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RECIP.NAME RECIPIENT AFFILIATION
MURLEY,T.E. Document Control Branch (Document Control Desk)

SUBJECT: Responds to NRC request for addl info re proposed plant spent fuel pool reracking & forwards proprietary Rev 1 to HI-88243, "Fluid Coupling in Fuel Racks..." & HI-91700, "Dynarack Validation...." Repts withheld (ref 10CFR2.790).

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AEP:NRC:1146C

Donald C. Cook Nuclear Plant Units 1 and 2
Docket Nos. 50-315 and 50-316
License Nos. DPR-58 and DPR-74
SPENT FUEL POOL RERACKING
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

U. S. Nuclear Regulatory Commission
Document Control Desk
Washington, D. C. 20555

Attention: T. E. Murley

April 1, 1992

Dear Dr. Murley:

Attachment 1 to this letter contains our responses to your staff's February 21, 1992 request for additional information regarding the proposed Donald C. Cook Nuclear Plant spent fuel pool reracking (TAC NOS. M80615 and M80616). Please contact us should you require additional information or clarification of our response.

Attachment 2 to this letter contains information proprietary to Holtec International. It is supported by an affidavit signed by Holtec, the owner of the information. The affidavit sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b)(4) of Section 2.790 of the Commission's regulations.

Accordingly, it is respectfully requested that the information which is proprietary to Holtec be withheld from public disclosure in accordance with 10 CFR Section 2.790 of the Commission's regulations.

Additionally, members of the NRC staff requested that, for this rerack project, we commit to Draft Regulatory Guide DG-8006, "Control of Access to High and Very High Radiation Areas in Nuclear Power Plants," dated October 1991. We will commit to this draft regulatory guide as it applies to the spent fuel pool reracking project license amendment request submitted in our letter AEP:NRC:1146 dated July 26, 1991.

In compliance with the requirements of 10 CFR 50.91(b)(1), copies of this letter and its attachments have been transmitted to

A001 /1

Mr. J. R. Padgett of the Michigan public Service Commission and to the Michigan Department of Public Health.

This document has been prepared following Corporate procedures that incorporate a reasonable set of controls to ensure its accuracy and completeness prior to signature by the undersigned.

Sincerely,

E. E. Fitzpatrick
Vice President

an

Attachments

cc: D. H. Williams, Jr. (w/o)
A. A. Blind - Bridgman (w/o Attachment 2)
J. R. Padgett (w/o Attachment 2)
G. Charnoff (w/o)
NFEM Section Chief (w/o Attachment 2)
A. B. Davis - Region III
NRC Resident Inspector - Bridgman (w/o Attachment 2)

ATTACHMENT 1 TO AEP:NRC:1146C

ADDITIONAL INFORMATION

DONALD C. COOK NUCLEAR PLANT

SPENT FUEL POOL RERACKING

Question 1. "With regard to Figure 2.2.1 [sic], Cook Spent Fuel Pool Layout, please describe as to what occupies each shaded area by providing size of equipments and machines, if any. Also, provide the elevation of the shaded area with respect to adjacent pool floor. Is the elevation of the shaded area level with the pool floor or recessed? Discuss if there is any barrier around the cask area to restrict translational movement of racks E4 and G."

Response to 1. In Figure 2.1.1 of our submittal AEP:NRC:1146 (Reference 5), the shaded area is the cask handling area. This area is normally empty of all equipment and material. The elevation of the cask area is 604' 10½" nominal. The pool floor is at an elevation of 606' 2½" nominal. There is no barrier around the cask area to prevent translational movement of racks E4 and G as it is not necessary.

The results of three runs of the whole pool multi-rack (WPMR) analysis are provided in the licensing report in Reference (5). The maximum displacements of Rack-E4 (Rack 18) and Rack-G (Rack 23) at rack baseplate level, which may be towards the cask area, are summarized from the results in Table 1. It is clear from Table 1 that a large margin exists against the racks tipping into the cask depression.

Question 2. "Provide drawings for the racks that depict dimensions including thickness of various members, weld locations and sizes, weight of the racks and fuel assemblies such that one may be able to perform engineering stress calculations. Also provide pool dimension that indicates relative position of racks to pool including water level during operation and, also, during refueling."

