Preliminary Design Report for Reracking the Indian Point Unit No. 2 Spent Fuel Pool

Consolidated Edison Company of New York, Inc.
Indian Point Unit No. 2
Docket No. 50-247
September, 1979

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1. INTRODUCTION

By letter dated February 27, 1979 Consolidated Edison submitted to the NRC the document entitled "Proposed Design Criteria for Reracking Indian Point Unit No. 2 Spent Fuel Pool." The information contained herein supplements and clarifies the aforementioned document and provides the results, where possible, of the preliminary analyses. It is anticipated that the final design report will be submitted to the NRC by January 1, 1980.

The high density spent fuel storage racks will provide storage locations for up to approximately 1000 fuel assemblies and will be designed to maintain the stored spent fuel, having an equivalent uranium enrichment of 3.5 weight percent U-235 in UO_2, in a safe, coolable, and subcritical configuration during normal and abnormal conditions.

1.1 History & Need for Increased Storage Capacity

By letter dated March 4, 1975 and supplements dated May 9, 1975, July 23, 1975, August 19, 1975, September 11, 1975, October 1, 1975 and October 10, 1975 Consolidated Edison requested, from the NRC, authorization to increase the storage capacity of the Indian Point Unit No. 2 spent fuel pool from 264 to 482 storage locations. On December 16, 1975 the NRC issued Amendment No. 14 to Facility Operating License No. DPR-26 for Indian Point Unit No. 2, authorizing such modification.

Presently there are 200 spent fuel assemblies stored in the spent fuel pool. The projected refueling schedules and expected number of fuel assemblies to be discharged in the spent fuel pool, while maintaining full core reserve (FCR), are given in Table 1-1.

It is anticipated that the existing storage capacity would be filled in 1981, with FCR maintained.

1.2 Construction Costs

The total cost to rerack the Indian Point Unit No. 2 spent fuel pool has been estimated to be $7,500,000. This estimate includes the following:

- design, materials, fabrication
- removal and disposal of old racks
- transportation and installation of new racks
- project management, licensing, quality assurance
- contingency allowance
- allowances for funds used during construction

Table 1-1

Projected Spent Fuel Discharges

Calendar Year	Estimated Annual Discharges- No. of Assemblies
current inventory	200
1980	72
1981	-
1982	68
1983	68
1984	-
1985	68
1986	68
1987	68
1988	-
1989	68
1990	68

1.3 Alternatives to Increasing the Storage Capacity

1.3.1 Reprocessing of Spent Fuel

None of the three commercial reprocessing facilities in the U.S., the General Electric Company's Midwest Fuel Recovery Plant (MFRP), the Nuclear Fuel Service (NFS) plant, and the Allied General Nuclear Services (AGNS) plant, are currently operating.

On April 7, 1977 the President of the United States issued a statement outlining a change in the national policy to defer indefinitely commercial reprocessing. Consequently the NRC issued an order dated December 30, 1977 terminating proceedings to license reprocessing facilities.

Due to this change in national policy Consolidated Edison cannot reprocess the Indian Point Unit No. 2 spent fuel.

1.3.2 Independent Spent Fuel Storage Installations (ISFSI)

There are no independent spent fuel storage facilities available at this time. In addition Consolidated Edison does not foresee this alternative to be available within the next 5 years or to be economic even if it were.

While the storage pools at NFS and MFRD are currently functioning as ISFSI, Consolidated Edison does not have any contracts to store spent fuel at these facilities.

For the reasons stated above, storage of spent fuel at an ISFSI is not a realistic alternative.

1.3.3 Storage at Another Reactor Site

Consolidated Edison owns only one other nuclear power plant, Indian Point Unit No. 1 which was shut down on October 31, 1974 and is presently in the defueled condition awaiting a decision by the Company whether or not to install an emergency core cooling system in accordance with the Commission's regulations. The Indian Point Unit No. 1 spent fuel pools have Indian Point Unit No. 1 spent fuel and other core components stored in them. In addition to the cost of reracking an Indian Point Unit No. 1 spent fuel pool and other associated costs, there would be the added cost of periodically transferring the spent fuel from the the Indian Point Unit No. 2 to the Indian Point Unit No. 1 spent fuel pool.

