Enclosure 1

DRAFT

SAFETY EVALUATION REPORT REGARDING HYDROGEN CONTROL MEASURES FOR CATAWBA NUCLEAR STATION, UNITS 1 AND 2

BACKGROUND

In Supplement 4 to the SER (NUREG-0954), the staff reported that the material provided in the license's May 22, 1984 submittal regarding hydrogen control measures for the Catawba Nuclear Station (Reference 1) did not adequately resolve the outstanding issues identified in Supplement 2 to the SER. These issues involve equipment survivability for a spectrum of accidents, air return fan and ice condenser door response to upper compartment burns, and igniter operability in a spray environment. The staff further indicated that the necessary information and upgraded analyses had been requested by letter dated October 3, 1984 (Reference 2), and that the license condition regarding hydrogen control measures would be modified to require the licensee to submit this material by April 1, 1985 for Catawba Unit 1.

In response to the staff's request for additional accident analyses, Duke stated in a November 7, 1984 letter (Reference 3) that the following actions were planned to resolve the outstanding technical concerns regarding equipment survivability. Duke would: (1) perform additional analyses of accident sequences using the Modular Accident Analysis Program (MAAP) code in lieu of the March 1.1 code, (2) develop a best estimate set of hydrogen burn characteristics based on the results of the large scale tests at the Nevada Test Site (NTS), (3) perform additional analysis of equipment survivability (thermal response) if the Duke review of the work performed by Sandia indicates the need for such analysis, and (4) perform additional analysis of air return fan and ice condenser door response if it appears that significant upper compartment burns are possible. The contingencies in the latter two actions should be noted.

The results of the planned actions by the licensee were provided by letter dated March 29, 1985 (Reference 4). In this letter, the licensee also advised the staff of their position that the design features of the McGuire and Catawba Nuclear Stations currently meet the requirements of the Final Rule on hydrogen control (10 CFR 50.44 (c)(3)(iv)) and that no schedule need be submitted pursuant to the rule. The staff has reviewed the information provided by the licensee to determine whether it adequately resolves each element of the license condition. The results of the staffs review are presented below.

LICENSE CONDITION 14 - HYDROGEN CONTROL MEASURES

License Condition 14 requires that:

> Prior to April 1, 1985, upgraded analyses and tests shall be provided on the following issues and submitted for staff review and approval:
>
> (1) thermal response of the containment atmosphere and essential equipment for a spectrum of accident sequences using revised heat transfer models,
>
> (2) effects of upper compartment burns on the operation and survival of air return fans and ice condenser doors, and
>
> (3) operability of the glow plug igniter in a spray environment typical of that expected in the upper compartment of the containment.

The license condition was placed on the Catawba operating license as a result of information developed following the licensing of the McGuire Nuclear Station.

At the time Supplement 7 to the McGuire SER (NUREG-0422) was issued, Duke had performed numerous analyses of the containment atmosphere pressure and temperature response during degraded core accidents with associated hydrogen release and combustion. Many calculations were performed, using the CLASIX code, to determine the sensitivity to variations in assumed combustion parameters, assumptions regarding availability of containment safety systems, and variations in the hydrogen and steam release to the containment. The staff required that Duke provide these studies in order to demonstrate adequacy of the igniter system to mitigate the consequences of a large fraction of degraded core accident sequences.

Although Duke performed many CLASIX analyses, these calculations were done with the primary intent of examining the resulting peak containment atmosphere pressure during the degraded core accident transient. For the equipment survivability study only the base case S_2D sequence analysis was used, with a variation on assumed flame speed and a variation on ignition concentration and combustion completeness. The CLASIX analyses performed using different hydrogen and steam releases or different heat removal system assumptions were not used in assessing equipment survivability. Rather than evaluate equipment performance against the containment atmosphere transients calculated for various sensitivity analyses using different hydrogen and steam releases, Duke argued that their S_2D case represented a reasonable upper bound scenario. This conclusion was based on a comparison of hydrogen release rates as well as total hydrogen released for various accident scenarios, as predicted using the MARCH code. The staff concluded in Supplement 7 to the McGuire SER that Duke had provided sufficient justification of equipment survivability for appropriate degraded core accident sequences even though calculations were performed only for the selected S_2D sequence. The staff reached this decision primarily on the basis that substantial margins existed between predicted temperatures and qualification temperatures. However, as noted above, the staff indicated in Supplement 7 to the McGuire SER, its intent to pursue this issue as a confirmatory item.

