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NORTHERN STATES POWER COMPANY

MINNEAPOLIS, MINNESOTA 55401

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U.S. NUCLEAR REGULATORY COMMISSION

March 31, 1981

Director of Nuclear Reactor Regulation
U S Nuclear Regulatory Commission
Washington, D C 20555

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
Docket No. 50-282 Licensing No. DPR-42
50-306 DPR-60

Supplemental Information - License Amendment Request
Dated January 31, 1980

Attached are additional responses to questions sent to L O Mayer from R A Clark on November 5, 1980, concerning the Prairie Island NGP Fuel Storage Facility modification.

Additional responses to question ASB-2,5 and SEB 2,3,4,7,9,10 are enclosed.

L.O. Mayer

L O Mayer, PE
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Attac.ment to March 31, 1981 Letter
AUXILIARY SYSTEMS BRANCH (ASB)

ASB-2 ADDITIONAL RESPONSE

As a result of the . generation calculation method change identified in reference 1, the parameters listed below have been recalculated. Originally (reference 2), the heat generation used for pool 1 was that from all the fuel in both pools. This was conservative but this situation could never exist. The following "time to boiling" for pool 1 assumes that a full core discharge of 121 assemblies and 266* assemblies generate the heat in pool 1. The "time to boiling" for pools 1 & 2 assumes total mixing between the two pools. Neither of the "times to boiling" account for the heat removal effect of evaporation prior to boiling.

	Previous Values**	Recalculated Values
Time to Boiling Pool 1	2.9 hr	2.9 hr***
Maximum Evaporation Rate (Pool 1 & 2)	44.7 gpm	51.4 gpm
Time to Boiling Pool 1 and 2	9.9 hr	8 hr

The following administrative controls will be adhered to prior to placing a full core discharge into pool 1:

1. All gates will be removed
2. All spent fuel pool cooling equipment will be operable.

The removal of the gates when making a full core discharge into Pool 1 will provide approximately 100 sq. ft. of flow area between the two pools and 100 sq. ft. between each pool and the canal allowing natural circulation to mix the two pools. This will increase the time to boiling to some value between 3.5 hrs and 8.0 hrs (8.0 hrs assumes total mixing). The requirement to have the spent fuel pool cooling equipment (pumps, heat exchangers, and valves) operable prior to making a full core discharge into Pool 1 will make the total loss of spent fuel pool cooling extremely unlikely.

If these requirements cannot be met, the full core discharge will be delayed until the requirements can be met or the fuel from the full core discharge will be split between the two pools or totally placed in Pool 2.

*The four removable racks in the shipping cask area will contain only the full core discharge. The other five racks will be filled with recently discharged fuel.

**See Reference 2 Exhibit C, page 3-63.
***The two effects offset one another

ASB-5 Additional Response

The tools commonly* used in the spent fuel pools are listed in the table below.

FUEL HANDLING TOOLS

Tool	Weight	Length	Max. Drop Height	Allowed Height Above Fuel	Bail Factor of Safet to Ultimate (Loaded)
BPRA Handling Tool	760 lbs	31.5 ft	15.3 ft	4 ft	4.8
Spent Fuel Handling Tool	343 lbs	31.75 ft	15.05 ft	8 ft	5.4
Thimble Plug Handling Tool	22[illegible] lbs	31.0 ft	15.8 ft	8 ft	8.9

These tools will be administratively restricted when handled over the new racks such that their potential energy will not be greater than 3250 ft-lbs. Identification marks will be located on the shafts of the tools to indicate how high the tools may be raised above fuel when unloaded. In the very unlikely event that a unloaded tool is raised above its maximum height the following items make the dropping of the tool extremely unlikely:

1. The Spent Fuel Pool Bridge Crane hoist hook has a keeper
2. The Spent Fuel Pool Bridge Crane hoist has a 6000 lb capacity
3. The bail factor of safety (see above table)
   NOTE: The fact that the bail will deform prior to failing was not considered in the calculations of the factors of safety- making the factors of safety i[illegible]ed conservative.
4. Trained, experienced NSP plant personnel will handle the tools.

