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SUBJECT: Forwards response to SA Varga 820730,0916 & 830810 requests for addl info re hydrogen combustion & control during degraded core accidents.

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INDIANA & MICHIGAN ELECTRIC COMPANY

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October 10, 1983
AEP:NRC:0500K

Donald C. Cook Nuclear Plant Unit Nos. 1 and 2
Docket Nos. 50-315 and 50-316
License Nos. DPR-58 and DPR-74
RESPONSES TO REQUESTS FOR INFORMATION ON
HYDROGEN COMBUSTION AND CONTROL

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

Dear Mr. Denton:

This letter and its Attachments provide additional information on hydrogen combustion and control during degraded core accidents for the Donald C. Cook Nuclear Plant Unit Nos. 1 and 2. More specifically, the information contained herein is being provided as a partial response to three (3) Requests For Information transmitted to Mr. J. E. Dolan (Indiana & Michigan Electric Company) by Mr. S. A. Varga (NRC). These Requests For Information are dated July 30, 1982, September 16, 1982, and August 10, 1983.

Attachment 1 to this letter presents a brief overview of the present status of our efforts to address your staff's concerns with regard to hydrogen control for ice condenser containments. In particular, ninety-three (93) issues of concern have been identified from the three (3) Requests For Information referenced above. Twenty-one (21) of these issues have previously been addressed via our submittals dated October 15, 1982 (AEP:NRC:0500J), and December 17, 1982 (AEP:NRC:0500L). An additional thirty-five (35) issues are addressed in Attachments 2 through 5 to this letter. Attachment 1 presents our plans to respond to the remaining thirty-seven (37) issues.

Attachment 2 to this letter provides responses to twelve (12) of the issues identified in Mr. S. A. Varga's July 30, 1982, Request For Information. Likewise, twenty-one (21) of the concerns raised in the September 16, 1982, Request For Information are addressed in Attachment 3 to this letter.

Attachment 4 contains a copy of the report entitled "Fog Inerting Analysis For PWR Ice Condenser Plants." This report is provided in response to Question 10 of the September 16, 1982, Request For Information.

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Attachment 5 contains a copy of a paper presented at the Second International Workshop on the Impact of Hydrogen on Water Reactor Safety (Albuquerque, New Mexico, October 3-7, 1982). This paper, entitled "Fog Inerting Criteria For Hydrogen/Air Mixtures," is provided in response to Question 11 of the September 16, 1982, Request For Information.

This document has been prepared following Corporate procedures which incorporate a reasonable set of controls to ensure its accuracy and completeness prior to signature by the undersigned.

Very truly yours,

M. P. Alexich
Vice President

MPA/cam

Attachments

cc: John E. Dolan - Columbus
W. G. Smith, Jr. - Bridgman
R. C. Callen
G. Charnoff
E. R. Swanson - NRC Resident Inspector, Bridgman

ATTACHMENT 1 TO AEP:NRC:0500K
HYDROGEN CONTROL QUESTIONS CHECKLIST
DONALD C. COOK NUCLEAR PLANT UNIT NOS. 1 AND 2

This Attachment presents a checklist of ninety-three (93) questions or "subquestions" on hydrogen combustion and control for the Donald C. Cook Nuclear Plant which were received by Indiana & Michigan Electric Company (I&MECo) via References (1.1), (1.2), and (1.3).

Of these ninety-three (93) questions or "subquestions", eighteen (18) were responded to via letter No. AEP:NRC:0500J, dated October 15, 1982 (Mr. R. S. Hunter (I&MECo) to Mr. H. R. Denton (NRC)). Three (3) additional responses were provided via letter No. AEP:NRC:0500L, dated December 17, 1982 (Mr. R. S. Hunter (I&MECo) to Mr. H. R. Denton (NRC)). Thus, seventy-two (72) questions remain to be addressed.

Attachments 2 through 5 to this submittal contain additional responses to thirty-five (35) of the seventy-two (72) outstanding questions. The enclosed checklist denotes those specific questions or "subquestions" for which we previously supplied responses (via our October 15 and December 17, 1982, submittals), and those to which we are responding via the present submittal.

Of the thirty-seven (37) questions which thus remain to be addressed, twenty-five (25) deal with equipment survivability during degraded core accidents, sonic flow transients within containment as a result of hydrogen burn conditions, CLASIX computer code models for ice bed and containment spray heat transfer, and the sensitivity of containment analyses to assumed flame speeds, hydrogen burn rates, and igniter effectiveness. We presently expect to respond to these twenty-five (25) questions on or before January 15, 1984.

The remaining twelve (12) questions deal with the CLASIX model for wall heat transfer, the survivability of air return/hydrogen skimmer system fans during hydrogen burn conditions, and the ultimate pressure capability of ice condenser doors. These topics were discussed at a meeting of American Electric Power Service Corporation (AEPSC), Tennessee Valley Authority, and Duke Power Company personnel in Knoxville, Tennessee, on September 27, 1983. AEPSC is currently reviewing the situation and expects to develop a schedule for response to these last twelve (12) questions in the near future.

Furthermore, we note that we expect to submit, on or before November 15, 1983, an Executive Summary Report which will summarize the results of the four research and development programs (i.e., Acurex, Factory Mutual Research Corporation, AECL - Whiteshell, and Hanford Engineering Development Laboratory) funded by the ice condenser utilities and the Electric Power Research Institute. This Executive Summary Report will also discuss the applicability of these programs to the Donald C. Cook Nuclear Plant Unit Nos. 1 and 2 hydrogen combustion and control program.

Hydrogen Combustion And Control Questions

Checklist

I. Questions contained in Reference (1.1):

Question No.	Topic	Letter No.	Date
1 a	Ice Bed Node	AEP:NRC:0500J	10/15/82
1 b	Ice Bed Node	AEP:NRC:0500J	10/15/82
2 a	Sonic Flow	________	1/15/84
2 b	Sonic Flow	________	1/15/84
2 c	Sonic Flow	________	1/15/84
2 d	Sonic Flow	________	1/15/84
3	Breakflow	This submittal	
4 a	Burn Model	AEP:NRC:0500J	10/15/82
4 b	Burn Model	This submittal	
4 c	Burn Model	This submittal	
4 d i	Burn Model	AEP:NRC:0500J	10/15/82
4 d ii	Burn Model	AEP:NRC:0500J	10/15/82
4 d iii	Burn Model	AEP:NRC:0500J	10/15/82
4 d iv	Burn Model	AEP:NRC:0500J	10/15/82
4 e	Burn Model	This submittal	
4 f	Burn Model	________	1/15/84
5 a	Wall Heat Transfer	________	______
5 b	Wall Heat Transfer	________	______
5 c	Wall Heat Transfer	________	______
6 a	Radiant Heat Transfer	AEP:NRC:0500J	10/15/82
6 b	Radiant Heat Transfer	AEP:NRC:0500J	10/15/82
7 a	Wall Heat Transfer	AEP:NRC:0500J	10/15/82
7 b	Wall Heat Transfer	AEP:NRC:0500J	10/15/82
8 a	Ice Bed Heat Transfer	________	1/15/84
8 b	Ice Bed Heat Transfer	________	1/15/84
8 c	Ice Bed Heat Transfer	________	1/15/84
8 d	Ice Bed Heat Transfer	________	1/15/84
8 e	Ice Bed Heat Transfer	________	1/15/84
8 f	Ice Bed Heat Transfer	________	1/15/84
8 g	Ice Bed Heat Transfer	________	1/15/84
9 a	Ice Melt Water	AEP:NRC:0500L*	12/17/82
9 b	Ice Melt Water	AEP:NRC:0500L*	12/17/82
9 c	Ice Melt Water	AEP:NRC:0500L*	12/17/82
10 a	Spray Model	________	1/15/84
10 b	Spray Model	AEP:NRC:0500J	10/15/82
10 c	Spray Model	AEP:NRC:0500J	10/15/82
10 d	Spray Model	AEP:NRC:0500J	10/15/82
11 a	Spray Model	________	1/15/84
11 b	Spray Model	________	1/15/84
12	Spray Comparison	This submittal	
13 a	TMD-CLASIX	AEP:NRC:0500J	10/15/82
13 b	TMD-CLASIX	AEP:NRC:0500J	10/15/82
13 c	TMD-CLASIX	AEP:NRC:0500J	10/15/82
13 d	TMD-CLASIX	AEP:NRC:0500J	10/15/82
14 a	CLASIX-COCOCLASS9	This submittal	

Question No.	Topic	Letter No.	Date
14 b	CLASIX-COCOCLASS9	This submittal	
15 a i	Fenwal-CLASIX	This submittal	
15 a ii	Fenwal-CLASIX	This submittal	
15 a iii	Fenwal-CLASIX	This submittal	
15 b	Fenwal-CLASIX	This submittal	
16	Conservation Equations	This submittal	

II. Questions contained in Reference (1.2):

Question No.	Topic	Letter No.	Date
1 a i	Acurex	This submittal	
1 a ii	Acurex	This submittal	
1 a iii	Acurex	This submittal	
1 b	FMRC	This submittal	
1 c	AECL-Whiteshell	This submittal	
1 d	HEDL	This submittal	
2 a	TAYCO Igniter	This submittal	
2 b	TAYCO Igniter	This submittal	
3 a	TAYCO Igniter	This submittal	
3 b	TAYCO Igniter	This submittal	
3 c	TAYCO Igniter	This submittal	
3 d	TAYCO Igniter	This submittal	
3 e	TAYCO Igniter	This submittal	
4	DIS	This submittal	
5 a	Local Detonation	This submittal	
5 b	Local Detonation	This submittal	
5 c	Local Detonation	This submittal	
6	Fan Survivability		
7 a	Equipment Survivability		1/15/84
7 b	Equipment Survivability		1/15/84
7 c	Equipment Survivability		1/15/84
8	Equipment Survivability		1/15-84
9	HEDL Gradients	This submittal	
10	Fog Formation	This submittal	
11	Fog Effects	This submittal	
12	Spray Model		1/15/84
13 a	Spray Model		1/15/84
13 b	Spray Model		1/15/84
13 c	Spray Model		1/15/84
14 a	Burn Parameters	This submittal	
14 b	Beam Length	This submittal	
14 c	8.5% Ignition	This submittal	
14 d	Flame Speeds		1/15/84
14 e	Igniter Effectiveness		1/15/84

III. Questions contained in Reference (1.3):

Question No.	Topic	Letter No.	Date
1 a	Wall Heat Transfer		
1 b	Wall Heat Transfer		
1 c	Wall Heat Transfer		

Question No.	Topic	Letter No.	Date
2 a	Fan Survivability	__________	______
2 b	Fan Survivability	__________	______
2 c	Fan Survivability	__________	______
2 d	Fan Survivability	__________	______
3	Ice Condenser Doors	__________	______

*NOTE: Supersedes response provided via letter No. AEP:NRC:0500J, dated October 15, 1982.

References, Attachment 1:

(1.1) Letter dated July 30, 1982, Mr. S. A. Varga (NRC) to Mr. J. E. Dolan (I&MECo), containing sixteen (16) questions on hydrogen combustion and control for the Donald C. Cook Nuclear Plant Unit Nos. 1 and 2.

(1.2) Letter dated September 16, 1982, Mr. S. A. Varga (NRC) to Mr. J. E. Dolan (I&MECo), containing fourteen (14) questions on hydrogen combustion and control for the Donald C. Cook Nuclear Plant Unit Nos. 1 and 2.

(1.3) Letter dated August 10, 1983, Mr. S. A. Varga (NRC) to Mr. J. E. Dolan (I&MECo), containing three (3) questions on hydrogen combustion and control for the Donald C. Cook Nuclear Plant Unit Nos. 1 and 2.

ATTACHMENT 2 TO AEP:NRC:0500K
RESPONSES TO QUESTIONS ON HYDROGEN CONTROL CONTAINED IN MR. S. A. VARGA'S 30 JULY 1982 LETTER
DONALD C. COOK NUCLEAR PLANT UNIT NOS. 1 AND 2

Question 1:

Provide additional details regarding the ice bed nodalization scheme used in CLASIX, specifically:

a) It is not clear whether all or just part of the volume initially occupied by ice is added to the lower plenum as the ice melts. Clarify how the free volume and ice volume in the ice bed are handled in CLASIX, both initially and as the ice melts; and

b) It is our understanding that the present version of CLASIX, unlike earlier versions, does not treat the ice bed as a separate volume. As a result combustion in the ice bed cannot be modelled. Combustion in this region can potentially be more severe than in the plenums due to the larger ice bed volume. Discuss the consequences of modelling the ice bed as a flow path rather than as an individual volume, and demonstrate that the CLASIX approach yields more conservative results than if combustion in the ice bed were permitted.

Response to Questions 1(a) and 1(b):

A response to Questions 1(a) and 1(b) was previously provided in the Attachment to Reference (2.1).

Question 2:

With regard to the CLASIX flow equations (A-4, A-8) provide the following information:

a) Equation (A-4) is used until a Mach number of one is reached without adjusting the loss coefficient for the variation of compressibility over this range of Mach number. Please justify the assumption of a constant loss coefficient.

b) The use of steady-flow equations assumes that the effects of transient phenomena, such as inertia, are not important. However, inertia would increase the pressure rise associated with a burn because pressure relief by outflow is reduced. Please describe the junction flow transients and transitions to sonic flow which occur at each of the flow junctions during blowdown and hydrogen burns, and justify that the steady-flow equations are valid for hydrogen burn transients.

c) The flow equations require a density and velocity. These should be the density and the velocity at the vena contracta (minimum flow area). However, the density defined by Equation (A-7) provides a density that is the average of the source and the sink volumes, which will not be the vena contracta density. In addition, the velocity used in Equation (A-4) is not defined. Please explain and justify the bases for the density and velocity used in the flow equations.

d) Two-phase flow conditions might result from 1) the breakflow or 2) a condensation fog from the ice condenser. As a result, the effects of mechanical (slip), thermal, and chemical (vapor diffusion) non-equilibria may become important. Justify the use of Equations (A-4) and (A-8) to estimate the transient flow of a two-phase fluid.

Response to Question 2:

A response to Questions 2(a) through 2(d) will be submitted on or before January 15, 1984.

Question 3:

Justify the CLASIX assumption that the breakflow can be assumed to separate immediately into a liquid portion that falls to the containment floor and a vapor portion that is added to the inventory of the containment atmosphere.

Response to Question 3:

Breakflow into a compartment or volume of lower thermodynamic state will seek thermodynamic equilibrium. The process of coming to equilibrium, which depends upon the relative thermodynamic states of the breakflow and the receiving volume, will ideally lead to the production of saturated vapor and saturated liquid at a single characteristic temperature and pressure.

At the critical point of water (approximately 705^{o}F) the internal energies of saturated liquid and saturated vapor are identical. As saturation pressure is reduced, however, both the internal energy and enthalpy of the vapor phase increase relative to the liquid phase. (At atmospheric pressure, saturated vapor has about six times as much internal energy or enthalpy as the liquid phase does.) Furthermore, the saturated vapor has a lower specific heat capacity than saturated liquid over the temperature range of interest in S_2D analyses.