Storage of the spent fuel at another nuclear power plant owned by another utility does not appear to be a realistic alternative. With the present situation in spent fuel storage capacity Consolidated Edison cannot rely on another utility for spent fuel storage space.

1.3.4 Shutdown of Facility

If Indian Point Unit No. 2 were forced to shutdown for lack of spent fuel storage space there would be a significant loss of economic benefit to our customers.

The present estimated additional fuel cost to replace the output of Indian Point Unit No. 2 on a day of full-power operation, utilizing existing oil-fired generating units, is approximately $1,000,000, not including applicable taxes. The above figure, which is in 1979 dollars, would increase in subsequent years due to the anticipated escalation in the price of oil.

Due to the fact that presently Consolidated Edison, excluding Indian Point Unit No. 2, primarily utilizes oil fired generating units (gas turbines are used for peak load needs) and our national energy policy is to decrease the use of imported oil, the alternative to shut down the reactor is not realistic.

2. STORAGE RACK DESCRIPTION

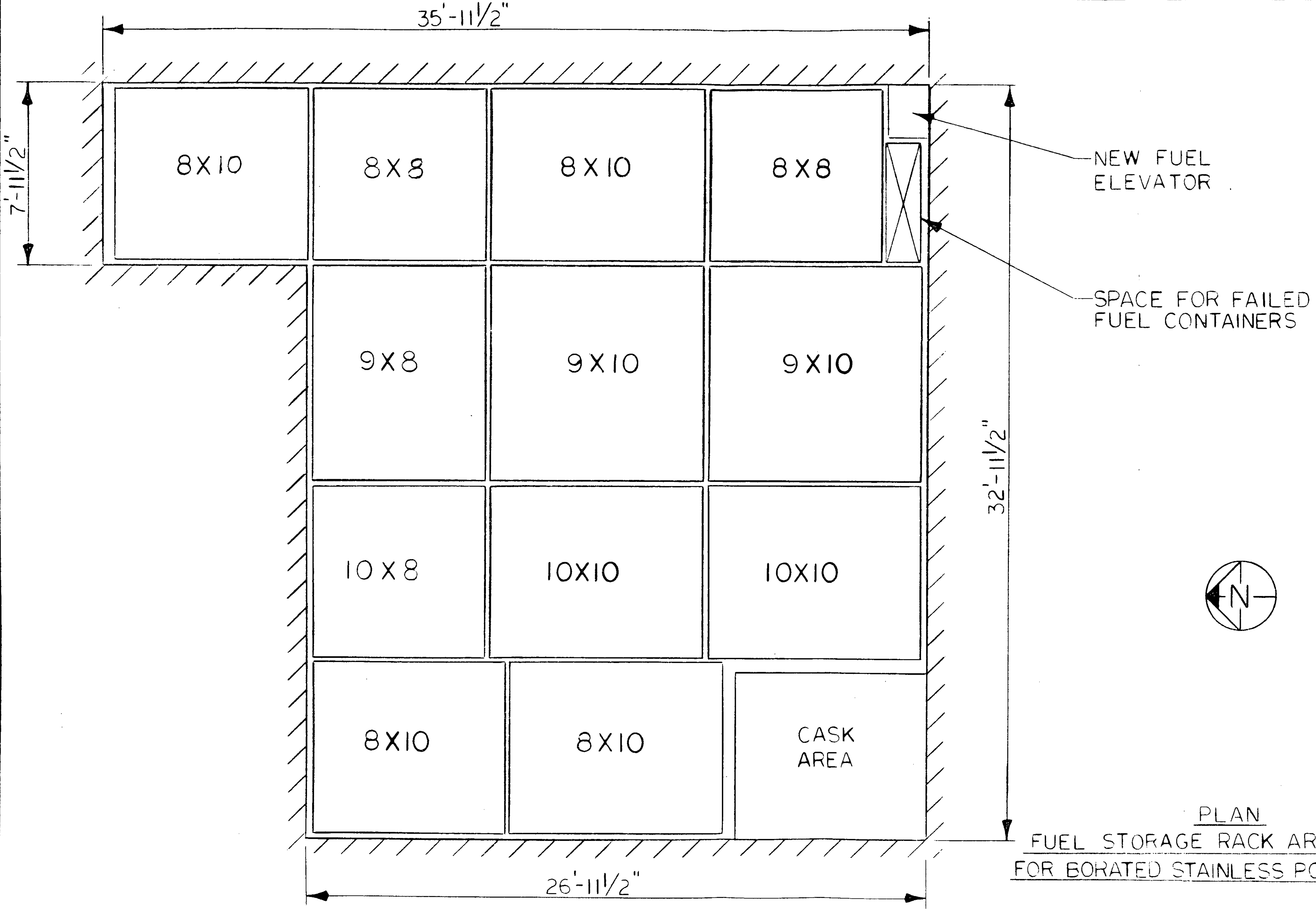
The spent fuel storage racks will be designed to provide a maximum storage capacity of up to approximately 1,000 locations in the spent fuel pool. The fuel storage rack arrangement will contain several sizes of storage racks with arrays ranging from 8x8 to 10x10 configurations, as shown in Figure 2-1. Typically, a 10x10-array storage rack will consist of a welded assembly of twenty-five (25) 2x2 modular cell units, each containing four (4) storage locations, as shown in Figure 2-2.