One approach for resolving this confirmatory issue was through the Hydrogen Burn Survival Program conducted at the Sandia National Laboratories for the NRC Office of Research. The Sandia investigation has been completed and documented in NUREG/CR-3954 (Reference 5). An important conclusion of this report, however, is that certain accident sequences possessing a core-melt frequency comparable to the base case S_2D sequence produced surface temperatures in excess of the temperature to which equipment is typically qualified. Also, many of the Sandia containment analyses (Reference 6) predicted hydrogen burning in the upper compartment of the containment, in contrast to the licensee's CLASIX analyses which predicted no upper compartment burning.

The staff also determined, as part of its ongoing investigation of hydrogen-related containment analysis codes, that the CLASIX code used by Duke contained errors in the heat transfer models. The effect of these errors would cause the code to underpredict the containment atmosphere temperature which serves as the boundary condition of the determination of equipment thermal response. This problem was alluded to in the staff October letter, and was expounded on in earlier correspondence with Duke (References 7 and 8). Finally, confirmatory analyses performed by the staffs contractor, Los Alamos National Laboratory (Reference 9), also support the findings of Sandia regarding equipment temperatures. The LANL analyses were performed using a hydrogen burn version of the COMPARE computer code, and one-dimensional heat structures to represent essential equipment.

As a result of the information obtained following the licensing of McGuire, the Catawba operating license was conditioned to require upgraded analyses of the thermal response of the containment atmosphere and essential equipment for a spectrum of accident sequences using revised heat transfer models.

In addition to requiring upgraded thermal response analyses, the license condition required that Duke address the effects of upper compartment burns on the operation and survival of air return fans and ice condenser doors. The results of the NTS pre-mixed tests provided the principal motivation for focusing on the impact of upper compartment burns on equipment survival. In the NTS tests, thermal igniters reliably ignited hydrogen-steam-air mixtures with hydrogen concentrations as low as approximately 5.5 volume percent. When taken in conjunction with the results of Sandia MARCH-HECTR analyses (which show higher steam fractions in the lower compartment and numerous upper compartment burns), and the results of the fog analyses sponsored by the Ice Condenser Owners Group (which show an increased flammability limit in the ice condenser upper plenum), the NTS test results suggest that hydrogen burns in the upper compartment are likely for many degraded core sequences. Accordingly, the Catawba operating license was conditioned to require further review of the effects of upper compartment burns.

The license was also conditioned to require that Duke address the matter of glow plug operability in a spray environment typical of that expected in the upper compartment. This requirement was prompted by the results of preliminary testing performed by Sandia for the NRC Office of Research (Reference 10), which indicated that glow plug igniters may be susceptible to excessive cooling by impinging containment spray droplets.

THERMAL RESPONSE ANALYSIS

Consistent with the first element of License Condition 14, the staff requested in its October 3, 1984 letter that Duke provide the results of analyses to determine the effects of hydrogen combustion on containment integrity and equipment survivability for spectrum of appropriate degraded core accidents. In response, the licensee cited several deficiencies in the Sandia analyses, and provided additional information to support the adequacy of the existing utility analyses; upgraded thermal response analyses were not provided.

