MISSISSIPPI POWER & LIGHT COMPANY
Helping Build Mississippi
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August 23, 1983

NUCLEAR PRODUCTION DEPARTMENT

Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Mr. Harold R. Denton, Director

Dear Mr. Denton:

SUBJECT: Grand Gulf Nuclear Station
Units 1 and 2
Docket Nos. 50-416 and 50-417
License No. NPF-13
File 0260/0272/0756
Supplementary Response to NRC Letter on Hydrogen Control
AECM-83/0479

References: 1. Letter from Mr. A. Schwencer to Mr. J. P. McGaughy, dated July 22, 1983

2. Letter AECM-83/0455, from Mr. L. F. Dale to Mr. H. R. Denton, dated August 13, 1983

Mississippi Power & Light Company (MP&L) committed in Reference 2 to providing supplementary information on hydrogen control at the Grand Gulf Nuclear Station (GGNS). This supplementary information consists of three attachments. Attachment 1 provides additional discussion on the use of the 1/20th scale test to describe thermal environments in the containment. Attachment 2 provides a discussion of the equipment response methodology which utilizes 1/20th scale data, results from these calculations, and more detailed equipment information. Figures describing the modeling approach along with preliminary results are included based on a thermal environment from a 0.4 lbm/sec hydrogen release rate. Attachment 3 provides supplementary information describing CLASIX-3 analyses which have been recently completed. These additions include modified treatment of the vacuum breakers, a two compressor case, and a modified radiation heat transfer case. A summary table and response curves are attached.

Additional information concerning thermal environment and equipment response will be provided upon completion of the 1/4th scale test program discussed in Reference 2. Also, a realistic assessment of source terms for the CLASIX-3 code is in progress which will identify release rates and sequences which are characteristic of recoverable degraded core events rather than severe accidents leading to core melt. This assessment will be coordinated with the EPRI BWR Heatup Code

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development work and will be submitted when available. It is believed that the results will be more characteristic of actual plant response to a degraded core event and result in demonstration of the survivability of essential equipment in the drywell.

Yours truly,

L. F. Dale
Manager of Nuclear Services

JRH/SHH:lm
Attachments

cc: Mr. J. B. Richard (w/o)
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PRELIMINARY EVALUATION OF THE THERMAL ENVIRONMENT*

TABLE OF CONTENTS

*Draft Material Prepared by EPRI as Part of 1/20th Scale Test Program

TABLES AND FIGURES

1. INTRODUCTION

The research program undertaken by the BWR6/Mark III Containment Hydrogen Control Owner's Group (HCOG) and managed by the Electric Power Research Institute includes hydrogen combustion testing in a 1/20th scale model of a Mark III containment. A description of this test facility, the test results obtained and a preliminary assessment of the full scale thermal environment derived from these results were presented to USNRC on June 29, 1983.

Based on the thermal environment so defined, a scoping evaluation of the thermal response of an igniter transformer was performed. The results of this evaluation indicated that for a sustained H_2 release rate of approximately 0.8 lbm/sec, the igniter transformer would remain below its survivability temperature of approximately 18 minutes with no credit for containment sprays. This is longer than the expected period of hydrogen release at 0.8 lbm/sec.

The preliminary evaluation of the expected thermal environment presented at the NRC/HCOG meeting on June 29, 1983 contained several significant conservatisms including:

- Containment sprays were not considered (the 1/20th scale tests did not include simulation of containment sprays)
- The 1/20th scale data evaluated was taken in the "hottest" chimney in the wetwell annulus. Two adjacent SRV discharge spargers were releasing hydrogen below that chimney while at most only one sparger would be releasing hydrogen below the other chimneys.
- Observed temperatures from the 1/20th scale facility are higher than would be expected in a larger model or the prototype due to laminar effects which result in taller flames.
- The durations specified for the thermal loading were long relative to those expected for such high H_2 release rates (0.8 to 2.0 lbm/sec) based on best estimate analysis of hydrogen release rates for recoverable degraded core accidents utilizing the BWR core heatup code.

The objective of this attachment is to document a more detailed analysis of the expected thermal environment resulting from hydrogen combustion as a steady diffusion flame in a Mark III containment. An estimate of the effects of containment spray operation is included.

The results of this analysis are preliminary pending thorough 1/20th scale data evaluation and preparation of the final test report expected in October 1983.

2. EVALUATION OF THERMAL ENVIRONMENTS

The thermal environments resulting from sustained H_2 releases of 0.8 and 0.4 lbm/sec are evaluated.

2.1 Thermal Environment from a H_2 Release of 0.8 lbm/sec (Full Scale)

Assumptions:

1. Total H_2 flowrate is 0.8 lbm/sec (full scale)
2. H_2 flow is split evenly among 9 spargers
3. Pool temperature is 185°F
4. Containment sprays are in operation - sprays are assumed to cool the gas but no credit is taken for actual heat removal from equipment due to direct contact with spray water.
5. Two adjacent spargers release H_2 below the "chimney" evaluated.

2.1.1 Gas Temperature Evaluation

Figure 1 is a typical temperature history measured during a 0.8 lbm/sec (full scale), 1/20th scale test (Test II-21). Note that following an initial temperature excursion (resulting from the initial deflagration burn from the lowest set of igniters to the pool surface) the temperature quickly attains a relatively low value and begins to gradually increase. At this point steady flames have been established above the pool and the gradual increase in temperature is due to overall heat addition to the containment air. The heated air is beginning to recirculate back to the base of the flames resulting in progressively higher gas temperatures at the HCU floor level. Eventually the heat lost to the walls equates to the heat added due to combustion and the temperature stablizes. The previous analysis assumed temperature values consistent with this evaluated equilibrium value.

It is postulated that with containment sprays in operation, the heat added due to combustion will be effectively removed from the recirculating air such that the air feeding the base of the flames will be maintained at or very near the spray water temperature. Under such conditions, the gas temperatures measured (in the 1/20th scale test) very soon after steady flames are established (before significant recirculation of heated air) represent an upper bound on those temperatures expected with containment sprays in operation.

Table 1 presents gas temperatures measured near the HCU floor early (first 30 seconds) in each 1/20th scale test performed with an equivalent full scale H_2 flowrate of 0.8 and 0.4 lbm/sec and with an elevated pool water level consistent with an upper pool dump. Note that the highest observed temperature during this time period was 480°F for the 0.8 lbm/sec tests (Test IV-2).

Figure 2 depicts the vertical gradient in gas temperature observed in Phase IV of the 1/20th scale test program. Phase IV testing was performed with minimal obstructions to vertical gas flow and resulted in the least decay in temperature with height. The points depicted as circles on Figure 2 represent the average temperatures observed at those locations for the three Phase IV tests performed with elevated water level. This approach provides the best estimate of the shape of the vertical temperature gradient. Since the highest temperature observed early in any Phase IV test was 480°F (at an equivalent of 2.5 feet below the HCU floor) this curve was translated to the right by 13°F to match that point. The new curve, depicted by triangles on Figure 2, provides an estimate of the maximum expected gas temperature distribution for a H_2 release rate of 0.8 lbm/sec with containment spray operation.

2.1.2 Gas Velocity Evaluation

Two independent methods were used to evaluate the gas velocity.

1. Visual observation (video tapes) of the vertical motion of hot gases above the flames.

In some tests (2.0 lbm/sec tests) small volumes of hot gases were observed as they were entrained in the upward gas flow above the flames. The motion of

these "hot gas volumes" was evaluated resulting in an apparent upward gas velocity of 6.5 ft/sec at 1/20th scale (Test II-4).

It would be expected that the corresponding velocity for lower H_2 release rates (0.8 lbm/sec & 0.4 lbm/sec) would be lower than this value.

2. Evaluation of convective heat flux data.

Convective heat flux at the HCU floor was measured during one 0.8 lbm/sec test (Test III-3). The convective heat flux measured early in that test (consistent with gas temperatures expected with spray operation) was 1950 Btu/hr ft^2.

The gas temperature measured near the heat flux sensor (TC 220) during that test was 450°F.

The heat flux (HF) sensor is constructed as shown in Figure 3. The sensing element itself is a flat disk approximately 1/8" in diameter. The sensor is held in a copper holder whose outside surface is cooled with 185°F water. The cooled holder effectively maintains the outside diameter of the HF sensor at approximately 185°F. The sensor measures the temperature difference between the center and outside diameter of the HF sensor and this ΔT is related to the incident heat flux. In Test III-3, the HF sensor face was polished to minimize radiant flux measurement.

For the purpose of evaluation, the holder arrangement was represented by a cylinder on its side for which empirical convective heat transfer correlations exist. The HF sensor was assumed to be measuring stagnation point convective heat flux. For this configuration, the velocity of the gas stream can be estimated using the equation:

$$Nu = \frac{h_c D_o}{K_f} = C \sqrt{v_\alpha D_o / v_f}$$ **(Equation 9-1, Kreith, Principles of Heat Transfer, second Ed.)**

where
Nu = Nusselt Number
h_c = Stagnation Point Convective Heat Transfer Coefficient
D_o = Diameter of Object Receiving Energy
K_F = Thermal Conductivity of Gas
v = Free Steam Velocity of Gas
ν_F = Kinematic Viscosity of Gas
C = 1.05 (for a Prandtl Number of 0.8)

Everything in this equation is known except velocity and h_c.

h_c is estimated as follows:

$$h_c = \frac{\text{measured convective flux at the stagnation point, i.e. at HF sensor}}{\text{measured } \Delta T \text{ between gas and HF sensor face}}$$

The ΔT from the gas to the HF sensor is taken as the measured gas temperature minus an average temperature on the surface of the HF element. For the measured millivolt output, the corresponding ΔT from the center to outside of the sensor face is 170°F. Assuming the outside surface to be at 185°F, the center would be at 185 + 170 or 355°F resulting in an approximate average surface temperature of $\frac{355 + 170}{2}$ or 263°F.

Therefore, the estimated ΔT between the gas and the HF sensor is 450° - 263° = 187°F and

$$h_c = \frac{1950 \text{ Btu/hr-ft}^2}{187^\circ F} = 10.4 \frac{\text{Btu}}{\text{hr-ft}^2\text{-}^\circ F}$$

The gas velocity can now be estimated as:

$$V_\alpha = \left(\frac{h_c D_o}{K_f c}\right)^2 \frac{\nu_f}{D_o} = \left(\frac{h_c}{K_f c}\right)^2 D_o \nu_f$$

$$V_\alpha = \left(\frac{10.4 \frac{\text{Btu}}{\text{hr-ft}^2 {}^\circ F}}{(.0235) \frac{\text{Btu}}{\text{hr-ft}^2 {}^\circ F} \times (1.05)}\right)^2 \times .06 \text{ ft} \times 2.0 \text{ ft}^2/\text{hr}$$

$$V_\alpha = 21{,}317 \text{ ft/hr} = 5.9 \text{ ft/sec}$$

This value is consistent with the visual observation of vertical gas stream velocity and scales to full scale as

$$V_{\alpha FS} = V_{\alpha\ 1/20\text{th}} \times \left(\frac{20}{1}\right)^{1/2}$$

$$V_{\alpha FS} = 5.9 \text{ ft/sec} \times (20)^{1/2} = 26.4 \text{ ft/sec}$$

2.1.3 Radiation Heat Flux

Equipment located in the Mark III wetwell will receive radiant thermal loading as a result of diffusive burns from two sources; i.e., emission from hot water vapor in the vicinity of the flames and from hot grating at the HCU floor level.

Radiation from Hot Water Vapor:

Radiant heat flux from a flame and hot plume above a sparger to a point on the HCU floor directly over the sparger was calculated. It was assumed that the flame/plume took the form of a cylinder of 10' diameter and height 20'; i.e., extending from pool surface to HCU floor. The vertical temperature distribution between the pool surface and the HCU floor was estimated using known boundary conditions; i.e., measured gas temperature (from the 1/20th scale test) in the flame (approximately 1500°F) and at the HCU floor level (approximately 480°F) and a correlation of temperature data taken in the plume of diffusion flames by D. J. Caffrey (NBS Report NBSIR 79-1910, October 1979, "Purely Buoyant Diffusion Flames: Some Experimental Results"). This correlation defines the temperature distribution in flame, intermittent and plume regions above the base. The intermittent region is between the flame and the plume. The temperature in the flame region is defined as constant with height and for this evaluation was assumed to equal 1500°F based on measured temperatures (1/20th scale test) when the thermocouples were immersed in flames.

The correlation also defines the ratio of heights of the top of the intermittent region and the top of the flame region to be 2.5. Within this region the temperature is defined to decay as x^{-1} (x is vertical distance measured from the base). The correlation also defines the temperature decay above the intermittent region as $x^{-5/3}$.

The approach used to define the temperature distribution was to assume a value for the height of the "flame" region such that the correlation equations and the known boundary conditions were satisfied. The resulting temperature distribution is presented in Figure 4.

The heat flux was calculated by segmenting the cylinder into smaller cylinders (Figure 5) and assuming each cylinder to be isothermal at a temperature equal to the average of the assumed gas temperatures at its upper and lower bounds. A mean beam length approximation was used to calculate the heat flux from each volume of gas to a point at the center of the upper surface (Hottel and Sarofim, 1967, p. 277). It was then assumed that the entire upper surface of each cylinder radiated at this flux to a point on the HCU floor appropriately accounting for its view factor to that point and the flux from each cylinder was summed to obtain total radiant heat flux. The upper most cylinder was treated separately since the mean beam length approximation gives the flux directly in that case.

Specifically the calculation proceeds as follows:

The heat flux to an element A_5 on the HCU floor is

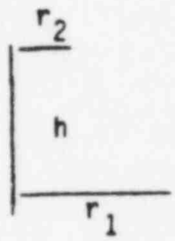
$$q = \frac{\sigma}{A_5} [A_1 F_{1-5} \varepsilon_1 T_1^4 + A_2 F_{2-5} \varepsilon_2 T_2^4 + A_3 F_{3-5} \varepsilon_3 T_3^4] + \sigma \varepsilon_4 T_4^4$$

where σ = Stefan-Boltzmann constant
A_i = Area Associated with Volume i
F_i = View Factor Associated with Volume i
T_i = Temperature of Volume i

View factors were computed from:

$$F_{1-2} = \frac{1}{2} [x - \sqrt{x^2 - 4(r_2/r_1)^2}]$$

where $x = 1 + \frac{1 + (r_2/h)^2}{(r_1/h)^2}$



**Ref: Siegel & Howell, 1972
Appendix C**

A specific receptor size (r_2 = 1") was assumed.

Gas emissivities were calculated from Hottel charts (Kreith, 1965, pp. 237) assuming 43% water vapor in air at a total pressure of 15 psia. The value of

43% H_2O vapor was estimated as follows.

Assumptions:

1. The initial gas temperature was 130-140°F.
2. The H_2O concentration in the flame/plume equals the concentration of H_2O in the combustion products.

Analysis:

at 133°F, the % H_2O is ~16%

$\therefore$ $2H_2 + O_2 + 4N_2 + H_2O$ (Initial H_2O) $\longrightarrow$ $3H_2O + 4N_2$

and the H_2O concentration in the combustion products = 3/7 = <u>0.43</u>

Using the approach described above, the radiant heat flux from hot water vapor to the HCU floor was computed to be 3600 Btu/hr-ft^2.

Radiation from Hot Grating:

Radiation from the HCU floor grating contributes to the heat flux to a piece of equipment. For an infinite plane grating located close to a piece of equipment, the radiant heat flux to the equipment is approximately:

$$q = \varepsilon \sigma F_{1-2} T_{grate}^4$$

where:
- ε = Emissivity of Grating
- σ = Stefan-Boltzmann Constant
- F = "view factor" of Grating to Equipment (Accounts for a 70% Open Area in Grating)
- T = Grating Temperature

Assume:

(1) grating temperature = maximum observed gas temperature at HCU level (480°F)

(2) $\varepsilon = 0.7$

(3) F is 0.3 if looking perpendicular to grating (i.e. equal to closed area of grating). Effective "closed area" increases off-axis due to finite depth of grating and becomes 1.0 at approximately 30°. Therefore, F is assumed to be approximately 0.5.

Grating temperature = 480°F = 940°R

$$q = \varepsilon\sigma F_{1-2} T^4_{grate} = 470 \text{ Btu/hr-ft}^2$$

Total Radiant Heat Flux:

The total radiant heat flux to an object located near the HCU floor is composed of radiation from the hot gas and radiation from the HCU grating. Two cases are considered:

Case 1: Equipment located below grating. This equipment sees the entire plume radiation on its lower surface and sees the entire grating radiation on its upper surface.

Case 2: Equipment located above grating. This equipment sees the entire grating radiation on its lower surface and in addition sees a fraction of the plume radiation on its lower surface. It sees only a fraction of the gas radiation because some of it is blocked by the solid fraction of the HCU floor grating.

Therefore, based on the evaluation described above, the total radiant heat flux for an H_2 release rate of 0.8 lbm/sec is estimated to be:

*Case 1) below HCU floor

$$q = q_{gas} + q_{grate} = 3600 \text{ (from below)} + 470 \text{ (from above)} = 4070 \frac{\text{Btu}}{\text{hr-ft}^2}$$

*Case 2) above HCU floor

$$q = 0.7\, q_{gas} + q_{grate} = 2500 + 470 = 2970 \text{ Btu/hr-ft}^2 \text{ (all from below)}$$

2.2 Thermal Environment for an H_2 Release of 0.4 lbm/sec (Full Scale)

The same methods and assumptions as were made in evaluating the thermal environment for 0.8 lbm/sec H_2 flow were applied in assessing the 0.4 lbm/sec environment.

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*These figures are the best current estimate. An earlier (and more conservative) data set was used for the actual analyses described in Attachment 2.

2.2.1 Gas Temperature Evaluation

Note from Table 1 that the maximum temperature measured below the HCU floor early in the 0.4 lbm/sec test (Test II-23) was 350°F. The vertical decay in this temperature was assumed the same as for the 0.8 case and is depicted in Figure 6.

2.2.2 Gas Velocity Evaluation

As no convective heat flux or visual data are available to estimate the gas velocity for this condition, the gas velocity is assumed to be the same as for the 0.8 case, i.e. 26 ft/sec (F.S.).

2.2.3 Total Radiant Heat Flux

The total radiant heat flux for an H_2 release rate of 0.4 lbm/sec is estimated to be:

*Case 1) below HCU floor

$$q = q_{gas} + q_{grate} = 2500 \text{ (from below)} + 260 \text{ (from above)} = 2760 \text{ Btu/hr-ft}^2$$

*Case 2) above HCU floor

$$q = 0.7\, q_{gas} + q_{grate} = 1750+260 = 2010 \text{ Btu/hr-ft}^2 \text{ (all from below)}$$

*These figures are the best current estimate. An earlier (and more conservative) data set was used for the actual analyses described in Attachment 2.

