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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

NOV 2 1983

MEMORANDUM FOR: E. Adensam, Chief, Licensing Branch #1, DL

FROM: W. R. Butler, Chief, Containment Systems Branch, DSI

SUBJECT: REQUEST FOR INFORMATION REGARDING HYDROGEN CONTROL
FOR CATAWBA, UNITS 1 & 2

As part of the Containment Systems Branch (CSB) review of hydrogen control measures for ice condenser plants, we have identified the need for additional information regarding the capability of the Duke Power Company's ice condenser containment buildings to withstand reverse pressure differentials which may develop following combustion of large quantities of hydrogen.

Specifically, the combustion of hydrogen removes oxygen from the containment atmosphere and in the long term may result in containment pressures lower than design, i..e, a reverse pressure differential greater than the 1.5 psid design value may develop. The Duke plants, to our knowledge, have no vacuum breaker system or other automatic means for relieving this reverse differential pressure. Therefore, we request that the licensee provide details and analyses, on the Catawba application, to show that reverse pressure differentials resulting from combustion of large quantities of hydrogen will not unduly threaten containment integrity. The licensee's submittal should include:

1) calculations of the reverse pressure differentials which would result from complete combustion of an amount of hydrogen corresponding to a 75% metal-water reaction, and the subsequent cooling of the containment atmosphere.

2) calculations of the ultimate external pressure capacity of the containment shell, including discussions of (a) the calculational method and material properties used; and b) the pressure retention capabilities of the penetrations for reverse pressure loads.

3) a description of the design provisions regarding automatic and manual means for relieving reverse pressure differentials.

4) a discussion of the operating procedures concerning monitoring of containment pressure, and operator actions to relieve reverse pressure differentials following onset of an accident.

We request that the above detailed concerns be transmitted to the Duke Power Company. Duke should also address the applicability of the responses to these concerns, to the McGuire plants.

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13pp.

W R Butler
W. R. Butler, Chief
Containment Systems Branch
Division of Systems Integration

C/1

cc: See page 2
Contact: R. Palla, CSB:DSI, 24762

cc: R. Mattson
R. Houston
B. Clayton
K. Jabbour
C. Tinkler

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MEMORANDUM

Form 847

DATE 1/30/84

TO KN Jabbour

ADDRESS

FROM RO Sharpe

SUBJECT Hydrogen

Attached are responses to recent questions on hydrogen. These responses will be included in a future revision to the McGuire "Red Book".

- Discuss applicability to McGuire
- ~~PSB~~.

will go in Sect 4

C/2

1) calculations of the reverse pressure differentials which would result from complete combustion of an amount of hydrogen corresponding to a 75% metal-water reaction, and the subsequent cooling of the containment atmosphere.

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3) a description of the design provisions regarding automatic and manual means for relieving reverse pressure differentials.

4) a discussion of the operating procedures concerning monitoring of containment pressure, and operator actions to relieve reverse pressure differentials following onset of an accident.

ROS

January 26, 1984

H. B. Tucker, Vice President
Nuclear Production Department

Attn: G. A. Copp

Subject: McGuire Nuclear Station
Containment Hydrogen Mitigation
Responses to NRC Questions

Attached are responses to several recent NRC questions and requests for additional information for inclusion in the Red Book. These responses complete Design Engineering action on containment hydrogen mitigation.

In order to complete the Red Book, the following figures marked "Later" should be replaced by the indicated Duke drawing:

Figure 3.1A-1 - delete this figure and indicate that the information has been incorporated into Figure 3.1A-6

Figure 3.1A-6 - CNEE 0165-02.01 and CNEE 0165-02.02

Figure 3.1A-7 - CN 1735-02.01

The following figures should be updated as indicated:

Figure 3.4-2 - delete and indicate that the information is now incorporated into Figure 3.4-7

Figure 3.4-7 - replace with MCEE 0162-02.01 and MCEE 0162-02.02

Figure 3.4-8 - delete

Figure 3.4-9 - replace with MC 1735-02.01

These new McGuire drawings are on limited distribution in the NSM files. Please call me if you need further assistance in preparation of the appropriate revision to the Red Book.

S. K. Blackley, Jr., Chief Engineer
Mechanical & Nuclear Division

A. L. Sudduth

A. L. Sudduth, Design Engineer II

ALS/kh

Attachment:

cc w/atta: C. L. Sansbury, R. E. Miller, ✓R. O. Sharpe
cc w/o atta: F. G. Hudson

Question:

1. With regard to the CLASIX code, the staff has previously requested clarification of the structural heat sink heat transfer models. The following pertinent points have been derived from the responses:

   i) Heat transfer is based on a temperature difference determined by ($T_{bulk} - T_{wall}$).

   ii) Heat transfer coefficients for degraded core accident analysis are determined from a natural convection (stagnant) correlation applicable to condensation heat transfer.

   iii) CLASIX does not explicitly model mass removal due to condensation heat transfer.

