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April 25, 1986

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

Attention: Mr. B. J. Youngblood, Project Director
PWR Project Directorate No. 4

Re: Catawba Nuclear Station
Docket Nos. 50-413 and 50-414
McGuire Nuclear Station
Docket Nos. 50-369 and 50-370

Dear Sir:

On April 8, 1986, representatives from Duke Power Company and the NRC Staff met at the NRC's offices in Bethesda, Maryland to discuss hydrogen control measures at Catawba and McGuire. As a followup to that meeting, Duke has prepared a plan for resolution of concerns on equipment survivability (Attachment 1) and on fans and doors (Attachment 2). A schedule for resolution of these outstanding issues is also included in the respective attachments.

Very truly yours,

Hal B. Tucker

Hal B. Tucker

ROS:slb

Attachments

xc: Dr. J. Nelson Grace, Regional Administrator
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Mr. W. T. Orders
NRC Resident Inspector
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NRC Resident Inspector
Catawba Nuclear Station

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ATTACHMENT 1

PLAN FOR RESOLUTION OF CONCERNS ON EQUIPMENT SURVIVABILITY

Purpose and Summary Description

The purpose of this document is to describe a proposed plan for the resolution of the issue of equipment survivability during deliberate ignition of hydrogen in the containment at Catawba. The plan consists of three parts as follows:

1. Evaluation of the hydrogen and steam releases to containment for an appropriate selection of accident sequences which lead to large releases of hydrogen into containment. The selection of accident sequences and the method of analysis is described below.

2. Using the results of the first part of the plan as input, evaluation of the response of the containment and its associated systems to the accident sequences, and a determination of the pressure and temperature in containment as a function of time. The specific method of performing this analysis, and the major assumptions and parameters to be used, are described below.

3. Using the results from the first two parts of the plan, determination of the response of equipment in containment to hydrogen burning and evaluation of its survivability. The steps in this part of the plan include selection of the equipment to be analyzed, determining the appropriate models for the analysis, comparison of results from the analysis with equipment qualification test data and hydrogen burn survivability tests performed under the sponsorship of NRC and EPRI, and assessing the margin associated with the equipment response.

Detailed discussion of each part of the plan follows.

Analysis of Accident Sequences

The first step in this part of the plan is the selection of the specific accident sequences to be analyzed. A spectrum of accidents sequences that envelope the range of hydrogen and steam release rates will be studied. Since steam flow through the core is the limiting factor for cladding oxidation, primary system pressure is the parameter of importance due to its effect on steam availability. Therefore the following sequences will be analyzed:

S1D (low primary system pressure)

S2D (intermediate primary system pressure)
TMLU (high primary system pressure)

As a result of NRC staff concerns about sequences involving ECCS failure in the recirculation mode, S2H will also be investigated. These accident sequences envelope the possible primary system pressure conditions under which hydrogen could be developed in the primary system, the release rates of that hydrogen to containment, and conditions in containment at the time of hydrogen release. Each sequence of events will be terminated by resumption of ECCS prior to excessive core melting, consistent with previous analyses of degraded core hydrogen generation.

Analysis of these accident sequences will be performed using MAAP 2.0. This code was developed by IDCOR and its contractors in order to assess the progress of degraded core events. The specific assumptions to be used are to be based on the best estimate models in MAAP which meet with NRC staff approval as a result of their ongoing review. In addition, the total amount of hydrogen to be considered for each sequence will be that produced by 75% m/w reaction of the clad or the maximum amount which can be generated by adjusting the time of resumption of ECCS flow, without employing non-mechanistic assumptions or extrapolations in order to force the release rate to be equivalent to 75% m/w. The S2D accident sequence will be extrapolated to 75% m/w, if necessary, in order to meet the requirement of the hydrogen rule that the effectiveness of the system be shown for hydrogen releases up to 75% of the clad oxidized.