Duke questioned the validity of three aspects of the Sandia work: (1) the way in which essential equipment was simulated in the HECTR analyses, (2) the hydrogen combustion assumptions used in the analyses, and (3) the use of MARCH to predict hydrogen and steam releases for the various sequences analyzed. Duke asserts that the one-dimensional heat sink models used in the HECTR analyses to simulate the thermal response of equipment are overly conservative. The one-dimensional models depict the heat sinks as being insulated on one side, and do not account for heat transfer from the back side or for three dimensional effects. This would produce surface temperatures higher than what would be expected in an actual accident situation. Duke also contends that: (1) the assumption in the HECTR analyses that burning does not occur until the hydrogen concentration reaches 8 volume percent is unrealistically conservative (high), and is not supported by recent large scale test results, and (2) the MARCH code, used to generate the hydrogen and steam release input for the HECTR analyses, consistently overpredicts the amount of water released from the primary system. The latter contention is based on a comparison by Duke between MARCH-computed hydrogen and steam release for the S_2D sequence, and the releases computed by Duke using the MAAP code developed by IDCOR. The licensee did not provide any details of the MAAP calculation by which the staff could assess the validity of this contention.

To buttress their position that the existing utility thermal response analyses provide an adequate basis for concluding on the acceptability of the Hydrogen Mitigation System (HMS) installed at Catawba, Duke provided several additional arguments. These include statements that all vital equipment for Catawba which is temperature sensitive is located either outside of containment or in the dead-ended compartments within the containment, and that the sequences considered by Sandia which produce equipment temperatures beyond the LOCA qualification temperature (S_1 sequences) should not be considered as design basis sequences for the igniter system because they occur with a lower probability

than the S_2D sequence, and quickly proceeded to core melt. On the basis of the arguments, and the previously mentioned aspects of the MARCH-HECTR analyses, Duke has concluded that additional analysis of containment and equipment thermal response is not warranted.

The staff has reviewed the information provided by Duke in Reference 4 regarding thermal response analyses. Based on our review, we believe that several of the issues raised by Duke are either unsubstantiated or would have little bearing on the overall conclusions of the report. For example, the staff recognizes that the NTS tests effectively demonstrate that ignition will occur at a hydrogen concentration lower than assumed in the Sandia and utility containment analyses, and that a downward revision of the hydrogen concentration value assumed for ignition can be justified for certain compartments in containment. Nevertheless, the staff does not consider the findings of the Sandia analyses regarding lower compartment thermal response to be invalidated by the use of the higher ignition values, or by the alleged overprediction of steam releases by MARCH, since the effect of each of these items is to shift the location of hydrogen ignition from the lower compartment to the upper plenum and the upper compartment, thereby reducing the lower compartment temperature.

On the other hand, we agree with several of the points raised by Duke, and are continuing our review in these areas. In particular, the staff recognizes that a major reason for the high surface temperature reported in the Sandia work is the use of extremely conservative models to simulate equipment, a point conceded in Sandia report. Because proper modeling of equipment is an important element of this type of analysis, the staff intends to perform further analyses of equipment survivability using a more accurate representations of equipment. We will defer judgement on the need for analysis of additional accident sequences by the utility until completion of this work.

EFFECTS OF UPPER CONTAINMENT BURNS

Consistent with the second element of the License Condition 14, the staff requested in its October 3, 1984 letter that Duke provide a complete evaluation of air return and hydrogen skimmer fan operability and survivability for degraded core accidents. The specific information requested from the licensee included:

(1) The identification of conditions which will cause fan overspeed, in terms of the magnitude and duration of differential pressures required to produce overspeed and hydrogen combustion events,

(2) The consequences of fan operation at overspeed conditions,

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

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

(5) An assessment of whether the requisite conditions for overspeed, tripping, or failure of the fan systems, will occur for each of the spectrum of degraded core sequences, and the impact of anticipated fan behavior on the progression of the accident.

In response to the staff's request, Duke asserted that the result of the NTS hydrogen combustion tests demonstrate that upper compartment burns, if they ever occur in a global manner, occur at hydrogen concentrations of 6.5 percent or less. Duke further stated that burns occurring at this hydrogen concentration do not create sufficient differential pressure across the fans to cause them

to reach synchronous speed. On this basis, Duke concluded that no further work is required on fan survivability.

