BNFL Inc.

TWRS PRIVATIZATION

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# RADIOLOGICAL AND NUCLEAR EXPOSURE STANDARDS FOR FACILITY AND CO-LOCATED WORKERS

## BNFL-5193-RES-01, Rev. 0

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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AIChE | American Institute of Chemical Engineers |
| ALARA | as low as reasonably achievable |
| CFR | *Code of Federal Regulations* |
| DOE | U.S. Department of Energy |
| ISFSI | Independent Spent Fuel Storage Installation |
| MRS | Monitored Retrievable Storage |
| NRC | Nuclear Regulatory Commission |
| PHA | process hazards analysis |
| SSC | structures, systems, and components |
| TWRS-P | Tank Waste Remediation System-Privatization |

## 1.0 INTRODUCTION AND PURPOSE

This document is the Radiation Exposure Standard for Workers Under Accident Conditions which is a radiological safety deliverable required by the Tank Waste Remediation System Privatization (TWRS-P) Contract (DE-AC06-RL13308). This document is used by the BNFL team during the process hazards analysis (PHA) and accident analysis to ensure worker safety through identification of the need for accident prevention and mitigation features that provide worker protection against radiological and nuclear hazards. In this document, where unmodified reference is made to workers, it applies collectively to facility workers and co-located workers as defined in Sections 3.5.1 and 3.5.2 below.

The U.S. Department of Energy (DOE), in DOE/RL-96-0006, Revision 0, *Top-Level Radiological, Nuclear, and Process Safety Standards and Principles for TWRS Privatization Contractors*, (DOE-RL 1996), provides Table 1, "Dose Standards Above Normal Background." In Table 1(referred to as DOE Table 1), there are entries labeled, “To be derived,” for which the contractor is to propose specific exposure standards for both facility workers and co-located workers for the following events:

- **Unlikely Events:** events that are not expected but may occur during the lifetime of the facility in the range of frequency between $10^{-2}$/yr and $10^{-4}$/yr (between once in 100 years and once in 10,000 years)

- **Extremely Unlikely Events:** events that are not expected to occur during the lifetime of the facility but are postulated because their consequences would include the potential for the release of significant amounts of radioactive material. Extremely unlikely events are in the range of frequency between $10^{-4}$/yr and $10^{-6}$/yr (between once in 10,000 years and once in 1 million years).

This document provides the required exposure standards and the bases for their selection. In addition, this document presents the BNFL approach for complying with DOE Table 1. The individual elements of this approach, as shown in BNFL Table A, included with this document, are conservative based on the requirements of the BNFL/DOE contract and, as such, satisfy the contract. For completeness, this document also discusses, and presents in BNFL Table A, public exposure standards and the assumed locations of the public, facility worker, and co-located worker for use in evaluation of accident consequences and normal radioactive material releases.

## 2.0 EXPOSURE STANDARDS FOR FACILITY AND CO-LOCATED WORKERS

The four "To be derived" cells in DOE Table 1 have been completed by imposing a radiological exposure standard not to exceed 25 rem/event to the TWRS-P Facility or co-located workers for either unlikely or extremely unlikely events.

The 25 rem/event exposure standard for both the facility and co-located workers for unlikely and extremely unlikely events corresponds to the once-in-a-lifetime accident or emergency exposure for radiation workers which, by recommendation of the National Committee on Radiation Protection (NCRP 1963), may be disregarded in the determination of their radiation exposure status. In addition, an exposure of 25 rem/event corresponds to a conditional probability of fatality of about $2 \times 10^{-2}$. For unlikely events (defined in BNFL Table A as having a maximum occurrence frequency of $10^{-2}$/yr), this equates to a maximum increase in worker lifetime risk of premature death of only $2 \times 10^{-4}$, which is considerably less than the average accidental death risk for workers in some of the safest industries (i.e., retail and wholesale trade, manufacturing, and service [EPA 1991]).

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 analyses. From this process, preventative and mitigative engineered and administrative controls are identified.

