January 28,, 2010

To:	J. N. McKamy	Manager, NCSP
From:	C. M. Hopper *Calvin M. Hopper*	Deputy Chair, CSSG

Subject: **CSSG Response to Tasking 2009-06**

In response to Tasking 2009-06 a subgroup of the Criticality Safety Support Group (CSSG) was organized to assist the DOE Office of River Protection review the technical criticality safety basis for the Hanford Tank Farm.

The response team consisted of the following members.

- Robert Wilson, CSSG Member and Team Lead
- Davis Reed, CSSG Member
- Fitz Trumble, CSSG Member
- Hans Toffer, CSSG Member Emeritus
- Larry Berg, DOE Chief of Nuclear Safety (CNS) staff
- Sandi Larson, Subcontractor - Nuclear Safety Associates

The report was reviewed by the entire CSSG and comments were incorporated into the version that is attached. This version represents a consensus position by the entire CSSG.

cc: CSSG Members
J. Felty
N. Ellis
L. Scott

DOE CRITICALITY SAFETY SUPPORT GROUP

Review of the Washington River Protection Solutions Tank Farm Operating Contractor Criticality Safety Technical Basis

December 7-11, 2009

Team Lead: Robert Wilson

Dr. Robert E. Wilson, DOE-HQ, EM-20

EXECUTIVE SUMMARY

A Criticality Safety Support Group (CSSG) review of the Washington River Protection Solutions (WRPS) Tank Operating contract criticality safety technical bases was performed in December 2009. The site visit was December 7-11. This review uncovered no underlying safety issues; however several areas for improvement were identified and are contained within this report. In addition, the Office of River Protection (ORP) requested a review of the results of recent Pulse Jet mixing studies and their implications on the criticality safety basis for the Waste Treatment Plant (WTP).

The test results will likely require changes to the WTP safely basis and should be reviewed by the Tank Farm contractor in revisions to criticality safety evaluations.

In general, the team is satisfied with the criticality safety approach taken at Washington River Protection Solutions (WRPS). However, the team's perception was that the program and the technical basis have been stagnant for at least the last decade. With the potential for ramping up the pace on tank transfer and retrieval, it would be prudent to bring the technical basis up to current standards and expectations. The current NCS strategy, while protecting criticality safety risks, has become somewhat disjointed between the various Criticality Safety Evaluation Reports (CSERs), Chapter 6 of the Documented Safety Analysis (DSA) and the Criticality Protection Specifications (CPS). These disconnects should be addressed to ensure that a clear and coherent criticality protection strategy can be expressed to the operations staff and supervision. Special care should be taken to ensure that results of any new sample data are carefully considered and evaluated against the existing assumptions and technical basis for criticality safety. Evaluation of new sample data applies to both the Tank Farm and WTP operations.

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LIST OF TERMS

AB	Authorization Basis
AOA	Area of Applicability
ANSI/ANS	American National Standards Institute/American Nuclear Society
BBI	Best Basis Inventory
BNI	Bechtel National Inc.
CNS	Chief of Nuclear Safety
CSE	Criticality Safety Engineer
CSER	Criticality Safety Evaluation Report
CSP	Criticality Safety Program
CSR	Criticality Safety Representative
CSSG	Criticality Safety Support Group
CWM	Conservative Waste Model
DCRT	Double-Contained Receiver Tank
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U. S. Department of Energy
DST	Double-Shell Tank
DQO	Data Quality Objective
FFTF	Fast Flux Test Facility
FGE	Fissile Gram Equivalent
ICSBEP	International Criticality Safety Benchmark Evaluation Project
HAZOP	Hazard and Operability Analysis
k_{eff}	Effective Neutron Multiplication Factor
k_{inf}	Infinite Neutron Multiplication Factor
MCNP	Monte Carlo N-Particle
MONK	A Criticality Safety Computer Code
MOX	Mixed Oxide
NCS	Nuclear Criticality Safety
NCSP	Nuclear Criticality Safety Program
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
ORP	Office of River Protection
PFP	Plutonium Finishing Plant
PRTR	Plutonium Recycle Test Reactor
SST	Single-Shell Tank
TOC	Tank Operating Contractor
TSR	Technical Safety Requirement
TWINS	Tank Waste Information System
URS	`URS Corporation
USQD	Unreviewed Safety Question Determination Evaluation
WRPS	Washington River Protection Solutions
WTP	Waste Treatment and Immobilization Plant

1.0 SCOPE

The scope of this assistance visit was delineated in Criticality Safety Support Group (CSSG) Tasking 2009-06 issued by the Nuclear Criticality Safety Program manager and which has been included as Appendix A. The Office of River Protection (ORP) requested that the team also review the results of recent tests with models of Pulse Jet Mixers for the Waste Treatment Plant (WTP). It was agreed that this would be added to the scope of the review.

1.1 Team Members

- Robert Wilson, CSSG Member and Team Lead
- Davis Reed, CSSG Member
- Fitz Trumble, CSSG Member
- Hans Toffer, CSSG Member Emeritus
- Larry Berg, DOE Chief of Nuclear Safety (CNS) staff
- Sandi Larson, Subcontractor - Nuclear Safety Associates

Team member biographies are provided in Appendix C.

1.2 Team Inbrief

An inbrief was conducted on Monday, December 7th for DOE and contractor staff to familiarize them with the purpose of the review, the composition of the team, and to provide information exchange on schedules, Point of Contacts, and expected review activities. In addition to the team, the entrance meeting was attended by:

- Jim Wicks, ORP Chief Engineer, Engineering & Nuclear Safety
- Vic Callahan, ORP Acting Nuclear Safety Division Director
- Jon Dowell, Assistant Manager, ORP Engineering & Nuclear Safety
- Herbert Berman, WRPS Chief Engineer
- Larry Eppler, WRPS Nuclear Safety Manager
- John Appel, WRPS Criticality Safety Representative (CSR)

1.3 WRPS Tour

A facility tour of the WRPS tank farms was not conducted; however a review of M-3 scale mixing facility was performed on December 9, 2009. This facility, which provides test data on the proposed WTP Pulse Jet Mixers, is located at the offsite Mid Columbia Engineering (MCE) facility. Don Alexander provided the tour following a briefing conducted by Mr. Alexander and Langdon Holton, both with the ORP organization.

1.4 Documents Reviewed

Appendix B provides a list of those documents which were evaluated as part of the review.

1.5 Interviews Conducted

As part of the review, interviews and conversations were held with DOE, WRPS, Bechtel National Inc (BNI) and URS employees as well as DOE contract support staff. Those interviewed included:

- Scott Finfrock, Subcontractor Criticality Safety Engineer (CSE) for WRPS TOC
- Langdon Holton, ORP/PNNL
- Don Alexander, DOE-ORP
- John Appel, WRPS Criticality Safety Representative (CSR)
- Jacob Reynolds, Tank Waste Inventory and Characterization Manager
- Marshall Perks, URS, WTP Radiological and Fire Safety Manager
- Robert Miles, URS, WTP Criticality Safety Engineer
- David Losey, URS, WTP Criticality Safety Engineer
- Steve Woolfolk, BNI Radiological Safety Lead

2.0 APPROACH TO REVIEW

The team received and reviewed key documents prior to the visit to expedite the review. The review was divided into the following six topic areas of interest with two members assigned to each topic.

