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The Control Identification Process for the Tank Waste Remediation System FSAR at Hanford

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
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The Control Identification Process for the Tank Waste Remediation System FSAR at Hanford

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Introduction

During calendar year 1996, Duke Engineering and Services Hanford, Inc. conducted a safety analysis in accordance with DOE-STD-3009-94 as part of the development of a Final Safety Analysis Report (FSAR) for the Tank Waste Remediation System (TWRS) at the DOE Hanford site. The scope of the safety analysis of TWRS primarily addressed 177 large underground liquid waste storage tanks and associated equipment for transferring waste to and from tanks. The waste in the tanks was generated by the nuclear production and processing facilities at Hanford.

The challenge facing the safety analysis team was to efficiently analyze the system within the time and budget allotted to provide the necessary and sufficient information for accident selection, control identification, and justification on the acceptability of the level of safety of TWRS. It was clear from the start that a hazard and accident analysis for each of the 177 similar tanks and supporting equipment was not practical nor necessary. For example, many of the tanks were similar enough that the results of the analysis of one tank would apply to many tanks. This required the development and use of a tool called the "Hazard Topography".

The use of the Hazard Topography assured that all tank operations and configurations were adequately assessed in the hazard analysis and that the results (e.g., hazard identification and control decisions) were appropriately applied to all tanks and associated systems. The TWRS Hazard Topography was a data base of all the TWRS facilities (e.g., tanks, diversion boxes, transfer lines, and related facilities) along with data on their configuration, material at risk (MAR), hazards, and known safety related phenomenological issues. Facilities were then classified into groups based on similar combinations of configuration, MAR, hazards and phenomena. A hazard evaluation was performed for a tank or facility in each group. The results of these evaluations, also contained in a data base, were then mapped back to all TWRS facilities and used to select candidate accidents for the SAR. The Hazard Topography and hazard evaluation results were then used to support the identification of controls that address all TWRS facilities.

The accident and hazard analysis results were used to identify safety-class and safety-significant Systems, Structures, and Components (SSCs), Technical Safety Requirements (TSRs), and other controls required to protect the public, onsite workers, TWRS facility workers, and the environment. Controls for protection of the public and onsite workers (100 m from the facility) were selected on the basis of the results of both the hazard analysis and the accident analysis. Controls for protection of facility workers and the environment were based primarily on the qualitative hazard analysis results.

The control identification process was developed and implemented to identify a set of safety SSCs and TSRs based on the TWRS safety analysis approach using the Hazard Topography. The process involved facility operations and engineering staff to assure that the control set was practical and had ownership by the TWRS operating organization. The control identification was based on the results of the accident and hazard analysis activities and the set of quantitative and qualitative risk guidelines [1,2,3] identified for the TWRS.

The process provided a set of controls - safety SSCs, TSRs, and other defense in depth and environmental controls - for inclusion in the TWRS FSAR. By addressing a series of questions for every accident analyzed, the control set was correlated directly to the results of accident and hazard analyses and TWRS facility characteristics. This established a consistent basis for review of the results and implementation of the controls. Although the results of the control identification process were TWRS specific, the process was general enough to be applied to any SAR activity.

Use of the Hazard Topography in the Process

The Hazard Topography was used both to identify the cases analyzed to produce a comprehensive set of hazard analysis results and to identify an adequate set of controls. The results from the hazard analysis were used to select a set of accidents to represent all the hazardous conditions with potential significant offsite public and onsite worker impacts. Controls were initially identified based on the accidents analyzed. The hazard topography was then used to determine if additional controls were necessary to address all the cases represented by each accident for all the TWRS tanks/equipment and operations within the scope of the FSAR. This was accomplished by examining the hazard identification, configuration, and phenomenological data in the hazard topography for all tanks/equipment to determine the applicability of the controls selected for the accident analyzed. For example, cover blocks were identified as a control for the spray leak accident in a valve pit. Examining the Hazard Topography indicated that spray leaks were postulated in Clean Out Boxes (COBs). COBs do not have cover blocks, but do have metal covers secured by bolts. These metal covers were identified as an equivalent control to the cover blocks for spray leaks in the COBs.