Use of qualitative methods is consistent with the American Institute of Chemical Engineers (AIChE) guidelines (AIChE 1992), U.S. Nuclear Regulatory Commission (NRC) guidance for the performance of integrated safety analysis for 10 *Code of Federal Regulations* (CFR) 70 special nuclear material licensees (NRC 1995a), as well as DOE-STD-3009 (DOE 1994) and DOE G 420.1-X (DOE 1995). Both DOE documents state the following:

> "Estimates of worker consequences for the purpose of a safety-significant SSC designation are not intended to require detailed analytical modeling. Considerations should be based on engineering judgement of possible effects and the potential added value of safety-significant SSC designation."

Because the primary purpose of the TWRS-P Facility and co-located worker exposure standards is to identify structures, systems, and components (SSC) required to protect these workers, the guidance cited above is both applicable and appropriate.

BNFL's principal approach for complying with the 25 rem/event worker exposure standard is the PHA. BNFL's PHA is a systematic, team-based review of the plant and treatment processes. The PHA identifies hazards and operability problems to a level of detail commensurate with the design detail available. Further hazard evaluation takes place in parallel with design development to ensure that safety continues to be built into the design process.

Having generated the list of hazards and hazardous situations, this list is subject to a further systematic team-based review where a binning process takes place. The binning process assigns postulated events to a certain hazard category and is essentially risk-based with categories of hazard defined according to a frequency/consequence matrix.

The 25 rem/event standard for unlikely or extremely unlikely events applies to events with frequencies less than $10^{-2}$/yr. For those frequencies, the PHA process assigns serious and major hazardous situations as undesirable, acceptable with controls, or acceptable. For a hazardous situation to be "acceptable", its consequences must be less than 25 rem. Where there is uncertainty as to where an event should be binned (i.e., assigning a hazard category), it is binned into a higher category to ensure that the accident analysis remains conservative.

The DOE-RU has provided a guidance document (DOE-RL 1997) to be used for review of the Radiation Exposure Standard for Workers Under Accident Conditions. This guidance document includes the worker accident risk goal and the accident risk goal of DOE/RL-96-0006.

The worker accident risk goal is stated in DOE/RL-96-0006 as, “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 the TWRS-P Project, BNFL satisfies this goal by calculating the risk of facility operation to the workers. This is a best estimate analysis based on realistic input and modeling assumptions. In performing this analysis, all structures, systems, and components capable of preventing or mitigating the event are considered. Estimates of system and component unavailabilities and unreliabilities consider failure to start and failure to run as well as maintenance-caused unavailabilities. Accident prevention and mitigation features are added to the design as necessary to satisfy the worker accident risk goal.

The accident risk goal is stated in DOE/RL-96-0006 as, “The risk, to an average individual in the vicinity of the Contractor’s facility, of prompt fatalities that might result from an accident should not exceed one-tenth of one percent (0.1%) of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed.” The DOE guidance document states that a radiation exposure standard of 100 rem/event would satisfy the accident risk goal. Because the BNFL standard is 25 rem/event, the guidance document is satisfied.

# 3.0 DEVELOPMENT OF THE BNFL APPROACH TO COMPLIANCE WITH TABLE 1 OF DOE/RL-96-0006

The overall BNFL approach to complying with DOE Table 1 is presented in this document. This approach takes the form of BNFL Table A. The "To be derived" cells have been completed as discussed. The remaining cells of BNFL Table A are either identical or conservative with respect to DOE Table 1. The following sections discuss differences between DOE Table 1 and BNFL Table A.

DOE Table 1 footnotes are not shown in BNFL Table A. Section 2.1 of DOE/RL-96-0006 states that the footnotes refer only to the origin of the specific standards and, as such, are not considered contractual requirements unless included elsewhere in the contract.

## 3.1 ESTIMATED FREQUENCY OF OCCURRENCE

The second column of DOE Table 1, "Estimated Probability of Occurrence (P) ($yr^{-1}$)," has been titled in BNFL Table A, "Estimated Frequency of Occurrence (f) ($yr^{-1}$)" because BNFL's approach is frequency based. In addition, the estimated frequency of occurrence for normal events of DOE Table 1 is redefined in BNFL Table A as any normal event regardless of frequency. The estimated frequency of anticipated events in DOE Table 1 is redefined as events with an annual frequency of occurrence of $10^{-2} < f \leq 10^{-1}$.

