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THE OFFICE OF SAFETY REGULATION POSITION ON THE CALCULATION OF FACILITY WORKER DOSES FROM SEISMIC AND NON-SEISMIC EVENTS

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PREFACE

As directed by Congress in Section 3139 of the *Strom Thurmond National Defense Authorization Act for Fiscal Year 1999,* the U.S. Department of Energy (DOE) established the Office of River Protection (ORP) at the Hanford Site to manage the River Protection Project (RPP), formerly known as the Tank Waste Remediation System. ORP is responsible for the safe storage, retrieval, treatment, and disposal of the high level nuclear waste stored in the 177 underground tanks at Hanford.

The initial concept for treatment and disposal of the high level wastes at Hanford was to use private industry to design, construct, and operate a Waste Treatment Plant (WTP) to process the waste. The concept was for DOE to enter into a fixed-price contract for the Contractor to build and operate a facility to treat the waste according to DOE specifications. In 1996, DOE selected two contractors to begin design of a WTP to accomplish this mission. In 1998, one of the contractors was eliminated, and design of the WTP was continued. However, in May 2000, DOE chose to terminate the privatization contract and seek new bidders under a different contract strategy. In December 2000, a team led by Bechtel National, Inc. was selected to continue design of the WTP and to subsequently build and commission the WTP.

On January 10,2001, the U.S. Department of Energy published the revised Nuclear Safety Management rule, 10 CFR 830. This rule, in Subpart B, "Safety Basis Requirements," established specific requirements for the establishment and maintenance of the safety basis of DOE nuclear facilities, including the River Protection Project Waste Treatment Plant (RPP-WTP) project.

A key element of the River Protection Project Waste Treatment Plant (RPP-WTP) is DOE regulation of safety through a specifically chartered, dedicated Office of Safety Regulation (OSR). The OSR reports directly to the ORP Manager. The regulation by the OSR is authorized by the document entitled *Policy for Radiological, Nuclear, and Process Safety Regulation of the River Protection Project Waste Treatment Plant Contractor* (DOE/RL-96-25) (referred to as the Policy) and implemented through the document entitled *Memorandum of Agreement for the Execution of Radiological, Nuclear, Process Safety Regulation of the RPP-WTP Contractor* (DOE/RL-96-26) (referred to as the MOA). These two documents provide the basis for the safety regulation of the RPP-WTP at Hanford, including the implementation of regulatory requirements such as 10 CFR 830..

The foundation of both the Policy and the MOA is that the mission of removal and immobilization of the existing large quantities of tank waste by the RPP-WTP Contractor must be accomplished safely, effectively, and efficiently.

The Policy maintains the essential elements of the regulatory program established by DOE in 1996 for the privatization contracts. The MOA clarifies the DOE organizational relationships and responsibilities for safety regulation of the RPP-WTP. The MOA provides a basis for key DOE officials to commit to teamwork in implementing the policy and achieve adequate safety of RPP-WTP activities.

The Policy, the MOA, the RPP-WTP Contract, and the four documents incorporated in the Contract define the essential elements of the regulatory program being executed by the OSR.

The four documents incorporated into the Contract (and also in the MOA) are as follows:

> *Concept of the DOE Process for Radiological, Nuclear, and Process Safety Regulation of the RPP Waste Treatment Plant Contractor,* DOE-96-0005,
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> *DOE Process for Radiological, Nuclear, and Process Safety Regulation of the RPP Waste Treatment Plant Contractor,* DOE/RL-96-0003,
>
> *Top-Level Radiological, Nuclear, and Process Safety Standards and Principles for the RPP Waste Treatment Plant Contractor,* DOE/RL-96-0006, and
>
> *Process for Establishing a Set of Radiological, Nuclear, and Process Safety Standards and Requirements for the RPP Waste Treatment Plant Contractor,* DOE/RL-96-0004.

DOE patterned its safety regulation of the RPP-WTP Contractor to be consistent with the concepts and principles of good regulation (reliability, clarity, openness, efficiency, and independence) used by the Nuclear Regulatory Commission (NRC). In addition, the DOE principles of integrated safety management were built into the regulatory program for design, construction, operation, and deactivation of the facility. The regulatory program for nuclear safety permits waste treatment services to occur on a timely, predictable, and stable basis, with attention to safety consistent with that which would occur from safety regulation by an external agency. DOE established OSR as a dedicated regulatory organization to be a single point of DOE contact for nuclear safety oversight and approvals for the WTP Contractor. The OSR performs nuclear safety review, approval, inspection, and verification activities for ORP using the NRC principles of good regulation while defining how the Contractor shall implement the principles of standards-based integrated safety management.