2.1 Hazard Identification

The current criticality safety evaluation report (CSER) for tank farm operations (RPP-7475 Rev. 4) utilizes, by reference, several prior criticality safety documents dating back to the early 1990s. Most of these prior documents focus on 1990s-era operations, such as static storage of waste, limited additions of new waste, and limited tank-to-tank processing (primarily, removal of extremely-low-Pu content supernatant from the tanks). RPP-7475 Rev. 4 does provide additional criticality safety evaluation content to address the recently expanded scope of tank farm operations.

The primary category of new tank farm operations is the retrieval of Pu-bearing sludge by various means. Retrieved sludge from source tanks is consolidated with sludge inventories in other tanks. The sludge retrieval activities support deinventory of certain single-shell tanks (SSTs) and staging of Pu-bearing sludge for future transfers to the Waste Treatment Plant (WTP).

One of the primary references of RPP-7475, WHC-SD-WM-TI-725, documents a multidisciplinary review by a team of technical personnel. This 1996 review (referred to here as the "Bratzel report") included participants knowledgeable in all technical areas relevant to criticality safety considerations for the tank farms.

The Bratzel report documented an exemplary study of then-current operations and noted that certain contents of that report (e.g., analyses of chemical and physical phenomena, particle transport mechanics) might be useful for later evaluations of expanded tank farm operations. However, the Bratzel report did not directly evaluate then-future (now current) operations, particularly sludge retrieval and consolidation. The Bratzel report appropriately stated that the conclusions of criticality incredibility are limited to tank conditions as they existed at the time of the report.

While the review team found no specific fault with the RPP-7475 Rev. 4 assessment of expanded tank farm operations, the review team could not determine that a multidisciplinary hazards evaluation process had been applied to support the expansion of tank farm operations. Use of a multidisciplinary team evaluation approach is considered beneficial, since tank farm hazards evaluation requires technical considerations and judgments that are typically outside the area of expertise possessed by criticality safety specialists (e.g., areas such as multi-phase fluid hydraulics, particle mechanics, and nuclear chemistry).

As an opportunity for improvement, the team suggests that a multidisciplinary review effort be utilized to assess criticality issues that may be associated with recently instituted tank farm operations. This review should focus on the retrieval and consolidation of Pu-bearing sludge, and should include consideration of

- tank sampling data obtained since 1996, including the tank SY-102 sample results documented in CH2M-0400872 and associated implications (for a PuO_2 particulate inventory that may not be bonded with neutron absorbers),
- potentially relevant new data regarding waste particle mechanics being developed by the M-3 testing program, and
- the applicability of Bratzel report technical content to any current operations that were not specifically evaluated by the 1996 review.

As an additional suggested opportunity for improvement, RPP-7475 should be updated to address natural phenomena hazards and other requirements from Order 420.1b.

Operations allowed by RPP-7475 were reviewed against the current Tank Farms DSA (RPP-13033, Rev 4, Chapter 2). There was good consistency between the two documents with RPP-7475 evaluating several mechanical retrieval processes that were not discussed directly in the DSA [fluidic eductor retrieval and mobile retrieval systems (MRS)] although waste transfer in general was discussed. There did not appear to be any activities listed in the DSA that were not evaluated in the RPP-7475 document.

2.2 Evaluations and Calculations

The 177 Hanford waste tanks contain fission products, chemical residues from reprocessing and approximately 2,000 kg of fissile materials. The fissile materials are dispersed among the 177 waste tanks. Chemical means are employed to settle and maintain fissile material in sludge. Particulates formed with absorber and fissile material such as Pu and its equivalents are expected to form during the neutralization of waste prior to being received in the tank farms. Models were developed evaluating sub-criticality of the materials in the tanks.

The representative waste model (RWM) was a method for predicting what waste compositions to expect in the Hanford waste tanks. This model was conceived by Roger Carter and is described in WHC-SD-SQA-20356, CSER 79-007, and WHC-SD-SQA-CSA-20109. The RWM served as a precedent for Charles Roger's conservative waste model (CWM) (WHC-SD-SQA-20356). The CWM is a simplified theoretical model of tank waste with emphasis on arriving at conservative criticality parameters. Its intended use was to be considered as the technical basis for controls and limits essential to safe operation of the waste storage tanks. Carter had four sample data points for checking and adjusting his RWM. In 1992, when Rogers formulated the CWM, he had 28 tank samples to work with. Two of the samples were later discarded. The basic assumption of the CWM is that it provides for controls and limits for normal operation and can also be considered for bounding analysis. The composition of the CWM favors low absorption elements. Controlled criticality parameters are mass and concentration. Values of these parameters corresponding to a k-eff or k-inf value of 0.95 with a 95% confidence level are calculated.

As more and more tank samples became available it was determined that significant amounts of applicable neutron absorbers were present in the waste, such as Fe, Mn, B, Cd, each, or in combination, and able to provide adequate sub-criticality.

Simple rules were established for absorber to Pu ratios and when and how to use them. Pu or Pu equivalent includes all the Pu isotopes, U233 and any U235 with an enrichment greater than natural uranium. When any one of the mass ratios is exceeded, sub-criticality is assured for all concentrations of Pu. Examples are the mass ratios Fe/Pu-239>160, Fe/U-235>77, and Mn/Pu>32, and the atom ratio H/Pu >3600. The ratios represent a most effective way to demonstrate sub-criticality. All 27 tank samples met the sub-critical limits. Multiple sub-critical ratios could be established for one tank or sample. There are restrictions on the use of CWM and where to use it. For hazard analysis, sub-critical limits need to be adjusted to be commensurate with the hazard analyzed. With larger numbers of samples, more opportunities exist to calibrate models with actual data. Macroscopic cross-sections can be calculated to ensure that the CWM is bounding for the new sample data.

When the Tank Farm is in a static state, controlled limited activities are allowed according to the controls and limits established by earlier analysis. Carter and Rogers have demonstrated that criticality is incredible under existing conditions.

Extensive calculations by Carter and by Rogers provided the technical basis to support this claim. Waste tanks maintained alkaline chemistry, pH11, and fissile material concentration was and is controlled by chemistry. It would take a massive amount of water or acid to put the Pu in solution and then concentrate the fissile material. Based on detailed analysis involving present tank contents, controls on fissile materials, and various models involving computer analysis and hand calculations, sufficient margins controlling sub-criticality were demonstrated for normal conditions and upset scenarios.

Through an arduous process, constructive controls can be extracted and condensed to a multitude of absorber to Pu ratios. One useful control measure for the conservative waste model CWM is a maximum allowed sub-critical concentration of 2.6 g/L Pu equivalent in sludges. The CWM is a model of tank waste based on seven common waste components with low neutron absorption cross sections. The total of these seven element absorption cross sections established a lower limit of 0.01096 cm^{-1}. The macroscopic absorption cross sections are relied upon as a basis for maintaining a threshold of sub-criticality and thereby establishing the critical Pu equivalent concentration 2.6 g/L (HNF-11467, Rev 0). With the subsequent availability of extensive tank waste sampling, concentrations of strong neutron absorbers became better defined. Individual absorption cross sections could possibly be used to relax conservatisms imposed by the CWM. .Typical concentration of Pu equivalent fissile material seen in available tank samples are less than 0.1 g/L Pu equivalent.