Thus, the removal of saturated liquid to the containment sumps (as assumed by the CLASIX code) results in a conservative estimate of specific internal energy and enthalpy for the containment atmosphere. Addition of energy to the atmosphere should then also yield conservative pressure and temperature rises, as the large saturated liquid heat sink is ignored by CLASIX.

Question 4:

Provide the following information regarding the CLASIX hydrogen burn model:

a) The burn time values used in CLASIX analyses submitted for two similar plants differ by as much as a factor of three for the same compartment and flame speed, thus suggesting an inconsistency in computing burn length. To clarify this point, describe the methodology for evaluating the burn length as it applies to containment analyses.

b) Discuss the rationale for precluding flame propagation in fan flow paths.

c) Describe how CLASIX might be applied to model containments with multiple ignition points within containments.

d) Equation (D-3) appears to be a calorimeter equation where the preburn mixture is at $70^{\circ}F$ and the products of combustion are cooled to the same temperature. Equation (D-4) appears to represent the net energy addition rate due to hydrogen burning. Clarify these equations, and explain how they are applied. Specifically:

   i) Provide a more detailed description of the heat rate parameters, HR_E and HR in Equation (D-3), and discuss the significance of the specific heat terms used to "correct" the heat rate of combustion. Include approximate parameter values used in CLASIX analyses.

   ii) Discuss the relevance of Equation (D-3) for the typical CLASIX analysis in which the containment temperatures before and after a burn are very different; i.e., the products of combustion are not cooled to the initial temperature.

   iii) Provide a more detailed discussion and development of Equation (D-4). Describe the significance of the specific heat terms, and how Equation (D-4) is ultimately applied.

   iv) Explain why in Equation (D-4) the effective heat rate is reduced due to the removal of hydrogen and oxygen but is not increased due to the formation of water vapor.

e) Describe where in the CLASIX calculations the mass inventory of oxygen and steam is adjusted due to combustion, and when in the calculations the energy released from a hydrogen burn is added.

f) It is our understanding that the hydrogen burn rate, $\dot{M}_B$, is determined upon ignition by Equation (D-2) and held constant for the duration of each burn, while the mass of hydrogen to be burned is updated each interval by Equation (G-20). Intuitively the burn rate should also be updated to reflect the mass of hydrogen present, which may be greater or lesser than that at the onset of burning depending on the hydrogen injection rate. Please justify the use of a constant burn

rate in view of the changing hydrogen concentration during a burn.

Response to Question 4(a):

A response to Question 4(a) was previously provided in the Attachment to Reference (2.1).

Response to Question 4(b):

Fan flow paths are user-specified in the CLASIX computer code in order to represent the forced recirculation air flow which may exist within a containment building. These forced air flow paths act as nodal volume connections which exist in addition to the conventional pressure driven flow paths shown in Figure 1 of the CLASIX Topical Report No. OPS-07A35.

Since flame propagation between nodal volumes is already allowed along the pressure driven flow paths, precluding flame propagation along a fan flow path should be considered unrealistic only if the fan flow path of concern connected two nodal volumes not already connected by a pressure driven flow path. Furthermore, the structure of CLASIX subroutine BURN coding ensures that, in the case of identical spontaneous ignition and propagation hydrogen gas concentrations, the use of propagation models is not of importance. This is due to the fact that the tests for spontaneous ignition within a compartment occur in the coding prior to the test for propagation delay time expiration along any flow path leading to that compartment.

In the case of the Donald C. Cook Nuclear Plant CLASIX analyses, identical ignition and propagation hydrogen concentrations were assigned to each individual compartment. Therefore, propagation along any pressure driven or fan flow path would not have had any effect upon reported results.

Response to Question 4(c):

CLASIX can be used to model any number of ignition points within a containment nodal volume by adjusting the burn time accordingly.

Response to Questions 4(d)(i) through 4(d)(iv):

A response to Questions 4(d)(i), 4(d)(ii), 4(d)(iii), and 4(d)(iv) was previously provided in the Attachment to Reference (2.1).

Response to Question 4(e):

CLASIX performs all mass and energy updates at the end of each time step. The code adjusts the mass inventory of oxygen and steam due to combustion and updates the compartment energy to reflect any energy released by hydrogen combustion during the time step.

Response to Question 4(f):

A response will be submitted on or before January 15, 1984.

Question 5:

Provide the following information regarding the calculation of heat and mass transfer to passive heat sinks:

a) Equation (B-1) provides for the use of either the Tagami or Uchida correlation to determine the heat and mass transfer to passive heat sinks. The Tagami correlation is for conditions very different from those expected for the application of CLASIX, that is, small-break containment analyses. The Uchida correlation is for natural convection heat transfer, including condensation, in the presence of a noncondensible gas. Clarify how Equation (B-1) is used and justify the use of the Tagami correlation.

b) The natural convection heat transfer correlation for $Gr < 10^9$ that is used in the Tagami/Natural convection heat transfer correlation Equation (B-6), yields heat transfer rates lower than other text book correlations by a factor of three. Please discuss this discrepancy.

c) Describe and justify the passive heat sink heat transfer assumptions regarding (i) the temperature difference used with the film coefficients; (ii) the model used to account for the removal of mass that is condensed on the heat sink surfaces; and (iii) the energy removal associated with the condensed mass.

Response to Question 5:

A schedule for response to Question 5 will be determined in the near future. This response will take into account Question 1 contained in Mr. S. A. Varga's August 10, 1983, letter to Mr. J. Dolan (Indiana & Michigan Electric Company).

Question 6:

Concerning the radiation heat transfer model used in CLASIX:

a) If the wall surfaces are assumed to be "black," the radiant heat transfer equation, (B-8), does not reduce to a classical expression of the form $Q_r = \sigma A(E_v T_v^4 - \alpha_v T_w^4)$ as it should. Provide the development of Equation (B-8), and justify the use of the vapor and wall emissivities as multipliers on the T^4 terms.

b) It is conceivable that the breakflow or fog at the ice condenser exit might be introduced as a dispersion of fine drops that would be transported throughout the containment.

The small drops might reduce the radiation from the water vapor to the heat sinks by affecting the beam length for radiation. Discuss the impact of this mechanism on the radiant heat transfer calculation.

Response to Questions 6(a) and 6(b):

A response to Questions 6(a) and 6(b) was previously provided in the Attachment to Reference (2.1).

Question 7:

For the internal heat transfer model, provide additional details with regard to:

a) The procedure for updating the surface temperature of a wall with two nodes in the surface layer; and

b) The evaluation of Q_c in Equation (B-17) when $NN = 2$ and $NN > 2$. Also, describe the subscript notation for these cases.

Response to Questions 7(a) and 7(b):

A response to Questions 7(a) and 7(b) was previously provided in the Attachment to Reference (2.1).

Question 8:

Regarding the analysis of heat transfer in the ice bed:

a) The assumption that no condensation occurs in the ice bed if the water vapor is superheated, and that condensation only occurs when the vapor is saturated does not seem realistic because (a) both heat and mass transfer can occur simultaneously if there is both a temperature and a concentration gradient; and (b) the vapor concentration gradient can extend into the superheated region. Provide justification for this assumption, perhaps via an analysis of the mass transport occurring in the superheated and in the saturated sections of the ice bed.

b) The possibility exists to produce a condensate fog in the ice bed capable of being convected along with the flowing gas instead of collecting on the surface of the ice bed. Provide analyses or cite relevant studies which would justify the assumption that no condensate fog leaves the ice condenser.

c) Provide additional details of the CLASIX ice bed heat transfer solution process, specifically, the procedure by which the ice condenser is subdivided into incremental lengths, and the superheat and saturated heat transfer correlations are applied.

d) In the condensing region of the ice bed, Equation (C-26) is applied until the flow temperature is equal to the outlet plenum temperature. Explain why the outlet plenum temperature is used as a cutoff point for the saturated heat transfer correlation rather than some fixed temperature.

e) The film coefficient correlation for heat transfer to the ice, Equation (C-1), was developed based on ice bed inlet conditions typical of design basis accidents, i.e., relatively low flow velocities and saturated to slightly superheated vapor qualities. Inlet velocities and degree of superheat resulting from a postulated lower compartment burn will be significantly higher than for the design basis accidents. Justify the use of the correlation under hydrogen burn conditions.

f) Specify the parameter dimensions, condensate length, and flow area assumed in Equation (C-1). Also provide some typical calculated values for the film coefficient in the superheated and condensing regions.

g) Discuss the basic differences between the CLASIX treatment of the ice bed heat transfer and the treatments used in other ice condenser codes such as LOTIC and TMD. Describe the method of handling the heat and mass transport under superheated and saturated conditions in each code.

Response to Question 8:

A response to Question 8 will be submitted on or before January 15, 1984.

Question 9:

Regarding the ice condenser melt water:

a) Discuss the heat transfer analyses and assumptions used to determine the melt water temperature on exit from the ice condenser. Provide approximate values of the melt water temperature for CLASIX analyses.

b) In the CLASIX description it is not clear whether ice melt water is transferred to the sump or assumed to remain at the ice node. Describe the melt water treatment and sump model used in CLASIX, especially with regard to how the lower compartment volume is adjusted due to the addition of water from melted ice and containment sprays.

c) Describe the effect of reduced lower compartment volume (due to added water) on containment pressure and temperature response.

Response to Questions 9(a) through 9(c):

A response to Questions 9(a) through 9(c) was provided in Attachment 2 to Reference (2.2).

Question 10:

With regard to the CLASIX spray model:

a) The mass, momentum, and energy transfer accounting seems to be incomplete. For example, the equations should account for the simultaneous occurrence of either vaporization or condensation with or without a change in the spray drop temperature. Please verify the CLASIX spray model by comparison with a spray model that includes a more thorough accounting for the mass, energy, and momentum transfers, such as the model developed by G. Minner (Reference (2.3)).

b) The assumption that the spray drops will desuperheat completely from the drop initial temperature to the saturation temperature corresponding to the total pressure results in a certain fraction of the drop mass immediately "flashing" to the atmosphere. It is possible that liquid drops can sustain superheats as much as 8°C, which will reduce the fraction of mass transferred by "flashing." Justify the CLASIX assumption and describe what effect a sustained superheat would have on reported results.

c) Heat and mass transfer during droplet fall is characterized as occurring in two regimes -- sensible heating at constant drop volume, and vaporization at constant drop temperature (with excess heat removal). Describe how the times at which each of these mechanisms occur, t_1 and t_2 respectively, are defined in the computations.

d) Please indicate whether the droplet velocity used in CLASIX is user-specified or calculated internally based on the input droplet diameter. Specify the velocity values used/calculated in the spray verification runs. Also, specify the input values for the spray film coefficient.

Response to Question 10(a):

A response to Question 10(a) will be submitted on or before January 15, 1984.

Response to Questions 10(b) through 10(d):

A response to Questions 10(b) through 10(d) was previously provided in the Attachment to Reference (2.1).

Question 11:

In the evaluation of the effect of a separate spray time domain, it is stated that: 1) the CLASIX spray model always predicts conservatively high containment pressure and temperature responses; and 2) the difference in the heat removal calculated using the CLASIX spray subroutine and the finite difference subroutine approaches zero as the transient progresses. In light of this,

a) Discuss why the CLASIX spray model underpredicts heat removal as the first statement implies. Holding compartment ambient conditions constant on an increasing temperature ramp would seem to support this. However, if ambient temperature would expose droplets to higher temperatures on the average, resulting in greater CLASIX spray heat removal. Provide additional comparisons of the rates of heat removal for the two models assuming increasing containment ambient conditions, decreasing ambient conditions, and postulated hydrogen burn conditions; i.e., a rapid ambient temperature increase followed by a gradual temperature decrease.

b) With regard to the second statement, describe the effect that non-linearities in heat transfer/thermodynamic processes have on the agreement between the two models.

Response to Question 11:

A response to Question 11 will be submitted on or before January 15, 1984.

Question 12:

Regarding the temperature and pressure responses (Figures D-1 and D-2) presented in the spray comparison, discuss the reason for the sudden change in slope between 120 and 125 seconds.

Response to Question 12:

The change in slope is due to changing heat and mass transfer regimes induced by going from superheated to saturated conditions in the spray compartment.

Question 13:

In the CLASIX-TMD comparison presented in Appendix A, the response of an ice condenser plant is modelled using both TMD and CLASIX. However, the input parameters for TMD (Tables A-1 and A-2) and CLASIX (Tables A-3 and A-4) do not seem analogous in several respects, and do not accurately represent Westinghouse ice condenser design. Specifically:

a) The upper compartment volumes used in the two analyses are not in agreement, presumably due to typographical error in the CLASIX value (Table A-3). Even so, the value of 698,000 ft^3

used in the analyses actually represent the sum of the upper compartment (651,000 ft^3) and upper plenum (47,000 ft^3) volumes. The upper compartment volume should not include a contribution from the upper plenum since the latter is represented as a separate node in both analyses.

b) In TMD the ice is distributed in the three ice bed compartments and the upper plenum (total volume ≈ 88,499 ft^3), while in CLASIX all the ice is assigned to the single ice bed node (volume ≈ 36,830 ft^3) and no ice is present in the upper plenum.

c) The lower plenum volume in TMD is 22,100 ft^3 versus 36,830 ft^3 in CLASIX. Equivalent volumes would seem to be more appropriate.

d) In TMD a loss coefficient of 0.5 is specified for each of the ice bed and plenum flow paths (paths 1 through 5 in Figure A2). To be consistent with the CLASIX analysis, TMD loss coefficients should be approximately 0.1 for paths 2 through 5 and 2.0 for path 6.

Discuss the aforementioned differences in the TMD and CLASIX input parameters, and verify the TMD-CLASIX comparison via revised analyses as appropriate.

Response to Question 13:

A response to Questions 13(a) through 13(d) was previously provided in the Attachment to Reference (2.1).

Question 14:

For the CLASIX-COCOCLASS9 comparison:

a) Explain why a transient hydrogen burn case wasn't considered in addition to the single burn case analyzed.

b) Specify the surface film coefficient assumed in cases 2 and 5 of this comparison, and discuss whether or not this value would account for pre-burn pressures and temperatures in cases 2 and 5 being less than in cases 3 and 6, respectively.

Response to Question 14(a):

The COCOCLASS9 code does not have the capability to model the addition of hydrogen during a burn. This limitation of the COCOCLASS9 code precludes the analysis of a transient hydrogen burn case.

Response to Question 14(b):

The pre-burn pressures and temperatures for CLASIX-COCOCLASS9 comparison cases 2 and 5 are less than cases 3 and 6 due to the wall surface film coefficient used. The smaller film coefficient used in

cases 3 and 6 allows for less energy removal from the atmosphere, resulting in higher pressures and temperatures. The film coefficient used in cases 2 and 5 was 5 Btu/hr-ft^2-^{o}F.

Question 15:

With regard to the comparison of CLASIX results with test measured results (Appendix C):

a) Complex burn-control parameter adjustments were required to predict conservatively the peak pressure for tests that had (1) a single non-uniform burn (CLASIX Case 10), and (2) multiple burns (Fenwal Case 2-2-2 Transient).

   i) Describe the burn-control parameter adjustments made for these cases;

   ii) Discuss the corresponding parameter adjustment procedure that would be used to perform an analysis for a nuclear power plant containment that has non-uniform or multiple burns; and

   iii) Provide results of CLASIX predictions for these two cases under a best estimate single set of burn parameters applied over the entire burn event. Compare the pressure trace to that obtained from (1) the "revised" CLASIX model; and (2) the actual test results.

b) Sensitivity studies with CLASIX are cited in Appendix C but few test results are provided. Please provide more details, specifically, the ranges over which the parameters were varied, and the results for the bounding cases.

