ENCLOSURE 2

TENNESSEE VALLEY AUTHORITY

TECHNICAL REPORT ON HYDROGEN CONTROL MEASURES AND EFFECTS OF HYDROGEN BURNS ON SAFETY EQUIPMENT

SEQUOYAH NUCLEAR PLANT
UNITS 1 AND 2
NRC UNRESOLVED SAFETY ISSUE A-48
10 CFR 50.44

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BACKGROUND

At the time that SQN Unit 1 was licensed, the NRC accepted the design of the Hydrogen Igniter System as providing adequate protection against the release of hydrogen following certain small break LOCA events as a result of the TMI accident (ref:6). The NRC included a confirmatory item on the license to evaluate the effect of hydrogen combustion on equipment for other events that had approximately the same probability of occurrence as the small break LOCA with a loss of ECCS injection. The requirement to provide this report on equipment survivability during hydrogen burns is based on the confirmatory item in NUREG 0011 Supplement 6, the Nuclear Regulatory Commissions USI/A-48, and the requirements of 10 CFR 50.44, "Standards for combustible gas control system in light-water-cooled power reactors". This commitment (refs:1,2 and 5) will be met by showing that the Duke hydrogen analyses for the Catawba Nuclear Station * performed to resolve the confirmatory item show essentially the same response as would occur at the Sequoyah Nuclear Plant and thus provide evidence that the issue can be considered resolved at Sequoyah.

* In the Duke Power Company analyses, the Catawba analysis is based on the McGuire Nuclear Station analysis. Therefore, information relative to Catawba may be labeled as McGuire.

ANALYSIS

TVA and Duke Power Company performed extensive analyses of the response of the primary containment to hydrogen burns as a result of the TMI accident. These analyses which were submitted to the NRC over the 1980 to 1982 time period in conjunction with a multi-faceted test program formed the basis for the approval of thermal igniters as a suitable mitigation to beyond design basis accident hydrogen generation. These analyses and sensitivity studies will be used to show that the response of the TVA and Duke plants to a small break LOCA with a loss of ECCS injection (S2D) were very similar. Using these analyses as the basis, TVA will establish that the current analyses for the Catawba plant reasonably approximate the expected response of the Sequoyah containment for a similar event.

First the physical similarity of the plants will be established.

1) Both Catawba and Sequoyah are 3411 MWt (core power), Westinghouse 4-loop ice condenser plants. These plants are very similar in basic design features applicable to this analysis. The plants utilize a

Westinghouse 17x17 core pattern with 194 fuel assemblies and operate at 2250 psia. Given the similarity in the reactor vessels, fuel, and RCS inventory the blowdown of both steam and hydrogen would be very similar. Appendix A compares the mass and energy release rates, the hydrogen generation rates and the fission product energy release rates from the Red Book and TVA's base case submittal for an S2D event. Based on the above it is concluded that for the same beyond design basis events, the rate of hydrogen production and release from the reactor vessel at Catawba and Sequoyah would be virtually the same. (refs: 7,8, and 9)

2) The geometric and physical configuration of the containment buildings is basically the same. The containment has 4 major compartments: the ice condenser, upper compartment, lower compartment, and the dead-ended compartments. The ice condenser has three regions; the upper plenum, lower plenum, and the ice bed. Appendix C shows a comparison of the volumes for these compartments at both plants. The principal interior structures of these plants are the crane wall and the divider barrier separating the upper and lower compartments. In addition, the containment volumes are similar (each having approximately 1.2 million cubic feet inside containment) and other structural features for both containments are considered equivalent for purposes of this analysis. As can be seen from the Appendix C, the plants are very similar physically. The differences in the volumes associated with the lower compartments and the dead ended regions are based on how the fan rooms were modeled. TVA modeled the fan rooms as part of the lower compartment volume and Duke modeled these in the dead ended compartments.