There is a plethora of ratios to select from to show sub-criticality. In sections of the reports, more clarification is needed using examples and illustrations. It is remarkable that the CWM survived since 1992. Greater availability of high-speed computers enables desk-top calculations of potentially heterogeneous configurations in waste tanks. The team encourages periodic verification that the CWM remains conservative for such activities as tank transfers. This would involve macroscopic absorption calculations, absorber to Pu equivalent determinations and may involve readjustment of the CWM for any suspected inhomogeneities. Isotopic ratios may be impacted by resonance overlap or resonance interference of the different isotopes in tank waste. Rather than evaluate a multitude of ratios, a direct calculation may be more expeditious. The Monte Carlo code MONK6A was verified and validated for limited Tank Farm application. MONK was subsequently replaced by the domestic Monte Carlo codes MCNP and KENO using ENDFB cross-sections. Validation referenced for Tank Farm application was incomplete and not consistent with ANS Standards (ANS 8.1 or ANS 8.17) as discussed in Section 2.3.

Infinite systems at various moderating ratios were considered in HNF-11467. Comparison calculations were performed for Al, C, Zr, Bi, Ni, Si, N, Cr, Ca, and Fe. For Ca, MONK6B results were higher than for the other elements. For other cases, KENO showed higher values by approximately 0.02 in k_{inf}. An explanation for the difference was ascribed to the use of British cross-sections vs ENDFB/5 and ENDFB/6. A resolution of this difference was delayed to the future and has yet to be dispositioned. In all situations the k_{inf} values were low and impact on tank reactivity would be minimal.

The development of the CWM and expanding the concept to neutron absorber ratios is a noteworthy accomplishment. On the other hand, using and understanding all the nuances of the expanded CWM concept is challenging. It is recommended that the streamlining of the CWM process be undertaken. Use of direct geometry and composition could prove useful, effective, less error prone, and provide identification of undue conservatism. Also, the uncertainty analysis in WHC-SD-SQA-20356 needs to be checked against the treatment required in Section 5 of ANS 8.17.

The levels of safety associated with tank operation controlled by the CWM and element ratios are illustrated in Figure 1-1 from RPP-41227. The drawing and other drawings in the report are positive features of this document and aid with the understanding of the subject matter. It helps to put the range of safety features in proper perspective.

Upon completion of the validation of the codes for mixed oxides systems (see section 2.3), a review of the role of Pu/U ratios and the definition of Pu equivalence should be undertaken to establish an improved level of the safety margin definition and perhaps conservatism.

The review in this section of the report focused on the information in RPF 7475, HNF 11467, WHC-WM-TI-725, WHC-50-SQA-CSA-507, and WHC-SD-SQA-20356.

2.3 Validation

The current validation basis for the tank farm calculations is contained in WHC-SD-SQA-CSWD-20015 (originally issued for MONK 6a in 1991, reissued for MONK 6b in 1994). Evaluated cases were comprised of 70 Pu metal, solution and oxide experiments. These experiments did not contain credited absorbers (other than a few cases with Cd) or potential reflection conditions associated with the tank farm conditions. This validation supported two separate calculations using Monk, the first being calculations of the minimum absorber ratios to equivalent Pu for a number of absorbing metals, the second being a maximum subcritical equivalent Pu concentration provided a minimum absorption ratio exists in the waste (defined and documented in the Conservative Waste Model (CWM).

A review of the validation document (WHC-SD-SQA-CSWD-20019) by the team noted that there are no experiments in the validation suite that contained both U and Pu, and that some of the absorbers credited had little experimental data. There are some mixed oxides (MOX) experiments now available within the International Criticality Safety Benchmark Evaluation Project (ICSBEP) handbook that may be germane to the conditions being modeled. These should be looked at for applicability and evaluated as potential contributors to code bias and uncertainty. Experimental results outside the ICSBEP Handbook could also prove useful; such as data from the Plutonium Recycle Test Reactor (PRTR), Fast Flux Test Facility (FFTF), and the Hanford Single Pass Reactors.

In 1994 the Plutonium Finishing Plant (PFP) reviewed the existing validation and noted some potential deficiencies. The validation was revisited to determine the effects of adding interstitial iron and concrete reflection. This was addressed with MCNP, since Monk was no longer available, and documented in WHC-SD-SQA-CSWD-20019 Rev 0A of the validation document in 1994. The conclusion of the evaluation was that the bias was not negatively impacted by adding these additional experiments – however the technical reviewer comment on this document stated that the interstitial iron effect was significant. These interstitial iron experiments were not included in a later MCNP validation (HNF-26564). This omission is not discussed.

Requirements for validation are contained in TFC-PLN-49 and include ANSI/ANS-8.1-1983R88 and ANSI/ANS-8.21-1995 with bias and uncertainty per desktop instruction and ANSI/ANS-8.17, 5.1 as applicable. Several shortcomings were identified in WHC-SD-SQA-CSWD-20019 and 20015 when compared against these requirements. The first of these is discussed above whereby the validation used is not evaluated against the specific experimental data available or used (not clear that the system was validated against experimental data for similar systems as required by ANSI/ANS-8.1). There was also not an area of applicability (AOA) defined for either the validation or the application to which it was applied. This is also required by ANSI/ANS-8.1.

The existing referenced validation also does not provide a justification for the value of the subcritical margin as required by ANSI/ANS-8.1.

WHC-SD-SQA 509, *MONK 6B Validation* from 1996 was reviewed as the validation report. In that report, only Pu solutions were analyzed, which lead to a bias being determined for MONK 6B of 0.015. The subcritical margin of 0.05 was chosen. This report appeared to be a re-cap of the WHC-SD-SQA-CSWD-20015 report discussed below.

WHC-SD-SQA-CSWD-20015, *MONK 6A Pu Validation* from 1991 was also reviewed. In this document, again using the 70 Pu solution experiments, the following statements are made about the subcritical margin

> "*Summary: This validation report evaluates the bias of MONK 6A code…for systems using Pu exclusively as the fissile material. A bias of 0.015 keff was derived, taking into account the uncertainty in both the criticality experiments and the MONK 6A calculations for the entire H/Fissile range. A subcriticality margin of 0.05 is then added to the bias to give a subcriticality limit on keff of 0.935 for future calculations of plutonium systems utilizing the MONK 6A program. This subcritical limit satisfies the criterion of Section 2 of WCH-CM-4-29 that the bias adjusted keff fall below 0.95 with a 95% confidence level."*
>
> *"Section 3. Statistical Analysis*
>
> *In addition to the code bias and statistical uncertainties, a 0.05 subcriticality margin is applied to establish a subcriticality limit on keff of 0.935 for a future calculation. The table describing the tolerance limit for all the data, Data Set One, in the statistical analysis letter, shows the 95% confidence level on 99.9% of the data is 0.9699. This indicates that the use of 0.05 safety margin in addition to the 95/95 tolerance limit results is a conservative limiting value for future keff calculations."*
>
> *"Section 4 Conclusions*
>
> *This validation study had determined that the code bias and statistical uncertainty of 0.015 for Pu only systems across the entire range of 0<H/Fissile<2790. A subcritical margin of 0.05 should be used in conjunction with this value. Taking both of these into account results in a limiting value of 0.935 for any future calculation. No obvious dependencies were found between k_{eff} and other parameters observed so the results may be applied to all analyses that fall with in the scope of the validation."*

The MONK6A User's Guide describes 44 validation calculations (UKAEA 1988b) carried out to determine code bias using the MONK6A Point Energy Nuclear Library. These 44 experiments were selected to represent uranium, plutonium, and mixed systems over a wide range of moderation and reflection. These validation calculations provide considerable assurance that MONK6A calculations using point energy nuclear data accurately determine k_{eff} for a wide range of comparable systems. (Ref WHC-SD-SQA-CSA-507, p. B-5, Criticality Parameters for Tank Waste Evaluation). It was not apparent, however, that these mixed systems were used to determine the 0.015 bias for the Pu only systems that is used for the tank farms.