The output of the MAAP analysis will be time histories of the mass and energy releases for hydrogen and steam into the containment. These time histories will be compared to those reported in References 1 and 2 to ensure that they are representative of calculations performed using MARCH.

Analysis of Containment Response to Hydrogen Burning

Several possibilities have been considered for performing the containment analysis portion of the plan. The long run times associated with CLASIX would make analysis using CLASIX very expensive. In our containment code development work, we have modified CONTEMPT4-MOD5 by adding better models for the ice condenser ice bed and doors, but deficiencies in the hydrogen burn models would require more development. For these reasons it has been determined that the HECTR code would represent the best choice for containment analysis. Action has been taken to obtain HECTR from the National Energy Software Center. Following receipt and installation of HECTR, it will be examined to ensure that the ice condenser model is not excessively conservative. Our concern over the ice bed model is prompted by the work reported in Reference 1 wherein ice bed meltout appears to occur prematurely when compared with LOTIC and CLASIX results. Any changes we make in HECTR as a result of our review will be documented. If HECTR cannot be made operational on our computer system, either CLASIX or CONTEMPT4-MOD5 will be selected for the analyses.

Regardless of which containment analysis code we select, a number of parameters will have to be determined for input to the code. These parameters affect the results of the code significantly and therefore need to be agreed to prior to starting the work. The following are the proposed containment analysis assumptions and parameters:

1. Spray and fan operation - based on best estimate analysis methods, it will be assumed that both trains of sprays and fans are started automatically at the proper time and operate throughout the accident. The fan performance will be based on vendor supplied curves derived from test data. Spray performance will be based on FSAR values for injection and recirculation sources. As a sensitvity analysis, response of the containment will be calculated for the case of a single train of fans and sprays available.

2. Ignition and propagation criteria - following study of the various hydrogen combustion tests performed by NRC and EPRI contractors, the following ignition and propagation criteria have been selected for a base case analysis.

a. Lower compartment - ignition and propagation at 6% hydrogen by volume.

b. Ice condenser - no igniters are present in the bed or lower plenum, therefore ignition cannot occur. Propagation upward from the lower compartment at 6%, propagation downward from the upper plenum at 8%. In the upper plenum, ignition at 8% hydrogen by volume, propagation downward from the upper compartment at 8% hydrogen. The upper plenum ignition and propagation concentrations will be adjusted downward in those cases where substantial ice melting (greater than 80%) has occurred and little or no ice remains in the ice bed.

c. Upper compartment - ignition at 6% hydrogen, propagation from the upper plenum at 6% hydrogen.

d. Deadended compartments - ignition at 6% hydrogen, propagation from the lower compartment at 6% hydrogen.

In all compartments, burning is suppressed if the steam concentration is greater than 55% by volume or if the oxygen concentration is less than 5% by volume.

3. Combustion completeness - combustion will be 60% complete at 6% hydrogen or less, 100% complete at 8% hydrogen.

4. **Flame speed** - a better measure of this parameter would be burnout time, the time it takes for hydrogen burning to burn completely in a compartment. The following burnout times will be used for the containment compartments:

lower compartment - 10 seconds
lower plenum and ice bed - 8 seconds
upper plenum - 7 seconds (will be increased consistent with the previous discussion on ignition concentration for accident sequences with less than 20% ice in ice bed)
upper compartment - 10 seconds
deadended compartments - 10 seconds

5. Heat transfer coefficients for containment heat sinks and equipment in containment - as reported in Reference 3, with a possible modification to the ice heat transfer coefficient to reflect proprietary correlations used in LOTIC and CLASIX.

6. Ice condenser drain temperature - 150F, as used in early CLASIX analysis, based on Westinghouse test data, for the early part of the transient when ice melt rate is significant. This temperature will be adjusted downward in the cases where the ice melt rate is very low at the time of the hydrogen burning.

7. Compartmentalization - as given in the example reported in Reference 3.

The results of the containment analyses will be time histories of compartment temperatures and indication of the number of hydrogen burns occurring in each compartment.

