The Consortium for Risk Evaluation with Stakeholder Participation III

*Consortium Universities: **Vanderbilt University**, Howard University, Oregon State University, Robert Wood Johnson Medical School, Rutgers University, University of Arizona, University of Pittsburgh*

C R E S P

August 15, 2007

Mr. Terrel J. Spears
Assistant Manager for Waste Disposition Project
U.S. Department of Energy
Savannah River Operations Office
Road 1A
Aiken, SC 29801

RE: CRESP Review of Alternatives for Treatment of Waste in SRS Tank 48

Dear Mr. Spears:

The following presents our findings and recommendations resulting from our review of the testing program in support of design of the fluidized bed steam reforming (FBSR) process and wet air oxidation (WAO) for treating high level waste currently stored in Tank 48 at the Savannah River Site (SRS). This letter report is in response to your request that an independent review of the testing programs for FBSR and WAO in support of treatment of Tank 48 waste be organized by The Consortium for Risk Evaluation with Stakeholder Participation (CRESP) under the leadership of Prof. David Kosson (Vanderbilt University and CRESP). Dr. Kosson chaired the review team and selected Dr. James Mathis, Dr. John Garrick, Dr. Stanley Sandler and Mr. Joel Case to participate as the additional team members. Dr. Bruce Mathews was recommended by Mr. Dae Chung, EM-60 and added as an additional team member. Biographies for each team member are provided as Attachment A.

SCOPE OF WORK

The specific objectives for the review team are provided in the Scope of Work (Attachment B) and summarized as follows:

1. Independently review the test plan, and results for the Tank 48 steam reforming Engineering Scale Test Demonstration. This review should be carried out in the context

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of the overall project objectives, and design requirements for treating Tank 48 wastes. Specifically the review should address the following questions:

   a. Are the objectives and scope of the Tank 48 steam reforming pilot studies sufficient to address the key gaps in knowledge and engineering development necessary to design and safely implement the full-scale Tank 48 waste steam reforming project? If not, what are the key gaps?

   b. What is the adequacy of the pilot scale testing completed to date to meet the stated test objectives and demonstrate that steam reforming can achieve the acceptance criteria based on requirements defined for subsequent processing by DWPF and other process requirements?

2. Independently review the test plan, and results for the Tank 48 WAO process efficacy evaluation. This review should be carried out in the context of the overall project objectives, and design requirements for treating Tank 48 wastes. Specifically the review should address the following questions:

   a. Are the objectives and scope of the Tank 48 WAO studies sufficient to address the key gaps in knowledge and engineering development necessary to design and safely implement WAO if needed as a back-up process for Tank 48? If not, what are the key gaps?

   b. What is the adequacy of the testing completed to date to meet the stated test objectives and demonstrate that WAO can achieve the acceptance criteria based on requirements defined for subsequent processing by DWPF and other process requirements?

3. Based on the review of the test plans and test results of the above Tasks 1 and 2, identify the relative strengths, weaknesses, limitations and uncertainties for application of either steam reforming or WAO technology to meeting the Tank 48 treatment needs.

4. Evaluate application of safety requirements and standards to the treatment technologies. Evaluate the facility limitations and other nuclear safety-related attributes and their potential impacts on technologies.[1]

APPROACH AND INFORMATION REVIEWED

A list of the information provided to the review team in advance of an in-person review meeting is provided as Attachment C. The review meeting was on 30-31 May 2007 at the Savannah River Research Campus, with participants representing DOE-SRS, DOE-HQ, WSRC and Savannah River National Laboratory contractor personnel, and the technology vendors for FBSR and WAO (THOR Treatment Technologies, LLC and Siemens Water Technologies Corporation). The review meeting agenda and list of attendees is provided as Attachment D.

This report represents a consensus of all six members of the review team.

[1] Objective 4 was added to the review scope after definition of the initial scope of work and therefore is not indicated in Attachment B.

FINDINGS AND RECOMMENDATIONS

Schedule

Finding 1. Minimizing the overall time required to return Tank 48 to service remains the highest program priority. This priority was a primary consideration underlying the Independent Technical Review (ITR, 2006) recommendations and remains a primary consideration in this evaluation.

a. Two important programmatic changes have occurred since the ITR recommendations were developed[2]: (i) the planned return to service date for Tank 48 has been moved back by approximately 2 years, from 2010 to 2012, and (ii) the planned maintenance approach for the Tank 48 treatment facility has changed from remote (e.g., robotic) maintenance to manual, contact maintenance. The more limited schedule, the advanced design experience, and the time required to develop that design for the remotely maintained FBSR based on the planned Idaho facility were important considerations in the ITR recommendations. Absence of experience for design of remotely maintained WAO nuclear facilities, and the time required to gain sufficient expertise in this area, were considered significant schedule barriers to implementing WAO. However, this distinction between the processes no longer appears valid in view of the programmatic changes mentioned above.

b. The overall time required to return Tank 48 to service must include consideration of the following programmatic elements, some of which are likely to occur partially in parallel: (i) completing of additional necessary testing (see below), (ii) Tank 48 treatment technology specific safety analyses, (iii) treatment process and associated facility design, (iv) regulatory review and permitting, (v) treatment facility fabrication, installation, systemization and start-up, and (vi) execution and completion of processing for Tank 48 contents, including process down-time for maintenance. FBSR has been operating at one radioactive waste commercial treatment facility (Erwin, TN) for approximately 8 years, treating primarily spent ion exchange resin from commercial nuclear power facilities. In addition, FBSR has been used for waste treatment and energy recovery in the pulp and paper industry (ca. 3 production units). WAO has been operating at approximately 200 non-radioactive commercial facilities for 50 years, with several treating caustic waste slurries under chemical, temperature and pressure conditions similar to those anticipated for Tank 48 (more than 10 facilities, see Attachment E). Currently operating FBSR and WAO facilities have been designed and operated under different constraints and requirements than necessary for DOE nuclear facilities at SRS. However, the extensive experience gained at both FBSR and WAO full-scale facilities can provide considerable information about schedule regarding design, fabrication, permitting, systemization, startup and operations (i.e., maintenance

[2] Two member of the CRESP review team (D. Kosson and J. Case) were participants in the Independent Technical Review. Substantial weight was given to the THOR team's FBSR design experience with respect to design requirements and remote maintenance in the discussions that led to the ITR recommendations.

requirements, design vs. actual processing rates, upset events, etc.). This experience base has not been carefully analyzed and utilized for overall schedule assessment.[3]

c. The projected processing rate for Tank 48 wastes using FBSR is 0.5 gal/min resulting in 18-24 months of projected processing time. The projected processing rate using WAO is 3-5 gal/min resulting in 3-6 months of projected processing time.[4]

Recommendation 1. The overall schedule for returning Tank 48 to service should be critically evaluated for both cases, implementation of FBSR and implementation of WAO, including detailed analysis of the experience base for technologies.

Testing of FBSR and WAO on Simulants for Tank 48 Waste

Finding 2. Extensive pilot-scale testing of FBSR was carried out at the Hazen test facility (Golden, CO).

a. Principal components of the anticipated FBSR system are (i) process feed supply systems, including temporary, in-process storage of Tank 48 Waste, storage of coal for the first stage fluidized bed reactor, storage of liquid reductant/fuel for the second stage fluidized bed reactor, (ii) first stage fluidized bed reactor, (iii) post-first-stage-reactor process filter[5], (iv) second stage fluidized bed reactor, (v) post-reactor (2nd stage) filter[5], (vi) process exhaust gas filtration for particulate (i.e., HEPA filter)[6], and (vii) solids product handling to separate and recycle residual, unreacted coal and transfer (e.g., dissolve /slurry) the solid FBSR product to the receiving SRS HLW tank.

b. Results of this testing indicated that coal was the only acceptable reductant/fuel source evaluated for the first stage fluidized bed reactor. The product from the first and second stage fluidized bed reactors during production runs ranged from 5 to 51 wt % particulate solids sized greater than 149 μm (100 mesh), consisting of unreacted coal and agglomerated product solids, and 2 to 8 wt % residual coal in solids less than 74μm, (200 mesh). This level of residual coal will require physical separation from the final treatment product. The necessary separation and subsequent recycle of uncombusted coal and transfer system (dry or slurry) for the particulate product to waste tanks for DWPF feed blending have not been designed or demonstrated. Separated solids (unreacted coal) for recycle to the reactor will be radiologically contaminated and therefore cannot be simply returned to the coal feed

[3] In addition to more careful evaluation of prior FBSR and WAO experience with respect to design, start-up and operations, a Basis of Interim Operation may be an option to reduce the overall schedule considering the short time planned for facility operation. This approach may save time and cost by not doing a full Documented Safety Analysis if appropriate safety considerations are otherwise addressed. This is not to shortcut safety evaluation, but rather may streamline the evaluation process.

[4] Actual processing time will be highly dependent on the design processing rate (e.g., 3 or 5 gal/min) and whether or not Tank 48 waste requires dilution for WAO processing. A refined estimate of processing time should result from pilot testing and development of a conceptual process design for WAO.