A key feature of this regulatory process is its definition of how the standards-based integrated safety management principles are implemented to develop a necessary and sufficient set of standards and requirements for the design, construction, operation, and deactivation of the RPP-WTP facility. This process meets the expectations of the DOE necessary and sufficient closure process (subsequently renamed Work Smart Standards process) in DOE Policy 450.3, *Authorizing Use of the Necessary and Sufficient Process for Standards-based Environment, Safety and Health Management*, and is intended to be a DOE approved process under DOE Acquisition Regulations, DEAR 970.5204-2, *Laws, Regulations and DOE Directives,* Section (c). DOE approval of the contractor-derived standards is assigned to the OSR.

The RPP-WTP Contractor has direct responsibility for WTP safety. DOE requires the Contractor to integrate safety into work planning and execution. This integrated safety management process emphasizes that the Contractor's direct responsibility for ensuring that safety is an integral part of mission accomplishment. DOE, through its safety regulation and management program, verifies that the Contractor achieves adequate safety by complying with approved safety requirements.

RECORD OF REVISION

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THE OFFICE OF SAFETY REGULATION POSITION ON THE CALCULATION OF FACILITY WORKER DOSES FROM SEISMIC AND NON-SEISMIC EVENTS

1.0 PURPOSE

This paper presents the position of the Office of Safety Regulation (OSR) on the calculation of facility worker radiation doses from seismic and non-seismic events at the proposed River Protection Project Waste Treatment Plant (RPP-WTP) facility. Consideration of the worker radiation doses from accidents is part of a process used to ensure that the facility is provided with adequate radiological safety. This position paper identifies an acceptable approach to calculating worker radiation doses, which are necessary to demonstrate conformance to two of the requirements for achieving adequate safety. These requirements are the Contractor-derived radiation exposure dose standard of 25 rem for workers in the Unlikely Event and Extremely Unlikely Event categories, and the Worker Accident Risk Goal.[1] The OSR's position and the associated analysis are presented with consideration of the nature of the initiator events, which are categorized as seismic and non-seismic events.[2] Other approaches to these calculations also will be acceptable, with adequate justification.

2.0 BACKGROUND

The Contractor's process for selecting and analyzing design basis events (DBEs) will be described in its Preliminary Safety Analysis Report (PSAR). The PSAR will identify a set of internal and external DBEs that defines a set of performance requirements for structures, systems, and components (SSCs) relied on to control the hazards. The performance requirements include the ability of the important-to-safety (ITS) SSCs to prevent and mitigate accidents such that conformance is achieved with both the radiation exposure standards (RES) for facility workers and the Worker Accident Risk Goal.

The Contractor is required to demonstrate through analysis of accident frequencies and radiation dose consequences that the facility design conforms to the RES presented in Table 2-1 of the Safety Requirements Document (SRD), Safety Criterion 2.0-1. The RES are applicable to credible events, which are those accidents with an event sequence frequency greater than 1×10^{-6} per year. The RES are standards for comparison to conservative calculations of dose consequences and event sequence frequencies of mitigated accidents. The RES for facility workers in the unlikely event and extremely unlikely event frequency ranges[3] are the same value of 25 rem per event.

1 24590-WTP-SRD-ESH-01-001-02, River Protection Project - Waste Treatment Plant Safety Requirements Document Volume II, Rev 0a, Safety Criterion 2.0-1 and DOE/RL-96-0006, Revision 2, Section 3.1.3, respectively.

2 For the purpose of this paper, a non-seismic event is considered to be an internal or external initiator event not associated with an earthquake.

3 An unlikely event is an event sequence with a frequency of 10^{-2} to 10^{-4} per year. An extremely unlikely event is an event sequence with a frequency of 10^{-4} to 10^{-6} per year.

In addition to the RES, the Contractor must also demonstrate conformance with risk goals. For this paper, the risk goal of concern is the Worker Accident Risk Goal presented as a General Safety Objective in DOE/RL-96-0006, *Top Level Radiological, Nuclear, and Process Safety Standards and Principles for the RPP Waste Treatment Plant Contractor*. The Worker Accident Risk Goal is as follows:

> "The risk, to workers in the vicinity of the Contractor's facility, of fatality from radiological exposure that might result from an accident should not be a significant contributor to the overall occupational risk of fatality to workers." (For evaluation purposes, workers are assumed to be located within the controlled area.)

