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In the Matter of Consolidated Edison Company of New York, Inc.
Indian Point Nuclear Generating Unit No. 2
Docket No. 50-247

Dear Mr. Roisman:

Transmitted herewith are the responses of the AEC regulatory staff to the ECCS questions you submitted on October 12, 1971.

Sincerely,

Myron Karman

Myron Karman
Counsel for AEC Regulatory Staff

Enclosure:
As stated

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hearing

INDIAN POINT UNIT 2 HEARING

AEC STAFF ANSWERS TO QUESTIONS

1, 3, 14, 20, AND 29 CONTAINED

IN INTERVENORS INQUIRY OF OCTOBER 12, 1971

CONSISTING OF 39 QUESTIONS

QUESTION 1

Discuss the Staff assumption that only 10% of the iodine released after a LOCA will be organic in light of the results reported in ORNL-4635 (pp. 59-61) indicating higher than expected amounts of the organic iodide CH_3I. Also explain how the use of 5% organic iodine rather than 10% organic iodine as discussed in the Staff October 4 letter to Richard Cruger produces higher radioactive releases to the public if the 10% figure is assumed to be more conservative than the 5% figure. Finally generally explain how the results of radioactive releases discussed in ORNL-4635 affect the assumptions used in your evaluations of this plant.

(a) ORNL-4635 reports a total release of only 0.189% of the available iodine for the TREAT Fuel Rod Failure Experiment FRF-1. Of this quantity, about 7% was organic iodides, or about 0.013% of the available inventory. This should be compared with the conservative AEC site evaluation criteria of 25% release of the entire core iodine inventory, with 2.5% of the entire inventory in the form of organic iodides. Therefore, the AEC assumed total I-131 release is more than 100 times the observed value and the AEC assumed release of organic iodides is 200 times the observed value. It should also be noted that for very small iodine releases, the fraction of the released iodine converted to organic iodides is expected to be higher. Table 5.1 of the above reference shows that the observed releases were only a small fraction of the calculated gap and void space inventory.

(b) The discussion in the letter from Dr. P. A. Morris to Mr. Cruger, dated October 4, 1971 was intended to supplement the comparison of thyroid dose calculations using an instantaneous plateout factor of two with calculations using a realistic, time-dependent plateout model acting in conjunction with the spray removal system. The assumption of conversion of 10% of the total iodine available for release after plateout (25% of the core inventory) to organic iodides is exactly equivalent to conversion of 5% of the iodine released from the core (50% of the core inventory), in terms of mass organic iodides present. The result of the time-dependent plateout calculation indicates a lower dose than obtained using the instantaneous plateout assumption and shows that the instantaneous plateout mechanism used in the original staff calculations yields the more conservative (higher) dose results.

(c) The results reported in ORNL-4635, in conjunction with many other experimental results, further confirm the conservatism of the assumptions used by the regulatory staff in site evaluation calculations.

QUESTION 3

What affect does the failure of RELAP 3 to predict pressures within 100 psia of those actually measured (see IN-1444, p. 13) have on the reliability of the ECCS predictions for this plant? How has this problem been corrected in the Staff and Applicant analysis?

The reference document (IN-1444) discusses the comparison of the RELAP 3 code calculations with experimental results for vessel blowdowns over the pressure range from approximately 2000 psig to atmospheric pressure. This comparison indicated a maximum difference between calculated and observed pressures of ± 100 psi for small breaks, and a maximum pressure difference of only ± 50 psi for large breaks. Since the postulated double-ended failure of a cold leg pipe (a large break) is the limiting LOCA, the agreement of calculation with experiment over this wide pressure range is considered satisfactory.

The calculation used in this comparison for the large break was made assuming a discharge coefficient of 0.6. The AEC's Interim Policy Statement states that a discharge coefficient of 1.0 shall be assumed. This assumption results in a significant underprediction of system pressure, with a resultant decrease in the heat transfer from the fuel rods to the coolant during blowdown. Therefore, the fuel cladding temperature transient calculated in accordance with the policy statement is conservatively higher than would be anticipated, and the assumed operating conditions for the ECCS would be more demanding. Consequently, the ECCS performance predictions for this plant would not be affected significantly by the minor discrepancies between calculated and observed pressures reported in IN-1444.

