UNITED STATES
NUCLEAR REGULATORY COMMISSION
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APR 27 1988

MEMORANDUM FOR: Hugh L. Thompson, Jr., Director
Office of Nuclear Material Safety and Safeguards

FROM: Eric S. Beckjord, Director
Office of Nuclear Regulatory Research

SUBJECT: TRANSMITTAL OF RESEARCH INFORMATION LETTER WITH RESPECT TO A METHODOLOGY TO ASSESS SAFETY DURING THE PRECLOSURE PERIOD OF A HIGH-LEVEL WASTE REPOSITORY RIL NO. 153

Enclosed are the Final Reports and accompanying Research Information Letter for research project FIN A1380, "High-Level Waste Preclosure Safety System Analysis." The design and operation of a high-level waste (HLW) repository by the DOE must comply with the NRC's HLW rule (10 CFR Part 60). The research project was initiated to develop a methodology, based upon existing quantitative techniques, to assess safety during the preclosure phase of repository development. The project consisted of a development phase (gathering, organizing, and assembling of information pertinent to the safety assessment of a nuclear waste repository during preclosure operations) and a demonstration phase. The developed methodology offers a systematic means of assessing the safety of operations and design of the preclosure period of a repository. The final reports (Phase 1 and Phase 2) provide documentation of the methodology and detail an application of the methodology on a sample problem. The application was done to test the utility of the methodology to identify structures, systems, components, and operations important to safety. If you have any questions, please contact Tim McCartin of my staff on extension 23847.

Eric S. Beckjord, Director
Office of Nuclear Regulatory Research

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RESEARCH INFORMATION LETTER ON THE SAFETY ASSESSMENT OF THE DESIGN AND OPERATION OF A HIGH-LEVEL WASTE REPOSITORY

BACKGROUND:

The performance objectives of 10 CFR Part 60 require the DOE to design and operate the geologic repository operations area to ensure that radiation exposures are within the limits set forth in 10 CFR 60.111a. The design requirements of 10 CFR 60.132.a2 require the DOE to identify structures, systems, and components important to safety. The DOE is also required by 10 CFR 60 Subpart G to implement a quality assurance program for "all activities affecting the safety related functions of those structures, systems, and components that prevent or mitigate events that would cause unreasonable risk to the health and safety of the public." The NRC licensing staff will need to determine if the DOE has made proper identification of all structures, systems, and components important to safety and has taken appropriate design and operation measures to assure compliance with the dose limits in 10 CFR 60.111a. In response to this need, the Office of Nuclear Regulatory Research initiated a project at Sandia National Laboratories to develop and subsequently demonstrate the applicability of a systematic methodology that would allow NMSS staff to perform an independent evaluation of the DOE's identification and quantitative prioritization of those structures, systems, components, and operations which are most important to safety during the preclosure phase of repository development.

RESEARCH FINDINGS

The contractor has completed development of a methodology to analyze safety during the preclosure phase of repository development (phase 1) and demonstrated use of the methodology by quantifying a sample problem consisting of a small subset of accident scenarios (phase 2). Due to the interrelationship between the development of a methodology and demonstration of its use, both phase 1 and phase 2 final reports are discussed in this summary.

Phase 1 METHODOLOGY DEVELOPMENT

In order to best understand and detail the types of problems to be addressed, methodology development began with a detailed analysis of the movement of high-level waste from its arrival at the repository site boundary until final borehole placement. The contractor obtained system design and details on individual operations/processes from a published report on a conceptual repository in basalt (J. M. Davis, "Conceptual System Design Description, Nuclear Waste Repository in Basalt," BWI-SD-005 (3 Vols), April 1983. Although the conceptual repository was sited in basalt, the design and operation of surface and subterranean equipment and facilities of a geologic repository is thought to be predominantly media independent.). This information was then analysed to identify equipment failures or human actions capable of process disruption, local personnel exposure/occupational injury, or challenge of facility barriers to radionuclide release (Phase 1 Final Report, Section 2.0). The contractor used this description of a repository system to identify the types of analyses to be included in the methodology and then evaluated existing quantitative methods and data for use in the preclosure methodology.

The contractor recommended a suite of quantitative tools to form the calculational framework of the methodology and provided a preliminary list of relevant data(see Sections 3-7 Phase 1 Final Report). The recommended techniques address the areas of consequence calculation, probability calculation (fault tree and event tree techniques), and the ranking of components and operations important to safety. Data, pertaining to the probabilities of accidents and calculation of consequences, were collected from the literature and government and industry data banks. The data base was grouped into the following categories; 1) initiating event frequencies, 2) intermediate event probability data, 3) basic event failure data, 4) human error rates, 5) radiological data, and 6) occupational injury data.

Phase 2 METHODOLOGY DEMONSTRATION

Having completed the gathering, organizing, and assembling of information and techniques and tools necessary to perform a safety assessment of a nuclear waste repository during preclosure operations, the contractor used the methodology to: 1) analyze accident sequences and probabilities for the five scenarios, 2) calculate consequences of the accidents, and 3) combine the consequences and probabilities of the accidents to rank the importance of the components and operations of the system.