The Worker Accident Risk Goal is a limit on the risk to workers within the controlled area from fatalities due to radiological exposure from an accident. As previously documented in RL/REG-2000-08, *Regulatory Unit Position on Conformance with the Risk Goals in DOE/RL-96-0006*, the regulatory position is that the risk goal is considered to be numerically equivalent to a fatality risk of 1×10^{-5} per year from both prompt and latent cancer fatalities.

There are distinct and important differences in the purpose of the RES and the risk goals. The purpose of the RES is to limit the potential radiation dose to any worker, co-located worker, or member of the public from normal operations and from each postulated accident event. These dose standards vary incrementally with the predicted frequency of the postulated event, and conformance is to be evaluated on a per-event basis. In contrast, the purpose of the risk goals is to limit the total risk from normal operations and all potential accident events at the facility. Conformance is to be evaluated on the basis of total risk from all postulated events. There is also a distinct difference in the approach used to demonstrate conformance to the RES versus the risk goals. Doses calculated for comparison to the RES are required to be conservative estimates while doses calculated to assess risk for comparison to the risk goals are required to be realistic or best estimates. Depending upon the number, nature, and uncertainty of the parameters used in the calculations, conservative estimates of dose could be up to an order of magnitude or more greater than best estimates. The OSR position on acceptable methods to demonstrate conformance to the facility worker RES and the Worker Accident Risk Goal are documented in this paper.

3.0 OSR POSITION

The OSR has the following positions on the calculation of radiation doses to facility workers from both seismic and non-seismic accident events:

- Doses to facility workers from accidents are difficult to quantify accurately.

- For seismic events, qualitative assessments are an acceptable method to demonstrate conformance to the RES for facility workers provided that at least one seismically qualified (i.e., Seismic Category 1) barrier separates the material at risk from locations that are routinely occupied by workers.

- In general, qualitative assessments are also an acceptable method for non-seismic events. For those few events for which it is appropriate to apply quantitative methods (as discussed in Section 4.5), the use of event-specific quantitative dose estimates is appropriate.

- Except for the few events discussed in Section 4.5 for which quantitative methods are appropriate, quantitative estimates of facility worker doses are not necessary to demonstrate conformance to the Worker Accident Risk Goal provided there is not a significant number of events with annual frequencies only slightly less than 1×10^{-6} that could result in doses much greater than 25 rem to facility workers.

4.0 OSR ANALYSIS

4.1 RPP-WTP Requirements

The regulatory approach to the RPP-WTP facility requires the Contractor to calculate radiation doses to workers from accidents in the evaluation of the facility design to ensure that adequate safety can be achieved. Two separate criteria are required to be satisfied: (1) Section 2.0 of DOE/RL-96-0006, which addresses radiation exposure standards for workers on a “per event” basis for various event frequencies, and (2) Section 3.0 of DOE/RL-96-0006, which includes the Worker Accident Risk Goal that ensures radiological risk to workers is low relative to their overall occupational fatality risk.

4.2 Considerations in Calculating Facility Worker Dose

There are numerous factors that impact the doses that would be received by facility workers in an accident. Methods to calculate radiation dose should consider these factors, which for the RPP-WTP facility worker include, but are not limited to:

- The relationship between the initiating events and the specific end states associated with the event and SSC failures (e.g., sizes of holes or cracks in cell walls, amount of radioactive material spilled from tanks);

- The specific locations of workers in the facility at the time of the event;

- The response of facility workers to the event (e.g., evacuation times and routes);

- The airflow characteristics within the facility, which determine the airborne concentration of material; and

- The particle size, suspension, resuspension, transport and deposition.

These and other considerations combine to present considerable difficulties in the quantitative estimation of facility worker doses from accidents. Such estimates will contain large uncertainties, and the extent of the uncertainties themselves will be difficult to quantify.