Justification for the selection of hydrogen burning parameters for the base case:

The selected hydrogen burn parameters are based on study of the various hydrogen burning experiments carried out under the sponsorship of NRC, the ice condenser owners, and EPRI. These are the test series at Factory Mutual, Acurex, Sandia (VGES), and Nevada Test Station (NTS). It is recognized that none of these experiments duplicates containment conditions during an accident exactly and that some judgment must be applied in order to establish parameters for analysis based on these experiments. iHowever, it is the best data available and its use in this regard is consistent with the best estimate nature of the analysis to be performed.

Lower Compartment Parameters - the relevant data is obtained from experiments in which fan induced turbulence is present. The sources of turbulence in the lower compartment will be the flow of the air return fans coming from various openings between the lower containment and the dead ended compartments and the continuing release of steam and gasses from the primary system.

It is noted from experiment that ignition occurs consistently at less than 6% hydrogen by volume under these conditions. Of particular interest are tests P-3, P-6', and P-7 from the NTS series in which hydrogen at 6% concentration or less was ignited in the presence of steam quantities representative of those found in the lower compartment during hydrogen release. These tests also indicate flame speeds in the range of 3-4 feet/second which translates based on compartment geometry to a burn time in the lower containment of 10 seconds. The actual burnout time in the lower containment will be longer than this due to the congested arrangement of equipment and the downward propagation of the flames.

Upper Plenum - the various experiments show that dry mixtures, as would be expected at the outlet of the ice condenser ice bed would be ignited at 5-6% hydrogen. The use of 8% in the analysis reflects the uncertainty over the presence of a fog in the flow out of the ice bed. Analysis performed by Westinghouse for McGuire (Reference 6) and tests 3.3 and 3.4 from Acurex confirm that mixtures of 8% hydrogen will ignite in the presence of fog. Flame speed is based on NTS tests P-4, P-5, and P-13' wherein upward propagation goes at 4-6 feet/second. This gives a compartment burnout time of 7 seconds based on igniter spacing and compartment geometry. This is considered conservative because the NTS tests were for upward propagation and propagation in the ice condenser is predominately downward and horizontal.

Upper compartment - the upper compartment parameters are based on the results of NTS experiments P-7 and P-22 in which mixtures of less than 5.5% hydrogen were easily ignitable and burned quickly in the presence of fans and spray. The burn time was conservatively extrapolated from test P-22 to be 10 seconds, though this is considered to be much faster than an actual burn would take in the upper compartment due to the larger volume over the NTS vessel (a factor greater than 30) and the predominate downward propagation. Ten seconds is also consistent with the spray droplet fall time which has traditionally been used for upper compartment analysis.

Dead Ended Compartments - conditions in the dead ended compartments are much like those of the lower compartment, with fan induced turbulence due to the air return fans, but at lower concentrations of steam in the atmosphere. Ignition concentration is selected at 6% hydrogen, but the flame speed and burnout times are longer due to the decreased turbulence (no blowdown sources in dead ended compartments) and the larger volume to igniter ratio (igniters are not as closely spaced). These assumptions are expected to be of no consequence to the analysis because previous experience shows that hydrogen does not burn in the dead ended compartments.

Where the analysis appears to be particularly sensitive to the selection of parameters, and where there is justification from experiment of theory that alternative parameters are possible, sensitivity studies will be performed. Guidance for such sensitivity studies will be based on that given in References 1 and 3. Of interest is the case of continuous hydrogen burning in the lower compartment because of results seen in certain of the NTS dynamic injection tests. The conditions under which such continuous burning might occur in containment will be evaluated by comparison to the parameters used in the NTS tests. If it appears appropriate for the ice condenser containment conditions, continuous burning will be considered in the evaluation of equipment survivability in lower containment.