Each 2x2 modular cell unit will consist of four (4) cells spaced nominally 10.9375 inches on centers. Each storage cell will be a single wall Type 304 stainless steel box with minimum inner dimension of 8.9375 inches and a minimum wall thickness of 0.080 inch. The opening of the storage cell will be flared to facilitate insertion of the fuel assembly; the bottom members of the storage cells will provide the level support surface required for the fuel assembly and will contain the cooling flow orifice.

Four (4) borated stainless steel plates with a nominal 1.7 w/o boron concentration (each 7 inches wide by 145 inches long by 0.0625 inches thick) will be intermittently attached (welded or clipped) to each storage cell within the four-cell module at an elevation corresponding to the active fuel region of an assembly placed within the cell. A cross-section view of the storage cell is shown in Figure 2-2.

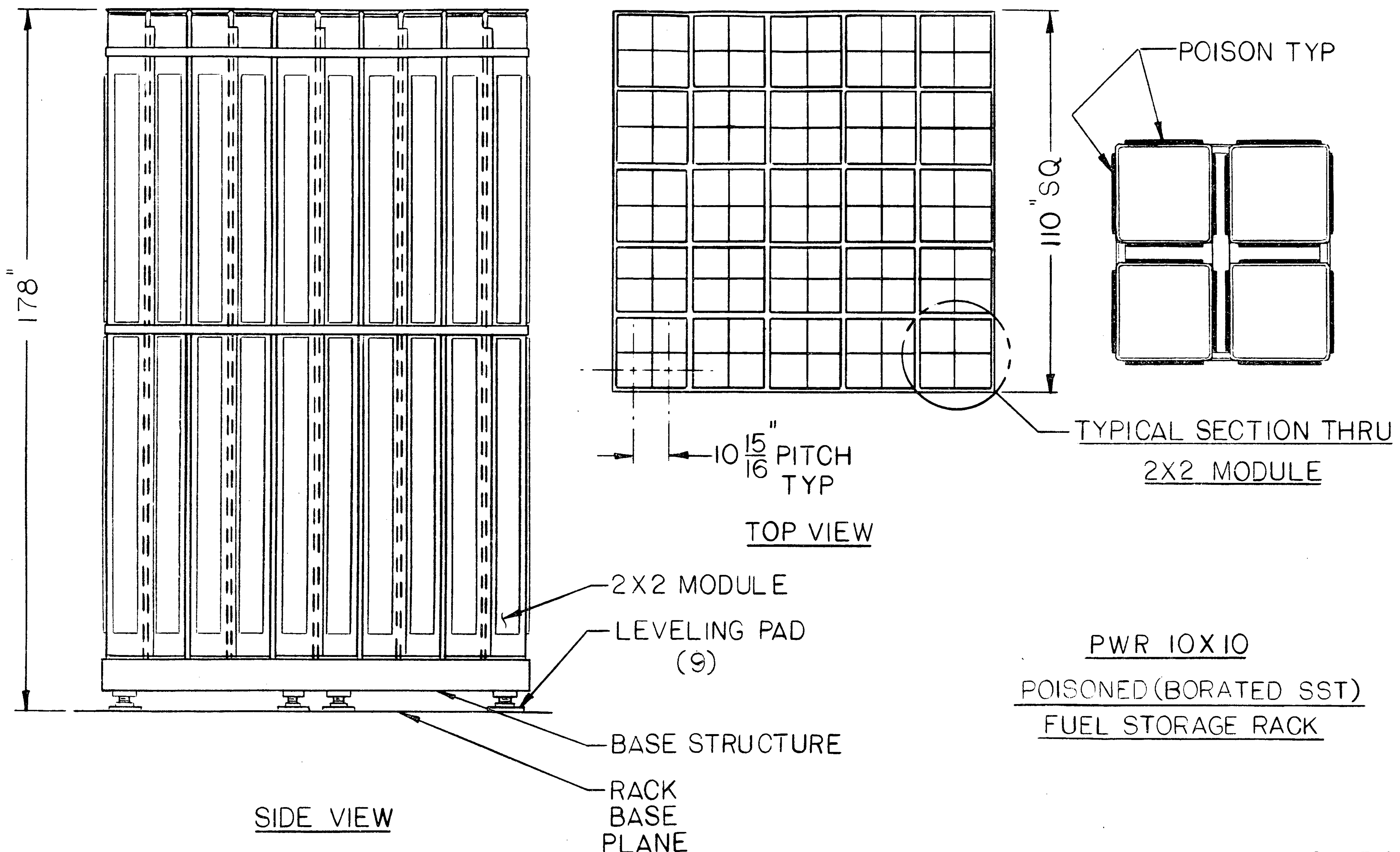
For each rack, two grid members will be provided to maintain the required pitch between modular cell units. The bottom of the cell modules will sit on and be welded to the rack base which is basically a grid structure constructed from box and I-beam members. Each fuel rack will be supported by nine (9) remotely adjustable and articulated feet which will raise the rack a sufficient height above the pool floor to provide an adequate cooling water supply plenum. The vertical deadweight and seismic loads will be transmitted directly to the pool floor by the support feet.

The fuel racks will be installed as free-standing components (the racks will be free to slide horizontally on the pool floor). Sufficient space shall be provided between the fuel racks and the pool walls to preclude impact/collision in the event that sliding occurs during a seismic event. Depending on the final design, the racks will either be tied together or separated from each other with adequate clearances to prevent collision during a seismic event. In either case, the horizontal seismic loads transmitted from the rack structure to the pool floor will be those associated with friction between the rack structure and the pool liner.



