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TITLE: ACCIDENT SELECTION METHODOLOGY FOR TA-55 FSAR

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Accident Selection Methodology for TA-55 FSAR

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As part of upgrading the Final Safety Analysis Report (FSAR) for the TA-55 plutonium facility at the Los Alamos National Laboratory, approximately 15 accident scenarios were chosen for refined analysis. These scenarios include criticalities, fires, explosions, releases of hazardous chemicals and radionuclides, and seismic events. Selection of a representative set of accidents for refined analysis from the numerous scenarios identified in hazards analyses (HAs) has, in the past, involved significant judgment and has been difficult to defend. In an attempt to improve this interface between HA and refined accident analysis for FSARs, an accident selection process was developed for the TA-55 FSAR that is mostly mechanical and reproducible in nature and fulfills the requirements of the Department of Energy (DOE) Standard 3009 (DOE-STD-3009). The resulting accident selection process is applicable to all types of DOE facilities.

The HA for TA-55 identified and characterized approximately 840 accident scenarios. Each scenario was qualitatively assigned a frequency estimate and consequence estimates for four types of consequence categories: workers, co-located workers, public, and environment. Also, each scenario was assigned an accident type such as fire, explosion, etc. In order to reduce the 840 accident scenarios to a limited set for refined analysis in the FSAR, a three-stage accident selection process was developed. The first two stages are purely mechanical in nature and are based on the placement of the HA scenarios into a risk matrix shown in Figure 1. (A separate risk matrix exists for each of the four consequence categories.) The first stage involved elimination of scenarios with low consequence levels (C or D in the figure), except if the risk rank was 2. The second stage involved selection of the highest risk-ranked scenario(s) within each accident type. Finally, the third stage involved judgment to choose among remaining scenarios of the same accident type and risk rank. The first two stages of the accident selection process reduced the 840 HA scenarios to 48. The last stage, involving both mechanical and judgmental decisions, resulted in a final set of 15 scenarios for refined accident analysis.

Consequence Level	V (low)	IV	III	II	I (high)
(high) A	3 (risk rank)	3	2	1	1
B	4	3	2/3	2	1
C	4	4	3	3	2
(low) D	4	4	4	4	3

Frequency

Figure. 1. HA scenario risk matrix.

The FSAR accident selection process developed for TA-55 is applicable to all types of DOE facilities and is mainly mechanical in nature. The selection process is being incorporated into HA software to provide for automated accident selection, except where judgment may be required in the third stage.

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In the past, the selection of representative accidents for refined analysis from the numerous scenarios identified in hazards analyses (HAs) has involved significant judgment and has been difficult to defend. As part of upgrading the Final Safety Analysis Report (FSAR) for the TA-55 plutonium facility at the Los Alamos National Laboratory (LANL), an accident selection process was developed that is mostly mechanical and reproducible in nature and fulfills the requirements of the Department of Energy (DOE) Standard 3009 and DOE Order 5480.23. Among the objectives specified by this guidance are the requirements that accident screening 1) consider accidents during normal and abnormal operating conditions, 2) consider both design basis and beyond design basis accidents, 3) characterize accidents by category (operational, natural phenomena, etc.) and by type (spill, explosion, fire, etc.), and 4) identify accidents that bound all foreseeable accident types. The accident selection process described here in the context of the TA-55 FSAR is applicable to all types of DOE facilities.

The success of the scenario screening process depends on the completeness and the consistency of the facility HA that is required by DOE-STD-3009 to identify process specific hazards and vulnerabilities to natural and man-made external events. The TA-55 HA identified and characterized approximately 840 accident scenarios ranging in description from minor worker injuries to environmental release of radionuclides. Each scenario was qualitatively assigned a frequency estimate and four consequence severity estimates, one for each of the consequence evaluation categories, workers, co-located workers, public, and the environment. Definitions of accident frequency and consequence severity are provided in Tables 1 and 2, respectively. Also, each scenario was assigned one or more accident type such as fire, explosion, spill, etc. according to the descriptions in Table 3.

