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May 22, 1984

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Ms. E. G. Adensam, Chief
Licensing Branch No. 4

Re: Catawba Nuclear Station
Docket Nos. 50-413 and 50-414

Dear Mr. Denton:

Attached herewith are twenty (20) copies of Revision 11 to Duke Power Company's report, "An Analysis of Hydrogen Control Measures at McGuire Nuclear Station." As noted in Revision 9, this report is applicable to Catawba Nuclear Station. This revision provides responses to the questions submitted to Duke Power Company by letter dated May 8, 1984 (E. G. Adensam, NRC/NRR, to H. B. Tucker, Duke Power Company). This information should be inserted in Section 7.0 of Volume 3.

Please advise if there are any questions regarding this matter.

Very truly yours,

Hal B. Tucker
ELS

Hal B. Tucker

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Attachments

cc: Mr. James P. O'Reilly, Regional Administrator
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NRC Resident Inspector
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cc: Mr. Jesse L. Riley
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Response to questions submitted by letter from NRC (Elinor G. Adensam) to Duke (H. B. Tucker) dated May 8, 1984.

1. With regard to the CLASIX code, the staff has previously requested clarification of the structural heat sink heat transfer models. The following pertinent points have been derived from the responses:

   i) Heat transfer is based on a temperature difference determined by $(T_{bulk} - T_{wall})$.

   ii) Heat transfer coefficients for degraded core accident analysis are determined from a natural convection (stagnant) correlation applicable to condensation heat transfer.

   iii) CLASIX does not explicitly model mass removal due to condensation heat transfer.

   Based on the description of the CLASIX structural heat sink model, it appears that the CLASIX model differs dramatically from generally accepted approaches and is not, as is claimed, consistent with standard methods such as those used in CONTEMPT. The differences are related to the treatment of the three items cited above. By comparison, previously accepted approaches are characterized by the following:

   i) Heat transfer is based on $(T_{sat} - T_{wall})$, when the surface temperature of the heat sink is less than T_{sat}; i.e., $T_{wall} < T_{sat}$.

   ii) Heat transfer coefficients are based on condensation only when $T_{wall} < T_{sat}$.

   iii) Condensed mass removal is based on condensation heat transfer with provisions for revaporizing a small fraction of the condensate.

   A more detailed description of accepted practice is contained in NUREG-0588 and NUREG/CR-0255

   The effect of the CLASIX models would appear to be the de-superheating of the atmosphere too rapidly thus reducing gas temperatures and possibly altering the combustion characteristics.

   Considering the above discussion, provide the results of analyses, with acceptable models to determine the effectiveness of deliberate ignition for the Catawba plant. The analyses should address the effects of hydrogen combustion on containment integrity and equipment survivability. Furthermore, the analyses should be performed to address a spectrum of appropriate degraded core accidents. Specific items that should be addressed include:

   a. Model input and analytical assumptions;

   b. Calculated compartment atmosphere pressure, temperature, and gas concentration transients;

   c. Equipment temperature response profiles;

d. Differential pressure transients between compartments which will allow for an evaluation of ΔP effects on interior structures and mechanical components (e.g., doors, fans); and

e. Considering the capability of the containment shell, crane wall, and the operating deck, perform an analysis to determine the maximum concentration of hydrogen which could be accommodated in a deflagration. Your estimate should consider realistic initial conditions and approximate combustion parameters.

Response:

A justification for the use of the heat sink models in CLASIX was presented to NRC when this question was first posed to Duke in Elinor G. Adensam's letter of August 18, 1983. That response appears on pages 7.0-129 - 7.0-133. We have reviewed that response and continue to support the case that it makes for the adequacy of the original analysis. Our conclusion is that no additional CLASIX analysis is required to justify the results of our original work.

