TENNESSEE VALLEY AUTHORITY
CHATTANOOGA, TENNESSEE 37401
400 Chestnut Street Tower II

April 17, 1981

RECEIVED APR 20 1981 U.S. NUCLEAR REGULATORY COMMISSION

Director of Nuclear Reactor Regulation
Attention: Mr. A. Schwencer, Chief
Licensing Branch No. 2
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Schwencer:

In the Matter of) Docket No. 50-328
Tennessee Valley Authority)

Enclosed are TVA's responses to the questions for unit 2 of the Sequoyah Nuclear Plant which were transmitted by R. L. Tedesco's letter to H. G. Parris dated April 14, 1981. These questions address the technical issues on hydrogen control considered in the course of the recent public hearing on the McGuire Nuclear Plant.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills, Manager
Nuclear Regulation and Safety

Sworn to and subscribed before me
this 17th day of April 1981

Notary Public
My Commission Expires 6/26/84

Enclosure
cc (Enclosure):
Mr. K. C. Canaday, Manager
Project Coordination & Licensing
Duke Power Company
P.O. Box 33189
Charlotte, North Carolina 28242

Mr. Juan Castresan
American Electric Power Service Co.
2 Broadway
New York, New York 10004

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ENCLOSURE

RESPONSES TO NRC QUESTIONS

Question 1

TVA views on the likelihood for inerting of the lower compartment with steam and/or fog

Response

TVA does not believe that the lower compartment would be inerted with either steam or fog following a small break (S_2D-type event during the time in which significant amounts of hydrogen could be released into containment. By definition, an inerted atmosphere would not be flammable for any concentration of hydrogen. For example, a 60-percent concentration of steam by volume would effectively inert any hydrogen-rich atmosphere. However, a smaller steam fraction could prevent the combustion of a very low hydrogen concentration mixture that might otherwise be flammable without steam simply by depressing the concentration below the lower flammability limit. (A mixture with a steam fraction of less than 60 percent by volume would not be inerted for concentrations of hydrogen above the lower flammability limit.)

As explained in our response of December 1, 1980, to the NRC Request for Additional Information on the Sequoyah Interim Distributed Ignition System (IDIS), Volume 2, item 4, the concentration of steam during the long term following a small break when hydrogen could be present is sufficiently low to have little effect on flammability limits and, therefore, the behavior of the igniters. When the air return fans are turned on at ten minutes after a phase B containment isolation signal, the lower compartment atmosphere is diluted with 80,000 cfm of air and rapidly deinerted. This occurs long before hydrogen generation would be expected. (See attached figure 1-1 from our previous submittal.)

Similarly, the potential for significant fog formation after a small break would be low due to the relatively low steam concentrations that would be present when hydrogen could be released. In addition, experimental evidence of fog inerting was observed after a stepwise injection of steam followed by ambient cooling. During a small break, the superheated steam and hot hydrogen would be released into the lower compartment continuously during the event. Such continual injection of a high enthalpy mixture would reduce the tendency for fog formation due to the increased energy removal required before dropwise condensation could result. Further, experimentally observed fogging appeared to be due to a wall-cooling effect; but the Sequoyah lower compartment has a much smaller ratio of surface area to volume than the experimental facility. Also, those surfaces would be prewarmed before any release of hydrogen, thus reducing their potential for condensation. Finally, it is expected that continual and local fog formation could only occur at the interface between colder upper compartment air and warmer lower compartment air during air return fan injection into the lower compartment. However, the cooler air from the upper compartment would tend to sink to the floor placing the localized interface away from the igniters and low in the volume where any fog would rain out to the water present at the floor.