In order to reduce the comprehensive HA scenarios to a limited set for refined analysis in the FSAR, a three-stage selection process was developed. The first two stages are purely mechanical in nature and are based on the placement of the HA scenarios into a risk matrix (Figure 1) according to their qualitative frequency and consequence designations. The risk rank assignments in each cell of the matrix form the basis for prioritizing among similar scenarios that might be appropriate representative accidents for quantitative analysis. Risk rank definitions provided in Table 4 conform to standard industrial safety practice, but they may be changed to suit a particular location or facility. These definitions of relative risk acceptance must be stated before scenario screening can proceed. Note that in the case of TA-55 at LANL, scenarios of frequency III and consequence level B were assigned a risk rank of 2 for the public and environment consequence categories and a risk rank of 3 for the worker and co-located worker consequence categories. It was felt that workers accept a higher risk of non-fatal injury or contamination from accidents that they are actively responsible for preventing as part of their occupation.

Stage 1, performed solely to facilitate manual screening of a large number of scenarios, removes from preliminary consideration all scenarios below an arbitrarily defined risk review region. The risk review region shown as the shaded cells in Figure 1 was defined to exclude incidental events that are expected during normal operation, but to include high frequency (I), moderate consequence (C) events which may indicate facility or procedural deficiencies that warrant further attention. Levels C (except CI) and D were also excluded because it was unlikely that appropriately bounding events for TA-55 would be found with low to moderate consequences. Approximately 140 of the TA-55 HA scenarios lie in the risk review region.

Figure 2 shows an example of the Stage 1 scenarios affecting workers. A similar risk matrix was formed for each of the evaluation categories. Each entry includes a number identifying the HA accident description and an

accident type designation from Table 3. Note that the same scenario number can appear with more than one accident type and that a given scenario may or may not appear in each of the four risk matrices depending on the consequence level assigned for each category.

The objective of Stage 2 screening is to retain at least one entry for each consequence category of each accident type that is present in the risk matrix. This objective is achieved by prioritizing similar scenarios according to the following selection rules:

1. Retain the highest risk scenario(s) of each accident type,
2. For scenario(s) of equal risk, retain those of highest consequence,
3. For scenario(s) of equal risk and equal consequence, retain those of highest frequency,
4. If this process selects an improbable event (frequency V), retain for review, but also select the next most dominant scenario(s) identified by the prioritization.

Implement these rules methodically by scanning each matrix from top (high consequence) to bottom (low consequence) and from right (high frequency) to left (low frequency) noting the occurrence of each accident type. In Fig 2, the scenarios marked with an "*" will remain following this selection process. Table 5 presents the results of Stage 2 screening for the TA-55 FSAR. Some scenarios may survive for more than one risk matrix, so the right hand column summarizes the set of 48 separate scenario numbers.

The Stage 3 process of selecting final scenarios for detailed quantitative analysis is both mechanical and judgmental in nature. The mechanical part is enforced by the following selection rule:

- Choose at least one scenario for each consequence category and accident type combination that remains .

Judgment is needed for cases where more than one scenario is present for a given consequence category and accident type combination. Judgment is also needed in cases involving scenarios with frequency V (<1.0E-6/yr).

Additional information from plant walk-downs and professional input from process technicians and specialists such as criticality or fire safety personnel may be required to choose the most appropriate representative accident scenarios for detailed analysis, so the rationale for screening or retaining each Stage 2 scenario should be carefully documented. If the HA was comprehensive, some scenarios such as external floods, air-craft crash or nuclear materials accountability may be referred to existing safety or security documentation for resolution rather than being carried through quantitative accident analysis. Some HA scenarios may be too generic to define a meaningful accident sequence, so interaction with the original HA team members may also be required.