Response to Question 15(a):

Hydrogen burns are modelled by CLASIX as single, uniform burns. The characteristics of the burn are established by user input and the containment conditions at the start of the burn, and are held constant for the duration of the burn. Because burning is assumed to initiate at conservatively high hydrogen concentrations and proceed at conservatively high burn rates, the total energy deposited in a volume by a burn and the rate at which this energy is deposited should result in conservatively high containment temperature and pressure responses.

Any burn which exhibits characteristics inconsistent with the conservative CLASIX burn assumptions is extremely difficult to model. However, utilizing the CLASIX restart capability and adjustment of the burn control parameters should enable a user to correctly simulate any hydrogen burn.

In the Fenwal case cited burning was not uniform in the test vessel, but rather occurred in three distinct "regions" with three different sets of burn parameters. Though the underlying assumptions in CLASIX are not applicable to this case, an attempt was made to model the

non-uniform burn by using the CLASIX code restart capability. The problem was stopped and restarted for each distinct region, and the burn parameters were adjusted to reproduce the pressure ramps seen in the test. At the end of the analysis the total volume percent of hydrogen predicted to remain in the vessel was compared to that measured at the end of the test. It took several tries before a good match of analysis and measured response could be achieved.

Response to Question 15(b):

Fenwal test results were previously provided in a report entitled "Report of the Safety Evaluation of the Interim Distributed Ignition System," submitted by the Tennessee Valley Authority (TVA). Sensitivity studies of the wall parameters used in CLASIX were performed to determine the overall impact on compartment conditions. The bounding values of the parameters with accompanying results for CLASIX Case 7 (Fenwal Test 6) have previously been provided by TVA in response to this question.

Question 16:

Justify that mass and energy are conserved by CLASIX for a large problem time and for the problem time steps used. Describe quantitatively the time steps and their variation during a typical problem.

Response to Question 16:

Mass and energy were not strictly conserved by the version of CLASIX used in performing the Donald C. Cook Nuclear Plant hydrogen control containment analyses. In particular, since the version of CLASIX utilized did not allow for modelling of recirculation flow from the sump, mass removed to the sump left the analysis and did not return to containment. Decreases in lower compartment volume due to increased sump mass were, however, correctly modelled, although energy and mass transfer interactions between the sump and the lower volume were not provided for.

Transfers of mass and energy in CLASIX are handled explicitly as in other large computer codes. Such explicit methods conserve mass and energy when sufficiently small time steps are used. A sufficiently small time step may be defined as a time step which ensures that changes in mass and energy transfer rates are sufficiently invariant to prevent the introduction of calculational instabilities. The CLASIX analyses performed to date for the Donald C. Cook Nuclear Plant have utilized a time step of 0.01 second. This time step size has been kept constant throughout the accident analyses.

References, Attachment 2:

(2.1) "Hydrogen Control - Partial Response To Mr. S. A. Varga's Letter Of July 30, 1982," Letter No. AEP:NRC:0500J, Mr. R. S. Hunter (Indiana & Michigan Electric Company) to Mr. H. R. Denton (NRC), dated October 15, 1982.

(2.2) "Report Of Coding Errors In CLASIX Computer Code; Revision To AEP:NRC:0500J Response Item 9," Letter No. AEP:NRC:0500L, Mr. R. S. Hunter (Indiana & Michigan Electric Company) to Mr. H. R. Denton (NRC), dated December 17, 1982.

(2.3) G. L. Minner, "Reactor Containment Spray Calculation," Thermal Reactor Safety CONF-770708 (July 1977), Vol. 1, pp. 569-582.

ATTACHMENT 3 TO AEP:NRC:0500K

RESPONSES TO QUESTIONS ON HYDROGEN CONTROL CONTAINED IN

MR. S. A. VARGA'S 16 SEPTEMBER 1982 LETTER

DONALD C. COOK NUCLEAR PLANT UNIT NOS. 1 AND 2

Question 1:

A substantial number of laboratory tests were conducted as part of the ICOG/EPRI R&D program for hydrogen control and combustion. Test results were transmitted from the utilities to NRC as they became available; however, for several of the research programs, only selected test results were reported and organized compilations of all pertinent test information were not provided. This information is required to confirm the adequacy of the test program and assumptions made in the containment analyses. In this regard provide the following:

a) ACUREX

i) a table of droplet size and droplet density estimates for each of the fog/spray tests;

ii) a table of estimated flame speed for each test (flame speed should be calculable from thermocouple locations and ignition time data); and

iii) pressure and temperature traces similar to those depicted in Figures 4-2 of the December 1981 ACUREX Project Report, but for tests 2.10, 2.11, and 2.12;

b) FACTORY MUTUAL

results of ignition tests in which a glow plug was used in place of the ignition electrodes;

c) WHITESHELL

tables summarizing pre- and post-burn conditions, igniter locations, maximum measured pressure rise, adiabatic pressure rise, completeness of burn, and estimated flame speed. These tables should be keyed to and cover all of the tests committed to in the test matrix (tables 1-4 in Appendix A.1 of the fourth quarterly report on the TVA research program, June 16, 1981) plus any additional AECL tests conducted under this program. Of particular interest to the staff are the results of the 8.5% H_2 test with 30% H_2O and top ignition. Discuss your plans for conducting tests at steam concentrations above 30%, as committed to in previous quarterly reports;

d) HEDL

figures depicting concentration gradients for each of the tests. Figures provided should permit better resolution than those included in the previous submittal.

Response to Question 1(a)(i):

The Acurex test vessel was not instrumented to obtain data on either droplet size or droplet density during the fog/spray tests. It is noted, however, that the Acurex Phase 1 test series utilized a single

Sprayco 1713 spray nozzle with a 15 gallons per minute (gpm) flow rate, whereas the Phase 2 tests utilized a manifold of nine Sprayco 2163-7604 pinjet nozzles. Depending upon the pressure drop across the nozzles, the total flow rate for the Phase 2 tests varied between 1.1 gpm and 1.4 gpm.

As previously stated in Appendix A.4 to Reference (3.1), vendor supplied information indicates that the number mean droplet diameter for a Sprayco 1713 nozzle is approximately 200 μ at a 15 gpm flow rate. Furthermore, an estimate of fog droplet size may be made for the Sprayco 2163-7604 pinjet nozzles, based upon work performed by Factory Mutual Research Corporation (FMRC). More specifically, FMRC test data presented in Appendix A.5 to Reference (3.1) indicates that the number mean droplet diameter for a single Sprayco 2163-7604 pinjet nozzle is on the order of 9-11 μ.

It should be noted, however, that substantial error may exist in any estimation of Acurex test conditions from either vendor information or FMRC test data. In particular, impingement of spray cones upon each other or upon test apparatus could lead to droplet breakup and/or coalescence, thereby affecting droplet diameters.

Response to Question 1(a)(ii):

The Acurex test vessel was not instrumented to measure localized flame speeds. Estimates of average global flame speeds have, however, been made from Acurex pressure rise data.

As previously explained in Section 7 of Reference (3.2), average flame speeds were determined by assuming that the flame front propagated through the test vessel in the shape of a disk. The base of a pressure spike represented ignition, whereas the pressure peak represented quenching of the flame. This approach was considered valid only for tests where discrete burns were observed and propagated throughout the entire vessel.

For seven such tests, calculated average flame speeds varied between 0.8 and 8.2 feet per second (fps). (See Section 7 of Reference (3.2) for the calculated results from these seven tests.) These values compare favorably with the flame speeds used in containment analyses (on the order of 6 fps for base case runs).

Response to Question 1(a)(iii):

The requested pressure and temperature versus time profiles for Acurex tests 2.10, 2.11, and 2.12 are presented in Figures 3-1 through 3-6.

Response to Question 1(b):

Results of FMRC ignition tests are provided in Tables 3-1 through 3-3. For each test, glow plug or spark ignition is identified in these Tables.

Response to Question 1(c):

Summary tables of AECL-Whiteshell combustion phenomena tests are provided in Tables 3-4 through 3-6. Adiabatic pressure rises were not calculated and the flame speeds were not measured. However, the pressure rise time, t_{max}, was measured and is included in the Tables. The pressure rise time is a parameter of importance in estimating the speed at which a combustion event occurs. It is noted that some tests were altered from the original test matrix listed in Reference (3.3) as the research progressed (e.g., Series 2 tests were revised to include tests at 40 and 50 volume percent steam).

The omission of the test at 8.5% H_2, 30% H_2O, top ignition was inadvertent. Five additional tests at low hydrogen concentrations have been conducted by AECL-Whiteshell. All tests were quiescent with the ignition source located at the top of the test vessel. The test results were as follows:

Hydrogen Concentration (v/o)	Steam Concentration (v/o)	ΔP (psi)
8.5	15	0
9.0	15	0.5
9.0	30	0
9.5	30	19.5
8.5	15	23.0

It should be noted that the last test listed above was conducted with fans operating. This test is more representative of dynamic post-accident conditions than the other four tests.

With regard to conducting tests at steam concentrations in excess of 30%, please note that Table 3-5 identifies two tests conducted at higher steam concentrations. In particular, one test was conducted at 40% H_2O while the other was conducted at 50% H_2O. In addition, we note that numerous tests, including several with high steam concentrations in lean hydrogen mixtures, were conducted as part of the AECL-Whiteshell small vessel igniter performance tests.

Response to Question 1(d):

Figures 3-7 and 3-8 provide the maximum hydrogen (helium) concentration gradients for the Hanford tests.

Question 2:

The majority of the ICOG/EPRI tests which serve to demonstrate the validity of the deliberate ignition concept utilized a GMAC glow plug as the ignition source. TVA currently intends to install 120 V TAYCO igniters in the Permanent Hydrogen Mitigation System instead of the glow plugs. Although igniter durability tests have been completed by Singleton, additional testing of the 120 V igniter is required to show that it is an acceptable replacement for the GMAC igniter. Specifically,

a) tests should be conducted to ensure that the igniter will continue to operate as intended in a spray atmosphere typical of that which would be expected in each region of containment where igniters are to be located;

b) endurance tests should be conducted on a suitable sample size to assure adequacy and consistency of igniter surface temperature and lifetime.

Response to Questions 2(a) and 2(b):

There is no intention at the present time to attempt replacement of the GMAC glow plugs installed at the Donald C. Cook Nuclear Plant Unit Nos. 1 and 2 with a 120 V TAYCO igniter system. Therefore, this question is inapplicable to the Donald C. Cook Nuclear Plant.

Question 3:

For the 120 V igniter system, describe the following:

a) performance characteristics of the igniters including surface temperature as a function of voltage and age;

b) a comparison of surface area, power density, and other relevant parameters for the original and currently proposed igniters;

c) igniter mounting provisions;

d) proposed preoperational and surveillance testing. If surveillance testing will be based on comparisons of measured voltage/current to preoperational values, specify the range for acceptance;

e) power distribution system for the igniters, in particular, the location of the breakers in the system and the number of igniters on a breaker.

Response to Questions 3(a) through 3(e):

There is no intention at the present time to attempt replacement of the GMAC glow plugs installed at the Donald C. Cook Nuclear Plant Unit Nos. 1 and 2 with a 120 V TAYCO igniter system. Therefore, this question is inapplicable to the Donald C. Cook Nuclear Plant.

Question 4:

Provide details regarding the number and location of permanent igniters in containment. Discuss the influence of considerations such as volume served per igniter, and preferred flame direction on the design of the permanent system.

Response to Question 4:

Table 3-7 provides a listing of GMAC glow plug locations in the Donald C. Cook Nuclear Plant Unit No. 2. These locations are typical for Unit No. 1. Figure 3-9 provides an overview of the Donald C. Cook Nuclear Plant ice condenser containment. Sectional drawings of the containment are also included as Figures 3-10 through 3-12, and identify the relative locations of the Train "A" and Train "B" igniters at each elevation.

At the present time, there are seventy GMAC glow plugs in each Unit of the Donald C. Cook Nuclear Plant (thirty-five igniters per train). Basic considerations in the design of the permanent hydrogen control system (Distributed Ignition System (DIS)) included coverage of likely hydrogen release points, coverage of areas of potential hydrogen accumulation, and proximity to safety related components. The reasons for installation of igniters in the Instrument Room have previously been reported in Attachment 1 to Reference (3.4). The volume served per igniter has not been a relevant consideration for the Donald C. Cook Nuclear Plant DIS design.

Question 5:

Recent tests conducted at McGill indicate that flame accelerations accompanied by large pressure increases, and detonations can occur at hydrogen concentrations as low as 13%. Although remote, the possibility of flame accelerations and local detonations occurring around obstacles and in confined regions of containment cannot be entirely dismissed. Further analysis of the probability and consequences of these events are thus warranted. In this regard:

a) Discuss the chain of events and conditions required to cause flame accelerations and detonations in containment, and the probability that such conditions might exist. Identify the locations in containment at which flame acceleration/detonation would most likely occur.

b) Provide quantitative estimates of the extent and magnitude of flame acceleration in containment and the resulting pressure increase and loads on structures and equipment.

c) Provide the results of a calculation (pressure versus time curve) for the largest conceivable local detonation which could occur in your containment. Demonstrate that the effects of such a detonation could be safely accommodated by structures and essential equipment. Also, provide an estimate of the limiting size of a cloud of detonable gas with regard to the structural capability of the containment shell.

Response to Question 5:

The results of tests conducted at McGill do not warrant further work on local detonation in the Donald C. Cook Nuclear Plant

containment. In particular, a review of References (3.5) through (3.8) indicates that:

- The critical tube diameter for detonation of hydrogen concentrations of 13 volume percent is greater than 10 meters; and,

- Approximately 50 kilograms (kg) of high explosive (i.e., tetryl, which releases about 4,270 Joules per gram) would be required to initiate a hydrogen-air detonation at about 13 volume percent hydrogen.

Since all "confined" areas within the Donald C. Cook Nuclear Plant are smaller in diameter than 10 meters and because such a high energy source is not present within containment, no further work need be done on hydrogen detonations in the Donald C. Cook Nuclear Plant at the present time.

Question 6:

The analysis provided to date concerning the survivability of air return fans and hydrogen skimmer fans neglects any overspeed or motoring which occurs as a result of postulated hydrogen combustion in the upper plenum and upper compartment. Describe how the fans will react to the differential pressure associated with hydrogen combustion, and justify the assumptions concerning fan overspeed. Describe the effects of combustion in the lower compartment, e.g., fan stalling.

Response to Question 6:

A schedule for response to this question will be determined in the near future. This response will take into account Question 2 contained in Mr. S. A. Varga's August 10, 1983, letter to Mr. J. Dolan (Indiana & Michigan Electric Company).