TEST	HYDROGEN FLOWRATE (FULL SCALE - lb/s)	INITIAL POOL TEMP (^{o}F)	TEMPERATURES (^{o}F)			
			TC-109	TC-110	TC-111	TC-112
II-19	0.8	185	360	450	300	272
II-21	0.8	125	440	440	310	300
II-23	0.4	125	290	350	200	160
			TC-209	TC-210		
III-1	0.8	185	380	450		
III-3	0.8	185	426	470		
			TC-309	TC-310	TC-320	
IV-1	0.8	185	405	470	460	
IV-2	0.8	185	450	480	440	
IV-3	0.8	185	410	450	430	

TABLE 1 - MEASURED TEMPERATURES AT AND BELOW HCU FLOOR

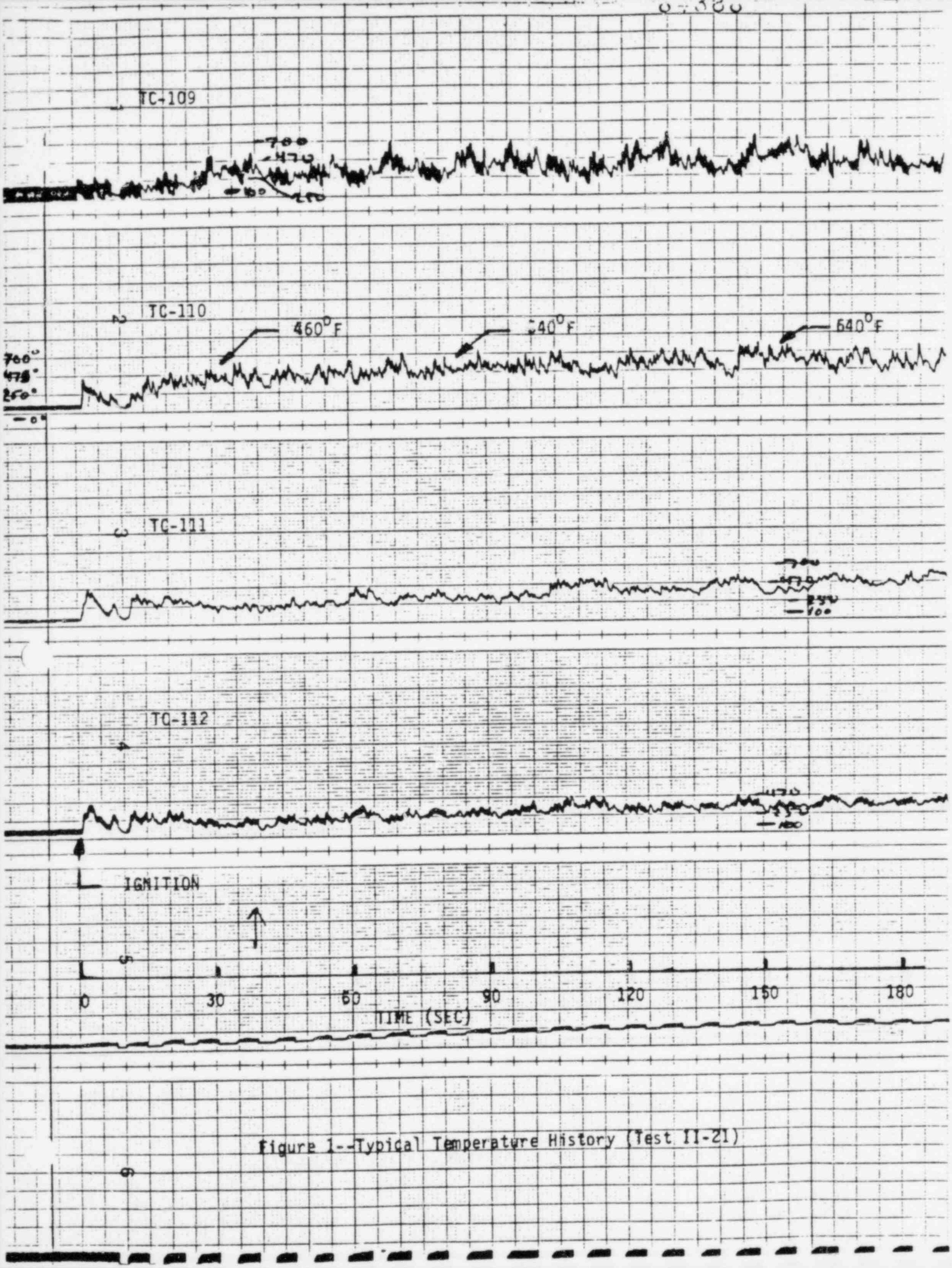


Figure 1--Typical Temperature History (Test II-21)

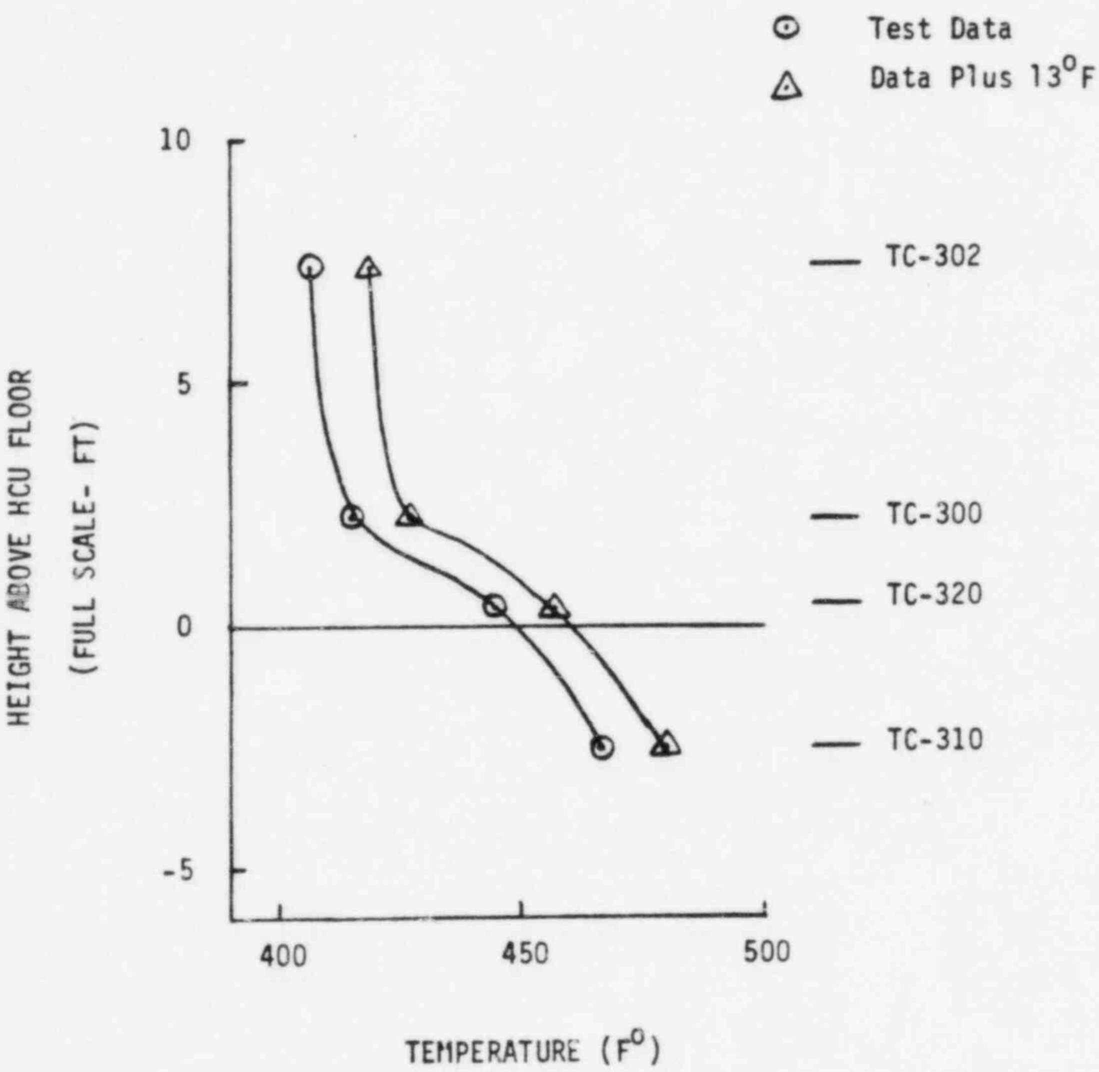


Figure 2--Vertical Temperature Distribution - 0.8 lb/s.

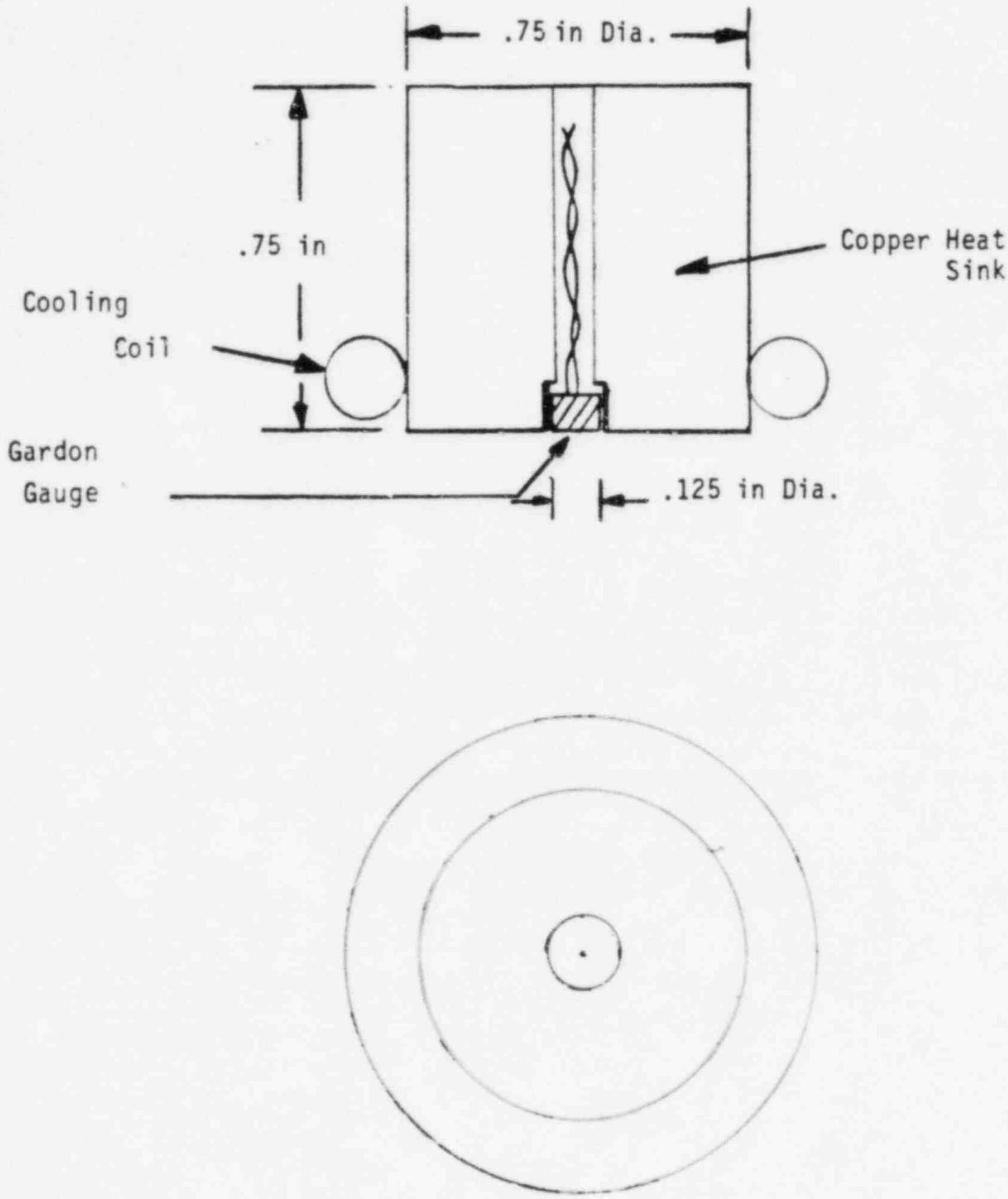


Figure 3--Gardon Gauge Assembly

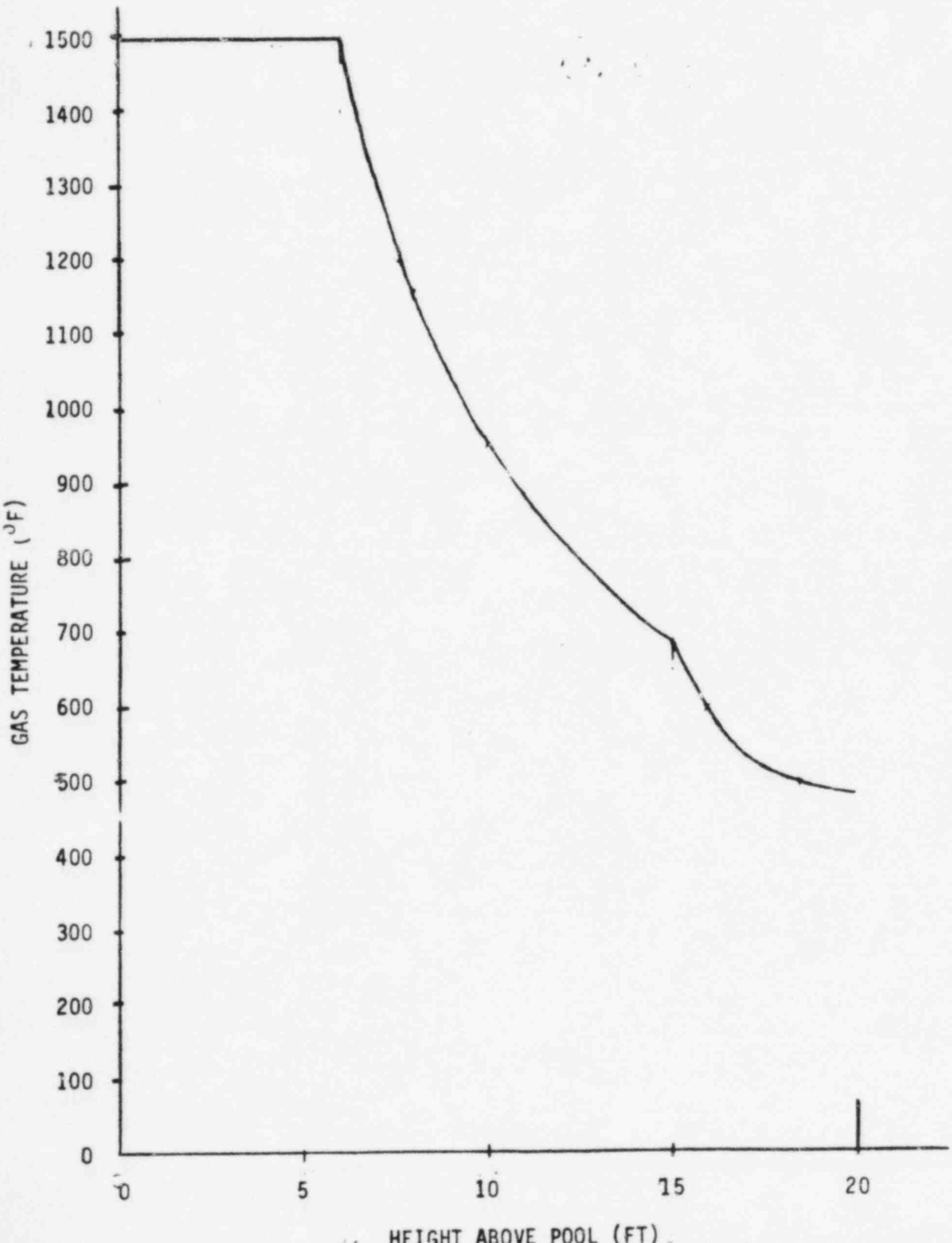


Figure 4--Assumed Temperature Distribution in Radiant Gas Plume - 0.8 lb/s.

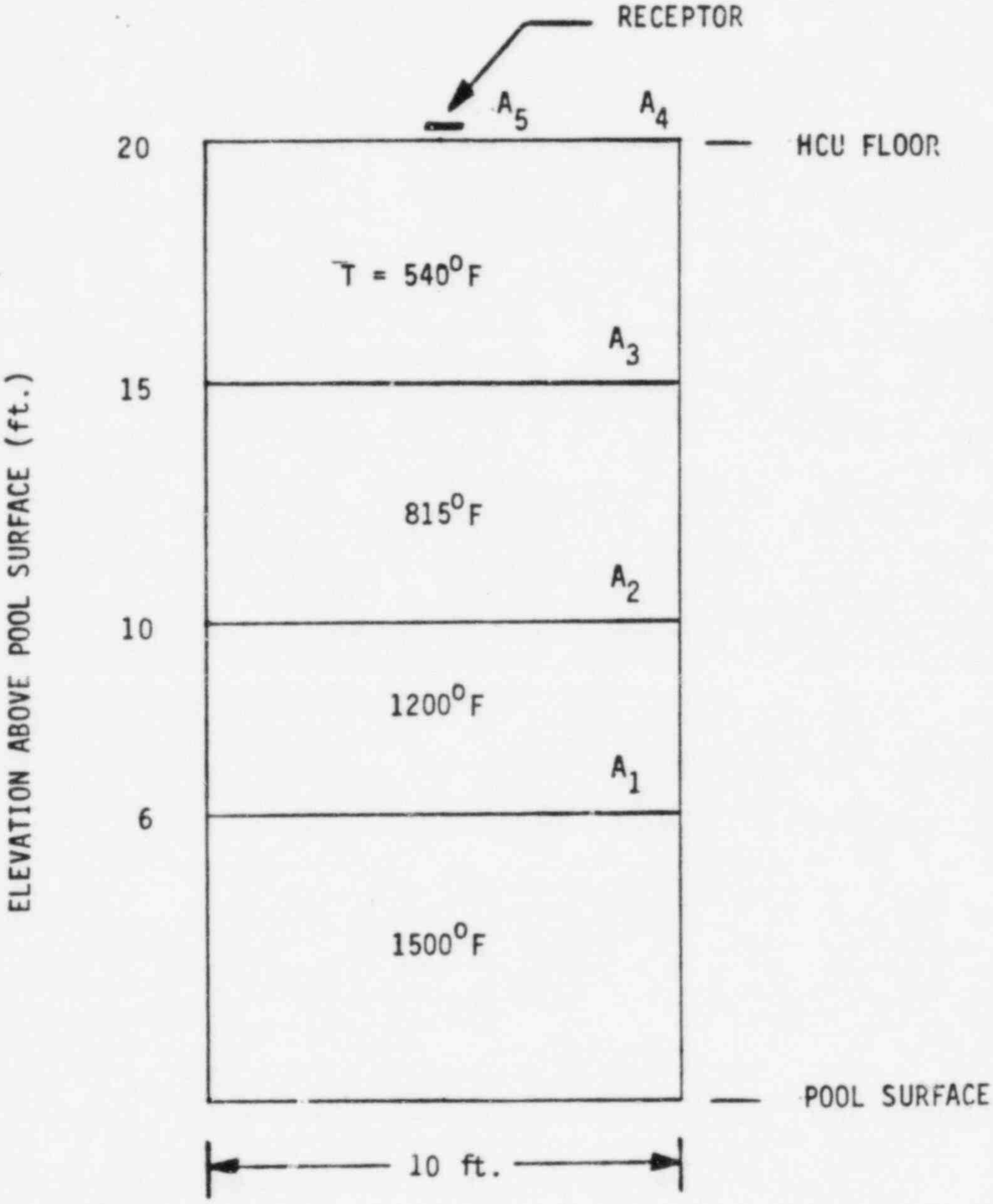


Figure 5--Model for Calculation of Radiation from Gas Plume (0.8 lb/s).

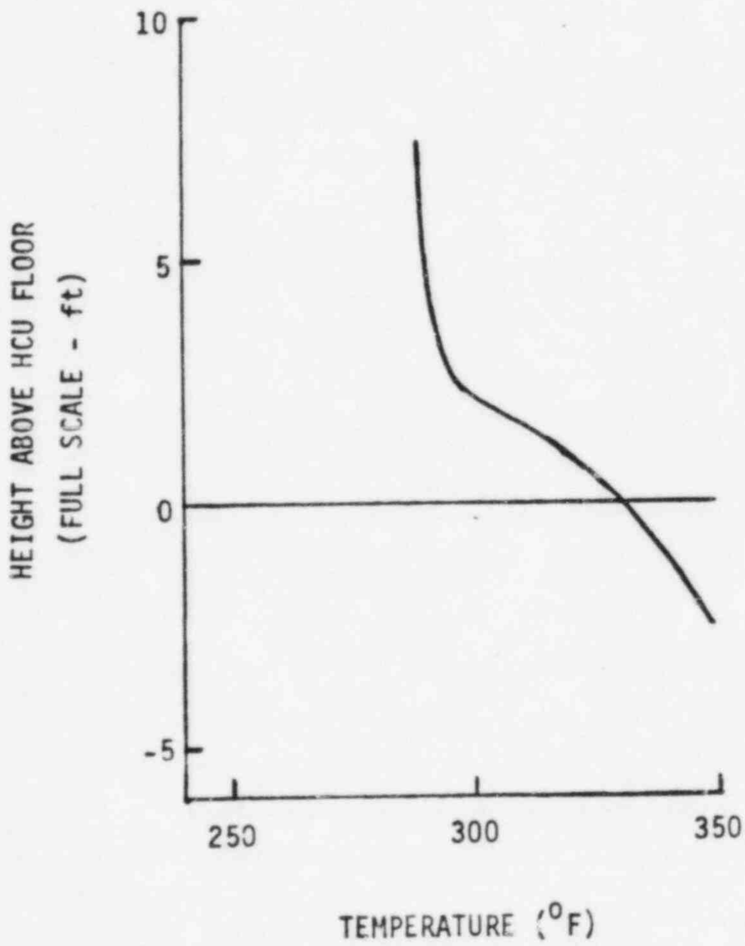


Figure 6--Vertical Temperature Distribution - 0.4 lb/s.