The tools very infrequently (less than once a year) need to be handled by the Auxiliary Bldg Crane. The tools will be handled by the 25 ton hoist which has a keeper.

*In recent refuelings the BPRA has not been needed to be used at all.

Structural Engineering Branch (SEB)

SEB-2 Additional Response

The design for the spent fuel storage modules utilized the AISC Code for beam and frame structure methodology. The basic material allowables were taken from ASME Section III and Standard Review Plan 3.8.4 for the applicable load combinations. The fabrication and installation of the modules is in accordance with ASME Section III Subsection NF, Articles 2000, 4000, and 5000 except as follows:

1. Material traceability for individual pieces to their associated CMTRs is not maintained when the material is incorporated into the fabricated assembly. Traceability is preserved for all hea s of material comprising each module. All materials used in the construction of the racks are drawn from a controlled lot of traceable, certified material.

2. The ASME Code does not address neutron absorber materials such as Boraflex. However, it has been purchased in accordance with the following:

   a) ANSI N45.2, Quality Assurance Program Requirements for Nuclear Power Plants.

   b) ANSI N45.2.2, Packaging, Shipping, Receiving, Storage, and Handling of Items for Nuclear Power Plants.

   c) ANSI N45.2.6, Qualifications of Inspection, Examination, and Testing Personnel for Nuclear Power Plants.

   d) ANSI N45.2.9, Requirements for Collection, Storage, and Maintenance of Quality Assurance Records.

   e) 10 CFR 50, Appendix B - Quality Assurance Criteria for Nuclear Power Plants.

3. The welds used to install the Boraflex into the fuel racks are made by the tig spot weld process. These welds are not structural welds. Their only purpose is to secure the neutron absorber. Each storage tube has approximately 100 of these tig spot welds. Random failure of 50% or more of these welds would not result in dislocation of the Boraflex.

   The ASME Code Section III Subsection NF does not address tig spot welds. In order to qualify this process and the welding operator for use on the fuel racks, ASME Code Case N-262, "Electric Resistance Spot Welding for Structural use in Component Supports," was used. Although this code case addreses the use of electric resistance spot welding, the qualification and test procedures included in the code case can be directly applied to tig spot welding. The test results have shown that this process consistently produces welds with strength well in excess of that required by the code case. In addition, two test samples are prepared and destructively examined prior to welding on each storage tube.

   Because of the use of Code Case N-262 and the extensive testing during fabrication, this welding process meets the intent of ASME Section III Subsection NF.

SEB-3 Additional Response

The structural evaluation of the proposed racks conforms to the applicable portions of the OT position referenced in the question.

The spent fuel racks are analyzed in accordance with Regulatory Guide 1.92. The fuel pool structure has been analyzed for the additional loads that would result from the proposed modification by utilizing the original Fluor-Pioneer calcualtions. In this analysis, the additional loads on the canal wall and the floor slab were computed using the conventional building analysis method. Since the proposed racks are not laterally supported from the pool walls, only the pool floor and the canal wall acting as a deep beam would carry additional vertical loads including additional vertical seismic loads. The vertical seismic loads were computed using the vertical seismic response spectrum from the original building seismic analysis report by John A. Blume & Associates. The increase in the horizontal seismic loads on the pool floor and the canal wall as a result of the proposed modification is negligible, and so the application of R.G. 1.92 is not applicable (R.G. 1.92 was issued after the design and construction of the Spent Fuel Pool).

SEB-4 Additional Response

a) When the rack drops on the built-up wide-flange beam at a location directly above the point where the beam rests on the concrete wall, a limited amount of concrete crushing is anticipated. The bearing area under the beam is about 7-inches by 12-inches. Hence, crushing will be limited to this area.