Certain additional models not previously employed in the CLASIX analysis reported in Reference 4 will also be used this time. Work by Westinghouse has confirmed the ability of the ice condenser drain flow to act as a lower compartment spray, desuperheating the atmosphere and condensing steam. Because of the consequences of the condensation of steam (increasing the hydrogen concentration) of lowering the temperature (less severe environments for lower compartment equipment survivability), this model will be included in the containment analysis done for hydrogen burning if NRC staff approval for that model has been obtained. In addition, in order to minimize the differential pressure developed between the upper and lower compartments if upper compartment burning is shown by analysis to occur, the containment analysis will include specific models for the bypass paths between upper and lower containment. These paths include the refueling canal drains and the ice condenser door bypass areas, including the ice condenser drains.

Establishment of Equipment Survivability

The first step in the process of establishing equipment survivability is to determine the specific equipment required to survive hydrogen burn events. The basic requirement is that equipment to maintain the unit in safe shutdown, to monitor the progress of the event, and to maintain containment integrity must be operable following hydrogen burning. This selection process has been performed for Catawba and the results reported in Reference 4. We plan to continue using this list.

There are two possible approaches to determine equipment survivability analytically. The first approach is to model the equipment of interest in the containment analysis code as heat sinks and determine the temperature response of the equipment directly. Due to the unsophisticated nature of the heat sink models in HECTR (one dimension slabs only), it would be necessary to modify the code to include the proper models. This approach will be investigated during the performance of the work contained in this plan and will be used if it proves to be feasible. Our analysis would be similar to that tried by Sandia and reported in

Reference 5, but with the elimination of excess conservatism and inappropriate assumptions.

An alternative approach to the analysis of the equipment temperature response is to repeat the method used in Reference 4 in which the equipment is modeled as a series of coupled differential equations based on conductive, convective, and radiative heat transfer relationships. These equations are solved using a general purpose differential equation solver. This approach will be used if the direct method described above proves infeasible.

Following the determination of the temperature response of the equipment, a comparison will be made with the equipment qualification temperature in a manner similar to that reported in Reference 4. In addition, the results of the extensive amount of actual testing of equipment performed under EPRI and NRC sponsorship will be reviewed to determine its applicability and cited wherever it is relevant.

Conclusion

Following completion of all analyses to be performed, appropriate revisions to Reference 4 will be prepared and submitte . to NRC. It is expected that sections 4, 5, and 6 of Reference 4 will be substantially rewritten as a result of this work. The work will include parameters specific to both McGuire and Catawba and will be applicable to both stations.

Schedule

The work required to carry out the plan is extensive. There are uncertainties in the proposal, such as the use of HECTR, which make determination of exact durations difficult. The following schedule is proposed:

September, 1986 - complete MAAP analysis of accident sequences. Complete installation and checkout of HECTR, or identify and make operational the alternative method of containment analysis. Submit the results of the MAAP analysis to NRC for approval.

December, 1986 - following staff approval of the MAAP analysis, begin containment response calculations.

March, 1987 - complete containment response analysis, submit results to NRC for approval.

June, 1987 - following NRC approval of the containment response analysis, begin equipment survivability analysis.

September, 1987 - complete equipment survivability analysis and submit to NRC for approval.

December 31, 1987 - following resolution of all comments, prepare and submit appropriate revisions to Reference 4.

This schedule is consistent with the nature of the analysis (being associated with beyond design basis events) and the conflicting responsibilities of the principal analysts involved in performing the work.

References

1. Camp, A. L., et. al., "MARCH-HECTR Analysis of Selected Accidents in an Ice Condenser Containment," NUREG/CR-3912, December, 1984

2. NRC letter (D. L. Wiggenton) dated December 16, 1985, reporting on a meeting held December 5, 1985 between NRC and IMEC

3. Camp, A. L., et. al., "HECTR Version 1.0 User's Manual," NUREG/CR-3913, February, 1985

4. Duke Power Company, "An Analysis of Hydrogen Control Measures at McGuire Nuclear Station," October, 1981, complete through Revision 14, April, 1986