SUPPLEMENT TO EQUIPMENT SURVIVABILITY
TABLE OF CONTENTS

TABLES AND FIGURES

EQUIPMENT SURVIVABILITY
INTRODUCTION

Mississippi Power & Light Company's submittal AECM-83/0455 included a discussion of our bases for evaluating equipment survivability. A preliminary list of essential equipment in the drywell was provided in response to NRC staff questions. This submittal provides additional information to assist the staff in their review of GGNS containment and drywell equipment survivability.

Revised thermal environment data has been supplied by EPRI to characterize the 1/20th scale facility test results for a full scale equivalent release rate of 0.4 lbm/sec. Table 1 summarizes this information, which was used for the thermal response curves shown in Figures 3, 6, and 9. Later EPRI best estimate information, submitted as attachment 1 to AECM-83/0479, further reduces the thermal environment from that shown in this attachment.

The methodology used to model and calculate essential equipment response to a specified thermal environment represents the bulk of this attachment. Figures describing the models and preliminary results are included.

A review of essential equipment located in the containment and drywell has been in progress for some time. Tables 2 and 3 provide supplementary information on system and component identification, component function, as well as physical location. These lists are being further evaluated against the proposed Final Rule for Degraded Core requirements. The components deleted from the list which was submitted in MP&L letter AECM-82/26 either were not sensitive components, such as hydrogen analyzer tubing, or were shown by preliminary review to not be required to comply with the proposed final rule. Only two other items, MSIV limit switches and drywell pressure instrumentation were removed from the original list. Further evaluation of electrical penetrations, hatches and personnel locks is still in progress.

Operator failure analysis is also in progress for both air-operated and motor-operated valves. Should the analysis demonstrate that once specified valves have functioned in the preburn environment, and their failure will not result in change in position, then these valves may be removed from the essential equipment list for which postburn survivability must be demonstrated.

Supplementary Figures 10 and 11 are also provided to locate equipment in the containment.

Follow-up discussions will be held with the NRC staff after which a final equipment evaluation submittal will be scheduled.

ESSENTIAL EQUIPMENT

EVALUATION METHODOLOGY

1.0 Essential Equipment

Three typical pieces of equipment have been selected to provide a basis upon which the effects of steady diffusion flames can be evaluated.

1.1 Hydrogen Igniter Assembly

The igniter assembly is an 8"x8"x6" stainless steel box with a removable access cover. It houses the transformer and terminal strip mounted on a stainless steel plate and also contains the associated wiring. The glow plug extends out through the front and is assumed to be insulated from the box by the glow plug mount. The igniter assembly is modelled as mounted on a 1" thick carbon steel plate. No credit is taken for shielding effects from supporting members or pool swell shields. The assembly is shown in Figure 1. The igniter assemblies are assumed to be exposed to the most severe burn environment located just below the HCU floor elevation. For this evaluation, the transformer is considered as the limiting component with a survival temperature of 400°F.

1.2 Pressure Transmitter

Pressure transmitters consist of the sensing module and the associated electronic circuitry. The electronic components are enclosed in a cast aluminum housing which is connected to the stainless steel sensing module housing. Pressure transmitters are mounted on instrument racks at the HCU floor elevation and the racks have pool swell shields along their base. The pressure transmitter is shown in Figure 4. For this evaluation, the electronics housing

is considered as the limiting component with a qualification temperature of 303°F.

1.3 Air Operated Valves

Air operated valves are controlled by air actuators which consist of a junction box, limit switches, filters and a solenoid valve. Due to the exposure of the solenoid valve, to the steady diffusion flame it is evaluated as the limiting component with a qualification temperature 330°F. The solenoid valve consists of a cylindrical stainless steel housing 2½" in diameter which encloses a copper coil and steel core assembly. The housing is connected to the stainless steel valve body assembly by a threaded coupling. Solenoid valves are assumed to be exposed to the most severe burn environment below the HCU floor elevation. The solenoid is shown in Figure 7.

2.0 Thermal Environment Data

The data used to evaluate the thermal response of the selected equipment was obtained from full-scale estimates of the 1/20-scale test results. The relevant data for equipment evaluation consists of the gas temperature profile, flow velocity, and radiant heat fluxes from both the flame and hot grating at the HCU floor elevation. Each piece of equipment is evaluated based on data in the most severe burning location of the test facility and the results are shown in Figures 3, 6, and 9. The containment sprays are credited only with lowering the free containment gas temperature and the effects of spray impingement on equipment is conservatively neglected. The radiant heat flux data is assumed to act as a steady-state heat load to the appropriate equipment surfaces independent of equipment temperature. The equipment is assumed to be at an initial temperature of 135°F.

3.0 Analytical Evaluation Models

For each piece of equipment analyzed, an appropriate HEATING-3[2] model was constructed. These models, besides considering heat transfer from the burn environment through the component, also consider radiative and convective heat transfer across air spaces. Best estimate thermal properties were utilized in these models; however, the geometry was chosen to maximize the thermal response of the limiting component. The level of detail developed for each model was dependent on the geometry of the component, material makeup and boundary conditions. Generally, a two-dimensional analysis, as used here, has been shown to provide an appropriate margin of conservatism to the actual equipment thermal response.

3.1 Hydrogen Igniter Assembly

The 2-D heat transfer model for the hydrogen igniter assembly is shown in Figure 2. The boundary conditions include forced convection to all outer surfaces from the gas temperature at 2.5 ft. below the HCU elevation. In addition, the radiant heat fluxes from the flame and hot grating are applied to the bottom and top surfaces of the assembly, respectively. Radiation and natural convection are modelled between the box inner surfaces and the transformer surfaces. The appropriate electrical heat load from igniter operation is included in the transformer region.

3.2 Pressure Transmitter

The 2-D heat transfer model for the pressure transmitter is shown in Figure 5. Included in the model is a representation of the instrument rack, to which the transmitter is mounted, and the pool swell shield attached to the bottom of the rack. The boundary

conditions included forced convection to all outer surfaces from the gas temperature at 0.5 ft. above the HCU elevation. The radiant heat flux from the flame is applied to the bottom surface of the pool swell shield and allowed to re-radiate to the bottom of the pressure transmitter. The surface emissivities, shape factors and gas absorptivities are selected so as to maximize heat transfer to the critical components. No credit is taken for decreased flow velocity past components due to obstructions.

3.3 Solenoid Valve

The 2-D heat transfer model for the solenoid valve is shown in Figure 8. The boundary conditions include forced convection to all outer surfaces from the gas temperature at 2.5 ft. below the HCU elevator. The radiant heat fluxes from the flame and hot grating are applied to the bottom and top surfaces of the solenoid, respectively. Radiation and natural convection are modelled between the internal surface of the solenoid housing and coil and the core rod. No credit is taken for shielding of the component from supporting members.

4.0 <u>Heat Transfer Methodology</u>

Heat transfer to the evaluated components is based on forced convection and radiation from the burn environment, conduction, natural convection and radiation within the component.

4.1 Forced Convection

Forced convection is based on flow past bluff bodies such as spheres, cylinders and plates[3]. A commonly used relation is the average heat transfer coefficient for flow past a cylinder.

$$\overline{Nu} = \frac{\overline{h}_c D_o}{K_f} = C\ Re^n = C\left(\frac{V\ D_o}{V_f}\right)^n$$

where

$\overline{Nu}$ = Nusselt number

$\overline{h}_c$ = average heat transfer coefficient

D_o = outside cylinder diameter

K_f = fluid thermal conductivity

Re = Reynolds number

V = free stream velocity

V_f = fluid kinematic viscosity

C,n = coefficients - functions of Re

Similarly, the heat transfer coefficient in the separated wake region behind a flat plate has been experimentally determined:

$$\overline{Nu} = \frac{\overline{h}_c D_o}{K_f} = .2\ Re^{2/3}$$

4.2 Natural Convection

Natural convection is calculated using the relation[4]:

$$h = h_c\ (\ T)^{h_e}$$

where,

T = temperature difference between the surface and fluid

h_c = coefficient of natural convection 6 function of surface orientation

h_e = exponent of natural convection (a function of surface orientation

4.3 Radiative Heat Transfer

Radiative heat transfer to the exterior surfaces of the equipment from the burn environment is modelled by applying the appropriate experimentally determined heat fluxes. Radiative heat transfer between air gaps is calculated by the relation:

$$Q_{1\rightleftarrows 2} = A_1 F_{1-2} T \left(T_1^4 - T_2^4\right)$$

where,

$Q_{1\rightleftarrows 2}$ = net rate of heat transfer between two surfaces

A_1 = radiative heat transfer area

F_{1-2} = radiative conductance (a function of surface emissivity, shape factor and surface orientation)

T_1, T_2 = surface temperatures

5.0 References

1. Report on Equipment Survivability for a Hydrogen Generation Event, letter from L. F. Dale (MP&L) to H. R. Denton (NRC) 1/19/82, Docket Nos. 50-416, 417 (AECM-82/26)

2. HEATING-3 - A UNIVAC 1110 Heat Conduction Program, ORNL-TM-3208 W. P. Turner and Simantov, February 1971

3. "Principles of Heat Transfer", F. Kreith, 3rd ed., Harper & Row

4. "Heat Transfer:, A. J. Chapman, 2nd ed. 1967

Table 1

Revised Thermal Environment Based on
1/20 Scale Test Data From .4 lbm/sec Hydrogen Flows

Temperature at HCU Floor	328°F
Temperature at 2.5' Below HCU Floor	350°F
Radiant Heat Flux Below HCU Floor	
Gas	3200 Btu/hr ft^2
Grating	260 Btu/hr ft^2
Radiant Heat Flux Above HCU Floor	
Gas	2200 Btu/hr ft^2
Grating	260 Btu/hr ft^2
Gas Velocity	26 ft/sec

H2 IGNITER ASSEMBLY

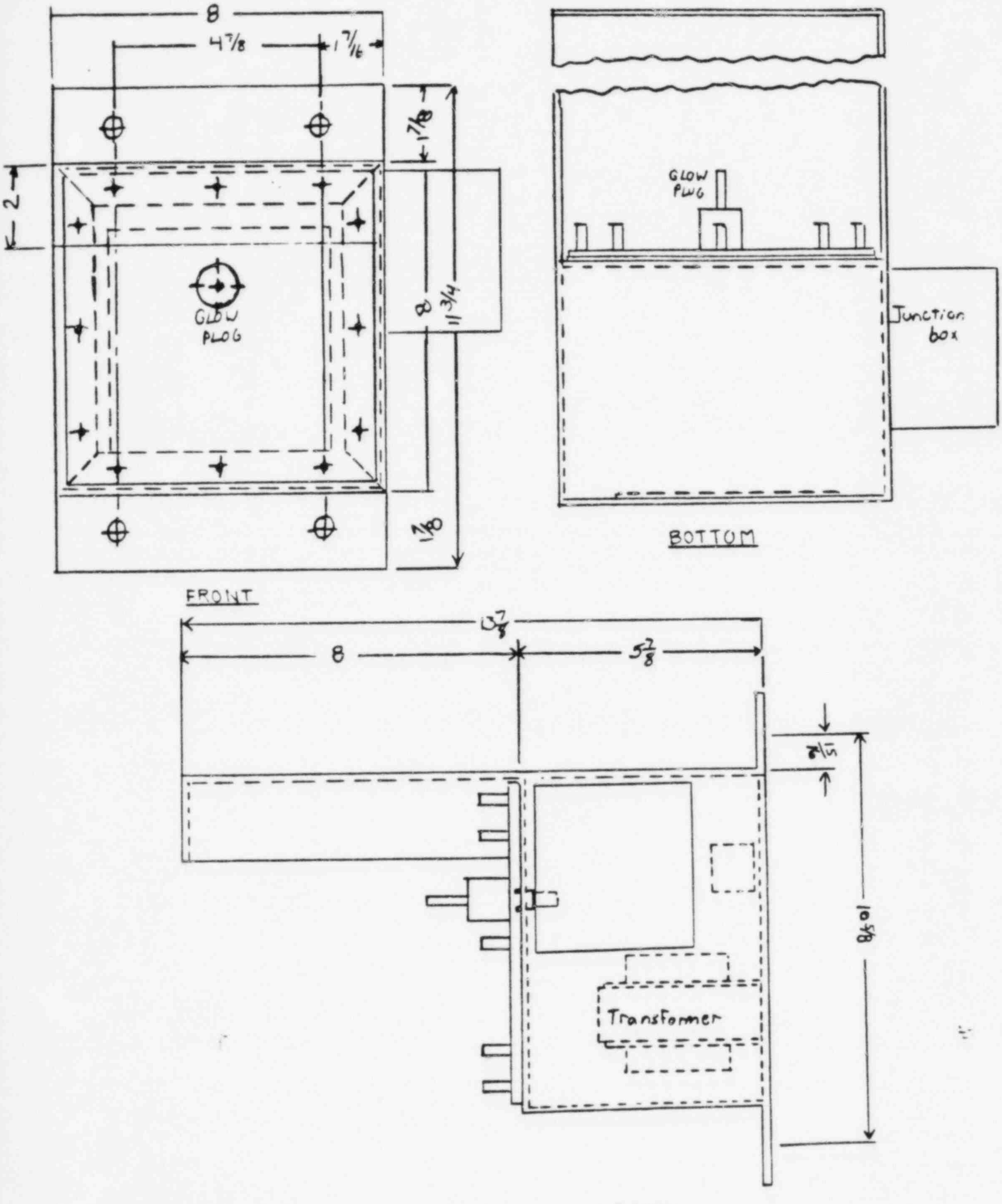


FIGURE 1

2-D IGNITER MODEL

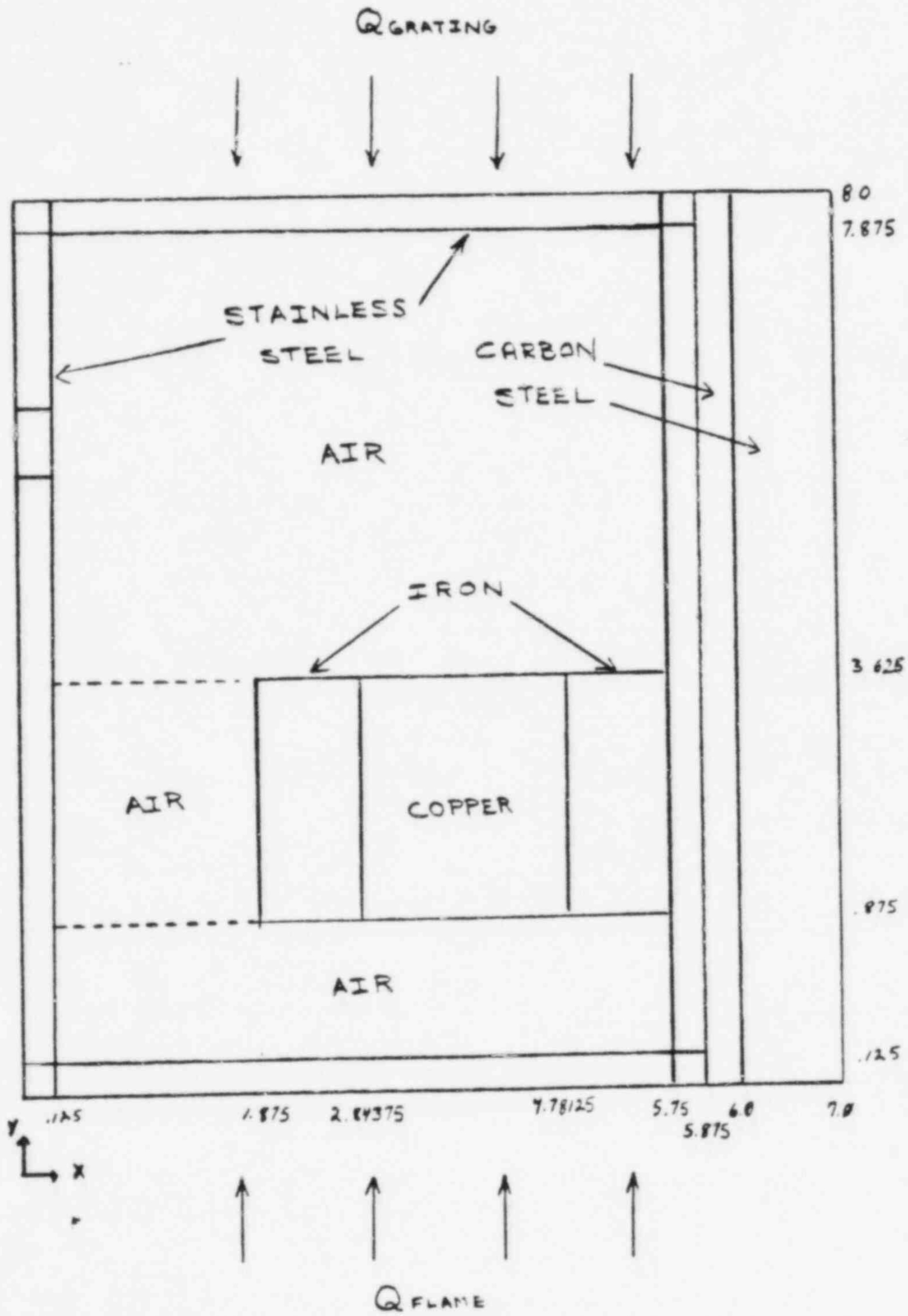
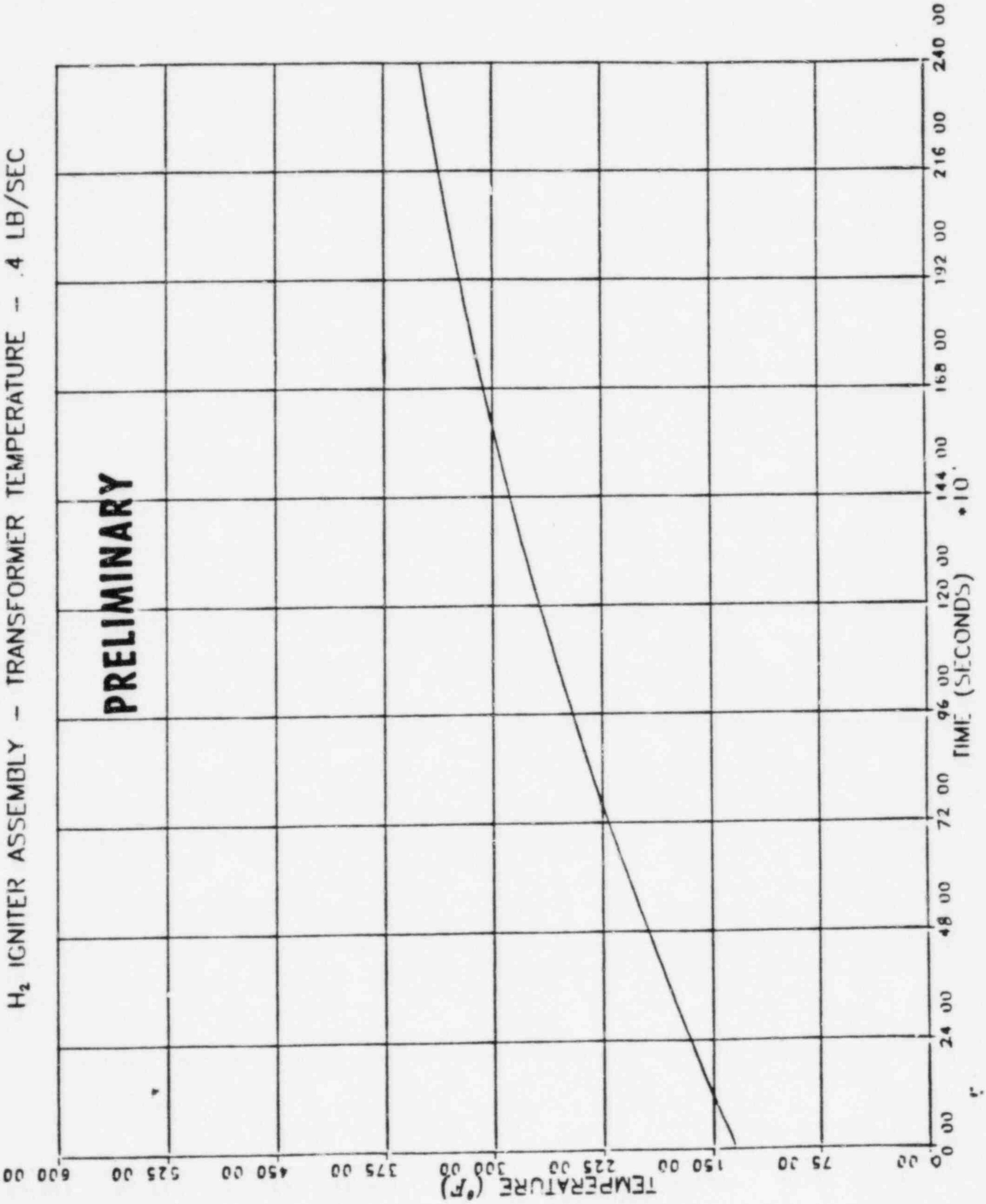


