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HUMAN RELIABILITY ANALYSIS FOR SEISMIC EVENTS

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March 1994

Presented at the
Probabilistic Safety Assessment &
Management Conference
San Diego, California

Work supported by
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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ABSTRACT

This paper presents the human reliability analysis (HRA) for selected post-accident human actions for potential seismic events at the Savannah River Site K-Reactor. This HRA was performed in support of Revision 1 to the probabilistic risk assessment (PRA) for the K-Reactor and provides human error probabilities for use in this PRA. This work was funded by the U.S. Department of Energy and was jointly managed and performed by the Westinghouse Savannah River Company and Pacific Northwest Laboratory.

1.0 INTRODUCTION

Under sponsorship from the U.S. Department of Energy, Pacific Northwest Laboratory (PNL)[a] collaborated with the Westinghouse Savannah River Company (WSRC) to perform a human reliability analysis (HRA) in support of revisions to the K-Reactor probabilistic risk assessment (PRA) for the Savannah River Site (SRS). The overall goal of this effort was to identify and apply a methodology for performing an HRA in the event of a seismic occurrence.

Analysis of human responses to an earthquake raises numerous questions that push the limits of HRA methodology. Modeling human behavior in response to infrequent and extreme circumstances, such as seismic events, requires treatment of very limited quantities of data on human actions performed under high-stress conditions, and a great deal of uncertainty.

In this collaborative study, evaluating HRA methodology related to seismic events included the following activities:

1. Identifying and applying an HRA methodology that is consistent with that used in other recently published PRAs (e.g., NUREG-1150) that have received broad acceptance.
2. Performing and documenting supporting task analyses and data evaluations that provide the bases for obtaining realistic human error probability (HEP) and uncertainty values.
3. Providing HEP values as input to the revised K-Reactor PRA for SRS.
4. Identifying areas that may reduce HEP values and have potential contribution to risk associated with seismic events.

This paper presents results of the human reliability analysis. Details of the evaluation are to be published as a PNL document at a later date.

(a) Pacific Northwest Laboratory is operated by Battelle Memorial Institute for the U.S. Department of Energy.

2.0 REVIEW AND SELECT HRA METHODOLOGY

State-of-the-art HRA methodologies were reviewed for the purpose of selecting the methodology best suited for estimating HEPs associated with seismic events (Mitts and Vo 1992). Based on this review, the THERP or ASEP methodologies were the recommended approaches for use in evaluating the HRA to support revisions of the SRS PRA. Test applications of the THERP and ASEP methodologies were also performed in support of this HRA effort (study by van Bujjtenen et al. 1993, to be published). Based on results of test applications, the ASEP methodology was chosen for this study. Use of the ASEP methodology provides the same benefits as using THERP methodology, but requires significantly fewer staff resources to perform.

The following key activities were performed while using the ASEP methodology as the basic approach.

- Construct HRA-Event Trees

The HRA-event trees were constructed for selected portions of the SRS seismic event Master Control Procedure DPSOL 105 MC-28-K or MC-28.[a] Procedure MC-28 is the main procedure used by the central control room (CCR) and others when responding to a seismic event. This activity included a detailed review of the appropriate operating procedures and development of task analyses.

- Evaluate Performance-Shaping Factors

This activity involved: 1) evaluation of performance-shaping factors (PSFs) and uncertainty bounds for human actions modeled in the HRA-event trees, and 2) the disposition of judgment issues in assessing HEP values. A seismic intensity level of 0.35G was selected as a threshold value for the analysis. This value was selected based on existing WSRC studies and on recommendations from experienced WSRC staff.

(a) Internal procedures for the Savannah River Site K-Reactor: DPSOL 105-MC-28-K, MC-28B-K, MC28C-K, MC-28D-K.

- Quantify Human Error Probabilities

Completion of the above steps led to quantifying HRA-event trees to obtain the overall HEP values for the human actions evaluated in this study. This effort also included identifying potential improvements, such as potential changes to procedure MC-28, that may reduce HEP values.