[5] Sintered metal filters.

[6] Information presented to the CRESP review team indicated the need for a mercury removal adsorber for off-gas treatment (see presentation by B. Mason and K. Ryan, May 30, 2007). Subsequent information provided by WSRC indicated that off-gas treatment for mercury removal has been further evaluated and is no longer considered necessary.

system and may require a separate storage and injection system for the first stage reactor. Design and control of the separation and recycle of unreacted coal from the first-stage fluidized bed reactor will require demonstration of the physical separation and materials handling, as well as process control for reintroduction into and operation of the fluidized bed reactor[7].

c. Greater than expected quantities of particulate fines were carried over from the first stage fluidized bed reactor, placing greater than expected burden on the sintered metal filters between reactor stages.

d. Alternative, liquid reductant/fuel sources (propylene glycol) were found to be acceptable for the second stage fluidized bed reactor.

e. Continuous, uninterrupted processing of Tank 48 waste simulant at anticipated process design conditions[8] was carried out for a maximum interval of 53 hours. This interval is insufficient to achieve steady state operating conditions, including multiple full turnovers of the reactor bed. This interval also is insufficient to demonstrate the reliability of important process hardware, including feed and oxygen injector nozzles, and post reactor sintered metal filters.

Recommendation 2. Additional pilot-scale testing of FBSR is required to demonstrate (i) stable continuous operations at design conditions for periods long-enough to achieve steady-state (i.e., greater than one complete bed turnover, (ii) reliability of key process components (i.e., injection nozzles and locations, filters), and (iii) demonstrate reliable, physical separation and transfer system for the particulate product. It is estimated that approximately 6-12 months would be required to schedule and complete the required testing.

Finding 3. Batch, bench-scale testing was carried out on WAO to provide preliminary evaluation of process conditions necessary for achieving acceptable destruction of organic constituents in Tank 48 wastes.

a. A conceptual design for WAO treatment of Tank 48 waste has not been completed. Principal components of a full-scale WAO system would be (i) process feed supply systems, including temporary, in-process storage of Tank 48 Waste, dissolved copper catalyst, diluents (if needed), (ii) high pressure pump for feeding Tank 48 waste to the reactor, (iii) a heat exchanger for pre-heating waste feed, (iv) a vertical, cylindrical reactor (potentially with internal baffles), (v) a post-reaction heat exchanger for cooling reactor effluent, (vi) pressure relief with liquid/gas separation, (vi) exhaust gas treatment (if needed), and (vii) exhaust gas filtration (HEPA).

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[7] Unlike the primary feed coal, the recycled material will be radiologically contaminated. The design of this separation and handling system will likely be based on an analogous system under development for the Idaho site integrated waste treatment unit (FBSR treatment of sodium-bearing high level tank wastes). The coal separator design for the Idaho site facility is planned to be tested in Spring 2008 (personal communication from W. Owca, DOE-ID, 24 July 2007).

[8] Operations during several of the production test runs included use of carbon dioxide as the fluidizing gas in the first stage fluidized bed reactor to prevent bed agglomeration. Discussion with the technology representatives indicated that this was not the preferred configuration for the Tank 48 treatment design.

b. Batch testing results indicated that operating conditions of approximately 300^{o}C with a 3 hour residence time and addition of < 750 mg/l soluble copper catalyst will result in acceptable destruction of tetraphenyl borate. Residual concentrations of biphenyl formed in the liquid effluent and amounts of benzene in effluent or off-gas are a concern, but may be a consequence of test conditions (i.e., temperature or reaction time) or limitation of batch testing (limits on proportion of oxygen available in the autoclave). Preliminary materials of construction testing indicate a high nickel alloy would be appropriate for full-scale reactor.

c. Pilot-scale testing is required to refine and demonstrate process conditions for reliable determination of residual biphenyl content in the liquid effluent and benzene content in the off-gas. A suitable pilot-scale test reactor is available from a recent test completed for the Department of Defense. Additional testing is required to verify selection of materials of construction, which can be carried out as part of pilot-scale testing.

Recommendation 3. Pilot-scale testing should be carried out for WAO to (i) establish operating conditions necessary to reliably achieve process objectives, (ii) demonstrate stable, continuous operations at design conditions for periods long enough to achieve steady-state (e.g., approximately three times the reactor mean residence time for liquid waste feed), and (iii) verify recommended materials of construction. It is estimated that approximately 6-12 months would be required to schedule and complete the required testing based on discussions with the technology vendor and review participants[9]. This effort should be carried out in parallel with other program activities so that it does not adversely impact overall program schedule.

Requirements for Compatibility with Downstream Processing and DWPF

Finding 4. Compatibility of Tank 48 waste after FBSR treatment with downstream processing including anticipated DWPF waste acceptance criteria was evaluated in detail[10].

a. Following FBSR treatment, Tanks 40, 43 and 38 provide likely viable options for receipt of the treated Tank 48 wastes based on schedule and operating constraints. Subsequently, the resulting blended material would be processed to form either sludge batch 5, sludge batch 6, or divided between the two batches as feed to DWPF.

b. Blending of treated Tank 48 waste with other wastes to form sludge batch 5 or sludge batch 6 would result in estimated dilution factors of approximately 17 and 32, respectively.

c. The evaluation was based on anticipated characteristics of sludge batches 5 and 6 in comparison with waste acceptance criteria for sludge batch 3 and earlier batches. DWPF waste acceptance criteria may be adjusted on the basis of the characteristics of individual

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[9] The technology representative from Siemens indicated that approximately 6 weeks of testing would be required with scheduling the testing at the pilot facility being the primary factor limiting overall time to completion of needed testing.

[10] WSRC LWO-PIT-2007-00013 rev 1. Tank Selection for Fluidized Bed Steam Reformer (FBSR) Product Receipt, 24 July 2007. (WSRC LWO-PIT-2007-00013 rev 1 was issued and provided to the CRESP review team after issuance of the factual accuracy review draft of this review report. The CRESP review was modified to reflect the additional information provided.)

DWPF feed (sludge) batches and evaluation during batch qualification, including composition and pretreatment requirements, and DWPF operating conditions.

d. Treated Tank 48 waste will require addition of depleted uranium to meet downstream processing requirements with respect to maximum U-235 enrichment.

e. Evaluation of results from pilot testing for FBSR indicates that Tank 48 treated by FBSR should be able to meet the necessary criteria for carbon (residual coal) content if the planned separation and recycle of solids greater than 149 µm (100 mesh) in the FBSR output streams is successful (see Finding 2 and Recommendation 2, above), and in combination with the anticipated downstream dilution achieved in blending with other wastes.

f. Additional testing and evaluation is required, but it appears that FBSR treatment should be compatible with downstream processing requirements or modifications achievable to meet necessary compatibility.

A preliminary evaluation was carried out for compatibility of Tank 48 waste after WAO treatment with downstream processing.

g. The currently limiting criterion on treatment using WAO is on volatile organic constituents, such that the safety criterion for the vapor space during processing should not be exceeded based on the lower explosive limit (LEL). Thus, the criterion for residual total dissolved organic constituents in the effluent from WAO was set at zero, to insure compatibility with DWPF. However, Tank 48 waste after treatment by WAO would likely be routed to the evaporator in the tank farm, making compatibility with this next processing step and tank farm requirements the likely limiting basis for establishing the criterion for residual volatile organic constituents in WAO effluent. Processing of WAO effluent through the evaporator (prior to blending into a sludge batch for feed to DWPF) would remove residual volatile organic constituents. Thus, evaluation of compatibility with the anticipated immediate downstream processing may result in less stringent criteria.

Additional flexibility may be gained for treatment of Tank 48 wastes from either FBSR or WAO through further evaluation downstream processing requirements.

Recommendation 4. A more detailed evaluation of WAO compatibility with downstream processing, storage and DWPF acceptance criteria should be carried out considering the anticipated downstream processing steps. Most important will be the limit on residual organic constituents with respect to meeting vapor space flammability limits. More robust evaluation carried out as part of on-going process development may relax the currently estimated requirements for meeting DWPF future waste acceptance criteria for the FBSR and/or WAO, providing greater latitude in Tank 48 waste treatment process design and operations.

Compatibility with Building 241-96H

Finding 5. The conceptual design for FBSR does not contain adequate detail to determine if the 241-96H facility can provide adequate services and support to safety systems; a conceptual design has not been completed for WAO. The building seems to be in reasonable condition and the three-zone ventilation system will provide defense in depth. Prior experience of WAO implementation for other applications suggests the WAO process is less complex and has a smaller footprint than FBSR for the same waste throughput. This allows a greater processing rate facility for WAO than FBSR within the same facility space constraints. Both technologies can be fabricated in a skid-mounted manner to allow for insertion into the building through the hatches in the building roof. The planned footprint for the FBSR equipment is tight with regard to space available. Specification of equipment layout, utility requirements and maintenance activities is needed to evaluate compatibility with the current 241-96H configuration. Both technologies will require compressed air (high volume at low pressure for FBSR, lower volume at higher pressure for WAO) and WAO will likely require a greater amount of process heat exchange (feed pre-heating and effluent cooling) compared to FBSR (e.g., reactor injector cooling, product cooling). FBSR will likely have higher loadings onto HEPA filtration resulting from fine particulate dispersal.