FIGURE 2



H2 IGNITER ASSEMBLY - TRANSFORMER TEMPERATURE - .4 LB/SEC
PRELIMINARY
0 00
24 00
48 00
72 00
96 00
120 00
144 00
168 00
192 00
216 00
240 00
TIME (SECONDS) *10
00
75 00
150 00
225 00
300 00
375 00
450 00
525 00
600 00
TEMPERATURE (°F)

FIGURE 3

PRESSURE TRANSMITTER

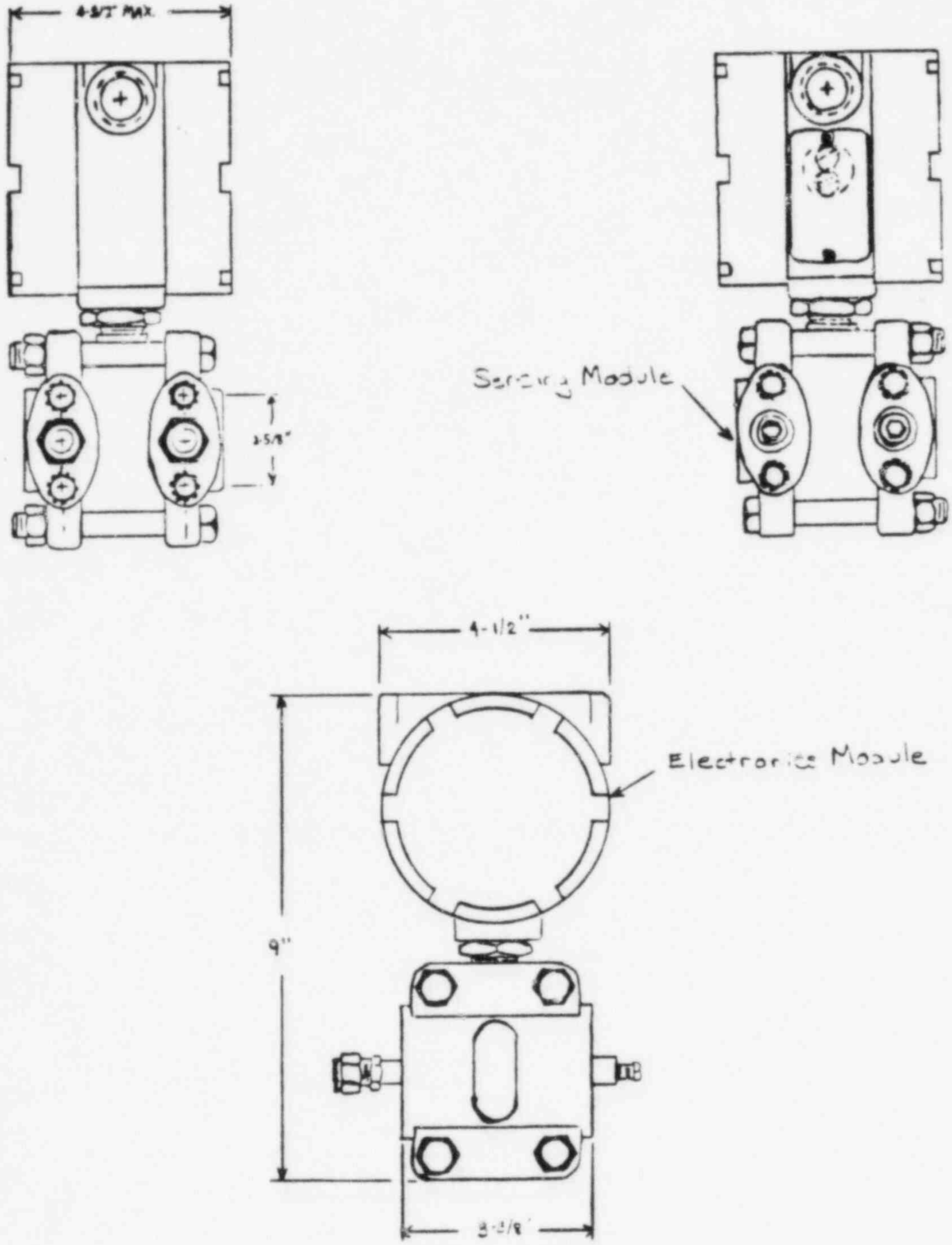


FIGURE 4

2-D PRESSURE TRANSMITTER MODEL

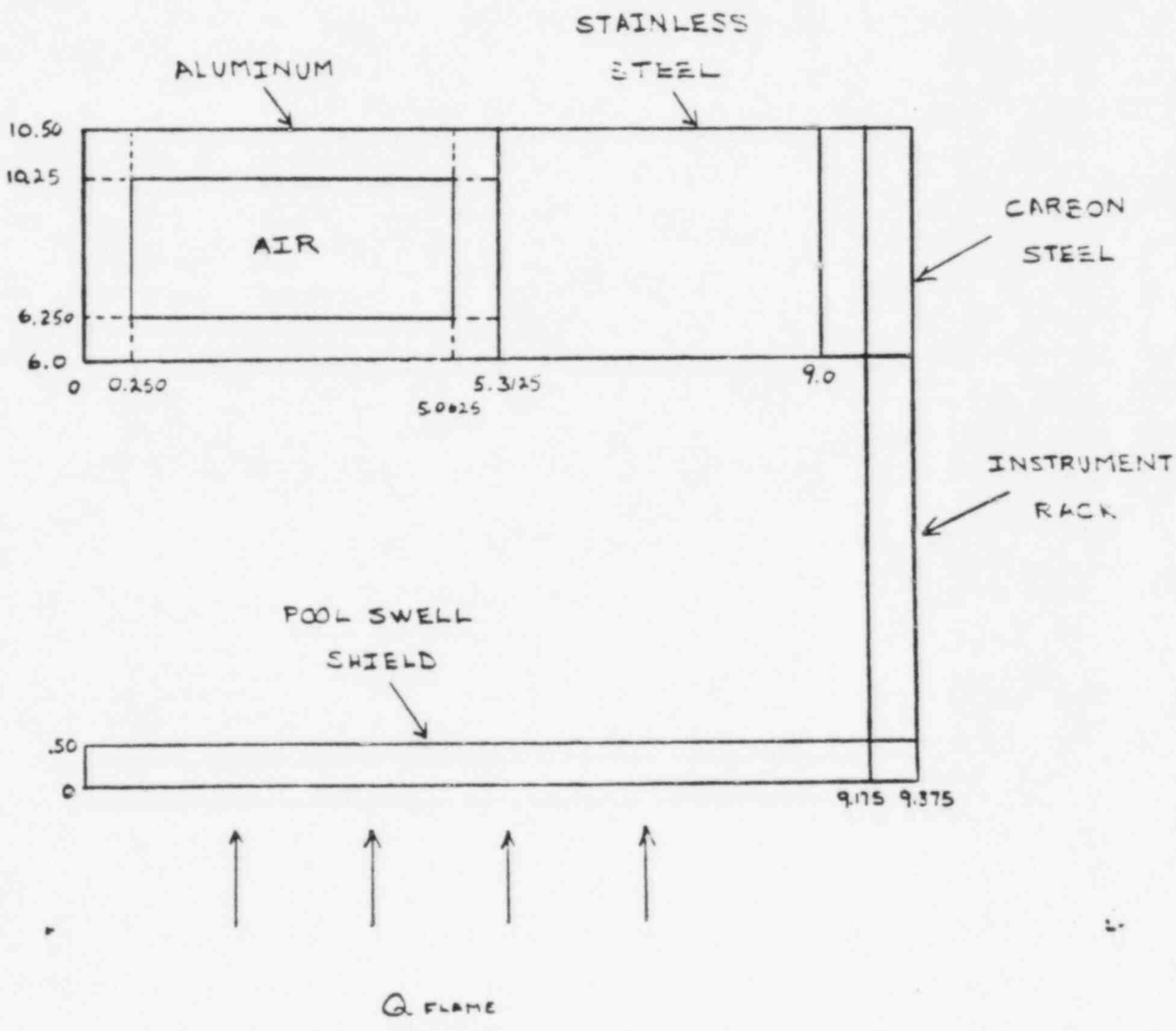
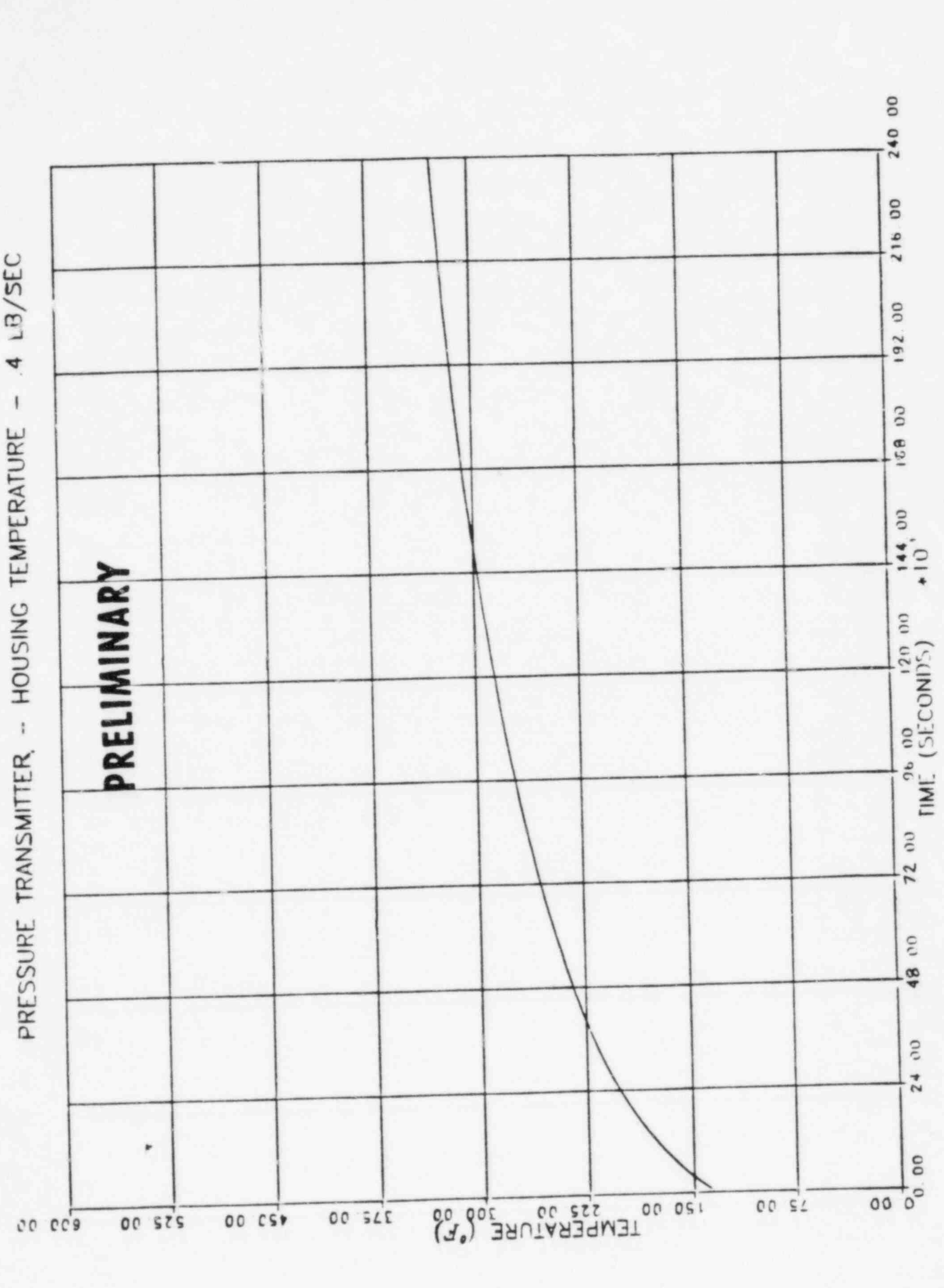


FIGURE 5



PRESSURE TRANSMITTER -- HOUSING TEMPERATURE - 4 LB/SEC
PRELIMINARY
TIME (SECONDS)
*10'
0.00
24 00
48 00
72 00
96 00
120 00
144 00
168 00
192 00
216 00
240 00
TEMPERATURE (°F)
00
75 00
150 00
225 00
300 00
375 00
450 00
525 00
600 00