Question 7:

With regard to the equipment survivability analysis, the level of conservatism implicit in the temperature forcing functions developed for the lower containment and the upper plenum is not apparent and quantifiable. Additional analyses should be conducted to provide a baseline or "best estimate" of equipment response, and to ensure that temperature curves assumed in the analyses embody all uncertainties in the accident sequence and combustion parameters. Accordingly, provide analyses of equipment temperature response to:

a) the base case transient assumed in the containment analyses;

b) the containment transients resulting from a spectrum of accident scenarios; and

c) the containment transients resulting under different assumed values for flame speed and ignition criteria for the worst

case accident sequence. The range of these combustion parameters assumed for the equipment survivability analyses should include but not necessarily be limited to the values assumed in the containment sensitivity studies, i.e., 1 - 12 ft/sec flame speed and 6 - 10% hydrogen for ignition.

Response to Question 7:

A response to this question will be submitted on or before January 15, 1984.

Question 8:

For the survivability analysis, it is our understanding that the current thermal model assumes radiation from the flame to the object only during a burn, with convection occurring at all times outside the burn period. In an actual burn, radiation from the cloud of hot gases following the flame front can account for a substantial portion of the total heat transfer to the object. An additional heat flux term or a combined radiation-convection heat transfer coefficient should be used to account for this radiant heat source. In this regard, clarify the treatment of heat transfer following the burn and justify the approach taken.

Response to Question 8:

A response to this question will be submitted on or before January 15, 1984.

Question 9:

HEDL containment mixing tests conducted as part of the ICOG/EPRI R&D program indicate that spatial hydrogen concentration gradients of as much as 2 to 7% can be expected to exist within containment at a given time. If such a gradient were to exist within the volume of a hydrogen cloud in which combustion has just been initiated, the volume-average hydrogen concentration for the cloud can conceivably be significantly higher than the hydrogen concentration at the point of ignition. In light of this, discuss the influence of hydrogen concentration gradients on the concentration requirement for ignition that is input to CLASIX, and justify the ignition concentration value used in the CLASIX containment analyses.

Response to Question 9:

The spatial hydrogen concentration gradients determined during the HEDL containment mixing tests are presented in Figures 3-7 and 3-8.

We note that HEDL research staff have concluded that the peak concentration differences of 7.5 and 3.8 volume percent helium measured after termination of the helium source in tests HM-2 and HM-1A, respectively, were not typical of ice condenser plant postulated accident conditions (see Reference (3.9)). During the period immediately following termination of the helium-steam source in those

two experiments, the temperature of the test (i.e., lower) compartment decreased and steam in that compartment condensed. The resultant test compartment pressure decrease led to a reversed gas flow situation which, coupled with a lack of a mixing mechanism from either the air return fans or the source jet itself, created an abnormally high helium (hydrogen) concentration gradient.

It is concluded that the reverse flow situation is not prototypic of ice condenser plant postulated accident conditions, since the ice condenser is provided with lower inlet doors which would simply close once the lower compartment pressure is less than the upper compartment pressure.

Furthermore, we concur with the HEDL research staff conclusions presented in Reference (3.9). In particular, we believe that concentration gradients on the order of less than 3.0 volume percent hydrogen may exist in containment during the gas release period. Following the gas release phase, however, forced and natural convection should very quickly lead to an even more uniform gas concentration.

It is thus concluded that the volume-average hydrogen concentration for a combustible containment compartment atmosphere would not be significantly higher than the hydrogen concentration at the point of ignition, due to the number and location of igniters within each containment region. It should also be noted that the three ice condenser utilities have performed sensitivity studies of containment response to the hydrogen lower ignition limit with the CLASIX computer code. The existence of hydrogen concentration gradients of the magnitude discussed herein (i.e., less than about 3.0 volume percent) would not be expected to yield a pressure or temperature response not already bounded by these previous sensitivity studies.

Question 10:

Describe in detail the fog formation study cited in response to question 9 of the July 21, 1981, Request for Information. Include in this description the analytical development of the models for fog formation and removal, methods for solution, assumptions, and input parameters. Provide plots of fog concentration and size as a function of time assuming various spray removal efficiencies, and mean droplet diameters.

Response to Question 10:

Reference (3.10) contains the requested information. A copy of this Reference is provided in Attachment 4 to this submittal.

Question 11:

Describe in detail the analyses of fog effects on hydrogen combustion cited in response to question 9 of the July 21, 1981, Request for Information. Include in this description the analytical development of the combustion kinetics and heat transfer models, and quantitative comparisons between the theoretical results and data obtained from the

Factory Mutual tests. Provide plots of fog droplet size and concentrations required to inert at various hydrogen concentrations under typical post-LOCA containment conditions.

Response to Question 11:

Reference (3.11) contains the requested information. A copy of this Reference is provided in Attachment 5 to this submittal.

Question 12:

In the CLASIX spray model it is not clear whether the mass of spray treated in a time increment is assumed to be only that amount of spray mass which is introduced in a single time step, or the mass of droplet accumulated in the atmosphere over the fall time period. Clarify the spray mass accounting used in CLASIX and the mass of spray treated in a single time step. Discuss the significance of any errors introduced by the apparent assumption that only one time increment of spray mass is exposed to the containment atmosphere during a single time step.

Response to Question 12:

A response to Question 12 will be submitted on or before January 15, 1984.

Question 13:

CLASIX spray model analyses provided to date have been limited to the comparison of pressure, temperature, and integrated heat removal for the purpose of evaluating the effect of the spray operating in a separate time domain. Additional information is needed, however, to confirm the adequacy of the heat and mass transfer relationships and assumptions implicit in the CLASIX spray model, especially in treating a compartment in which hydrogen combustion is taking place. In this regard:

a) Provide a quantitative description of the spray heat and mass transfer under containment conditions typical of a hydrogen burn. Include in your response plots of containment temperature, spray heat transfer, spray mass evaporation, and suspended water mass as a function of time for both the CLASIX spray model and a model in which the spray mass is tracked throughout the fall (and allowed to accumulate in the containment atmosphere).

b) Provide analyses of spray mass evaporation and pressure suppression effects for an upper compartment burn.

c) Justify the drop film coefficient value assumed in the spray model analyses (20 Btu/hr-ft^2-^{o}F) and discuss the effect of using a constant value throughout a burn transient.

Response to Question 13:

A response to Question 13 will be submitted on or before January 15, 1984.

Question 14:

Concerning the CLASIX containment response analyses:

a) Justify the burn time and burn propagation delay times used (reported burn times for Sequoyah and McGuire differ by a factor of 2 to 3);

b) Justify the radiant heat transfer beam lengths used (a beam length of 59 ft. for the lower compartment in Sequoyah seems high - 20 to 30 ft. may be more appropriate);

c) The base case and majority of S_2D sensitivity studies assume that combustion occurs at an 8% hydrogen concentration with an 85% completeness of burn. Available combustion data for hydrogen/dry air mixtures indicate that lean mixtures of approximately 8% H_2 and below are prevented from reacting completely and adiabatically due to buoyancy, diffusion and heat loss effects. Only as hydrogen concentration is increased to about 8.5% will the reaction begin to approach adiabaticity. While arguments for an 8% ignition concentration may be valid, provide the results of additional CLASIX analyses to indicate the effect of an increase in ignition concentration from 8% to 8.5-9%.

d) Provide the results of CLASIX analyses for flame speeds of 10 and 100 times the present value;

e) To assess the effect of igniter system failure or ineffectiveness, provide the results of sensitivity studies in which the lower and dead-ended compartments are effectively inerted, and the upper plenum igniters burn with low efficiency or not at all. Assume combustion in the upper compartment at 9-10% hydrogen.

Response to Question 14(a):

A discussion of burn time values used in CLASIX was previously provided in the Attachment to Reference (3.12). Burn propagation delay times are of no consequence in the Donald C. Cook Nuclear Plant CLASIX containment analyses (see "Response to Question 4(b)," Attachment 2).

Response to Question 14(b):

The CLASIX analyses submitted via Reference (3.13) utilized a lower compartment effective beam length of 25 feet for the Donald C. Cook Nuclear Plant.

Response to Question 14(c):

The purpose of providing results of CLASIX analyses which utilized ignition criteria of 6, 8, and 10 volume percent hydrogen was to preclude the running of a multitude of cases at slightly varied ignition criteria. These analyses are believed to be sufficient to evaluate igniter performance. Furthermore, results for an 8.5% H_2, 100% burn completeness case have previously been submitted for the McGuire Nuclear Plant by Duke Power Company. The results for that case indicate that there is no substantial difference between 8 and 8.5% H_2 ignition criteria.

Response to Question 14(d):

A response to this question will be submitted on or before January 15, 1984.

Response to Question 14(e):

A response to this question will be submitted on or before January 15, 1984.

References, Attachment 3:

(3.1) "Tennessee Valley Authority, Sequoyah Nuclear Plant, Research Program On Hydrogen Combustion And Control, Quarterly Progress Report #5, January 15, 1982," transmitted via letter dated January 22, 1982, L. M. Mills (TVA) to E. Adensam (NRC).

(3.2) "An Analysis Of Hydrogen Control Measures At McGuire Nuclear Station," Revision 5, transmitted via letter dated November 5, 1982, H. B. Tucker (Duke Power Company) to E. Adensam (NRC).

(3.3) "Tennessee Valley Authority, Sequoyah Nuclear Plant, Research Program On Hydrogen Combustion And Control, Quarterly Progress Report #4, September 16, 1981."

(3.4) "Hydrogen Mitigation And Control Studies," Letter No. AEP:NRC:0500E, dated July 2, 1981, R. S. Hunter (Indiana & Michigan Electric Company) to H. R. Denton (NRC).

(3.5) Lee, J. H. S., R. Knystautas, and C. Guirao, "The Link Between Cell Size, Critical Tube Diameter, Initiation Energy And Detonability Limits," Fuel-Air Explosions, University of Waterloo Press (1982), pp. 157-187.

(3.6) Lee, J. H. S., "Explosion Research Of The Shock Wave Physics Group At McGill," Fuel-Air Explosions, University of Waterloo Press (1982), pp. 753-770.

(3.7) Dabora, E. K., "The Relation Between Energy And Power For Direct Initiation Of Hydrogen-Air Detonations," paper presented at the Second International Workshop on the Impact of Hydrogen on Water Reactor Safety, Albuquerque, New Mexico, October 3-7, 1982.

(3.8) Lee, J. H. S., R. Knystautas, C. Guirao, W. B. Benedick, and J. E. Shepherd, "Hydrogen-Air Detonations," paper presented at the Second International Workshop on the Impact of Hydrogen on Water Reactor Safety, Albuquerque, New Mexico, October 3-7, 1982.

(3.9) Bloom, G. R., L. D. Muhlestein, A. K. Postma, and S. W. Claybrook, "Hydrogen Distribution In A Containment With A High Velocity Hydrogen-Steam Source," paper presented at the Second International Workshop on the Impact of Hydrogen on Water Reactor Safety, Albuquerque, New Mexico, October 3-7, 1982.

(3.10) Tsai, S. S., "Fog Inerting Analysis For PWR Ice Condenser Plants," November 1981.

(3.11) Tsai, S. S., and N. J. Liparulo, "Fog Inerting Criteria For Hydrogen/Air Mixtures," paper presented at the Second International Workshop on the Impact of Hydrogen on Water Reactor Safety, Albuquerque, New Mexico, October 3-7, 1982.

(3.12) "Hydrogen Control - Partial Response To Mr. S. A. Varga's Letter Of July 30, 1982," Letter No. AEP:NRC:0500J, dated October 15, 1982, R. S. Hunter (Indiana & Michigan Electric Company) to H. R. Denton (NRC).

(3.13) "Hydrogen Mitigation And Control Studies," Letter No. AEP:NRC:0500H, dated September 30, 1982, R. S. Hunter (Indiana & Michigan Electric Company) to H. R. Denton (NRC).

Table 3-1

HYDROGEN-WATER FOG INERTING DATA AT 20°C

Nozzle	Pressure (psig)	Spray Angle (Full)	Drop Size Vol. Mean (Micron)	Drop Size No. Median (Micron)	Conc. $\frac{cm^3 H_2O}{cm^3 Mix}$	Igniter	Hydrogen LFL (vol %)
Spraco	10		111	9.8±	8.1×10^{-4}	Spark	4.42 ± 0.11
2163-7604	20	>60°	54.5	4.7±	3.8×10^{-4}	Spark	4.76 ± 0.31
~60°	25		44.1	3.8±	2.7×10^{-4}	Spark	4.76 ± 0.3
	30	~60°	20.6	1.5±	2.8×10^{-4}	Spark	4.72 ± 0.21
	30	~60°	20.6	1.5±	2.8×10^{-4}	Glow Plug	5.0 ± 0.24
Spraco	10	61°	139	13±	3.6×10^{-3}	Spark	4.64 ± 0.12
[illegible]0-1704	20		86.2	6.8±	8.5×10^{-4}	Spark	4.76 ± 0.31
	25		58.4	4.8±	2.9×10^{-4}	Spark	4.76 ± 0.31
	30	80°	35.7	5.6±	1.5×10^{-4}	Spark	5.26 ± 0.19
Spraco	10		136	13±	9.4×10^{-5}	Spark	4.40 ± 0.10
1806-1605	20		59.3	5±	6.0×10^{-5}	Spark	4.76 ± 0.31
	25		66	4±	5.7×10^{-4}	Spark	4.76 ± 0.31
	30	~40°	47.8	6.4±	3.2×10^{-4}	Spark	4.65 ± 0.34
Spraco	10		136	14±	4.5×10^{-3}	Spark	4.64 ± 0.12
1405-0604	20		110	10±	2.2×10^{-2}	Spark	4.76 ± 0.31
(20-30°)	25		114	11±	2.7×10^{-2}	Spark	4.76 ± 0.31
	30	20°	115	14±	3.3×10^{-2}	Spark	5.26 ± 0.19
S[illegible]re 03514	20		–	5	1.1×10^{-3}	Spark	7.2 ± 0.22

Table 3-2

HYDROGEN-WATER FOG INERTING DATA AT 50°C

Nozzle	Pressure (psi)	Drop Size Vol. Mean (Micron)	Drop Size No. Median (Micron)	Conc. $\frac{cm^3 H_2O}{cm^3 Mix}$	Igniter	Hydrogen LFL (vol %)
Spraco	40	33.1	5.2±	1.4×10^{-4}	Spark	7.19 ± 0.22
2163-7604	30	21.4	4.2±	8.1×10^{-5}	Spark	5.55 ± 0.11
	20	34.5	4.5±	1.9×10^{-4}	Spark	5.55 ± 0.11
Spraco	40	24.5	3.8±	9.3×10^{-5}	Spark	7.19 ± 0.22
2020-1704	30	27.1	4.2±	1.1×10^{-4}	Spark	7.19 ± 0.22
	20	50.3	6.2±	4.0×10^{-4}	Spark	6.32 ± 0.22
Spraco	10	-	-	-	Glow Plug	4.98 ± 0.22
1806-1605	20	43.2	-	9.7×10^{-5}	Glow Plug	5.22 ± 0.42
	30	15.2	-	1.6×10^{-5}	Glow Plug	5.44 ± 0.22
	40	11.2	3±	1.9×10^{-5}	Glow Plug	5.18 ± 0.42
	40	11.2	3±	1.9×10^{-5}	Spark	5.35 ± 0.42
Spraco	40	87.8	9.6±	3.2×10^{-2}	Spark	5.55 ± 0.11
1405-0604	30	91.8	11.5±	2.0×10^{-2}	Spark	5.55 ± 0.11
	25	115	14±	1.7×10^{-2}	Spark	5.55 ± 0.11
Sonicore	25	24	2.4±	1.1×10^{-3}	Spark	7.93 ± 0.23
035H	20	24.4	2.8±	1.1×10^{-3}	Spark	7.19 ± 0.22