WHC-SD-SQA-CSWD-20019, rev 0A was also reviewed. This was a revision to the MONK 6B document (it appeared that in 1994, Ed Miller ran cases with MONK 6B that allowed the application of the MONK 6A bias and uncertainty to also be applied to the MONK 6B code) to address concrete reflection and interstitial iron. Conclusion was that the existing bias and uncertainty would be unaffected had either concrete reflection or interstitial iron been included in the MONK validation. One of the independent reviewer comments (Carter) stated however that: “However, the calculational results for the experiments that you used have shown that the iron effect was significant and, therefore, the iron effect has been included in your validation data set.” This seems inconsistent with later MCNP validations (HNF-26564) where it appears that the concrete reflected cases from this study were included, but there was no evidence that the interstitial iron cases were included.

In 2002, a comparison was developed looking at the computed value of k_{inf} for the subcritical absorber ratios (HNF-11467). For iron, one of the major absorber constituents, there appears to be an unexplained three percent difference between the calculated absorber ratio reactivity for MONK and that for KENO (see Appendix A, Table A12). Other similar differences were seen in this comparison. Issues with iron cross sections may not have been seen in the validation documents as they did not include interstitial iron, thus the intercode comparison may point to as much as 3% of that 5% margin eaten up by cross section uncertainties. It may be that further study would show that either the KENO cross section had an issue, or that there was something “unusual” in the iron results, but without some additional information, it seems that this item alone would account for much of the subcritical margin selected.

More contemporary validations such as HNF-26564, Rev 0 (not yet referenced in the WRPS TOC CSER), have some of these expectations addressed, however not all of them. It is not clear that an active evaluation has been performed to determine if these contemporary validations meet the area of applicability requirements of the WRPS TOC applications. While there were quite a few more cases considered in the validation (a total now of 143 cases), there was no additional justification associated with the 0.05 subcritical margin selected in this document as well. Reviews of the experiments included did show the concrete cases were now in the validation suite but that the interstitial iron (PST01310, PST01322, PUMF15) were not included.

ANSI/ANS-8.17 would expect that a determination of the experimental uncertainty be considered in determining the bias and uncertainty. Despite the statement in the summary section of 20015, it was not clear that any estimate or explicit value was considered in the statistical evaluation of bias and uncertainty.

Given the very low reactivities associated with the actual waste calculations, there does not appear to be any safety issue associated with the current subcritical margin being used.

2.4 Use of Sampling Data

RPP-SPEC-25386 Rev 0, *Criticality Data Quality Objectives for Tank Core Samples*, provides the process that ensures appropriate data is collected to support the criticality safety basis. This criticality Data Quality Objective (DQO) is invoked whenever a core sample is taken and the fissile content as well as the content of credited absorbers, uranium-238, chromium, iron, manganese and nickel are determined. As required by the procedure for Preparation of Tank Sampling and Analysis Plan, TFC-ENG-CHEM-D-23, the Criticality Safety Representative is notified if the fissile concentration in a waste sample exceed 1 g/L, which is well below the subcritical limit of 2.6 g/L but higher than the expected fissile concentration.

The composition of the CWM was derived in CSER 92-009 (WHC-SD-SQA-CSA-20356) based on core sample data. The goal of the CWM was to create a composition of materials present in the tanks that has a lower macroscopic neutron absorption cross-section than the actual tank waste. CSER 92-009 confirmed that this goal was met both in terms of relative absorption and k_{inf} compared to 26 waste samples.

The Best Basis Inventory (BBI) has been developed as part of the Tank Waste Information System (TWINS) to provide the best estimate of the waste composition in each tank. In 2002, BBI data from 15 tanks, including all with a Pu-equivalent inventory of 20 kg or greater, was reviewed to confirm that the waste had a higher macroscopic cross-section than the CWM. The characterization data confirmed the CWM for all tanks evaluated except Tanks TX-119 and AW-105. The solids in two waste layers of these tanks had enough neutron absorption only if the minimum water content was included.

The BBI is updated quarterly with any new available data. An algorithm to calculate the macroscopic neutron absorption cross-section of the waste has been programmed into TWINS. The calculation uses BBI data for each waste layer. A report is run quarterly and reviewed by the CSR. The latest report was provided to the review team. The cross-section is calculated with and without water. When water is included, all waste layers in all tanks that contain in excess of 200 Pu fissile gram equivalents (FGE) have a cross-section in excess of the lower limit of 0.011/cm. The team considers review of this data as a good practice but the practice needs to formalized and the review documented.

An issue was identified where data taken and evaluated outside of the BBI had criticality safety implications but was not adequately conveyed or reviewed by criticality safety personnel. Tank sample results from Tank SY-102 documented in CH2M-0400872 found PuO_2 that may not be bonded with neutron absorbers. This sample was taken 4 years ago but the CSR has only known about the result for a few months and the criticality safety analyst was not aware of it. Communication concerning new sample data could be improved.

2.5 Adequacy of Controls

The current CSER for tank farm operations, RPP-7475 Rev. 4, proposes criticality limits and controls for tank farm operations in Section 1.3.1. Section 7.1 of the CSER provides brief summaries of the technical bases and means of implementation for the proposed limits and controls.

Of the various criticality control limits proposed in RPP-7475 Rev. 4, *these limits apply specifically to new waste being added to the tank farm inventory from non-tank farm facilities* (excludes the 242-A evaporator, which may return concentrated supernatant):

- The alkalinity (pH) shall be $\geq$ 8.0.

- If the fissile material concentration of the new waste is greater than 0.001 g/L Pu-equivalent, the sum of the subcritical mass fractions for five tabulated insoluble absorbers shall be > 1.
- The fissile material concentration must be less than 0.04 g/L Pu-equivalent.

For new waste, the five absorbers that may be credited (for purpose of the new-waste absorber limit) and their mass ratios (elemental to Pu-equivalent mass ratios) are

Chromium (Cr)	135
Iron (Fe)	160
Manganese (Mn)	32
Nickel (Ni)	105
Total Uranium (U)*	770

* To employ this absorber ratio, the U must contain no more than 0.72 weight % U-235.

Of the various criticality controls proposed in RPP-7475 Rev. 4, *only the following limit is proposed for solids materials that are already in the tank farm system*:

- Solids (sludge and saltcake) in the DCRTs (double-contained receiver tanks), the DSTs (double-shell tanks) and the SSTs (single-shell tanks) shall have a fissile material concentration less than 2.6 g/L Pu-equivalent.