We note, however, that the additional CLASIX analysis requested by the staff was performed by AEP using heat transfer models which were in accordance with the staff's request that the models conform to those of NUREG 0588 and NUREG/CR-0255. The results of this analysis were reported to NRC by M. P. Alexich's letter dated march 30, 1984. These results are very interesting in view of the theoretical arguments presented previously by Duke Power Company in support of the original CLASIX heat transfer models. In their work, AEP compared directly the original heat transfer models with those requested by the staff using identical geometries, initial conditions, and release rates. The AEP results indicate:

1. Pressure and temperature profiles are generally similar for the two sets of heat transfer correlations.

2. The original CLASIX analysis tends to underpredict the temperature in containment at the peaks associated with the hydrogen burning by about 100°F.

3. The original CLASIX analysis tends to overpredict the baseline containment temperatures (the temperature of the containment between hydrogen burning). This indicates that the original CLASIX heat sink models remove less energy from the containment atmosphere in the period immediately following a hydrogen burn and therefore provide a conservative baseline containment temperature profile.

4. Further evidence of the conservatism of the original CLASIX heat sink models can be found from examining the containment pressure response. In every case, pressures during the hydrogen burn period were higher for the original CLASIX analysis than for the analysis using the "corrected" heat sink models. This indicates again that the original CLASIX heat sink models remove less energy from the containment atmosphere per unit time than the heat sink models based on NUREG-0588 and those used in CONTEMPT.

In summary, analysis performed by AEP wherein a head-to-head comparison of heat sink models was made supports the position taken by Duke Power in its previous submittal concerning the question of CLASIX heat sink models (Revision 10). These models have been shown to be conservative from both a theoretical and an analytical standpoint. The higher peak temperatures during hydrogen burning predicted by the "corrected" heat sink models are of no consequence to the analysis of equipment survivability as our survivability analysis used the adiabatic flame temperature (1400°F) rather than a lower temperature predicted from CLASIX results.

The ability of the hydrogen ignition system has been shown to be effective in controlling the concentration of hydrogen to levels less than 8.5% by volume in CLASIX analyses, small scale testing, and more recently, in the large scale Nevada tests. Our structural analysis has consistently shown considerable margin in the containment design in its ability to withstand the pressures and differential pressures associated with hydrogen burning at this concentration. To seek some maximum theoretical higher concentration which could be tolerated represents an unrealistic extension of our previous work and, at best, can be considered of academic interest only, and of no consequence in proving the adequacy of the concept of deliberate ignition.

Further support for the adequacy of the CLASIX code is presented in reference (a), wherein CLASIX is compared with HECTR. For identical input conditions, and in spite of considerably increased technical complexity in many of the HECTR models, results from the two codes are nearly identical. We conclude that the models contained in CLASIX are suitable for use in analysis of beyond design basis conditions, and that further discussion of CLASIX is unlikely to affect our confidence in it as an analytical tool for the study of deliberate ignition in ice condenser containments.

2. Provide a complete evaluation of fan (both air return and hydrogen skimmer as applicable) operability and survivability for degraded core accidents. In this regard discuss the following items:

   a. The identification of conditions which will cause fan overspeed, in terms of differential pressure and duration, and hydrogen combustion events.

   b. The consequences of fan operation at overspeed conditions. The response should include a discussion of thermal and overcurrent breakers in the power supply to the fans, the setpoints and physical locations of these devices, and the fan loading conditions required to trip the breakers.

   c. Indication to the operator of fan inoperability, corrective actions which may be possible, and the times required for operators to complete these actions.

   d. The capability of fan system components to withstand differential pressure transients (e.g., ducts, blades, thrust bearings, housing), in terms of limiting conditions and components.

Response:

This identical question was submitted by letter from NRC (Elinor Adensam) to Duke (H. B. Tucker) dated August 18, 1983. It was answered in Revisions 8 and 10.

3. Provide an analysis of the pressure differential loading on the ice condenser doors created by hydrogen combustion in the upper plenum and upper compartment. Describe and justify the assumed or calculated door positions. Provide an evaluation of the ultimate capability of the ice condenser doors to withstand reverse differential pressures. Discuss the probable failure modes and the consequences of such failures; including the impact on a) adjacent equipment and structures, b) ice bed integrity, and c) flow maldistribution.