Recommendation 5. Conceptual designs for both FBSR and WAO should include specification of layout, maintenance and utility needs (e.g., process heat exchange; facility ventilation, heating and cooling; and power) to the extent necessary to insure design compatibility with the ability to meet such needs at Building 241-96H.

Safety Evaluation

Finding 6. Only limited information was provided on the application of safety requirements to the WAO process, so it is not possible to make an accurate safety distinction between the two candidate processes. While hazard evaluations done for the FSBR process determined that impacts beyond the facility boundary are unlikely, not all the unique hazards have been considered.

a. Preliminary bounding hazard and accident assessments for FBSR and WAO focused only on potential impacts to people and facilities beyond the boundary of Building 96H. The bounding analysis presented for the FBSR suggests that worst-case off-site and collocated worker dose consequences would be very low for both candidate processes. A more detailed, but still limited hazard assessment was carried out for FBSR based on the conceptual design for the treatment process; however, the accident analysis was limited because it is based on a preliminary conceptual design[11]. An analogous safety analysis was not completed for WAO. An assessment of the broad experience base with respect to hazardous events and upset conditions that have occurred in other applications has not been provided for either FBSR or WAO. Conceptually, the two candidates have some different safety issues: FBSR operates between 700 and 950^{o}C at ambient pressure, WAO operates at 280 to 320^{o}C at pressures up to 210 atmospheres; FBSR burns coal (1000 lbs/day) to initiate the reaction, WAO does not use a combustible source; FBSR produces small sized dry powders that require further physical separation and handling prior to discharge to the receiving waste tank, WAO is a wet process; WAO may require venting of volatile organic

[11] WSRC-SA-2006-00010 rev. 1. Tank 48 Fluidized Bed Steam Reforming Conceptual Safety Design Report. February 2007.

constituents. The Tank 48 alternative selection process did not use safety as a specific criterion, so it is not clear if the above differences are important.

b. Facility workers participating in maintenance activities or responding to process upset events are the population most likely at the highest risk during treatment of Tank 48 wastes by either FBSR or WAO. In spite of the absence of a design, and consistent with ALARA principles, safety[12] should still be a major evaluation criterion along with technical maturity, degree of complexity, and impact on mission need[13]. A structured event sequence (scenario) analysis of the two processes using the existing experience base (absent design details) would reveal some important insights of the safety and risk issues. Both processes have prior operating history in other applications. The legacies of the processes are a robust experience base seldom available for new plant decision-making and design of nuclear facilities. While plant specific conditions are only estimated or qualitatively known, a sufficient basis exists to assess important safety factors. First and foremost would be an assessment of the actual operating experience to date from the most relevant analogous operating facilities for each technology, especially with respect to worker safety since offsite consequences are not expected to be serious. Safety information of great value would be the development of a database on worker injuries and fatalities, significant leaks and process stream releases, in- and out-of-plant contamination events, off-gas events, plant upsets, maintenance requirements and associated worker activities, equipment failures, shutdown events, including their frequency, duration and cause; and loss of control events (transients). To some extent, the data could be sorted by process and application. For example, for wet air oxidation the experience with depressurization events would be important to know and for fluidized bed steam reforming the history on fire related events and particulate dispersal (during upset events and maintenance) is important. The result could be valuable insights on process-specific safety considerations.

c. The Conceptual Safety Design Report for FBSR assigned a Hazard Category 2 designation with no Technical Safety Requirements, no Safety Class or Safety Significant controls and a PC-2 designation. The conclusion that safety significant controls are not required is not clearly supported in the Conceptual Safety Design Report[14]. For example, the low risk categorization and worker safety depend on controlling Material At Risk and maintaining the configuration of shielding; yet the Conceptual Safety Design Report does not designate these as safety requirements. Similarly, some of the energetic events may require worker safety programs that are not considered in the existing DSA for the Concentration, Storage,

[12] Although safe operations are required by DOE directives, relative safety can be an important discriminator. Inherent process conditions and designs may result in safety advantages to one process in comparison to another, such as requiring fewer or less risky worker maintenance activities. Thus, comparable hazards analyses are considered beneficial as part of the decision process. Extensive programs and procedures are in place at DOE facilities which are designed to reduce the potential for injury to "as low as reasonably achievable (ALARA)."

[13] G-AES-H-00009 rev 1. Tank 48 Return to Service Alternative Evaluation Report. December 2006.

[14] A Hazard Category 2 facility with no technical safety requirements is unusual (maybe even a contradiction in terms). The FBSR Preliminary Consolidated Hazard Analysis states, "SC or SS controls are not required because the potential events do not challenge the SC or SS criteria E& Manual Procedure 2.25." The conclusion is on solid ground as long as all unique hazards are evaluated.

and Transfer Facilities (CTSF) [15]. While this approach may be justified based on the bounding and conservative accidents evaluated, the contradiction (Hazard Category 2 designation with no Technical Safety Requirements) must be thoroughly rationalized based on detailed hazard evaluations and accident scenarios using an accurate flowsheet and process parameters.

The major seismic issue will be the interface with the Tank 48 transfer line. Building 241-96H is designated as PC-2, but the transfer line and valve box must be protected to a PC-3 level to meet current documented safety analysis criteria. The project engineers are well aware of the issue and will have to solve the problem for either candidate.

d. Radiation doses and shielding requirements have been considered for the FBSR conceptual design and will likely be similar for WAO. The dry processing and amount of fine particulates could be a disadvantage for the FBSR process because the secondary confinement does not appear to be leak tight; the enclosure provides a tortuous leak path to preclude migration of radioactive particles. The relative simplicity of WAO and potentially lower maintenance requirements, may be an advantage for WAO. In general, the shielding and ventilation designs inherent in the building seem conservative and support ALARA principles.

Recommendation 6. Comparative safety evaluation should be a criterion in process technology selection. More thorough safety assessments should be carried out for both FBSR and WAO considering (i) facility-specific upset scenarios that could impact worker safety, (ii) potential for contamination dispersal within Building 96-H, and (iii) maintenance activities. These safety assessments should be informed by analysis of the operating history of the most analogous FBSR and WAO facilities, and explicitly consider worker safety and features that distinguish between the technologies in terms of the nature and impact of major upset events (e.g., fires for FBSR, rapid depressurization for WAO). Conceptual designs[16] should be available for both FBSR and WAO as part of the safety analysis.

Information Needed for Robust Technology Selection

Finding 7. Substantially more resources specific to Tank 48 waste treatment have been invested in FBSR than WAO (full pilot-scale testing vs. limited laboratory bench-scale testing), even though the overall advantages of FBSR over WAO with respect to Tank 48 treatment needs are not clear. This uneven application of resources has the potential to bias the selection process without a sound technical basis. Similarly detailed (i) levels of testing to define and demonstrate

[15] The FBSR Preliminary Consolidated Hazard Analysis states, "Types and quantities of chemical and hazardous material used by the FSBR Project are not different from those already being used in the rest of the CSTF." While the unique aspects of FBSR will likely be resolved before the Operational Readiness Review, experience says that the earlier safety is designed into a process the lower the final costs and the easier to get approval from regulators and overseers.

[16] Conceptual designs should include estimates of the sizes, flow rates and operating conditions for major equipment and process steps, the amount of material in inventory (e.g., in-process Tank 48 waste, other feed materials and combustible materials) and preliminary process layout. Definition of utility requirements for both FBSR and WAO will also facilitate evaluation of compatibility with existing services.

process efficacy at the pilot scale, (ii) conceptual designs, (iii) safety assessments, (iv) schedule evaluations, and (v) cost evaluations are needed for determining if one technology has a clear advantage for achieving programmatic objectives with respect to Tank 48. Preliminary assessment of WAO potential advantages in terms of schedule, relative process simplicity, and safety, coupled with the need for additional FBSR testing to demonstrate process efficacy, suggests that a more robust evaluation of WAO is warranted.

Recommendation 7. Unless more detailed overall schedule (Recommendation 1) or safety (Recommendation 6) assessment clearly indicates that WAO will not offer potential advantages over the FBSR, sufficient resources should be applied to carry out for both FBSR and WAO similarly detailed (i) levels of testing to define and demonstrate process efficacy at the pilot-scale, (ii) preliminary designs, (iii) safety assessments, (iv) schedule evaluations, and (v) cost evaluations. This information should be used as input for final process selection.