Following Stage 3, some assessment of the suite of final accidents should be conducted to ensure completeness. Approximately 15 final scenarios were chosen for the TA-55 FSAR including the following major accident types: criticality, explosions involving radionuclides, fires involving radionuclides, chemical releases, radiological releases, and seismic events. This range of accidents was deemed sufficient for describing the operational activities at TA-55, however, if some accident type appears to be missing from the final selection for a particular facility, then the screening for that accident type should be repeated with a more inclusive risk review region at Stage 1. Figure 3 shows how the selected scenarios cover the entire risk spectrum. While each scenario was chosen for the highest risk it posed to any one evaluation category, secondary concerns for the other categories will also be addressed during quantitative analysis.

No single prescription for accident selection exists that will satisfy every safety review board. However, the combined scrutiny of a facility wide HA and a methodical selection process provide a very satisfactory framework for documenting the safety analysis process. Some observations regarding the effectiveness of this method for the TA-55 FSAR include:

1. Additional hazards that may be identified can be evaluated in a logically consistent manner.
2. Final scenarios are directly linked to facility specific hazards identified in the HA.
3. Redundant selection rules give each scenario multiple opportunities for being chosen.
4. Risk prioritization is appropriate for defining the facility safety envelope, but additional moderate risk accidents may be needed to adequately specify Safety Significant Structures, Systems, and Components
5. Mechanical selection of large data bases can easily be automated.
6. The definition of mechanical selection rules, particularly frequency vs. consequence risk ranking, encourages logical and effective broad screening and minimizes personal bias from later stages.

Table 1. Qualitative accident frequency definitions used in the TA-55 Hazards Analysis.

FREQUENCY LEVEL (yr^{-1})	DEFINITION
I (1 to 0.1)	Normal operations; frequency as often as once in 10 operating years or at least once in 10 similar facilities operated for 1 year.
II (0.1 to 0.01)	Anticipated events; frequency between one in 100 years and one in 10 operating years or at least once in 100 similar facilities operated for 1 year.
III (10^{-2} to 10^{-4})	Unlikely; frequency between one in 100 years and one in 10,000 operating years or at least once in 10,000 similar facilities operated for 1 year.
IV (10^{-4} to 10^{-6})	Very unlikely; frequency between one in 10,000 years and once in 1 million years or at least once in a million similar facilities operated for 1 year.
V ($< 10^{-6}$)	Improbable; frequency of less than once in a million years.

Table 2. Qualitative consequence severity definitions used in the TA-55 Hazards Analysis.

Consequence Level	Consequence Categories			
	Public	Co-Located	Worker	Environment
A	• Immediate Health Effects	• Immediate Health Effects	• Loss of Life	• Significant Off-Site Contamination Requiring Cleanup
B	• Long-Term Health Effects	• Long-Term Health Effects	• Severe Injury / Disability • Rad > MPBB	• Moderate to Significant On-Site Contamination • Minor Off-Site Contamination
C	• Irritation or Discomfort but no Permanent Health Effects	• Irritation or Discomfort but no Permanent Health Effects	• Lost Time Injury but no Disability • Rad Uptake / Dose Causing Temporary Radiation Worker Restriction	• Significant Facility Contamination • Minor On-Site Contamination
D	• No Significant Off-Site Impact	• No Significant On-Site Impact	• Minor or No Injury and Disability	• Minor or No Facility Contamination • No On-Site Contamination

Definitions:
1. OFF-SITE = Public, private, or Indian lands not a part of Laboratory property.
2. ON-SITE = Laboratory property, but not necessarily the originating technical area.
3. FACILITY = Originating technical area of the Laboratory (e.g. TA-55).
4. TEMPORARY WORKER RESTRICTION = Restrictive work duty for worker that gets a large enough dose that might place them in jeopardy of exceeding the annual dose limits (5 Rem/yr). This restriction ensures that the worker does not exceed the limit.

Table 3. Generic accident type definitions.