Table 3-3

HYDROGEN-WATER FOG INERTING DATA AT ~70°C

Nozzle	Press. (psi)	Igniter	Hydrogen LFL (vol %)
Spraco	10	Glow Plug	6.76 ± 0.22
2163-7604	20	Glow Plug	7.18 ± 0.22
	30	Glow Plug	7.62 ± 0.22
	40	Glow Plug	8.46 ± 0.22
Spraco	10	Glow Plug	5.88 ± 0.21
1405-0604	20	Glow Plug	6.32 ± 0.21
	30	Glow Plug	7.62 ± 0.21
	40	Glow Plug	7.62 ± 0.21

Table 3-4

CTP EXPERIMENTAL SERIES I

Exp. No. CTP-	Hydrogen (%)	Steam (%)	Air (%)	Fan	ΔP_m kPa	t_{max} sec	Burn (%)
101	5	0	95	off	13	9.5	~ 20
102	5.5	0	94.5	off	24	6	~ 26
110	5	15	80	off	10	6.5	~ 20
111	5	15	80	off	8	7.0	~ 20
124 R	5	30	65	off	~ 7	7.0	~ 20
123	6.2	0	93.8	off	~.47	6.0	30
105	5.5	0	94.5	on	105	1.5	~ 83
106	7	0	93	off	125	7.0	~ 100
107	7	0	93	on	161	1.2	100
125	6	15	79	on	87	1.5	60
126	6	30	64	on	65	1.6	50
108	8	0	92	off	146	4.2	100
113	8	15	77	off	126	4.9	100
116	8	30	62	off	38	5.0	38
109	8	0	92	on	187	0.8	100
117 (CI)	7	0	93	off	110	11.4	100
118 (CI)	7	15	78	off	45	4.5	~ 0
118A (CI)	7	15	78	on	142	1.0	100
119 (CI)	10	0	90	on	215	0.53	100
120 (CI)	14	0	86	on	290(?)	0.4	100
CT 704 (TI)	11	0	89	on	225	0.6	100
CT 701 (TI)	8	0	92	on	180	0.9	100
CT 702 (TI).	8.5	0	91.5	off	157	3.2	100
CT 700 (TI)	7	0	93	on	145	1.1	100
CT 703 (TI)	5.7	0	94.3	on	75	1.9	~ 72
*CT 502	8.4	0	91.6	off	175	---	~ 100
*CT 501	10	0	90	off	260	---	~ 100
*CT 504	5	0	95	off	10	5.5	----
*TST 10	6	0	94	off	175	---	----
*TST 16	8.5	0	91.5	off	232	---	----
103	6	0	84	off	27	5	~ 23

Table 3-4 (continued)

•TST 13	7.5	0	92.5	off	20	---	----
•TST 11	5.5	0	94.5	off	19	---	----

NOTE: All experiments at 100°C

- Conducted at 28 ± 2°C

Initial pressure 98 kPa
Unless stated, all experiments are with bottom ignition

CI = central ignition
TI = top ignition

Table 3-5

CTF EXPERIMENTAL SERIES 2 & 3

Exp.No. CTF-	Hydrogen (%)	Steam (%)	Air (%)	Final H_2 (%)	ΔP_m kPa	t_{max} sec	Burn (%)
204	41.5	0.0	58.3	20.0*	403	0.07	56
230	41.6	0.0	58.4	19.7*	424	0.06	59
203	32.6	0.0	67.4	6.0*	452	0.06	84
222	36.5	0.0	63.5	13.0*	434	0.06	70
203A	31.0	0.0	69.0	2.4*	455	0.06	94
223	27.0	0.0	73.0	0.0	441	0.07	100
236	29.6	0.0	70.4	0.0	469	0.05	100
217	15.0	0.0	85.0	0.0	303	0.11	100
202C	20.0	0.0	80.0	0.0	390	-----	100
201R	10.0	0.0	90.0	0.0	215	0.87	100
233	36.4	20.0	43.6	20.0*	331	0.12	50
232	24.6	20.0	55.4	1.5*	369	0.12	93
219	25.0	20.0	55.0	2.2*	359	0.18	92
212	35.5	20.0	44.5	19.0*	338	0.13	52
231	29.5	0.0	70.5	0.0	462	0.05	100
205	11.0	10.0	79.0	0.0	216	0.72	100
237	30.0	10.0	60.0	5.5*	410	0.09	84
209	10.0	20.0	70.0	0.0	159	2.40	100
213B	10.0	30.0	60.0	0.0	148	3.20	100
219B	10.0	40.0	50.0	0.0	112	6.10	100
210	16.0	20.0	64.0	0.0	293	0.27	100
219C	10.0	50.0	40.0	10.0	0.0	----	0
207	27.0	10.0	63.0	0.7*	407	0.15	98
211	28.0	20.0	52.0	7.0*	365	0.13	78
229	21.0	30.0	49.0	0.5*	321	0.22	98
238	28.6	10.0	61.4	3.2*	407	0.07	90
220 (Bot Ign)	27.0	0.0	73.0	0.0	434	0.09	100
221	25.4	0.0	74.6	0.0	434	0.075	100
216A	30.4	30.0	39.6	15.0*	255	0.45	55

Table 3-5 (continued)

214	15.6	30.0	54.4	0.0	255	0.60	100
234	29.0	30.0	41.0	13.0*	283	0.24	59
235	31.0	0.0	69.0	2.0*	463	0.05	94
218 (Bot Ign)	20.0	0.0	80.0	0.0	386	0.14	100
226	22.2	30.0	47.7	2.5*	300	0.27	90
224	25.0	10.0	65.0	0.0	407	0.08	100
201R	10.0	0.0	90.0	0.0	210	0.80	100
207A (Fan)	27.0	10.0	63.0	0.5*	400	0.07	98
208	40.0	10.0	50.0	21.0*	345	0.11	53
310	20.0	0.0	80.0	0.0	359	0.09	100
308 (Fan)	7.0	0.0	93.0	0.0	145	1.50	100
306	6.0	0.0	94.0	3.0	55	5.50	51
309	15.0	0.0	85.0	0.0	283	0.24	100
307B (Bot Ign)	10.3	0.0	89.7	0.0	179	1.25	100
307A (Bot Ign)	11.5	0.0	87.9	0.0	186	1.00	100
307 (Bot Ign)	6.71	0.0	93.3	0.25	85	4.0	96

* Calculated

Initial temperature: 100 °C

Expt. 300 series is with gratings

Unless stated expt. are with central ignition

Initial pressure: 98 kPa

Table 3-6

CTF EXPERIMENTAL SERIES 4

CTF	H_2 (Pipe) (%)	H_2 (Sphere) (%)	ΔP_m (kPa)	Δt_m (sec).	Burn (%)
405 (EI)	10	10	248	6.75	100
402A (EI) Fan on	8	8	210	14.75	100
402A Fan off	8	8	10	16	~0
404 (EI) Fan on	6.5	6.5	115	23	70
404 (EI) Fan off	6.5	6.5	2	24	~0
401 (EI) Fan off	20	20	510	0.2	100
407A (CI) Fan off	8.5	8.5	165	14	100
409 (CI) Fan off	10	10	225	1.8	100
408 (CI) Fan off	20	20	500	0.15	100
410 (CI) Fan off	25	25	1300	.075	100
411 (EI) Constriction	10	10	260	5.5	100
412 (EI) Constriction	20	20	525	0.2	100
418 (EI) Burst Disk	12	6	105p, 135	1.1	~0
419 (EI) Burst Disk	15	6	115p, 115s	.35p, .85s	70
416 (EI) Burst Disk	15	10	120p, 325s	0.28p, .375s	100*
415 (EI) Burst Disk	15	20	120p, 525s	0.32p, .4s	100*

Table 3-6 (continued)

NOTE: 1. All experiments at 24 ± 2°C, 98 kPa

2. s = sphere; p = pipe

3. EI = pipe end ignition

CI = sphere central ignition

* = assumed

Table 3-7

IGNITER ASSEMBLY LOCATIONS*

TRAIN 'A' No.	TRAIN 'A' Compartment/Area-Elevation		TRAIN 'B' No.	TRAIN 'B' Compartment/Area-Elevation	
A-1	Ice Cond. Upper Plenum	- 708'	B-1	Ice Cond. Upper Plenum	- 709'
A-2	Ice Cond. Upper Plunum	- 709'	B-2	Ice Cond. Upper Plenum	- 709'
A-3	Ice Cond. Upper Plenum	- 709'	B-3	Ice Cond. Upper Plenum	- 709'
A-4	Ice Cond. Upper Plenum	- 709'	B-4	Ice Cond. Upper Plenum	- 709'
A-5	Ice Cond. Upper Plenum	- 709'	B-5	Ice Cond. Upper Plenum	- 709'
A-6	Ice Cond. Upper Plenum	- 710'	B-6	Ice Cond. Upper Plenum	- 709'
A-7	Ice Cond. Upper Plenum	- 709'	B-7	Ice Cond. Upper Plenum	- 709'
A-8	Inside #1 SG Enclosure	- 686'	B-8	Inside #1 SG Enclosure	- 686'
A-9	Inside #2 SG Enclosure	- 686'	B-9	Inside #2 SG Enclosure	- 686'
A-10	Inside #3 SG Enclosure	- 686'	B-10	Inside #3 SG Enclosure	- 686'
A-11	Inside #4 SG Enclosure	- 686'	B-11	Inside #4 SG Enclosure	- 685'
A-12	Inside PZR Enclosure	- 686'	B-12	Inside PZR Enclosure	- 682'
A-13	Outside #1 SG Enclosure	- 659'	B-13	Outside #1 SG Enclosure	- 662'
A-14	Outside #2 SG Enclosure	- 662'	B-14	Outside #2 SG Enclosure	- 659'
A-15	Outside #3 SG Enclosure	- 662'	B-15	Outside #3 SG Enclosure	- 659'
A-16	Outside #4 SG Enclosure	- 662'	B-16	Outside #4 SG Enclosure	- 659'
A-17	Outside PZR Enclosure	- 662'	B-17	Outside PZR Enclosure	- 659'
A-18	Primary Shield Wall	- 647'	B-18	Primary Shield Wall	- 642'
A-19	Primary Shield Wall	- 648'	B-19	Primary Shield Wall	- 637'
A-20	Primary Shield Wall	- 648'	B-20	Primary Shield Wall	- 636'
A-21	Primary Shield Wall	- 648'	B-21	Primary Shield Wall	- 636'
A-22	Primary Shield Wall	- 641'	B-22	Primary Shield Wall	- 637'
A-23	Primary Shield Wall	- 648'	B-23	Primary Shield Wall	- 645'
A-24	East Fan/Accumulator Room	- 631'	B-24	East Fan/Accumulator Room	- 630'
A-25	East Fan/Accumulator Room	- 629'	B-25	East Fan/Accumulator Room	- 629'
A-26	West Fan/Accumulator Room	- 629'	B-26	West Fan/Accumulator Room	- 623'
A-27	West Fan/Accumulator Room	- 634'	B-27	West Fan/Accumulator Room	- 634'
A-28	Vicinity of PRT	- 618'	B-28	Vicinity of PRT	- 618'
A-29	Upper Volume Dome Area	- 760'	B-29	Upper Volume Dome Area	- 760'
A-30	Upper Volume Dome Area	- 760'	B-30	Upper Volume Dome Area	- 760'

Table 3-7 (continued)

TRAIN 'A' No.	Compartment/Area-Elevation	TRAIN 'B' No.	Compartment/Area-Elevation
A-31	Upper Volume Dome Area - 760'	B-31	Upper Volume Dome Area - 760'
A-32	Upper Volume Dome Area - 748'	B-32	Upper Volume Dome Area - 748'
A-33	Upper Volume Dome Area - 748'	B-33	Upper Volume Dome Area - 748'
A-34	Upper Volume Dome Area - 748'	B-34	Upper Volume Dome Area - 748'
A-35	Instrument Room -620'	B-35	Instrument Room -620'

KEY: SG - Steam Generator
PZR - Pressurizer
PRT - Pressurizer Relief Tank

* The locations given are for Donald C. Cook Unit No. 2 and are typical for Unit No. 1.

Figure 3-1

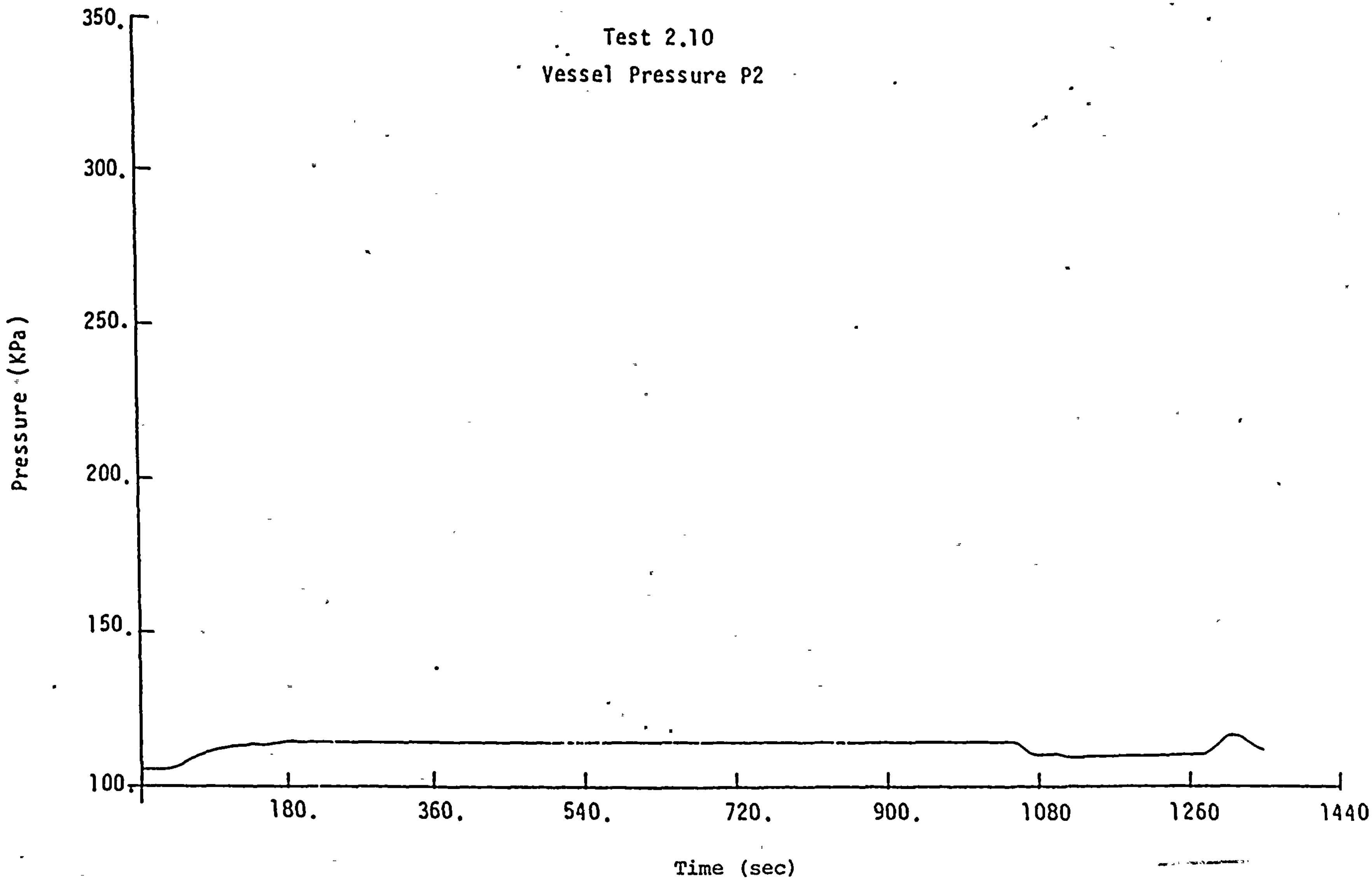

Test 2.10
Vessel Pressure P2
350.
300.
250.
200.
150.
100.
Pressure (KPa)
180.
360.
540.
720.
900.
1080
1260
1440
Time (sec)