4.3 Contractor's Approach and Methodology

The Contractor's standards for evaluating facility worker doses for the purpose of demonstrating conformance with the RES and the risk goals have been established in the SRD. The Contractor has committed to ensuring that doses are well below the RES values[4] and to evaluating facility worker doses in a primarily qualitative fashion.[5] To supplement the SRD, the Contractor has provided information on the methods it intends to use to calculate radiation doses to facility workers. The Contractor has also provided preliminary analysis results for a limited number of DBEs.[6] The Contractor's proposed methodology has been presented in the following documents:

- *Methods for Assessing Consequences of Potential Accidental Radiological Releases from the WTP*, RPT-W375-NS00001, Revision 3, 2001
- *Methods for Assessing Consequences of Potential Accidental Releases from the RPP-WTP Following a Seismic Event*, RPT-W375-NS00006, Revision 1, 2001
- *Seismic Probabilistic Risk Analysis Methods*, RPT-W375-NS00005, Revision 0, 2000
- *Integrated Safety Management*, 24590-WTP-GPC-SANA-002, Revision 0, 2001
- *Radiological Consequence Analysis*, 24590-WTP-GPP-SANA-004, Revision 0, 2001
- *Radiological Dose Rate Calculations*, 24590-WTP-GPP-SRAD-001, Revision 0, 2001.

The OSR has reviewed the Contractor's approach and methodology for calculating facility worker doses from both seismic and non-seismic events. Other nuclear safety accident analyses usually only consider doses to members of the offsite public, not facility workers.[7] There is substantial experience in developing and applying accident analysis methods, models, and parameters for estimating doses to members of the public. From this experience, protocols and accepted methods for showing compliance with public dose limits have been established. Numerical methods for estimating airborne concentrations at distances beyond 100 m following the release of radioactive materials have been peer reviewed, published, and accepted for accident analysis.

In addition to these methods, the Contractor has developed accident analysis methods for calculating radiation doses to facility workers located at distances of less than 100 m from the source material. These methods are designed to ensure that the results are conservative in order

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4 SRD, Table 2-1, Radiological Exposure Standards Above Normal Background, Note 3.

5 SRD, Appendix D, *Radiological Exposure Standards for the RPP-WTP Project*, which on page D-2 states that "Compliance with the 25 rem/event standard is established using qualitative methods supported, where necessary, by numerical analysis that may include the development of event trees and fault trees and/or the performance of consequence analysis."

6 *Design Basis Event Analysis for the Bounding Process Vessel Waste Spill in the HLW Vitrification Facility*, Calculation No. 24590-HLW-04C-078T-00001.

7 For example, see DOE-STD-3009.

to ensure conformance to the RES and risk goals. However, no accepted methods or protocols have been previously established for such calculations. For example, there is no peer-reviewed and published method for accident analysis that can reliably calculate doses to facility workers at close distances where near-field effects can dominate. The physical design of the facility and the specific conditions encountered under accident conditions make near-field modeling subject to considerable uncertainty.

The Contractor's methodology models the accident event sequences with considerable detail to develop quantitative estimates of radiation doses. Because of the lack of consensus methods, assumptions, and data available for calculating worker doses under accident conditions, the Contractor has acknowledged that the methodology will have significant uncertainties. Although the Contractor's approach is to select conservative values for parameters used in the calculations, such values are typically either not well known or defensible for every parameter affecting the facility worker dose estimate.

Moreover, the Contractor's method relies on an evaluation of numerous parametric distributions, and use of complex models such as HADCRT[8] to calculate airborne radionuclide concentrations and decontamination factors (DFs) across barriers within the facility under accident conditions. Many of the individual parameters associated with these calculations have more than an order of magnitude of uncertainty; these parameters include airborne release rates and fractions, rate of transport across compromised barriers, dilution as the air is transported through the workplace, inhalation fractions (which are highly dependent on particle size distributions), and worker evacuation times. For this reason, the combined uncertainties in the resulting facility worker dose estimates could be several orders of magnitude.

Notwithstanding the uncertainties in the Contractor's dose assessment methodology for workers, there are numerous factors that provide reasonable assurance that the RES and risk goals will be met for facility workers in the absence of precise quantitative dose estimates. One factor is that despite the uncertainties involved, the Contractor's methodology overestimates both doses and event frequencies. Other factors include the required application of defense-in-depth principles in the facility design, and the use of consensus design standards. As described below, these factors have allowed the OSR to conclude that qualitative assessments are likely to be as reliable as quantitative assessments in demonstrating conformance to the RES and risk goals for facility workers at this stage of the facility design. As the design matures, quantitative estimates of facility worker doses may become more reliable and, therefore, more useful in demonstrating conformance to the standards.

