September 27, 1996

Mr. C. Randy Hutchinson
Vice President, Operations ANO
Entergy Operations, Inc.
1448 S. R. 333
Russellville, AR 72801

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION PERTAINING TO NRC BULLETIN 96-04, ARKANSAS NUCLEAR ONE, UNITS 1 AND 2 (TAC NOS. M96321 AND M96322)

Dear Mr. Hutchinson:

The Nuclear Rgulatory Commission (NRC) staff is continuing its review of the Entergy Operations, Inc. response to Bulletin 96-04, "Chemical, Galvanic, or Other Reactions in Spent Fuel Storage and Transportation Casks." The enclosure to this letter contains another request for additional information. Please respond to this request by letter. If necessary, the NRC staff is available for additional discussions of issues related to the bulletin.

Sincerely,

Original signed by
Thomas W. Alexion, Project Manager
Project Directorate IV-1
Division of Reactor Projects III/IV
Office of Nuclear Reactor Regulation

Docket Nos: 50-313 and 50-368

Enclosure: Request for Additional Information

cc w/encl: See next page

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

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Mr. C. Randy Hutchinson
Entergy Operations, Inc.

Arkansas Nuclear One, Units 1 & 2

cc:

Executive Vice President
& Chief Operating Officer
Entergy Operations, Inc.
P. O. Box 31995
Jackson, MS 39286-199

Director, Division of Radiation
Control and Emergency Management
Arkansas Department of Health
4815 West Markham Street, Slot 30
Little Rock, AR 72205-3867

Winston & Strawn
1400 L Street, N.W.
Washington, DC 20005-3502

Manager, Rockville Nuclear Licensing
Framatone Technologies
1700 Rockville Pike, Suite 525
Rockville, MD 20852

Senior Resident Inspector
U.S. Nuclear Regulatory Commission
P. O. Box 310
London, AR 72847

Regional Administrator, Region IV
U.S. Nuclear Regulatory Commission
611 Ryan Plaza Drive, Suite 400
Arlington, TX 76011-8064

County Judge of Pope County
Pope County Courthouse
Russellville, AR 72801

Vice President, Operations Support
Entergy Operations, Inc.
P. O. Box 31995
Jackson, MS 39286-1995

Wise, Carter, Child & Caraway
P. O. Box 651
Jackson, MS 39205

REQUEST FOR ADDITIONAL INFORMATION ON ARKANSAS NUCLEAR ONE'S RESPONSE TO NRC BULLETIN 96-04

Information Requested

Demonstrate that the Zircaloy cladding will be protected during storage against degradation that leads to gross ruptures, or that the fuel is otherwise confined such that degradation of the fuel will not pose operational safety problems with respect to the removal of the fuel from storage [§72.122(h)(1)]. Storage conditions over the 20-year licensed period should be considered in this evaluation. Provide pertinent data and analyses to support your conclusions, such as:

- data on the diffusivity of zinc (or a reasonable estimate) in the grain boundaries (g.b.) of Zircaloy at the appropriate storage temperatures, or other data that could lead to a reasonable conclusion that the extent of g.b. diffusion over a 20-year storage period is low;

- information about reaction rate kinetics that support the position that no significant amount of reaction between zinc and Zircaloy will occur over the approved 20-year storage period, at the appropriate partial pressure of zinc;

- information about the effect of zinc on the properties and behavior of Zircaloy either when it is present in the matrix, or more importantly, in the grain boundary.

- an evaluation of the potential for corrosion along grain boundaries, cracking in the grain boundaries, and loss of ductility or strength, and for any likely effects, a discussion on the implications for posing operational safety problems with respect to the removal of the fuel from storage; and

- a justification of the applicability of the zinc-injection test data (EPRI TR-104702) to dry storage conditions.

Bases for the Request

The staff is concerned about the potential for degradation that leads to gross rupture of the fuel cladding due to diffusion of zinc in the grain boundaries of Zircaloy. The Entergy submittals (by facsimiles) dated September 12, 19, and 20, 1996, do not sufficiently address grain boundary diffusion, the properties of Zircaloy containing zinc, and the potential consequences with respect to fuel clad integrity as discussed below.

- Calculations were made on the diffusion of zinc through zirconium using a single value of the diffusivity of zinc in zirconium ($D = 2.8 \times 10^{11}$ cm^2/s at 826°C, from Smithells Metals Reference Book,

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sixth edition). This diffusivity value apparently represents lattice diffusion. Based on extrapolation of this value and without knowing the activation energy, calculations were made to show that zinc will penetrate only microns through the Zircaloy clad by lattice diffusion at dry storage temperatures. However, there are cases in which the postulated diffusion along the g.b. may be several orders of magnitude higher along the g.b. Because D(lattice) decreases much faster with temperature than D(g.b.), the ratio D(g.b.)/D(lattice) increases rapidly as temperature decreases (Refs. 1, 2, and 3).

- An equilibrium diagram of zinc and zirconium was used to conclude that no reactions would occur between these two metals until the temperatures at the eutectoid temperature are obtained. The diagram indicates that at low concentrations of zinc, the equilibrium phases that tend to form between zirconium and zinc are alpha zirconium, where the solubility is believed to be low for zinc but has not been measured, and the intermetallic phase ZnZr which would form in proportion to the location on the diagram. Further, the temperatures of interest, for dry storage conditions, are near the melting point of zinc and the eutectic between zinc and zirconium. This is an indication that, being near its melting point, the reactivity of zinc could be relatively high and the formation of intermetallic phases may be possible in short times. In absence of appropriate diffusion data to the contrary, the staff cannot yet conclude that the kinetics are too slow for the formulation of ZnZr at the temperatures in question (Refs. 4 and 5).

- Although zinc-injection tests were performed on BWR systems (EPRI TR-104702), it is not clear how the data from these tests pertain to conditions inside the MSB during dry storage, where the zinc levels may be four orders of magnitude higher and the cladding temperatures could be 700°F to 800°F.

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2. Whittle, D., Y. Shida, G. Wood, F. Stott and B. Bastow, Enhanced Diffusion of Oxygen during Internal Oxidation of Nickel-Base Alloys, 1982, Phil. Mag., vol. 46, 931.

3. Verhoeven, Hohn D., "Fundamentals of Physical Metallurgy," John Wiley and Sons, 1975, Chapter 6 (p. 155) (TN690.V46).

4. Reed-Hill, Robert E., and Reza Abbaschian, "Physical Metallurgy Principles," PWS Publishing Co., Boston, Third Edition, 1994, Chapter 12 (TN690.R43).

5. Porter, D. A. and K. E. Easterling, "Phase Transformations in Metals and Alloys," Van Nostrand Reinhold Co. Ltd. 1981 1st Edition, Chapter 5 - "Diffusion Transformations in Solids" (TN690.P597).