Figure 3-2

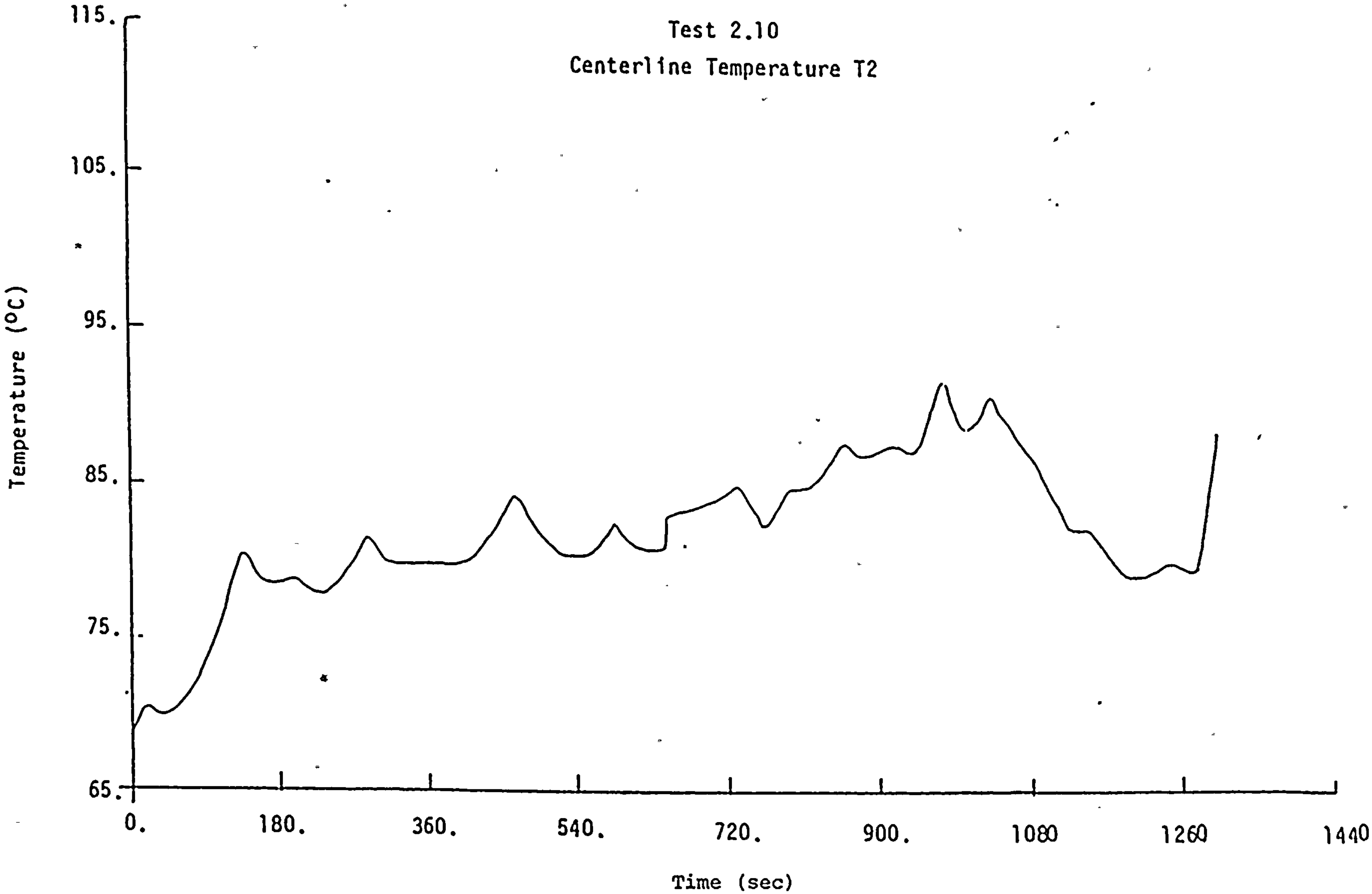
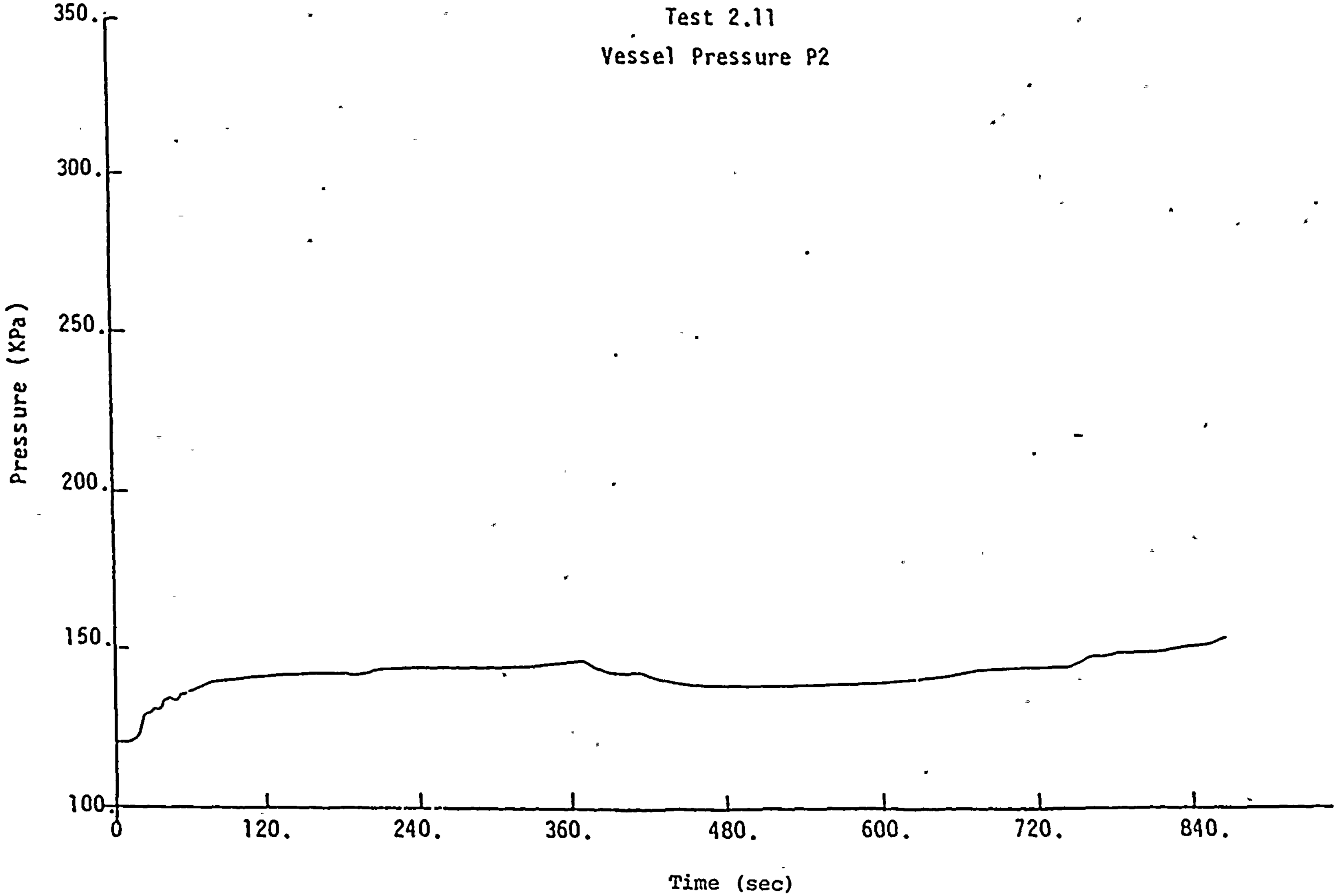
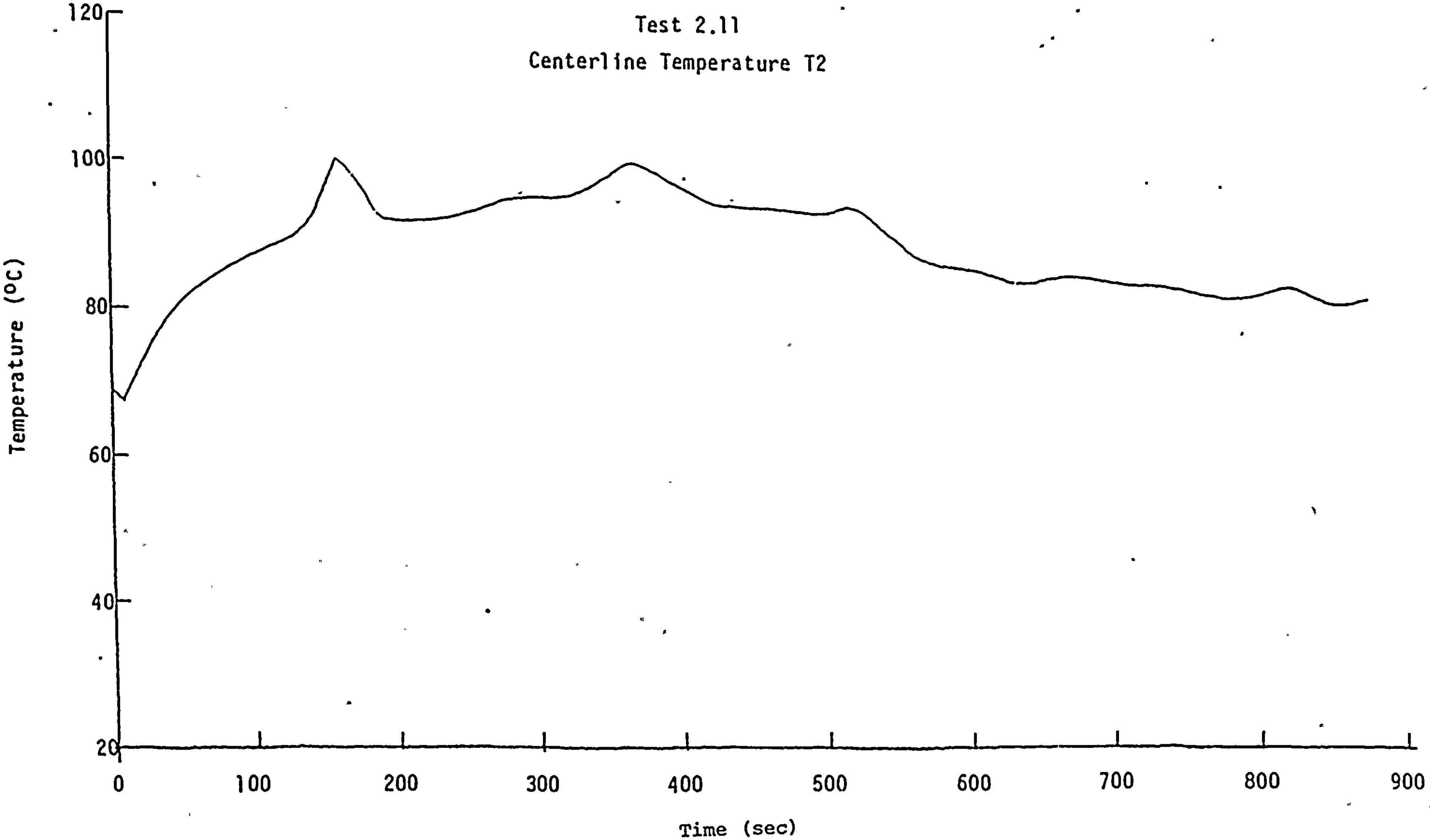

Test 2.10
Centerline Temperature T2
Temperature (°C)
115.
105.
95.
85.
75.
65.
0.
180.
360.
540.
720.
900.
1080
1260
1440
Time (sec)

Figure 3-3



Test 2.11
Vessel Pressure P2
350.
300.
250.
200.
150.
100.
Pressure (KPa)
0
120.
240.
360.
480.
600.
720.
840.
Time (sec)

Figure 3-4



Test 2.11
Centerline Temperature T2
120
100
80
60
40
20
Temperature (°C)
0
100
200
300
400
500
600
700
800
900
Time (sec)