With these changes, events routinely performed (e.g., melter replacement) are considered normal events rather than accidents, irrespective of frequency of occurrence. As normal events, the radiological assessment is subject to the more restrictive "per year" exposure standards rather than "per event" exposure standards. Consequently, these changes are conservative in comparison to DOE Table 1.

## 3.2 NORMAL EVENTS/PUBLIC EXPOSURE STANDARD

Clarifying notes have been added to the Normal Events/Public cell of BNFL Table A explaining that the second $\leq$100 mrem/yr standard applies to a member of the public entering the controlled area and the $\leq$25 mrem/yr standard is the public primary exposure standard for radioactive waste. The removal of DOE Table 1 footnotes (as noted above) necessitated the addition of these clarifying notes.

## 3.3 ANTICIPATED EVENTS/WORKER AND CO-LOCATED WORKER EXPOSURE STANDARDS

References to as low as reasonably achievable (ALARA) standards have been removed for the Anticipated Events/Worker and Co-Located Worker cells of BNFL Table A. The ALARA design objective of 10 CFR 835, "Occupational Radiation Protection," is applied to normal events as shown in BNFL Table A. However, with the redefinition in Table A of anticipated events as those events with an annual frequency of occurrence of $10^{-2} < f \leq 10^{-1}$, the ALARA objective no longer applies because anticipated events are not part of normal operation.

This change complies fully with Section 3.2, “Radiation Protection Objective,” of DOE/RL-96-0006, which states the following:

> “Ensure that during normal operation radiation exposure within the facility and radiation exposure and environmental impact due to any release of radioactive material from the facility is kept as low as is reasonably achievable (ALARA) and within prescribed limits, and ensure mitigation of the extent of radiation exposure and environmental impact due to accidents.”

This aspect of BNFL Table A also represents compliance with contractual requirements because footnote 3 of DOE Table 1 references 10 CFR 835.1002(b). This section, and 10 CFR 835.202 which it references, establishes design requirements for occupational exposures other than planned special exposures and emergency exposures. Administrative limits for planned special exposures and emergency exposures are addressed in 10 CFR 835.204 and 10 CFR 835.1302 and are complied with by the TWRS-P Project.

Finally, a note has been added to the Anticipated Events/Worker and Co-Located Worker cells of BNFL Table A stating that compliance to the 5 rem/event standard is established using qualitative methods supported, where necessary, by numerical analysis. This is consistent with the worker exposure standards for unlikely and extremely unlikely events as discussed in Section 2.0.

### 3.4 EXTREMELY UNLIKELY EVENTS/PUBLIC EXPOSURE STANDARD

A note has been added to the Extremely Unlikely Events/Public cell of BNFL Table A stating that a public exposure standard target value of $\leq$5 rem/event is applied to extremely unlikely events. This target value is based on the following:

- The philosophy is that the public should be protected by a lower exposure standard than a worker. This philosophy recognizes the fact that the worker has agreed to work on the Hanford Site and has received training for avoiding hazards and dealing with hazardous situations.

- A goal to facilitate transition to the NRC as the regulatory agency with jurisdiction over nuclear safety for DOE facilities. With the exception of a 25 rem/event guideline value of 10 CFR 100 for the establishment of the exclusion area and low population zone for commercial power reactors, the NRC has not established a public exposure standard that exceeds 5 rem/event. A public exposure standard of 5 rem/event is also included in proposed rulemaking for 10 CFR 70 (NRC 1995b), which further supports the BNFL Table A value.

- With the same 5 rem/event public exposure standard for both unlikely and extremely unlikely events, there is no need to bin accidents in one of these two event frequency categories for the purpose of establishing protection of public safety.

### 3.5 LOCATION OF RECEPTORS

In BNFL Table A, a new last row has been added to clarify in DOE Table 1 of

DOE/RL-96-0006 the assumed location for the facility worker, the co-located worker, and the public, for the purpose of establishing compliance with the radiological standards of DOE Table 1. The bases for the receptor locations included in this row are provided.