PLAN
FUEL STORAGE RACK ARRANGEMENT
FOR BORATED STAINLESS POISON DESIGN

FIGURE 2-1



178"
110" SQ
POISON TYP
TYPICAL SECTION THRU 2X2 MODULE
10 15/16" PITCH TYP
TOP VIEW
2X2 MODULE
LEVELING PAD (9)
BASE STRUCTURE
RACK BASE PLANE
SIDE VIEW
PWR 10X10
POISONED (BORATED SST) FUEL STORAGE RACK

FIGURE 2-2

3. STORAGE RACK EVALUATION

3.1 Structural and Seismic Analyses

The Indian Point Unit No. 2 spent fuel storage racks will be designed to meet the requirements for Seismic Category I structures. Detailed structural and seismic analyses of the high density storage racks will be performed to verify adequacy of the design to withstand the loadings encountered during installation, normal operation, the severe and extreme environmental conditions of the Operating Basis and Design Basis Earthquakes and the abnormal loading condition of an accidental fuel assembly drop event.

3.1.1 Applicable Codes, Standards and Specifications

The following design codes and regulatory guides will be used in the design/analysis of spent fuel storage racks:

1. A.I.S.C. Manual of Steel Construction, Seventh Edition, 1970.

2. USNRC Regulatory Guide 1.29, "Seismic Design Classification" Rev. 3, Sept. 1978.

3. USNRC Regulatory Guide 1.92, "Combination of Modes and Spatial Components in Seismic Response Analysis", Rev. 1, February, 1976.

4. USNRC Standard Review Plan, Section 3.8.4.

5. USNRC Guidance on spent fuel modifications entitled, "Review and Acceptance of Spent Fuel Storage and Handling Applications," April 14, 1978, and Supplement, January 18, 1979.

3.1.2 Loads and Load Combinations

The following load cases and load combinations will be considered in the analysis in accordance with the requirements of USNRC Standard Review Plan, Section 3.8.4.

1. Load Cases:

   Load Case 1 - Dead Weight of Rack, D + L (Normal Load)

   Under normal operating conditions, the rack is subjected to deadweight loading of the rack structure itself plus, loads resulting from the storage cells and fuel assemblies stored in the cells. Deadweight analysis will consider two storage conditions: (1) a fully loaded; and (2) a partially loaded rack.

   Load Case 2 - Dead Weight of Rack Plus Uplifting Loads, D + U.L. (Abnormal Load)

   The possibility of the fuel handling bridge fuel hoist grapple getting hooked on a fuel storage cell will be considered. The axial upward force considered for this load case will be 10,000 pounds.

Load Case 3 - Operating Basis Earthquake, E (Severe Environmental Load)

The rack, fuel assemblies, and virtual water mass react to the simultaneous loading of horizontal and vertical components of the seismic response acceleration spectra (1% damping) specified for the Operating Basis Earthquake in the Indian Point Unit 2 Seismic Design Specifications. The seismic loading will be considered for two storage conditions: (1) a fully loaded; and (2) partially loaded rack.

Load Case 4 - Design Basis Earthquake, E' (Extreme Environmental Load)

Same as Load Case 3 except, the seismic response acceleration spectra corresponding to the Design Basis Earthquake will be used in the analysis.

Load Case 5 - Assembly Drop Impact Load, I.L. (Abnormal Load)

The possibility of dropping a fuel assembly on the rack from the highest possible elevation during spent fuel handling will be considered. A 1650 pound weight (fuel assembly) will be postulated to drop on the rack from a height of 48 inches above the top of the rack. Three cases will be considered: (1) a direct drop on the top of the rack; (2) a subsequent tipping of the assembly onto the surrounding storage cans; (3) a straight drop through the storage cell and impact onto the rack base structure. The accidental drop of a fresh fuel assembly from the highest possible height of 13 ft above the water level will also be evaluated.

Thermal Loading, T (Normal Load)

The stresses and reaction loads due to thermal loadings are expected to be insignificant since small clearances are provided to allow unrestrained growth of the racks and rack sub-base structure for the normal maximum pool temperature of 150°F.

2. Load Combinations:

a. For service load conditions, the following load combinations will be considered, using elastic working stress design methods of AISC:

(1)	D + L	(1a)	D + L + T
(2)	D + L + E	(2a)	D + L + T + E

b. For factored load conditions, the following load combinations will be considered, using elastic working stress design methods of AISC:

(3) D + L + T + E'
(4) D + T + U.L.
(5) D + L + T + I.L.