Response to 2. Attachment 2 to this submittal contains Holtec International proprietary drawings 666-Revision 3, 667-Revision 3, 668-Revision 3, and 669-Revision 2, which depict rack dimensions including thickness of various members, weld locations and sizes and weight of the racks. Dimension and weight data on fuel assemblies can be found in Tables 3.2.1-1 and 3.5.1-1 of the Unit 1 UFSAR and Tables 3.1-1 and 3.3-1 of the Unit 2 UFSAR. Pool dimensions that indicate the relative position of the racks to the pool are given in Holtec International Drawing 666. The pool floor is at elevation 606' 2 1/2" nominal and the normal water level is at elevation 645' 1 1/2". High and low water level alarms are at 645' 8 3/4" and 644' 8", respectively. The pool water level is not a function of reactor mode of operation, thus it is nominally the same during operation and refueling.

Question 3. "In pages 6-8, it is stated that the Coulomb friction between the racks and pool liners must be simulated by appropriate piecewise linear spring. Provide exact mathematical formulation of model and also discuss theoretical and experimental bases for the model. Discuss your representation of Coulomb friction damping with the model discussed in Reference 4 and explain the differences."

Response to 3. The classical definition of Coulomb friction is:

$$F \leq \mu N$$

where N is the normal force on the friction interface, μ is the coefficient of friction and F is the supportable lateral force available from friction. The Coulomb friction force is reactive, rather than active. In other words, it develops only to counteract a laterally applied external force and its value cannot exceed the lesser of μN and the applied external force, P; i.e., referring to Figure 1:

> F = Absolute Minimum (AMIN) [P,μN] were P and N are absolute values. The direction of F is such as to oppose the direction of actual or impending motion.

It therefore follows that the body A subject to given interface load N will begin to slide if the lateral load reaches μN. The lateral displacement, δ, of body A will have the relationship depicted by Figure 2, which can be written symbolically as:

$$\delta = 0 \text{ if } P \leq \mu N$$

$$= \infty \text{ if } P > \mu N$$

δ can be viewed as the slip between the point 0′ and 0 at the friction interface in Figure 1.

The "ideal" Coulomb friction force-displacement profile shown in Figure 2 can be written in a more generalized form by referring to Figure 3:

$$F = \text{AMIN } [P,\ K\delta],\ \text{if } K\delta < \mu N,\ \delta \approx 0$$

$$= \text{AMIN } [P;\ \mu N];\ \text{if } K\delta > \mu N,\ \delta \approx 0$$

where K is the stiffness of the theoretical spring connecting point 0 and 0′ at the interface in Figure 1. Reference [6.4.3] of the licensing report in Reference (5) states that the spring constant, K, should be chosen an order of magnitude larger than the characteristic elastic stiffness of the interface structure.

The relationship exhibited by the above formula is the Coulomb piecewise linear spring utilized in DYNARACK. It is a standard procedure in numerical simulation of friction interfaces and is succinctly described in Reference [6.4.3] in the licensing report in Reference (5). It is consistent with the methodology described in the literature on nonlinear dynamics including the references cited in the request for additional information and other texts.

Question 4. "Discuss in detail what numerical values are used for the hydrodynamic masses with associated discretized rack mass. Provide a quantitative discussion as to how such values are calculated including supporting experimental bases particularly with regard to multi-mass system and narrow-gaps. Note that the Reference 6.5.1 of the submittal only discusses idealized simple objects. One should also note that, in the reference, the model assumes irrotational flow in the derivation whereas some of the experiments performed in the reference 6.5.1 realized turbulence."

Response to 4. The development of the fluid coupling terms in multi-body (rack) motion involving small rack-to-rack gaps is presented in the proprietary report, "Fluid Coupling in Fuel Racks: Correlation of Theory and Experiment, Holtec International Report No. HI-88243 (1989)," which is being provided to the Commission in Attachment 2 to this submittal under the appropriate provisions for proprietary materials submitted on a docket. This document provides the theoretical bases and experimental validation of the fluid coupling terms.

It should be noted that fluid coupling terms used to incorporate the contribution of water in rack dynamics utilize irrotational flow in the interest of conservatism and to comply with USNRC guidelines, in particular the OT Position paper, which disallows any credit for fluid damping. Irrotational flow implies no viscous damping; in fact, no dissipation of energy at all. Turbulence, wake shedding, etc., are mechanics of energy extraction that are conservatively neglected in the analysis. The fluid coupling effect, therefore, merely entails transfer of energy (no loss of energy) among the individual racks. The methodology is, therefore, uniformly conservative.