3) Both plants have a hydrogen mitigation system (igniters) and these are located in the same compartments. Catawba has 74 igniters located as follows. Forty-eight igniters are in the lower compartment or dead ended compartments, 12 in the upper compartment and 14 in the ice condenser upper plenum area. In comparison, Sequoyah has 68 igniters. Thirty-eight are located in the lower compartment and dead ended compartments, 14 in the upper compartment and 16 in the ice condenser upper plenum area. The previous submittals established that both plants had a sufficient number of igniters distributed throughout the containment to assure that hydrogen combustion would occur whenever the ignition criteria were met in a given compartment. The test program results showed that both the GM igniter used by Duke and the Tayco igniter used by TVA would ignite hydrogen at low

concentrations below those assumed in the analyses. Hence, hydrogen burn profiles should be analogous.

4) The ECCS design is similar, therefore injection and reflood parameters are considered analogous. In addition, by the nature of the events analyzed, loss of all ECCS is assumed. However, both plants have modeled charging pumps, safety injection pumps, low pressure injection pumps (residual heat removal), cold leg accumulators, auxiliary feedwater and containment spray. The Sequoyah containment spray flow rate is higher than Catawba (9500 gpm vs. 6800 gpm), however this would be considered a benefit to Sequoyah due to more complete mixing of the containment atmosphere. This mixing would discourage areas of hydrogen concentration and therefore limit the availability of hydrogen for burning. In addition, the additional spray flow would provide for a cooler containment atmosphere temperature with respect to the Catawba analysis and therefore limit peak containment temperatures associated with hydrogen burning.

Comparing the original analyses for both Catawba and Sequoyah (refs: 7, 8 and 9), it is evident that the CLASIX results obtained for both plants demonstrated that hydrogen burn profiles were similar. Based on the testing of the different igniter designs, the previous CLASIX analyses for both Sequoyah and Catawba, and the latest information contained in the Duke analyses, it is concluded that the Sequoyah design is fundamentally bounded by the Duke analyses. Results reported in the original analyses indicated that the burn parameters (ie, flame speed, consumption, temperature and pressure) of the plants was very similar.

5) The four degraded core sequences {S2D - Small LOCA (2 inch diameter break) with failure to maintain reactor coolant inventory during injection, S2H - Small LOCA (2 inch diameter break) with failure to maintain reactor coolant inventory during recirculation, S1D - Medium LOCA (6 inch diameter break) with failure to maintain reactor coolant inventory during injection and TMLU - station blackout (loss of power, failure of main feedwater, failure of ECCS, and MSIVs closed)} selected for the Duke Catawba analysis are acceptable based on these being the dominant sequences for hydrogen generation. The Individual Plant Evaluation for Sequoyah also identifies these sequences as the dominant sequences for hydrogen generation during degraded core accidents. The Duke analyses utilized the MAAP and HECTR codes as required by the NRC (refs:3, 4 and 10).

The analyzed 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. Based on the Catawba analysis, ECCS was not recovered until hydrogen production had reached a peak value and break locations were located in the hot leg to allow for minimum holdup time of the hydrogen as it is produced in the core Based on the results of NUREG/CR-4551, 63% of all postulated core damage is from LOCAs and 25% is from station blackouts. Therefore, 88% of all evaluated core damage frequencies for Sequoyah are from similar events that have been utilized in these analyses. In addition, the Individual Plant Examination recently completed for Sequoyah identifies the top 10 sequences as events which lead to small break LOCAs.

7) Appendix B provides a comparison of the original Red Book and TVA analyses for the S2D event. The differences in the number of hydrogen burns as reported in the original analyses for both plants is due to the hydrogen concentration assumed for ignition and the amount of hydrogen consumption during burns. Sequoyah reported 7 burns in the lower compartment and 30 burns in the upper plenum, whereas Duke reported 6 burns in the lower compartment and 23 burns in the upper plenum. TVA assumed the ignition point of hydrogen to be 8 vol % while Duke utilized 8.5 vol % hydrogen. In addition, burn completeness assumptions were different between the analyses. Duke assumed that 100% of all hydrogen was consumed (ie., less total burns available) while TVA utilized an 85% consumption criteria. These input parameter differences allowed the Duke analysis to obtain burn patterns that were longer in duration and hotter in region temperature (based on the slightly higher adiabatic flame temperature of 8 vol % verses 8.5 vol %). However, all assumptions relative to hydrogen parameters are conservative with respect to the testing performed in support of the original analyses. Thus it can be concluded that the differences in the analytical results are due to the differences in the hydrogen burn parameters and are not due to the slight physical differences between the plants.