Sample Problem Definition

The contractor selected a small sample problem to both demonstrate the applicability of the proposed methodology and show its utility to identify and quantitatively prioritize components and operations which are important to safety (Phase 2). Although limited in scope, the sample problem was selected to cover a meaningful spectrum of preclosure operations and facility designs. The events selected for the sample problem encompassed operational errors, equipment failure, and natural events. Specifically, five scenarios tested the methodology: 1) liquid radwaste leakage from a process tank; 2) fall of a transfer cask down the repository shaft; 3) cask transport vehicle collision and resulting fire in the waste placement room; 4) canister breach during borehole insertion; and 5) surface facility hot cell damage due to an earthquake (Section 2, Phase 2 Final Report).

Accident Consequence and Probability Calculations

The analysis of acccident sequences and probabilities made use of event tree/fault tree analyses to systematically identify an abnormal occurrence (initiating event) coupled to system and operator actions (intermediate events) capable of influencing event consequences. The combination of initiating event and subsequent intermediate events define an accident scenario. Accident frequencies were then calculated using: 1) data based on industry and vendor statistics (i.e., failure rate of blower motors), extrapolation of experience of similar fuel cycle facilities (i.e., hot cell facility), and extrapolation of mining accident statistics; 2) common-cause failure analysis (the SETS computer program was used for this analysis); and 3) human reliability analysis (the Technique for Human Error Rate Prediction, THERP, was used to evaluate human reliability).

After the calculation of probabilities, the next step in the methodology is to calculate the radiological consequence of the accident. The consequence of concern during preclosure operations is a public radiological exposure. The only exposure pathway likely to result in a significant consequence is the air pathway. Therefore, the CRAC-2 computer program was used for calculating consequence. This program consists of a set of models that simulate radioactive material as it disperses downwind from a point source, deposition onto the ground, and the biological effects of airborne and deposited material on man.

Importance Measure Calculation

The contactor completed the demonstration by combining the accident probabilities and consequences to identify the components and operations important to safety. The VALUE computer program was used in calculating the Fussel-Vesely importance measure for: 1) analysing the fractional contribution of basic event failures to the overall system failure; and 2) ranking accident intermediate events according to their contribution to overall risk. Accident scenario two, a fall of the transfer cask down the shaft, was identified as the dominant risk contributor among the considered accidents. Of the events analysed, fuel canister/fuel rod failure due to excessive applied force, transfer cask failure, and shaft ventilation system failure were identified as major contributors to the total risk. Additionally, human error was found to be the dominant contributor to exhaust system failures, while, mechanical failures dominated the probability of the fall of a transfer cask down the shaft. The methodology, although performed on a limited number of accident scenarios, was able to identify and quantitatively prioritize systems, subsystems, and operations important to safety during the preclosure phase of a repository.

REGULATORY IMPLICATIONS

The preclosure safety analysis project developed a methodology that NMSS staff can use to assess safety during the preclosure phase of a nuclear repository. This project developed event trees and fault trees, evaluated accident consequences, gathered data for the quantitative evaluation of a repository system, and demonstrated the methodology using a sample problem. The application of the methodology to the sample problem demonstrated its usefulness in identifying and prioritizing components and operations important to safety.

Caution should be exercised in reading this report as the usefulness of this project is not the numerical results of the demonstration. In fact, due to the limited scope of the sample problem, the results should not even be considered as bounding estimates of risk. The primary value of this project is its documentation of a methodology for identifying structures, systems, and components important to safety (Q-List). The methodology can be used by licensing staff in their evaluations of the DOE repository design and in current discussions with the DOE on strategies for identifying items to be placed on Q-list.

As this is the first documented methodology to comprehensively assess safety during the preclosure phase of a repository, certain tasks provided other benefits independently useful outside of their use in the methodology development. For example, the contractor compiled a mine-related data base and performed an analysis of human reliability with respect to repository operations. This will be useful to the staff in various ways. First, the mine-related data provides NRC with accident statistics that can be used for analysing the safety of subterranean activities and equipment of the DOE design. Second, the human reliability of the repository operations was analysed and provided a number of insights on design and human factors (Phase 2 Final Report, Section 4).

Other recommendations by the contractor may well be of use to the NMSS staff. Based on the anticipated high stress environment of the subterranean workers, the contractor recommended: 1) worker training and experience must be commensurate with the expected working conditions; and 2) enhancement of human reliability should be accounted for in the early stages of design. Additionally, the contractor provided a number of specific design recommendations (Phase 2 Final Report, Section 4.1) which can aid licensing staff review of the DOE design.

The development stage of the preclosure safety methodology has been completed with the publication of the Phase 1 and Phase 2 final reports. The methodology provides licensing staff with a means to systematically assess safety of operations and design of the repository during the preclosure phase of development. The methodology and associated documentation can assist and help direct reviews as the DOE repository design matures.