FIGURE 6

SOLENOID VALVE

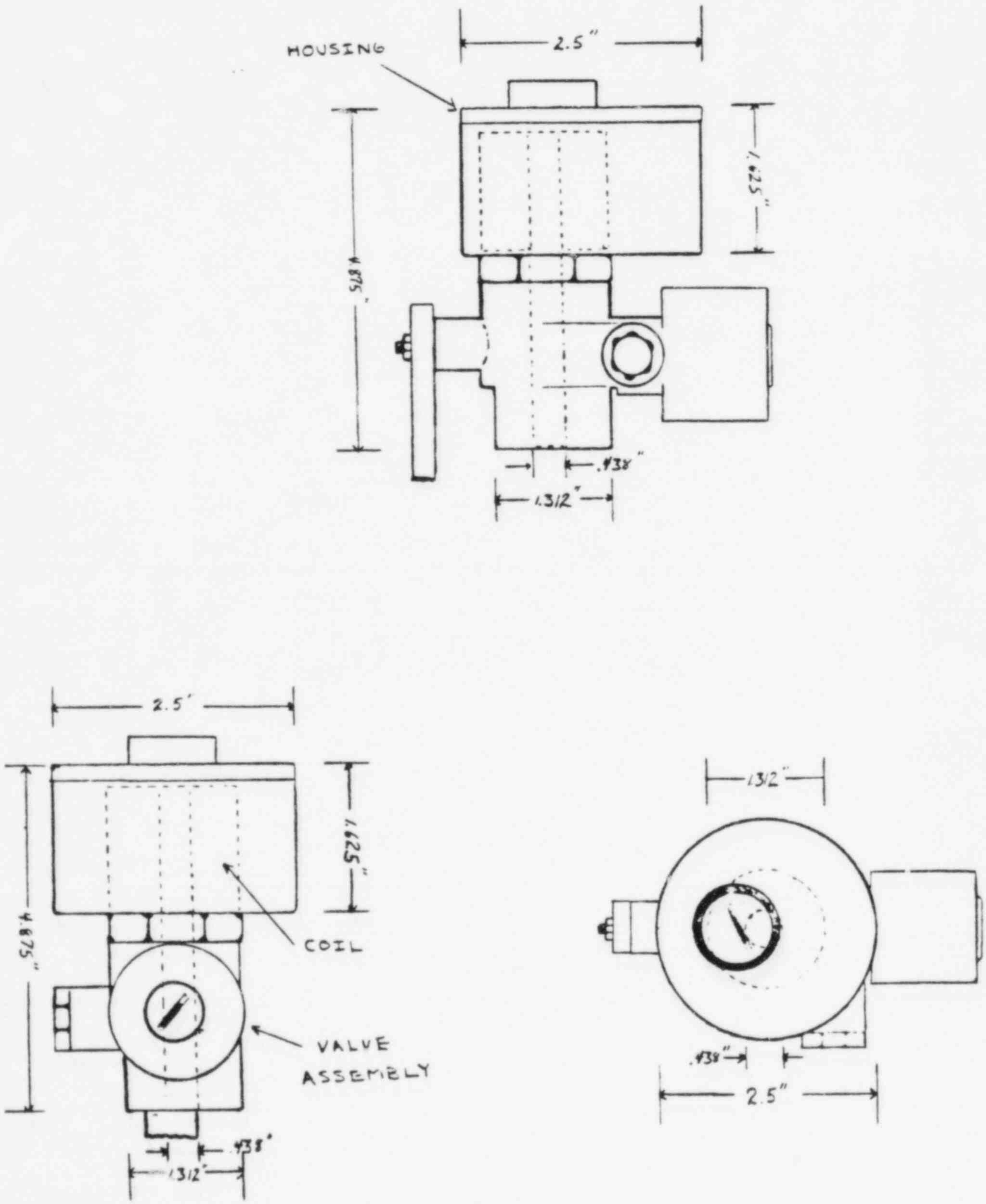


FIGURE 7

2-D SOLENOID MODEL

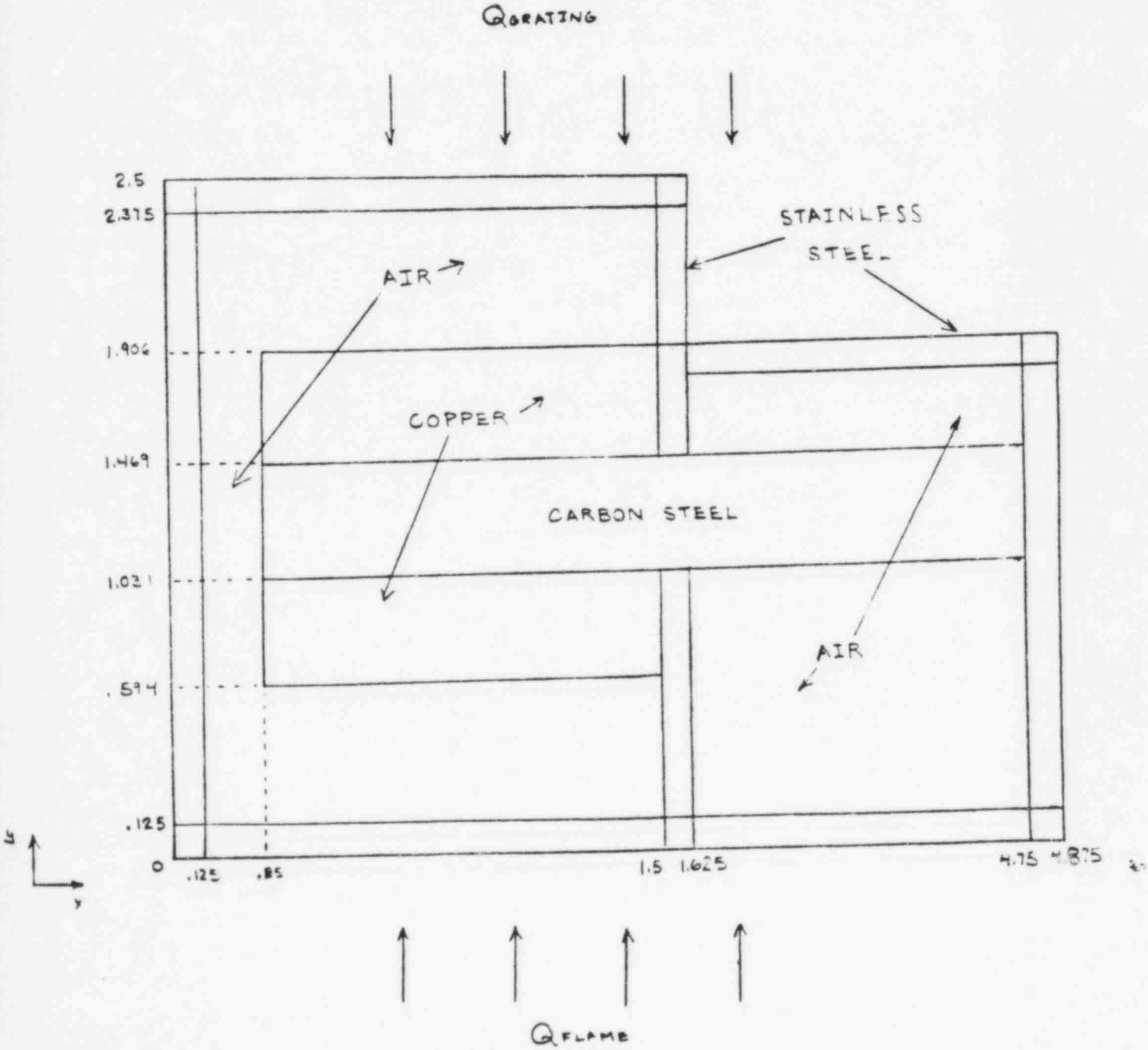


FIGURE 8

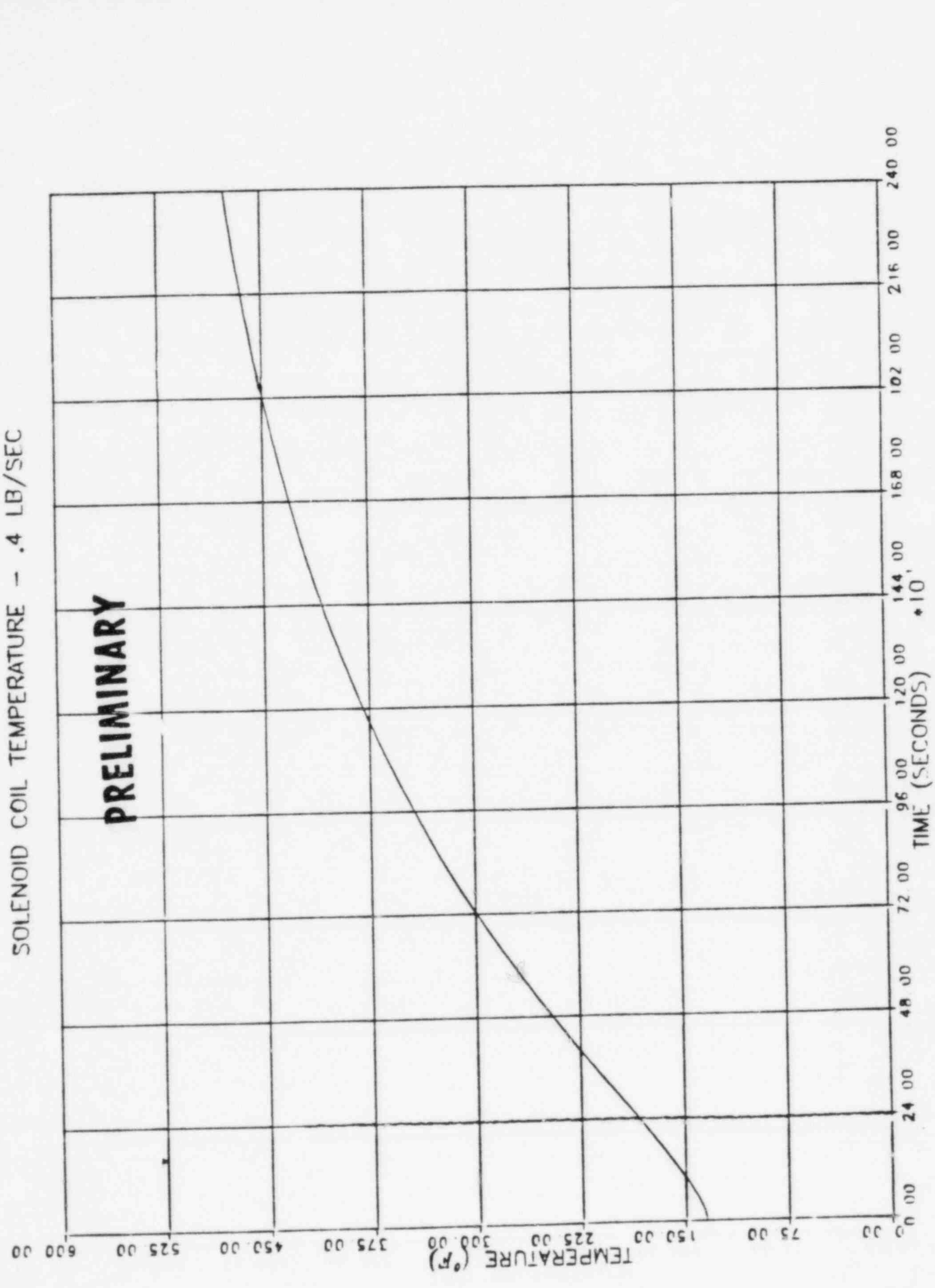

SOLENOID COIL TEMPERATURE - .4 LB/SEC
PRELIMINARY
TIME (SECONDS)
TEMPERATURE (°F)
0 00
24 00
48 00
72 00
96 00
120 00
144 00
168 00
216 00
240 00
75 00
150 00
225 00
300 00
375 00
450 00
525 00
600 00

FIGURE 9

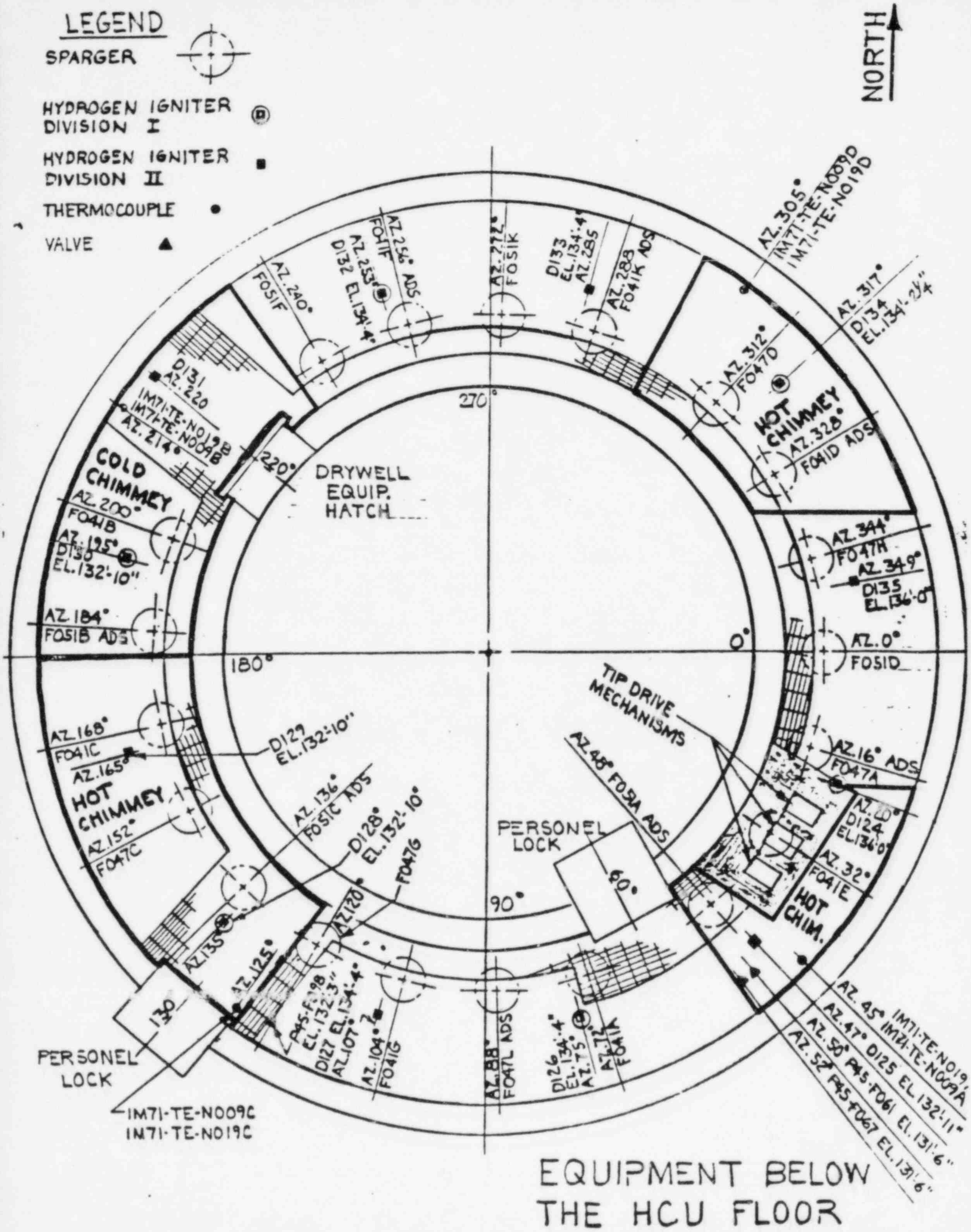

LEGEND
SPARGER
HYDROGEN IGNITER DIVISION I
HYDROGEN IGNITER DIVISION II
THERMOCOUPLE
VALVE
NORTH
DRYWELL EQUIP. HATCH
COLD CHIMMEY
HOT CHIMMEY
HOT CHIM.
PERSONEL LOCK
TIP DRIVE MECHANISMS
270°
180°
90°
0°
220°
130
60°
IM71-TE-N009C
IM71-TE-N019C
EQUIPMENT BELOW THE HCU FLOOR

FIGURE 10

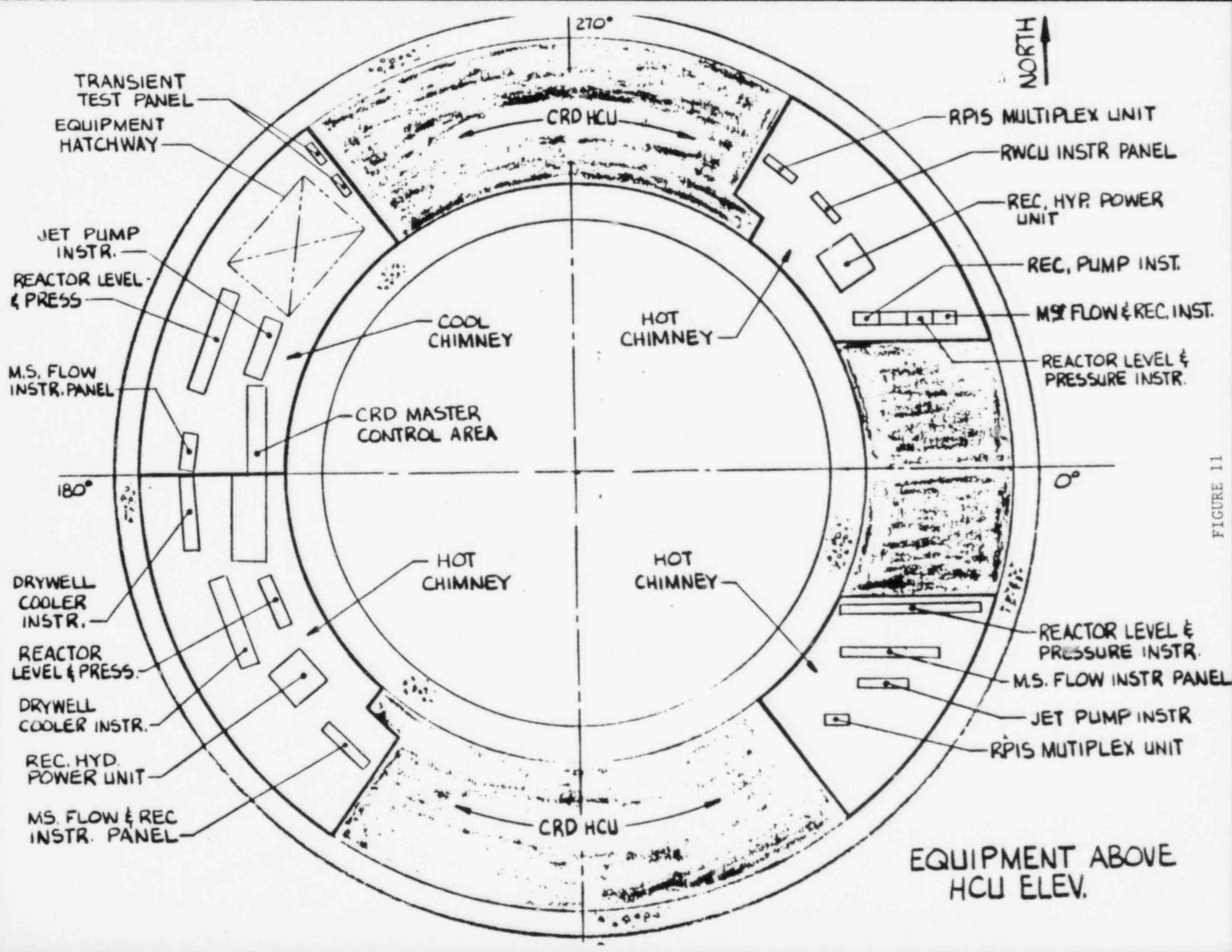

270°
NORTH
TRANSIENT TEST PANEL
EQUIPMENT HATCHWAY
CRD HCU
RPIS MULTIPLEX UNIT
RWCU INSTR PANEL
REC. HYP. POWER UNIT
REC. PUMP INST.
MS FLOW & REC. INST.
REACTOR LEVEL & PRESSURE INSTR.
JET PUMP INSTR.
REACTOR LEVEL & PRESS
COOL CHIMNEY
HOT CHIMNEY
M.S. FLOW INSTR. PANEL
CRD MASTER CONTROL AREA
180°
0°
DRYWELL COOLER INSTR.
HOT CHIMNEY
HOT CHIMNEY
REACTOR LEVEL & PRESS.
REACTOR LEVEL & PRESSURE INSTR.
M.S. FLOW INSTR PANEL
DRYWELL COOLER INSTR.
JET PUMP INSTR
RPIS MUTIPLEX UNIT
REC. HYD. POWER UNIT
MS. FLOW & REC INSTR. PANEL
CRD HCU
EQUIPMENT ABOVE HCU ELEV.

FIGURE 11

TABLE 2

ESSENTIAL EQUIPMENT INSIDE
CONTAINMENT (OUTSIDE DRYWELL)

System	Equipment Identification	Function	Elevation	Azimuth	Dist. from Center Line of Reactor	Comment
Residual Heat Removal Syst. (RHR)	E12-F042A (1)	LPCI-A	144'-3"	39	46'-0"	Motor-operated
	E12-F028A (1)	Cmtmt. Spray	170'-9"	30	59'-0"	Motor-operated
	E12-F037A (1)	FPCC Inter-tie	163'-6"	32	57'-0"	Motor-operated
	E12-F042B (3)	LPCI-B	137'-10"	325	59'-0"	Motor-operated
	E12-F028B (3)	Cmtmt. Spray	170'-9"	330	59'-0"	Motor-operated
	E12-F037B (3)	FPCC Inter-tie	163'-4"	331	57'-0"	Motor-operated
Combustible Gas Control System (CGCS)	E61-F010 (3)	Containment Isolation	173"-3"	330	59'-0"	Air-operated
	E61-F056 (3)	Containment Isolation	177'-9"	330	59'-0"	Air-operated
	E61-C003A	Recombiner	208'-10"	130	57'-0"	
	E61-C003B	Recombiner	208'-10"	330	57'-0"	
	E61-C001A	Purge Comp.	184'-6"	135	37'-0"	
	E61-C001B	Purge Comp.	184'-6"	300	33'-0"	
	E61-F004A	Post-LOCA Vacuum Relief	194'-0"	220	33'-0"	Swing Check Valve
	E61-F004B	Post-LOCA Vacuum Relief	194'-0"	220	33'-0"	Swing Check Valve
	E61-F005A	Post-LOCA Vacuum Relief	194'-0"	240	33'-0"	Motor-operated
	E61-F005B	Post-LOCA Vacuum Relief	194'-0"	240	33'-0"	Motor-operated
Fuel Pool Cooling & Cleanup System	G41-F044 (2)	Containment Isolation	201'-9"	152	59'-0"	Motor-operated
Containment Cooling System	M41-F012 (3)	Containment Isolation	173'-3"	334	59'-0"	Controlled by Solenoid Valves F531
	M41-F034 (3)	Containment Isolation	177'-9"	334	59'-0"	and F50, respectively

TABLE 2 (Cont'd)

ESSENTIAL EQUIPMENT INSIDE
CONTAINMENT (OUTSIDE DRYWELL)

System	Equipment Identification	Function	Elevation	Azimuth	Dist. from Center Line of Reactor	Comment
Component Cooling Water System	P42-F068 (2)	Containment Isolation	148'-6"	168	55'-0"	Motor-operated
Plant Service Water System (PSWS)	P44-F070	Containment Isolation	146'-6"	172	59'-0"	Motor-operated
Floor & Equip. Drains System	P45-F061 (4)	Containment Isolation	131'-6"	50	57'-0"	Air-operated
	P45-F067 (4)	Containment Isolation	131'-6"	52	57'-0"	Air-operated
	P45-F098 (4)	Containment Isolation	132'-3"	120	59'-0"	Air-operated
--		Containment Personnel Lock	208'-10" 120'-10"	140 130	62'-0" 62'-0"	
--		Equip. Hatch	166'-0"	240	62'-0"	
--		Level Transmitter	(5)	(5)	(5)	
--		Temperature Transmitter	(5)	(5)	(5)	
--		Pressure Transmitter	(5)	(5)	(5)	

NOTES:

(1) In open area near azimuth 32°, shown as hot chimney in 1/20 scale test.
(2) In open area near azimuth 152°, shown as hot chimney in 1/20 scale test.
(3) In open area near azimuth 312°, shown as hot chimney in 1/20 scale test.
(4) Underneath the concrete HCU floor near hot chimney.
(5) In various locations above the HCU floor.

BD2

TABLE 2 (Cont'd)

Equipment Qualification
Temperatures

Component	NUREG-0588 Qualification Temp	Duration
Pressure Transmitter	318°F	26 minutes
Level Transmitter (Model 1152)	350°F	10 minutes
D/W Purge Compressor Motor	192°F (A)	22 hours
Hydrogen Recombiner	316°F	330 days
M.O.V.	200°F (B)	200 hours
Control Cables	346°F	3 hours, 20 minutes
Instrument Cables	340°F	6 hours
Power Cables	346°F	3 hours, 20 minutes
Thermocouple Ext. Wire	340°F	5½ hours
Terminal Blocks	340°F	5½ hours

NOTES:

(A) After 22 hours in a 192°F ambient, the steady state temperatures of various components are substantially below the maximum recommended temperatures. It is concluded that a 200°F ambient is still acceptable.

(B) Equipment is exposed to accident environment for 30 days. Maximum temperature at 340°F.