CONCLUSIONS

The CRESP Review Team believes that it has responded to all the points in the scope of work. Our major conclusion is that SRS should aggressively go forward with both FBSR and WAO technologies in a manner that does not adversely impact overall programmatic schedule. The FBSR effort should proceed with the necessary testing to resolve issues of coal separation and downstream carbon disposition. It should also develop a more technical basis for the backend solid to slurry process for the preparation of DWPF feed. Safety data and preliminary accident analysis should be more visible in the evaluation process, particularly with respect to process specific hazards, worker safety and additional factors that may distinguish the two technologies (e.g., fires for FBSR, depressurization for WAO). The WAO effort should also be aggressive with respect to pilot testing to better resolve such issues as the performance of a total integrated plant, the potential for and amount of benzene off-gas and the uncertainties about biphenyl destruction. In the safety area, given its frequent reference as a negative, more evidence needs to be presented on depressurization events and the reliability of the pressure reduction system of the process. This should not only be a part of the pilot testing scope, but a direct result of a systematic and independent review of past experience.[17]

The project team should keep the option open of adopting WAO technology should the technical and economic evidence support such a decision as being in the public interest.

[17] DOE and evaluation team visits to operating facilities should be considered as part of this assessment.

The CRESP Review Team is available to answer any questions about this report or the review process. We look forward to discussing this with you and your response.

Sincerely,

David S. Kosson, Ph.D.
Chairman, Review Team

B. John Garrick, Ph.D., P.E.
Review Team Member

Joel T. Case (DOE-ID)
Review Team Member

R. Bruce Mathews, Ph.D.
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cc:

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Attachment A

Review Team Bios

DAVID S. KOSSON

PROFESSIONAL PREPARATION

Rutgers, The State University of New Jersey, B.S. high honors, Chem. & Biochem. Eng., 1983
Rutgers, The State University of New Jersey, M.S., Chemical & Biochemical Eng., 1984
Rutgers, The State University of New Jersey, Ph.D., Chemical & Biochemical Eng., 1986

APPOINTMENTS

2000 - Present	Professor and Chairman, Vanderbilt University, Department of Civil and Environmental Engineering; also Professor of Chemical Engineering (2000-), Professor of Earth and Environmental Sciences (2005-)
1996 - 1999	Professor I**,** Rutgers, The State University of New Jersey, Department of Chemical and Biochemical Engineering
1990 - 1996	Associate Professor with Tenure, Rutgers, The State University of New Jersey, Department of Chemical and Biochemical Engineering
1986 - 1990	Assistant Professor, Rutgers, The State University of New Jersey, Department of Chemical and Biochemical Engineering

JOURNAL PUBLICATIONS (REPRESENTATIVE, >80 IN-PRINT OR IN-PRESS TO-DATE)

Van Gerven, T., Cornelis, G., Vandoren, E., Vandecasteele, C., Garrabrants, A.C., Sanchez, F. and Kosson, D.S. (2006) Effects of progressive carbonation on heavy metal leaching from cement-bound waste. AIChE J. 52(2):826-837.

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SYNERGISTIC ACTIVITIES

Chairman, Department of Civil and Environmental Engineering.
Co-PI on NSF IGERT Interdisciplinary Reliability and Risk Engineering and Management Doctoral Prog.
National Research Council Committees (Board on Army Science and Technology):
- Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons: Phase 2 (ACW II), Member 2000 to 2002.
- Chair, Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program (Standing Committee), July 1998-July 2000; Member, 1993-2000.
- Panel on Review and Evaluation of Alternative Chemical Disposal Technologies, Member,1995-1996.

Chairman of Leadership Committee - Vanderbilt Institute for Environmental Risk and Resources Management.
The Consortium for Risk Evaluation with Stakeholder Participant (CRESP) – Chairman of Remediation and Risk Mitigation Technology Center of Expertise

COLLABORATORS AND CO-EDITORS

David Stensel, University of Washington; Joel Massman, University of Washington, Mark Benjamin, University of Washington, David Stahl, University of Washington, Joanna Burger, Rutgers University, Micheal Greenberg, Rutgers University, Panos Georgopolous,Rutgers University, Lily Young, Rutgers University, Gary Taghon, Rutgers University, Taylor Eighmy, University of New Hampshire, William Rixey, University of Houston, Paul Lioy, University of Medicine and Dentistry of New Jersey. Institutional Conflict: Rutgers University

Thesis Advisor: Dr. Robert C. Ahlert (currently emeritus)

Total number of graduate students as primary advisor: 33 completed, 4 current
Total number of post-docs supervised: 10 completed, 2 current

JOEL CASE

Mr. Case is the Federal Project Director for the Sodium Bearing Waste Treatment Project under the Idaho Cleanup Project at the Idaho National Engineering Laboratory (INL). The Sodium Bearing Waste Treatment Project is a capital project for the design and construction of treatment facility to treat the remaining liquid radioactive tank waste at the INL. Mr. Case has over 25 years experience in the nuclear engineering field in both the commercial and government sector. Mr. Case has been with DOE since 1991 involved in the waste cleanup program. In his current position, Mr. Case is responsible for the management oversight for the treatment of the INL remaining tank waste and tank farm facility closure.

Mr. Case has a Bachelor of Science Degree in Microbiology and a Master of Science degree in Nuclear Engineering from the University of Florida.

Dr. B. John Garrick, PE, NAE
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Garrick received his Ph.D. in engineering and applied science from the University of California, Los Angeles, in 1968. His fields of study were neutron transport, applied mathematics, and applied physics. Prior to his Ph.D., he received an M.S. in nuclear engineering from UCLA in 1962, attended the Oak Ridge School of Reactor Technology in 1954-55, and received a B.S. in physics from Brigham Young University in 1952. He is a Fellow of three professional societies: the American Nuclear Society, the Society for Risk Analysis, and the Institute for the Advancement of Engineering.

A founder of the firm, PLG, Inc., Garrick retired as President, Chairman and Chief Executive Officer in 1997, after 22 years of service. PLG was an international engineering, applied science, and management consulting firm specializing in the application of the risk sciences to technology based industries. In 1957 he joined the engineering firm of Holmes and Narver, Inc., as Chief Nuclear Scientist and resigned in 1975 as a group president in charge of all engineering and technology activities. Prior to that Garrick was a physicist for the U.S. Atomic Energy Commission in Washington, D.C., and the National Reactor Testing Station in Idaho. Garrick is continuing his career with an executive consulting practice.

A physicist and engineer, Garrick has been a major contributor to the development and application of the risk sciences to many technology based industries including nuclear power, marine systems, space, chemical, defense, and transportation. His accomplishments include his Ph.D. thesis on unified systems safety analysis that advocated what is now known as probabilistic risk assessment (PRA); the building of the first and largest staff of scientists and engineers dedicated exclusively to quantitative applications of risk assessment (PLG, Inc.); a major contributor and spokesman for the analytical methods and thought processes of PRA; and a prime mover in elevating risk assessment to a science and engineering discipline.

His work in the risk field spans both methods development and applications. Garrick and his colleagues have contributed extensively to methods now generally employed in the risk and safety field. These include the "triplet" definition of risk, the scenario and pinch point method of structuring a risk model, as well as many of the specific techniques for processing data and assembling results into quantitative measures of risk. The applications have included nuclear power plants, marine systems, nuclear waste facilities, defense systems, space systems (including the space shuttle), chemical and petroleum facilities, and many others.

Garrick's nuclear experience is highlighted by having directed and participated in more than 40 nuclear power plant PRAs. He has been a consultant in risk, reliability, engineering analysis, and management analysis of nuclear plants of all types throughout the U.S. and the international community, including plants in Japan, Switzerland, Taiwan, Korea, France, and Eastern Europe. Garrick has served on plant nuclear safety committees, design review boards, and independent corrective action and verification teams. He was a member of GPU Nuclear's General Office Review Board that advised the CEO on the safety of their two nuclear power plants, Three Mile Island and Oyster Creek, and was a member of the Nuclear Safety and Risk Assessment Committees of both plants. He has also directed the evaluation of safety practices in the management and disposition of nuclear weapon stockpiles. He was appointed to the U.S. Nuclear Regulatory Commission's Advisory Committee on Nuclear Waste in 1994, for which he was chairman from 1997-2001; he was re-elected as chairman on July 1, 2003, a position he held until September 2004. He has served as co-chairman of several ad hoc joint subcommittees of the Advisory Committee on Reactor Safeguards and the ACNW. For the U.S. Department of Energy (DOE), he has served on several oversight and review committees relating to national laboratory programs and the Generation-4 Nuclear Energy Systems Subcommittee of DOE's Nuclear Energy Research Committee. He also served as the coordinating member of the Senior Technical Advisory Panel on Nuclear Explosive Safety for the National Nuclear Security Administration. On September 10, 2004, President George W. Bush appointed Garrick to the U.S. Nuclear Waste Technical Review Board as Chairman.

In the marine field Garrick's activities included serving on the National Research Council's Committee on Risk Assessment and Management of Marine Systems, Chairman of that committee's Panel on Risk Assessment Methodologies for Marine Systems, and consultant to the US Coast Guard on risk assessment methodologies applicable to marine systems**.** The latter assignment resulted in the publication in 1999 of a report for the USCG titled, "Risk Assessment Methodologies Applicable to Marine Systems." At a 1999 conference sponsored by the National Research Council on Risk Management in the Marine Transportation System, Garrick chaired the discussion session on "Risk Assessment Models: Practical Applications and Guidance."

