UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

SUPPORTING USE OF 25 TON SPENT FUEL SHIPPING

CASKS NFS-4 AND NAC-1

NORTHERN STATES POWER COMPANY

MONTICELLO NUCLEAR GENERATING PLANT

DOCKET NO. 50-263

Introduction

By letter dated February 4, 1974, Northern States Power Company (NSP) was requested to provide an analysis and relevant information to determine the potential consequences of a spent fuel shipping cask drop at the Monticello Nuclear Generating Plant. It was further requested that if the results of the evaluation indicated changes to the facility were necessary to protect plant structures, systems, or components important to safety or to prevent damage to irradiated fuel, information on the plant modifications should be provided as well as the schedule for design, fabrication, and installation of any modifications.

NSP's evaluation of a fuel cask drop revealed that not all of the Monticello Plant structures could withstand the impact of a dropped cask assuming use of a 70-ton cask and the presently installed crane system. Therefore, NSP notified the NRC of their intention to utilize 25-ton, two-element casks and existing handling equipment on an interim basis until the installation of redundant lifting features onto the existing crane could be completed. The proposed interim plan, documented by letter dated January 22, 1976, was supplemented by letters dated February 13, June 16, and October 27, 1976.

This Safety Evaluation presents the results of our review of the information provided by NSP relative to the interim use of NFS-4 and NAC-1 25-ton, two-element spent fuel shipping casks with the existing handling equipment.

Discussion

1. Potential effect on spent fuel storage pool - The licensee was asked to determine whether dropping a cask into the storage pool could damage the pool floor to the extent that adequate makeup water could not be assured or resultant flooding could cause critical systems to become inoperable. As analyzed by NSP and presented in its January 22, 1976 submittal, the spent fuel pool floor slab can withstand, without through-slab cracking and subsequent leakage, a drop of the cask in a vertical position at the edge of the slab or in a horizontal position at the middle of the slab. Both drops were assumed to be from six inches above the elevation of the operating floor. The dead weight of the pool structure and the weight of water in the fuel pool were included in the analysis. For both drop locations the principles of conservation of energy and conservation of linear momentum were used to evaluate the effects of impact on slabs and beams for flexure, bending shear, punching shear, and perforation in accordance with Topical Report BC-TOP-9A, "Design of Structures for Missile Impact," approved by the NRC staff on November 25, 1974. The analyses allowed plastic deformation of the beams and slabs and took credit for energy absorption by the deformation of the cask impact devices and the increase in allowable stresses in concrete and steel due to the dynamic nature of the loads. The effects of buoyancy and drag forces were also included, but the licensee conservatively disregarded the mitigating effects of the steel liner plate, cask setdown pad, control rod racks and spent fuel racks.

   NSP's analyses indicated that the minimum factor of safety for the spent fuel pool floor slab would be 1.5 for the vertical drop at the cask setdown pad (edge of the slab). At this location, shear is the critical mode of behavior and cracking would not be expected to occur. Results of these analyses were compared with code allowable values in accordance with the NRC's Standard Review Plan, Section 3.8.4, "Other Seismic Category I Structures." We have reviewed the above analyses and found them to be acceptable.

2. Potential effect on fuel stored in the reactor vessel and spent fuel storage pool - The licensee has incorporated spent fuel cask handling procedures which prohibit moving the shipping cask over the reactor vessel or over fuel in the spent fuel storage pool and permit the cask to be lifted over the pool only in the area above the cask laydown pad on the south end of the pool.

In addition, irradiated fuel will not be stored in the south half of the storage pool when the cask is to be handled above the pool.

Because there are empty spent fuel storage racks and control rod racks in the south half of the pool, and an other-than-vertical drop into the pool could impact these racks, NSP was requested to analyze the possibility of subsequent tipping or collapsing of these racks against the stored spent fuel. NSP's response indicated that the empty racks would buckle and crush rather than tip into filled racks. The NSP analysis included evaluation of the capability of rack hold-down lugs to resist both moment and shear caused by the impact of an obliquely-oriented cask on the edge of a rack. The lugs were determined to be adequate. We agree with this assessment and concur that the drop of the cask in an other-than-vertical position would not cause damage to the spent fuel stored in the north half of the pool.

