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TELEPHONE: AREA 704
373-4083

March 11, 1982

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: McGuire Nuclear Station
Docket Nos. 50-369, 50-370

Dear Mr. Denton:

Attached herewith are 20 copies of Revision 3 to Duke Power Company's report "An Analysis of Hydrogen Control Measures at McGuire Nuclear Station". This revision provides responses to additional requests for information pertaining to equipment survivability transmitted by Mr. Robert L. Tedesco's letter of February 10, 1982. This revision should be inserted in Section 7.0 of Volume 3.

Please advise if there are further questions regarding this matter.

Very truly yours,

William O. Parker, Jr.

GAC/jfw
Attachment

cc: Mr. P. R. Bemis
Senior Resident Inspector
McGuire Nuclear Station

Mr. J. P. O'Reilly, Regional Administrator
U. S. Nuclear Regulatory Commission
Region II
101 Marietta Street, Suite 3100
Atlanta, Georgia 30303

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Response to Request for Information on Equipment Temperature Response to Hydrogen Burn Transmitted by Mr. Robert L. Tedesco's Letter of February 10, 1982

1. Provide a description of the equipment modeled in your analysis. Describe the corresponding mathematical models.

Response:

The following equipment was considered in the analysis of heat transfer from hydrogen burning in Containment:

1. Hydrogen igniter - described in Sections 3.5 and 5.4.1.
2. Electrical cables - described in Section 5.4.2.
3. Instrumentation transmitters - described in Section 5.4.3.
4. Ice condenser walls - described in Section 5.5 and in Section 6.2.2.2 of the McGuire FSAR.

The instrumentation transmitters and hydrogen igniter were modeled using actual physical dimensions from manufacturer's drawings. The various internal parts were considered as lumped masses inside shells, and conductive and convective heat transfer was used between the shell and internals. Cables were modeled as multilayered structures with conduction between the layers and dimensions and physical properties obtained from the manufacturers. The ice condenser walls were modeled explicitly using a three dimensional heat transfer computer code. Further details on the models used may be found in the following sections:

Hydrogen igniter - Section 5.4.2.2

Electrical cables - Section 5.4.2.3

Instrumentation transmitter - Section 5.4.3

Ice condenser walls - Section 5.5.2

2. In your response to item A.1.c in our letter dated September 24, 1981, you indicate that the temperature reached by the equipment during a hydrogen burn is below the qualification temperature for this equipment. Since the actual temperature reached by the equipment during qualification tests is not measured demonstrate by analytical or experimental means that this temperature will exceed the temperature reached by the equipment during a hydrogen burn. Provide also the data used in making this comparison.

Response:

While it is true in some cases that the temperature reached by equipment in qualification tests is not measured explicity, in those tests the maximum temperature is maintained for periods of from 20 minutes to many hours, as discussed in Section 5.4.2.4. The components considered in the heat transfer analysis whose survivability is based on comparisons with qualification temperature have relatively small masses and thus small heat capacities, with relatively large surface to volume ratios. These geometric considerations result in efficient convective heat transfer such that the equipment reaches equilibrium with the environment relatively quickly. Therefore, for the particular equipment considered in this analysis, it is our judgement that thermal equilibrum was obtained during the qualification testing and therefore actual equipment temperature was equal to the qualification temperature.

3. Your analysis is based on arbitrarily chosen two flame velocities of 1fps and 6fps. The 1fps flame emits more energy to the environment, but it corresponds to 3 burns in the lower compartment as compared to 6 burns for the 6fps flame. Since 1fps flame velocity was used in evaluating survivability of the equipment located in the lower compartment, show that this constituted a conservative assumption.

Response:

As noted in Section 5.3 and discussed again in Section 5.3.1, survivability analysis was performed for both flame speeds. The temperature rises for equipment in the lower compartment given in Section 5.4.2.4 are the worst of the two cases; however, differences in response between the two cases were minor. For the instrumentation transmitter of Section 5.4.3, a single flame speed of two feet/second was used in the analysis, but the temperature rise was so small that it was considered unnecessary to repeat the analysis with a different flame speed.

4. List and discuss the assumptions (e.g. shape factors, emissivities, etc.) used in calcualting the heat transfer from the stationary flame in the ice condenser. Provide a justification for your assumption that the temperature of hot gases below the flames front drops abruptly to 250°F (See Fig. 5.5-1 in the submittal).