5. Dandini, V. J., and W. H. McCollough, "HECTR Analysis of Equipment Temperature Responses to Selected Hydrogen Burns in an Ice Condenser Containment," NUREG/CR-3954, February, 1985

6. Tsai, S. S., "Fog Inerting Analysis for PWR Ice Condenser Plants," Westinghouse Electric Corporation, October, 1982

ATTACHMENT 2

PLAN FOR RESOLUTION OF CONCERNS ON FANS AND DOORS

Purpose and Summary Description

The purpose of this document is to describe a proposed plan for the resolution of the issue of performance of the air return fans and ice condenser doors during an upper compartment hydrogen burn. The plan consists of two parts as follows:

1. Evaluation of the response of the containment and its associated systems to the accident sequences involving upper compartment burns, and a determination of the differential pressure across the fan and doors as a function of time. The specific method of performing this analysis, and the major assumptions and parameters to be used, will be identical to those used in the analysis of equipment survivability.

2. Using the results from the first part of the plan, determination of the response of the fans and doors to upper compartment hydrogen burning and evaluation of the effects on subsequent performance.

Because of the importance of fan and door operability, additional analysis has been performed. This analysis supports the previous conclusion contained in Reference 1 that fans and doors are not adversely affected by imposed differential pressure due to upper compartment hydrogen burning. The refinements to the analysis reported in Reference 1 include elimination of conservatism in the calculation of containment response to upper compartment hydrogen burning which in turn lowers the developed differential pressure between the upper and lower compartments. The details of this additional analysis are discussed herein. The plan for resolution of the issue of fan and door operability consists of confirmation of this most recent analysis using the containment analysis tools described in our plan for resolution of equipment survivability issues.

Analysis of Fan Response to Upper Compartment Burns

As was discussed in the plan for equipment survivability, it has been determined that the HECTR code would represent the best choice for containment analysis. Action has been taken to obtain HECTR from the National Energy Software Center. Following receipt and installation of HECTR, it will be used to analyze a number of containment events in the program for establishment of equipment survivability. Certain of those sequences should include representative upper compartment burning, or upper compartment burning can be forced to occur through selection of appropriate burn parameters. The differential pressure response from that analysis will be used to assess the effects on long term performance of the ice condenser doors and air return fan. The hydrogen burn parameters selected for analysis will be those described in the plan on equipment survivability, specifically in the upper compartment:

Ignition at 6% hydrogen by volume, propagation from the upper plenum into the upper compartment at 6%, and burn completeness of 60%. The burnout time for the upper compartment will be 10 seconds. Both trains of containment sprays will be operational, and credit will be taken for the following mitigative effects on fan and door differential pressure - increased flow through the air return fan, bypass directly from the upper compartment to the lower compartment through the refueling canal drains, and flow back through the ice condenser bypass areas associated with the upper doors, intermediate deck doors, and lower inlet drains. As a sensitivity study, analysis will be performed for the case where only one train of sprays and fans are available, with the inoperable fan windmilling in free flow.

The selected hydrogen burn parameters are based on study of the various hydrogen burning experiments carried out under the sponsorship of NRC, the ice condenser owners, and EPRI. These are the test series at Factory Mutual, Acurex, Sandia (VGES), and Nevada Test Station (NTS). It is recognized that none of these experiments duplicates containment conditions during an accident exactly and that some judgment must be applied in order to establish parameters for analysis based on these experiments. However, it is the best data available and its use in this regard is consistent with the best estimate nature of the analysis to be performed. Sensitivity studies will be performed around this base case set of burn parameters where either experimental evidence or theory justifies the examination of different burn criteria, using guidance contained in References 2 and 3.

Upper compartment - the upper compartment parameters are based on the results of NTS experiments P-7 and P-22 in which mixtures of less than 5.5% hydrogen were easily ignitable and burned quickly in the presence of fans and spray. The burn time was conservatively extrapolated from test P-22 to be 10 seconds, though this is considered to be much faster than an actual burn would take in the upper compartment due to the larger volume over the NTS vessel (a factor greater than 30) and the predominate downward propagation. Ten seconds is also consistent with the spray droplet fall time which has traditionally been used for upper compartment analysis.