As noted in Section 2.1, RPP-7475 Rev. 4 relies heavily on reference to older nuclear criticality safety documents for computations, analysis, and various conclusions. Those older documents were examined to determine the underlying bases for the RPP-7475 limits for new waste additions and the limit for the existing solids (sludge and saltcake) inventory. The RPP-7475 limits were found to be derived in a 1993 document, WHC-SD-SQA-CSA-20356.

For the RPP-7475 limits for new waste additions, WHC-SD-SQA-CSA-20356 indicates that each of the five tabulated absorber ratios are adequate to ensure subcriticality for solids admitted to the waste system, *independent of the resulting Pu-equivalent concentration in settled solids*. That is, new waste admitted to the tanks should remain subcritical provided the RPP-7475 absorber ratio limit is met, even if solids accumulation (wet or dry) within the tanks at a concentration exceeding 2.6 g/L Pu-equivalent were to result.

For the (single) RPP-7475 limit applicable to the existing solids inventory, WHC-SD-SQA-CSA-20356 provides the basis for the 2.6 g/L Pu-equivalent subcritical limit. This limit is conditional:

> *The 2.6 g/L Pu-equivalent limit is valid for application only if absorbers are mixed with the fissile material, such that the neutron absorption removal probability is greater than 0.01096 per centimeter.*

Thus, the proposed criticality control of RPP-7475 Rev. 4, applicable to the tank farms solids inventory, is incomplete. If a new sample of waste solids is obtained and verified to contain less than 2.6 g/L Pu-equivalent, that action alone does not verify the sample (or the associated tank solids inventory) is within the technical basis for subcriticality as derived by WHC-SD-SQA-CSA-20356.

Document CPS-T-149-00012 is the "Criticality Prevention Specification" (CPS) for tank farm operations. The limits and control statements of the CPS (for new waste additions and for existing solids waste) are consistent with those proposed by the CSER.

The CPS also states the following under "Required Activities":

- *Should a potential nonconformance with this CPS be discovered, recovery actions shall be taken in accordance with procedure TF-AOP-016, Response to Criticality Prevention Specification Nonconformance.*
- *Tank Fissile material inventory data for DSTs, SSTs, and DCRTs must be available for the purpose of calculating tank waste fissile material concentrations before and after transfers*.
- *The data review process within the tank waste characterization program shall include a means of verifying that no CPS limits are exceeded for tank waste. The analytical data collected for core samples shall include data needed to verify that no CPS limits are exceeded for tank waste.*

The CPS does not state as a limit, control, or required action, that new samples of tank solids be analyzed for compliance to any specification other than the solids fissile concentration limit (2.6 g/L Pu-equivalent).

Therefore, neither CSER RPP-7475 Rev. 4 nor CPS-T-149-00012 require action to ensure that new samples of solids (or mixtures/accumulations of solids resulting from tank-to-tank sludge transfers) have the necessary levels of neutron absorption as required for valid application of the 2.6 g Pu/L solids concentration limit.

The review team did determine that as a matter of informal practice (not required by the CSER or the CPS), that tank farm staff performed checks for neutron absorber properties of tank solids samples. (See the discussion under Section 2.4, above.)

The CSER, the CPS, and any associated implementing procedures or plans should be updated to ensure that

- limits for tank solids,
- requirements for the tank sampling program, and,
- requirements for tank-to-tank sludge transfers and consolidations are technically complete and consistent with derivations of subcritical limits for sludge fissile concentration and absorber ratios.

Note: This section does not address the adequacy of the subcritical limits derived by WHC-SD-SQA-CSA-20356. See Sections 2.2 and 2.3 for discussions regarding limit computations and associated computational method validation.

2.6 Regulatory Issues

RPP-39991, Rev 1, dated November 19, 2009, describes the Washington River Protection Solutions (WRPS) Criticality Safety Program Description Document. As required by DOE Order 420.1B, RPP-39991, Rev 0, was approved by DOE, with conditions, by letter dated November 2, 2009. RPP-39991, Rev 1, addresses the DOE comments. Section 1.4 of RPP-39991 states that the WRPS Criticality Safety Program is implemented via TFC-PLN-49. TFC-PLN-49, Rev C-2, dated July 16, 2009, has been developed to meet the requirements of 10 CFR 830.204(b)(6), “Documented Safety Analysis”; DOE O 420.1B, “Facility Safety,” Attachment 2, Chapter III, “Nuclear Criticality Safety,” RPP-13033, “Tank Farms Documented Safety Analysis;” and HNF-SD-WM-TSR-006, “Tank Farms Technical Safety Requirements,” Administrative Control 5.7, “Safety Management Programs.”

Section 1.5 of RPP-39991 states that the WRPS Criticality Safety Program adheres to the requirements of the revisions of consensus nuclear criticality standards in effect as of December 22, 2005, and that the individual ANSI/ANS requirements are directly traceable through TFC-PLN-49. The team noted that the ANSI/ANS standards listed in Section 14.1 of TFC-PLN-49 were not current as of December 22, 2005, and several standards which were in effect have not been included. Missing standards include, but are not limited to, ANSI/ANS-8.14 and 8.23. According to DOE Order 420.1B, the CSP description document must describe how the contractor will implement the requirements in the CRD including the standards invoked by that Order. All recommendations in applicable ANSI/ANS standards must be considered and an explanation provided to DOE through the CSP description document whenever a recommendation is not implemented. Based on a review of RPP-39991, the team was not able to determine 1) that the list of standards in Section 14.1 was complete; 2) that listed standards were applicable; 3) that there were no exceptions to any of the SHALL statements included in the standards; and 4) that WRPS was not implementing recommendations.

The team noted that Section 2.1 of RPP-39991 includes a discussion of criticality safety control strategies, including dual parameter compliance with the double contingency principle; single parameter compliance (with DOE approval) for situations where criticality is credible; and single parameter compliance for situations where criticality is incredible. Section 5.1.3 of TFC-PLN-49, however, concerns only credible criticality situations; does not require DOE approval for single parameter control strategies; and does not address incredible scenarios.

The team also noted that Section 2.1 of RPP-39991 states that CSERs approved after the issuance of Revision 0 of RPP-39991 will be prepared in accordance with DOE-STD-3007-2007. Section 5.3 of TFC-PLN-49, however, states that DOE-STD-3007-1993 will be used.

TFC-PLN-49 defines the WPRS Criticality Safety Program, as required by 10 CFR 830.204(b)(6), "Documented Safety Analysis"; DOE O 420.1B, "Facility Safety," Attachment 2, Chapter III, "Nuclear Criticality Safety," RPP-13033, "Tank Farms Documented Safety Analysis;" and HNF-SD-WM-TSR-006, "Tank Farms Technical Safety Requirements," Administrative Control 5.7, "Safety Management Programs." Administrative Control 5.7, a generic TSR requiring the establishment of the safety management programs described in the DSA, does not contain specific Criticality Safety Program elements such as the development of criticality safety controls, performance of criticality safety inspections/audits, criticality infraction reporting and follow-up, and maintenance of criticality incredibility criteria, typically included in a programmatic Criticality Safety program TSR at other sites.

