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PSA-OPERATIONS SYNERGISM FOR THE ADVANCED TEST REACTOR SHUTDOWN OPERATIONS PSA

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ABSTRACT

The ATR PSA update for shutdown operations, cask handling, and canal draining is a successful example of the importance of good PSA-operations synergism for achieving a realistic and accepted assessment of the risks and for achieving desired risk reduction and safety improvement in a best and cost-effective manner. The implementation of the agreed-upon upgrades and improvements resulted in the reductions in the estimated mean frequency for core or canal irradiated fuel uncovery events shown in Table 1, a total reduction in risk by a factor of nearly 1000 to a very low and acceptable risk level for potentially severe events.

I. INTRODUCTION

The Advanced Test Reactor (ATR) is a Department of Energy (DOE), high neutron flux materials irradiation test reactor located at the large Idaho National Engineering Laboratory (INEL) reservation in Eastern Idaho. The ATR has frequent scheduled shutdowns for refueling and experiment changes, 10 to 15 a year, and a lot of the operations activity at ATR is associated with shutdown operations. A probabilistic safety assessment (PSA) for shutdown operations, heavy load (cask) handling, and storage canal draining events for the ATR, referred to as the ATR shutdown PSA, was completed in 1994. Important to these operations and to the ATR are fuel and experiment transfer operations and storage in the ATR working and storage canals and movements of irradiated experiment assemblies and used ATR fuel in heavy casks. Therefore, much of the shutdown PSA focused on these operations outside of the reactor system, which included canal and heavy load movement operations when the reactor itself was operating at power. The shutdown PSA identified a need for significant risk reduction actions. Therefore, as has been the approach at ATR since the PSA effort first began in 1987, recommendations and upgrades for risk reduction were pursued in parallel with the PSA completion such that the documented PSA and PSA models incorporated most of the risk reduction measures. The identified facility and operational upgrades for risk-reduction were completed in mid-1995.

The ATR shutdown PSA was successful because: 1. The PSA resulted in a realistic, believable, and accepted assessment of the risks of the analyzed operations and systems; 2. the PSA identified important risk vulnerabilities that represented an unacceptable level of risk for high consequence accidents; and 3. in parallel with the PSA development, risk-effective and cost-effective risk-reduction measures were defined which could be reasonably implemented and readily accepted by operations management and DOE. Important to the success of the ATR shutdown PSA was the interfaces and cooperation between the ATR PSA project and ATR operations management and systems engineering personnel which resulted in a successful PSA-operations synergism.

The interfaces and cooperation between the PSA project and ATR operations and engineering was integral to and important to the ATR shutdown PSA in each of the phases of the PSA development.

A. During System Familiarization

The assistance of the ATR system engineers and safety analysts was essential to understanding the systems, their use, and potential accidents and consequences for shutdown operations, cask handling, and the ATR canal. An extensive safety investigation and analysis had been conducted for heavy load drop accidents at ATR shortly before the shutdown PSA effort began.

B. During Event Sequence Development

Facility and system walk downs were important in the development of accident sequences and event trees. Operations management and personnel participated in the walk downs and provided important information and insights for failure modes, operational interfaces, procedures and practices, and expected responses to off-normal conditions.

C. During Human Reliability Analyses

Operations management and personnel cooperated fully with the human factors analysts. Synergism between operations and the human factors analysts resolved important issues regarding control of heavy load movements to reduce the potential for load drops and to control the potential consequences of load drops.

D. During Reviews of PSA Sequences and Results

The draft results of the ATR shutdown PSA were distributed to the operations and maintenance and support engineering organizations for review and comment. A condensed summary of the shutdown PSA and its key results and input sufficient to provide busy personnel and managers with an overview of the PSA and an understanding of the important sequences was prepared and was important to this review. A list of important review questions was also developed and provided. A series of meetings were held to present the results and to discuss the results and obtain review feedback. This review process resulted in development of an understanding and appreciation by operations for the risks and the need to reduce the risks, and also an understanding and appreciation for the facility operations and the need to accommodate those operations by the PSA team. This synergism was essential to development of a successful and useful product.

E. Developing Risk-Reduction Recommendations

The effort expended to include operations in the development of the shutdown PSA and the open and cooperative review process paid off when it came to developing and implementing risk-reduction measures. Operations management had developed confidence and trust in the lead PSA analysts and cooperated fully in the development of risk-reduction recommendations. Walk downs were again performed with operations management to look for risk-reduction options and to help develop the most reasonable and cost-effective solutions. Those risk-reduction actions which could be directly implemented by operations were implemented promptly.

F. During Finalization of the ATR Shutdown PSA

Finalization of the ATR shutdown PSA and the risk-reduction recommendations required fine-tuning of the PSA and of remaining risk-reduction recommendations requiring engineering or operational upgrades. PSA-operations synergism was again important for this fine-tuning as the models, options, and recommendations were again reviewed for impact, costs, and reasonableness and changes were made in both the PSA and in the risk reduction recommendations.