Establishment of Fan Operability

The concern associated with the air return fan has to do with the possible windmilling of the fan when a large forward flow causes the fan to first be unloaded, then to change to a wind turbine, with the electric motor becoming a generator. In this case, the fan may be tripped on overcurrent by the electrical devices associated with it, or it may fail structurally due to overspeed. In an attempt to address these issues, we have provided several conservative analyses to NRC which show that these adverse situations are not possible. Further preliminary analysis has been performed in support of our previous work, specifically to remove conservatism from our previous analyses and demonstrate the wide margin available before any concerns with the fans and doors would exist. The results of this analysis are discussed below.

In determining the magnitude and duration of adverse differential pressure on the fans, it is necessary to account for all of the bypass paths associated with the operating deck. It is the flow through these bypass areas that causes an equilibration of pressure between the upper and lower compartments and thus minimizes the imposed differential pressure on the components which lie between. It is also necessary, in calculating the possible effects on the fan, to consider that the differential pressure between compartments is imposed on the fan duct, not just on the fan blades, and that part of the pressure drop between compartments occurs in the duct. In a preliminary evaluation of these effects, an analysis was performed using CLASIX, under the same assumptions reported in Reference 1 as having produced a differential pressure of approximately 8 psid across the fans and doors. The following changes were made in this analysis:

1. The air flow through the fan was increased in the forward direction as the differential pressure was imposed. The air flow increase was scaled from test data from the fan vendor for a similar (but larger) fan which was evaluated for forward windmilling. The exact curve used for this analysis showed a flow rate of 40000 cfm at 0 psid rising to 100000 cfm (increase by a factor of 2.5) with 1 psid imposed on the fan in the forward direction. The flow of 100000 CFM was the maximum flow permitted. Justification for the selection of this flow rate is presented below.

2. The bypass areas associated with the refueling canal drains and ice condenser doors were included. Appropriate adjustments were made for the presence of liquid water in the flow paths (by reducing the available area). These paths consisted of 2 square feet for the refueling canal drains and 10 square feet for the ice condenser lower drains.

The results of the analysis showed the development of a maximum differential pressure across the fan of 3.6 psid. The idifferential pressure across the door was smaller, less than 3 psid. These differential pressures are sufficiently small that no adverse effects on the fan or doors is anticipated.

In order to justify the selected increased flow rate through the air return fan, discussions were held with the fan vendor concerning the available test data for this fan in the forward windmilling direction. There was extensive data on a similar, but larger fan (same size hub, but with larger blades, total diameter of 7 feet vice the 4 feet of the Catawba air return fan) but this data did not include large pressure drops across the fan and therefore could not be applied directly. It was decided to proceed on the basis of assessing fan performance based on general models found in fan literature, then try to relate those to the test data at the end. Proceeding in this manner led to the following approach.

It was necessary first to establish a conservative estimate for the duration of a differential pressure transient on the fan. Since the burnout time in the upper compartment is ten seconds, a transient differential pressure will be high enough to be of concern no more than this time. Previous CLASIX analysis shows the peak of the differential pressure to be relatively sharp, perhaps no more than 6 seconds duration. The time of ten seconds is considered conservative for the duration of the imposed transient. Looking at the thermal overload curve for the air return fan, the current required to trip the thermal overload in ten seconds is 503 amps. [NOTE: there is an error in Reference 1, page 7.0-155. The minimum motor load rating of the thermal overload for the air return fan is 77.4 amps vice 57.4 amps. This will be corrected in a subsequent revision to Reference 1.] At a power factor of 0.9, this corresponds to an electrical power of 418 kw. To determine the input power required from the air stream to produce this output power, the output power was divided by the efficiency of the turbine-generator combination which was conservatively taken as 0.4. (The fan manufacturer indicates from test data that the fan efficiency as a wind turbine for operating speeds in the range of normal operation is 0.37. Losses in the generator were neglected in this calculation and the efficiency rounded up to 0.4.) The input power to the fan is found to be 1045 kw, which corresponds to 1400 hp extracted from the air stream. From fan handbooks, it is possible to relate the input horsepower to the fan to the flow rate through and pressure rise in the fan. From this one can derive a curve of flow and differential pressure for the fan, under the conditions that it is generating sufficient power as a turbine to trip the thermal overload in 10 seconds. The following are the pertinent equations, where