In relation to aerospace risk and safety technologies, Garrick served on the National Research Council's Committee on Space Shuttle Criticality Review and Hazard Analysis following the Challenger disaster. He was a risk and safety consultant to the National Aeronautics and Space Administration's Associate Administrator for Mission Safety. He served as consultant to the United Space Alliance, the space flight operations contractor, in the implementation of a risk assessment capability and the evaluation of upgrades for the space shuttle. He was the study director for a quantitative risk assessment of the space shuttle auxiliary power systems. He recently served on the National Academies' Committee for the Assessment of Options for Extending the Life of the Hubble Space Telescope.

As a consultant to the U.S. Army, Garrick led a team in the development of the first computer-based method for analyzing stockpile to target sequences for the storage, transport, and deployment of biological weapons in the early 1960s and participated in early design studies of chemical weapons disposal systems. For seven years in the 1990s he served on the National Research Council's Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program and was the lead member on the recommendation of strategies and practices adopted by the Army in the assessment of risks of chemical weapons disposal facilities. He later served on two other Academy committees relating to the disposal of chemical agent weapons. In the late 1990s, Garrick Co-Directed with the eminent Russian scientist Acad. Evgeny N. Avrorin a NATO Advanced Research Workshop on the use of the risk sciences to evaluate disarmament strategies and technologies, with emphasis on chemical weapons disposal.

His national society and academic activities have included chairmanships of national meetings and special symposia; lecturer at the annual Reactor Safety Course at the Massachusetts Institute of Technology; and Adjunct Professor, UCLA School of Engineering and Applied Science, on risk, reliability, and nuclear engineering. He served for five years on the Commission of the Accreditation Board for Engineering and Technology and led numerous accreditation teams reviewing U.S. engineering schools. Garrick organized and conducted extensive short courses, seminars, and workshops at universities, government agencies, corporations, and other institutions, such as the U.S. Department of Energy, United Kingdom's National Center of

Systems Reliability, the Electric Power Research Institute, and the Governor of California's Emergency Task Force on Earthquake Preparedness. He was a member of the American Nuclear Society's 14-member delegation to Czechoslovakia and Hungary on Nuclear Power Plant Safety in 1991 and the United States representative on several international panels and delegations offering technical advice to foreign nations including Eastern Europe.

Garrick was elected to the National Academy of Engineering in 1993; President of the Society for Risk Analysis 1989-90; and recipient of that Society's most prestigious award, the Distinguished Achievement Award in 1994. He has been a member and has chaired several National Research Council committees, past Vice Chair of the Academies' Board on Radioactive Waste Management and a past member of The Academies Commission on Geosciences, Environment, and Resources. He recently chaired the National Academy of Engineer's Committee on Combating Terrorism. Among other National Academy committees he has chaired are the Committee on the Waste Isolation Pilot Plant, and the Committee on Technologies for Cleanup of High-Level Waste in Tanks in the DOE Weapons Complex. Other Academy committee memberships included space applications, automotive safety, and chemical weapons disposal. He is a member of the first class of lifetime national associates of the National Academies.

He has published more than 200 papers and reports on risk, reliability, engineering, and technology; author of several book chapters; and editor of the text, The Analysis, Communication, and Perception of Risk. He is a registered professional engineer in the state of California.

Curriculum Vitae, James F. Mathis

DOB	September 28, 1925	
Education		
BSChE	Texas A&M University	1946
MS	University of Wisconsin	1951
PhD	University of Wisconsin	1953

Employment History

<u>ExxonMobil Corporation</u>

Research Engineer, Baytown TX	1946-49, 1953-61
Manager, Baytown R&D	1961-63
Manager, Specialty Products, Houston TX	1963-65
Vice President, ERE, Linden NJ	1966-68
Sr.VP, Director, Imperial Oil Ltd., Toronto Ontario	1968-1971
Vice President Technology, Exxon Chemical NJ	1971-80
Vice President, Science & Technology NY	1980-84

<u>Corporate Directorships</u>

NL Industries	1985-86
Laser Recording Systems	1989-93
Hanlin Corporation	1989-99
Beaver Lake Realty Company	1995-98

<u>Other Positions</u>

US Naval Air Corps	1944-45
Dir.& Chmn., Chemical Industry Institute of Toxicology	1975-83
Consultant, Arthur D Little	1985-92
Consultant, ChemShare Corp.	1989-92
Chairman, NJ Commission on Science & Technology	1988-96
Trustee & Pres., Wisconsin Alumni Research Foundation	1984-2004
Member, National Academy of Engineering	1990-
Member, NRC “Stockpile Committee”	1998-2003
Member, NRC ACWA Program Committee	2004-

Family & Residence

Married to Frances Ellisor, September 4, 1948
Son: Alan Forrest (dec.) Daughter: Lisa Lambeth, Grandson: James Lambeth
Residence: 2714 S Southern Oaks Dr, Houston TX 77068
Phone: 281-587-0117
Email: jfmathis@aol.com

Robert Bruce Matthews

R. Bruce Matthews has over thirty-five years of scientific and engineering experience in nuclear technologies with a primary focus on nuclear materials, nuclear reactor fuels, nuclear facility operations, and nuclear safety. Matthews worked at national laboratories as a scientist, line manager, and project leader and has been involved in Department of Energy programs in stockpile stewardship, nuclear materials disposition, environmental management, and space and terrestrial nuclear power systems. He has direct experience in nuclear facilities management including operations, construction, regulatory compliance, integrated safety management, and safeguards and security. Matthews is the author or co-author of over eighty journal publications, conference proceedings and technical reports. He initiated the international Plutonium Futures Conference and is a Fellow of the American Nuclear Society.

Education
Ph.D., Materials Science, 1970, University of Wales, Swansea, Glamorgan, UK.
MS, Materials Science, 1966, University of Denver, Denver, Colorado. BS, Metallurgy, 1964, BS, Pennsylvania State University, University Park, Pennsylvania.

Experience
Bruce Matthews, LLC (January, 2006 to present) Matthews is an independent consultant to Perot Systems Government Services. In addition he serves on the National Nuclear Accrediting Board for the Institute of Nuclear Power Operations, the University of California's ES&H Panel, and the Safety Oversight Subcommittee for Sandia National Laboratory.

Defense Nuclear Facilities Safety Board (April 2002 – December 2005) Matthews was appointed by President George W. Bush, to be a Member of the Defense Nuclear Facilities Safety Board. The Board provides independent oversight of the Department of Energy's nuclear weapons, materials, and environmental management activities. In addition to his oversight responsibilities, Matthews focused on safety management of high-hazard nuclear facilities and implementation of Integrated Safety Management.

Los Alamos National Laboratory (February 1980 – April 2002) From 1980 to 1993, Matthews was a research scientist and line manager responsible for research, development, fabrication and demonstration of advanced reactor fuels for space and terrestrial nuclear reactor fuels programs. In 1993 Matthews became the Division Director for Nuclear Materials Technology. He had overall responsibility for the TA-55 Plutonium Facility and the Chemistry Metallurgy Research Building. That position had two major aspects: (1) Managing nuclear facilities infrastructure including nuclear facility construction projects, facilities operations, nuclear materials control and accountability, waste management, environmental compliance, industrial and radiation safety, training, quality assurance, and safeguards and security. (2) Managing technical and programmatic nuclear materials activities for DOE missions in stockpile stewardship, materials disposition, environmental stewardship, and nuclear energy.

Pacific Northwest Laboratories May 1978 - February 1980: Matthews was a research scientist responsible for development of (U,Th)02 proliferation resistant fuels for advanced reactors.

Atomic Energy of Canada January 1970 - May 1978: Matthews' was a research scientist responsibilities included development and testing of sol-gel, sphere-pac, and silicide fuels for CANDU reactors.

STANLEY I. SANDLER

Present Employment: Department of Chemical Engineering, University of Delaware (since 1967)
Henry B. du Pont Chair (since 2000)
Director, Center for Molecular and Engineering Thermodynamics (since 1992)
Professor of Chemistry and Biochemistry (since 1993)
Editor, AIChE Journal (since 2000)

Place of Birth: New York City, New York

Education

1962 City College of New York, B.Ch.E.
1966 University of Minnesota, Ph.D. (Chemical Engineering)

Previous experience

University of Delaware
Interim Dean, College of Engineering (1992)
Henry B. du Pont Professor (1982-2000)
Chairman, Department of Chemical Engineering (1982-86)
Professor of Chemical Engineering (1973-82)
Associate Professor of Chemical Engineering (1970-73)
Assistant Professor of Chemical Engineering (1967-70)

University of Maryland
National Science Foundation Postdoctoral Fellow at the Institute for Molecular Physics, 1966 - 1967Ames Research Center
National Aeronautics and Space Administration, Moffett Field, California
NASA-ASEE Summer Faculty Fellow, 1970
Mobil Research and Development Corporation, Princeton, New Jersey, Engineer (Summer), 1977

Visiting and Honorary Professorships

Honorary Professorial Fellow, University of Melbourne (Australia), 2004-2009.
ExxonMobil Professor, National University of Singapore, 2006-2009.
University of California, Berkeley
Visiting Professor, Department of Chemical Engineering, 1995
Technische Universitat Berlin (West)
Visiting Professor at the Institut fur Thermodynamik und Anlagentechnik, 1981, 1988, 1989
University of Queensland (Brisbane, Australia)
Visiting Professor, Department of Chemical Engineering, 1989, 1996
Universidad Nacional Del Sur (Bahia Blanca, Argentina)
Visiting Professor in Departmento Ingenieria Quimica and Planta Piloto de Ingenieria Quimica 1985
Imperial College (London)
Visiting Professor in the Department of Chemical Engineering and Chemical Technology 1973 -1974

NATIONAL AND INTERNATIONAL HONORS AND AWARDS

Fellow, Institute of Chemical Engineers (Britian), 2004.