Our analysis also included the possibility of cask overturn due to a seismic event. We determined that for Safe Shutdown Earthquake (SSE) floor response values of 0.12g horizontal acceleration and 0.08g vertical acceleration (derived from the Monticello FSAR) the spent fuel cask will not overturn.

3. Handling of other Large Crane Loads - In addition to the shipping cask, the overhead handling crane will be required to handle other heavy loads, such as the reactor vessel head, reactor internals and reactor vessel shield plugs, during refueling operations. NSP states that the loads associated with refueling will only be handled when the plant is in a cold shutdown condition. Also, the consequences of dropping one of these refueling loads has the potential of causing equipment damage but the event would not pose a safety hazard. Further, NSP stated that sufficient diversity exists in the plant design to maintain the reactor in a cold shutdown condition should one of the refueling loads be dropped.

   To reduce the potential for equipment damage and to improve the future load handling capability during offsite shipment of fuel, NSP expects to complete the long term program of upgrading the overhead crane in approximately two years.

   Provided that handling of the heavy refueling loads is limited to occasions when the plant is in a cold shutdown condition, we concur that sufficient diveristy exists to maintain the plant in a safe cold shutdown condition in the unlikely event of a load drop. On this basis, we find the proposal acceptable.

4. Operational Capabilities of Crane Hoist -

The proposed interim offsite fuel shipment program involves the use of a NFS-4 or NAC-1 25-ton, two-element shipping cask and impact limiter. The maximum cask drop height will be limited to six inches when traveling over the prescribed path above the operating floor. Using these factors, NSP performed an analysis of the adequacy of the structure. The lowest factor of safety at the operating floor level was found to be 1.23 for the floor slab.

In response to our concerns regarding "two blocking" of the hoist, NSP has indicated that they will install two, directly actuated hoist upper limit switches on the upper load block assembly. To provide additional assurance that the carrying height above the operating floor will not exceed six inches, NSP states that it will set one of the redundant upper load block limit switches such that the hoist motor will stop automatically with the cask less than six inches above the operating floor.

With regard to our concerns on the ability of the hoist to elevate the cask to an acceptable elevation above the operating floor, NSP stated: (a) the minimum clearance required, to avoid having the cask hit the floor due to load swing caused by the application of either the bridge or trolley brakes, is 0.8 inches; (b) administratively, the minimum operating clearance between the floor and cask will be held to two inches to provide sufficient assurance that the cask will not hit the floor during a load swing; (c) the NSP operating experience with the existing hoist, obtained in handling heavy refueling loads, has demonstrated that the crane operator can accurately position the load within one-half inch of the desired elevation.

Therefore, NSP concludes and we concur that the cask can be positioned within the four inch band between the six inch maximum and two inch minimum elevation above the floor.

The analysis of the structural adequacy of the operating floor, in the event of a cask drop accident on the floor, assumes the cask will follow a prescribed path of travel. Bright colored floor markings will define the path and serve as a guide to the crane operator during cask handling. NSP states there are no critical drop locations within about plus or minus 2 feet of this prescribed travel path. Further, NSP will install bridge and trolley limit switches to preclude cask movement outside the north and west limits of travel to preclude travel over stored spent fuel or the reactor vessel.

Based on the precautions discussed above, we conclude that adequate interim measures have been taken, when handling a NFS-4 or NAC-1 cask above the operating floor (elevation 1027'-8") to preclude unacceptable consequences following a cask drop accident on this floor, and therefore, in this respect the proposal is acceptable.

5. Precautions Taken to Preclude The Crane From Experiencing A Hard Stop -

During the lifting of the shipping cask, several potential points exist where the load or load carrying members could encounter a hard stop (i.e., a rigid structure causing a sudden stop) that would create excessive dynamic loads which in turn could lead to the failure of a load carrying member and the loss of the load. One example of such a possibility is for the hoist lower load block to contact the upper load block while lifting the cask. NSP initially stated that the two upper limit switches, directly coupled to the drum rotation would preclude the above described event from occurring. Considering the relatively short distance between the limit switch settings and where "two-blocking" could occur, we expressed concern regarding this indirect method of establishing the upper limit height of the load and its accuracy. The potential for erroneous information by the present system exists if the cable should jump the cable drum grooves or if a failure should occur in the gear train that transmits load travel information to the limit switch actuator.

