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Natural Phenomena Risk Analysis - An Approach for the Tritium Facilities 5480.23 SAR Natural Phenomena Hazards Accident Analysis

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NATURAL PHENOMENA RISK ANALYSIS - AN APPROACH FOR THE TRITIUM FACILITIES 5480.23 SAR NATURAL PHENOMENA HAZARDS ACCIDENT ANALYSIS

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INTRODUCTION

A Tritium Facilities (TF) Safety Analysis Report (SAR) has been developed which is compliant with DOE Order 5480.23. The 5480.23 SAR upgrades and integrates the safety documentation for the TF into a single SAR for all of the tritium processing buildings. As part of the TF SAR effort, natural phenomena hazards (NPH) were analyzed. A graded approach strategy was developed using a team approach to take advantage of limited resources and budgets.

During development of the Hazard and Accident Analysis for the 5480.23 SAR, a strategy was required to allow maximum use of existing analysis and to develop a graded approach for any new analysis in identifying and analyzing the bounding accidents for the TF. This approach was used to effectively identify and analyze NPH for the TF. The first part of the strategy consisted of evaluating the current SAR for the RTF to determine what NPH analysis could be used in the new combined 5480.23 SAR. The second part was to develop a method for identifying and analyzing NPH events for the older facilities which took advantage of engineering judgment, and followed a graded approach. The second part was especially challenging because of the lack of documented existing analysis considered adequate for the 5480.23 SAR and a limited budget for SAR development and preparation. This paper addresses the strategy for the older facilities.

The strategy for the older facilities was to develop sequence and damage state analyses which identify the NPH accident scenarios (seismic and wind) by integrating the NPH hazard with the building and equipment fragilities to develop damage states and damage state frequencies. Input to the analysis consisted of SRS specific NPH hazard curves and fragility analysis for the principle structures, systems, and components relied upon to protect the offsite public and facility workers from tritium releases. The input data was integrated up to and including the evaluation basis NPH events (0.2g earthquake and 137 MPH wind) and the full hazard. The results of the analyses consisted of a description of the damage states for the seismic and wind events, estimates of fractional releases from confinement failures, and estimated frequencies for each sequence and damage state. These results were used for binning the NPH events and estimating source terms for consequence analysis.

Fragility Analysis

The purpose of the fragility analysis was to provide fragility estimates for structures and equipment of the Tritium Facilities (TF) to be used as input to the Damage State and hence Risk Analysis performed as a part of the SAR for the TF. The fragilities for three buildings and three neighboring stacks were provided for Natural Phenomena Hazard (NPH) events, namely, earthquake and wind/tornado.

The fragility analysis was based on a review of design and analysis documentation, study of structural and construction drawings, engineering calculations and reports, walkdowns of structures and equipment, earthquake experience data, and engineering judgment.

Fragility is a conditional probability of failure or a relationship between the probability of failure and the capacity which is expressed in terms of the peak ground acceleration (pga) and the fastest miles per hour (fmph) for seismic and wind/tornado events, respectively. Seismic fragility methodology,[1, 2 and 3] was extended to wind/tornado events.

Structural failure was assumed to occur when deformations were considered large enough to potentially affect the safety class equipment inside or attached to the structure. Equipment was assumed to fail when it no longer could perform its intended function.

The fragility of each structure and equipment of the TF was defined by three parameters which included median capacity, and logarithmic standard deviations for capacity due to randomness and uncertainty. The fragilities were expressed as a lognormal model with the parameters representing a set of fragility curves. High Confidence Low Probability of Failure (HCLPF) capacity values were also provided.

SEQUENCE AND DAMAGE STATE ANALYSIS

Sequence and damage state analysis was performed using seismic probabilistic safety assessment (SPSA) methodology. SPSA requires four elements:

- A seismic or wind hazard curve
- A seismic or wind logic model
- Failure probability information (fragilities) for structures and equipment
- Model quantification and uncertainty analysis

A seismic hazard curve specific to the TF was not available. However, seismic hazard curves were developed for the Savannah River Site (SRS) from curves developed by Lawrence Livermore National Laboratory (LLNL) and the Electric Power Research Institute (EPRI). Because of significant differences between these two seismic hazards, they were conservatively combined and a correction factor applied using the methodology in DOE-STD-1024-92[4] to develop a seismic hazard curve for the TF. A site specific high wind hazard curve was previously developed for SRS and was used in the analysis. The SRS seismic hazard curve is presented in Figure 1.