   Based on the description of the CLASIX structural heat sink model, it appears that the CLASIX model differs dramatically from generally accepted approaches and is not, as is claimed, consistent with standard methods such as those used in CONTEMPT. The differences are related to the treatment of the three items cited above. By comparison, previously accepted approaches are characterized by the following:

   i) Heat transfer is based on ($T_{sat} - T_{wall}$), when the surface temperature of the heat sink is less than T_{sat}; i.e., $T_{wall} < T_{sat}$.

   ii) Heat transfer coefficients are based on condensation only when $T_{wall} < T_{sat}$.

   iii) Condensed mass removal is based on condensation heat transfer with provisions for revaporizing a small fraction of the condensate.

has been checked
"against code"

   A more detailed description of accepted practice is contained in NUREG-0588 and NUREG/CR-0255.

   The effect of the CLASIX models would appear to be the de-superheating of the atmosphere too rapidly thus reducing gas temperatures and possibly altering the combustion characteristics.

   Based on the above discussion, provide justification for the models incorporated in CLASIX or provide the results of analyses with acceptable models as outlined above. The analyses should encompass selected sensitivity studies to assure that the effects of the changes are determined for both containment integrity and equipment survivability considerations.

Response:

The following additional information is provided concerning the method by which CLASIX models heat transfer to the passive heat sinks.

1. A close examination of the CLASIX code reveals that all heat transfer for the cases reported in our analysis used heat transfer coefficients based on the stagnant portion of the Tagami correlation:

[illegible]

$$H\left(\frac{BTU}{hr\ ft^2\ {}^oF}\right) = 2 + 50\left(\frac{\text{Mass of steam}}{\text{Mass of noncondensables}}\right)$$

Table 1 compares this value of heat transfer coefficient with the Uchida correlation used in CONTEMPT4, Reference (2). It can be seen that, for the small break LOCA case analyzed by Duke Power, CLASIX consistently selected conservative convective heat transfer coefficients. At no time did CLASIX use the correlations for natural convection of the form

$$Nu = f\ (Pr,\ Re)$$

due to the program logic associated with the particular heat transfer option selected for our analysis.

2. The use of T_{bulk}, rather than T_{sat}, to compute the temperature difference appropriate to passive heat sink heat transfer is supported by experimental and analytical work. This type of heat transfer is dominated by a boundary layer containing noncondensables, particularly in an ice containment where operation of the air return fans assures that a continuous source of noncondensables is available in all compartments. An examination of CLASIX output reveals that typical values of the mass ratio of noncondensables to steam is greater than 1.5, even immediately following a hydrogen burn. As discussed in reference (1), use of T_{sat} rather than T_{bulk} to calculate heat transfer in the presence of noncondensables is "inappropriate."

3. CLASIX does not remove mass from the atmosphere by condensation at the walls. There is therefore no credit taken for condensing heat transfer and no atmospheric temperature decrease due to energy removal by condensate revaporization. This does not affect the period of most interest in analysis of hydrogen burning in containment - the period during and immediately following a hydrogen burn during which the passive heat sinks function to desuperheat the atmosphere. Energy deposition in the heat sinks of compartments where hydrogen burning occurs causes T_{wall} to rise to temperatures above T_{sat}. These wall temperatures remain above saturation for the duration of the period during which hydrogen burning occurs. Therefore no condensing heat transfer can take place on heat sinks in compartments where hydrogen burning occurs, and the fact that CLASIX cannot model wall condensation is irrelevant. The principal cooling mechanism for the lower compartment atmosphere is the flow from the upper compartment due to operation of the air return fan.

In summary, it is apparent that CLASIX handles convective heat transfer in a conservative manner consistent with the physical processes occurring in the containment atmosphere. As noted in Table 1, the heat transfer coefficients are lower than those used in the Uchida correlation of CONTEMPT4. The use of the temperature difference between the wall and the atmosphere is justified by the actual ratio of steam [illegible] noncondensables present during the period of hydrogen burning. We conclude that no further CLASIX analysis is required.

References:

(1) Lamkin, D., A Koestel, R. Gido, and P. Baranowsky, Containment Main Steam Line Break Analysis for Equipment Qualification, NUREG/CR-1511, June, 1980.

(2) Cheng, T. C., L. Metcalfe, J. Hartman, W. Mings, and A. Crail, CONTEMPT4/MOD3, A Multicompartment Containment System Analysis Program, NUREG/CR-2558, December, 1982.

Table 1 **Heat Transfer Coefficients**

$\frac{\text{Mass of steam}}{\text{Mass of noncondensables}}$	H (CLASIX) (BTU/ft^2 hr ^{o}F)	H (CONTEMPT4) (BTU/ft^2 hr ^{o}F)
0.02	3	2
0.05	4.5	8
0.10	7	14
0.20	12	21
0.33	18.7	29
0.43	23.7	37
0.56 *	29.8	46
0.77	40.5	63
1.25	64.5	98
2.0	102	140

*According to data from CLASIX results, the mass ratio before, during, and after hydrogen burning lie in this range. The CLASIX heat transfer coefficients are about 35% less than those used in CONTEMPT4 in this range.