In response to our concerns, NSP has agreed to install two limit switches on the upper load block and thereby remove these uncertainties (also see 4. above).

In addition, a hard stop may occur when the cask is lifted from the transporter. Should the bridge, trolley or cask transporter be improperly positioned during this lift, it is possible for the lower load block assembly or cask to be stopped by the underside of the floor at elevation 962'-6". To preclude such an occurrence, the following steps will be taken: (a) the bridge and trolley will be properly positioned over the equipment hatch prior to hoisting the cask; and (b) power to the bridge and trolley drive motors will be locked out to prevent horizontal movement while the cask is being raised clear of the transporter. Further, while hoisting the cask in the equipment hatch, the maximum lift speed will be limited to five feet perminute, thereby reducing the kinetic energy and the developed dynamic loads in the unlikely event that a hard stop should be encountered.

We conclude that the proposed interim measures are adequate to assure that a hard stop will not occur while lifting the cask in the equipment hatch and to ameliorate the effects in the unlikely event that a hard stop is experienced. Therefore, in this respect the proposal is acceptable.

6. Spent Fuel Shipping Cask -

The NFS-4 or NAC-1 shipping cask and lifting yoke will be delivered to the plant site by a transporter. Impact limiters are attached to the cask to protect it from axial and radial accident impact loads that may be experienced during transport. In the NSP analysis of structural adequacy of the reactor building operating floor, it was assumed that the cask bottom head impact limiting device is not removed from the cask. The analysis takes credit for the resulting reduction in impact load due to the action of the impact limiter. NSP intends to leave the lower impact limiter attached during cask use.

We expressed concern regarding the potential effects of variations in crushing strength of the stainless steel encased balsa wood impact limiting device if it should become water logged. The licensee stated that the potential for water-logging of the balsa wood, when it is submerged in the storage pool, does not appear probable for the following reasons:

(a) the past nuclear industry operating experience with two 25 ton casks show that in 2,500 setdown conditions, no observable damage or leakage has occurred to the impact limiter;

(b) in addition to the preoperational tests on the cask impact limiters, i.e., dye penetrant and leak tests, the impact limiter is leak tested annually using the bubble check method. Furthermore, the cask is subjected to a thorough visual inspection at the reactor site; and

(c) during fabrication of the impact limiting device, each individual piece of balsa wood is coated with epoxy and once the pieces have been assembled, the entire assembly is recoated with epoxy. These epoxy coatings provide additional assurance that water-logging of the balsa wood is unlikely if the encasing stainless steel water barrier were to develop a leak.

We conclude that adequate measures have been taken to preclude a change in the impact limiting characteristics due to water-logging. Therefore, in this respect, the proposed interim use of the NFS-4 or the identical NAC-1 cask. is acceptable.

7. Adequacy of Shipping Cask Trunnions and Handling Yoke -

NSP stated that the interim shipping cask (NFS-4 or NAC-1) lifting trunnions and handling yoke, respectively, have static safety factors, at rated load, of 5.7 and 3.0. We were initially concerned with the adequacy of the design when subjected to the maximum dynamic loads capable of being developed by the existing overhead handling system.

The analysis attached to NSP's letter of October 27, 1976, responding to our concerns, was based on the following assumptions:

1. A 50,000 pound load is being lowered at its maximum rate of 15 feet per minute.

2. The length of rope available for stretch during the impulse loading is 5 feet 6 inches, the distance between block sheave pins when the hook eye is at the upper most travel at elevation 1049 feet 6 inches.

3. The reeving is equally stressed. Each of the 12 rope parts has an effective cross-sectional area of 0.513 squre inches.

4. The rope breaking strength is 105,000 pounds with an elastic modulus of 15×10^6 psi for well broken-in rope.

5. The hoist brakes stop the downward motion of the rope instantaneously. No sag, deflection or rotation occurs in the hoist drive train (i.e., rigid hoist).

6. Only rope stretch is permitted.

Based on these assumptions, NSP determined that: (a) the trunnions static safety factor of 5.7 was reduced to 3.3 under dynamic loading conditions; and (b) yoke static safety factor of 3.0 was reduced to 1.73.