Question 5. "The governing equation of the motion presented in pages 6-17 is stated to be a representative of a system of twenty-two degrees of freedom. Also, they are highly nonlinear because of gap, fluid structure interaction and friction damping. The proprietary code "DYNARACK" is said to perform numerical solution of the equation using a central difference scheme. We have reviewed a similar submittal in the FitzPatrick

application and had several questions with regard to the numerical analysis of the finite central difference application. In particular, for a stable system (this is determined by experiments), one should demonstrate that the governing equation and the numerical scheme is "well posed" in a form discussed in Reference 3. Otherwise, one should define carefully unstable regions of the rack response from experiments and demonstrate that "DYNARACK" simulates unstable response adequately and is able to bound the results such that it can provide a conservative design (References 1 and 2).

"Alternatively, the following information should be provided to resolve the questions:

(a) Two extreme cases of the rack boundary conditions consist of one fully fixed base rack and the other case a rack completely free of friction at the base. Rack response to the fully fixed case may represent the most extremely stressed case where as [sic] the case with frictionless base may produce a maximum potential of a rack to pool wall or to an adjacent rack. Understanding of these two extreme cases would provide a confidence in assessing rack responses. Please provide calculations for these cases.

(b) Associated physical experiment performed by you as well as by others which would support the adequacy and engineering validity of your analysis code."

Response to 5. The nonlinear equation set, represented in matrix differential equation form on pages 6-17 of the licensing report in Reference (5), was reviewed by the NRC in the James A. FitzPatrick submittal, as well as multiple other dockets, and subsequently approved. Over a thousand dynamic simulations of spent fuel rack structures were performed using DYNARACK in support of previous licensing submittals, and hundreds of analyses by others using other computer codes have uncovered no evidence of dynamic instability discernible in such structures. DYNARACK, in particular, has been tested in a wide range of nonlinear problems and has demonstrated its ability to simulate instability in unstable systems without fail. The DYNARACK Validation Manual documents the capability and veracity of this code in capturing nonlinear effects. It is submitted herein in Attachment 2, under proprietary provisions, to assist you in gaining confidence in this analysis code.

Experiments are not the only vehicle to understand dynamic response of structures; numerical methods are widely recognized as a powerful and reliable tool. The standard component element formulation described in the text by Levy, et.al., (Reference [6.4.3] of the licensing report in Reference (5)) uses the classical central difference discretization scheme. This formulation is used in solving technical problems referenced in permanent literature, as noted in the DYNARACK Validation Manual. This formulation has never been reported to suffer from the defect of being "ill-posed." There is no evidence--technical, mathematical or heuristic--to suggest that the DYNARACK solutions do not bound the actual rack response, or that the motion of high density fuel racks is intrinsically unstable.

We trust that the above response, in conjunction with the DYNARACK Validation Manual, clarifies the issue of stability of racks and DYNARACK's ability to simulate rack motions.

The alternative approach (a) suggested in the RAI does not provide a complete problem definition and is non-linear if the fuel in the rack is not fixed. Our experience with fuel rack dynamic simulation suggests that bounding models of the type suggested in alternative approach (a) are of little value in assessing dynamic responses in closely spaced high density rack layouts. The DYNARACK Validation Manual offers various simulations which more directly relate to the dynamic responses of rack modules in realistic scenarios.

The DYNARACK Validation Manual and Holtec Report HI-88243 are being submitted to comply with item (b) of the alternative approach.

References:

(1) Holems, P. J., and Shaw, S. W., "A Periodically Forces Piecewise Linear Oscillator," Journal of Sound and Vibration 1983.

(2) Thompson, J. M. T., and Ghaffari, R., "Chaos After Period-Doubling Bifarcations in the Resonance of an Impact Oscillator," Physics Letters, 1982 (Vol. 2A, Number 1).

(3) Issacson, E., and Keller, H. B., "Analysis of Numerical Methods," John Wily and Sons, New York 1966.

(4) Stoker, J. J., "Nonlinear Vibrations," Interscience Publishers, New York 1966.

(5) Letter, AEP:NRC:1146, E. E. Fitzpatrick to T. E. Murley, July 26, 1991, and its attachment, "Licensing Report for Storage Densification of D. C. Cook Spent Fuel Pool," Holtec International.