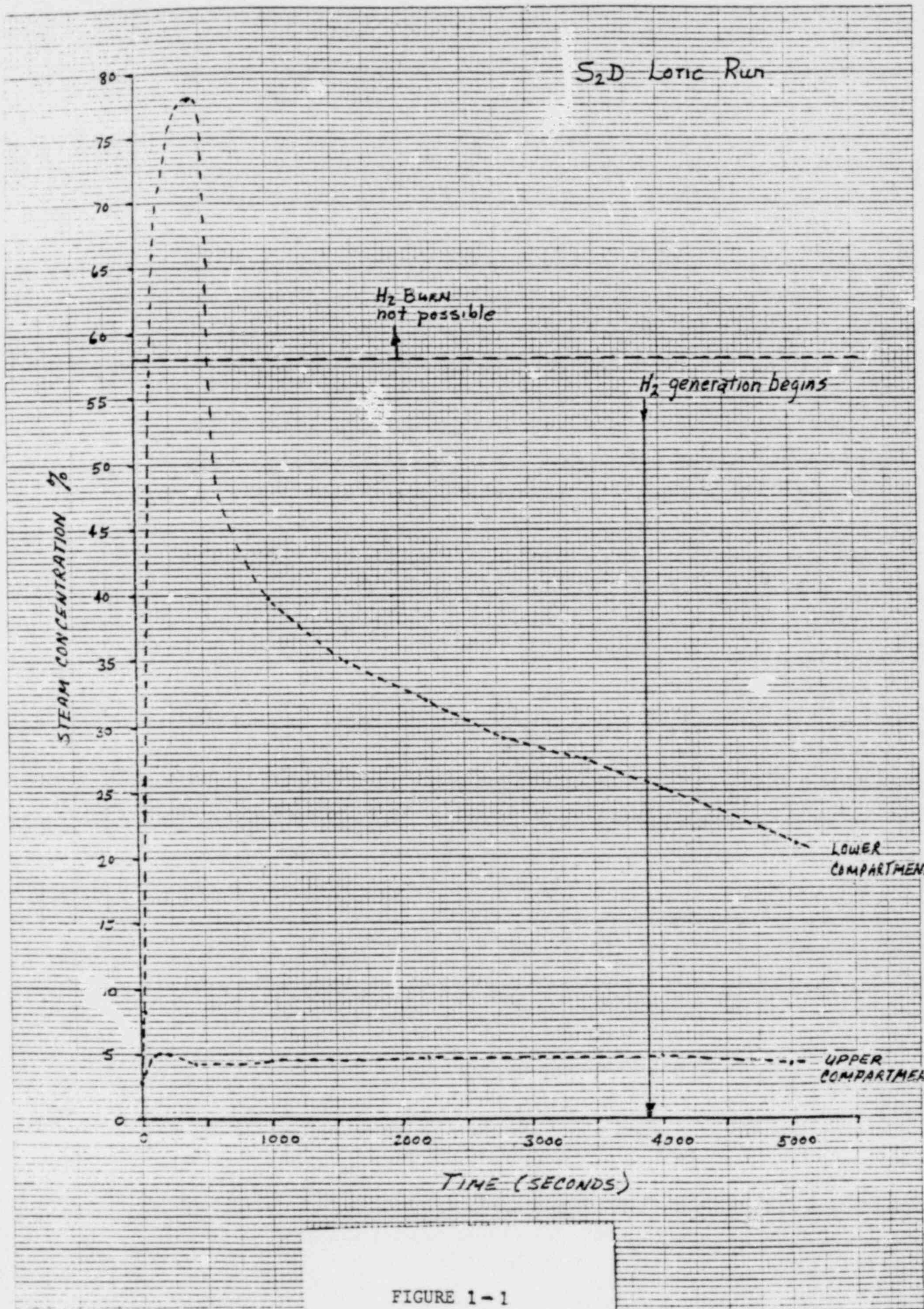

FIGURE 1-1

POOR ORIGINAL

Question 2

Whether continuous burning of hydrogen gas can be expected in the upper plenum of the ice condenser for a significant fraction of degraded core scenarios or for significant durations of selected degraded core scenarios

Response

Controlled burning above the ice bed was addresed by TVA in section IV.B of our submittal of September 2, 1980, on the Sequoyah IDIS and our response of December 1, 1980, to NRC Request for Additional Information on the Sequoyah IDIS, item 5. Burning was considered to be likely in this location due to the concentrating effects of the ice condenser on noncondensible gases. For this reason, igniters were originally located in and above the upper plenum to provide for controlled burning. TVA continues to maintain that upper plenum igniters are desirable and beneficial.

For a small break (S_2D) event, a recent base case containment analysis using the revised CLASIX code that incorporates a separate upper plenum volume shows that semicontinuous burns would occur in the upper plenum (and in no other volume) throughout the hydrogen release portion of the event.

Such a characteristic pattern of burning could be dependent on assumptions made for the calculation such as lower flammability limit and burn completeness fraction. However, this pattern certainly bounds one end of the realistic containment burning response spectrum with the pattern of predominantly lower compartment burns as submitted earlier bounding the other end.

Question 3

The Sandia National Laboratory views regarding the potential for "transition to detonation" in the upper plenum of the ice condenser that may be brought about by obstructions in the flow path or by jetting effects as hot gases or combustible products leave the ice condenser and enter the upper compartment

Response

The phenomenon of "transition to detonation" observed experimentally was dependent on the simultaneous presence of at least two factors that can be shown not to exist in the upper plenum of the ice condenser following a degraded core event. First, detonable or near-detonable concentrations of hydrogen must be present. Second, a narrowly-confined linear geometry which may have wake-producing obstacles must exist for the transition to accelerate through. Also, high-velocity flows from self-acceleration of the gas would have to result along the axis of the confined geometry to create sufficient turbulence to collapse a highly packed flame brush and initiate the detonation.