Based on the above conservative assumptions and a review of NSP's analysis, we find that the designs for the shipping cask trunnions and handling yoke are adequate to safely withstand the dynamic loads imposed by the existing overhead handling system. We conclude that the shipping cask trunnions and handling yoke load capabilities are compatible with the overhead handling system and are, therefore, acceptable.

8. Cask Drop in Equipment Hatch Area -

The postulated accident which could result in the most serious damage is to drop the loaded cask down the 93'2" vertical equipment hatch, through which the cask must be lifted from the transporter to the operating floor and returned to be loading for shipping.

The NFS-4 and NAC-1 casks have been designed to withstand a free fall of 30 feet onto a hard surface without rupture of the cask. However, the concrete slab onto which the cask would fall can only withstand a 10 foot drop of the cask without allowing the cask to penetrate and fall to the floor below, when it would in all probability be ruptured resulting in damage to the fuel and release of the fission gases contained therein. To assure reactor building integrity in the event of a cask drop NSP will administratively require both airlock double doors into the reactor building, through which the transporter must pass to remain closed whenever the cask is more than 10 feet above the floor. This will assure that gaseous radioactive releases will be treated by the standby Gas Treatment System and exhausted thru the plant stack.

Our analysis of a cask drop under these conditions, assuming rupture of the cask, destruction of the fuel, release of the radioactive gases, but no violation of reactor building integrity results in radioactive releases well below the 10 CFR 100 guidelines which is acceptable.

Because there is safety-related equipment, such as the pressure-suppression pool (torus), located beneath the equipment hatch floor through which the cask would fall should a drop greater than 10 feet occur the consequences of such a drop on the capability of the plant to be shut down was of concern.

The NRC Standard Review Plan 9.1.4, Page 9.1.4-3, Paragraph II.7, states:

"For the case where a single failure-proof crane has not been provided, the proposed facility design will be acceptable if it can be determined that the consequences of a load drop would not affect the ability of the plant to be shutdown or result in the release of significant amounts of radioactive materials."

Having determined that the radioactive material released would be insignificant NSP was requested to provide their analysis of the capability to shut the plant down, should the torus and residual heat removal systems be rendered inoperable by the drop of the cask.

In response, NSP stated:

"...it is not likely that both the torus and RHR would be rendered inoperable. Under worst case conditions, however, it is conceivable that the torus and RHR systems could be damaged sufficiently to prevent their use in the ensuing plant shutdown and cooldown. We have determined that a complete shutdown and cooldown can be completed without the torus and RHR systems. In this situation, the normal plant cooldown procedure can be utilized until steam generation in the vessel has been terminated. At this time, the reactor vessel would be flooded up to the level of the main steam lines. Reactor water would then be recirculated to the main condenser through main steam line drains and the turbine bypass line. The mechanical vacuum pump would be used to maintain a vacuum in the condenser. The condensate pump would be used to supply water to the reactor vessel and to recirculate water over the condenser tubes through the condensate recirculation line. Detailed procedures for cooldown without the RHR system will be prepared prior to conducting cask handling operations. These procedures will be available at the site for inspection by Region III Inspection and Enforcement personnel.

The worst case cask drop in the equipment hatch would pose operational problems, as stated above, but would have a negligible effect on the health and safety of the public. The consequences of this accident are well below those of other accidents for which the plant was designed."

Based on our review of NSP's submittal, we find that because (a) the crane is rated for 85 tons; (b) the likelihood of dropping the 25 ton cask during the interim program for offsite shipment of spent fuel in such a fashion as to cause unacceptable damage to the torus and RHR system is very remote; and (c) alternate means are available for bringing the reactor to a safe cooldown condition in the unlikely event that an equipment hatch cask drop occurs and damages both the torus and RHR system, it is our conclusion that adeauate measures have been taken to preclude occurrence of the postulated event during the interim period and to assure the consequences of a cask drop will be acceptable.

Conclusion

Based on our review of the analyses and descriptive information provided by NSP, as discussed above, we have concluded that the provisions for preventing postulated spent fuel shipping cask accidents at the Monticello Nuclear Generating Plant are acceptable and that the results of such postulated accidents have been shown to be acceptable. We, therefore, conclude that NSP's interim use of the NFS-4 and NAC-1 25-ton, two-element spent fuel shipping casks at the Monticello Nuclear Generating Plant is acceptable.

Dated: January 25, 1977