QUESTION 14

CLAD TEMPERATURE CRITERIA

Upon what basis was 2300°F set as the maximum permissible rod temperature level in a LOCA? What will occur at 2301°F which will not occur at 2300°F?

The 2300°F temperature limit was established in part to limit local cladding embrittlement and in part to provide margin for the energy release by metal-water reactions. At temperatures above 2300°F nominal heat transfer may be insufficient to prevent clad melting because of metal-water energy release.

The processes which bring about embrittlement of Zircaloy cladding during a postulated loss-of-coolant accident are fairly well understood. Brittle materials are characterized by their inability to withstand sudden loadings. During a LOCA, the Zircaloy cladding on the fuel is subjected to an environment which may cause embrittlement of the metal such that the applied stresses may result in cladding fragmentation. The cause of the embrittlement is oxygen which reacts with the Zircaloy and diffuses into the interior of the clad. Many experiments have been performed with Zircaloy cladding in a steam or water environment to study zirconium-oxygen chemical reactions and the extent of clad embrittlement. Three recent reports have been published on this topic

(Hesson[1], 1970; Meservey[2], 1970; Graber[3], 1971). Post-test metallographs of the cladding samples tested reveal three distinct layers of cladding material ZrO_2, oxygen stabilized α Zr, and prior β Zr. The layers of ZrO_2 and α Zr formed are always structurally weak. Since oxygen pickup and, therefore, embrittlement is a diffusion controlled process, it is dependent on the temperature reached and on the time at temperature. Graber notes that the location of the oxygen is as important as the total amount of oxygen in the cladding; and that under slow cooldown conditions, the prior β Zircaloy layer anneals and is also structurally weak.

Hesson classifies the cladding as very brittle if the ZrO_2 is 18% or more of the total original clad thickness. This would correspond to a ZrO_2 plus α Zr thickness of 40% of the clad. The 18% ZrO_2 limit was determined under "light handling" stress conditions. The Rod Burst Program conducted by Westinghouse showed no cladding fragmentation upon quenching if the ZrO_2 thickness was less than 16% of the cladding (Moore[4], 1970). Figure 1 shows the proposed Westinghouse area of safe operation with the 16% reaction limit and the 18% Hesson "very brittle" limit. Also plotted are points calculated from Rittenhouse's ORNL work[5] in which his time at temperature summary points for embrittlement were converted to a corresponding percent clad reaction for a PWR fuel pin based on the Baker-Just[6] equation for Zr-H_2O reaction.

Although excessive embrittlement values have been defined under "light handling" conditions, cladding fragmentation will not occur during a LOCA unless the stress-embrittlement combination are above an as yet undefined value. Potential causes of cladding stresses, other than those caused by the weight of the fuel, which could exist during the accident are: thermal, residual, hydraulic, and vibratory forces.

Because fragmentation cannot be expected until oxygen adsorption occurs, fragmentation will not occur early in the accident. Moreover, Meservey states that:

> "Oxidized Zircaloy material that demonstrates brittle behavior at room temperature does not do so at 1800°F. The brittle-ductile transition for previously embrittled material appears to lie in the range 900 to 1800°F."

This fact is important to the consequences of cladding fragmentation because it means that fragmentation is unlikely until after the peak cladding temperatures have been attained, and the cladding is in the cooldown phase of the accident. Temperature peaks obtained during the first few seconds following DNB are of such short duration that, unless they are as high as about 2600°F, they will probably not lead to enough embrittlement to cause fragmentation during initial temperature declines. The ECC cooldown phase of the accident may last for several minutes. It is during these relatively long cooldowns that most of the local metal-water reaction and cold embrittlement will occur. But even the longest transients calculated to date show less than 10% local reaction which is still below any of the limit lines shown in Figure 1.