3.0 ANALYSIS

This section describes the analysis of HRA application for seismic events. Specific details of the analyses can be found in Benhardt et al. (1993, to be published). The analysis includes the following tasks: 1) data collection and evaluation, and 2) application of the methodology.

3 1 DATA COLLECTION AND EVALUATION

This task included preparation for data collection and evaluation, desktop procedure review, plant walkdown, and simulator review.

3.1.1 Preparation for Data Collection

One of the first steps in the HRA process was the development of a systematic method for collecting and consolidating information used in the analysis. Second, a task analysis format (or form) was developed that incorporated the information required to support the data collection task. The task analysis approach to HRA development included the following steps:

- identification of a consistent method to identify specific actions throughout the process
- identification of the individual(s) taking the action, and equipment used by the individual when carrying out the action
- description of the action to be taken by the individual
- feedback so the individual knows that the action taken has been completed or is successful
- identification of the exact location where the action takes place, and the time required to perform the action

- assessment of errors that an individual might make in performing the action
- identification of information that may influence the way the individual performs the action.

3.1.2 Desktop Procedure Review

The task analysis began by developing a task list based on the MC-28 procedures (MC-28B, MC-28C, and MC-28D). The individual steps of each procedure were considered as tasks that needed to be performed by an operator. Each of these steps was analyzed to determine if the step actually consisted of multiple tasks or task activities. Based on this analysis, appropriate additions were made to the task list.

3.1.3 Plant Walkdown

The walkdown was a planned and coordinated activity that involved the HRA analysts, personnel familiar with plant operations, and personnel familiar with the design of the systems. Two plant walkdowns were conducted during the course of this study. The walkdowns involved general orientation of the K-Reactor and its systems, as well as visits to the areas where activities described in the MC-28 procedures were performed. Video cassette recordings of plant operators performing the actions of the MC-28 procedures were also reviewed.

3.1.4 Simulator Review

The simulator offered the analyst an opportunity to view details of the procedures that can not normally be observed in the control room. In addition to studying details of control room actions, the simulator staff and training records provided valuable data on operator training and experience levels. A walkdown was conducted in the reactor control room simulator to perform a step-through review of the MC-28 procedures. This walkdown provided data for the task analysis that was used to conduct the ASEP analysis. In addition, other plant relevant, information and site-specific documentation were reviewed.

3.2 APPLICATION OF METHODOLOGY

Human actions that impact plant safety, in the event of a seismic occurrence, were selected for HRA evaluation. The following specific actions, as identified in the SRS K-Reactor PRA were selected for the analysis:

- Start of recirculation pumps per MC-28 (Step 14 and MC-28C).
- Trip supplementary safety system (SSS) per MC-27 (step 2) and MC-28 (steps 2 and 3).
- Start of recirculation pump diesel generators (DGs) per MC-28C (steps N8.1 through N8.8).
- Set automatic transfer switch (ATS) for the recirculation pump DGs per MC-28C (Step 13a).
- Operate moderator recovery system (MRS) per MC-28 (step 23 and MC-28D).
- Close heat exchanger isolation valves per MC-28 (steps N30 and N31).

The ASEP approach was used to perform the HRA for these specific operator actions using the task analysis associated with the following procedures: MC-28, MC-28B, MC-28C, and MC-28D. ASEP HRA-tables and HRA-event trees were constructed to model critical human actions for responding to seismic events. Evaluation of individual actions in the task list was performed to assign an HEP values and associated error factors from the tables provided in NUREG/CR-4772. Once the HEP values were assigned, the ASEP tables, and tree models, as well as items in the task list, were reevaluated to include dependencies and PSFs.

The PSFs applied to the tasks included considerations of seismic intensity, location of the action, and availability of personnel to perform the action. Other PSFs were inherent in the conservative values in the ASEP tables. Considerations were evaluated on the basis of the simplified task analysis and with knowledge of human action steps from the governing procedures. Provision to perform a more detailed and thorough HRA for a given human action or subtask exists within the ASEP methodology by applying the THERP methodology. However, additional data and information must be obtained before applying the THERP methodology.