Figure 3-5

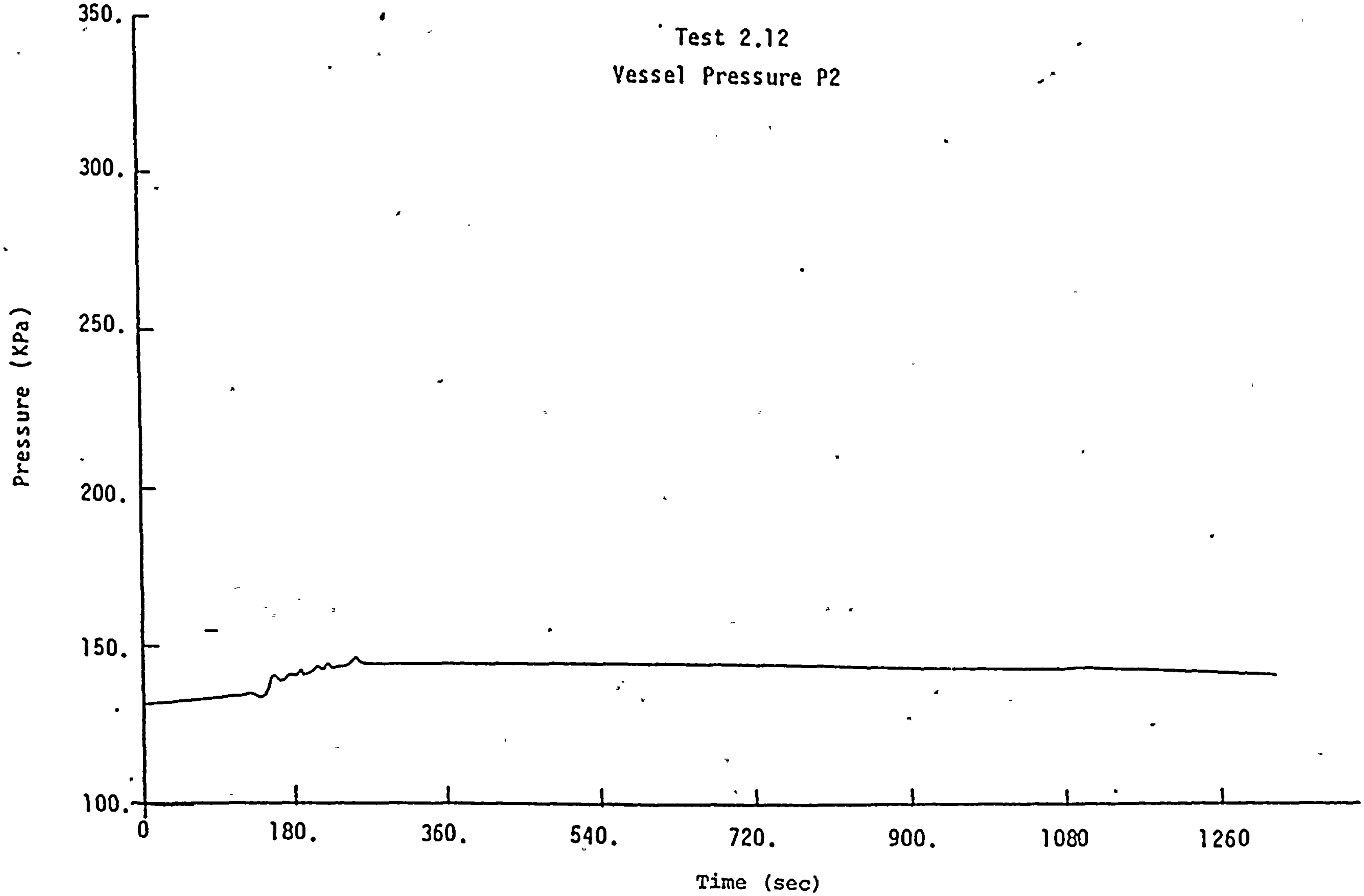
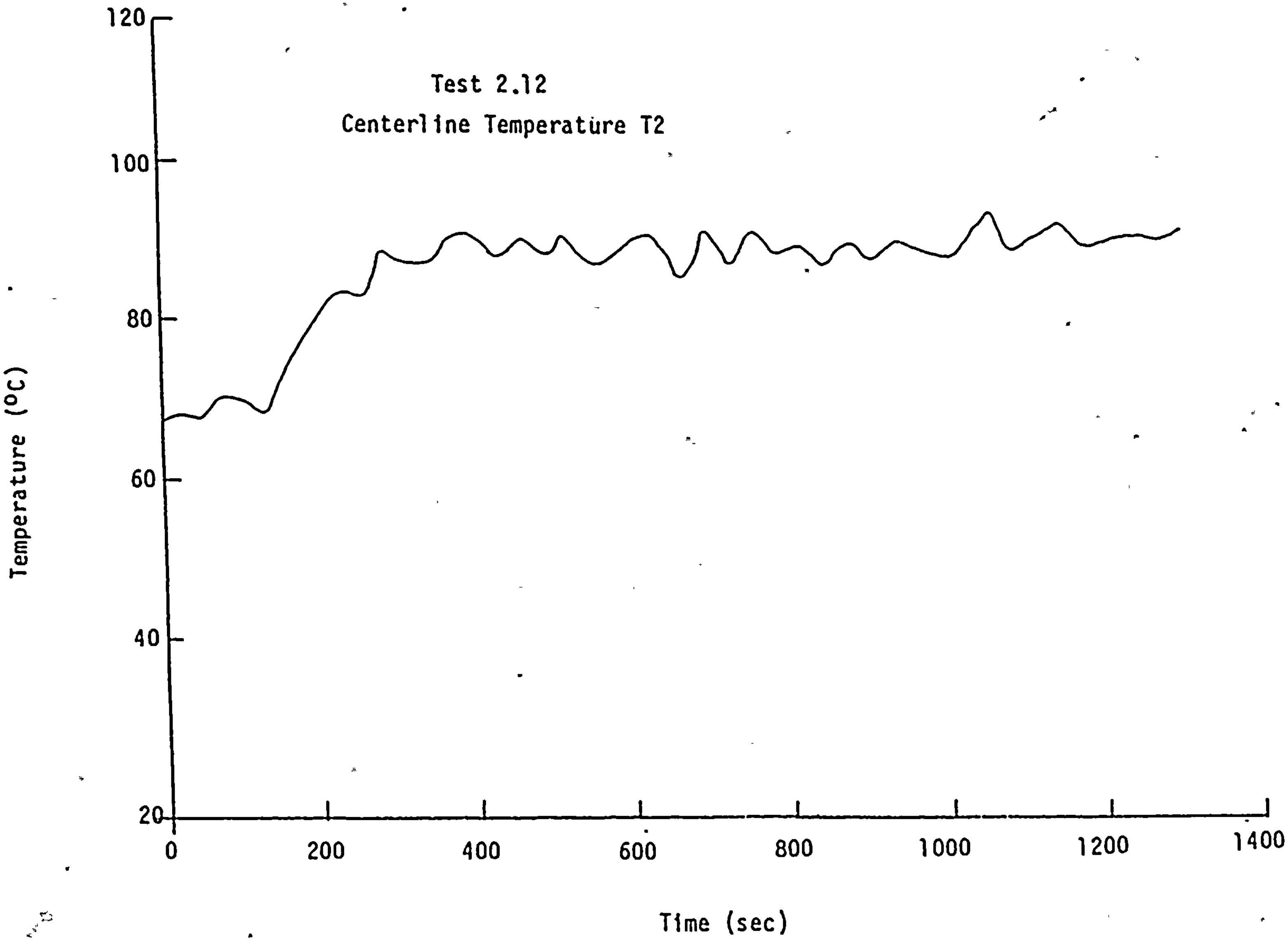

Test 2.12
Vessel Pressure P2
Pressure (KPa)
350.
300.
250.
200.
150.
100.
0
180.
360.
540.
720.
900.
1080
1260
Time (sec)

Figure 3-6



Test 2.12
Centerline Temperature T2
Temperature (°C)
120
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
Time (sec)

MAXIMUM GAS CONCENTRATION DIFFERENCE
FOR TEST HM-1A, HM-2, HM-4C, AND HM-6

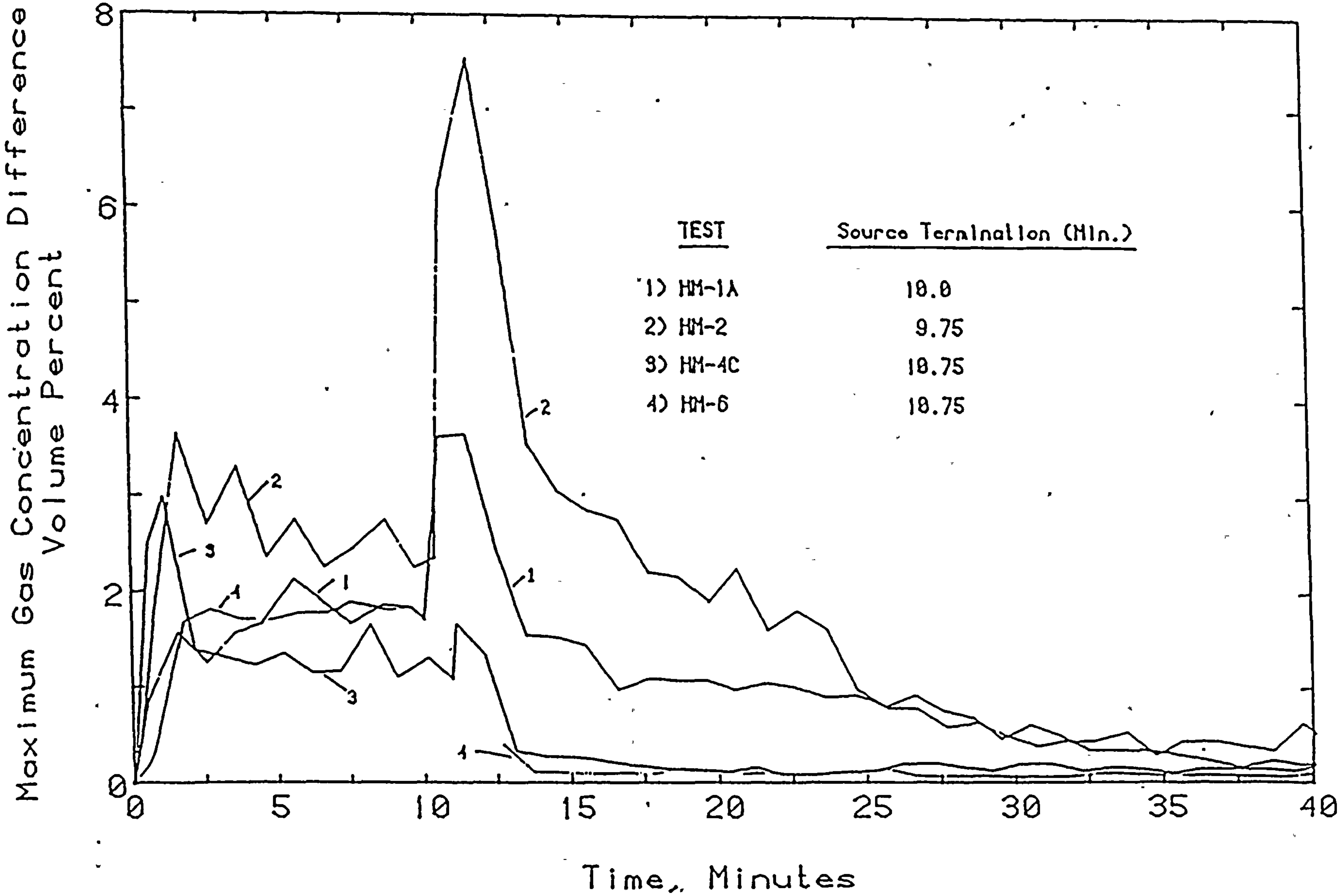


Figure 3-7

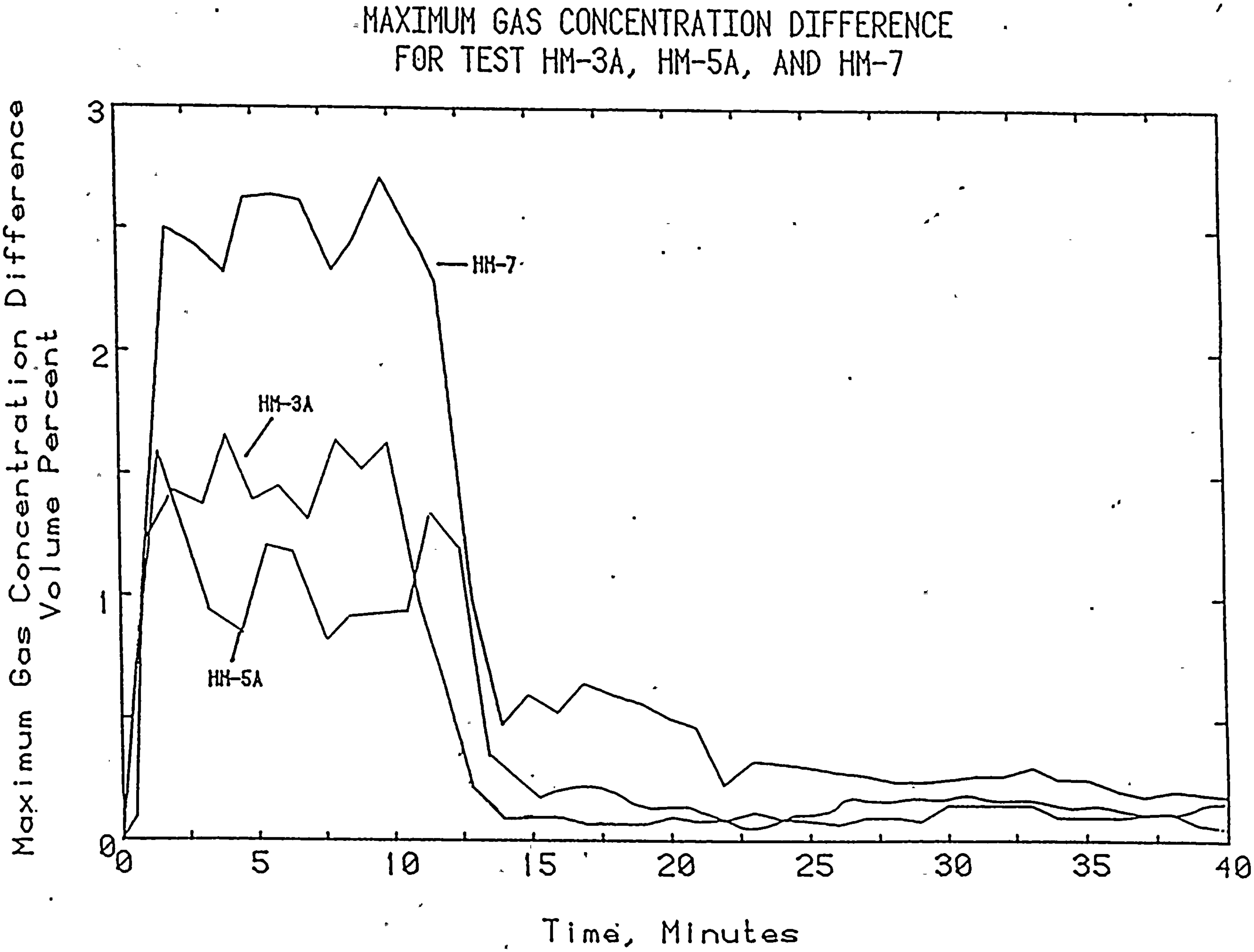
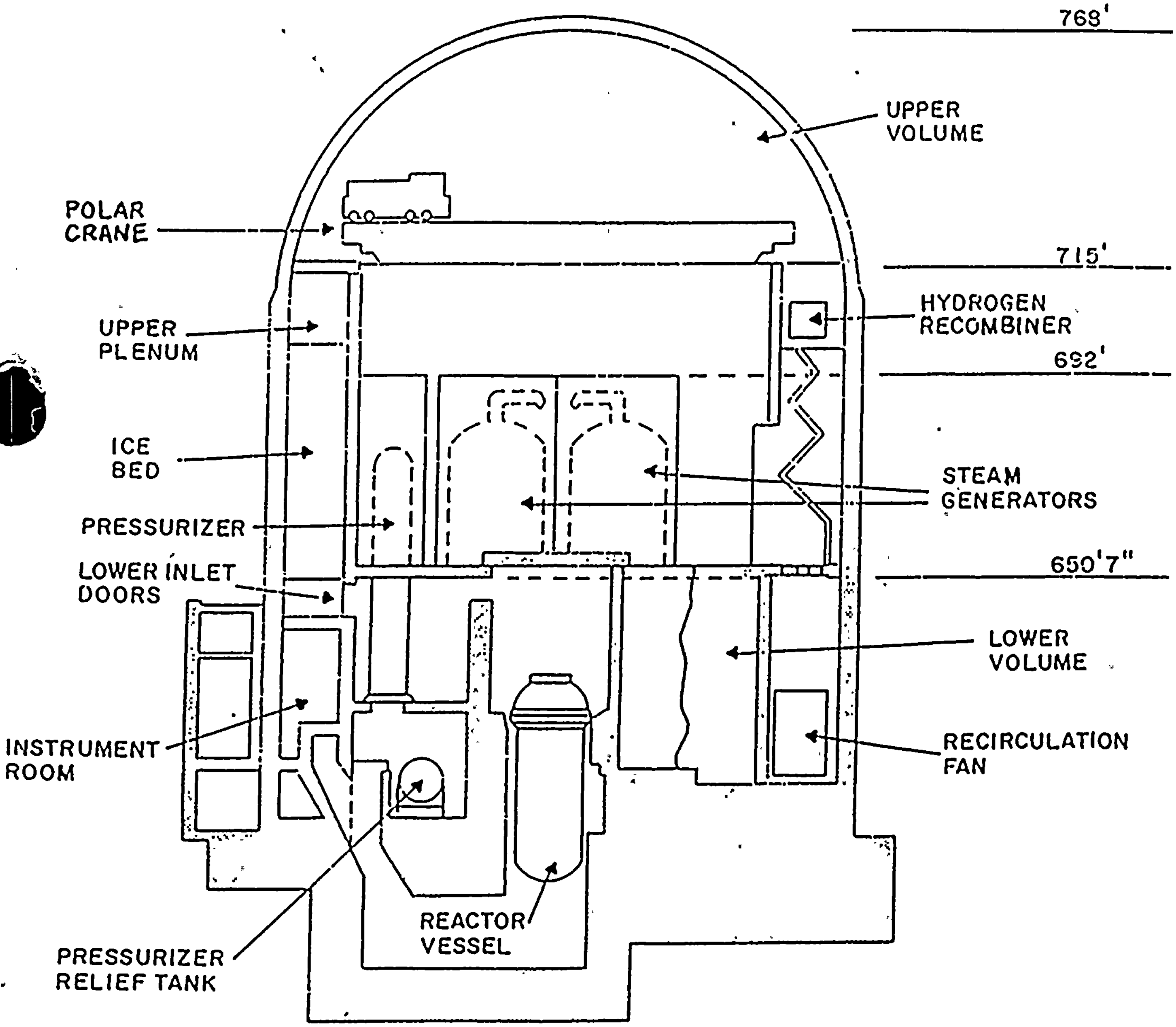