The Control Decision Process

The process was carried out in a series of meetings called "Control Decision Meetings". The results of the meetings were documented in a set of Control Decision Records to capture both the basis and results. The process consisted of addressing questions for each accident analyzed. If the answer to any question was "No", controls were identified for that part of the process. Figure 1 illustrates the control decision process.

The first three questions in the order asked were:

1. Is the accident risk (frequency/consequence combination) acceptable without controls?

2. Is the accident risk acceptable at each applicable TWRS facility?

3. Is the risk acceptable for each hazardous condition represented by the accident?

After controls were identified based on the first three questions, controls to protect facility workers were identified by examination of the hazardous conditions with facility worker consequences and asking if additional controls to those already identified were appropriate. This process was also repeated for hazardous conditions with environmental impact.

Question 1 was answered in the context of the accident being analyzed. For example, an accident which results in a surface leak of radioactive waste due to overflowing a valve pit during a waste transfer from one tank to another was identified by the hazard analysis, analyzed by the accident analysis, and controls identified for leaks in a valve pit. The controls included pit leak detectors and the above ground portions of the pit structure. Question 2 was answered by looking at all the other possible locations for a surface leak, and resulted in the identification of additional controls for pump pits, diversion boxes, and clean out boxes. In answering question 3, additional leak controls were identified for the service water system based on the hazardous conditions represented by the accident analyzed, including controls to address the possibility of a leak due to back flow from a transfer line to the service water system or a flow of service water into the waste system resulting in an overflow.

Question 3 also raised some of the more complex issues associated with hazardous conditions represented by the accidents analyzed. One accident analyzed was a fire in a contaminated pit. This accident was postulated to result from a vehicle accident spilling fuel in a pit with subsequent ignition of that fuel. The resulting fire provided the driving force to release any residual contamination in the pit. The controls identified for this accident included SSCs - physical barriers marking areas and/or structures and TSRs - vehicle operations controls within marked areas and emergency fire response.

When addressing question 3, it was discovered that the fire in contaminated area was used to represent the hazardous condition of dropping a load in a contaminated area (pit) with the kenetic energy of the load providing the driving force for the release. While the fire accident consequence analysis results were logically used to bound the consequences of the load drop, the fire controls identified were inappropriate for this hazardous condition. As a result, a TSR - load handling controls was identified for the load drop to complete the identification of the controls for all hazardous conditions resulting in releases from contaminated areas.