4.4 Evaluating Conformance with the RES for Facility Workers and the Worker Accident Risk Goal: Seismic Events

The SRD requires the Contractor to demonstrate conformance with the RES for facility workers from seismic events. The seismic design basis for the RPP-WTP facility requires that ITS items be designed to achieve acceptable performance at a horizontal peak ground acceleration of 0.26 g. The Contractor established the seismic design basis using a 2000 year earthquake, which

[8] Fuel Cycle Facility Source Term Model HADCRT 1.3: User's Manual, FAI/01-68.

corresponds to an annual frequency of 5×10^{-4}. Given the design requirements, no radiation dose to facility workers is expected following such an event even though 25 rem is the RES standard for this frequency. Moreover, the design requirements result in a seismic margin that significantly mitigates the effect of an earthquake of higher magnitude; therefore, a more severe earthquake than the seismic design basis earthquake is necessary to cause radiation doses approaching 25 rem to facility workers.

Conformance to the RES is required to be demonstrated by comparing conservative estimates of dose to the standards. As indicated in Section 4.3, the Contractor has selected a method that results in quantitative estimates of facility worker dose that include considerable uncertainties. Given the uncertainties in estimating doses to facility workers for beyond design basis seismic earthquakes, the OSR has concluded that a qualitative approach to estimating dose (e.g., determine whether the dose is likely to be well below the standard, could approach the standard, or could be above the standard) is acceptable to demonstrate conformance to the RES. The OSR position is that a qualitative approach to demonstrate conformance to the RES for facility workers can be used provided that a seismically-qualified (i.e., Seismic Category 1) barrier separates the material at risk from locations that are routinely occupied.

The Contractor's approach to demonstrating conformance with the Worker Accident Risk Goal for seismic events is to perform a detailed and quantitative probabilistic risk analysis (PRA) for accident event sequences and to calculate the radiation doses to facility workers using quantitative methods. As discussed above, a more severe earthquake than the seismic design basis is necessary to cause radiation doses approaching 25 rem to facility workers. Additionally, the 25 rem RES limit for facility workers is based on calculations using conservative assumptions. This combination of factors suggests that for seismic events with magnitudes exceeding that corresponding to the seismic design basis frequency of 5×10^{-4} per year, the calculated cancer fatality risk would likely not exceed the Worker Accident Risk Goal of 1×10^{-5} per year. This can be demonstrated using the equation below:

$$\text{Freq}_{SE} \times \text{Dose}_{SE} \times \text{Conversion Factor}_{FC/D} = \text{Risk}_{FC}$$

where: Freq_{SE} = Annual frequency of seismic event within a range of magnitudes
Dose_{SE} = Dose expected for facility workers within the corresponding range of magnitudes
$\text{Conversion Factor}_{FC/D}$ = Risk of fatal cancer per unit dose
Risk_{FC} = Annual risk of fatal cancers associated with the corresponding range of magnitudes

Consider the following bounding scenario, which would correspond to workers receiving the maximum allowable dose (per the RES) of 25 rem for any credible earthquake with a magnitude that is beyond the design basis. In this case, the risk of fatality would be:

$$5 \times 10^{-4} \text{ events/year X } 25 \text{ rem/event X } 1 \times 10^{-3} \text{ fatalities/rem} = 1.25 \times 10^{-5} \text{ fatalities/year}$$

The bounding risk value for seismic events calculated above is essentially identical to the Worker Accident Risk Goal (1×10^{-5} fatalities/year). However, for the reasons discussed above (e.g., seismic margin, conservative nature of dose calculations) it is plausible that the actual risk to workers from seismic events will be significantly less than this value. For example, seismic margin ensures that earthquakes with magnitudes greater than that corresponding to an annual frequency of 5 x 10^{-4} will be necessary to result in significant facility damage and worker doses; this results in a reduction in the risk value calculated above. An example of a more realistic assessment of facility worker risks using the above equation is presented in the following table:

Frequency Bin[9]	**$Freq_{SE}$**[10]	**$Dose_{SE}$**[11]	**Conversion $Factor_{FC/D}$**[12]	**$Risk_{FC}$**
5 x 10^{-4} – 1 x 10^{-4}	4 x 10^{-4}	<< 25	5 x 10^{-4}	<< 5 x 10^{-6}
1 x 10^{-4} – 5 x 10^{-5}	5 x 10^{-5}	< 25	1 x 10^{-3}	< 1 x 10^{-6}
5 x 10^{-5} – 1 x 10^{-5}	4 x 10^{-5}	< 25	1 x 10^{-3}	< 1 x 10^{-6}
1 x 10^{-5} – 5 x 10^{-6}	5 x 10^{-6}	< 25	1 x 10^{-3}	< 1 x 10^{-7}
5 x 10^{-6} – 1 x 10^{-6}	4 x 10^{-6}	< 25	1 x 10^{-3}	< 1 x 10^{-7}
1 x 10^{-6} – 0	1 x 10^{-6}	Unlimited[13]	1 x 10^{-3}	< 1 x 10^{-6}

Total Risk: < 3 x 10^{-6}

According to the above table, the risk of fatal cancer for facility workers from seismic events is less than 3 x 10^{-6} per year. Although no analysis will provide a precise estimate of the actual risk, it appears plausible to the OSR that the contribution to risk from seismic events will be significantly less than the Worker Accident Risk Goal.

Based on the analyses discussed above, the OSR has concluded that quantitative estimates of facility worker doses from seismic events are not required to demonstrate conformance to the Worker Accident Risk Goal provided that at least one seismically qualified (i.e., Seismic Category 1) barrier separates the material at risk from locations that are routinely occupied by workers.

4.5 Evaluating Conformance with the RES for Facility Workers and the Worker Accident Risk Goal: Non-Seismic Events

The SRD also requires the Contractor to demonstrate conformance with the RES and Worker Accident Risk Goal for non-seismic events, which can be caused by a variety of internal and external initiator events. There are important differences in the analysis of non-seismic accident

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[9] Can also be considered a seismic magnitude range. For example, the first frequency bin may correspond to a magnitude range of 0.26 g to 0.4 g.

[10] Value represents the frequency of occurrence of a seismic event in the associated frequency bin, i.e., the frequency of a seismic event within a particular range of magnitudes.

[11] Value of 25 rem is the maximum permissible dose to a facility worker per event at the seismic level indicated. While it is recognized that some incredible event sequences may result in doses above 25 rem, the values in this column reflect the estimated average doses for the corresponding initiating event frequencies.

[12] Value of 5 x 10^{-4} corresponds to an exposure below 10 rem; 1 x 10^{-3} corresponds to an exposure above 10 rem.

[13] For calculational purposes, a nominal value of 1000 rem has been assumed so that the product of the dose and the conversion factor is 1, which represents the maximum possible probability of a fatality.

events as compared with seismic events. These differences affect the determination concerning whether to calculate doses to facility workers and the degree of uncertainty in the calculations.

Unlike seismic events, the non-seismic initiator events typically do not involve performance failures of multiple SSCs. Most non-seismic accident analysis sequences begin with the failure of only one SSC. Other SSCs are relied upon to prevent or mitigate the event such that no individuals are exposed to radioactive materials. In the accident analysis, each accident event is evaluated to determine whether the initiator event has the potential to affect other SSCs. The predicted failure rates of the relevant SSCs are included in the estimation of the frequency of the accident sequence.

There is less uncertainty in calculating doses to facility workers from non-seismic initiator events than from seismic events. For seismic events, numerous types of SSCs that are affected by ground acceleration can fail. Furthermore, damage to the structure and equipment supports can adversely affect facility worker evacuation plans and procedures for safe shutdown of processes, as well as airflow patterns within the facility. The uncertainty associated with the state of the facility, the transfer or movement of radioactive materials in the facility, and the mobility of workers out of affected areas makes the estimates of doses to facility workers highly uncertain. These uncertainties are not as prominent in the estimates of doses to facility workers from non-seismic events.

Unlike for seismic events, there is no single design requirement comparable to the seismic design basis that affords safety for all non-seismic events. For this reason, the evaluation of non-seismic events must consider a wide range of initiator events and accident sequences. Evaluation of these initiator events and accident sequences considers the resulting proximity of radioactive materials to facility workers, the type of exposure condition anticipated (i.e., external or internal radiation dose) and the frequency of the sequence.

In quantitative terms, adequate radiological safety for the facility worker is achieved by limiting their dose from each credible non-seismic event to less than 25 rem, and limiting the risk from all such events to less than 1×10^{-5} per year. In qualitative terms, adequate radiological safety for the facility worker is achieved during accident conditions by maintaining the separation between the radioactive material and the locations routinely occupied by facility workers.