MAXIMUM GAS CONCENTRATION DIFFERENCE
FOR TEST HM-3A, HM-5A, AND HM-7
Maximum Gas Concentration Difference
Volume Percent
Time, Minutes
HM-7
HM-3A
HM-5A
0
1
2
3
0
5
10
15
20
25
30
35
40

Figure 3-8



768'
UPPER VOLUME
POLAR CRANE
715'
HYDROGEN RECOMBINER
UPPER PLENUM
692'
ICE BED
STEAM GENERATORS
PRESSURIZER
LOWER INLET DOORS
650'7"
LOWER VOLUME
RECIRCULATION FAN
INSTRUMENT ROOM
REACTOR VESSEL
PRESSURIZER RELIEF TANK

Figure 3-9

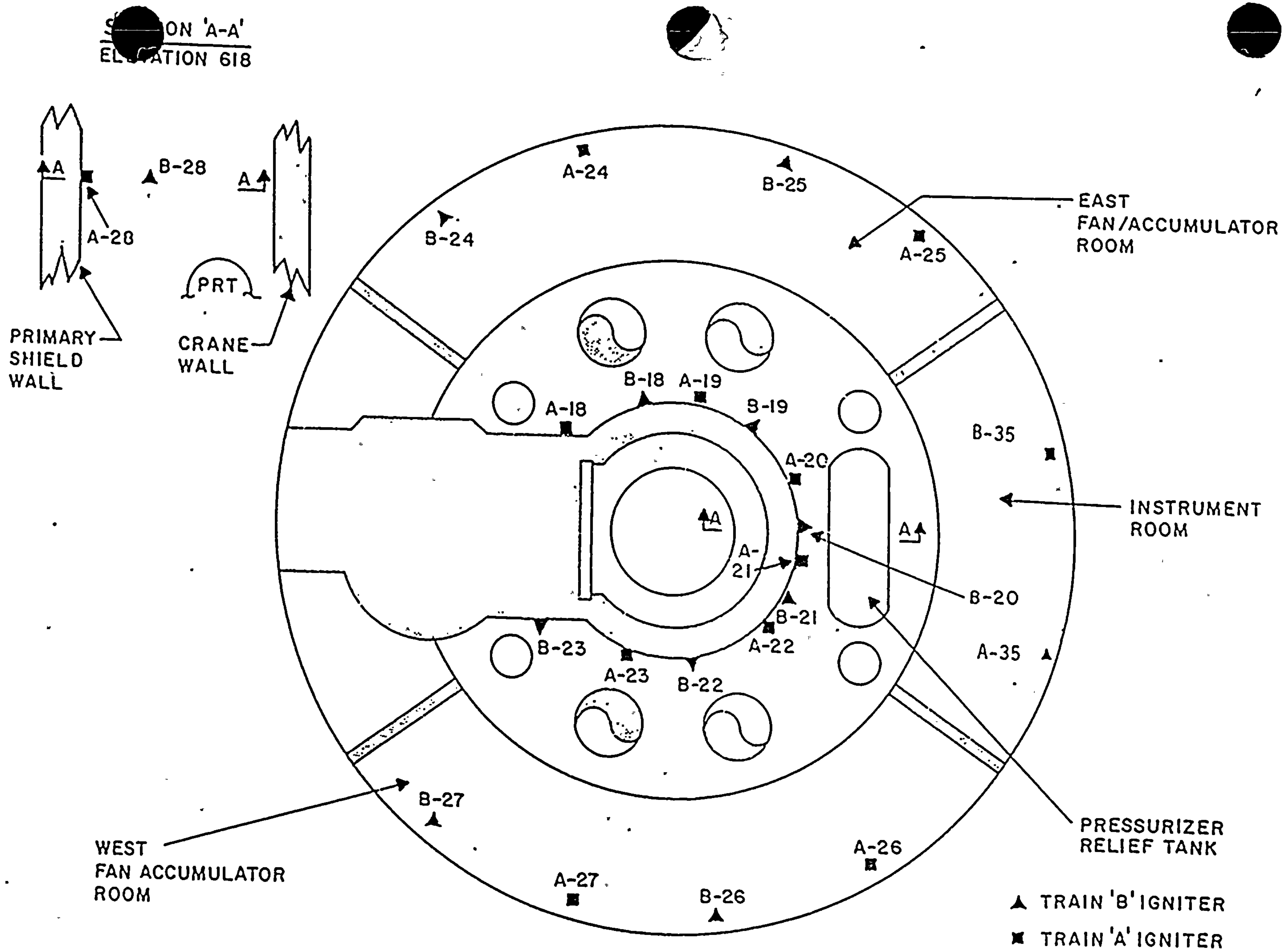
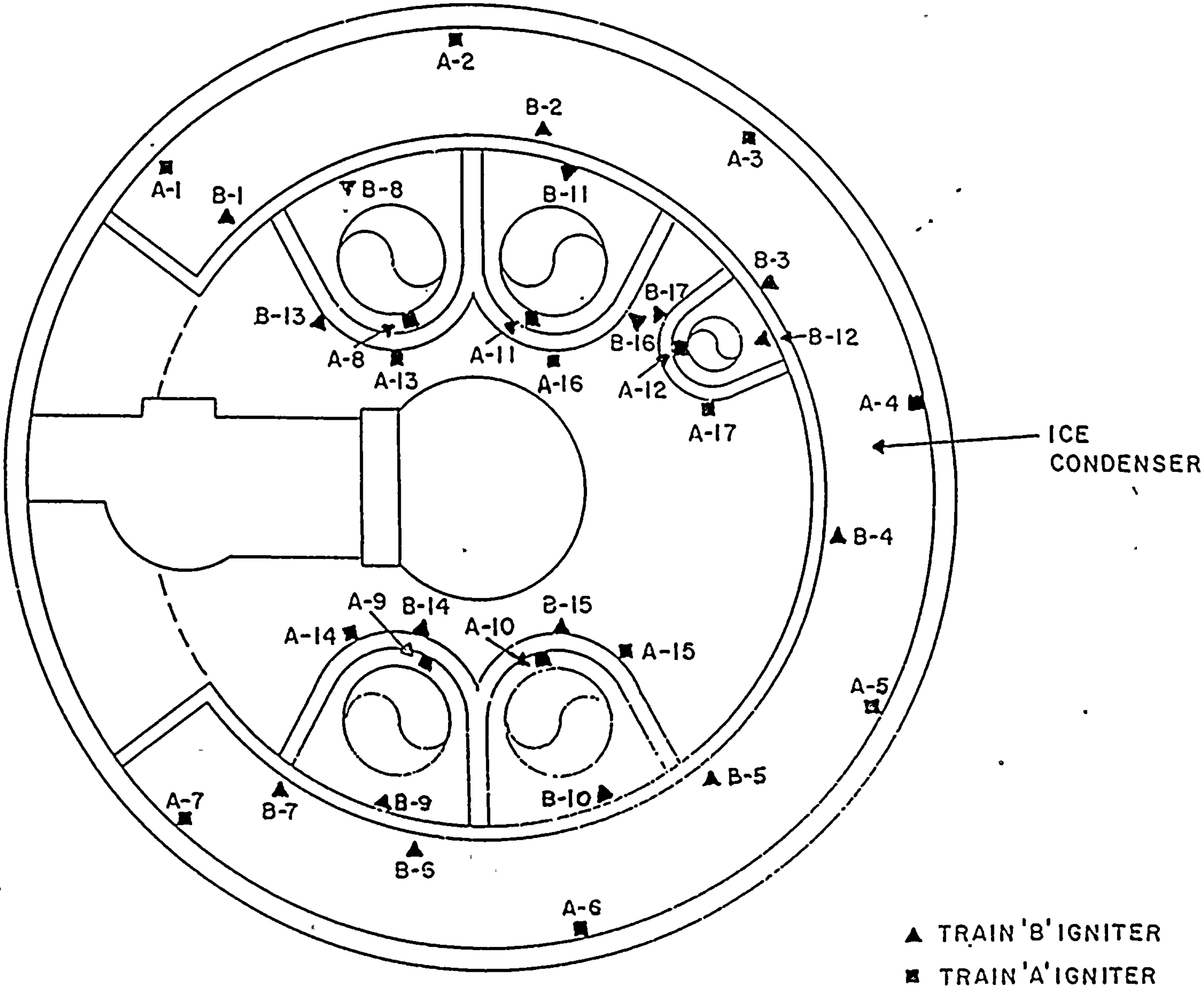


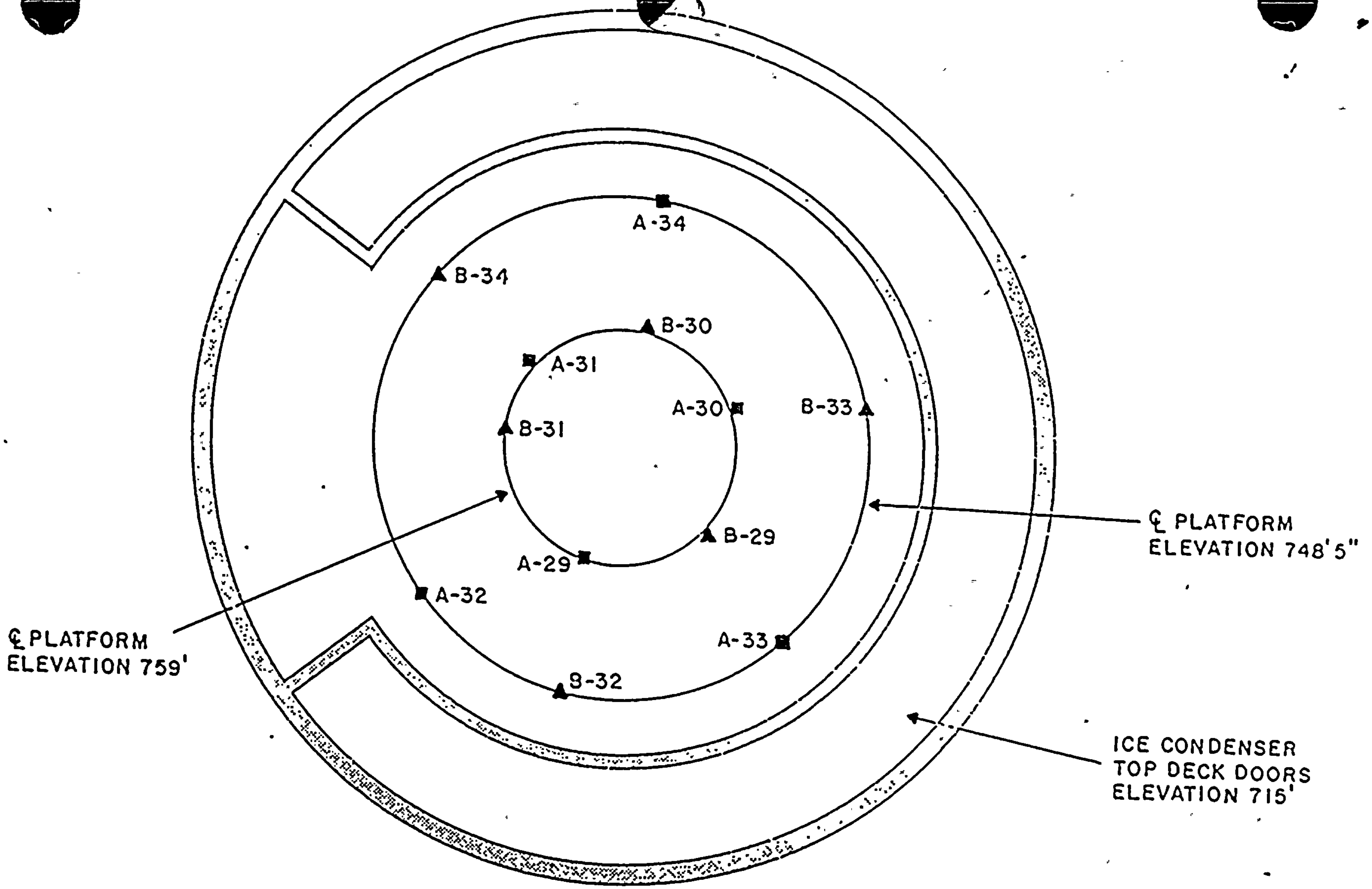
Figure 3-10

D.C. COOK UNIT NO. 2
CONTAINMENT PLAN BELOW
ELEVATION 652'7"



D.C. COOK UNIT NO. 2
CONTAINMENT PLAN ABOVE
ELEVATION 652'7"

Figure 3-11



D.C. COOK UNIT NO. 2
CONTAINMENT PLAN ABOVE
ELEVATION 715'

Figure 3-12

ATTACHMENT 4 TO AEP:NRC:0500K
FOG INERTING ANALYSIS FOR PWR ICE CONDENSER PLANTS
DONALD C. COOK NUCLEAR PLANT UNIT NOS. 1 AND 2