Chartered Engineer (Europe), 2004; Chartered Scientist (Europe), 2004

Miegunyah Fellow, Univ. of Melbourne (Australia), 2003.

E. V. Murphree Award, American Chemical Society, 1998.★

Rossini Lecturer, Commission 1.2, International Union of Pure and Applied Chemistry, 1998. ☆ (Lecture delivered in Porto, Portugal, July 1998)

National Academy of Engineering, 1996

Warren K. Lewis Award, American Institute of Chemical Engineers, 1996. ★

Fellow, American Institute of Chemical Engineers, 1993.

Alexander von Humboldt Foundation Distinguished U.S. Senior Scientist Award, 1988.

3M Chemical Engineering Lectureship Award, American Society for Engineering Education, 1988.★

Professional Progress Award, American Institute of Chemical Engineers, 1984; Award Lecture, 1985.★

Research Fellowship, Alexander von Humboldt Foundation (Bonn, West Germany), 1980-81 for research at the Technical University of Berlin.

Camille and Henry Dreyfus Foundation Faculty - Scholar, 1971-1976.*

National Science Foundation Postdoctoral Fellowship, 1966-67.

REGIONAL AND LOCAL HONORS AND AWARDS

Inaugural E. A. Mason Memorial Lecturer, Brown University, 1997.★

Merck Collaboratus Lecturer, Rutgers University, 1995

ICI Distinguished Lecturer, University of Alberta, 1994.★

Ashton Cary Lecture Award, Georgia Institute of Technology, 1994.★

Francis P. Alison Award, University of Delaware, 1993.▲

Phillips Lectureship in Chemical Engineering, Oklahoma State University, 1993.★

Stanley Katz Memorial Lecture, City College of New York, 1992.★

Warren McCabe Lectureship, North Carolina State University, 1990.

Delaware Section Award, American Chemical Society, 1989.

Center for Advanced Study Fellowship, University of Delaware, 1986-87.

Henry Belin du Pont Professor of Chemical Engineering, since 1982.

Fellow, Center for Teaching Effectiveness, University of Delaware, 1978-79.

Eliza Ford Prize, City College of New York, 1962.

★ Awarded to one chemical engineer nationwide each year.
☆ Awarded to one chemist, chemical engineer or physicist worldwide every other year.
* Generally awarded to only one chemical engineer nationwide each year.
▲ Awarded to one faculty member at the University of Delaware each year.

PLENARY AND KEYNOTE LECTURES

25th Australian Colloid and Surface Science Student Conference, Beechworth, Victoria, Australia, 2006

CHEMECA 2003, Adelaide, Australia, 2003.

VI Iberoamerican Conference on Phase Equilibria and Fluid Properties for Process Design, Foz do Iguassu, Brazil, 2002.

At seminar in my honor, 5th International Symposium of E.S.I.Q.I.E., I. P. N., Mexico City, 2002

4th International Symposium of E.S.I.Q.I.E., I. P. N., Mexico City, 2000.

E.S.I.Q.I.E. 50th Aniversario Symposium, Mexico City, 1998.

IX Coloquio Anual De Termodinamica, Guadalajara, Mexico, 1994

12th Symposium on Thermophysical Properties, NIST, Boulder, CO, 1994

International Symposium on Thermodynamics in Chemical Engineering & Industry, Beijing, China, 1994

E.S.I.Q.I.E. Aniversario Symposium, Mexico City, 1993.

Czechoslovak-French-Polish Calorimetry and Experimental Thermodynamics, Prague, 1993.

NATO Advanced Study Institute on Supercritical Fluids, Antalya, Turkey, 1993.

BIOGRAPHICAL CITATIONS

Who's Who in the World, Who's Who in America, Who's Who in the East

Who's Who in Technology, Who's Who in Finance and Industry

American Men and Women of Science, Stirling's Executive Who's Who

PROFESSIONAL AFFILIATIONS

- American Institute of Chemical Engineers
- American Chemical Society
- Society of Sigma Xi (Honor Society)
- Cosmos Club (Washington, DC)
- Tau Beta Pi (Honor Society)
- Omega Chi Epsilon (Honor Society)
- American Society for Engineering Education
- Institution of Chemical Engineers (Britian)

MISCELLANEOUS

Executive Director, Karl W. Böer Solar Energy Medal of Merit Trust, 1994-2000

Member, Cyclical Review Panel, Dept. of Chem. Eng., University of Melbourne (Australia), 1997

Head, Review Committee, Dept. of Chem. Eng., University of Notre Dame, 1998

Head, Review Committee, Dept. of Chem. Eng., Ben Gurion University (Israel), 2000

CURRENT RESEARCH INTERESTS

- Applied thermodynamics and phase equilibrium
- Environmental engineering (fate of chemicals in the environment, safety)
- Computational quantum chemistry
- Computer-assisted engineering education
- Separations and purification (including of pharmaceuticals and proteins)
- Computer-aided process design
- Statistical mechanics

Attachment B

Scope of Work

17 April 2007

Scope of Work

CRESP Review of
Test Results in Support Technology Selection for Treatment of SRS Tank 48

Objective: To provide independent review and input to the DOE Savannah River Site (SRS) Assistant Manager for Waste Disposition Project (Mr. Terrel Spears) on the testing carried out to support selection and design of a treatment process for the wastes contained in Tank 48 at Savannah River Site that would enable final treatment of the Tank 48 wastes using the Defense Waste Processing Facility.

Background: The primary goal of the selected treatment process will be reduce the concentration of organic constituents, primarily tetraphynelborate (TPB), in Tank 48 that are present as a consequence of the failed in-tank precipitation process. The primary effluent stream from the selected treatment process also must meet any additional criteria necessary for planned downstream processing by DWPF. Blending of the process effluent from treatment of Tank 48 wastes may be a step in meeting DWPF requirements. Any secondary effluents or emissions from the proposed treatment process must be able to meet applicable environmental requirements and have a defined path for final disposition. Process testing of steam reforming technology and wet air oxidation technology was carried out following the Independent Technical Review (ITR) of the Path Forward for Savannah River Site (SRS) Tank 48 (Aug. 2006, ITR-T48-2006-01). The ITR recommended steam reforming as the lead processing approach, considering schedule constraints and on-going design of the technology for treatment of sodium bearing wastes at the Idaho Site, with wet air oxidation (WAO) as a potential back up technology. Specific relevant ITR recommendations are as follows:

> Recommendation 4-1: Steam Reforming should be designated as the primary approach for treating wastes from Tank 48. Pilot-scale testing should be used to demonstrate the ability of the process to achieve a solid product compatible with DWPF processing requirements. Preliminary design evaluation should be used to verify process compatibility with 241-96H facility constraints.
>
> Recommendation 4-2: WAO should be designated a back up process. The planned testing program for WAO should be continued only to the point necessary to demonstrate the process viability and effluent compatibility with DWPF processing.
>
> Recommendation 4-3: The requirements for the product from Tank 48 treatment to be acceptable as a feed stream to DWPF should be clearly defined.

Subsequently, testing of the steam reforming and WAO processes has been carried out, and DWPF requirements have been defined on behalf of SRS to address these recommendations. The purpose of this review is to evaluate the results of the steam reforming and WAO testing in response to Recommendations 4-1, 4-2 and the requirements for DWPF processing defined in response to Recommendation 4-3.

Period of Performance: Starting in March 2007, provide support through CRESP for the peer review team needs indicated below. Up to 80 hours of support, including one 3-day meeting at SRS is anticipated between March 2007 and June 2007. Additional support for on-going review may be required after June 2007.

Review Team: The review team will be carried out as part of the functioning of the Consortium for Risk Assessment with Stakeholder Participation (CRESP). The review team lead will be David S. Kosson and will have up to 4 additional members providing expertise in (i) chemical engineering process scale-up and design, (ii) nuclear engineering (including safety), and (iii) environmental/regulatory requirements. The anticipated additional members of the review team are B. John Garrick, Stanley Sandler, James Mathis, and Joel Case (DOE-ID). Support for participation by Joel Case will be provided by DOE-EM through the Idaho Site.