TABLE 3

DRYWELL EQUIPMENT REQUIRED
TO SURVIVE A HYDROGEN BURN

System	Equipment Identification	Function	Elevation	Azimuth	Dist. from Center Line of Reactor	Comment
Combustible Gas Control System (CGCS)	E61-D106	Mitigate Hydrogen Generated in a Degraded Core Scenario	146'-3 7/8"	0	22'-10"	Location drawings are shown in the hydrogen control report, AECM-81/336, dated 8-31-81.
	E61-D107		145'-7"	63	29'-3"	
	E61-D108		146'-2"	120	29'-8"	
	E61-D109		147'-1"	180	26'-3"	
	E61-D110		148'-7"	240	29'-1 1/2"	
	E61-D111		145'-7"	313	25'-1 1/4"	
	E61-D112		160'-7 7/8"	0	27'-3 3/8"	
	E61-D113		160'-11 3/4"	60	29'-8 3/4"	
	E61-D114		160'-4"	135	27'-0 3/8"	
	E61-D115		160-11 1/2"	180	26'-10"	
	E61-D116		160'-6"	232	26'-1"	
	E61-D117		160'-6"	324	26'-4 5/8"	
	E61-D118		179'-0"	0	26'-4 5/8"	
	E61-D119		179'-0"	65	26'-3 3/4"	
	E61-D120		179'-0"	125	26'-3 3/4"	
	E61-D121		179'-0"	185	26'-3 3/4"	
	E61-D122		179'-0"	245	26'-3 3/4"	
	E61-D123		179'-0"	305	26'-3 3/4"	
Nuclear Boiler System (NBS)	B21-F016	Isola. Drain Valve	141'-3"	8	34'-6"	Motor-operated
	B21-F022A	Isola. Valve MSIV	150'-7"	8	31'-0"	Air-operated
	B21-F022B	Isola. Valve MSIV	150'-7"	340	31'-0"	Air-operated
	B21-F022C	Isola. Valve MSIV	150'-7"	20	31'-0"	Air-operated
	B21-F022D	Isola. Valve MSIV	150'-7"	352	31'-0"	Air-operated
	B21-F047A	ADS	154'-0"	34	22'-0"	Air-operated
	B21-F041D	ADS	154'-0"	315	21'-0"	Air-operated
	B21-F047L	ADS	154'-0"	53	27'-6"	Air-operated
	B21-F041F	ADS	154'-0"	288	26'-6"	Air-operated
	B21-F041K	ADS	154'-0"	304	27'-0"	Air-operated
	B21-F051A	ADS	154'-0"	45	22'-0"	Air-operated
	B21-F051B	ADS	154'-0"	272	25'-6"	Air-operated
	B21-F051C	ADS	154'-0"	77	26'-0"	Air-operated
	B21-F051D	SRV	154'-0"	327	21'-6"	Air-operated

TABLE 3 (Cont'd)

DRYWELL EQUIPMENT REQUIRED
TO SURVIVE A HYDROGEN BURN

System	Equipment Identification	Function	Elevation	Azimuth	Dist. from Center Line of Reactor	Comment
Reactor Core Isolation Cooling System	E51-F063	Isolation Valve	143'-2"	0	30'-0"	Motor-operated
	E51-F076	Isolation Valve	143'-2"	0	30'-0"	Motor-operated
Reactor Water Cleanup System	G33-F001	Isolation Valve	139'-5"	3	33'-0"	Motor-operated
	G33-F252	Isolation Valve	166'-10"	7	33'-0"	Motor-operated
Residual Heat Removal System	E12-F009	Isolation Check Valve - LPCI Injection	124'-7"	0	25'-0"	Motor-operated
	E12-F041A		140'-4"	39	30'-0"	Motor-operated
	E12-F041B		147'-6"	219	21'-6"	Motor-operated
	E12-F041C		148'-2"	141	21'-0"	Motor-operated
High Pressure Core Spray	E22-F005	Check Valve - HPCS Injection	153'-9"	120	19'-0"	Motor-operated
	E22-F006		153'-2"	30	19'-0"	Motor-operated
	D21-RE-N048A	Containment Monitoring Devices	161'-10"	0	36'-0"	Ref. Drawing J1508
	D21-RE-N048D		161'-10"	183	36'-0	Ref. Drawing J1508
	M71-TE-N008A	Temp. Elements	161'-10"	40	36'-0"	Ref. Drawing J1508
	M71-TE-N008B	Temp. Elements	161'-0"	250	36'-0"	Ref. Drawing J1508
	M71-TE-N008C	Temp. Elements	161'-0"	135	36'-0"	Ref. Drawing J1508
	M71-TE-N008D	Temp. Elements	161'-0"	310	36'-0"	Ref. Drawing J1508
	M71-TE-N013A	Temp. Elements	94'-6"	55	10'-7"	Ref. Drawing J1505
	M71-TE-N013B	Temp. Elements	94'-6"	225	10'-7"	Ref. Drawing J1505
	M71-TE-N013C	Temp. Elements	94'-0"	112	10'-3"	Ref. Drawing J1505
	M71-TE-N013D	Temp. Elements	94'-6"	280	10'-7"	Ref. Drawing J1505
Containment Isolation Valves Limit/ Position Switches		[See Valve Locations]				

TABLE 3 (Cont'd)

EQUIPMENT QUALIFICATION TEMPERATURES

Component	NUREG-0588 Qualification Temp	Duration
Hydrogen Igniters	330°F	3 hours
Transformer	400°F	--
Valves (E12-F009, G33-F001, G33-F252, E51-F063, B21-F016, E51-F076)	340°F	--
Valves (B21-F022A, B, C, & D)	330°F	1 hour
Valves (B21-F047, F041, F051)	349°F	4 days
Valves Limit/Position Switches, Excludes MSIVs	330°F	--
Power Cables	346°F	3 hours, 20 minutes
Control Cables	346°F	3 hours, 20 minutes
Instrument Cables	340°F	6 hours
Thermocouple Ext. Wire	340°F	5½ hours
Terminal Blocks	340°F	5½ hours
Instrumentation		
D21-RE-N048A, D	340°F	
M71-TE-N008A, B, C, D N013A, B, C, D	340°F	6 hours

SUPPLEMENT TO REVISED CLASIX-3 ANALYSES

TABLE OF CONTENTS

TABLES AND FIGURES

1. INTRODUCTION

A revised base case DC1 was prepared and submitted in AECM-83/0455 to respond to various NRC Staff questions and to reflect a more mechanistic approach to the analysis. Additional CLASIX-3 sensitivity runs have been prepared to complete this response. Table 1 compares these results with those previously submitted.

Evaluation of the CLASIX-3 model has continued in an attempt to make it as consistent as possible with actual plant operation and system response. Several changes have already been made in the code including timing and flow split due to ADS, time and volume of drawdown, options for heat transfer as well as treatment of condensation. Further evaluation of source inputs is in progress as well as a more mechanistic treatment of flow split. This will be accomplished by a more mechanistic March analysis. The revised MARCH analysis will, within the capabilities of the MARCH program, attempt to partition actual mass flow according to the reactor vessel pressure and the discharge pressure. After approximately 30 minutes, when ADS is actuated, the reactor vessel pressure will drop much more rapidly than in the MARCH results presently being used as the source term for steam and hydrogen release. In addition to this modification to the MARCH analysis, periodic reflood will be imposed to minimize calculated core melt. The present source term is based on 100% core melt and core slump into the bottom head. The objective of the new analysis will be to limit core melt to no more than 20%.

It is expected that this revised analysis, which will be more representative of a degraded core event, will result in reduced energy addition to the drywell, a different time response for hydrogen production, and reduced rate of hydrogen production. MARCH presently only treats unmitigated events, therefore this work will be coordinated with the EPRI BWR Heatup Code development which will address various reflood scenarios. These considerations, it is believed, will result in lower temperature and total energy addition to the drywell.

Equipment response analyses which utilize the MARCH data will be submitted after the CLASIX-3 mechanistic base case is prepared. It is believed that

these revised results will demonstrate the survivability of essential equipment in the drywell.

2. SUPPLEMENTARY INFORMATION

2.1 Vacuum Breakers

In the initial evaluation of the Combustible Gas Control System (CGCS), it was presumed that the purge compressors would provide sufficient differential head to preclude operation of the check valves in the by-pass line event when the containment pressure significantly exceeded the drywell pressure. Subsequent analysis has indicated that significant flow would pass through these lines. Even at only one psi differential, the check valve flow would be almost an order of magnitude greater than the flow through the compressor.

It was concluded that this could have an impact on transient results any time the containment pressure exceeded the drywell pressure. In the analyses reported in Reference (a) and the present analyses, this occurs at the time of the containment burn in the base case, as discussed in Reference (a), and in the two compressor case discussed later.

Simulation of the check valves in the by-pass lines around the compressors, was modeled as a separate, independent flow path. The net effect in the model is that there are three parallel flow paths with check valves and one or two, as appropriate, independent purge compressors.

The revised model of the CGCS was implemented and to evaluate the impact, the base case was restarted just prior to the containment burn. Pressure and temperature plots for the pertinent portion for the base case and revised model of the CGCS are shown in Figures 1-6 and Figures 7-12 respectively. The results are also tabulated in

Table 1 as DC7. The only significant impacts are on the peak pressure as surmised in Reference (a). Because of the pressure relief through the check valves, the peak pressures in the containment and wetwell are slightly mitigated. As a direct consequence the peak pressure in the drywell, which occurs as a result of the burn in the containment, is increased by 1.8 psi.

2.2 Two Compressor Case

The revised base case was rerun with two air compressors to evaluate the effect of the additional air flow on the transient results. The revised model of the CGCS system was also used for this evaluation. The results of the transient analysis are shown in Figures 13-33 inclusive. Pertinent results are also presented in Table 1.

The most significant impact of the two compressor configuration is that the added flow provides sufficient oxygen to the drywell to reach combustible limits at approximately 5500 seconds into the transient. In the base case, there are no burns in the drywell until after cessation of hydrogen generation because there is insufficient oxygen. In the two compressor case after the first burn and until near the end of hydrogen generation, ignition is limited by insufficient hydrogen.

At the first burn in the drywell, the temperature rises rapidly expelling most of the gaseous mass out of the drywell volume. After the burn, the temperature, and consequently the pressure, in the drywell drops rapidly and ingests air from the containment through the check valves and from the wetwell through the vents in the suppression pool. From this point until near the end of hydrogen generation, the burning is limited by hydrogen concentration.

The major impact of operation of 2 compressors is the burning in the drywell and the corresponding increase in the drywell temperature.

2.3 Beam Length

As a result of the NRC concern over the magnitude of the beam length used in the radiant heat transfer in the drywell, MP&L has reevaluated the method of calculating the beam length. Using the Chemical Engineers' Handbook, Reference (b), the beam length can be calculated from

BL = 3.5 V/A

Where:

BL = beam length

V = volume

A = area of walls

Based on the net free volume and the boundary walls, the beam length is found to be 24.29 ft. If the internal grating and steel floors are included, the beam length is reduced to 11.08 feet. To evaluate the importance of the magnitude of the beam length, a portion of the two compressor cases was rerun with the beam length reduced from the original 48.67 feet in the drywell to 20 feet.

The result for the pertinent portion of the two compressor case and the same portion with the reduced beam length are shown in Figures 34-39 and Figures 40-45 respectively. Pertinent values are listed in Table 1. The only significant effect of the decrease in the beam length is slight increase in the peak pressures created by the burn.

3. REFERENCES

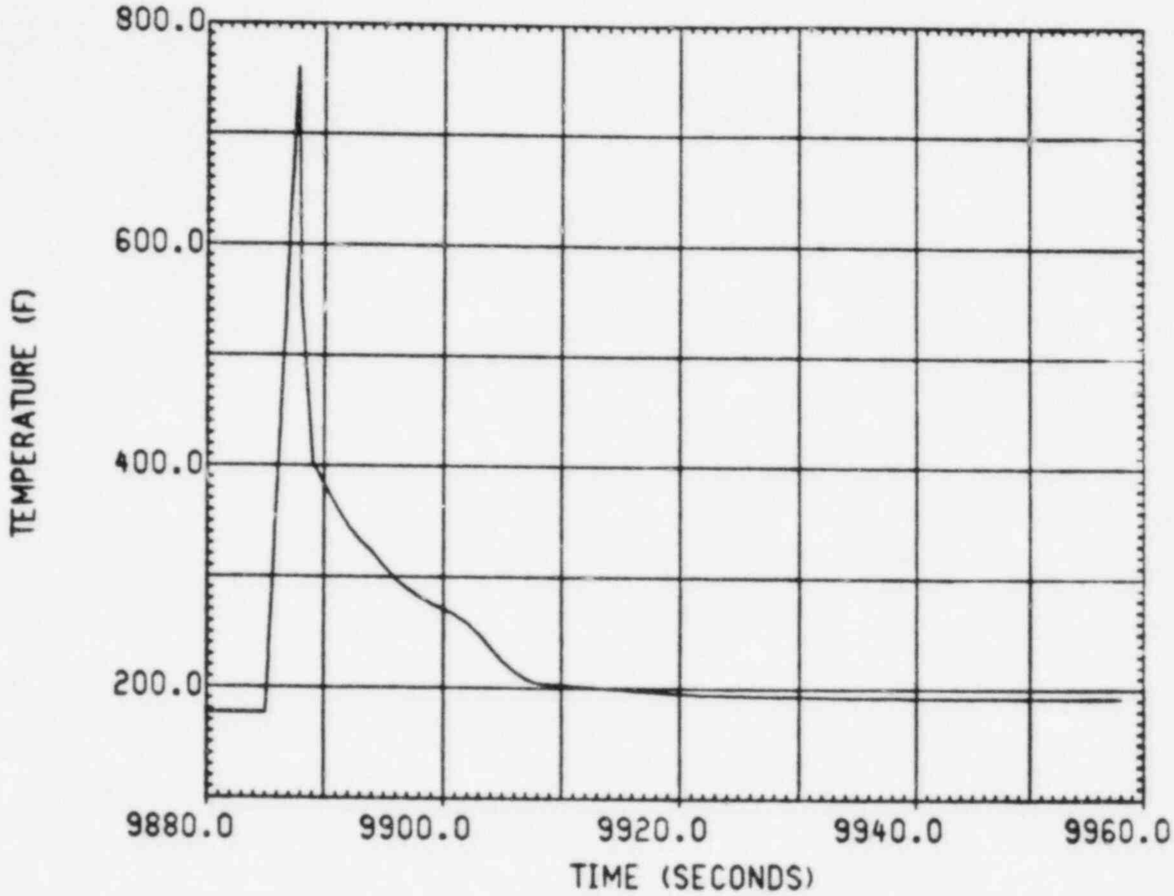
a. Letter number AECM-83/0455, dated August 13, 1983, from Mr. L. F. Dale to Mr. H. R. Denton.

b. Perry, R. H. and Chilton, C. H., Chemical Engineer's Handbook, 5th Ed. 1973 p 10-56.

TABLE 1
GRAND GULF RESULTS SUMMARY

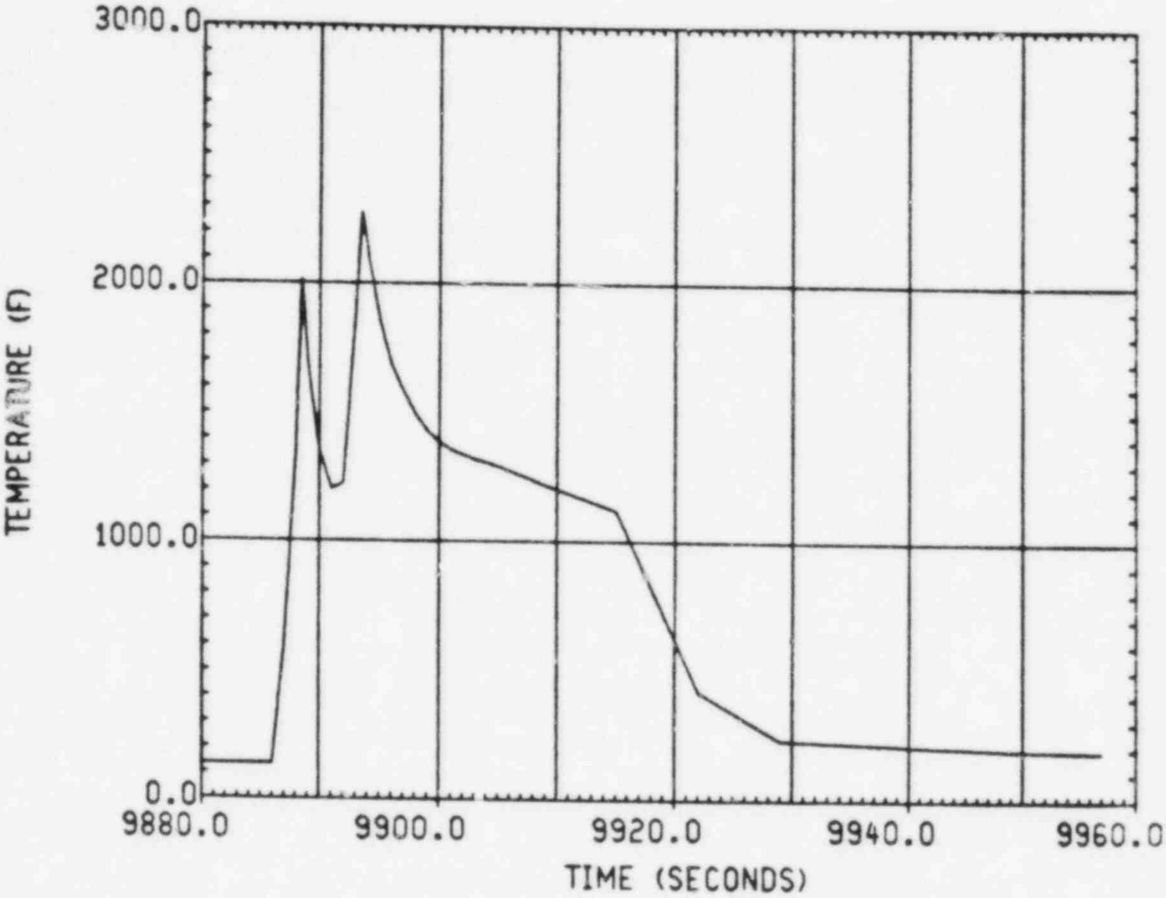
DESCRIPTION	DA4 * MOD MARCH 50/50 SPLIT-20M 2 CGCS COMP-20M IGN-20M DMP-30M DRAWDOWN-30M 1 SPY TRN WW C-O 8/85	DC1 MOD MARCH 70/30 SPLIT-30M 1 CGCS COMP-20M IGN-20M DMP-30M 1 SPY TRN WW C-O 8/85 DRAWDOWN-123M REV HT	DC2 CONTINUOUS BURN	DC3 NO SPLIT	DC4 DRAWDOWN-128M	DC5 2 CGCS COMP 1050 CFM EA	DC5 BL=48.67 FT	DC6 BL=20.00 FT	DC1 1 VB	DC7 3 VB
TRANSCIENT TIME (SECONDS)	0-12300	0-11010	0-8010	0-2410	0-10010	0-7807	5500-5780	5500-5780	9880-9960	9880-9960
NUMBER OF BURNS										
DW**	0 [1]	0 [1]	(1)	-	0 [1]	7	1	1	[1]	[1]
WW	26 [6]	52 [4]	51	-	52 [4]	40	3	3	[2]	[2]
CT	0 [1]	0 [1]	0	-	0 [1]	0	0	0	[1]	[1]
TOTAL H_2 BURNED (LBM)										
DW	0 [104]	0 [98]	95	-	0 [102]	451	96	97	[98]	[98]
WW	1233 [319]	1517 [208]	1479	-	1496 [200]	1402	101	103	[127]	[126]
CT	0 [587]	0 [484]	0	-	0 [496]	0	0	0	[484]	[483]
H_2 REMAINING (LBM)										
DW	712 [240]	569 [197]	488	-	583 [213]	201	74	74	[203]	[206]
WW	21 [15]	28 [18]	59	-	35 [13]	89	47	47	[16]	[16]
CT	629 [114]	499 [92]	492	-	499 [94]	471	217	215	[87]	[87]
PEAK TEMPERATURE (°F)										
DW	296 [707]	323 [760]	356	326	323 [807]	1269	1223	1225	[760]	[760]
WW	1110 [2295]	1192 [2274]	1192	125	1192 [2380]	1195	1071	1057	[2274]	[2280]
CT	196 [860]	176 [898]	175	85	173 [902]	186	170	172	[898]	[895]
PEAK PRESSURE (PSIG)										
DW	12.3 [16.3]	14.1 [14.0]	14.1	9.1	14.3 [14.7]	15.0	15.0	17.0	[14.0]	[15.8]
WW	11.9 [31.6]	11.8 [30.7]	11.7	2.5	9.1 [31.3]	9.9	8.5	9.1	[30.7]	[30.4]
CT	11.7 [32.1]	9.1 [30.7]	9.0	2.5	6.9 [31.3]	7.5	6.7	6.8	[30.7]	[30.5]

[ ] - VALUES DUE TO EXTENSION PAST END OF HYDROGEN RELEASE
( ) - CONTINUOUS BURN
* MOD MARCH - ASSUMED CONSTANT RATE OF 1 LB/SEC AFTER CORE SLUMP
CGCS - COMBUSTIBLE GAS CONTROL SYSTEM
SPLIT - WETWELL/DRYWELL FLOW DIVISION FOR H_2, STEAM AND ENERGY RELEASES
IGN - IGNITERS
DMP - UPPER POOL DUMP
SPY TRN - SPRAY TRAIN
WW C-O - WETWELL CARRYOVER
REV HT - REVISED HEAT TRANSFER
VB - VACUUM BREAKER
BL - BEAM LENGTH
** DRYWELL, WETWELL AND CONTAINMENT ARE ABBREVIATED AS DW, WW AND CT