Concrete crushing depth reported in Reference 3 was computed using an energy balance equation. Accordingly, the kinetic energy of the falling rack was equated to the plastic strain energy absorbed in the process of crushing the 7-inch by 12-inch concrete bearing area. In that evaluation, it was conservatively assumed that all the kinetic energy of drop would be absorbed by crushing the concrete.

b) Major chipping of concrete was not considered in Reference 3 analysis because of the following reasons:

i) The presence of the wide-flange beam and the pad between the falling rack and the concrete wall would "soften" the impact.

ii) The presence of the pool liner which is welded to an angle member at the top inside corner of the pool wall would prevent the concrete from chipping and falling in the pool.

iii) The presence of reinforcing bars in both vertical and horizontal directions (No. 11 bars @ 6" c/c), would prevent major chipping and spalling of concrete.

However, in response staff concerns, the possibility of chipping the corner of the pool has been evaluated. The method of this evaluation and results are presented in the following paragraphs.

The impact load resulting from the drop was calculated using an energy balance method; considering the energy absorption by the wide-flange beam, the compressible pad and the concrete. The load-deformation properties of the wide-flange beam, the pad and the concrete underneath were represented as three springs in series having elasto-plastic characteristics. Using the energy-balance equation, the impact load was calculated by iterative procedure. For the 6" drop of the 24.8 kip rack, an impact load of 275 kips was obtained. This predicted impact load is very conservative because of the following reasons:

i) Energy absorption by the cross-stringers and the cover plate of the pool cover were not included.

ii) Energy absorbed by the local crushing of the concrete was not included.

iii) Energy absorption by the reinforcing steel was not considered, even though it was assumed that the impact load would cause a diagonal crack in the inside corner of the wall.

Using this impact load, and assuming a 45° diagonal crack at the top inside corner of the wall starting from the outer edge of the pad, the lateral and vertical deformation of the cracked corner of the wall was computed. The bending and dowel action of the reinforcing bars were evaluated by idealizing the bars as beams on elastic foundation. The resulting lateral and vertical deformation of the cracked corner was computed to be less than one-tenth of an inch. Such a small deformation will neither compromise the liner integrity nor will it cause chipping or spalling of concrete into the pool.

c) Because of the lack of clearance, the thickness of compressible pad cannot be increased. Nor is it necessary, since chipping or spalling is not predicted and since the maximum postulated crushing depth is very small (actual crushing depth will be smaller than 0.53" predicted in Reference 3 when energy absorption by the existing pad and the wide-flange beam is taken into account).

SEB-7 Additional Response

The stress values reported in the original licensing report (reference 2) were based on the assumption that the rack and fuel assemblies move in-phase. Rattling analysis presented in refernce 3 assumed that the rack and the fuel assemblies move out-of-phase. This resulted in additional amplification factors which were computed and presented in reference 3. In this analysis, to obtain upper-bound amplification factors, all the fuel assemblies were assumed to move in-phase with themselves but out-of-phase with the rack. The original seismic stress values (based on in-phase motion) were then multiplied by these amplification factors to account for the out-of-phase motion between the rack and the fuel assemblies and to obtain the final design stresses.

Assumption 'b' of the SEB-7 response refers to the fact that

a) the basic seismic stresses in the original document were computed assuming that the racks are not free to slide (in addition to assuming that the fuel assemblies move in-phase with the rack). This is a very conservative assumption and predicts higher stresses since sliding releases seismic stresses; and

b) the amplification factors presented in reference 3 were also computed assuming that no energy loss took place due to sliding, and all the energy would be available to the fuel assemblies to impact on the rack.

Thus, the stresses reported in reference 3 represent very conservative and upper-bound values.

1.0 ADDITIONAL EVALUATION OF RACK-TO-RACK IMPACT PHENOMENON

Since the proposed racks are free-standing, they may slide towards each other and impact during a postulated seismic event. The evaluation of the scenario where two adjacent racks impact on each other has been presented in the original licensing report as well as in response to SEB Question 9 (reference 3). This additional evaluation is to determine the effect of (a) four adjacent racks impacting on the central rack (Figure 1a) and (b) six racks in one row impacting on the seventh or last rack at the end of the row (Figure 1b). Evaluations of these two scenarios are performed using the results of the original impact analysis as described in the following two paragraphs.