The staff concurs in the Duke assessment that upper compartment burns would occur at a hydrogen concentration of approximately 6.5 percent or less, but is unable to conclude on the impact of the postulated burns on fan operability without additional information. We will require that the licensee provide for staff review, the details of the fan response calculation. Information we consider necessary to resolve this matter includes hydrogen combustion assumptions (e.g., flame speed, burn completion, compartment venting, containment spray heat removal) and the fan and electrical system models and assumptions. We will report the results of our review in a future SER.

The second element of the license condition also requires an evaluation of ice condenser door survivability when subjected to hydrogen burn pressure loads. In this regard the staff requested Duke to: (1) provide a quantitiative assessment of the pressure loading on each of the ice condenser doors created by hydrogen combustion in a) the upper plenum and b) the upper compartment, (2) describe and justify the assumed or calculated door positions, (3) provide an evaluation of the ultimate capability of ice condenser doors to withstand reverse differential pressures, and (4) discuss the probable failure modes and the consequences of such failures.

In response to this request, the utility claimed that the CLASIX code predicts large pressure differentials between compartments as a result of flow model assumptions intended to maximize containment pressure response, and that the CLASIX code predictions were not confirmed by HECTR c. COMPARE results. The licensee further noted that venting between compartments, combined with burning at the low hydrogen concentrations observed in the NTS tests, would effectively reduce differential pressures. On this qualitative basis, Duke concluded that a more detailed structural analysis of the ice condenser doors need not to be performed.

The staff has reviewed the utility response and finds that it does not adequately address the key staff concern, namely, that upper compartment burns can produce differential pressures across ice condenser doors in excess of their reported structural capacity. While we acknowledge that the differential pressures calculated by CLASIX appear to be greater than predicted by other codes, and that upper compartment burns will likely occur at a hydrogen concentration lower the 8 percent, we are unable to conclude on the matter of ice condenser door survivability based on the available information. For example, utility responses to staff questions regarding reverse differential pressure loads on ice condenser doors indicate an apparent inconsistency in reported values for both reverse pressure capability of the doors and the peak calculated differential pressures. The reverse pressure capability for the intermediate deck doors was reported to be 6 psid for Catawba and 2.9 psid for D.C. Cook; the peak differential pressures across these doors resulting from an upper plenum burn was reported to be 1.2 psid for Catawba and 12.6 psid for D.C. Cook. Furthermore, utility responses do not provide a quantitative assessment of the reverse pressure differential loads across each of the three sets of doors resulting from an upper compartment burn. The staff estimates that the differential pressure resulting from an upper compartment burn at a hydrogen concentration of 6 percent would be approximately 7 to 14 psid for an assumed flame speed of 6 to 12 feet per second, respectively.

It is the staff's view that the pressure loads resulting from upper compartment burns need to be further examined, using refined modeling techniques if necessary, in view of recent tests and analyses which suggest a greater frequency of upper compartment burns than indicated in the utility analyses. (The MARCH/HECTR analyses do not lend themselves to this application since the analyses addressed peak compartment pressures rather than peak differential pressures.) Accordingly, we will request the utility to provide the information delineated in our October 3, 1984 letter so that we may make a determination regarding the survivability of ice condenser doors. We will provide the results of a further review of this matter in a future SER.

OPERABILITY OF THE GLOW PLUG IN A SPRAY

Consistent with the third element of License Condition 14, the staff requested in its May 8, 1984 letter that Duke address the need for supplementary spray shields for the glow plug igniters. In response, Duke indicated that none of the igniters which they consider necessary for adequate coverage of the upper compartment are exposed to a spray environment. Furthermore, the only four igniters which are exposed might still be expected to function, as evidenced by the successful operation of glow plug igniters in small and large-scale combustion tests in which sprays were present. These four exposed igniters were installed as a result of the staff's evaluation of the McGuire HMS, to provide improved igniter coverage in the upper compartment.

The staff has reviewed the tests cited by the licensee to justify glow plug operability in a spray environment, namely, the small-scale tests performed by ACUREX, and the large-scale NTS tests. Based on our review, we conclude that in each case the spray conditions present in the test do not adequately simulate those expected in the upper compartment. Specifically, the spray flux in the tests is substantially lower than would be expected in a containment.