3.1.3 Design and Analysis Methods

Static/Seismic Amplified Response Spectra (ARS) Analysis

Static, dynamic and stress analyses will be performed using finite element methods. An individual fuel storage rack will be mathematically modeled as a finite element structure consisting of discrete three-dimensional elastic beam and plate elements interconnected at a finite number of nodal points. Stiffness characteristics of the structural members will be related to the plate thickness, cross sectional area, effective shear area and moment of inertia of the element sections. Six degrees of freedom (three translations and three rotations) will be permitted at each nodal point.

Appropriate support connections will be provided at the support feet for both static and dynamic analysis. In order to determine the maximum seismic response of the storage racks, the racks will be conservatively assumed to be pinned (not sliding) to the pool floor at the support feet locations.

For the static dead weight and live load analysis, the distributed masses of the structural elements, storage cells, borated steel plates, and fuel elements will be lumped at the system nodal points.

The eigenvalues (natural frequencies) and the eigenvectors (mode shapes) for each of the natural modes of vibration will be calculated using the Lanczos Modal Extraction Methods. The Seismic Response Analyses will be performed by the Response Spectrum Modal Superposition Methods of dynamic analysis, using the Indian Point 2 Response Spectra Curves. Individual modal response of the system will be combined in accordance with Section 1.2.1 of Regulatory Guide 1.92. The maximum response of the system for each of the three orthogonal spatial components (two horizontal and one vertical) of an earthquake, will be combined on a square root of the sums of the squares (SRSS) bases (Regulatory Guide 1.92).

The effects of water surrounding the storage racks will be accounted for by adding hydrodynamic masses to the real masses of the fuel assemblies, storage cells and

contained water. The hydrodynamic masses will be calculated using the guidelines given in References 1 and 2.

The static, seismic and stress analyses for the fuel storage racks will be performed utilizing the STARDYNE computer code (Ref. 3).

Fuel Assembly Impact Load

The "rattling" effects of the fuel inside the cell will be accounted for by increasing the seismic inertia loads produced by the impacting masses by applying a suitable impact factor and adding the resultant load to the seismic inertial load produced by the non-impacting masses.

Water Sloshing Effects

The sloshing effects of water on the fuel racks will be evaluated using the analytical methods given in Reference 4.

Accidental Fuel Assembly Drop Analysis

The assembly drop load case (Load Case 5) will be performed with linear and non-linear analysis techniques using energy-balance methods.

Sliding Analysis

Detailed non-linear time history seismic analyses will be performed to evaluate the maximum sliding of the storage racks and to determine the maximum frictional resistance load transmitted by the storage racks to the pool floor liner plate during the Design Basis Earthquake.

The fuel rack will be mathematically modeled as a multi-degree-of-freedom finite element structure incorporating the stiffness characteristics of the storage rack and fuel assemblies, the structural non-linearities that exist at the fuel assembly/storage cell interface, and the storage rack leveling pad/pool floor interface. The hydrodynamic effect of the spent fuel pool water and the effect of fuel assembly impact will be included in the analysis.

The non-linear time history seismic analyses will be performed by step-by-step integration techniques (Houbolt Method - Ref. 5) using the ANSYS computer program (Ref. 6).

3.1.4 Structural Acceptance Criteria

The calculated stresses for the storage racks will be compared to the allowable stress values given in the applicable sections of the following codes and standards: AISC Specification for the Design, Fabrication and Erection of Structural Steel for Building, the Uniform Building Code; SRP 3.8.4 and the NRC Guidance entitled, "Review and Acceptance of Spent Fuel Storage and Handling Applications."