A. Effect of Four Adjacent Racks Impacting on the Central Rack

Simultaneous impact of four adjacent racks on the central rack, even though theoretically possible, would be an extremely rare event, since the to-and-fro sliding motions of the five racks are likely to be quite random in nature. The resulting potential damage to the racks from this postulated impact would be well within acceptable limits for the following reason: Evaluation results for a single rack impacting on the adjacent rack showed that, even if the computed impact velocity is increased by a factor of 2.7 (i.e., 12 over 4.43), the maximum crushing length of rack storage tubes due to impact is only 1.2 inches. This was computed by an energy balance method in which the kinetic energy of impact was equated to the strain energy of deformation of the impacting outer tube walls. This calculation was performed (as described in the response to SEB 9) by arbitrarily increasing sliding velocity from 4.43 inches/sec. to 12 inches/sec. and by ignoring the energy expended in tilting the racks. Since, in the case of a four-way impact, the outer tube walls of any particular side of the central rack would be impacted by only one sliding rack, the postulated damage to the impacted tube walls would remain the same.

B. Effect of Six Racks in a Row Impacting on the Seventh Rack

The scenario is also very improbable because the to-and-fro sliding motions of the racks are random in nature and for the six racks to be moving in the same direction is very unlikely. Even more unlikely is the scenario in which all the six racks are moving at the peak velocity in the same direction. However, based on earlier single rack-to-rack impact analysis, this scenario is evaluated in a simple but conservative way to show the adequacy of the rack.

It is assumed that the combined kinetic energy of the six racks will be available as the energy of impact on the seventh or last rack. The total impact energy will then be six times 3759 in-lb (based on the computed peak sliding velocity of 4.43 inch/sec) or 22,554 in-lb.

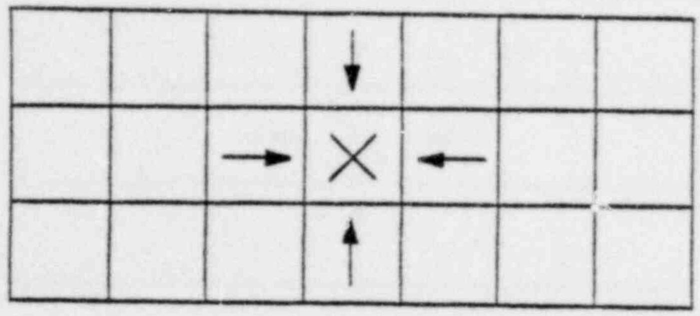

FIGURE 1a
FOUR RACKS IMPACTING CENTRAL RACK

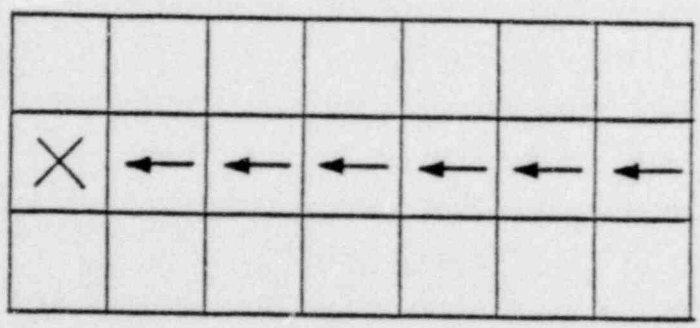

FIGURE 1b
SIX RACKS IMPACTING END RACK

As described in reference 3, the single rack-to-rack impact analysis was performed using an arbitrary sliding velocity of 12 in/sec instead of the computed value of 4.43 in/sec. This was done so as to show the existence of high margin of safety. The impact energy of a single rack at the 12 in/sec velocity is 26,733 in-lb. Thus, the rack was already evaluated for an impact kinetic energy of 26,733 in-lb, which is more than the 22,554 in-lb determined for six racks at the computed 4.43 in/sec velocity. Thus, even for the case when six racks in a row are postulated to impact on the seventh rack simultaneously, the damage to the rack storage tubes would not exceed 1.2 inches from the top. This was previously shown to be well within acceptable limits.