P_f = power out of fan (watts)

V = voltage (600 volts)

I = current (503 amps)

P_i = power into fan (turbine) from air stream

eff = efficiency of conversion process

Q = fan flow (CFM)

dp = fan pressure drop (in. w.g.)

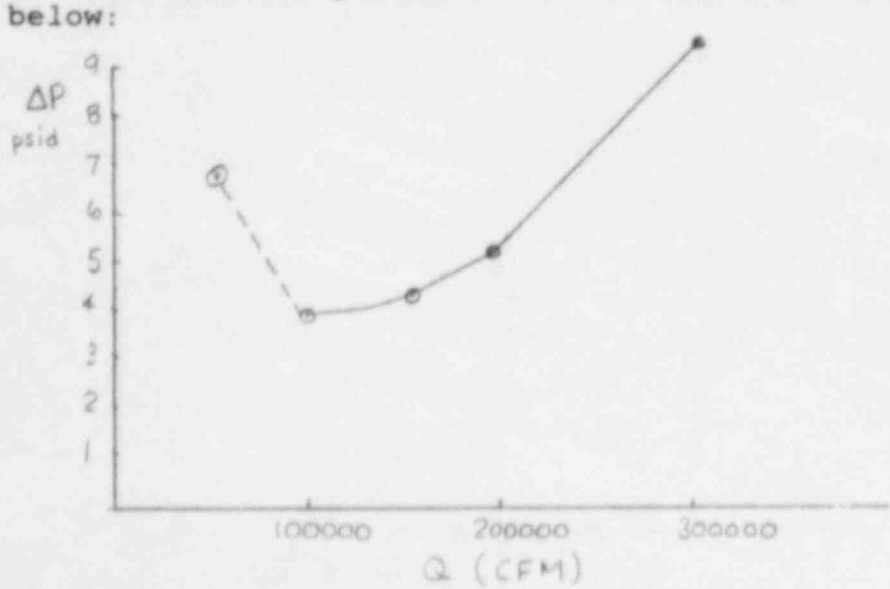
$$P_f = 1.732 \, V \, I \cos \theta$$

$$P_i = P_f / \text{eff}$$

$$P_i = .0001575 \, Q \, dp \qquad \text{(from fan handbooks)}$$

$$Q \times dp = 8.89 \times 10^6$$

There is a corresponding relationship between pressure drop and flow for the fan duct itself. This duct contains dampers, restrictions, and changes in diameter. From the original calculation performed for Catawba, it is found that the fan duct has a loss coefficient associated with it of 4.54. It is possible to combine the relationship for the fan (at a generating condition of 503 amps) and the fan duct pressure drop to get a total pressure drop curve for the fan operating as a turbine in the duct at a point corresponding to fan trip on thermal overload if the condition persists for ten seconds. That curve is shown below:



The upslope represents the stable operating condition. From this curve, it is seen that a set of minimum conditions may be established for the fan to develop the 10 second trip current of 503 amps. These conditions are a differential pressure across the fan duct of approximately 4 psid and a flow through the fan of approximately 100000 CFM. But as indicated by preliminary CLASIX analysis with venting through the fan of 100000 CFM, it is not possible to develop as much as 4 psid across the fan duct during the transient described in Reference 1 (ignition at 6% hydrogen, 60% burn completion, 10 second burn time). The calculated differential pressure under these conditions with upper to lower compartment venting included is 3.6 psid and the duration is less than 5 seconds. Note also from the curve above that small increases in differential pressure result in substantial increases in flow rate through the fan duct and thus even greater venting from the upper to the lower compartment. This would tend to further mitigate the developed differential pressure between the compartments. In summary, providing adequate allowance in analysis for the bypassing of flow from the upper to the lower compartments, particularly by accounting for the increased flow through the fan duct, the total differential pressure between upper and lower compartments is reduced and the fan is not threatened.

