel providing services to the U.S. Department of Energy across the DOE Complex (e.g., LANL, LLNL, SNL, Hanford, Y-12, Pantex, NNSS, INL) as well as the domestic and international nuclear power industry. Dr. Weinacht is a registered professional engineer in seven states (NM, CA, TX, WA, ID, SC, SD).

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