From: Christopher Ryder
Sent: Wednesday, March 14, 2007 3:21 PM
To: Albert Wong
Cc: Sheena Whaley
Subject: Revised Phase II sequence eval
Attachments: Phase II Sequences (revised).wpd

Albert,

The number you cited, 10e-2, should be 10e2, I fixed this.
I added a reference to Table 2.

You should send it to team members.

Chris

Hearing Identifier: HLW_YM_NonPublic_EX
Email Number: 75

Mail Envelope Properties (Christopher.Ryder@nrc.gov20070314152101)

Subject: Revised Phase II sequence eval
Sent Date: 3/14/2007 3:21:01 PM
Received Date: 3/14/2007 3:21:01 PM
From: Christopher Ryder

Created By: Christopher.Ryder@nrc.gov

Recipients:
"Sheena Whaley" <Sheena.Whaley@nrc.gov>
Tracking Status: None
"Albert Wong" <Albert.Wong@nrc.gov>
Tracking Status: None

Post Office:

Files	**Size**	**Date & Time**
MESSAGE	153	3/14/2007 3:21:01 PM
Phase II Sequences (revised).wpd	74122	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
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March 14, 2007

NOTE TO: Albert Wong

FROM: Chris Ryder

SUBJECT: Evaluation of Three Event Sequences of Phase II

Per you request, I evaluated three sequences that were being considered in the Phase II exercise:

- A TAD, with an unsecured lid, is dropped while moving it a preparation area.
- While moving fuel from a DPC to a TAD, the lift height of a fuel assembly is exceeded.
- Crane operator impacts a cask into fuel pool wall, causing the cask to drop.

In my opinion, there is sufficient information to suggest that these sequences not be pursued any further. Please realize that my evaluations here are brief due to the time constraints of Phase II. In contrast, during previous PRAs, such as the PRA of dry cask storage, much more resources were expended to evaluate events. Nevertheless, the evaluations described below begin to implement a suggestion from Tina Ghosh about having the evaluations placed on a technical basis.

1 Sequence 1: Open TAD is Dropped

1.1 Description

Presumably, the TAD is in a transfer overpack for two reasons; the overpack provides shielding; the overpack allows the TAD to be carried from the spent fuel pool to a preparation area. For discussion, when the TAD is in the transfer overpack, the two together are referred to as a transfer *cask*.

The transfer cask has been loaded in the spent fuel pool and lifted out of the pool. The lid rests on the TAD, but the lid is not secured.

1.2 Discussion

An outline of the dry cask storage operation from the pool to the preparation is as follows in Table 1. This outline was developed from observing an operation at a plant. The point being made is that the cask is on the floor when it is being prepared.

The sequence of events leading to a release of radioactive material inside the facility is the following:

- transfer cask is lifted
- transfer cask is dropped
- fuel rods rupture

From dry cask storage operations, about 3 to 4 days is expected to unload a DPC, load a TAD, and dry the TAD. Therefore, about 100 TADs/year could be loaded. The initiating event frequency is taken to be 10-2. From data in NUREG-1774, the probability of dropping a heavy load is about 10^{-5}.

Table 1. Stages of the dry cask operation from loading fuel to sealing the cask.

Stage	Description	Lift Height m	Lift Height ft
1	Loading fuel assemblies into the MPC.	4.8	16
2	Placing the MPC lid onto the MPC and engaging the lift yoke on the transfer overpack.	0	0
3	Lifting the transfer cask out of the cask pit.	13	42.5
4	Moving the transfer cask over a railing of the spent fuel pool.	0.9	3
6	Moving the transfer cask to the preparation area.	0.3	1
7	Lowering the transfer cask onto the preparation area.	0.3	1
8	Partially drain the DPC to bring the water away from the lid.	0	0
9	Weld the lid is welded to the shell of the DPC.	0	0
10	Complete draining the DPC.	0	0
11	Vacuum dry the DPC.	0	0
12	Inert the DPC with helium.	0	0
13	Leak test the lid/shell weld.	0	0
14	Install and weld the port covers.	0	0
15	Leak test the port cover welds.	0	0
16	Install a ring on the DPC and weld the ring to the lid and shell.	0	0

In the dry cask storage PRA, engineering analyses were performed to determine the loads on a fuel rod and the response of the fuel rod to the loads. A fuel rod was analyzed as an elastic-plastic beam-column with initial curvature under dynamic impact. Failure of the fuel rod is determined by comparing the maximum strain in the cladding to a strain limit based on experimental data. An impact event entails the interaction of potentially hundreds of rods, their spacer grids, tie plates, fuel spacers, basket, cask, and target under dynamic loading, computational efficiency was achieved by modeling a single fuel rod. A finite element analysis model of a single fuel rod with lateral displacement constraints was used to study the inelastic behavior of a fuel rod under dynamic impact loads. For drop heights of 1, 5, 20,and 40 feet, the maximum principal strain in the cladding and the failure strain limit was determined as shown in Table 2.