Response:

The computer program HEATING5 was used to calculate heat transfer to the ice condenser wall. The capabilities of HEATING5 allow for heat transfer by conduction, convection, and radiation. This capability was utilized as follows:

1. For conduction, the necessary thermal conductivities were obtained for all materials and input to the code. No further programming work is required for the conducting mode.
2. For radiation, the geometry that was modeled was radiation between parallel planes. Even though the nearest ice basket is 0.5 feet from the wall, the flame and hot gas layer radiating to the wall was assumed to be one foot thick. Calcualtion of the necessary shape factors was then performed by HEATING5. The emissivity of the flame and hot gasses was 0.3, in accordance with information from Dr. Bernard Lewis.
3. For convection, a convection boundary condition was imposed on the wall as represented by Figure 5.5-1. The temperature of the convective boundary conservatively assumed to be 250°F for the following reason. Recall that the ice condenser is an area of constant upward flow. A mixture of steam and non-condensable gasses enters the ice bed at the bottom through the lower inlet doors and passes up through the ice at 1 - 2 feet/second. The ice bed lowers the temperature of this mixture and condenses some of the steam. The maximum temperature in this region of the ice condenser, as predicated by CLASIX, is about 200°F. A temperature of 250°F was selected as a worst case value to reduce the cooling effect of this flow on the wall and generate higher wall temperatures. The actual temperatures on the face of the duct immediately below the flame

are, of course, higher than 250°F due to conduction and radiation from the hotter regions above, but this wall area is continuously cooled by the flow of the steam/gasses mixture from below. It is our judgement that Figure 5.5-1 represents, therefore, a conservative convective boundary condition for use in HEATING5.

5. Show that the assumption made by you that considers only conduction of heat from the exterior to the interior of the devices analyzed is conservative. In some of these devices, as for example Barton transmitters, heat may be transmitted by other mechanisms than conduction from the outside casing to the components located inside.

Response:

As discussed in Section 5.4.1, heat transfer analysis of the igniter assembly box from the flame considered both radiative and convective heat transfer. In determining the heat transfer from the metal box to the transformer assembly inside, all three modes of heat transfer were considered - conduction through the metal mounting posts of the transformer assembly, radiation from the walls of the box to the transformer, and convection by the establishment of natural convection currents in the closed box. Because conservative assumptions were made in consideration of each mechanism of heat transfer, and a conservative assumption was made for the amount of transformer self heating due to losses, the total temperature rise for the transformer presented in Section 5.4.1 is considered to be an upper bound.

With regard to the analysis of the Barton transmitter presented in Section 5.4.3, because it was necessary to alter the containment analysis to force a flame to occur in the vicinity of the transmitter, and because the result of that flame was such a small temperature rise of the transmitter, it was not considered necessary to increase the complexity of the analysis of the transmitter beyond the original lumped mass model. It is our judgement that a more detailed analysis would result in a slightly higher temperature, but would not affect our conclusion that the Barton transmitter has substantial margin with respect to surviving hydrogen burning.

6. In your submittal you indicate that during hydrogen burn, the predicted pressure differentials will not exceed the limiting values of 10 psid for the Air Return Fan and 25 psid for the Hydrogen Skimmer Fan. Provide the basis for the above conclusion; also indicate the pressure differentials across the Air Return and Hydrogen Skimmer Fans calculated by the modified CLASIX Code.

   Response:
   We have reviewed very carefully the results of our CLASIX analysis of the containment, including the sensitivity work, looking at the differential pressures across these fans. The maximum calculated differential pressure across either fan is less than 3 psid.

7. Identifiy and describe the heat transfer codes used in calculating thermal response to hydrogen burn of different pieces of equipment

mentioned in your analysis. Describe also the HEATING5 code used in calculating heat transfer in the ice condenser walls.

Response:

All heat transfer analysis, except that for the ice condenser walls, was performed using classical methods of calculating heat transfer by conduction, convection, or radiation, as applicable. These classical methods consist of writing sets of differential equations which describe the heat transfer as a function of time, then solving these systems of equations using a general simulation code (we used CSMP). All parameters which are needed for these calculations are determined by hand calculations or short computational programs using FORTRAN.

HEATING5 is a general purpose code for heat transfer analysis. This code was obtained by Duke Power from the National Energy Software Center and has been installed and verified on Duke's computer. The following description of this code is from <u>HEATING5 - An IBM 360 Heat Conduction Program</u>, by Turner, Elrod, and Siman-Tov, published as ORNL/CSD/TM-15:

"HEATING5, a modification of the generalized heat conduction code HEATING3, is designed to solve steady-state and/or transient heat conduction problems in one-, two-, or three-dimensional Cartesian or cylindrical coordinates or one-dimensional spherical coordinates. The thermal conductivity, density, and specific heat may be both spatially and temperature-dependent. The thermal conductivity may be anisotropic. Materials may undergo a change of phase. Heat generation rates may be dependent on time, temperature and position, and boundary temperatures may be time-dependent.

The boundary conditions, which may be surface-to-boundary or surface-to-surface, may be fixed temperatures or any combination of prescribed heat flux, forced convection, natural convection, and radiation. The boundary condition parameters may be time- and/or temperature-dependent. The mesh spacing can be variable along each axis. The code is designed to allow a maximum of 100 regions, 50 materials, and 50 boundary conditions. The maximum number of lattice points can be easily adjusted to fit the problem and the computer storage requirements. The storage requirements on an IBM 360 machine range from approximately 250K bytes for one lattice point to 1256K bytes for 6000 lattice points."