Specific Tasks:

1. Independently review the test plan, and results for the Tank 48 steam reforming Engineering Scale Test Demonstration. This review should be carried out in the context of the overall project objectives, and design requirements for treating Tank 48 wastes. Specifically the review should address the following questions:

    a. Are the objectives and scope of the Tank 48 steam reforming pilot studies sufficient to address the key gaps in knowledge and engineering development necessary to design and safely implement the full-scale Tank 48 waste steam reforming project? If not, what are the key gaps?

    b. What is the adequacy of the pilot scale testing completed to date to meet the stated test objectives and demonstrate that steam reforming can achieve the acceptance criteria based on requirements defined for subsequent processing by DWPF and other process requirements?

    The review team will be provided the (i) ITR report (Aug. 2006, ITR-T48-2006-01) (ii) Tank 48 steam reforming project objectives and scope (iii) the basis of design, waste characterization report, preliminary safety analysis, and relevant current design information for full-scale implementation, (iv) the pilot-scale test plan (including objectives, experimental design, quality control plans), and (v) results of the pilot-scale testing. The review team will receive appropriate briefings by the project team to provide an overview of the above information and to answer questions from the review team. Individual members of the review team may also visit the pilot-scale test facility (Hazen Research Facility) and discuss steam reforming technology with the technology vendor.

2. Independently review the test plan, and results for the Tank 48 WAO process efficacy evaluation. This review should be carried out in the context of the overall project

objectives, and design requirements for treating Tank 48 wastes. Specifically the review should address the following questions:

a. Are the objectives and scope of the Tank 48 WAO studies sufficient to address the key gaps in knowledge and engineering development necessary to design and safely implement WAO if needed as a back up process for Tank 48? If not, what are the key gaps?

b. What is the adequacy of the testing completed to date to meet the stated test objectives and demonstrate that WAO can achieve the acceptance criteria based on requirements defined for subsequent processing by DWPF and other process requirements?

The review team will be provided (i) Tank 48 WAO test objectives and scope (ii) the WAO test plan (including objectives, experimental design, quality control plans), and (iii) results of the WAO testing. The review team will receive appropriate briefings by the project team to provide an overview of the above information and to answer questions from the review team. Individual members of the review team may also visit the WAO test facility and discuss WAO technology with the development vendor.

3. Based on the review of the test plans and test results of the above Tasks 1 and 2, identify the relative strengths, weaknesses, limitations and uncertainties for application of either steam reforming or WAO technology to meeting the Tank 48 treatment needs.

4. Other related tasks as defined.

Deliverables:
Verbal briefing to the DOE designees by the review team to discuss preliminary findings and recommendations on completion of review meetings for Tasks 1-2, followed by a draft letter report for factual accuracy review no later than 4 weeks following completion of the on-site review. DOE will provide comments on the FAR draft within 2 weeks following submittal and CRESP will finalize the review report within 2 weeks after receiving comments on the FAR draft. The final review report will be made available on the CRESP web site 30 days after it is provided to DOE.

Protocol:
The review schedule and agenda will be developed with input from both DOE-SRS and DOE-EM. The review meeting verbal briefing will include participation by both DOE-SRS and DOE-EM, if desired. DOE-SRS contact will be Assistant Manager for Waste Disposition Project (Mr. Terrel Spears). DOE headquarters contact will be EM-20 (Mr. Mark Gilberston). The FAR draft and final report will be provided to both the DOE headquarters contact and DOE-SRS contact at the same time via e-mail.

Allowable Cost:
Hourly rate for consultants, travel, lodging, and per diem following the government's allowable rates as needed to complete stated tasks.

Attachment C

List of Documents Made Available for Review Team:

List of Documents Made Available for Review Team:

Adu-Wasu, K. and Shah, S.C. Interoffice Memo: Siemens Water Technology Corporation Report on Evaluation of Wet Air Oxidation Treatment of Tank 48H Simulated Waste Slurry, Savannah River National Laboratory, 2007. SRNL-CST-2007-00035 Rev. 1.

DeVine, J.C., Crimmins, T.M., Cussler, E., Hinkley, B.E., Huvard, G.S., Kelley, J.A., Kosiancic, E.J., Kosson, D.S., Pezone, A.L., Tavlarides, L., and Watson, J.S. Independent Technical Review for the Path Forward for Savannah River Tank 48, 2006. ITR-T48-2006-001

Dorfler, G.E. Tank 48 Fluidized Bed Stream Reforming Conceptual Safety Design Report, Washington Savannh River Company, 2006. WSRC-SA-2006-00010

Gober, M., Pallon, M., Conrad, D., Cedardahl, B., and Spires, R. Conceptual Design Package for Tank 48 Treatment Process, Washington Savannah River Company, 2006. G-CDP-H-00019

Jantzen, C. M. and Maxwell, D. "Compatibility of Tank 48 Fluidized Bed Steam Reforming (FBSR) with DWPF Processing" presented SRNL Aiken, S.C. 2007. WSRC-STI-2007-270S

Kumfer, R., Lehmann, R., Felch, C. Evaluation of Wet Air Oxidation Treatment of Tank 48H Simulated Waste Slurry Bench Scale Test Program Final Report, Siemans Water Technology Corp., 2007.

*Maxwell, D. and Jantzen, C.M. Tank Selection for Fluidized Bed Steam Reformer (FBSR) Product Receipt, Washington Savannah River Company, 2007. LWO-PIT-2007-00013

Noller, D.K. Tank 48 Return to Service Alternative Evaluation Report, Washington Savannah River Company, 2006. G-AES-H-00009

Shah, S.C. FBSR Performance Requirements, Savannah River National Laboratory, 2007.

*Shah, S.C. Task Requirements and Criteria - Tank 48 Disposition by Fluidized Bed Steam Reforming Project Rev. 3, Washington Savannah River Company, 2007. G-TC-H-00046-R3

*Smith, L.M., and Maxwell, D. Requirements of for Addition of Uranium to FBSR output Stream. Washington Savannah River Company Interoffice Memo, 2007. LWO-PIT-2007-00036

Winship, G. Project #G-002 Tank 48 Treatment Process (TTP) Risk Analysis Report, Washington Savannah River Company, 2006. Y-RAR-H-00065

Winship, G. C. Tank 48H Return to Service Systems Engineering Evaluation (SEE) Results Report, Washington Savannah River Company, 2006. G-ADS-H-00011

*These documents were provided after DOE review of the Factual Accuracy Review (FAR) draft of this report and were considered in preparation of the final report.

Attachment D

List of Attendees

CRESP Tank 48 Review Meeting Attendees

Name	Affiliation
David Kosson, Chair	CRESP
Joel Case	CRESP
B. John Garrick	CRESP
James Mathis (via telecon.)	CRESP
R. Bruce Matthews	CRESP
Stanley Sandler	CRESP
John Contardi	DOE-DNFSB
Harry Harmon	DOE-PNNL
Hoyt Johnson	DOE-EM
Larry Ling	DOE
Michael Mikolanis	DOE
Terrel Spears	DOE
Pat Suggs	DOE-SR
Tom Temple	DOE-SR
Vickie Wheeler	DOE
Richard Lehmenn	Siemens Water Technology, Corp.
Brad Mason	Thor Treatment Technologies, LLC.
Kevin Ryan	Thor Treatment Technologies, LLC.
Kofi Adu-Wusu	WSRC
Michael Augeri	WSRC
Brett Cederdahl	WSRC
Dennis Conrad	WSRC
Gene Daniel	WSRC
Dave Grimm	WSRC
Charles Lampley	WSRC
Tom Miniard	WSRC
John Schwenker	WSRC
Sam Shah	WSRC
Mike Smith	WSRC

Attachment E

List of WAO Facilities

(provided by R. Lehmann of Siemens Water Technology, Corp.)

SIEMENS

Water Technologies
Rothschild, WI

Zimpro® Wet Oxidation Units
Industrial Wastewater Applications

Installation	Flow	Application	Unit(s) @ Oper. Temp./ Pressure	Start-up	Comments
Repsol Polimeros Sines Olefins Sines, Portugal	28 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	U.C.	
Opti Canada Long Lake Upgrader Project Alberta, Canada	280 gpm	Gasifier Soot	2 Units, (290°C)/2100 psig	U.C.	
Dushanzi Petro Chemical Company Dushanzi, Xinjiang, PRC	90 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	U.C.	
AGIP Kazakhstan North Caspian Operating Company - Kazakhstan	2.6 gpm	Ethylene Spent Caustic	500°F (260°C)/1600 psig	U.C.	
OL2K Ethylene Project – Dow/PIC Al-Shuaiba, Kuwait	9 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	U.C.	
Ras Laffan Olefin Company Ras Laffan, Qatar	22 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	U.C.	
US Army/Shaw Environmental, Inc. Texas Molecular LLC Deer Park, Texas	26.5 gpm	Neutralized Chemical Warfare Material	572°F (300°C)/2300 psig	U.C.	
Fujian Refining and Ethylene Project Quanzhou City, Fujian Providence, PRC	64 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	U.C.	
China Petrochemical International Co., Ltd. Maoming, China	56 gpm	Ethylene Spent Caustic	392°F (200°C)/500 psig	2006	
Formosa Petrochemical Company (OL-3) Mailiao, Yun-Lin, Taiwan	90 gpm	Ethylene Spent Caustic	392°F (200°C)/500 psig	U.C.	