Table 2.

Drop Height (feet)	Maximum Principal Strain in Cladding (in/in)	Strain Limit Selected for High-Burnup Fuel (in/in)
1	0.0043	0.010
5	0.0062	0.010
20	0.0072	0.010
40	0.011	0.010

Source: USNRC, “A Pilot Probabilistic Risk Assessment Of a Dry Cask Storage System At a Nuclear Power Plant, draft. Table 13. Probability of Fuel

For drop heights of 20 feet or less, the principle strain is less than the strain limit. Therefore, failure is not predicted; the failure probability is taken to be zero. For 40 feet and higher, the principle strain is greater than the strain limit; the failure probability is taken to be one.

Uncertainty in the loads and the strains was not quantified because an analytical treatment is difficult to implement and justify in the context of a pilot study. One could say that for the 1-foot height, where the transfer cask is carried, there is sufficient margin to account for uncertainty. Therefore, one can conclude that the fuel rods will remain intact; the probability of the fuel rods failing can be taken to be zero.

The sequence frequency is determined as follows:

$$\overbrace{10^{2}}^{\substack{Casklift\\ freq.}}\ \overbrace{10^{-5}}^{\Pr(crane)}\ \overbrace{0}^{\Pr(fuel)} = 0$$

This event sequence is below Category 2. Neither worker dose nor public dose need to be determined.

Even if fuel rods were breached, the releases would be only noble gases. The TAD is filled with water and the lid is in place, though unsecured. Particulates would be scrubbed by the water in the TAD.

1.3 Conclusion

Consequences do not need to be determined for this sequence.

2 Sequence 2: Lift Height of a Fuel Assembly is Exceeded

2.1 Description

While a fuel assembly is lifted in a pool, the assembly is brought close to the surface of the pool water. The assembly is insufficiently shielded, causing exposures to workers performing the operation.

2.2 Discussion

Three reasons for discounting this sequence as being insignificant are the mechanical design and operation of a fuel handling machine, operating experience, and relative importance.

<u>Design and Operation</u>

Some documentation on spent fuel handling machines can be found in the FSAR of power plants. The discussion is brief.

In the FSAR of the Columbia Generating Station, the fuel handling machine is discussed in Chapter 9.1. The refueling platform is a gantry crane to transport fuel and reactor components between pool storage and the reactor vessel. The platform has two systems, one for moving fuel and the other for moving reactor components. The control panel is on the main trolley.

- A telescoping mast and grapple suspended from a trolley moves and orients assemblies in the core, storage rack, or spent fuel cask. The fuel grapple is a telescoping grapple that can extend to the proper work level. The grapple is raised with redundant cables inside the mast and lowered by gravity. The normal retracted position maintains 7.5 feet of water over the top of the active fuel for shielding. The lift height restriction is accomplished with limit switches. With a control system on the platform, hook engagement of an assembly and load can be verified.

- Two 1000-lb capacity auxiliary hoists, one on the main trolley and the other on an auxiliary trolley, are also on the same platform. The auxilary hoists are used to move reactor components. An auxiliary hoist had redundant electrical interlocks to preclude raising radioactive material out of the water. The cables on the hoist have an adjustible, removable stop that jams the hoist cable against the platform of the fuel handling machine when the free end is at a preset distance below the water level.

The three hoist are precluded from operating simultaneously because control power is supplied to only one system at a time.

During fuel operations, the position of the fuel is monitored. Three ways of assessing the height of the fuel are by video camera, by direct observation using binoculars, or by a height indicator ruler that is part of the machine.

<u>Operating Experience</u>

From data published by DOE, the number of times that spent fuel assemblies were discharged during the period 1968 through 2002 was estimated to be 159,600 (including both BWR and PWR fuel assemblies). Each of these assemblies were moved at least once in the reactor vessel. Thus, each assembly can be taken to have been moved twice, once in the reactor during refuel and the other time to the spent fuel pool. The number of times that fuel assembles were lifted is estimated to be 319,200. There have been no reported occurrences where fuel assemblies were inadvertently lifted too close to the pool surface.

<u>Relative Importance</u>

The pools at the power plants are typically about 40 feet deep. Spent fuel from the reactor is highly radioactive; for some assemblies, only days have elapsed since the fuel was at full power. Yet the fuel handling operations at the plants are viewed as being more or less routine.

The pool at the GROA is expected to be about 60 feet deep. The fuel is expected to be at least five years old. The operations at the GROA should be viewed as being more or less routine.