Section 1.0 of TFC-ENG-CHEM-P-02, Rev B-6 describes the purpose of the Criticality Safety Inspections and Assessments procedure as ensuring that the criticality safety program is maintained at an adequate level for the tank operations contractor facilities. A note at the bottom of Section 4.1 states that the internally imposed semi-annual frequency of inspections satisfies the requirement of ANSI/ANS-8.1 and 8.19 for operational reviews to be conducted at least annually. In addition, Section 4.2 states that facility "inspections are conducted to verify that facility configuration and activities comply with the tank operations contractor Nuclear Criticality Safety Program (TFC-PLN-49). As no physical controls are required to maintain criticality safety for the tank farms, facility inspections generally consist of observation of preparation for tasks and verification of field procedures and training." To carry out facility inspections, operationally oriented lines of inquiry in the form of a checklist have been identified in HNF-3323, Rev 4.

Section 7.8 of ANSI/ANS-8.19 states, in part, that the operational reviews are to ensure that process conditions have not been altered to affect the nuclear criticality safety evaluation. Given the lack of lines of inquiry specifically tailored towards review of the associated criticality safety evaluation report, and the lack of a full-time criticality safety engineer who is knowledgeable in nuclear criticality safety, the team was not able to determine whether the criticality safety inspection program adequately meets ANSI/ANS-8.19 requirements.

Section 4.1 of TFC-ENG-CHEM-P-02 identifies a five-year frequency in which to address all inspection elements, with the exceptions of the 242-A Evaporator and the 222-S facility, which are procedurally required to be reviewed semiannually. Section 4.1 assigns the responsibility for maintaining HNF-3323, "Tank Farms Nuclear Criticality Safety Facility Inspection and Assessment Plan," to the nuclear safety manager for addressing the description of facility segments, activities, or program area being inspected or assessed, and suggested inspection and assessment review criteria (e.g., lines of inquiry). The team noted that HNF-3323 identifies the inspection segments at a very high level, without specification of actual facilities/equipment covered by that segment. The team reviewed documentation of completed inspections and could not verify compliance with the 5-year inspection frequency with all segments. For example, the documentation identified single shell tanks under Segment A. Inspections were completed for single shell tanks in 1999 and in 2006. Although waste tanks are also described in the documentation as being included in Segment A, the team noted no completed inspections. Written justification for not performing inspections as required by TFC-ENG-CHEM-P-02 was not provided for review.

2.7 Waste Treatment Plant Mixing Issues

A report from the previous Tank Farm contractor (CH2MHill) in May of 2004 confirmed the presence of Pu solids not associated with neutron poisons. This was potentially significant as the criticality safety basis for WTP operations was that the fissile material was tightly bound to the absorber material. If the amount of unbound Pu material was trivial, the concern could likely be readily dispositioned.

A likely more serious issue was discussed with the team by two technical experts (Don Alexander and Langdon Holton), who reported on the testing of scale models of the WTP Pulse Jet Mixers. They reported that these mixers would break up the simulated co-precipitated solids and the heavier solids would accumulate in mounds on the mixing vessel bottom without careful arrangement of the jet discharges. This anomalous behavior of the mixing system raises several problems for criticality safety control in the mixing tank operation

- The pulse jet operation breaks up the agglomerated solids, or solids with weak chemical bonds, and has the potential to separate the lighter material from the heavier particles. The piles of heavier particles observed in the testing could be a criticality risk if they are predominately plutonium.
- The WTP CSER assumes sampling of input batches would have an uncertainty of 5%. This would no longer be a safe assumption.

- The current design does not assure heel removal of the mixing tank.

The team visited the M-3 testing facility and discussed future testing plans with the staff. Possible repositioning of the jet nozzles could solve the problem of heel removal and may reduce the problem of piles of heavy particles. These issues need to be pursued in revisions of the WTP Criticality Safety Evaluation Report. The fundamental issue of the possible separation of nuclear poisons from fissile material needs a resolution. The WTP criticality safety staff was not aware of the issues from the pulse jet mixer and had no prior opportunity to postulate solutions. However, the staff reported to the team a plan to address the issue of Pu particles currently in the tank farm by reviewing past tank samples for further evidence of fissile particles without poisons.

Possible ways of resolving the issue of the pulse jet mixing separating the particles were discussed with the WTP criticality safety staff:

1. Demonstrating that sufficient uranium would be associated with the plutonium particles to assure the required absorber ratio.
2. Mixer operation could be designed to assure the heavier particles would not separate into piles and the particles may well re-agglomerate with absorber particles in the mixing tank.

These and likely other approaches should be pursued and any applicable results incorporated into the WTP safety basis.

3.0 RESULTS

3.1 Recommendations for WRPS

- The hazards analysis created by a multi-disciplinary, integrated team of experts in 1996 should be reviewed and/or updated to ensure that all current operations are addressed.
- CSER core assumption that Pu and absorbers could not separate and concentrate is challenged by current M-3 testing (fluidic transfers approved for tank farm) and SY-102 (2004) sample data. The effect of this data on the CSER needs to be addressed.
- The Tank Farm CSER needs to address natural phenomena hazards.
- Calculations performed with MONK, MCNP and KENO-V.a give significantly different results and those which are combined to provide the safety basis need to be reconciled.
- Computer code validation needs to be updated to 1) address the safety basis of the effect of neutron absorbers, 2) discuss the applicability of the validation to the tank farm application, 3) justify the subcritical margin selected, and 4) meet current regulatory expectations.
- The control strategy for the current sludge inventory needs to be clarified in the CSER. The text states that absorber ratio is most important whereas the CPS only gives a Pu concentration limit.
- Outdated ANSI/ANS standards listed in TFC-PLN-49 should be updated to reflect current versions of the ANSI/ANS standards which are applicable to tank farm operations; exceptions to the SHALL requirements from applicable ANSI/ANS

standards should be documented; and any exceptions to recommendations from applicable ANSI/ANS standards should be described in the DOE approved Criticality Safety Program Description document.

- RPP-39991 and TFC-PLN-49 should be aligned to reflect current DOE expectations
- Facility criticality safety inspections should determine whether changes in process conditions could affect the nuclear criticality safety evaluation.
- Tank farms have been in static storage mode. Activity will increase for tank-to-tank sludge transfers/reconfiguration of kg-quantities of Pu in the near-future. A CSER and supporting calculations and validation that meet current regulatory expectations would look quite different than the current documentation, in part because WRPS has committed to meet DOE-STD-3007-2007 with the next CSER revision. Team suggests that contractor not wait until a CSER change is needed to start working on the next revision.

3.2 Opportunities for Improvement for WRPS

- The CPS should specify that new sludge samples be analyzed for agreement with absorber properties of the CWM or that action be taken if the CWM is not met. (Note that this is being done quarterly but is not required by the CPS. See Section 3.3.)
- The facility criticality safety inspection program should be robustly defined such that applicable facilities/equipment are identified with a frequency commensurate with criticality risk.
- Communication concerning new sample data could be improved as tank farm contractor developed data on anomalous PuO_2 samples 4 years ago but NCS staff was not informed until this year.
- Periodic communication between TOC and WTP personnel would help share information and assist in consistency of approach.
- It is appropriate to have a programmatic Criticality Safety program Administrative Control TSR with high level attributes of the program listed.