Although the combustion tests cited by Duke do not adequately demonstrate igniter operability in a containment spray environment, the results of an investigation performed by Sandia for the NRC Office of Research appear to support this finding. The Sandia investigation included a battery of combustion tests in which a glow plug igniter was exposed to simulated containment spray fluxes both with and without the igniter spray shield installed. Additional thermal tests were conducted with an unshielded igniter in air to determine the relationship between spray flux and air velocity on igniter surface temperature. The tests indicate that the glow plug igniter is capable

of maintaining a surface temperature greater than required for ignition for spray fluxes as high as approximately 1.0 gpm per square foot (in the absense of air flow) and for air velocitites as high as approximately 10 meters per second (in the absence of spray flow). An assessment of the effect of combined air and spray flow on igniter temperature is currently being performed by Sandia, as are scoping analyses of upper compartment flow velocities and spray distributions. On the basis of the favorable results obtained to date, we will defer judgement on the need for additional tests/analyses by the utility, until completion of the Sandia work. We will report the results of our review of igniter operability in a spray environment at that time.

CONCLUSIONS

The staff has reviewed the information provided by the licensee to determine whether it satisfactorily resolves the three outstanding technical issues identified in License Condition 14. Based on our review, we conclude that additional information and analyses are required from the licensee to address the effect of upper compartment burns on air return fan and ice condenser door survivability, but that further action by the licensee regarding thermal response analyses and igniter operability in a spray environment can be deferred pending completion of the staff investigation of equipment thermal response and the completion of glow plug related testing and analysis by Sandia. The Sandia work will be completed in early FY 86.

REFERENCES

1. Letter from H. B. Tucker to H. R. Denton, May 22, 1984.

2. Letter from E. G. Adensam to H. B. Tucker, October 3, 1984.

3. Letter from H. B. Tucker to H. R. Denton, November 7, 1984.

4. Letter from H. B. Tucker to H. R. Denton, March 29, 1985

5. NUREG/CR-3954, "HECTR Analysis of Equipment Temperature Responses to Selected Hydrogen Burns in an Ice Condenser Containment," Sandia National Laboratories, February 1985.

6. NUREG/CR-3912, "MARCH/HECTR Analysis of Selected Accidents in an Ice Condenser Containment," Sandia National Laboratories, December 1984.

7. Letter from E. G. Adensam to H. B. Tucker, May 8, 1984

8. Letter from E. G. Adensam to H. B. Tucker, August 18, 1983.

9. Letter Report from R. G. Gido, Los Alamos National Laboratory, to C. G. Tinkler, US NRC August 1, 1984.

10. Letter Report from L. S. Nelson, Sandia National Laboratories, to P. Worthington, US NRC, March 7, 1984.

ENCLOSURE 2

REQUEST FOR ADDITIONAL INFORMATION
REGARDING HYDROGEN CONTROL MEASURES AT
CATAWBA NUCLEAR STATION, UNITS 1 AND 2

1. Provide details of the fan response calculation to support the statement in Duke's March 29, 1985 letter that burns occuring at hydrogen concentrations of 6.5% or less do not create a sufficient pressure differential across the fans to speed them up to synchronous speed. Include in your request a description of the hydrogen combustion assumptions (e.g., flame speed, burn completion, compartment venting, containment spray, heat removal), and the fan and electrical system models and assumptions.

2. Using an appropriate modelling technique, provide a quantitiative assessment of the pressure loading on each of the ice condenser doors created by hydrogen combustion in a) the upper plenum and b) the 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.

Please provide the additional information requested in Enclosure 2 as soon as possible but no later than 60 days from the date of this letter. Should you have questions regarding the enclosure or be unable to meet the requested response date, please contact the Project Manager, Kahtan Jabbour at (301) 492-9789.

Sincerely,

B. J. Youngblood, Director
PWR Project Directorate #4
Division of PWR Licensing-A, NRR

Enclosure: As stated

cc: See next page

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