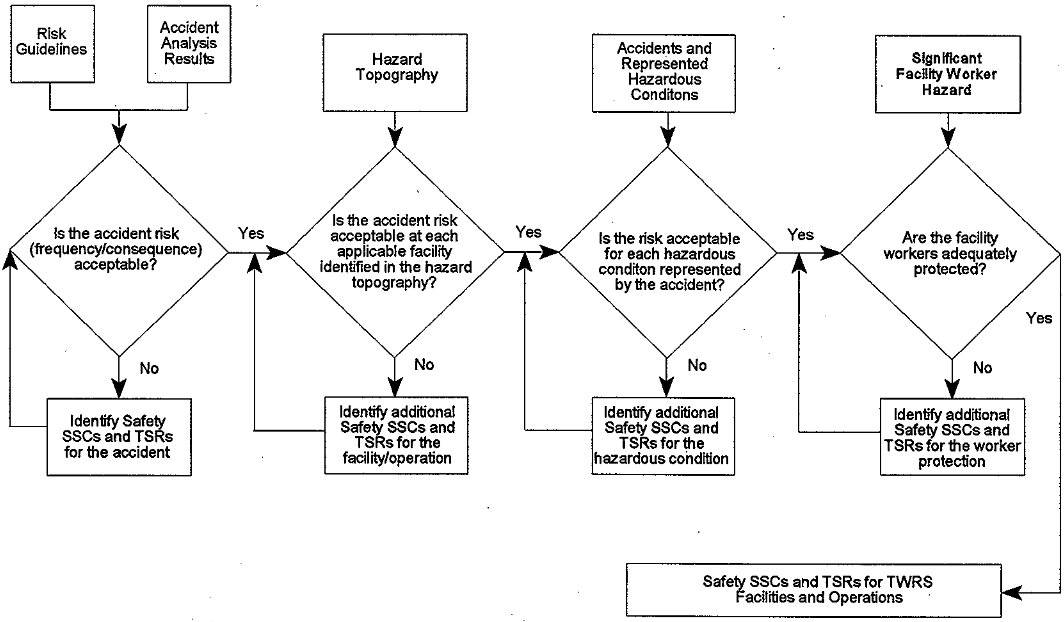

Figure 1. Process to Identify Controls.

Control Decision Criteria

The principal bases used for identifying safety SSCs and TSRs to protect the public and the workers were the accident analysis results and quantitative risk evaluation guidelines [3]. The objective of the control identification was to identify the necessary and sufficient safety SSCs and TSRs that result in satisfying the risk evaluations guidelines and providing defense in depth. The risk guidelines used for the offsite public and onsite workers are shown in Table 1.

Table 1. Risk Guidelines.

Event frequency category	Event frequency (yr^{-1})	Effective dose equivalent mSv (rem)	
		Onsite	Offsite
Radiological risk guidelines			
Anticipated	$>10^{-2}$ to 10^{0}	5.0 E-03 (0.5)	1.0 E-03 (0.1)
Unlikely	$>10^{-4}$ to $\leq 10^{-2}$	50.0 E-02 (5)	5.0 E-03 (0.5)
Extremely unlikely	$>10^{-6}$ to $\leq 10^{-4}$	100.0 E-01 (10)	40.0 E-02 (4)
Event frequency category	Event frequency (yr^{-1})	Primary concentration guidelines	
		Onsite	Offsite
Toxic chemical risk guidelines			
Anticipated	$>10^{-2}$ to 10^{0}	≤ ERPG-1	≤ PEL-TWA
Unlikely	$>10^{-4}$ to $\leq 10^{-2}$	≤ ERPG-2	≤ ERPG-1
Extremely unlikely	$>10^{-6}$ to $\leq 10^{-4}$	≤ ERPG-3	≤ ERPG-2

ERPG = Emergency Response Planning Guideline.
PEL = permissible exposure limit.
TWA = time-weighted average.

Qualitative criteria were used to identify additional controls for the hazardous conditions represented by the accidents analyzed and all hazardous conditions with significant facility worker consequences (S1), and with an uncontrolled frequency of anticipated (F3). Figure 2 shows the qualitative risk criteria used for all hazardous conditions identified by the hazard analysis. This criteria is based on the DOE guidance for the hazard analysis activity for a SAR [2]. The risk matrix indicates what type of control decision was made for each hazardous condition based on the qualitative hazard evaluation results.

Likelihood	Consequences			
	S0	S1	S2	S3
F3	7	11	14	16
F2	4	8	12	15
F1	2	5	9	13
F0	1	3	6	10

Figure 2. Risk Matrix

Risk Matrix Legend	
(light shading)	Considered for Identification of Safety Structures, Systems, and Components and Technical Safety Requirements.
(dark shading)	Requires Identification of Safety Structures, Systems, and Components and Technical Safety Requirements
Likelihood	Category Definition
F3 (>.01)	Anticipated events: frequency greater than once in 100 operating years
F2 (10^{-2} to 10^{-4})	Unlikely: frequency between once in 100 years and once in 10,000 operating years
F1 (10^{-4} to 10^{-6})	Extremely unlikely: frequency between once in 10,000 years and once in 1 million years
F0 ($<10^{-6}$)	Beyond extremely unlikely: frequency of less than once in a million years
Consequence	Category Definition
S3	Significant radiological or chemical exposure to the public
S2	Significant radiological or chemical exposure to onsite worker
S1	Significant radiation or chemical exposure to facility worker
S0	No significant effect outside facility systems. No consequences for facility workers, onsite workers, or public

