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HUMAN ERROR MODEL ADAPTATION AND VALIDATION FOR SAVANNAH RIVER SITE NONREACTOR FACILITIES

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INTRODUCTION

As part of an overall effort to improve safety analysis methods for the Savannah River Site (SRS) nonreactor nuclear facilities, a comprehensive human reliability analysis (HRA) methodology has been developed and selectively validated. The HRA methodology covers a wide variety of human errors that may exist in risk analyses of the nonreactor nuclear facilities. Such risk analyses are an integral part of safety analysis reports (SARs) at the SRS, forming the basis for severe accident analysis and assisting in the identification of safety classes for equipment. Nonreactor nuclear facilities at the SRS include nuclear fuel fabrication and reprocessing, nuclear waste processing, and nuclear waste storage and disposal.

The SRS HRA methodology improvement included both adaptation of existing human error models and validation of selected model results with SRS-specific data on actual human errors. The data were obtained from three existing SRS data bases: 1) Fuel Processing, 2) Fuel Fabrication, and 3) Waste Management. These three are part of the Risk Analysis Methodology (RAM) Fault Tree data banks. Events in these data banks are obtained from a wide variety of sources, including operator log books, occurrence reports, safety newsletters, and others. Validation of the human error models involved comparison with SRS-specific data and calibration of model results where appropriate.

Development of the SRS HRA methodology involved a six-step process:

1. Generation of a comprehensive list of human errors applicable to the SRS nonreactor nuclear facilities

2. Adaptation of HRA models

3. Collection of SRS-specific human error data

4. Validation and calibration of SRS HRA models, using SRS-specific data

5. Independent peer review of the final SRS HRA models

6. Documentation of the methodology.

The first four steps are discussed in the remainder of this paper. Conclusions concerning the overall project are also presented.

LIST OF REPRESENTATIVE SRS HUMAN ERRORS

Risk models of SRS nonreactor nuclear facilities may include initiating event fault trees, event trees, and/or fault trees for event tree top events. These models contain a wide variety of human errors from many different types of facilities. A comprehensive SRS HRA methodology must cover most, if not all, of these types of human errors. Also, this methodology should apply to future nuclear facilities or facility changes at the SRS. The comprehensive list of SRS human errors was developed with both goals in mind.

An initial list of representative human errors was generated using three basic inputs:

1. Review of existing SRS nonreactor SARs to identify human error events in risk models

2. Review of typical human errors being modeled in ongoing SAR upgrade efforts

3. Limited review of actual human errors listed in the RAM Fault Tree data banks (1991 - 1993).

Given these inputs, a list of approximately 25 representative human errors was generated. This list was expanded to the final 34 events when concerns associated with completeness and applicability to future facilities were addressed. The final list of 34 human errors is presented in Table 1. The list includes typical events such as miscalibration, failure to respond to an alarm, misdiagnosis, and selection of incorrect controls. Also, for waste management facilities there are events associated with manual fire suppression, forklift and crane operations, and transportation.

ADAPTATION OF HRA MODELS

Given the 34 representative human error events in Table 1, an applicable human error model and quantification methodology was desired for each. To accomplish this, a limited survey of HRA practices at other Department of Energy (DOE) sites was conducted. Results of the survey indicated that the Technique for Human Error Rate Prediction (THERP)[1] and Accident Sequence Evaluation Program (ASEP)[2] methodologies were most widely used. Also some limited use has been made of INTENT[3] and Human Cognitive Reliability (HCR).[4]

Model adaptation for the 34 SRS human errors involved choosing one of these four models (or others as appropriate) for each error, identifying the influencing factors that result in different human error probabilities, developing a representative set of three probabilities (low, medium, and high) to cover these influencing factors, and providing guidance for deciding which value is appropriate for the application in question. Results of this process for seven of the 34 SRS human errors are presented in Table 2. The generic human error probabilities presented in the table reflect SRS practices, where appropriate, but do not reflect actual SRS experience.

Table 1. Representative human error events.