Examples of the results of the successful synergism between the shutdown PSA team and operations, maintenance, and systems engineering are discussed in the following section. The final implemented upgrades and improvements have not all been incorporated into the full ATR PSA model, but will be incorporated into the current 1996 PSA update.

II. BENEFICIAL RISK REDUCTION UPGRADES AND OPERATIONAL IMPROVEMENTS

A. Shutdown LOCA Risk Reduction

One of the significant reactor fuel uncovery and damage risks identified by the ATR shutdown PSA was for a maintenance induced loss-of-coolant accident (LOCA) during shutdown or outage operations while irradiated fuel (fuel with a high enough decay power to result in fuel damage and fission product release if the fuel is uncovered by water) was still in the reactor core. In this accident sequence, an inadvertent or uncontrolled opening in the primary coolant system (or reactor coolant system) boundary in specific locations could drain the reactor vessel and uncover irradiated fuel remaining in the reactor core. Although about half of an outage is with an empty core, the shutdown or outage periods with irradiated fuel in the core are still significant, especially since irradiated fuel from a prior operating cycle is usually part of the next core loading.

Because of the potential inability to mitigate a vessel draining due to an opening in the vessel bottom closure, activities involving the vessel bottom closures were recommended to be restricted to when the core is unloaded. Since this was already the accepted but informal practice, the PSA simply emphasized the necessity of the restriction and resulted in formalizing the restriction in procedures and the Technical Specifications.

The other shutdown LOCA risk concern had to do with removal or dismantling of pumps or valves during shutdown. After several iterations between the PSA team and operations regarding recommendations for shutdown operations controls involving pumps or valves in the primary coolant system, appropriate controls and lock outs for isolation valves were agreed to and appropriate specifications were adopted that adequately control the shutdown LOCA risk. The other acceptable option was to restrict the disassembly or removal of the pumps or valves to when the core is unloaded. Unlike the infrequent occasions for activities involving the vessel bottom closures, the primary pump check valves have required frequent repair work and inspection of the valve internals. Therefore, a restriction for this type of operation to when the core was empty would unnecessarily lengthen the outage periods.

Good synergism between the PSA team and operations, maintenance, and systems engineers resulted in raising the risk and safety consciousness of operations concerning the potential for a shutdown LOCA and improved and formalized controls on those maintenance operations which were determined to most likely cause a severe shutdown LOCA.

B. Cask Handling in the Storage Canal

The most significant risk identified as a part of the shutdown operations, heavy load handling, and canal draining, risk assessment was for an uncovery of irradiated fuel stored in the ATR storage canal due to the potential for a dropped spent fuel transport cask or another routinely used cask into the canal. The ATR storage canal has an eight foot thick reinforced concrete floor and walls, but the canal is suspended over a lower ATR reactor building basement area. An analysis was performed for a heavy cask drop from above the canal which predicted that the canal floor would be crushed and turned to rubble. This consequence of a cask drop would result in a large leakage rate out of the canal into the lower basement of the reactor building and the stored irradiated fuel would have a significant probability of being uncovered.

Three significant upgrades were identified to greatly reduce the probability for canal floor damage and stored irradiated fuel uncovery.

1. Canal irradiated fuel storage area bulkhead. When the significant risk for irradiated fuel uncovery due to a canal cask drop event was defined early in the risk assessment, a short canal bulkhead was fabricated and installed to isolate the end of the canal containing stored irradiated fuel from the main working and storage canals and the cask handling area. With this upgrade, a cask drop or other canal draining initiator originating in the main canal activity areas would not uncover the irradiated fuel. This upgrade, plus the addition of a small canal emergency makeup line installed at the same time, reduced the frequency for uncovery of the stored irradiated fuel in the canal from 3.5E-3/yr to 4.3E-5/yr, a factor of 80 reduction and a reduction from a relatively probable level to a relatively improbable level.

2. Cask drop impact absorber pads. An old but wise saying is that the best medicine is prevention. It is also true and wise that the best mitigation is prevention. Therefore, it is desirable to not only isolate the irradiated fuel for potential canal draining events but to prevent damage to the canal due to a potential cask drop. An upgrade of the canal area overhead crane could reduce the estimated probability for a cask drop, but a crane upgrade would be very expensive and would still not affect the consequences of a drop. Cask drop impact absorber pads (or cask drop pads) were found to be in use at the Idaho Chemical Processing Plant. These pads were determined to be able to absorb the energy of a dropped cask from the maximum lift height above the ATR canal without damaging the floor without modification of the design even if the dropped cask contacted the pad with an edge impact. The pads are constructed of stainless steel plate and are filled with 508 mm thick high density polyurethane foam. With installation and use of a cask drop pad in the ATR canal cask loading area, the potential for a canal draining event due to a cask drop is nearly eliminated. Only very low probability cask drop and canal damage sequences remain involving cask movements over restricted zones (a Technical Specification violation) or a cask deflection or tipping scenario such that the cask misses the large cask drop pad.