### 3.5.1 Facility Worker

The facility worker is located at the most limiting location within the BNFL contractor-controlled area as defined in DOE/RL-96-0006.

Section 6.0, "Glossary," of DOE/RL-96-0006 defines the controlled area as the following:

> "The physical area enclosing the facility by a common perimeter (security fence). Access to this area can be controlled by the Contractor. The controlled area may include identified restricted areas."

The controlled area for TWRS-P used to define the location of the facility worker, is that land leased by DOE to BNFL for the TWRS-P Project and land associated with Tank AP-106. The controlled area may include land beyond the TWRS-P Facility security fence if that fence is located within the leased area, because BNFL would have control of that area between the fence and the boundary of the leased land.

### 3.5.2 Co-Located Worker

Section 6.0, "Glossary," of DOE/RL-96-0006 defines the co-located worker as the following:

> "An individual within the Hanford Site, beyond the Contractor-controlled area, performing work for or in conjunction with DOE or utilizing other Hanford Site facilities."

For evaluation of the TWRS-P Facility design to the exposure standards of DOE Table 1, the location of the co-located worker is either at the BNFL controlled area boundary or beyond that boundary if such a location results in higher exposure. For a ground-level release, the location of the co-located worker is considered no closer than 100 m from the release point.

### 3.5.3 Public

The location of the public (i.e., the offsite receptor) for the purpose of establishing compliance with the last column of DOE Table 1 of DOE/RL-96-0006, is established at the most limiting radiological exposure location along the near bank of the Columbia River, Highway 240, and a southern boundary as shown in Figure 1.

This area includes land for which it is reasonable to assume DOE will retain the right to control activities and limit access under accident conditions for the operating life of the TWRS-P Facility. Specifying the near river bank excludes the Columbia River for which DOE does not control activities (DOE-RL 1995). Specifying Highway 240 excludes the Arid Lands Ecology Reserve of which DOE might relinquish control during the operating life of the TWRS-P Facility. The southern boundary serves to exclude the Washington Public Power Supply System's WNP-2 commercial nuclear power plant (whose workers should be considered members of the public), and the Hanford Site 300, 400, and 1100 Areas. The

400 Area includes the Fast-Flux Test Facility.

In footnotes 10 and 12, DOE Table 1 of DOE/RL-96-0006 makes reference to 10 CFR 72, "Licensing Requirements for the Independent Spent Fuel (ISFSI) and High Level Radioactive Waste," and 10 CFR 100, "Reactor Site Criteria," to relate to the public exposure standards for unlikely and extremely unlikely events. While the siting requirements and guidance of Parts 72 and 100 are not applicable to the TWRS-P Facility, the requirements for establishing the location of the offsite receptor in these two cited regulations are useful for locating the offsite receptor for a waste processing facility such as TWRS-P. Section 72.106, "Controlled Area Boundary of an ISFSI or Monitored Retrievable Storage (MRS)," includes the following statements relative to the boundary to be assumed for the evaluation of radiological exposure to the public:

> "The minimum distance from the spent fuel or high-level radioactive waste handling and storage facilities to the nearest boundary of the controlled area shall be at least 100 meters."
>
> "The controlled area may be traversed by a highway, railroad or waterway, so long as appropriate and effective arrangements are made to control traffic and to protect public health and safety."

Title 10 CFR 100 establishes a guideline value of 25 rem for 2 hr at the exclusion area boundary. For the exclusion area, 10 CFR 100.3, "Definitions," states the following:

> "(a) *Exclusion area* means that area surrounding the reactor, in which the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area. This area may be traversed by a highway, railroad, or waterway, provided these are not so close to the facility as to interfere with normal operations of the facility and provided appropriate and effective arrangements are made to control traffic on the highway, railroad, or waterway, in case of emergency, to protect the public health and safety. Residence within the exclusion area shall normally be prohibited. In any event, residents shall be subject to ready removal in case of necessity. Activities unrelated to operation of the reactor may be permitted in an exclusion area under appropriate limitations, provided that no significant hazards to the public health and safety will result."