Accident Category	Accident Class	Accident Type	Designator	Guidelines for Selection
Process Related		Fire (radiological or chemical)	FRR or FRC	Fire-induced dispersion of radionuclides or chemicals
		Explosion (radiological or chemical)	EXR or EXC	Explosion-induced dispersion of radionuclides or chemicals. Covers fires with the potential for explosion.
		Material release (radiological or chemical)	MRR or MRC	Any type of radiological or chemical release (spill, gas release, etc.). Also covers inadvertent overexposure. Also covers accidents resulting in additional maintenance or cleanup and resultant exposure.
		Criticality	CRT	
		Industrial accident	IND	Any injury or death not related to radionuclide or chemical exposure. Includes contaminated cuts.
		Equipment Damage	EQD	Any equipment damage not resulting in injury, death, or radionuclide or chemical exposure.
		Equipment Shutdown	EQS	Any equipment shutdown not resulting in injury, death, or radionuclide or chemical exposure.
Natural Phenomena	Seismic activity		SEI	
	Extreme wind/tornado		EWT	
	External flooding		EFL	
	External fire		EFR	
	Other		ONP	High/low temperatures, lightning, snow loading, etc.
External Events	Nearby facility accident		NFA	
	Transportation accident		TRA	
	Aircraft impact		AIR	
	Other		OEE	

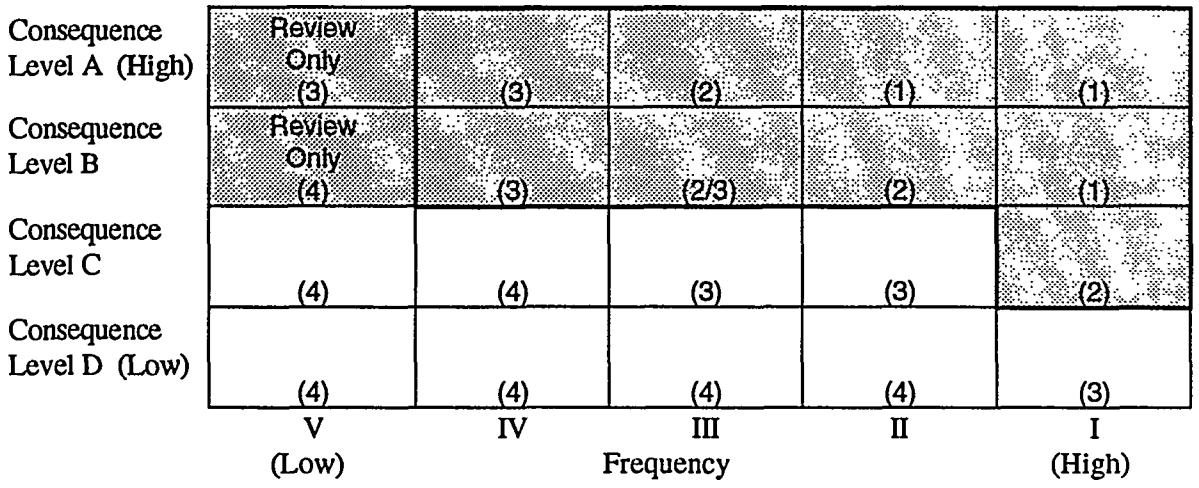

Fig. 1. Generic risk matrix with Stage 1 risk review region shaded.

Table 4. Risk rank definitions used in the TA-55 Hazards Analysis.

Risk Level	Recommendation
1	Should be mitigated to risk rank 3 or lower as soon as possible.
2	Should be mitigated to risk rank 3 or lower within a reasonable time period.
3	Verify that procedures, controls, and safeguards are in place.
4	No action necessary.