As explained in our responses of December 1, 1980, to NRC Request for Additional Information on the Sequoyah IDIS, Volume 2, items 5 and 10, TVA does not believe that highly concentrated pockets of hydrogen would exist in the upper plenum following a degraded core event (item 10) nor that hydrogen concentrations would approach the detonable limit effect due to steam stripping in the ice condenser (item 5). In addition, the igniters would burn any hydrogen entering the upper plenum as soon as it reached a flammable concentration, preventing any buildup in the plenum. Therefore, as stated in our previous submittal, detonable hydrogen concentrations would not be present in the ice condenser upper plenum after a degraded core event.

The upper plenum is bounded above and below around its entire circumference by door panels which allow flow in from the ice condenser and out to the upper compartment. Upon initiation of a burn in the upper plenum, the top deck blanket doors would begin to open at a pressure of much less than 1 lbs/in^2. Their opening would not only promote dilution, mixing, and the addition of moisture from the action of the containment sprays but would preclude the narrow geometric confinement essential to the transition phenomenon.

If a deflagration occurred in the upper plenum due to ignition of flammable hydrogen mixtures from the ice condenser, the flame would be relatively slow and could not generate the self-accelerating process leading to the transition effect. The flows issuing from the ice condenser are low velocity and would not provide an initial jet impetus for acceleration around the plenum. The deflagration would expand in all directions around the plenum and up through the opening top deck blankets preventing any confined propagation and dispersing any pressure waves. Also, any burning that might occur in the turbulent wake of obstructions in the upper plenum would be very slow compared with velocities required for the transition phenomenon to occur.

Since these conditions necessary for the transition to detonation phenomenon do not exist in the upper plenum, TVA does not believe that it is a safety concern for operation of a controlled ignition system.

Question 4

The inventory, distribution, and protective encapsulation for the polyurethene foam insulation

Response

TVA's September 4, 1980, submittal from J. L. Cross to Robert L. Tedesco provides the type, location, quantity, and encapsulating material for the polyurethane foam insulation in the Sequoyah ice condenser. See attached table 4-1 for information from our previous submittal. The intermediate deck doors contain an additional 1500 pounds of urethane foam enclosed in galvanized steel. The top deck blankets contain 500 pounds of polyurethane foam encapsulated above and below in stainless steel sheets.

TABLE 4-1

ICE CONDENSER POLYURETHANE INSULATION SUMMARY

Containment Wall

Type: Rigid urethane foam, "Chempol 30-1324/30-1426" (Freeman)

Conductivity: 0.21 BTU-in./hr-ft^2-$^\circ$F

Density: 3 lb/ft^3

Total Weight: Approximately 26,000 lb.

Flammability: Self extinguishing as installed per Westinghouse test

Encapsulation: Foamed-in-place behind multilayer steel duct panel

Questions 5 and 6

5) The thermal response of polyurethene foam to various assumptions as to semi-steady flame positions in the ice condenser

6) The effects of continuous burning of the wall panel duct including the temperature increase and subsequent decrease in structural capability which if severe enough could result in rupture of the ducting

Response

TVA has not performed an analysis of foam heatup due to continuous burning in the ice condenser. However, analyses have been performed by Duke Power Company to study the effects of a continuous burn on the wall panel insulation. The design and construction of the ice condensers at Sequoyah and McGuire are essentially the same; therefore, the results of the Duke studies, as presented at the McGuire ASLB hearings should be equally valid for either plant. As was noted in the McGuire hearings, should burning take place in the ice condenser, the "semi-steady flame position" would be expected to occur fairly low in the ice bed due to the steam stripping by the large quantity of ice present. However, in order to maximize the amount of heat input to the wall panel foam, the center of the ice bed was chosen for the burn location to reduce radiative heat losses outside the bed. The Duke Power Company studies were also conservative in that all the hydrogen produced was assumed to burn, no heat transfer to the ice was allowed, the flame was assumed to remain at the same elevation throughout the burning, and a larger flame width than is believed to occur was considered. The heat transfer calculation considered convection, conduction, and radiation. The result of the analysis showed that the surface temperature of the foam behind the air ducts would not exceed 370°F. The surface temperature of the ductwork steel, except in the vicinity of the flame, was calculated to be 400°F from energy balance considerations. At joint connections between ducts, a total of 3 to 4 square feet of steel-encapsulated foam would be exposed to the flame.

Based on values provided by Duke and Westinghouse (see attached Table 5/6-1), the small amounts of encapsulated foam exposed to the flame could rapidly pyrolize. However, no significant pyrolysis of the foam behind the air ducts would occur at the calculated temperature of 370°F. Thus, the temperatures produced by a continuous burn in the ice condenser would pyrolyze insignificant quantities of polyurethane foam.