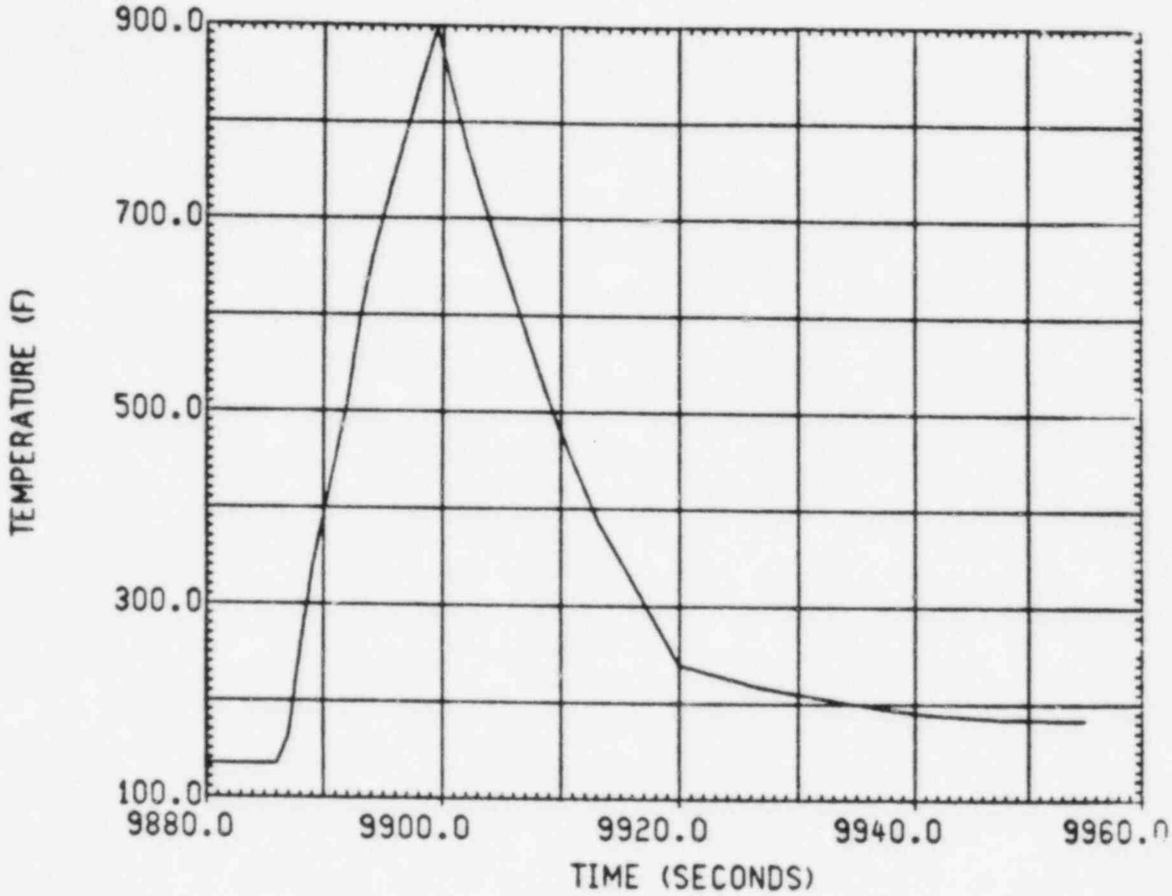
70/30 DRYWELL BREAK BASE CASE
GRAND GULF NUCLEAR STATION
DRYWELL TEMPERATURE

FIGURE 1



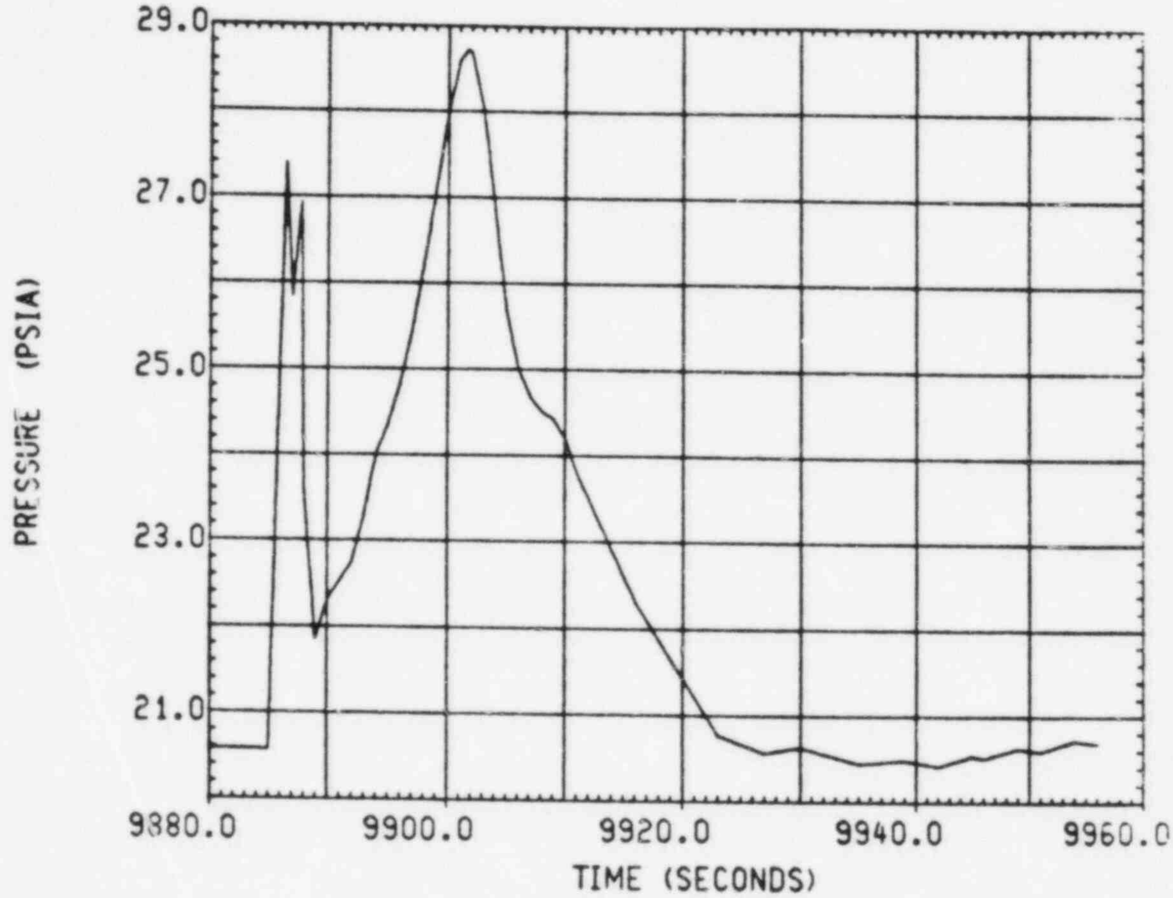
70/30 DRYWELL BREAK BASE CASE
GRAND GULF NUCLEAR STATION
WETWELL TEMPERATURE

FIGURE 2



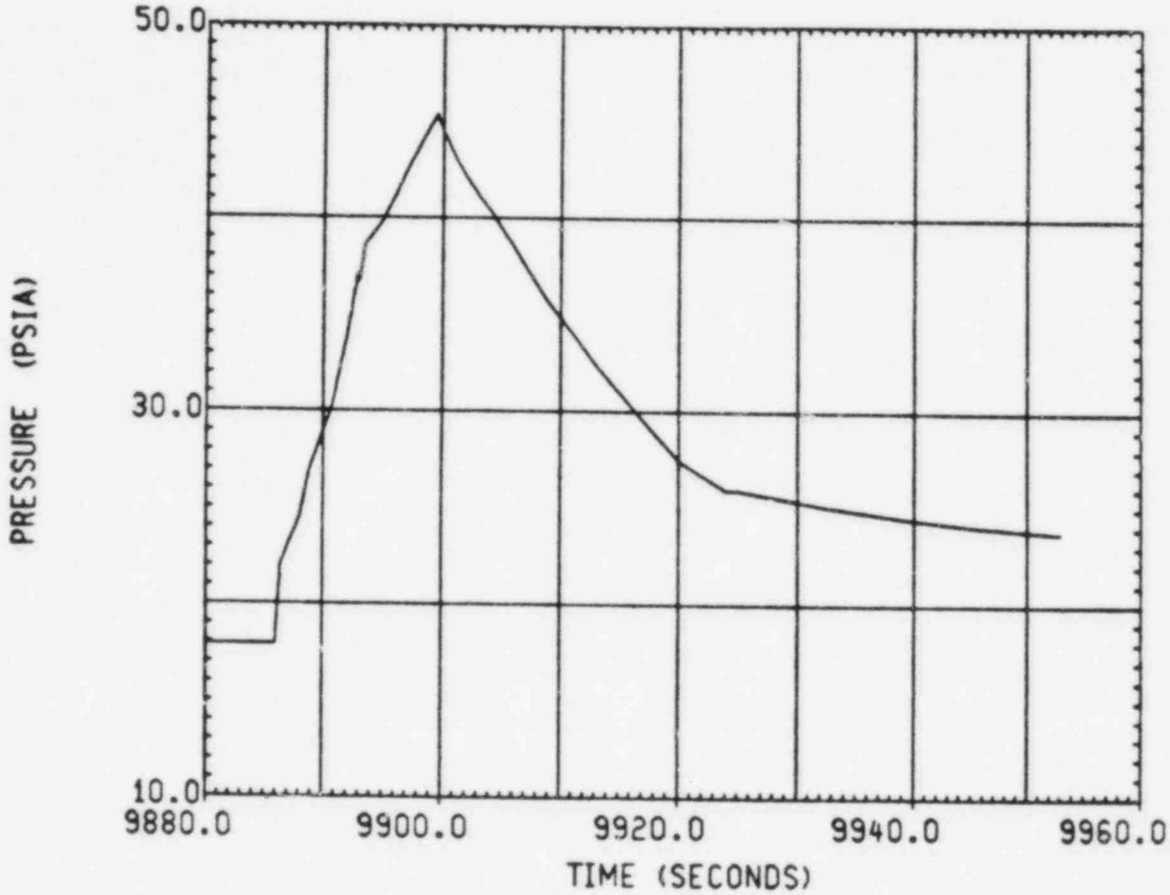
70/30 DRYWELL BREAK BASE CASE
GRAND GULF NUCLEAR STATION
CONTAINMENT TEMPERATURE