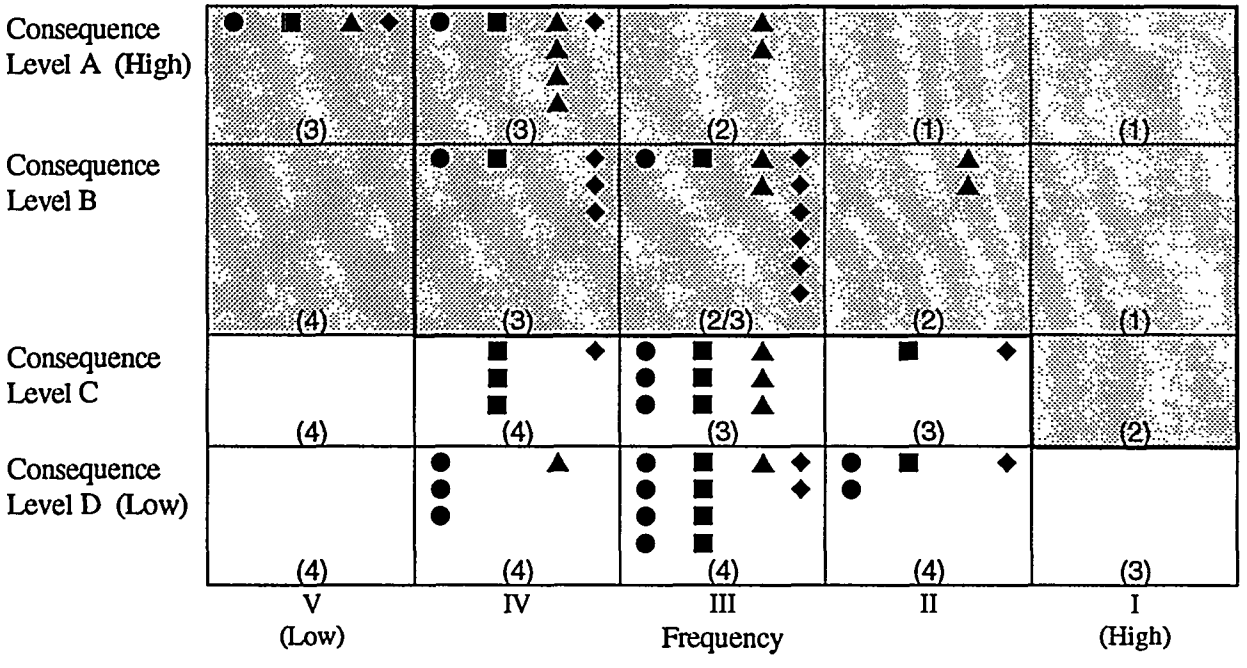

Fig. 3. Risk scatter matrix of final FSAR accident scenarios.