The acceptance criteria for Load Case 5, the accidental fuel assembly drop onto the rack, will be that the resulting impact not adversely affect the leak-tightness integrity of the fuel pool floor and liner plate and that the deformation of the impacted storage cells not adversely affect the value of k_{eff}.

3.2 Nuclear Analysis

A detailed nuclear analysis will be performed to demonstrate that for all anticipated normal and abnormal configurations of fuel assemblies within the fuel storage racks, the k effective of the system is below 0.95. Certain conservative assumptions about the fuel assemblies and racks will be used in the calculations as described in Section 3.2.1.

The principal calculational method used for the criticality analysis will be diffusion theory using HAMMER and EXTERMINATOR. Verification calculations will be done either by transport theory using GGC3 and DOT or a Monte Carlo Code (KENO IV), as appropriate. A detailed description of the calculational method and codes is presented in Section 3.2.2, together with a description of a benchmark of the diffusion theory method.

3.2.1 Design Criteria and Assumptions

The criticality design criterion established for the Indian Point Unit No. 2 will be that the multiplication constant (k_{eff}) shall be less than 0.95 for all normal and abnormal configurations as confirmed by transport theory or a Monte Carlo Code.

The following conservative assumptions will be used in the criticality calculations performed to verify the adequacy of the rack design with respect to the design critieria:

1. The pool water has no soluble poison.
2. The fuel assemblies have no burnable poison.
3. The fuel is fresh with 3.5 w/o U_{235} enrichment.
4. The rack configuration is infinite in the two radial directions.

3.2.2 Configurations Analyzed

The possible various configurations of fuel within racks, will be classified as either normal or abnormal configurations. Normal configurations result from the placement of fuel within racks and the variation in rack dimensions permitted in fabrication. Abnormal configurations are typically results of accidents or malfunctions such as seismic events, malfunction of the fuel pool cooling system, etc.

The normal configurations which will be considered in the analysis include:

1. Central positioning of fuel assemblies within the storage cells and storage cells with normal dimensions (the reference configuration).

2. Eccentric positioning of adjacent fuel assemblies with the storage cells as permitted by the assembly-to-cell clearances.

3. Storage cells at minimum center-to-center spacing permitted by fabrication tolerances and resulting from normal structural loading.

4. Storage cells at maximum I.D. and/or wall thicknesses permitted by fabrication tolerances.

All abnormal configurations which are required to obtain NRC licensing approval for the NES fuel storage rack design, will be considered in the analysis. The principal abnormal configurations include:

1. Bulk pool temperature variations from 68°F to 260°F with further reduction in water density to determine the effects of boiling.

2. Storage cells at minimum center-to-center spacing resulting from seismic vibration/displacements.

3. Fuel handling incident in which a fuel assembly is placed adjacent to a fully loaded rack.

4. Fuel handling incident in which a fuel assembly is dropped on top of the storage racks, and falls to a horizontal position.

3.2.3 Calculational Methods

Analysis of Cases

The reference configuration will be analyzed by representing a rack with nominal cell pitch, 3.5 w/o 15x15 Westinghouse low parasitic fuel assemblies, nominal wall stainless steel cans, borated stainless steel plates with a nominal 1.7 w/o boron concentration, and a 68°F water temperature. The effect of pool temperature variation will be analyzed. Cell pitch and fuel enrichment will also be varied.

The eccentric configuration will be studied by a full assembly problem representing an assembly placed in the corner of a can. This is a conservative representation because it actually represents the entire rack array having all groups of adjoining assemblies placed as close as possible to one another.

Codes

HAMMER (Ref. 7) is a multi-group integral transport theory code which is used to calculate lattice cell cross sections for diffusion theory codes. This code has been extensively benchmarked against D_2O and light water moderated lattices with good results. EXTERMINATOR (Ref. 8) is a 2-D multigroup diffusion theory code used with input from HAMMER to calculate k_{eff} values.

GGC-3 (Ref. 9) is a consistent B_n or P_1 code for the calculation of fast neutron spectra and associated multigroup constants. Resonance calculations are performed by Nordheim methods.