3.3 Positive Practices for WRPS

- Sampling data is well managed in TWINS/BBI database.
- Although not required by the CPS, TWINS has been programmed to calculate the absorber properties to determine if the assumption of the CWM is met.

3.4 Recommendations for WTP

- The fundamental issue of the possible separation of nuclear poisons from fissile material, raised by results of testing scale models of the WTP Pulse Jet Mixer, needs a resolution. The issue of heel removal from the mixing tank also needs resolution.
- The Pulse Jet Mixer testing also raises issues on the mixing tank sampling uncertainty assumptions in the WTP preliminary CSER. Further data is needed to determine a reasonable sampling uncertainty.

3.5 Team Outbrief

An out brief, with presentation slides, was conducted on December 11, 2009, for DOE and contractor staff to discuss the results by the CSSG review team. The out brief participants accepted the review results as appropriate with minor editorial suggestions on the slides.

Attendance at the out brief included:

Contractors:

- Herb Berman, Chief Engineer, WRPS
- Larry Eppler, WRPS Nuclear Safety and Licensing Manager
- Marshall Perks, BNI Radiological and Fire Safety Manager, Environmental &Nuclear Safety

Office of River Protection (ORP)

- Shirley Olinger , Manager
- Guy Girard, Acting Assistant Manager, WTP
- Stacy Charboneau, Assistant Manager, Tank Farms Project
- Jon Dowell, Assistant Manager, Engineering & Nuclear Safety
- Jim Wicks, Chief Engineer, Engineering & Nuclear Safety
- Vic Callahan, Acting Nuclear Safety Division Director

Appendix A. CSSG Tasking 2009-06

Date Issued: November 6, 2009

Task Title:

CSSG Review of the Technical Criticality Safety Basis for the Hanford Tank Farm

Task Statement:

At the request of the Office of River Protection Chief Engineer, James Wicks, the CSSG will perform a review of the technical criticality safety basis supporting construction of the Hanford Tank Farm. The criticality safety basis document is entitled; "Criticality Safety Evaluation for Hanford Tank Farms Facility," RPP-7475, Rev. 4, 2008.

- The CSSG Chair, in coordination with the ORP will identify a team of at least three members from the CSSG to perform the review under the direction and with the assistance and coordination of Dr. Robert Wilson.
- Documentation for the review is to be provided by the Office of River Protection.
- The structure, history, and content of the documents will be discussed with safety and project staff of the Tank Farm during a visit to the site of the proposed facility at the Hanford Site in Richland, Washington.
- The team will review the criticality documentation, and discuss the safety basis and analysis approach including the following:
    - Criticality Limit Derivation
    - Criticality Control Strategies
    - Identification of Credible Abnormal Operating Conditions

Period of Performance:

The on-site review will take place doing the first quarter of FY10.

Resources:

Funding for the contractor CSSG members will be provided by the ORP. DOE members of the team will be funded from their home organization.

Task Deliverables:

The team will forward a report on their conclusions and recommendations, if any, to the CSSG for concurrence. The CSSG chair will send the report to NCSP

Manager who will review the report and forward it on to the Office of Environmental Management and the Office of River Protection. Email transmittal of the report to the NCSP Manager is preferred.

Task Due:

The report of the review is due no later than February 1, 2010.

Appendix B. Documents Reviewed

CPS-T-149-00012 Rev B-10, *Criticality Prevention Specification Tank Farm Facility*, June 2009.

HNF-3323 Rev 4, *Tank Farms Nuclear Criticality Safety Facility Inspection and Assessment Plan,* March 31, 2008.

HNF-11467, *A Review of the Analytical Model for Evaluating Criticality Safety in Tank Waste*, Rogers, C. A. and C. S. Eberle, September 2002.

HNF-26564 Rev 0, *Computer Code Validation Report for MCNP 4C and Plutonium Systems*, D.G. Erickson, December, 2002.

RPP-1303, Rev 4, *TOC DSA*, Chapter 2.0 Facility Description.

RPP-ASMT-41717 Rev 0, *July 2009 Inspection Record for 222-S Laboratory Nuclear Criticality Safety*, July 2009.

RPP-ASMT-43373 Rev 0, *Tank Farms NCS Inspection Record: October 2009*, October 2009.

RPP-SPEC-25386 Rev 0, *Criticality Data Quality Objectives for Tank Core Samples*, April 2005.

RPP-7475 Rev. 4, *Criticality Safety Evaluation for Hanford Tank Farms Facility*, September 2008.

RPP-19809 Rev 0, *CSER 04-001: 244-CR Vault Stabilization Process*, March 2004.

RPP-39991 Rev 1, *Washington River Protection Solutions (WRPS) Criticality Safety Program Description*, November 19, 2009

RPP-41227 Rev 0, *Review of Criticality Safety for 241-C-104 Retrieval*, May 2009.

TFC-ENG-CHEM-D-23 Rev C-6, *Preparation of Tank Sampling and Analysis Plan*, September 21, 2009

TFC-ENG-CHEM-P-02, Rev B-6, *Criticality Safety Inspections and Assessments*, June 11, 2009.

TFC-PLN-49, Rev C-2, *Tank Operations Contractor Nuclear Criticality Safety Program*, July 16, 2009.

WHC-SD-SQA-CSA-507, *Criticality Parameters for Tank Waste Evaluation*, Rogers, C. A., K. N. Schwinkendorf, and H. Harris, 1996.

WHC-SD-SQA-CSA-20356, *CSER 92-009: An Analytical Model for Evaluating Subcritical Limits for Waste in Hanford Site Storage Tanks*, Rogers, C. A., October 1993.

WHC-SD-SQA-CSWD-20015 Rev 0, *MONK6A Pu Validation*, Miller, 1991.

WHC-SD-SQA-CSWD-20019 Rev 0, *MONK6B Pu Validation,* Miller, 1994, and Rev 0A, *MONK6B Comment Resolution*, Erickson, 1998.

WHC-SD-WM-TI-725, *Tank Farm Nuclear Criticality Review*, Bratzel, D. R., W. W. Schulz, R. Vornehm, and A. E. Waltar, 1996.

Appendix C. CSSG Review Team Biographies

Robert Wilson is the Criticality Safety Program Manager for the DOE Office of Environment Management. He obtained a Bachelor and Masters of Science degree in Engineering Physics from the University of California at Los Angeles and a PhD in Nuclear Engineering from the University of Washington.

He completed a dissertation in Critical Mass Physics at the Plutonium Critical Mass Laboratory in Richland, Washington and post doctoral work in safety analysis for the FFTF Reactor. Following academia he assumed responsibility for managing the Criticality Safety Program at the Idaho Chemical Processing Plant (ICPP). While at the ICPP he managed the safety response to a criticality accident in 1978 and managed the rebuilding of the criticality safety program. Following ICPP, he worked as the senior criticality safety specialist for the U.S. Nuclear Regulatory Commission. In 1995, he assumed responsibility for the criticality safety program at the Rocky Flats Environmental Technology Site and instituted the program manual, the Criticality Safety Officer Program and safety analysis methods.