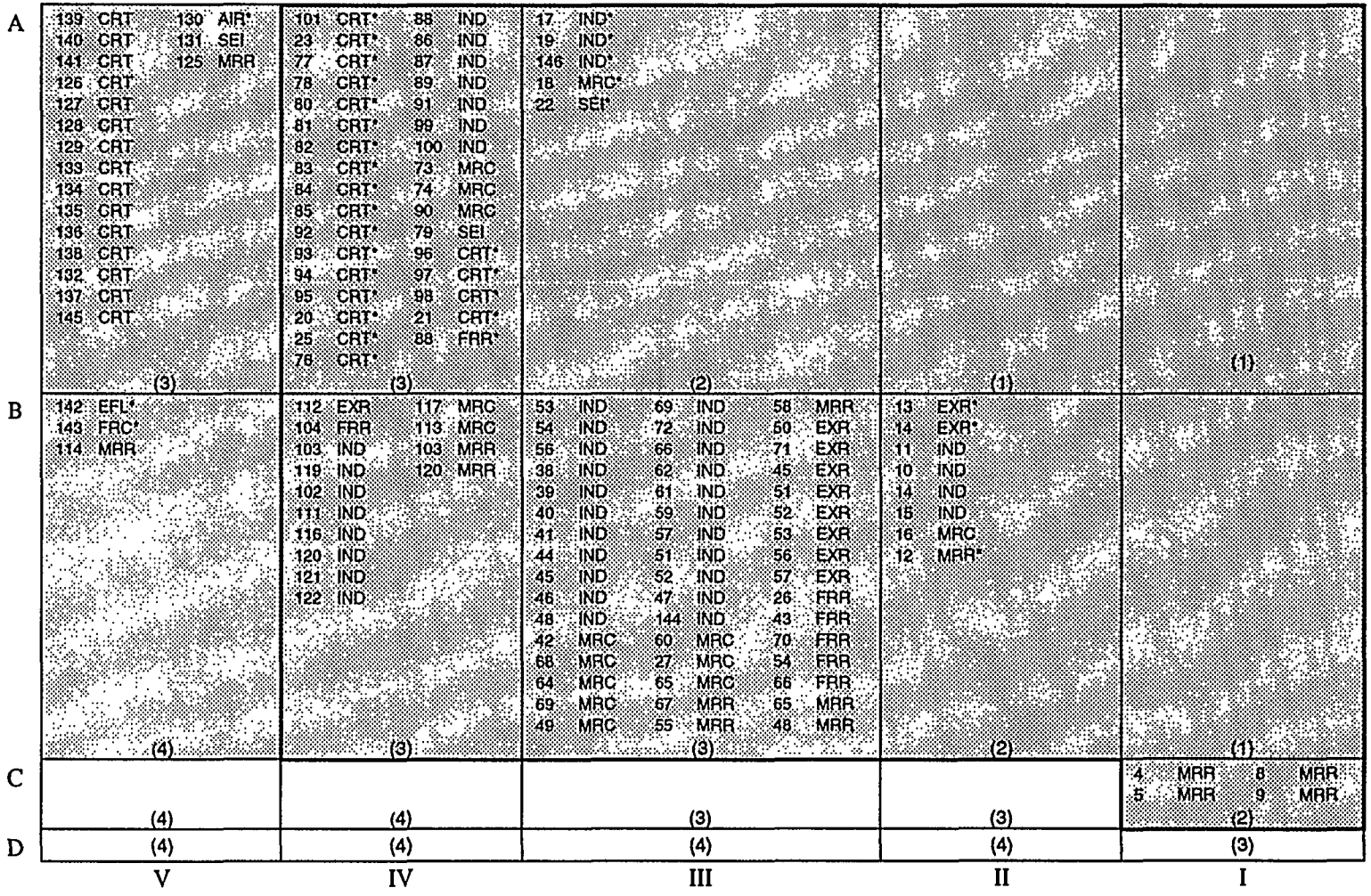

Fig. 2. Risk matrix for TA-55 Stage 1 scenarios affecting workers.

Table 5. Stage 2 screening scenarios for the TA-55 FSAR.

Type	Public	Co-Located Worker	Worker	Environment	Combined Scenarios
MRC	27 III B 2	27 III B 3	18 III A 2		18 27
MRR	75 IV A 3	75 IV A 3	12 II B 2	29 III B 2 33 III B 2 30 III B 2 34 III B 2 37 III B 2 35 III B 2 31 III B 2 36 III B 2 32 III B 2	75 32 12 33 29 34 30 35 37 36 31
SEI	79 IV B 3 131 V A 3	79 IV B 3 131 V A 3	22 III A 2	22 III B 2	22 79 131
CRT			20 IV A 3 21 IV A 3 23 IV A 3 25 IV A 3 101 IV A 3 77 IV A 3 78 IV A 3 80 IV A 3 81 IV A 3 82 IV A 3 76 IV A 3 83 IV A 3 84 IV A 3 85 IV A 3 92 IV A 3 93 IV A 3 94 IV A 3 95 IV A 3 96 IV A 3 97 IV A 3 98 IV A 3	20 IV B 3 83 IV B 3 21 IV B 3 84 IV B 3 23 IV B 3 85 IV B 3 25 IV B 3 92 IV B 3 101 IV B 3 93 IV B 3 77 IV B 3 94 IV B 3 78 IV B 3 95 IV B 3 80 IV B 3 96 IV B 3 81 IV B 3 97 IV B 3 82 IV B 3 98 IV B 3 76 iv B 3	101 83 20 84 21 85 23 92 25 93 77 94 78 95 80 96 81 97 82 98 76
IND			17 III A 2 19 III A 2 146 III A 2		17 19 146
EXR			13 II B 2 14 II B 2		13 14
FRR			88 IV A 3	26 III B 2 28 III B 2	26 28 88
AIR			130 V A 3		130
EFL			142 V B 4	142 V B 4	142
FRC			143 V B 4		143

Note: Table entries denote Scenario #, Frequency Category, Consequence Category, and Risk Level.