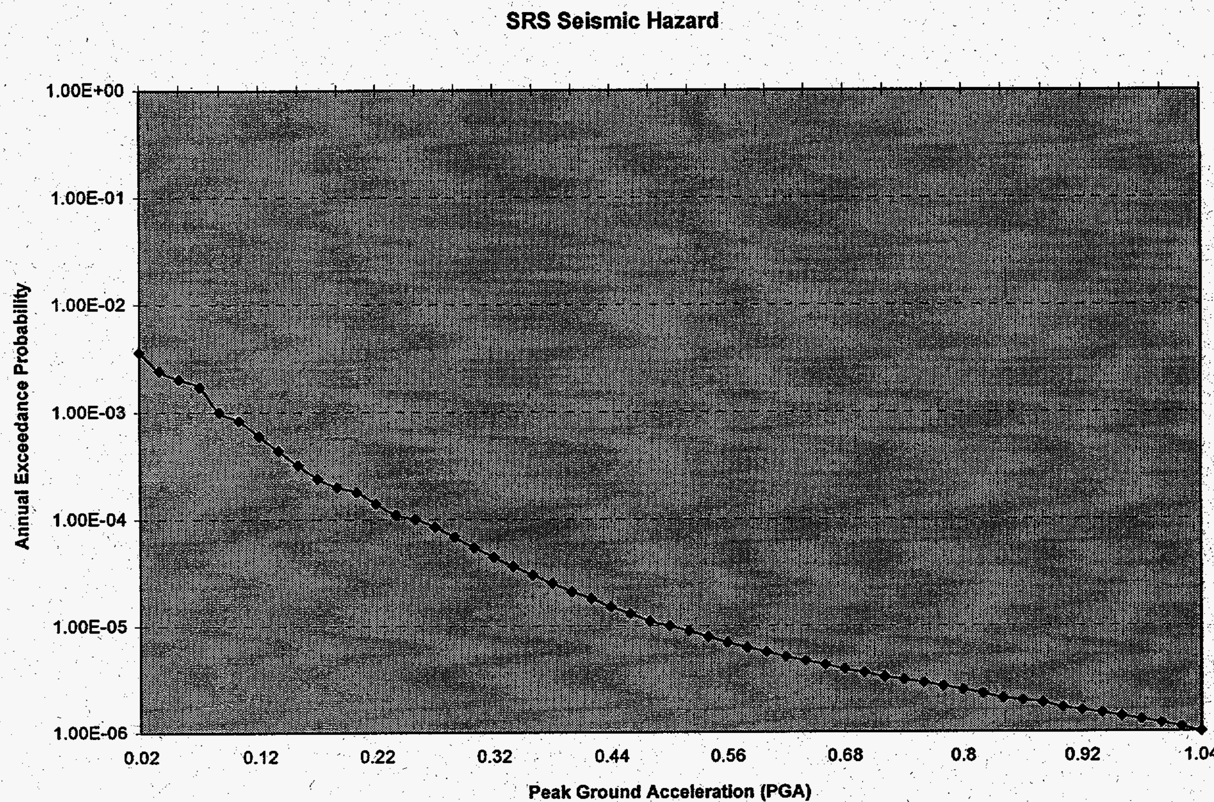

Figure 1, SRS Seismic Hazard

An example of the logic model for one of the older process buildings is presented in Figure 2. The event tree shown was developed to permit quantification of sequences that led to tritium releases caused by seismic events. The top events in the tree model the various structures and components in the building process that effect the release of tritium in a seismic event. The top events in the tree are placed in order of decreasing severity from the standpoint of facility damage. In Figure 2, a branch that divides downward indicates a failure of the top event, an upward dividing branch indicates the top event is true, and a path through an event with no branches indicates that the event is not relevant to the path being followed through the tree. The example tree has six top events that define seven sequences following a seismic event that lead to a release of tritium. Sequence logic expressions were constructed for each failure and success (branch) in each path through the tree. Similar logic models were developed for the high wind analyses.