CONCLUSION

Based on the similarities between the McGuire, Catawba and Sequoyah plants, it is considered acceptable to utilize the information contained in the Duke report to encompass the Sequoyah plant. For the given set of

conditions as utilized in the analyses, it is expected that the Sequoyah plant would obtain similar results for the same given conditions. The level of detail in the Duke report is considered acceptable and technically adequate to utilize for Sequoyah. In addition, the original TVA Volume 1 hydrogen submittal and the referenced Duke "Red Book" analysis were very similar in both methodology and results. The main difference in these analyses was the number and magnitude of hydrogen burns. This is directly related to the selected burn criteria (ie., 8% for Sequoyah and 8.5% for Catawba). As previously discussed, TVA considers the analytical assumptions and parameters associated with the Catawba Station to be applicable to Sequoyah for equipment survivability after a degraded core accident.

It is sufficient to state that the basis of this comparison is inherently contained in the original hydrogen reports submitted by both TVA and Duke Power to the NRC (ref:7, 8 and 9). The final analyses from Duke Power Company (ref: 10) concluded that the reanalysis of the original CLASIX models utilizing the HECTR code continue to demonstrate the survival of equipment in containment when subjected to the environment resulting from hydrogen burns. Therefore, TVA confirms acceptance of the Catawba analysis for applicability to Sequoyah. The original analyses performed by both TVA and Duke Power Company were comparable, hence it is highly probable that if a Sequoyah specific analysis was performed equivalent to the Catawba analysis, similar results would be obtained.

Therefore, TVA considers the results of the Catawba analysis in combination with the original Sequoyah specific analyses, to meet the intent and requirements of 10 CFR 50.44.

REFERENCES

1) Letter from TVA to NRC dated November 21, 1989 L44891121801, "Request for information concerning status of implementation of unresolved safety issue (USI) requirements"

2) Letter from TVA to NRC dated January 29, 1988 L44880129805, "Additional hydrogen rule analyses submittal"

3) Submittal from Duke Power Company to NRC dated July 28, 1988, Docket Nos. 50-413 and 50-414, Part I

4) Submittal from Duke Power Company to NRC dated January 4, 1989, Docket Nos. 50-413 and 50-414, Part I

5) Letter from TVA to NRC dated February 19, 1987 L44870219802, "Additional Hydrogen Rule Analysis Submittal"

6) NUREG 0011 Supplements 4 and 6

7) Submittal from TVA to NRC dated September 2, 1980, "Core Degradation Program" Volume 1, Hydrogen Study

8) Submittal from TVA to NRC dated September 2, 1980, "Core Degradation Program" Volume 2, Report on the Safety Evaluation of the Interim Distributed Ignition System

9) "An Analysis of Hydrogen Control Measures at McGuire Nuclear Station" - The Red Book - Duke Power Company, October 1981

10) Letter from Duke Power Company to TVA dated March 10, 1992 with attachment of Parts II and III of the Additional Hydrogen Rule Analysis.

Appendix A

Comparison of CLASIX Input Parameters

Note: Catawba Nuclear Station input parameters are based on McGuire Nuclear Station Red Book Analysis. Therefore, the Red Book information is labeled as McGuire.

TABLE 1

Sequoyah CLASIX Input

MARCH Reactor Coolant Mass and Energy Release Rates

S2D Sequence

Time (seconds)	H_2O Mass Release Rate (lbm/sec)	H_2O Energy Release Rate (Btu/sec)
0.0	197.2	1.167×10^{5}
2172	190.5	1.097×10^{5}
2478	44.85	5.230×10^{4}
3180	53.53	6.547×10^{4}
3804	34.82	4.262×10^{4}
4428	21.40	2.842×10^{4}
4752	48.42	5.558×10^{4}
5700	19.42	2.182×10^{4}
6012	14.07	1.583×10^{4}
6960	5.253	5.989×10^{3}
7062	4.718	5.388×10^{3}
7206	4.060	4.693×10^{3}