2.0 ASSUMPTIONS AND METHODS USED FOR IMPACT ANALYSIS

The assumptions and method of analysis used to determine the depth of the plastic region in the event of a rack-to-rack impact are describe below.

A. Assumptions

1. The racks impact on each other when their velocities are at the peak.

2. All the kinetic energy of impact is absorbed only by the plastic deformation of the tube walls parallel to the direction of motion. This assumption is conservative because of the following reasons:

   a. The energy spent in tilting the rack to a position where the two racks may impact is not considered.

   b. The rebound energy, which is quite significant, is not considered.

   c. Elastic strain energy of deformation is ignored.

   d. Elastic and plastic energy of deformation of the tube walls perpendicular to the direction of motion is not considered.

3. The stainless steel is assumed to have elasto-plastic stress-strain properties.

4. The impact energy is computed using the combined real and hydrodynamic mass. This is conservative, since only the real mass will contribute to the impact energy.

5. The two faces of the two adjacent racks impact only at the top edges deforming each other. This assumption is more conservative than assuming a flat surface impact. Considering the very small gap between the racks, the possibility of one point impact is judged to be small. Also, initial point impact, if any, would cause the racks to rotate and the result would be a line impact.

B. Method of Analysis

Presented below is a step-by-step outline of the method of analysis:

1. The kinetic energy of impact is computed using the peak sliding velocity and total combined mass.

2. Impact energy on a single tube wall is computed by dividing the total kinetic energy by the number of tubes in the impacting side of the rack. For each tube, the two tube walls parallel to the direction of motion are assumed to absorb the energy, since the stiffness of the walls perpendicular to the direction of motion is small compared to the walls parallel to the direction of motion.

3. Evaluation is made to determine whether the tube wall geometry permits buckling before compression yielding. It was found that the compression yield load is smaller than the buckling load, and hence the energy absorption would result from crushing rather than buckling.

4. The top edge of the tube is assumed to get crushed. The extent of the crushing is defined as "a" in Figure 2. The value of "a" depends on the impact energy. Using an iterative method, the value of "a" is determined by equating the elasto-plastic strain energy of the crushed corner to the impact energy.