Cladding fragmentation is a result of stresses applied following thermal transients which result in cladding embrittlement. The magnitude of embrittlement is a function of time-at-temperature and has been adequately investigated for all but slow cooling cases (5°F/sec and below). At more rapid cooling rates the prior material is not brittle and fragmentation does not occur under "light handling" stress conditions unless the $ZrO_2 + \alpha$ Zr thickness is 40% or more of the total thickness. This degree of embrittlement is attained only if clad temperatures exceed 2460°F. Therefore, we conclude that for typical time-temperature transients expected in a LOCA a limit of 2300°F on cladding temperature is conservative.

2300°F does not represent a threshold above which sudden changes occur in physical effects. No phase changes occur at 2300°F, no embrittlement threshold is reached, nor does any step changes in energy release occur. When the Baker-Just equation is used to describe metal-water reaction rates in this temperature region, the calculated rate increases only 1/2 of 1% from 2300°F to 2301°F.

REFERENCES

1. Hesson, J. C., et al, Laboratory Simulations of Cladding Steam Reactions Following Loss-of-Coolant Accidents in Water-Cooled Reactors, ANL-7609 (January 1970)

2. Meservey, R. H., Herzel, R., Brittle Behavior of Zircaloy in an Emergency Core Cooling Environment, IN-1389 (September 1970)

3. Graber, J. J., Zelezny, W. E., Schmunk, R. E., A Mettallurgical Evaluation of Simulated BWR Emergency Core Cooling Tests, IN-1453 (February 1971)

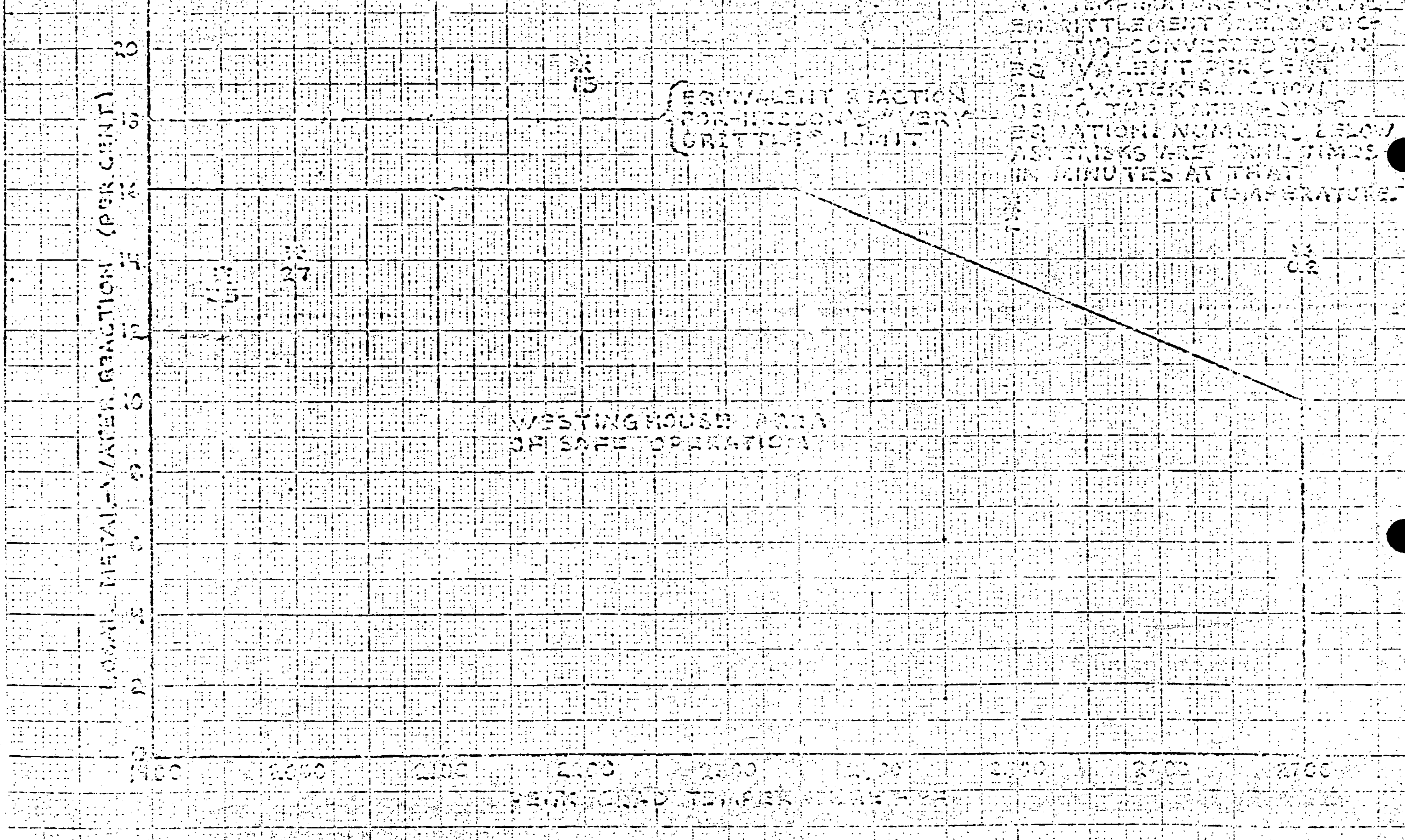
4. Moore, J. S., Westinghouse PWR Core Behavior Following a Loss-of Coolant Accident, WCAP-7422 (August 1971)