Basic	
	Failure to notice/respond to an alarm/annunciator/other compelling signal
	Failure to verify status of instrument/control in control room
	Failure to verify status of instrument/control outside control room
	Error in selecting or operating a control in control room
	Error in selecting or operating a control/component outside control room
	Communication error
	Failure of supervisor/checker authorization/verification
	Incorrect reading/recording of data
Complex	
	Miscalibration
	Failure to restore following test
	Failure to restore following maintenance
	Failure of administrative control
	Diagnosis error
	Failure to lock out
	Chemical addition/elution error
	Transfer error (transfer liquid to incorrect tank)
	Overfilling of tank
	Failure of visual inspection
	Analysis error (laboratory operations)
	Failure to verify parameter with calculation
	Incorrect labeling/tagging
	Failure of manual fire detection
	Failure of fire suppression by occupant
	Failure of fire suppression by non-occupant
	Random actuation/shutdown of component/system
	Failure of accident recovery over hours or days
	Vehicle collision with stationary object
	Single vehicle accident during transportation
	Vehicle collision with another vehicle during transportation
	Dropping of load when using forklift
	Puncturing of load with forklift forks
	Dropping of load when using hoist/crane
	Impact of hoist/crane with stationary object
	Excavation errors

COLLECTION OF SRS-SPECIFIC HUMAN ERROR DATA

Human error data at the SRS were collected by performing searches on the RAM Fault Tree data banks to determine the numbers of events and by interviewing operations personnel to estimate the numbers of opportunities for such errors. Results are summarized in Table 2 for selected human errors. Based on the interviews with operations personnel, the actual numbers of events may be as high as twice that reported in the RAM Fault Tree data banks. This underreporting is mainly the result of differing requirements for the data banks compared with this project. Also, the estimates for numbers of opportunities were estimated to have an uncertainty range of plus or minus fifty percent.

Table 2. Selected SRS human error models and data.

SRS Human Error	HRA Model Used to Determine Generic Human Error Probabilities	Generic Human Error Mean Probability (low, medium, and high)[a]	SRS Data[a]	SRS-Specific Human Error Mean Probability (low, medium, and high)[a,b]
Error in selecting or operating a control in control room	THERP	3.0E-3, 6.0E-3, 1.5E-2	4 events in 1000 attempts	3.0E-3, 5.0E-3, 1.0E-2
Error in selecting or operating a control/component outside the control room	THERP	5.0E-3, 1.0E-2, 2.5E-2	8 events in 1000 attempts	5.0E-3, 1.0E-2, 3.0E-2
Miscalibration	THERP	6.0E-4, 3.0E-3, 1.5E-2	5 events in 22500 attempts	1.0E-4, 5.0E-4, 3.0E-3
Transfer error	THERP	1.0E-5/h-tank, 5.0E-5/h-tank, 1.0E-4/h-tank	55 events in 250000 tank-hours	3.0E-5/h-tank, 1.0E-4/h-tank, 3.0E-4/h-tank
Diagnosis error	HCR, INTENT	1.0E-3, 1.0E-2, 1.0E-1	2 events in 1000 attempts	5.0E-4, 5.0E-3, 5.0E-2
Random actuation/shutdown of component/system	None identified		8 events in 100000 system-hours	1.0E-5/h-system, 1.0E-4/h-system, 1.0E-3/h-system
Dropping of load when using hoist/crane	Generic data	1.3E-5/h, 1.3E-4/h, 1.3E-3/h	4 events in 10000 h	3.0E-5/h, 3.0E-4/h, 3.0E-3/h

a. These numbers may change in the final draft of the paper.

b. The results were rounded to 1, 3, or 5 times the appropriate power of ten.

VALIDATION AND CALIBRATION OF SRS HRA MODELS

The SRS-specific human error data were used to validate or calibrate the HRA models and error probabilities shown in Table 2. As an example, for the selection error outside the control room (second entry in Table 2), the SRS data indicate eight such events in 1000 opportunities. Not enough events with detailed descriptions were identified to try to determine the impact of influence factors on the human failure probabilities. However, the SRS data were used in a Bayesian update process, using the medium generic estimate as a prior, assuming a lognormal distribution for the prior and an error factor of ten.[5] The magnitude of the change in the generic estimate caused by the Bayesian update was also applied to the low and high generic failure probabilities. The results were then rounded to 1, 3, or 5 times the appropriate power of ten. This process was used to calibrate six of the seven human errors listed in Table 2. The remaining human error event, "random shutdown/actuation of component/system," was quantified using a Bayesian update of a noninformative prior[5], because no generic model was identified.

None of the SRS data contained sufficient information to determine the impacts of influence factors on the human error probabilities. However, the data were sufficient to calibrate the medium generic error probability.

CONCLUSIONS

The SRS HRA model development has resulted in a set of three human error probabilities for each of the 34 representative human errors. In addition, most of the probabilities were modified based on SRS-specific data. This site-specific data collection was important, because the data resulted in up to a factor of ten change in the generic model results. However, the data collection was not detailed enough to discern impacts of influence factors on the probabilities.

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