Once HEPs were assigned and modified to reflect the performance environment and the effects of dependence, the individual error probabilities and uncertainty bounds were propagated through the HRA-event trees to determine the final probabilities and uncertainty bounds. Generally, error factors obtained from the ASEP HEP tables (NUREG 4772) were used for the actions considered.

4.0 RESULTS AND DISCUSSION

Table 1 summarizes results applicable to the SRS K-Reactor PRA for seismic events. Results show that "Moderator Recovery System (MRS) Activation" has the highest HEP values at seismic intensity levels both less than and greater than 0.35G. These actions are performed under extremely high stress and involve several dynamic tasks with dependence between some actions. In addition, this task requires radio communication and coordinated efforts among personnel in various locations. At seismic intensity levels greater than

TABLE 1. HRA Results for Selected Human Actions for PRA

Procedure Action	Total HEP[a] @ <0.35G	Total HEP[a] @ >0.35G
MC-28D MRS Activation	3.0E-1	8.8E-1
MC-28 Throttle Heat Exchanger Valves	1.2E-1	6.6E-1
MC-28C Start Recirculation Pumps	6.3E-2	5.0E-3
MC-28C Set ATS for Recirculation Pump Diesel Generators	3.0E-3	1.9E-1
MC-28C Start Recirculation Pump Diesel Generators	1.0E-3	5.0E-2
MC-28 SSS Activation	2.5E-4	2.5E-4

(a) These results present "best estimate" HEP values. An error factor of 5 is used to address uncertainties for the HEP values, except for the MC-28C (Set ATS for Recirculation DGs) HEP values, which have an error factor of 10.

0.35G, access to the seismic MRS control stations could be impeded because of equipment damage, jammed doors, etc. This contributes to the highest estimated HEP values.

High HEP values were also found for the action of "Throttling Heat Exchanger Valves." The high values were attributed to the extremely high-stress conditions under which staff operated. The actions are dynamic and require radio communication and coordinated efforts among personnel in various locations. Actions involve manually closing ten 24-inch gate valves to throttle the heat exchanger flow and maintaining the ultimate heat sink (within 4.5 hours). Because of potentially damaged structures and systems, access and personnel availability to perform these actions may be restricted at seismic intensity levels above 0.35G.

The human action with the next highest HEP value was "Start Recirculation Pumps." The high HEP value for this action is driven by the dynamic nature of the situation in the CCR where MC-28C must be assigned and initiated. The HEP value is higher at seismic event intensities greater than 0.35G because the likelihood of visible structural damage and potential failed systems will cause stress levels to be extremely high. The HEP values for "Starting the Recirculation Diesel Generators" and "Setting the Automatic Transfer Switch" are considerably lower because the possibility of failing to initiate MC-28C is already accounted for in the HEP value for "Starting the Recirculation Pump."

The last human action, "Supplementary Safety System Activation," is a simple task that can be completed from the CCR; therefore, the HEP value for MC-28 is relatively low. This HEP value does not change for a seismic intensity level greater than 0.35G because the action is performed within the control room by personnel dedicated to these positions and functions.

The results, as presented in Table 1, are based on "best estimates" with uncertainty estimates based on error factors of 5, except for diagnosis actions, which have an error factor of 10. Analyses were based on assumptions made using plant-specific information and on WSRC staff experience. Thus, these results are plant specific and should be interpreted cautiously.

5.0 ACKNOWLEDGMENTS

The authors wish to acknowledge the direction and support provided by Dr. K. Jamali, DOE Project Manager, and Carl E. Beyer, PNL Project Manager. Acknowledgments are also addressed to H. Benhardt, A. Beyrer, K. O'Kula, and S. Topp, Westinghouse Savannah River Company, B. F. Gore, PNL, and W. Wheeler, Human Affairs Research Center, for their contributions to this work.

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