2.3 Conclusion

This sequence is not risk-significant for the following reasons:

- The fuel handling machine is equipped with limit switches and a mechanical stop to prevent a fuel assembly from being raised too high.

- Spent fuel movement is monitored by at least one of three ways, observation by camera, direct observation using binoculars, or by a ruler device.

- During an estimated 300,000 lifts of fuel, there have been no instances were fuel was brought too close to the surface of the covering water.

- Fuel handling is viewed as being more or less routine at power plants. Fuel handling at the GROA is much less significant because the fuel is colder and the pool is deeper.

When spent fuel assemblies are placed in a cask, the fuel handling machine orients the fuel. The orientation of the cask is not an issue.

3 Sequence 3. Crane Operator Impacts Cask into Fuel Pool Wall

3.1 Description

The scenario is documented in a internal NRC report on fuel handling. The report documents a qualitative HRA, based on a dry cask storage operation. On page 81 is a scenario where a cask strikes the edge of the pool while it is being moved to a preparation area.

> Operator does not lift cask sufficiently to clear pool wall – The crane operator must depend on the height indicator on the control panel to determine whether the cask has been raised to a height sufficient to clear the spent fuel pool wall when it is moved, as his view from above does not afford him a suitable angle to judge height above the pool surface once the bottom of the cask clears the surface. One important assumption in this scenario is that a designated spotter for the crane operations either has not been assigned, or the assigned spotter is temporarily unavailable or distracted during the lift.
>
> Maintenance workers fail to notice error – At this point in the process, the workers do not have a particular role with respect to the cask. They have completed the spraying of the cask surface, and are now preparing to dry the cask surface once it is moved away from the pool. Their focus is on putting away the equipment used for spray and radiation monitoring and getting the equipment needed for wipe down and drying. The[y] are unlikely to be expecting any problems with the simple move of the crane.
>
> Operator not paying attention, cask hits pool wall and tilts over as crane moves, angle of cask causes yoke arms to slip off trunnions – The crane operator is likewise not expecting any problems with this move. He is primarily focused on the position indication on the control panel and/or on the crane to get him to the position where he needs to pause for the drying process.
>
> Potential Human Performance Vulnerabilities for Scenario 3:
> - Visual cues relatively useless to the crane operator.
> - The maintenance workers are not tasked to monitor the progress of the move.
> - The simplicity of this task adds a level of complacency to the crew.

3.2 Discussion

The scenario as presented insufficiently represents the dry cask storage operation as it is done, at least at the plant which it is based. Of course, the potential for dropping a cask should be of concern if done with inadequate controls. But controls are present.

The reports states that the crane operator must depend on the height indicator on the control panel to determine whether the cask has been raised to a height sufficient to clear the spent fuel pool wall when it is moved, as his view from above does not afford him a suitable angle to judge height above the pool surface once the bottom of the cask clears the surface. But the crane operator does not depend on observing the operation itself. The crane operator relies on other people for signals. At one plant, communication is by radio. At another plant, communications are by hand signals because the practice is not to depend on hand-held radios.

The report states that once the cask is out of the pool, the workers do not have a particular role with respect to the cask. They have completed the spraying of the cask surface, and are now preparing to dry the cask surface once it is moved away from the pool. Their focus is on putting away the equipment used for spray and radiation monitoring and getting the equipment needed for wipe down and drying. The[y] are unlikely to be expecting any problems with the simple move of the crane. But the workers are not walking away from the operation to store equipment. There is no equipment to store. The equipment consists of two spray hoses, two survey meters, towels, and a mop. Only the hoses remain at the pool. Two people spray the cask as it is lifted from the pool. Two health physicists survey it as it leaves the pool and in brought over the refueling floor. The side of the transfer cask is dried to the level that it can be reached. A health physicist continues to survey the bottom. A worker is mopping the water that drips onto the floor while the cask is moved to a preparation area. A worker, who is wearing a headset, walks with the cask. Moving a 100-ton cask next to scaffolding is not necessarily simple.

The report states that the crane operator is likewise not expecting any problems with this move. He is primarily focused on the position indication on the control panel and/or on the crane to get him to the position where he needs to pause for the drying process. But he is not watching a position indicator; I am unsure if there is such an indicator. Even if there is, the crane operator receives audio and, when possible, visual information about the position of the cask from the workers on the floor. At the subject plant, three workers have headsets—the crane operator, a worker next to the cask, and another worker who oversees the operation. The limit number of headsets keeps the audio information to a manageable level as is judged by the person who is responsible for the operation.

3.3 Conclusion

This scenario needs to be more thoroughly developed and understood before any more can be said. The issue should be to model the operation as it is performed to assess vulnerabilities.