From preliminary hazard analysis information provided by the Contractor[14], only a few DBEs are expected to potentially result in doses to a facility worker that approach the RES. For most DBEs identified, doses to facility workers will be much less than the RES because the events will not involve the release of radioactive material to the occupied areas in the workplace. In these cases, the material will remain separated and confined from facility workers behind shielding walls. For doses to facility workers to approach the RES, the events will have to involve a failure of the confinement barriers and the process ventilation system, which removes, transports, and filters the air in the facility.

[14] The Contractor has presented information on hazard analysis, design basis event selection, safety analysis and risk analysis during topical meetings to support its Preliminary Construction Authorization Request (PCAR).

Preliminary information has indicated that the process ventilation system is to be designed to be highly reliable.[15] Given the low frequency of most initiating events and the low failure frequency of highly-reliable SSCs, it is likely that most events resulting in radiation doses to facility workers that approach the RES will be of sufficiently low probability as to be not credible (i.e., $< 1 \times 10^{-6}$ frequency per year). For example, using conservative estimates of dose and frequency, if the failure probability of a highly-reliable SSC is less than about 1×10^{-3} to 1×10^{-4}, and the annual frequency of most initiating events is less than 1×10^{-3}, event sequence frequency is likely less than 1×10^{-6}. For the purposes of assessing conformance to the RES, estimates of facility worker dose are not required for events that are not credible.[16]

For a limited number of event sequences, it is appropriate to apply quantitative methods to estimate the doses to facility workers. In these cases, event-specific analyses to estimate doses are likely to be a more reliable method for demonstrating conformance to the RES than are doses calculated from a less event-specific and uncertain methodology. Event-specific analyses are possible because the accident conditions and associated basic parameter values used in the dose calculations will be relatively well understood and quantifiable. The parameters needed for calculating external doses are duration of exposure (time), distance from the source material (distance) and amount of material attenuating the radiation (shielding). Similarly, the parameters needed for calculating internal doses are duration of exposure, concentration of airborne material in the breathing air, and the distribution of radionuclides in the airborne material.

The event sequences that can be reliably associated with quantitative dose estimates for facility workers are those that, based on a qualitative analysis, have a reasonable potential to challenge the RES. Such events are likely to involve the following elements:

- A failure of the confinement barriers that maintain a separation between the radioactive material and the locations routinely occupied by facility workers
- A failure of the process ventilation system that removes, transports, and filters the air in the affected location of the facility
- An estimate of event frequency per year that is greater than approximately 10^{-7}.

In these situations, the use of event-specific, quantitative dose methods is preferable to the use of less event-specific methods that are likely to result in more uncertain results. Less event-specific methods may be used, with adequate justification of their basis.

It does not appear likely that the Worker Accident Risk Goal will be challenged by non-seismic events for three reasons:[17] (1) There are expected to be only a few non-seismic events resulting in a dose to facility workers approaching the RES. (2) Demonstration of conformance to the RES is very conservative. (3) Different sets of facility workers are likely to be impacted by each event. Nonetheless, an acceptable method of facility worker dose calculation will include the

[15] Calculation No. 24590-HLW-U3C-750-00001, *HLW C5 System Preliminary Design System Models*.
[16] Such events are not included in the RES table, which is limited to a frequency of 1×10^{-6} per year.
[17] Similar to the calculations demonstrated above for seismic events, the risk for non-seismic events is not likely to exceed 1×10^{-5} per year.

non-seismic event contribution for these events, for which quantitative doses were calculated. Additionally, an acceptable methodology will demonstrate that there are not a significant number of non-seismic events with annual frequencies only slightly less than 1 x 10^{-6} that could result in significant doses to facility workers (i.e., much greater than 25 rem).

5.0 REFERENCES

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6.0 LIST OF TERMS

BNI	Bechtel National Inc.
CAR	Construction Authorization Request
DOE	U.S. Department of Energy
ITS	important-to-safety
NCRP	National Council on Radiation Protection and Measurements
NRC	U.S. Nuclear Regulatory Commission
ORP	Office of River Protection
OSR	Office of Safety Regulation
RES	Radiological Exposure Standard for Workers Under Accident Conditions
RPP	River Protection Program
SRD	Safety Requirements Document
SSCs	structures, systems, and components
TWRS-P	Tank Waste Remediation System Privatization
WTP	Waste Treatment Plant