McGuire CLASIX Input

MARCH Reactor Coolant Mass and Energy Release Rates

S2D Sequence

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3804	34.82	4.262×10^{4}
4428	21.40	2.842×10^{4}
4752	48.42	5.558×10[illegible]
5700	19.42	2.182×10^{4}
6012	14.07	1.583×10^{4}
6960	5.253	5.989×10^{3}
7062	4.718	5.388×10^{3}
7206	4.060	4.693×10^{3}

Appendix A

Comparison of CLASIX Input Parameters

Note: Catawba Nuclear Station input parameters are based on McGuire Nuclear Station Red Book Analysis. Therefore, the Red Book information is labeled as McGuire.

TABLE 2

Sequoyah CLASIX Input

MARCH Hydrogen Generation Rates and Temperatures

S2D Sequence

Time (seconds)	H_2 Mass Release Rate (lbm/sec)	H_2 Temperature (F)
0.0	0.0	61
3480	0.0	61
3804	0.0413	67
4116	0.260	1582
4428	0.740	795
4752	1.07	771
5700	0.430	612
6330	0.223	555
6648	0.160	535
6960	0.117	519
8070	0.0367	519

Table 4.3-2

McGuire CLASIX Input

MARCH Hydrogen Generation Rates and Temperatures

S2D Sequence

Time (seconds)	H_2 Mass Release Rate (lbm/sec)	H_2 Temperature (F)
0.0	0.0	61
3480	0.0	61
3804	0.0413	67
4116	0.260	1582
4428	0.740	795
4752	1.07	771
5700	0.430	612
6330	0.223	555
[illegible]	[illegible]	535
6960	0.117	519
8070	0.0367	519

Appendix A

Comparison of CLASIX Input Parameters

Note: Catawba Nuclear Station input parameters are based on McGuire Nuclear Station Red Book Analysis. Therefore, the Red Book information is labeled as McGuire.

TABLE 3

Sequoyah CLASIX Input

MARCH Fission Product Energy Release Rates

S2D Sequence

Time (seconds)	Energy Release Rate (Btu/sec)
0.0	0.0
3810	0.0
4116	1803
4428	4800
4752	6708
5376	7000
7080	7135

Table 4.3-3

McGuire CLASIX Input

MARCH Fission Product Energy Release Rates

S2D Sequence

Time (seconds)	Energy Release Rate (Btu/sec)
0.0	0.0
3810	0.0
4116	1803
4428	4800
4752	6708
5376	7000
7080	7135

Appendix A

Comparison of CLASIX Input Parameters

Note: Catawba Nuclear Station input parameters are based on McGuire Nuclear Station Red Book Analysis. Therefore, the Red Book information is labeled as McGuire.

TABLE 4

Sequoyah CLASIX Input

Burn Parameters

	Lower Compartment	Ice Condenser Lower Plenum	Ice Condenser Upper Plenum	Upper Compartment	Dead Ended Region
Hydrogen V/F for Ignition					
Case 1	0.10	0.10	0.10	0.10	0.10
Case 2	0.08	0.08	0.08	0.08	0.08
Case 3	0.06	0.06	0.06	0.06	0.06
Hydrogen V/F for Propagation					
Case 1	0.16	0.10	0.10	0.10	0.10
Case 2	0.08	0.08	0.08	0.08	0.08
Case 3	0.06	0.06	0.06	0.06	0.06
Hydrogen Fraction Burned					
Case 1	1.0	1.0	1.0	1.0	1.0
Case 2	0.85	0.85	0.85	0.85	0.85
Case 3	0.60	0.60	0.60	0.60	0.60
Minimum Oxygen V/F for Ignition	0.05	0.05	0.05	0.05	0.05
Minimum Oxygen V/F to Support Combustion	0.0	0.0	0.0	0.0	0.0
Burn Time (sec)*	2.5	5.4	2.7	8.0	3.2

*Based on a flame speed of 6 ft/sec.