As can be seen from the above excerpts, the assumed location for the offsite receptor for TWRS-P satisfies the requirements of 10 CFR 72 and 10 CFR 100. In addition, the proposed southern boundary takes advantage of the road junction at the Wye barricade (Figure 1) for control of access to the site during accident conditions.

Table A. Exposure Standards above Normal Background.

| Description | Estimated Frequency of Occurrence f ($yr^{-1}$) | General Guidelines | Worker | Co-located Worker | Public |
|---|---|---|---|---|---|
| **Normal Events:** Events that occur regularly in the course of facility operation (i.e., normal facility operations). | Any Normal Event | Normal modes of operating facility systems should provide adequate protection of health and safety. | ≤5 rem/yr<br>≤50 rem/yr any organ, skin, or extremity<br>≤15 rem/yr lens of eye<br>≤1.0 rem/yr ALARA per 10 CFR 835 design objective | ≤5 rem/yr<br>≤1.0 rem/yr ALARA design goal | ≤10 mrem/yr (airborne pathway)<br>≤100 mrem/yr (all sources)<br>≤100 mrem/yr (public in the controlled area)<br>≤25 mrem/yr (radioactive waste) |
| **Anticipated Events:** Events of moderate frequency that may occur once or more during the life of a facility (e.g., minor incidents and upsets). | $10^{-2} < f \leq 10^{-1}$ | The facility should be capable of returning to operation without extensive corrective action or repair. | ≤5 rem/event (Compliance established using qualitative methods supported where necessary by numerical analysis.) | ≤5 rem/event (Compliance established using qualitative methods supported where necessary by numerical analysis.) | ≤100 mrem/event |
| **Unlikely Events:** Events that are not expected, but may occur during the lifetime of a facility (e.g., more severe incidents). | $10^{-4} < f \leq 10^{-2}$ | The facility should be capable of returning to operation following potentially extensive corrective action or repair, as necessary. | ≤25 rem/event (Compliance established using qualitative methods supported where necessary by numerical analysis.) | ≤25 rem/event (Compliance established using qualitative methods supported where necessary by numerical analysis) | ≤5 rem/event |
| **Extremely Unlikely Events**: Events that are not expected to occur during the life of the facility but are postulated because their consequences would include the potential for the release of significant amounts of radioactive material. | $10^{-6} < f \leq 10^{-4}$ | Facility damage may preclude returning to operation. | ≤25 rem/event (Compliance established using qualitative methods supported where necessary by numerical analysis.) | ≤25 rem/event (Compliance established using qualitative methods supported where necessary by numerical analysis.) | ≤25 rem/event (≤5 rem/event target)<br>≤300 rem/event to thyroid |
| **Location of Receptor** | | | Within the BNFL TWRS-P Controlled Area Boundary, including Tank AP-106 | The most limiting location at or beyond the BNFL TWRS-P Controlled Area Boundary | The most limiting location along the near-river bank/Hwy 240/southern boundary |

Figure 1. Boundary for Location of Offsite Receptor for the Purpose of Implementing DOE/RL-96-0006, Rev. 0, Table 1, Public Exposure Standard.

## 4.0 REFERENCES

10 CFR 70, "Domestic Licensing of Special Nuclear Material," *Code of Federal Regulations*, as amended.

10 CFR 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," *Code of Federal Regulations*, as amended.

10 CFR 100, "Reactor Site Criteria," *Code of Federal Regulations*, as amended.

10 CFR 835, "Subpart C - Standards for Internal and External Exposure," *Code of Federal Regulations*, as amended.

AIChE, 1992, *Guidelines for Hazards Evaluation Procedures, Second Edition with Worked Examples*, Center for Chemical Process Safety, American Institute of Chemical Engineers, New York, New York.

DOE 1994, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*, DOE-STD-3009-94, U.S. Department of Energy, Washington, D.C.

DOE 1995, *Implementation Guide for Nonreactor Nuclear Safety Design Criteria and Explosives Criteria*, DOE G 420.1-X, Revision G, U.S. Department of Energy, Washington, D.C.

DOE-RL 1995, *Clarification of Hanford Site Boundaries for Current and Future Use in Safety Analysis*, letter Walter B. Scott, DOE-RL to Contractors, dated September 26, 1995, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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