Further, the distributed temperatures resulting from the energy balance assumption are not high enough to cause structural damage to the ductwork. Local hot spots that might occur have not been analyzed in detail. However, we believe that the ducts would remain fastened in place on the containment shell and that they would be unlikely to fail in a manner to expose the foam due to their double duct and flange design.

TABLE 5/6-1

FOAM PYROLYSIS AS A FUNCTION OF TEMPERATURE

1. At 400°F, 4 to 5% of the foam insulation will pyrolyze in 6 hours.

2. At 500°F, 20 to 30% will pyrolyze in 6 hours.

3. At 1000°F, 100% of the foam will pyrolyze in 10 minutes.

4. Below 400°F, pyrolysis is not significant, although some release of the gaseous CO_2 trapped in the foam will be experienced.

5. The rate of pyrolysis increases with temperature as can be seen in 1-3 above. As a gross approximation, the reaction rate may be assured to double for each 10°C rise if one wants to consider the effect between the temperature values given in 1-3 above.

6. The values given in 1-3 above are based on experimental measurement.

Question 7

The pyrolysis and combustion potential for the foam insulation resulting from the thermal responses called for in item 5

Response

The response to questions 5 and 6 provides worst-case conditions for heatup of the foam wall panels. The other components using foam in the ice condenser are the top blanket and intermediate deck doors. As stated in our response to questions 5 and 6, if a burn occured in the ice bed, it would be well below the intermediate deck doors. Radiative heat transfer would reduce the flame temperature to approximately 500°F within 10 feet of the flame. At this temperature, foam pyrolysis is a slow process. For a burn in the ice condenser, based on values given in Table 5/6-1, no more than four percent of the foam in the intermediate deck doors would be expected to pyrolyze. Since the top deck doors are further removed and covered above and below with stainless steel, even less pyrolysis of their foam would occur.

Question 8

The consequences on containment structural integrity as a result of a release and possible combustion of the decomposition products from the polyurethene foam

Response

The effects of foam pyrolysis on the structural integrity of the containment are negligible. Duke Power Company calculated that insignificant quantities of the wall foam would pyrolyze due to a continuous hydrogen burn in the ice condenser (see our response to questions 5 and 6). However, even if one percent of the total wall panel foam inventory was assumed to completely pyrolyze, an energy release of only three million BTU would occur. Also, if all the foam in both the top deck blanket and the intermediate deck doors was assumed to pyrolyze, 24 million BTU would be added to the containment. The energy input to the containment due to this conservative approximation of the amount of foam pyrolyzed is much less than the energy added from the hydrogen burn (90 million BTU).

The energy additions due to pyrolysis of the foam and a continuous hydrogen burn are small compared to the heat removal capability of the containment sprays. The energy removal rate of the Sequoyah sprays, considering only sensible heat, is five billion BTU/hr.

Question 9

The merit of the tripping of electrical power to the air handling units located in the upper plenum of the ice condenser as a means for resolving concerns regarding:

a. rapid hydrogen combustion in the duct work;

b. ingestion of hot gases into the duct increasing the temperature response of the polyurethene foam

Response

Removing electrical power to the ice condenser air handling units (IC AHU's) before possible hydrogen generation and release to the containment would stop forced circulation of air through the IC air ducts. The cooling function of the AHU's would not be required after a LOCA and was not assured in the original design. Even after tripping the AHU's, however, the intake grilles of the AHU's and the return ducts would still be open to the general upper plenum space. Two intake grilles are located on the front face of each AHU. The AHU discharge flows into a horizontal circumferential supply header, down into the vertical supply ducts, turns and flows up into the vertical return ducts, and then out into the upper plenum. Since the AHU intake grilles and associated return ducts are located within a few feet of each other around the upper plenum, they would be exposed to essentially the same pressure during an upper plenum burn. Thus, there would be no differential pressure mechanism to set up flow in the now-stagnant duct system which could induce significant quantities of either hydrogen or hot gas. Therefore, tripping the IC AHU's would preclude hydrogen combustion in the duct system and appreciable foam heatup due to ingestion of hot gases into the ducts.

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L. M. Mills

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Sworn to and subscribed before me
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Alice P. Haynes

Notary Public
My Commission Expires 6/26/84

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Mr. A. Schwencer April 17, 1981

cc (Enclosure):
- ARMS, 640 CST2-C
- A. W. Crevasse, 401 UBB-C
- H. N. Culver, 249A HBB-K
- E. Ford, Sequoyah-NRC
- H. J. Green, 1750 CST2-C
- J. A. Raulston, W10C126 C-K
- H. S. Sanger, Jr., E11B33 C-K
- F. A. Szczepanski, 417 UBB-C

COORDINATED: EN DES/Williams

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