It should be noted that this analysis, except for the selection of the fan efficiency, is independent of the performance characteristics of the fan. In the particular case analyzed, the pressure drop required across the fan blades for a flow of 100000 CFM is 3.2 psi, where the fan is extracting 1400 hp from the air stream. In the vendor testing of the 7 foot diameter fan of similar design, the maximum hp the fan could extract from the air in the forward windmilling direction was less than 200 hp. This is due apparently to a significant decrease in efficiency of the fan as a turbine as the flow velocity through it increases greatly beyond its normal operational value. It appears therefore that the air return fan is unlikely to be able to develop a level of delivered power anywhere close to that required to trip the fan motor protective devices.

Our plan for resolution of the issue of fan operability consists of confirmation of the analysis above using HECTR for containment analysis and attempting to obtain more specific information from the vendor on performance of the air return fan in its forward turbine operation.

Additional Information on Ice Condenser Door Operability

An analysis has been performed of the ice condenser lower inlet doors to determine their strength to resist reverse differential pressure and the failure mode of the doors if differential pressure is excessive. The results of this evaluation are as follows:

1. The door structure has the strength to withstand 16 psid without yielding. The strength of the hinges and imbedments associated with the door frame are approximately the same as the door panel itself.

2. The limiting component in the door assembly is the narrow beam which goes up the middle of the door frame. This beam will start to yield when the differential pressure across the door is 7 psid. This value is in agreement with results previously reported by TVA. The consequence of the yielding of this beam is that the doors will push slightly inward (toward the lower compartment), breaking the seal between the door and the beam and creating a small opening which will cause enough leakage to reduce the differential pressure and limit the yielding.

3. There is no failure mode identified which would cause the door to become stuck in the frame unable to open. To cause significant yielding of the door frame, pressures much greater than 7 psid would have to be present, an impossible situation once the initial yielding breaks the door seal at the beam in the middle between the two doors and vents the ice compartment into the lower compartment.

4. The doors all have bypass flow areas associated with them which will tend to equilize door differential pressure. The lower inlet doors are bypassed by the ice condenser drains. These drains are closed to backflow (flow from the lower compartment) by a counterweighted check valve. If a differential pressure is imposed on the door in the backward (closing) direction, the check valve associated with the drain will open (it is designed to be fully open with less than 1 psid imposed on it) and allow a significant amount of flow to bypass the door. Any drain flow associated with ice melting will be small at this time and will not interfere with flow of atmosphere from the ice bed area through the drains and into the lower compartment. Combined with the flow bypassing from the upper to the lower compartment at other locations, the total pressure differential across the door will be substantially mitigated.

The plan for addressing door operability consists of confirmation of the above discussion by examining the results of the containment analysis to be performed for equipment survivability and identifying the magnitude of the differential pressure generated on the door. This will then be compared with the structural strength to determine operability.

Schedule

The schedule for completion of the confirmatory analysis of fan and door survivability is tied to that of the equipment survivability, since it will be the same containment analysis which will be used to determine the imposed differential pressure transient. The results for the fan and doors will be available in June, 1987.

Reference

1. Duke Power Company, "An Analysis of Hydrogen Control Measures at McGuire Nuclear Station," October, 1981, complete through Revision 14, April, 1986.

2. Camp, A. L., et. al., "MARCH-HECTR Analysis of Selected Accidents in an Ice Condenser Containment," NUREG/CR-3912, December, 1984.

3. Camp, A. L., et. al., "HECTR Version 1.0 User's Manual," NUREG/CR-3913, February, 1985.