DOT (Ref. 10) is a 2-D multi-group discrete ordinate transport theory code with a general anisotropic scattering used with GGC-3 and HAMMER input to calculate k_{eff} values. KENO IV is a 3-D multi-group Monte Carlo criticality code used to verify k_{eff} (Ref. 12).

Benchmark Calculation for Diffusion Theory

Both HAMMER and EXTERMINATOR are used by NES as versions available at Combustion Engineering at Windsor Locks, Connecticut. The combination has been benchmarked against a cold critical experiment performed at the LaCrosse Boiling Water Reactor with excellent results (Ref. 11). The calculated k_{eff} differed from the experimental value by only 0.0017.

This critical experiment was similar to the configuration used in the fuel storage racks in that the fuel was enclosed in stainless steel shrouds and water gaps existed between these shrouds.

3.3 Thermal Analysis

The adequacy of natural circulation flow to cool the spent fuel assemblies in the rack matrix will be verified by establishing, for the worst rack row with the maximum number of assemblies, a thermal-hydraulic balance between the driving head produced by decay heat generation and the pressure losses existing in the natural circulation flow path. Pressure losses in the downcomers, in the rack inlet plenum, and along the fuel assemblies will be explicity considered in the analysis. Cross-flows in the inlet plenum area will be conservatively neglected.

The racks will be designed to promote cooling of the spent fuel assemblies by natural circulation to reduce the potential for local boiling in the high density fuel storage configuration. The possibility of water stagnation in some sub-channels is minimized by providing adequate orifice areas and communication on all sides of the cell base structure allowing for extensive crossflow.

3.4 Radiological Analysis

Radionuclide concentrations in the spent fuel pool water will also be determined assuming 0.25% failed fuel and a 90-hour cool-down period between shutdown and refueling operations. Dose rates at the surface of the spent fuel storage pool, from both the spent fuel pool water and from transfer operations, will be evaluated. The assembly in transfer will be assumed to have maximum burnup with 90-hour in-vessel cooling after shutdown.

An analysis will be performed to determine the doses at the nearest site boundary (@ $X/Q=6.6X10^{-4}$ sec/m^3) resulting from the following conditions:

1. One fuel assembly (with maximum burnup) is dropped on the racks 90 hours after shutdown. Release of all gap activity from the assembly shall be assumed.

2. The spent fuel transfer cask is dropped on occupied spent fuel racks 90 days following shutdown. The analysis shall be performed in accordance with Regulatory Guide 1.25.

4. INSTALLATION

The installation of the new high density spent fuel racks and the disposal of the old spent fuel racks will be described in Consolidated Edison's final design report.

The use of the crane in the Fuel Handling Building is restricted by Technical Specification 3.8.A.7 which states the following:

> "If the spent fuel pit contains spent fuel, the spent fuel cask shall not be moved over any region of the spent fuel pit until the cask handling system has been reviewed by the Nuclear Regulatory Commission and found to be acceptable."

Even though the weight of the heaviest new high density spent fuel rack is expected to be less than the weight of a standard three element spent fuel cask, Consolidated Edison plans to use administrative controls to assure that a spent fuel rack, whenever possible, will not be moved over a section of the spent fuel pool that has stored spent fuel.

5. RADIOLOGICAL EVALUATION

The information for the NRC radiological evaluation, as described in the NRC Guidance entitled "Review and Acceptance of Spent Fuel Storage and Handling Applications", will be submitted as part of the Final Design Report.

6. REFERENCES

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10. WANL-TME 1982, DOT IIW User's Manual, December 1969.

11. NES 81A0260 "Criticality Analysis of the Atcor Vandenburgh Cask" R.J. Weader, February 1975.

12. ORNL-4938 "KENO IV - An Improved Monte Carlo Criticality Program", L.M. Petrie, N.F. Cross, November 1975.