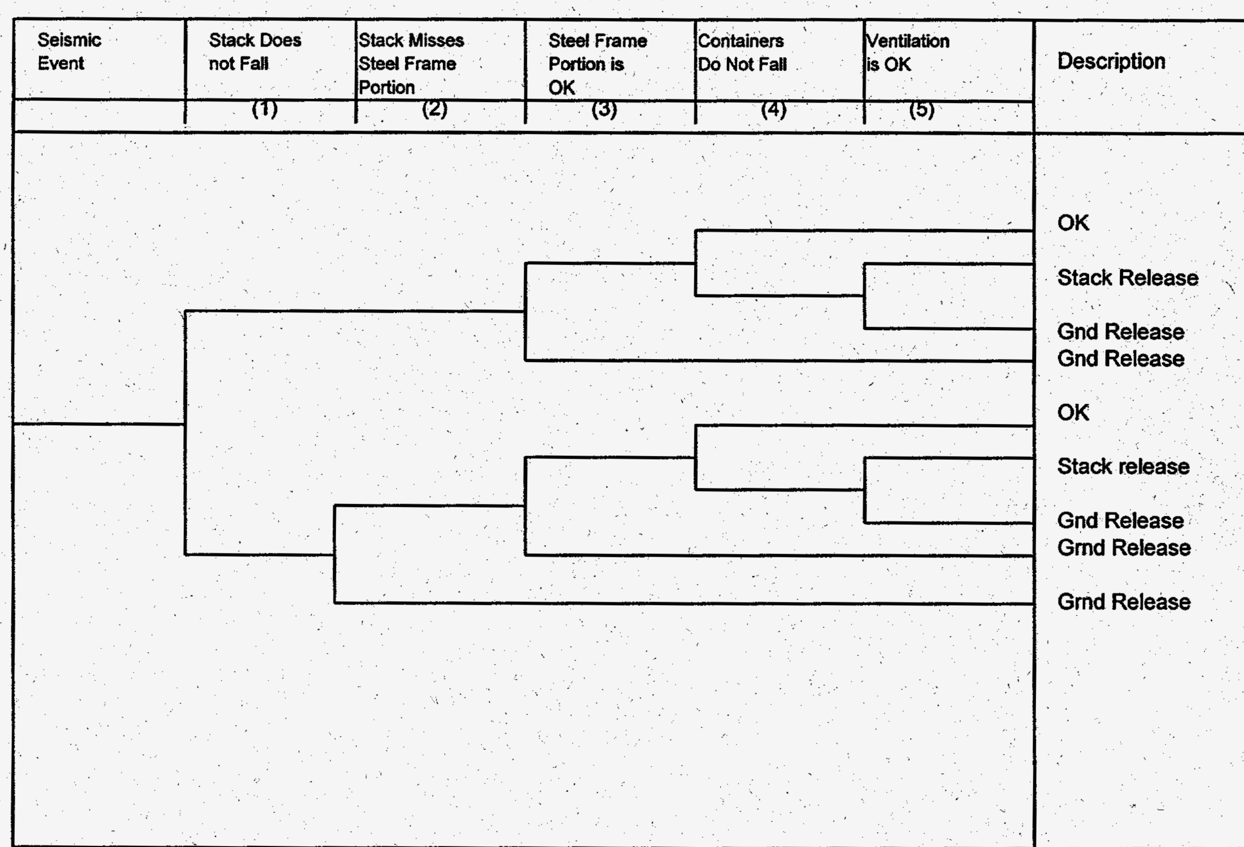

Figure 2, Process Building PRB 4 Seismic Event Tree

The SHIP[5] computer code was used to quantify the event tree models and to determine the effects of uncertainty in the fragility values on the final outcome. The code performs the quantification in the following manner. First, each top event in the logic model is evaluated to determine the probability of failure at each ground motion level step (top event fragility curve). The top event fragility curves are then combined according to the sequence logic expressions to create sequence fragility curves. The sequence fragility curves are then integrated with the information from the hazard curve to compute the frequency of failure for each sequence. Finally, the individual failure frequency information is combined into damage state bins.

The SHIP code was run in the uncertainty mode for these calculations using 150 simulations to determine the effect of uncertainty in the fragility information on the sequence frequency values. SHIP reported the final results as a mean and several different fractiles.

Two sets of calculations were performed for each type of NPH event. For the first set of calculations, the hazard curve was integrated with the system fragility model up to the design basis (0.2g PGA seismic; 137 mph; high wind). For the second set of calculations, the full hazard curve (beyond design basis) was integrated with the system fragility model. For the Tritium Facilities, none of the damage state frequency bins changed between the two sets of calculations, therefore, the design basis calculations were used in the SAR.

The results of the seismic evaluation for the model in Figure 2 are shown in Table 2.

SOURCE TERM/CONSEQUENCE ANALYSIS

The outputs of the SHIP code are accident sequences that include various modes of failure of TF process buildings, exhaust stacks, and equipment. Sequences with similar sets of failures are grouped in a single damage state. . The results of the SHIP analysis are damage states and the associated frequencies. The source term analysis considered two levels of damage for each building, an unlikely event in which the hazard curve was integrated up to the design basis event but few serious secondary events occurred, and an extremely unlikely event in which the design basis event was followed by secondary events such as fires. The damage state with the most severe releases for a particular frequency bin was selected as the case reported as the bounding scenario for that frequency bin.