5. Rittenhouse, P. L., Progress in Zircaloy Cladding Failure Modes Research, ORNL-TM-3188, Pgs. 15 and 16 (December 1970)

6. Baker, L., Just, L. C., Studies of Metal-Water Reactions at High Temperature, III. Experimental and Theoretical Studies of Zirconium Water Reactions, ANL-6548 (May 1962)

7. Cadek, F. F., et al, PWR-FLECHT, Final Report, WCAP-7665 (April 1971)

FIGURE 1
PER CENT LOCAL METAL-WATER REACTION
VS.
PEAK CLAD TEMPERATURE



QUESTION 20

In the Staff analysis of rod burst tests by suppliers, what inadequacies were found that warranted the conduct of additional tests by ORNL?

The tests conducted by ORNL were part of a program initiated by the AEC in the interest of exploring the problem of fuel failure. This program was the first of its kind in the United States and represented an effort by the AEC to resolve the unknown questions relating to the potential effects of fuel failure during a LOCA. The reactor suppliers were encouraged subsequently to participate in programs of their own to implement and supplement the government program in order to appreciate and understand the problem in terms of their own studies applicable to their particular reactor systems.

QUESTION 29

What are the differences between the Staff calculations and assumptions and those contained on p. 6 of the 6/1/71 Report? Also the differences in the transition boiling correlation (p. 24 of the same Report), reflooding heat transfer (p.33) and discharge coefficient (p. 35).

The FSAR calculation for Indian Point 2 was done according to WCAP-7422-L. Pages 3-5 of the June 1, 1971 report outline proposed changes by Westinghouse to the procedures outlined in 7422-L. The results on page 6 of the June 1, 1971 report compare calculations done according to WCAP-7422-L and those done with the proposed changes. The staff in its interim policy statement of June 19, 1971 did not accept the use of an .8 discharge coefficient as proposed but required the use of a 1.0 coefficient. The result is that the system blowdown is more rapid and the period of adiabatic heatup is longer. All other additional exceptions are set forth in the Interim Policy Statement (IPS) and result in higher clad temperatures.

The new transition boiling correlation was accepted by the IPS except that the first term was changed. A comparison of the new with the old first term is shown in Figure 6.2.1 on page 27 of the June 1, 1971 report.

The exceptions for the reflooding calculation are noted in Item 7 of the Commission's interim policy statement. The reflood heat transfer correlation used by Westinghouse was accepted by the staff.