5. The vertical length of damaged rack "D" is computed from "a".

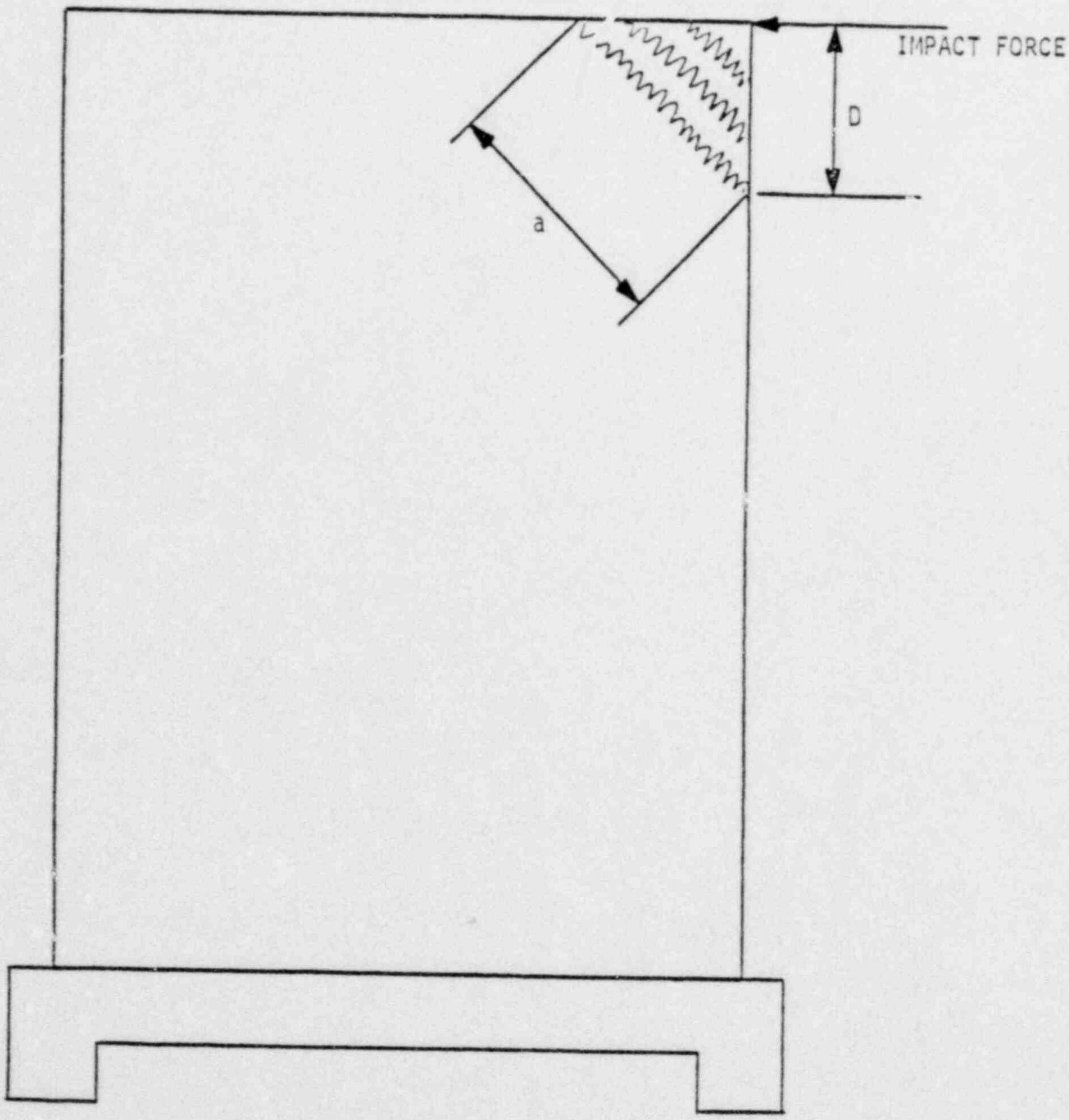

FIGURE 2

FUEL RACK CRUSHING LOCATION

3.0 OVERALL EFFECT OF IMPACT ON THE RACK STRUCTURE

The rack base assemblies are very stiff in the horizontal direction. Hence, when two racks impact at the base, the racks will rebound. The impact, however, will result in a high impact force at the base having an extremely short duration. This force will cause only local deformation. Due to the short duration of the force, the total energy transmitted to the rack will be small. Using an energy balance method and equating the impact energy (22,554 in-lb) to the elasto-plastic strain energy resulting from the crushing of the projected edge of the base assembly, this local deformation was computed to be much less than the projection.

4.0 THERMAL STRESSES

Three types of thermal stresses may occur in a spent fuel rack. These are:

Q = Thermal stresses resulting from placing a hot fuel bundle in an empty rack.

T_o = Thermal stresses resulting from the increase in the fuel pool water temperature during normal operation.

T_a = Thermal stresses resulting from the increase in fuel pool water temperature during accident condition.

Thermal stresses resulting from Q loads have been considered in the design of the proposed racks.

In order to allow room for thermal expansion of the racks without exerting forces on adjacent racks, the arrangement of racks in the pools will be modified to provide a gap between the rack bases. The thermal expansion of the rack base (in the B cell direction) for a temperature increase from 70°F to 212°F is 0.11 inch. A gap of 0.25 inch will be provided between adjacent racks.