Response:

Referring to previous CLASIX results for measures of the intercompartmental differential pressures results in unrealistically conservative answers. This result is caused by the manner in which CLASIX models the lower inlet and intermediate deck doors. The dynamics of door closing contains no inertial term; therefore the doors close instantaneously whenever the net force in the closing direction is greater than zero. For example, as soon as an upper plenum burn is initiated and upper plenum pressure increases, the intermediate deck doors closed instantaneously. The pressure rise in the upper plenum will therefore be conservatively high as venting into the ice bed will be precluded. This effect was noted in the comparison of CLASIX analysis with similar analyses using HECTR and COMPARE reported in reference (a). In addition, reference (a) states:

> "During burns, CLASIX predicts fairly large pressure differentials between the compartments, which we would not expect to occur, given the large flow areas connecting the compartments. HECTR predicts rapid pressure equilibration, and only small pressure differences between compartments. As shown later, COMPARE also predicts rapid pressure equilibration".

Based on the discussion above, differential pressures obtained from CLASIX might be considered a gross upper bound for the differential pressures which would be developed in an actual hydrogen burn situation. A review of previous CLASIX analysis reveals the following results. For an upper plenum hydrogen burn initiated at 8.5% by volume, and a flame speed of 6 feet/second, the maximum indicated differential pressure across the intermediate deck doors is 1.2 psid.

As reported in an answer to a previous question, the reverse differential pressure capability of the intermediate deck door is 6 psid. There is therefore substantial margin in the intermediate deck to withstand the reverse differential pressure associated with an upper plenum burn, even under the bounding conditions of an analysis using CLASIX.

For an upper compartment burn, which is shown to be precluded except under the most extreme assumptions, the pressure rise time is relatively slow due to the length of time it takes for the flame to propagate throughout this large compartment. Results of the EPRI Nevada large scale tests show that hydrogen is reliably ignited by top ignition at 6% by volume in the presence of sprays or fans, and that the corresponding flame speed is less than 10 ft/sec. Pressure rise times are less than one psi/second generally for the cases where typical plant conditions have been modeled. We conclude that upper compartment burns cannot exert large differential pressures across the top deck doors, even if the doors are assumed to be fully closed. In an actual hydrogen burn, the differential pressure would be minimized by the increase in flow area caused by dislocation of the top deck blankets during the early portion of the accident.

4. Identify the essential equipment needed to function during and after a degraded core accident. Provide the location inside containment for this equipment.

Response:

This information has been furnished previously to the staff on at least two occasions. Refer to reference (b), Section 6.2, and to Section 5.2 of this volume.

5. In view of the recent TVA test results with Tayco igniters which indicate desirability of additional spray shielding, please discuss whether supplementary spray shields may be appropriate for the glow plug igniters.

Response:

None of the glow plug igniters found by Duke Power to be required for adequate coverage of the containment is exposed to a spray environment. The four additional igniters added to the upper compartment at the request of the staff are in the environment created by the containment sprays; however, we note the following:

1. During the small scale testing reported in Chapter 2, there was no evidence that a spray environment had an adverse effect on the performance of the glow plug igniter.

2. The tests performed in the large scale test vessel in Nevada, in which ignition was started by glow plug igniters located at the center and bottom elevations (and thus in the spray) show no evidence that containment spray inhibits the ignition of hydrogen by glow plug igniters.

We conclude that no further testing or modification of the glow plug igniters is required for McGuire or Catawba.

References:

(a) Camp, Allen L., Vance L. Behr, and F. Eric Haskin, MARCH-HECTR Analysis of Selected Accidents in an Ice Condenser Containment, Sandia National Laboratories.

(b) An Analysis of Hydrogen Control Measures at McGuire Nuclear Station, Volume III, dated January 5, 1981 (this has been referred to as the "Grey Book").