Since the oxide form of tritium is significantly more hazardous than the elemental form, and NPH events are capable of compromising large amounts of tritium in the process buildings, secondary fires are particularly important contributors to the risk of operating the TF. The analysis assumed a 10% chance of a significant secondary fire following an NPH event based on additional calculations that verify that this is a conservative assumption. Once the fire was initiated, it was assumed to grow to a full area fire as defined in the TF fire accident analysis. Propagation to a full area fire was assumed based on the detection and suppression systems not being available due to damage from the NPH event. Fire Department response to fires during the NPH events was conservatively not credited due to account for the possibility that widespread damage from the NPH event alters the response characteristics of the fire department.

The airborne pathway was of primary interest for the TF. DOE-STD-1027-92 quotes observations of the Nuclear Regulatory Commission (NRC) to the effect that "for all materials of greatest interest for fuel cycle and other radioactive material licenses, the dose from inhalation pathways will dominate the overall dose"[6]. Airborne source term is typically estimated by the following linear equation.

Source Term = MAR x DR x ARF x RF x LPF, where
MAR = Material at Risk (curies, grams, lbs)
DR = Damage Ratio
ARF = Airborne Release Fraction
RF = Respirable Fraction, and
LPF = Leak Path Factor

For the TF, the only significant releases consist of elemental tritium and tritium oxide vapor. The ARF, RF, and LPF were conservatively assumed to be 1.0 for both release types. Therefore, the source term equation reduced to Source Term = MAR x DR. The final component of the source term, which is primarily a concern for the secondary fires, is the fraction of the released tritium inventory which is oxidized. Tritium oxide is four orders of magnitude more hazardous than elemental tritium and dominates the EDE from tritium releases. Tritium oxidation depends on many factors and requires a detailed analysis of the building damage state, tritium releases, and the fire growth. Since parts of the TF may suffer considerable damage in an NPH event, a complex analysis of multiple damage states and fire scenarios was not considered to be in line with the graded approach philosophy for a 5480.23 SAR. Thus, secondary fires were conservatively assumed to oxidize 100% of the inventory at risk within any fire area that is damaged by an NPH event.

The consequence of tritium releases under postulated accident conditions were evaluated with Version 1.5.11.1 of the MACCS code. For a unit curie ground-level release of tritium oxide, the 50-year committed effective dose equivalent (EDE) incurred by the Maximum offsite Individual (MOI) is 6.82E-8 rem/Ci for the short duration event (3 minutes) and 4.89E-8 rem/Ci for the longer duration event (20 minutes). For elemental tritium releases, the release is assumed to contain 0.1% tritium oxide with resulting doses based only on the tritium oxide as the contribution from the elemental tritium is negligible.

RESULTS

The fragility inputs and results from the quantification of the logic model in Figure 2 are presented in Tables 1, and 2 The fragility values for structures and equipment for the seismic events modeled in Figure 2 were evaluated by SRS structural mechanics engineers. Parameters provided in the fragility parameters were used to define fragility curves for the sequence and damage state analyses.

Table 1, Fragility Information.

Component	Median PGA	Randomness	Uncertainty	HCLPF
Stack	0.33	0.36	0.43	0.09
Building	0.15	0.36	0.33	0.05
Container Fall	0.37	0.20	0.35	0.15
Ventilation	0.30	0.25	0.50	0.09

The mean results for the process building calculations are provided in Table 2 for each of the three damage states for the 0.2g design basis case and the full hazard case (see Figure 1).

Table 2, Mean Process Building Damage State Frequencies

Damage State	Mean Frequency, 0.2g Hazard	Mean Frequency, Full Hazard
Steel frame struck by stack	1.57E-5	2.98E-5
Steel frame damaged due to inertial loading	3.79E-4	4.79E-4
Steel frame not damage but containers fall from seismic event	3.63E-6	6.00E-6

Typical results from the from the accident analysis for NPH seismic events are presented in Table 3.

Table 3, Radiological Release Summary for Seismic Events

Process Building	Accident Scenario	Frequency Bin	MOI (rem)	Evaluation Guidelines (rem)
PRB 2	Failure of test facility with secondary fire	Unlikely	9.5E-1	5.0
	Test facility collapse with failure of high risk tanks with secondary fires	Extremely Unlikely	3.8	25
PRB 3	Confinement failure, no fire	Unlikely	5.3E-3	5.0
	Confinement failure with secondary fire	Extremely Unlikely	4.7	25
PRB-4	Building Collapse, no fire	Unlikely	6.0E-3	5.0
	Building Collapse with secondary fire	Extremely Unlikely	4.3	25

CONCLUSIONS

This paper demonstrates a graded approach for SAR NPH accident analysis by describing the regulatory basis, rationale, and process for the analysis. The paper further describes the purpose, methodology, results, and use of the fragility, sequence and damage state, and source term/consequence analyses in the development of the TF 5480.23 SAR.

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