Table 4.3-4

McGuire CLASIX Input

Burn Parameters

	Lower Compartment	Ice Condenser Lower Plenum	Ice Condenser Upper Plenum	Upper Compartment	Dead Ended Region
Hydrogen V/F for Ignition	0.085	0.085	0.085	0.085	0.085
Hydrogen V/F for Propagation	0.085	0.085	0.085	0.085	0.085
Hydrogen Fraction Burned	1.0	1.0	1.0	1.0	1.0
Minimum Oxygen V/F for Ignition	0.05	0.05	0.05	0.05	0.05
Minimum Oxygen V/F to Support Combustion	0.0	0.0	0.0	0.0	0.0
Burn Time (sec)*	9	6	7	13	7

*Based on a flame speed of 6 ft/sec.

Appendix B

Comparison of CLASIX Sensitivity Analysis for S_2D Base Case

Note: Catawba Nuclear Station input parameters are based on McGuire Nuclear Station Red Book Analysis. Therefore, the Red Book information is labeled as McGuire.

TABLE 18

SEQUOYAH CLASIX S_2D PARAMETER SENSITIVITY RESULTS SUMMARY

		Case Base S_2D Base (HFW2)	Case 1A 1 Fan, 1 Spray (A3)	Case 1B 10-100 (U1)
Number of Burns	LC	7	8	0
	UP	30	22	39
	UC	0	0	0
Magnitude of Burns (lbm)	LC	104	9[illegible]	-
	UP	31	[illegible]	40
	UC	-		-
Total H_2 Burned (lbm)		1092	[illegible]	950
H_2 Remaining (lbm)		445	443	587
Peak Temperature (°F)	LC	[illegible]	1210	214
	U[illegible]	12[illegible]	1195	1840
	UC	1[illegible]3	201	171
	DE	2[illegible]7	265	130
Peak Pressure (lb/in^2a)	LC	33.4	32.3	[illegible]2.7
	UP	27.8	30.7	27.3
	UC	25.1	26.8	24.4
	DE	32.8	31.3	22.1
Ice Remaining (lbm)		7.83×10^5	9.35×10^5	7.82×10^5
Figures		3-[illegible]4	35-50	51-6[illegible]

Table 4.4-1

McGuire CLASIX Results Summary

Flame Speed - 6 ft/sec

Basic Transient

Number of burns	LC	6
	UP	23
Magnitude of burns (lbm)	LC	75-110
	UP	20-25
Total H_2 burned (lbm)		1032
H_2 remaining (lbm)		503
Peak temperature (F)	LC	1358
	LP	305
	UP	1526
	UC	173
	DE	255
Peak pressure (psig)	LC	12.5
	LP	12.3
	UP	12.6
	UC	12.1
	DE	12.5
Ice remaining (lbm)		1.14×10^6

LC - Lower Compartment

LP - Lower Ice Condenser Plenum

UP - Upper Ice Condenser Plenum

UC - Upper Compartment

DE - Dead-Ended Regions (Accumulator Rooms, etc.)

Appendix C

Comparison of CLASIX Compartment Specific Conditions

Note: Catawba Nuclear Station input parameters are based on McGuire Nuclear Station Red Book Analysis. Therefore, the Red Book information is labeled as McGuire.

TABLE 5

Sequoyah CLASIX Input

Compartment Initial Conditions

	Lower Compartment	Ice Condenser Lower Plenum	Ice Condenser Upper Plenum	Upper Compartment	Dead Ended Region
Volume (ft^3)	289000	24200	47000	651000	94000
Temperature (F)	100	32	32	85	100
O_2 Pressure (psia)	3.12	3.12	3.12	3.12	3.12
N_2 Pressure (psia)	11.78	11.78	11.78	11.81	11.78
H_2O Pressure (psia)	0.09	0.09	0.09	0.05	0.09

Table 4.3-5

McGuire CLASIX Input

Compartment Initial Conditions

	Lower Compartment	Ice Condenser Lower Plenum	Ice Condenser Upper Plenum	Upper Compartment	Dead Ended Region
Volume (ft^3)	237400	24200	47000	670000	130900
Temperature (F)	100	32	32	75	100
O_2 Pressure (psia)	3.08	3.12	3.12	3.11	3.08
N_2 Pressure (psia)	11.63	11.78	11.78	11.75	11.63
H_2O Pressure (psia)	0.28	0.09	0.09	0.13	0.28