8. The thermal analysis presented in Section 5.0 of your submittal is for cables protected by metal braids. However, in discussing secondary fires in the containment, your are using these results to demonstrate that all cables would not reach ignition temperature. Since some of the non-safety related cables may not be protected by metal braids, show that the results of the analysis apply equally well to these cables.

Response:

The results of analysis of small diameter cables with braided metal armor cannot be applied in a quantitative manner to the large diameter Hypalon insulated cable. The association is done in a qualitative fashion as follows. The Hypalon insulated cable, of which there is very little in containment, is much larger in diameter and has a much greater mass per unit length than the small diameter armored cable. Therefore more energy input will be required to raise one unit length of this cable one degree than would be required for the smaller diameter cable. With the substantial margin to ignition of 400°F, it is our judgement that the Hypalon insulated cables are of no concern when considering the probability of secondary fires.

9. The TVA (Sequoyah) analysis of accident sequences is based on an S_2D sequence. In addition, variations of this sequence were calculated in which the rate and scheduling of hydrogen and steam release encompassed other sequences and situations. The TVA submittal is considered sufficiently complete in this respect, with the exception noted in 2.

At this time, a correspondingly wide group of scenario analyses has not been received from Duke (McGuire) or IMEC (Cook). We require either:

(a) that analyses be submitted by Duke and IMEC of scenarios similar in scope to that furnished by TVA but directed specifically to the McGuire and Cook plants, or

(b) that Duke and IMEC utilities affirm the similarity of their plants to the Sequoyah plant in regard to potential accident scenarios and affirm the applicability of the TVA analyses to their particular plants in this regard.

Response:

The detailed assessment of various accident types with MARCH and the use of MARCH results as input for containment analysis is at best an uncertain situation. The limitations of the MARCH code are well documented by ACRS and others, including the authors of the code. Accordingly, consideration of multiple accident sequences through the use of MARCH as an essential part of demonstrating the effectiveness of the Hydrogen Mitigation System, while it would be an interesting and expensive technical exercise, would do little to increase our confidence in the margins available in Hydrogen Mitigation System performance beyond our previously performed sensitivity studies.

We have reviewed the TVA submittal referenced by the question and note that the maximum H_2 release rate computed during the accident sequences examined was 30% of the maximum used in the sensitivity studies reported by Duke Power Co. (see Figure 4.6.-27). Even when the differences between McGuire and Sequoyah are taken into account, our sensitivity work bounds with considerable margin any of the likely accident sequences which will present a challenge to the Hydrogen Mitigation system. Additionally, it should be noted that even at unrealistically high H_2 release rates, the Hydrogen Mitigation System functions to maintain H_2 below a detonable limit in all compartments and the total pressure rise in containment is kept well below the calculated failure pressure of the containment. With so much margin available in all aspects of containment response, further analysis of the performance of the Hydrogen Mitigation System is not justified.

10. (for all three applicants) In the T_B B_2 scenario analyzed by TVA it is not clear that the restoration of AC power and actuation of glow plugs (or random electrical ignition sources) would not come at a time when excessive amounts of hydrogen are present in the containment. In this connection discuss for your particular utility grid, whether the failure of all AC power to the plant is an event of such low probability that this type of scenario can be justifiably excluded from consideration. If it cannot be excluded, discuss the appropriateness of providing an additional reliable backup electrical supply for the igniters.

Response:

For the McGuire station, events such as failure of all AC power are of much lower probability than the S_2 sequence which has been considered as the reference case in assessing Hydrogen Mitigation System performance. Hydrogen is produced in loss of coolant accidents only after a considerable time period. Because the igniters are supplied presently with an emergency power source from redundant diesel generators, a sequence involving actuation of the igniter system significantly after the beginning of a loss of coolant accident is considered sufficiently unlikely that it need not be included in the design basis for the Hydrogen Mitigation System.

The design of McGuire Nuclear Station and the Duke System insure a highly reliable supply of offsite power to the McGuire plant. The McGuire Nuclear Station is located in the center of the Duke Power System and is connected to the grid by five (5) double circuit 230KV and four (4) 500KV transmission lines. Each of the McGuire Generating Units is provided with two immediate access circuits to the off-site power system. Each of these two circuits is separate and powered on independent towers from the switching stations to each unit's two step-up transformers. In addition, there are two interties provided between Unit 1 and Unit 2 power systems at the 6900/4160 volt levels such that, in a back-up mode, the above two incoming off-site power sources to either unit may be utilized to supply the engineered safety features loads to the other unit.

The Duke System at present contains three (3) operating nuclear units, thirty (30) fossil units, twenty-five (25) major hydro units, eighteen (18) combustion turbine units, twenty-five (25) single circuit interconnections with five (5) other transmission systems outside of the Duke System. This makes Duke's system a very strong system. Duke's Grid System, due to its many diverse power generating units and its many inter-connections, is not susceptible to gross failures as may have happened in pennisular or remote systems with few interties or adverse environmental conditions.