Increase in pool water temperature during normal operation (T_o) and during the design basis accident (T_a) would cause thermal loads if it is assumed that the friction between the rack leg and the pool floor liner does not permit thermal growth of the rack. This friction would also resist the horizontal movement of the rack during a seismic event. However, the maximum resistance to both seismic loads and the thermal growth will be limited by the maximum frictional force that can develop between the rack and the pool floor. Thus, if the stresses in the rack components are computed for this maximum frictional force applied at the bottom of the rack, the resulting stresses would constistute the upper bound stresses that can result from any load combinations.

Maximum frictional force to be applied at the bottom of the rack legs was computed by multiplying the weight of the rack with the maximum coefficient of friction of 0.8. This frictional force was applied in all four legs in two orthogonal horizontal directions. The stresses in the critical leg member interfacing the pool floor and the other critical components were determined using conventional elastic structural analysis methods.

The results of this upper-bound stress analysis are presented in Table 3C for the three critically stressed components. These results show that the stresses resulting from the upper-bound analysis described here are well within the allowable stress values. In performing this evaluation, the allowable stresses were selected very conservatively. In fact, allowable stresses applicable for the D + OBE load combination (per Standard Review Plan 3.8.4) were used even though per OT position the allowable stresses would be much higher. It is concluded that stresses resulting from T_o and T_a would not cause any overstress condition in the rack when considered to be primary stresses.

RESULTS OF UPPER-BOUND STRESS ANALYSIS
PERFORMED TO EVALUATE ADEQUACY OF
THE RACKS UNDER THERMAL LOADS

Rack Components	Stress index values: Upper-Bound Analysis	Stress index values: Allowable
Floor Leg Connection	0.682	1.0
Vertical Corner L-Beam	0.813	1.0
Base Assembly Girders	0.458	1.0

SEB-10 Additional Response

A concern was raised by the staff concerning the spent fuel pool liner. The liner load will not increase with the installation of the new racks. The new racks weigh less than present racks. The largest new rack contains fewer assemblies per rack than the largest existing rack. The new rack feet have a larger area of contact with the floor, than the present rack feet. For these reasons, the liner has a unchanged or lower probability of being penetrated with the new racks as compared to the present racks.

However, if the liner is penetrated, a leak detection system will identify and limit the amount of the leakage.

The leak detection system consists of a series of channels in the concrete floor and walls of the transfer canal and spent fuel pools just beneath the stainless steel liner. These channels are directed to twelve intermediate collection points located along the sides of the transfer canal and spent fuel pools. These twelve collection points are piped to a central collection area which is located in the decontamination area on the ground floor. Thus, any leakage through the stainless steel liner would drain to the central collection area. This collection area then drains to the radioactive waste disposal system.

If the liner were penetrated at the boundary between two areas served by different collection points, the maximum leakage though any two collection lines would be less than 120 gal/min. (resulting in a level loss rate of less than 0.12 in/min).

This slow level loss rate gives the operator ample time to discover the leak and close the isolation valves prior to any significant loss of level. In addition, the maximum loss rate of 120 gpm is well within the capability of the make-up systems (see reference 4).

REFERENCES

1. Letter from L O Mayer to the Director of Nuclear Reactor Regulation dated March 10, 1981 - Supplemental Information - License Amendment Request dated January 31, 1980.

2. Letter from L O Mayer to the Director of Nuclear Reactor Regulation dated January 31, 1980 - License Amendment Request

3. Letter from L O Mayer to the Director of Nuclear Reactor Regulation dated February 3, 1981 - Supplemental Information - License Amendment Request dated January 31, 1980.

4. Letter from L O Mayer to the Director of Nuclear Reactor Regulation dated June 10, 1980 - Supplemental Information - License Amendment Request dated January 31, 1980.