Controls for environmental protection were also identified on the basis of the set of safety SSCs, TSRs, and other controls providing defense in depth identified for the protection of the public and workers and on other TWRS information. First, the set of controls identified for the protection of the public, onsite worker, and facility worker are examined to determine hazardous conditions for which the environment is also protected. Results of the controls examination are incorporated in the hazard analysis. Secondly, the existing TWRS programs and activities that address the hazardous conditions with severe environmental (i.e., E3 or E2) consequences are identified and included in the TWRS final safety analysis report.

Decisions on classifying SSCs as safety class and safety significant, selecting required TSR controls, identifying defense-in-depth controls, and identifying additional controls specifically for environmental protection were developed with a disciplined methodology and process using established control decision criteria [3]. Applying this control decision methodology and process, controls were derived on the basis of control decision criteria, the best available information, and the collective expertise and experience of the participating hazard and accident analysts, engineering, operations, and management personnel.

Additional criteria that guided control decisions were the following.

- Controls are primarily limited to existing SSCs. Exceptions were made if the control could be rapidly implemented and no reasonable alternative existed

- Control preferences are as follows:

  1. Controls that prevent the accident versus those that mitigate its consequences

  2. Passive engineered versus active engineered controls

  3. Engineered controls versus administrative controls.

- Controls providing significant defense in depth are classified as safety SSCs or are elevated to a TSR control

Other criteria that were important considerations in control decisions are listed below.

- Control reliability, availability, and maintainability

- Control effects on facility workers (i.e., increased radiation doses or toxicological exposures - as low as reasonably achievable issues)

- Control optimization and integration

- Control cost/benefit

- Control human factors impacts

- Control impacts on TWRS mission.

Because control decisions depend on the postulated accident consequence analyses, the conservatism of the accident analyses also influenced control decisions. As required by DOE 5480.22 [4] and Section 6 of WHC-CM-4-46, key initial conditions in the accident analysis that are under the control of an operator are identified and protected by TSR controls.

The assessment of alternative controls with respect to the above criteria was based on the knowledge and experience of cognizant operations, engineering, safety analysis, and management personnel. For example, when evaluating alternative controls to prevent or mitigate a postulated accident, the reliability, availability, and maintainability of potential safety SSCs were assessed qualitatively based on discussions with TWRS operating and engineering personnel.

Systems with known high failure rates, low availability, or maintainability problems were either not selected or multiple controls were selected. In some cases, historical experience was available to indicate a potential control was not sufficiently singularly reliable. In a limited number of cases, a human factors task analysis was performed and quantified (e.g., assessment of operator response time to shut down a waste transfer pump following receipt of an alarm). The estimated reliability of a safety SSC, along with the postulated accident frequency and consequences, provided a qualitative estimate of risk that was considered in assessing the sufficiency of a safety SSC control. Where judged necessary, additional controls were identified. Human reliability was similarly considered, with an assumed error rate of 1×10^{-2} per year.

References

1) U.S. Department of Energy, Washington, D.C., "Nuclear Safety Analysis Reports", *DOE 5480.23*, **Change 1**, (1994).

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

3) Westinghouse Hanford Company, Richland, Washington, "Nonreactor Facility Safety Analysis Manual", Section 6, "Technical Safety Requirements," Rev. 1; Section 7, "Risk," Rev. 1; and Section 9, "Safety Classification of Structures, Systems, and Components," Rev. 2, *WHC-CM-4-46*, (1989).

4) U.S. Department of Energy, Washington, D.C., "Technical Safety Requirements", *DOE 5480.22*, **Change 2**, (1992).