3. Redundant and diverse emergency makeup. Redundant and diverse emergency makeup systems were eventually installed for the irradiated fuel storage area behind the short bulkhead in order to reduce the expected frequency for irradiated fuel uncovery to a very low level desired for an accident with a potentially severe release. These systems are not designed to prevent canal draining but only to prevent uncovery of the stored irradiated fuel. Even though the short bulkhead will prevent irradiated fuel uncovery, except for a few very

low frequency initiating event sequences originating in the stored irradiated fuel area, the bulkhead may be expected to leak into an adjacent but drained canal area. Therefore, the emergency makeup is needed to make up for bulkhead leakage plus heatup and evaporation of the water due to the decay heat of the irradiated fuel. These systems are discussed more under the example of the following section II.C.

These three upgrades to the ATR storage canal and for canal operations reduced the frequency for canal stored irradiated fuel uncovery to a very low level (by more than a factor of 200, see Table 1) and brought this previously unrecognized risk under control.

C. Canal Irradiated Fuel Emergency Makeup

The synergism between the shutdown PSA team and systems engineering and operations was fruitful regarding the design of the canal stored irradiated fuel area emergency makeup systems. Redundant and diverse systems were defined as required in order to reduce the irradiated fuel uncovery frequency to a very low level with which the Department of Energy and operating contractor management were comfortable. The risk goal for canal irradiated fuel uncovery such that the potentially severe event would not be likely to occur was a goal of below 1E-6/yr for all sequences and below 1E-7/yr for any specific event sequence. A manually actuated system, but readily accessible right at the canal, was installed in quick response to the first revelations of the serious risk for irradiated fuel uncovery, along with the isolation of the irradiated fuel behind a short bulkhead. This system is supplied by the same demineralized water source used for normal canal makeup. The preferred water source for the redundant system was fire water since this source was fully redundant and diverse to the demineralized water and is capable of being available even during a total power outage or following a design basis earthquake. However, operations was concerned with the potential for inadvertent discharge of untreated water into the canal. Systems engineering was concerned with the operability, installation and costs. Design alternatives were evaluated including the acceptability of alternatives to even having a redundant makeup system. The PSA was used to evaluate the alternatives. Iterations between the PSA team, operations and engineering resulted in a simple, leak resistant design (the risk assessment determined that the risk goals could be achieved with series valves) which would automatically actuate but only at a very low canal level indicative of a failure to mitigate canal draining.

D. Human Factors for Cask Transport by Forklift

Human factors synergism with canal operations was required to respond to a significant identified risk associated with a possible drop of an isotope or experiment cask being transported into and out of the canal operations area by a large forklift. An area of the canal operations area floor is risk sensitive to a potential cask drop because a drop over the sensitive area could result in damage to primary piping in a pipe tunnel running under and perpendicular to the canal. A drop over this area could result in a reactor loss-of-coolant.

Human reliability analyses were performed for the forklift operation to define the probability for a dropped load as well as to define procedures and other means to adequately reduce the probability for a drop by the forklift over the sensitive area. This activity resulted in a decision to install a standpipe barrier which would not allow the large forklift to pass while still allowing other traffic. Procedures improvements and formal restrictions on forklift movement were determined to be insufficient by themselves to achieve the desired risk reduction. Additionally, the canal operations floor was painted to identify movement restrictions and precautions for both forklift movement and movement of crane suspended loads.

III. CONCLUSIONS

The ATR PSA update for shutdown operations, cask handling, and canal draining is a successful example of the importance of good PSA-operations synergism for achieving a realistic and accepted assessment of the risks and for achieving desired risk reduction and safety improvement in a best and cost-effective manner. Because of the involvement of operations in most phases of the shutdown PSA, the PSA is believed and accepted and the risk-reduction measures were readily supported and implemented. The ATR shutdown PSA and the excellent synergism and cooperation between the PSA team, reactor operations, maintenance, and systems engineering has resulted in a better disciplined and controlled operation with improved normal and abnormal operating procedures, formal restrictions, and a few added components and systems. The implementation of the agreed-upon upgrades and improvements resulted in the reductions in the estimated mean frequency for core or canal irradiated fuel uncovery events shown in Table 1, a total reduction in risk by a factor of nearly 1000 to a very low and acceptable risk level for potentially severe events.

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Table 1. ATR shutdown irradiated fuel uncovery frequency reduction by risk reduction upgrades and improvements implemented at ATR

	Shutdown Irradiated Fuel Uncovery Mean Frequency/yr		
Upgrade	Canal draining events	Non-canal draining events	Total shutdown fuel damage frequency
Before upgrades	3.5E-3	1.5E-5	3.5E-3
Short irradiated fuel storage area bulkhead & manual emergency makeup	4.3E-5	1.4E-5	5.7E-5
Use cask drop pad	5.4E-6	1.4E-5	1.94E-5
Shutdown LOCA controls	4.7E-6*	3.2E-6	7.9E-6
Irradiated fuel storage Redundant fire water emergency makeup	3.0E-7	3.2E-6	3.5E-6

* the frequency for canal draining through an open discharge chute interface between the reactor vessel and the canal is also reduced.