Question:

2. Provide a complete evaluation of fan (both air return and hydrogen skimmer as applicable) operability and survivability for degraded core accidents. In this regard discuss the following items:

   a. The identification of conditions which will cause fan overspeed, in terms of differential pressure and duration, and hydrogen combustion events.

   b. The consequences of fan operation at overspeed conditions. The response should include a discussion of thermal and overcurrent breakers in the power supply to the fans, the setpoints and physical locations of these devices, and the fan loading conditions required to trip the breakers.

   c. Indications to the operator of fan inoperability, corrective actions which may be possible, and the times required for operators to complete these actions.

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

Response:

This question was addressed previously by Duke Power. Refer to pages 7.0-123 and 7.0-124 of the Red Book.

Question:

3. Provide an evaluation of the ultimate capability of ice condenser doors to withstand reverse differential pressures.

[illegible] as generic -- identical

Response:

The top deck blankets rest on grating. In a reverse differential pressure situation, the grating would be the primary structural component if the closed blankets were pressed down on the grating. Calculations performed by TVA show a nominal static failure loading of 4 psi. The limiting component for the intermediate deck is the door which is conservatively estimated to fail at a static loading of 6 psi.

lower doors ?

Any reverse differential pressure across either the top or intermediate decks would be mitigated by the existing bypass area and any additional bypass area created by flow through the ice condenser which displaces the top deck blankets laterally. However, our previous analysis has demonstrated that for all reasonable assumptions on the course of events associated with a recoverable degraded core, hydrogen burning is precluded in the upper compartment. Therefore, we do not consider the case of reverse differential pressure on the ice condenser doors to represent a realistic loading condition.

earlier analyses show it burns in UC

- blankets will never flip 90°
- intermediate doors reclose

Additional information concerning contaiment conditions following the hydrogen burn period:

It has been postulated that when the containment had been cooled down to ambient temperature following hydrogen burning that the pressure in containment would become subatmospheric. In order to check this postulation, the following calculations were made:

Taking the initial conditions in the containment at the start of the small break LOCA from CLASIX input, we note the following atmospheric constituents

mass of oxygen - 22265 lbm $n_{O_2} = 696$
mass of nitrogen - 73627 lbm $n_{N_2} = 2628$
mass of hydrogen - 0 lbm
mass of water vapor - 658.1 lbm $n_{H_2O} = 37$

3361 too high

if we assume that 1500 lbm of hydrogen is added to the containment and burned, then we consume 12000 lbm of oxygen in burning. Also, at the end of the hydrogen burn period, the air return fans and containment sprays have served to mix the atmosphere and create 100% relative humidity throughout containment.

Assuming that there is no net reduction in available free space in containment (a conservative assumption which assumes no flow from the engineered safeguards systems outside containment into either the high pressure injection or containment spray systems), we can calculate the atmospheric constituents in containment when the containment is cooled to ~~100°F.~~ → Too high!

partial pressure of H_2O at 100°F = .9503 psia would be 105 @ 80°F

corresponding amount of water vapor in air = 3650.4 lbm $n = 203$

mass of oxygen = 22265 - 12000 = 10265 lbm $n = 321$
mass or nitrogen is unchanged
mass of hydrogen = 0

on a molar basis:

n (water) = 202.9
n (nitrogen) = 2629.5
n (oxygen) = 320.8

final pressure at 100°F = $\frac{\Sigma nRT}{V}$

we would assume 80°F

$$P = \frac{(202.8 + 2629.5 + 320.8)(10.73)(560)}{1.2823 \times 10^6}$$

where did this come from

P = 14.8 psia

therefore only a slight vacuum is drawn in containment upon containment cooldown, well within the containment reverse pressure capability.

It is not difficult to see why this is true. In the preaccident containment, most volumes contain little water vapor: post accident conditions will have a saturated atmosphere in all containment compartments due to the action of the containment spray and the primary coolant release from the break. If one makes the more realistic assumption that the containment sump water level will rise due to injection of water from the Refueling Water Storage Tank via the high and low pressure injection systems and the containment spray, then the final pressure upon containment cooldown will be higher. Finally, the assumption that all 1500 lbm of hydrogen released to containment will burn is unrealistically conservative. Once the hydrogen concentration falls below 4% by volume, further burning will be impossible, and the remaining hydrogen will be removed by the electric hydrogen recombiners over a period of several days.

A system to control containment pressure is available to the operator. If containment pressure falls below -0.25 psig, an alarm sounds in the control room. The operator can then manually add air from the Auxiliary Building to the containment to restore pressure to atmospheric. This alarm provides substantial margin to the containment design reverse pressure of 1.5 psig. Information concerning the reverse pressure capability of containment is contained in the Catawba FSAR, Section 6.2.1.1.1. The system which the operator uses to control containment pressure and mitigate a vacuum condition in containment is described in the Catawba FSAR, Section 9.5.10.

What procedures instruct him to do this?