TABLE 1

WPMR Analysis Run I.D.	Loading Case	MAXIMUM DISPLACEMENT OF PEDESTAL PROXIMATE TO THE CASK AREA Rack E-4 in N-S Direction (inch)	Rack-G in E-W Direction (inch)
MP1	Regular fuel, fully loaded; DBE seismic friction coeff. = 0.2	0.09693	0.04812
MP2	Regular fuel, fully loaded; DBE seismic, friction coeff. = random	0.1913	0.2388
MP3	Regular fuel, fully loaded; DBE seismic, friction coeff. = 0.8	0.4526	0.1033
Required Pedestal Movement for pivoting at the edge of the cask area depression		8.69	10.76

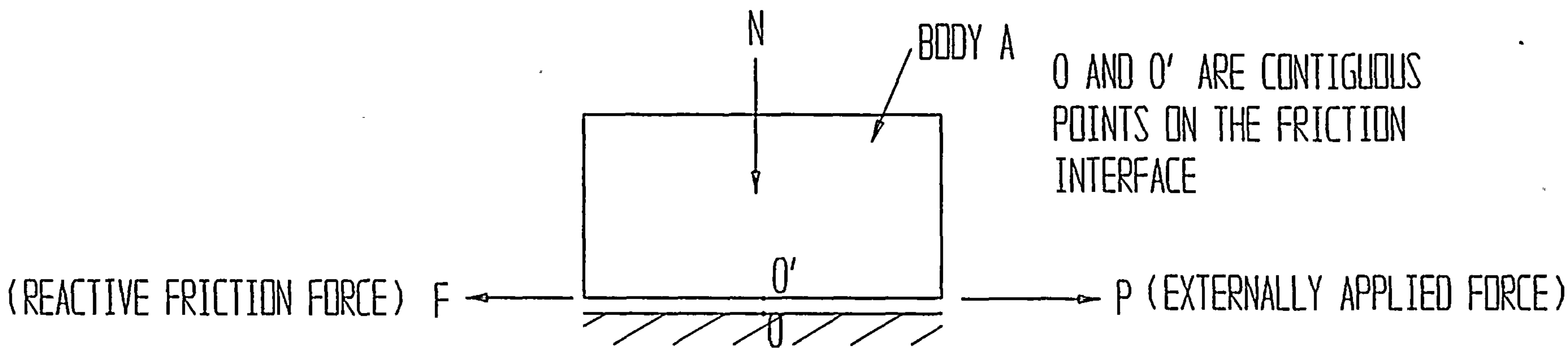

FIGURE 1

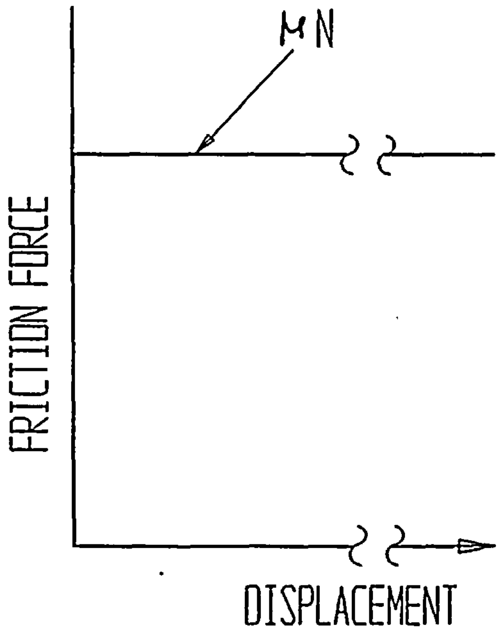

FIGURE 2

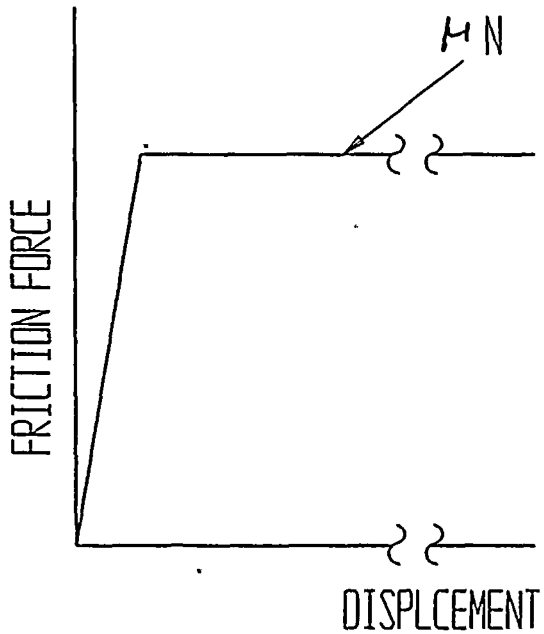

FIGURE 3

ATTACHMENT 2 TO AEP:NRC:1146C

HOLTEC INTERNATIONAL PROPRIETARY DRAWINGS

(666-R3, 667-R3, 668-R3 AND 669-R2),

HOLTEC INTERNATIONAL PROPRIETARY REPORT HI-88243 (1989),

DYNARACK VALIDATION MANUAL HI-91700 (1991),

AND ACCOMPANYING AFFIDAVIT