Dr. Wilson is a Fellow of the American Nuclear Society. He has served as a member of the Argonne National Laboratory Nuclear Facility Safety Committee, the DOE Nuclear Criticality Technology and Safety Panel (1989 - 1993), and the DOE Criticality Safety Support Group (1997 - present). He has been the General Chairman and Program Chairman for ANS topical meetings in criticality safety. He has twice served as chair of the ANS Nuclear Criticality Safety Division. He is currently chair of the Colorado Section of the ANS. He has served as an Affiliate Professor of Nuclear Engineering for the University of Idaho and has lectured at 18 sessions of the University of New Mexico Short Course on Nuclear Criticality Safety.

Dr Wilson is a member of several ANSI writing groups for criticality safety related standards and is a member of N-16, the Nuclear Criticality Safety Consensus Committee for the American National Standards Institute.

Fitz Trumble provides programmatic direction, resource allocation, customer interface and regulatory interaction activities for criticality safety, radiological engineering, accident analysis, risk technology, fire protection, emergency management/preparedness and safety documentation. Mr. Trumble has over twenty years experience in the performance and management of applied analysis in the fields of criticality safety, reactor physics, and health physics in both the commercial and Department of Energy (DOE) sectors. He is active in the leadership of the criticality safety community serving on ANSI Std writing groups, the Nuclear Criticality Safety Division and the DOE Criticality Safety Support Group.

Mr. Trumble has managed or led successful teams in a variety of technical areas. He served as the Manager for SRS Criticality Safety Policy and Programs. He is currently a member of the International Criticality Safety Benchmark Evaluation Project (ICSBEP), an OECD-NEA sponsored activity. While Mr. Trumble was the technical lead for Criticality Validation; his team developed and implemented a set of state-of-the-art criticality code validation procedures covering area of applicability, development of benchmark descriptions, statistical treatment of code bias and uncertainty, and selection of subcritical margin. These methods were subsequently adopted by the Nuclear Regulatory Committee and published as a NUREG. Mr.

Trumble led a team providing operating criticality support (criticality control limits, double contingency analyses and operating procedures) for the enriched uranium separations and plutonium recovery processes as well as providing criticality safety support to the SRS tank farms and DOE dry fuel storage activities. He has served on both internal and external Criticality Review Committees for production sites as well as in laboratory environments. He is proficient in the use of the criticality safety/shielding codes MCNP and SCALE, as well as reactor physics neutronic codes. Mr. Trumble is knowledgeable on the application of 10 CFR 830, DOE Order 420.1 and the ANSI/ANS 8 series of standards.

Mr. Trumble has a BS in Nuclear Science and Engineering from Virginia Tech and a Masters in Nuclear Engineering from NC State.

Davis Reed is a member of the ANSI/ANS-8 Subcommittee 8 for NCS Standards, a member of the DOE Criticality Safety Support Group (CSSG), a staff member of the ORNL Radiation Transport and Criticality Group, and an instructor in nuclear criticality safety for continuing-education and graduate-level University of Tennessee courses since 1995. Former assignments/positions include chair of the ANSI/ANS-8.3 Work Group for criticality accident alarms (1987-2008), a member of the Y-12 Plant Criticality Safety staff (1981-1995), a member of the ORNL Nuclear Criticality Safety staff (1995-1999), the ORNL NCS Program Lead (supervisor for ORNL NCS staff, 1999-2008), and a member of the Bechtel-Jacobs Nuclear Criticality Safety Committee (2001-2006). In addition to multiple NCS program reviews and formal investigations of off-normal events for the Y-12 plant and Bechtel-Jacobs EM projects, Reed has participated in DOE CSSG reviews of the Los Alamos National Laboratory NCS program, the NCS design basis for the Hanford Bulk Vitrification Project, and the Y-12 technical bases for criticality accident source terms, criticality accident alarm system configuration, and criticality accident response planning. Reed has experience in performing critical and subcritical measurements.

Reed has operational experience supporting low- and high-enrichment uranium operations, U-233 operations, Pu operations, transplutonium element processing, reactor operations support (fuel handling and storage) and on-site/off-site fissile material transport. Reed has a B.S. degree in nuclear engineering from Mississippi State University (1979) and has performed graduate studies in nuclear engineering at the University of Tennessee (early 1980s). Reed was also the first intern to participate in the DOE's former Office of Nuclear Safety, NCS intern program (1984-1985). The intern program involved a three-month assignment at ORNL to assist in testing of the initial version of the SCALE/KENO array-of-arrays capability and a three-month assignment at LANL TA-18 to support experimental measurements

Dr. Hans Toffer, Fellow of the American Nuclear Society is an emeritus member of the Department of Energy Criticality Safety Support Group (CSSG). He recently retired from Fluor Federal Services after 44 years in the nuclear field. His main areas of expertise are in nuclear criticality safety and reactor physics. He served as an individual contributor and as a manager of reactor physics, applied physics and criticality safety for 34 years. Currently, he remains active as a consultant in nuclear criticality safety, nuclear standards development, and organizing technical society meetings. Recently, he has participated in assessments and special document reviews for Y-12 Oak Ridge, Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Hanford River Protection, and the Hanford Waste Treatment Project. His expertise and accomplishments are captured in over one hundred publications covering criticality safety, reactor physics, and instrumentation development. Dr. Toffer has a PhD in Nuclear Engineering from the University of Washington, a MS in Physics from Iowa State University, and a BS from Muhlenberg College (Allentown, PA). He achieved the highest level of recognition with the Fluor Corporation as a technical expert. He recently resigned as chairman of the ANSI/ANS 8.21 Standard Committee where he was responsible for the development for the standard for **Use of Fixed Neutron Absorbers Outside Reactors.** In addition, he has performed unique experiments with irradiated fuel and developed the Criticality Parameter Study Database, an essential tool for criticality safety analysts.

Larry Berg is the Nuclear Materials Handling (Criticality Safety) Engineer from the staff of the Energy and Environment Chief of Nuclear Safety. Mr. Berg has extensive criticality safety expertise as both a practitioner and as a regulator. He was a lead criticality safety engineer for Rocky Flats and the Y-12 plant during enriched uranium operations restart. Prior to coming to the Department, Mr. Berg was a member of the NRC staff as the lead criticality safety technical reviewer for the Portsmouth and Paducah Gaseous Diffusion plants and the lead criticality safety inspector for commercial fuel fabrication and enrichment facilities. Mr. Berg has a Bachelors degree in Nuclear Engineering, and has completed graduate course work with specialization in Criticality Safety from the University of Tennessee.

Sandra Larson is the Criticality Safety Manager for Nuclear Safety Associates. She has over 15 years of experience in Criticality Safety and Readiness Assessment. Most recently, she has supported the Y-12 National Security Complex in the areas of Criticality Safety and Readiness. In the area of criticality safety, Ms. Larson has supported chemical processing operations in writing evaluations. In other arenas, she has performed analyses for storage facilities including the Waste Isolation Pilot Plant, Hanford tank waste, Vitrification processes, shipping casks, and experimental laboratory facilities. In the area of Readiness, she has been a team member or team leader for Implementation Validations Reviews (IVRs), validating implementation of safety basis controls, at most nuclear facilities on-site. She has also been a Readiness Assessment (RA) team member assessing criticality safety, safety basis and some areas of configuration management for the startup of multiple projects. Ms. Larson has B.S. and M.S. degrees in Nuclear Engineering from the Massachusetts Institute of Technology.