Installation	Flow	Application	Unit(s) @ Oper. Temp./ Pressure	Start-up	Comments
Repsol Petroleo Refinery Tarragona, Spain	40 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	Basic Engineering	
Chevron Phillips Chemical Co., LP Baytown, Texas	20 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	2004	
Shanghai Ethylene Cracker Complex (BP-Sinopec Petro Chemicals JV) Shanghai, China	77 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	2005	
Rio Polimeros Gas Chemical Complex Rio de Janeiro, Brazil	18 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	2005	
Repsol - YPF LaPampilla, Peru	3 gpm	Refinery Spent Caustic	500°F (260°C) /1260 psig	2005	
Fujian Petrochemical Company, Ltd. Xiacuo, Fujian China	9 gpm	Refinery Spent Caustic	500°F (260°C)/1260 psig	2002	
Q-Chem Mesaieed Industrial City, Qatar	34 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	2002	
ADNOC Borouge, Abu Dhabi	12 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	2001	
NODCO Refinery Mesaieed, Qatar	5 gpm	Refinery Spent Caustic	500ºF (260°C)/1250 psig	2002	
Borealis AB Stenungsung, Sweden	16 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	2000	
BASF/FINA Port Arthur, Texas	54 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	2001	
Exxon Chemical Co. Jurong Island, Singapore	42 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	2000	
Formosa Plastics Corp. (OL-2) Point Comfort, TX	24 gpm	Ethylene Spent Caustic	450°F (232°C)/800 psig	2001	
Repsol Quimica, Tarragona, Spain	286 gpm	StyreneMonomer/ Polyol Wastewater	563°F (295°C)/1350 psig	2000	Engineering Design

Installation	Flow	Application	Unit(s) @ Oper. Temp./ Pressure	Start-up	Comments
Saudi Yanbu Petrochemical Co. Yanbu, Saudi Arabia	55 gpm	Ethylene Spent Caustic	392°F (200°C)/450 psig	2000	
Formosa Plastics (FOL-2) Mai-Liao, Taiwan	81 gpm	Ethylene Spent Caustic	392°F (200°C)/450 psig	2000	
ATOFINA Rho, Italy	55 gpm	Methylmethacrylate Wastewater	536°F (280°C)/1700 psig	1999	
Petroquimica de Venezuela SA (Pequiven) El Tablazo, Venezuela	65 gpm	Ethylene Spent Caustic	302°F (150°C)/115 psig	2002	
Formosa Plastics (FOL-1) Mai-Liao, Taiwan	33 gpm	Ethylene Spent Caustic	464°F (240°C)/800 psig	1999	
Hyundai Petrochemical Co., Ltd. Daesan, Korea	3 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	1997	
Westlake Petrochemicals Corporation Sulfur, LA	15 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	1997	
Exxon Chemical Company Baytown, TX	28 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	1997	
Nigerian National Petrochemical Port Harcourt, NIGERIA	35 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	1996	
Chinese Petroleum Corp Talin Refinery Kaohsuing, TAIWAN, ROC	5 gpm	Refinery Spent Caustic	3 Units, 500°F (260°C)/1260 psig	1995	
Refineria de Petroleos de Manguinhos Rio de Janeiro, BRAZIL	2 gpm	Refinery Spent Caustic	500°F (260°C)/1260 psig	1995	
Chinese Petroleum Corp Lin Yuan Petroleum Plant Kaohsuing, TAIWAN, ROC	16.7 gpm	Ethylene Spent Caustic	392°F (200°C)/430 psig	1994	
Formosa Plastics Corp (OL-1) Point Comfort, TX	21 gpm	Ethylene Spent Caustic	450°F (232°C)/800 psig	1994	

Installation	Flow	Application	Unit(s) @ Oper. Temp./ Pressure	Start-up	Comments
Phillips 66 Refinery Sweeny, TX	66 gpm	Ethylene Spent Caustic	302°F (150°C)/100 psig	1993	Pre-treatment ahead of PACT System
Sterling Organics Dudley, Northumberland, UNITED KINGDOM	30 gpm	Pharmaceutical Wastewater	500°F (260°C)/1500 psig	1992	Pre-treatment prior to sewering
Westlake Petrochemical Corp. Lakes Charles, LA	10 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	1992	
Finaneste Antwerpen, BELGIUM	25 gpm	Ethylene Spent Caustic	392°F (200°C)/400 psig	1991	Engineering Design
Quantum Chemical Corp Deer Park, TX	21 gpm	Ethylene Spent Caustic	446°F (230°C)/800 psig	1991	
Chinese Petroleum Corp Kaohsuing Refinery TAIWAN, ROC	25 gpm	Ethylene Spent Caustic	3 Units, 392°F (200°C)/400 psig	1990	1 unit an "installed spare"
Unocal Refinery Rodeo, CA	15 gpm	Carbon Regeneration	470°F (243°C)/900 psig	1989	Regeneration of powdered carbon and destruction of bio-slurry
Lomac Chemical Co. Muskegon, MI	10 gpm	Toxic Herbicide Waste	536°F (280°C)/1700 psig	1983	
U.S. Division Quantum Chemicals Morris, IL	12 gpm	Ethylene Spent Caustic	608°F (320°C)/2100 psig	1981	On Standby
Dofasco Hamilton, Ont. CANADA	8 gpm	Coke Oven Gas Scrubbing Liquor	520°F (271°C)/1250 psig	1980	Ammonium Sulfate Recovery

Installation	Flow	Application	Unit(s) @ Oper. Temp./ Pressure	Start-up	Comments
Midtec Paper Co. Kimberly, WI	85 gpm	Mill Sludge Waste	536°F (280°C)/1730 psig	1980	Filler Clay Recovery; Steam Production
Shell Chemical Moerdijk, HOLLAND	101 gpm	Propylene Oxide/Styrene Monomer	610°F (321°C)/3000 psig	1978	Steam Recovery Engineering Design
Papierfabrik Biberist, SWITZERLAND	38 gpm	Mill Waste	536°F (280°C)/2000 psig	1977	Filler Clay Recovery; Steam Production
Nippon Konan Co. Ohgishima, JAPAN	64 gpm	Coke Oven Gas Scrubbing Liquor	500°F (260°C)/1065 psig	1976	Ammonium Sulfate Recovery
Stone Container Ontonagon, MI	300 gpm	Spent Pulping Liquor	608°F (320°C)/2800 psig	1976	Na_2CO_3 Recovery; Power Generation
Sumitomo Chemical Ehime, JAPAN	66 gpm	Acrylonitrile Waste	500°F (260°C)/1100 psig	1976	Ammonium Sulfate Recovery
Tokyo Gas Co. Yokohama, JAPAN	200 gpm	Coke Oven Gas Scrubbing Liquor	500°F (260°C)/1065 psig	1976	Ammonium Sulfate Recovery
UBE Kosan Co. Sakai, JAPAN	40 gpm	Caprolactam Waste	482°F (250°C)/925 psig	1976	Ammonium Sulfate Recovery
Mitsubishi Petrochemical Yokkaichi, JAPAN	22 gpm	Ethylene Spent Caustic	392°F (200°C)/500 psig	1975	

Installation	Flow	Application	Unit(s) @ Oper. Temp./ Pressure	Start-up	Comments
Nippon Steel Hyogo, JAPAN	67 gpm	Coke Oven Gas Scrubbing Liquor	500°F (260°C)/1065 psig	1975	Ammonium Sulfate Recovery
Nippon Steel Muroran, JAPAN	67 gpm	Coke Oven Gas Scrubbing Liquor	2 Units, 500°F (260°C)/1065 psig	1975	Ammonium Sulfate Recovery
Sumitomo Chemical Chiba, JAPAN	147 gpm	Acrylonitrile Waste	464°F (240°C)/850 psig	1974	
Niito Chemical Yokohama, JAPAN	183 gpm	Acrylonitrile Waste	500°F (260°C)/1200 psig	1973	
Asahi Chemical Co. Kawasaki, JAPAN	147 gpm	Acrylonitrile Waste	482°F (250°C)/1000 psig	1972	
Mitsui Toatsu Chemical Sakai, JAPAN	101 gpm	Acrylonitrile Waste	482°F (250°C)/1000 psig	1972	Rebuilt for catalytic WO in 1974
Sumitomo Chemical Ehime, JAPAN	110 gpm	Acrylonitrile Waste	470°F (243°C)/850 psig	1972	Ammonium Sulfate Recovery
Toray Thiokol JAPAN	24 gpm	Synthetic Rubber Waste	410°F (210°C)/500 psig	1972	
Associated Pulp & Paper Burnie, AUSTRALIA	200 gpm	Black Liquor	2 Units, 608°F (320°C)/3000 psig	1966 1979 (2nd Unit)	99% COD reduction; 20,000 lbs/hr usable steam produced