FIGURE 3



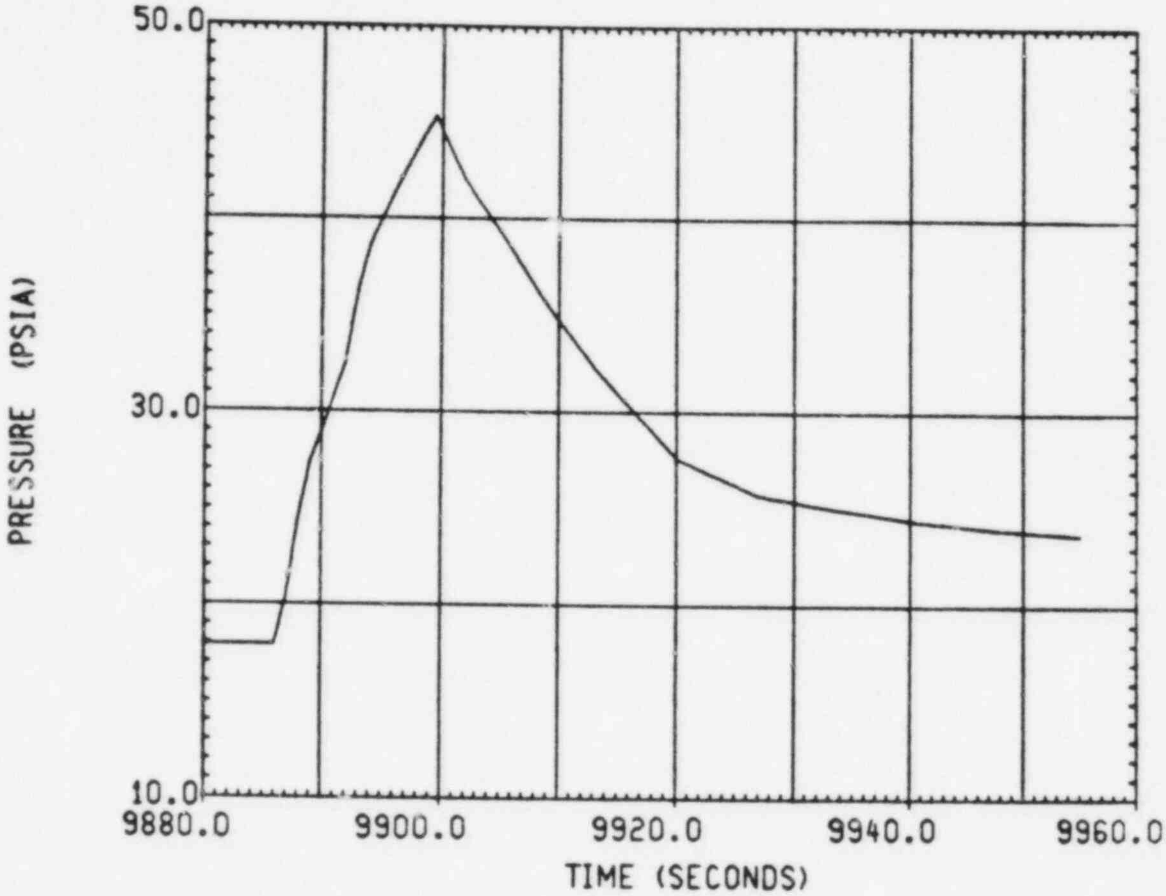
70/30 DRYWELL BREAK BASE CASE
GRAND GULF NUCLEAR STATION
DRYWELL PRESSURE

FIGURE 4



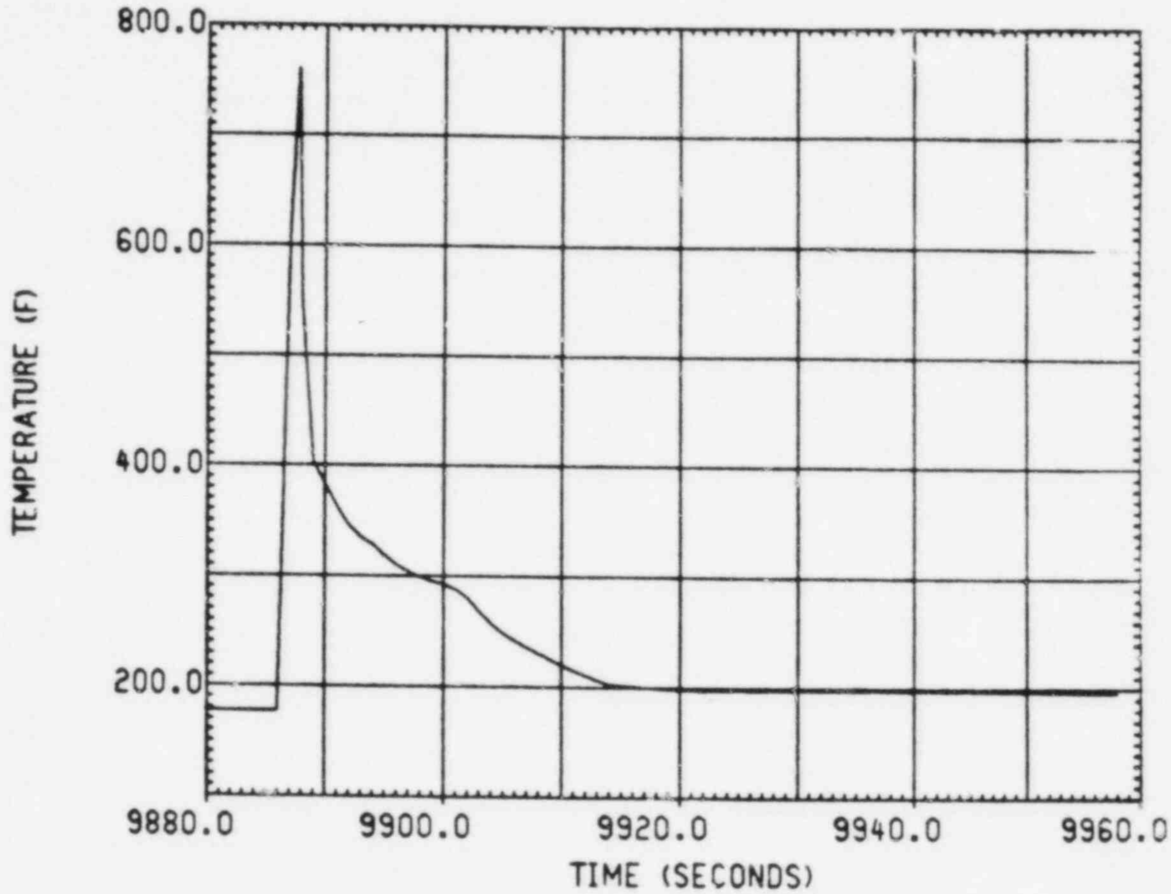
70/30 DRYWELL BREAK BASE CASE
GRAND GULF NUCLEAR STATION
WETWELL PRESSURE

FIGURE 5



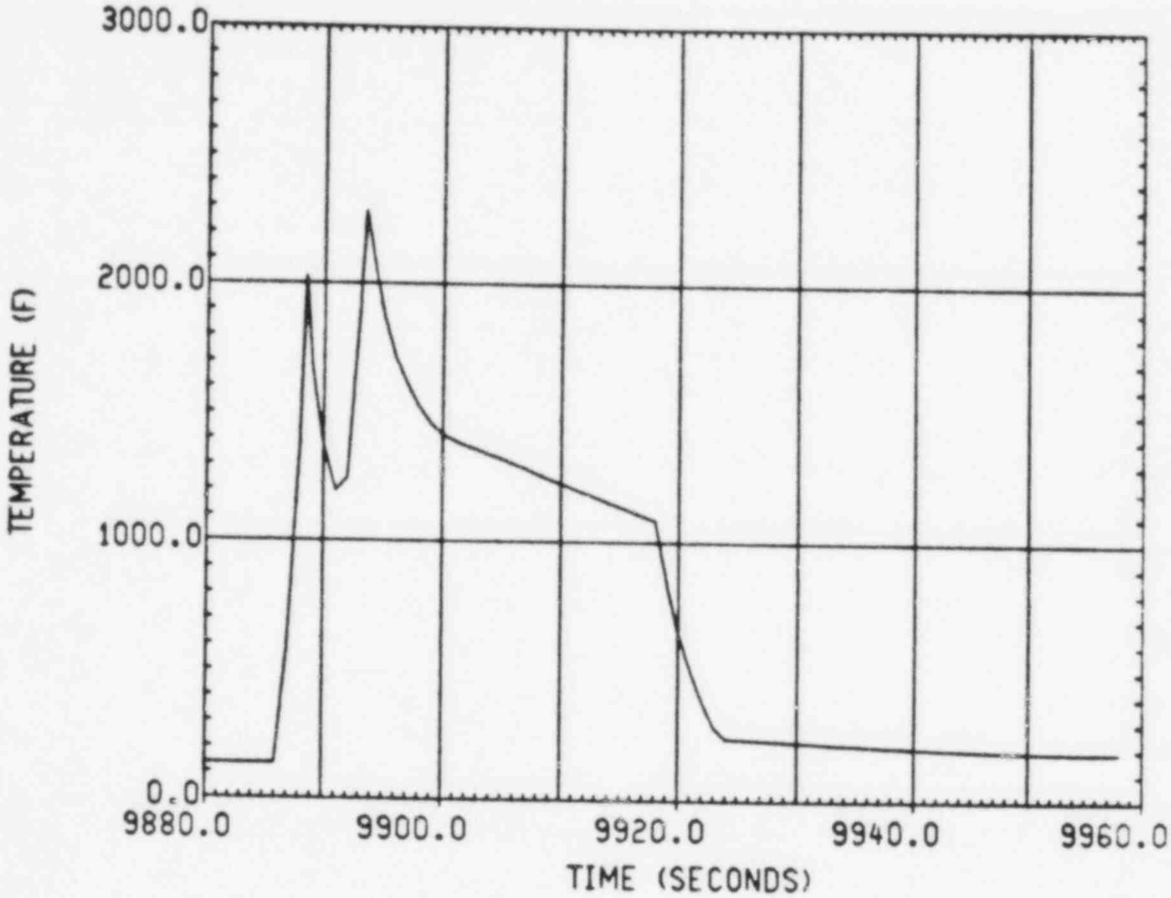
70/30 DRYWELL BREAK BASE CASE
GRAND GULF NUCLEAR STATION
CONTAINMENT PRESSURE

FIGURE 6



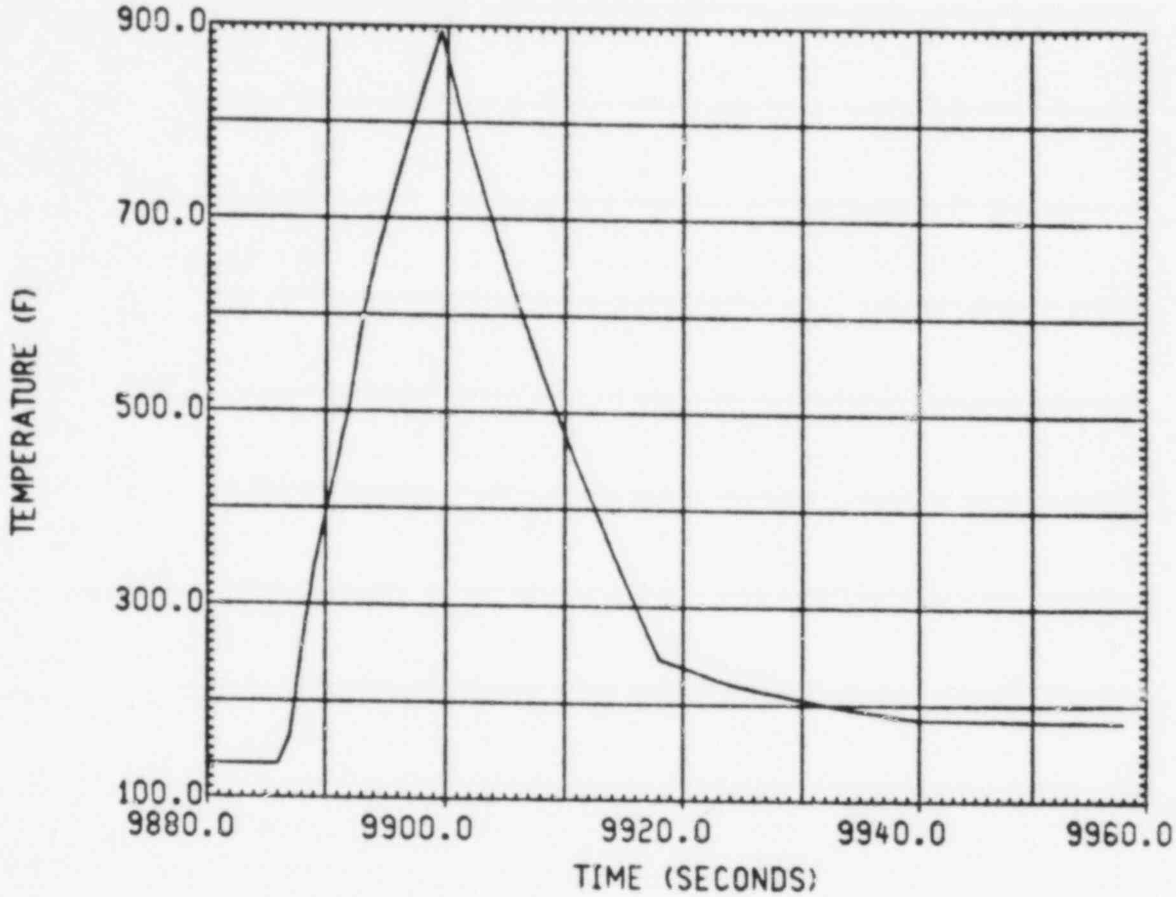
70/30 DRYWELL BREAK BASE CASE NEW VB
GRAND GULF NUCLEAR STATION
DRYWELL TEMPERATURE

FIGURE 7



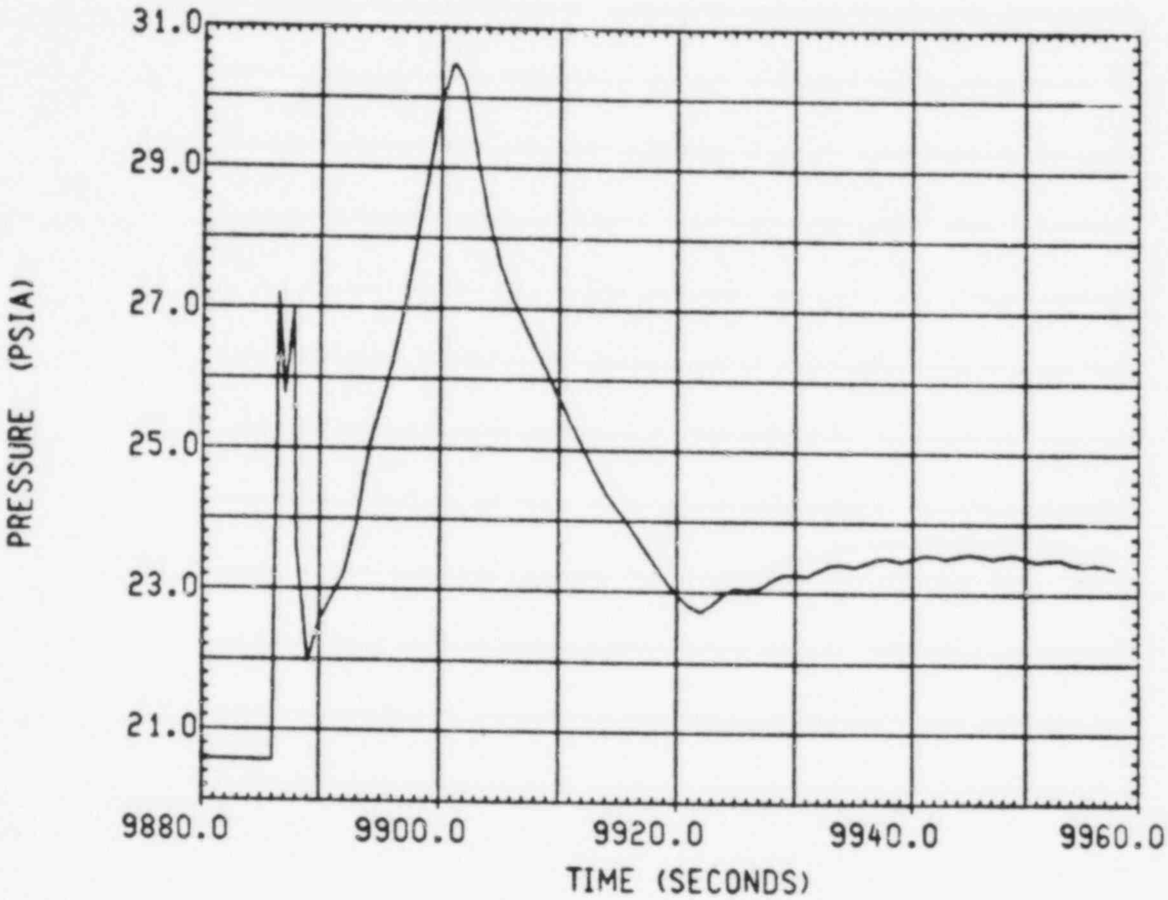
70/30 DRYWELL BREAK BASE CASE NEW VB
GRAND GULF NUCLEAR STATION
WETWELL TEMPERATURE

FIGURE 8



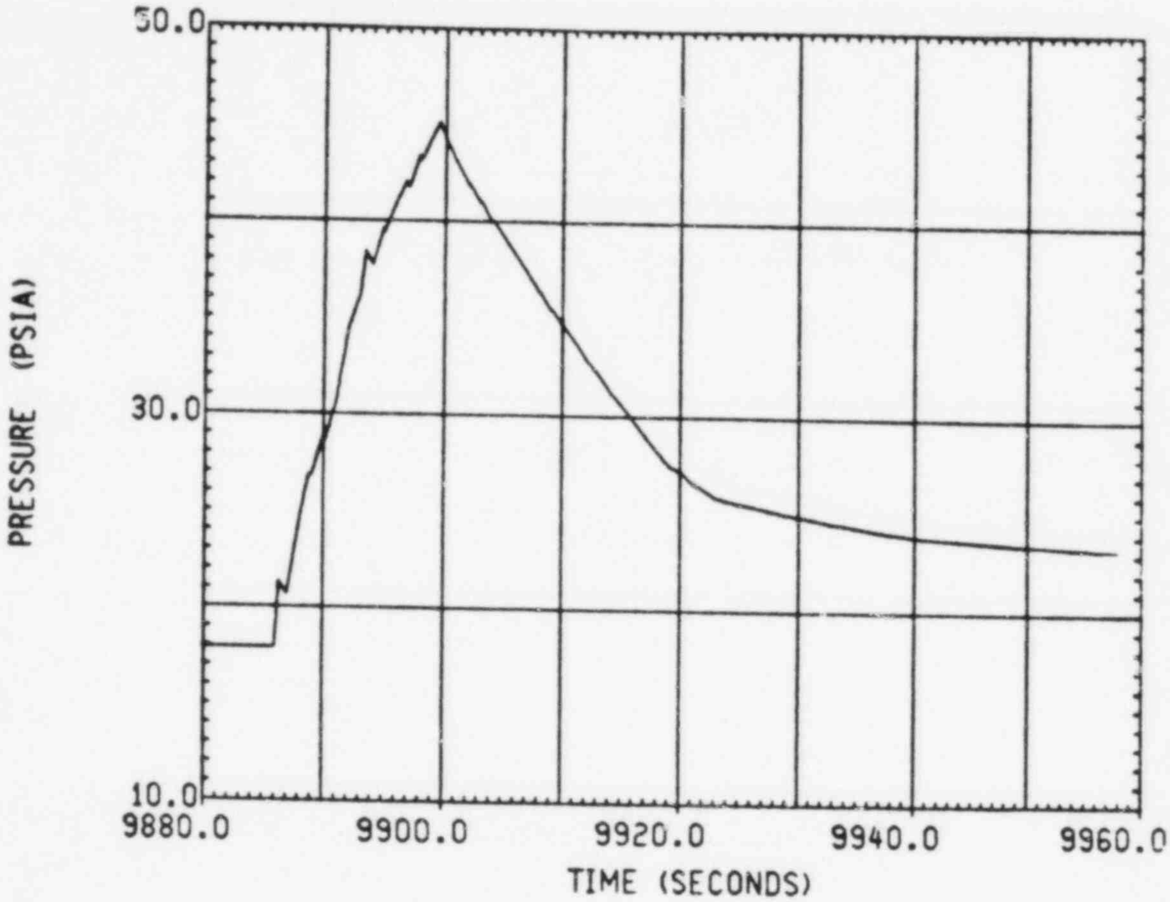
70/30 DRYWELL BREAK BASE CASE NEW VB
GRAND GULF NUCLEAR STATION
CONTAINMENT TEMPERATURE

FIGURE 9



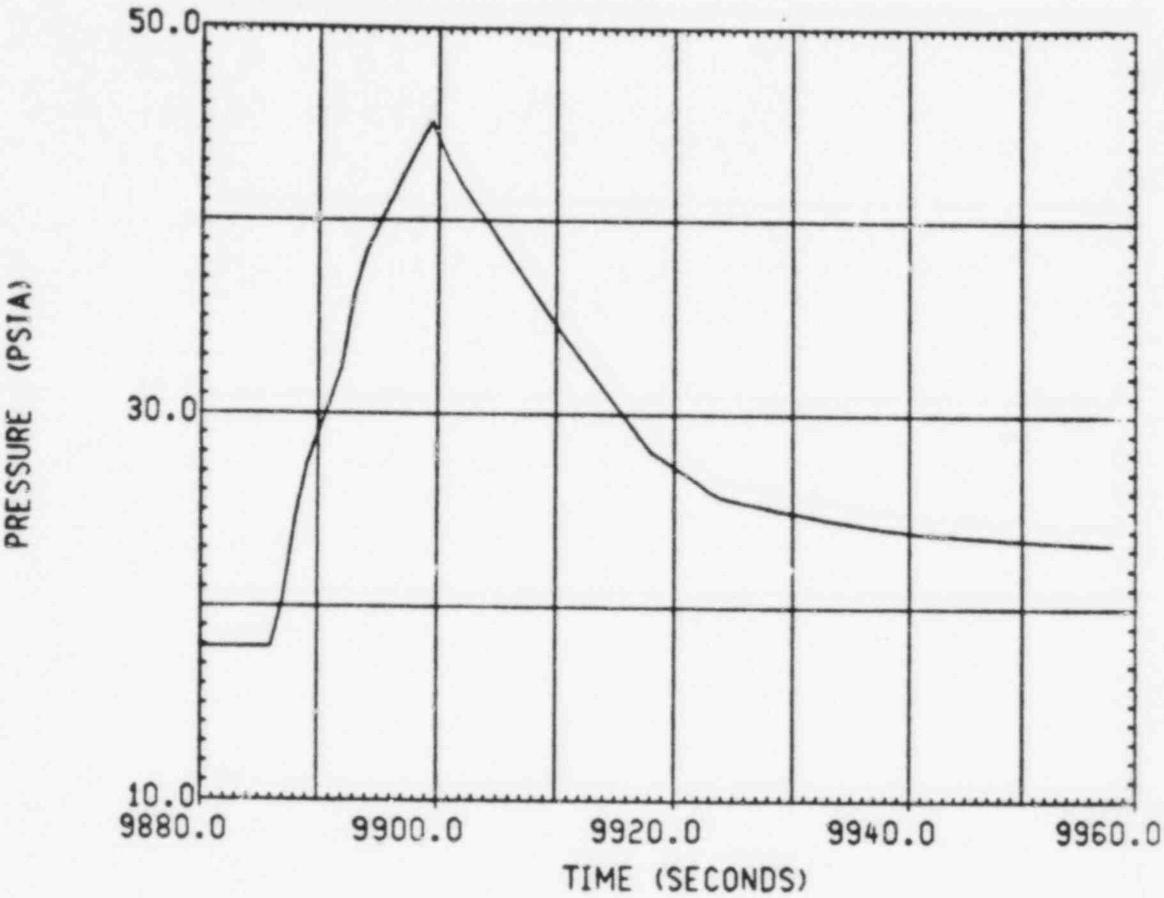
70/30 DRYWELL BREAK BASE CASE NEW VB
GRAND GULF NUCLEAR STATION
DRYWELL PRESSURE

FIGURE 10



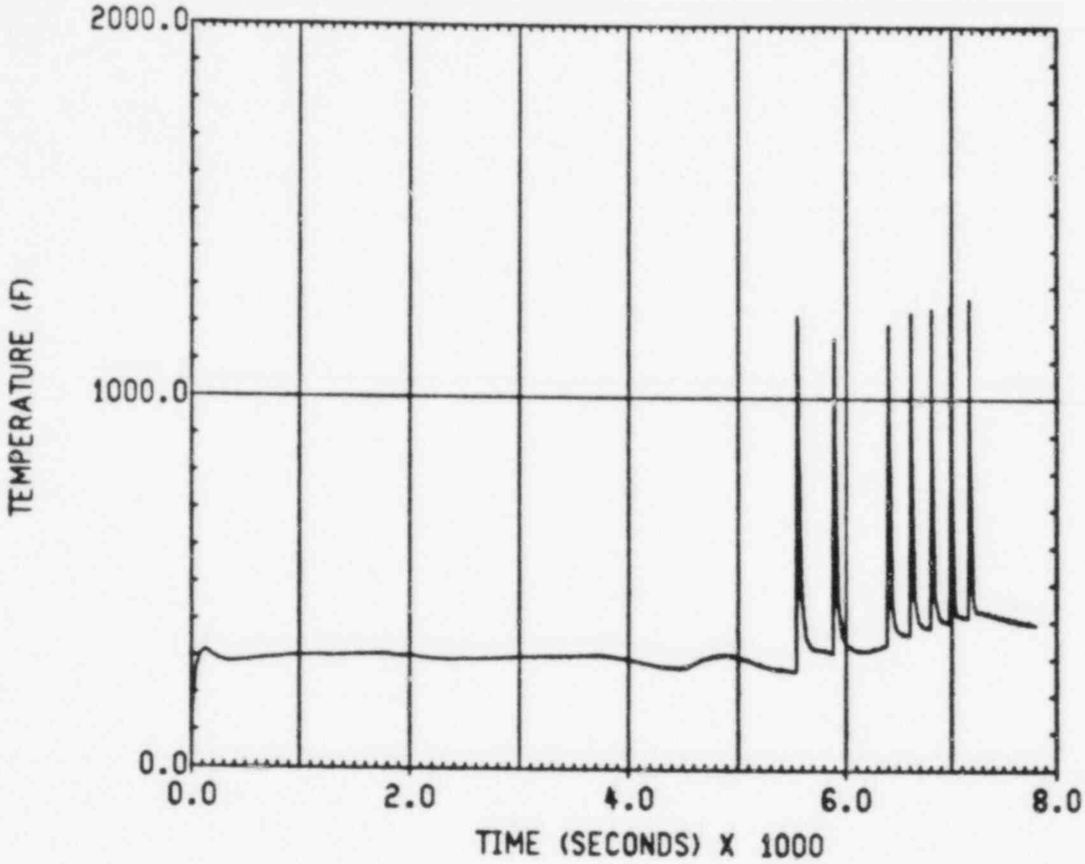
70/30 DRYWELL BREAK BASE CASE NEW VB
GRAND GULF NUCLEAR STATION
WETWELL PRESSURE

FIGURE 11



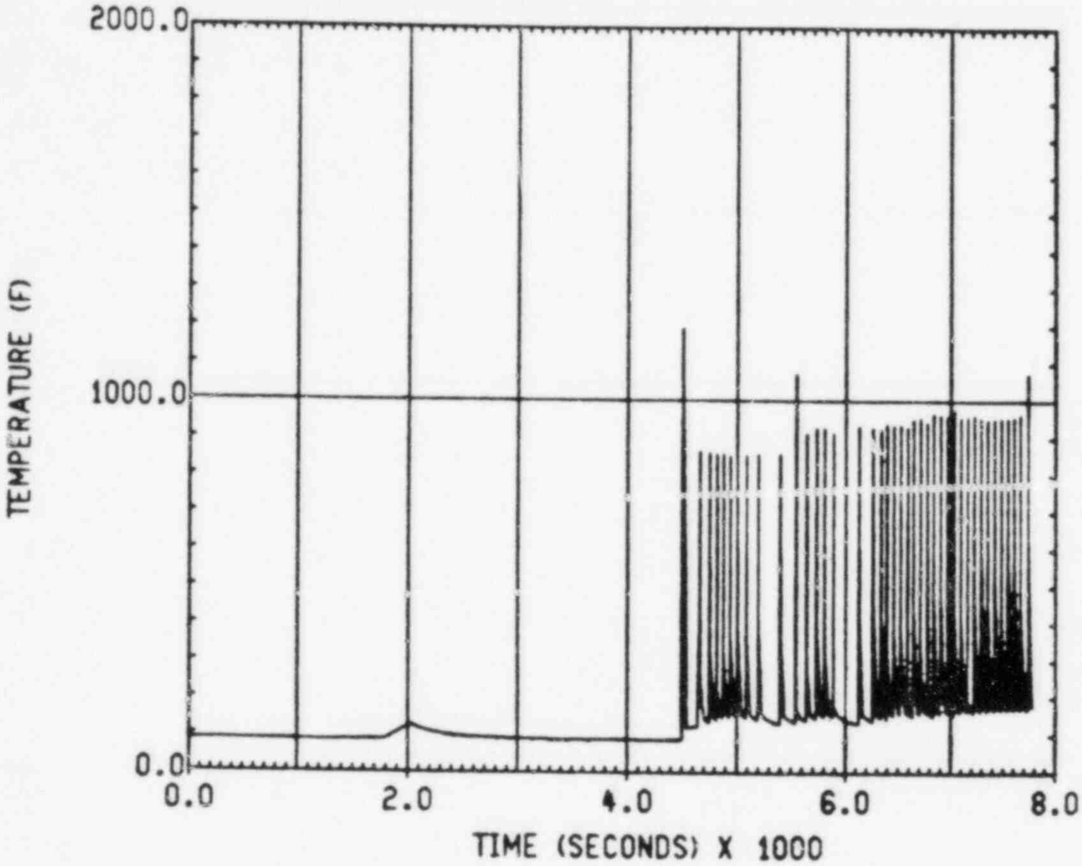
70/30 DRYWELL BREAK BASE CASE NEW VB
GRAND GULF NUCLEAR STATION
CONTAINMENT PRESSURE

FIGURE 12



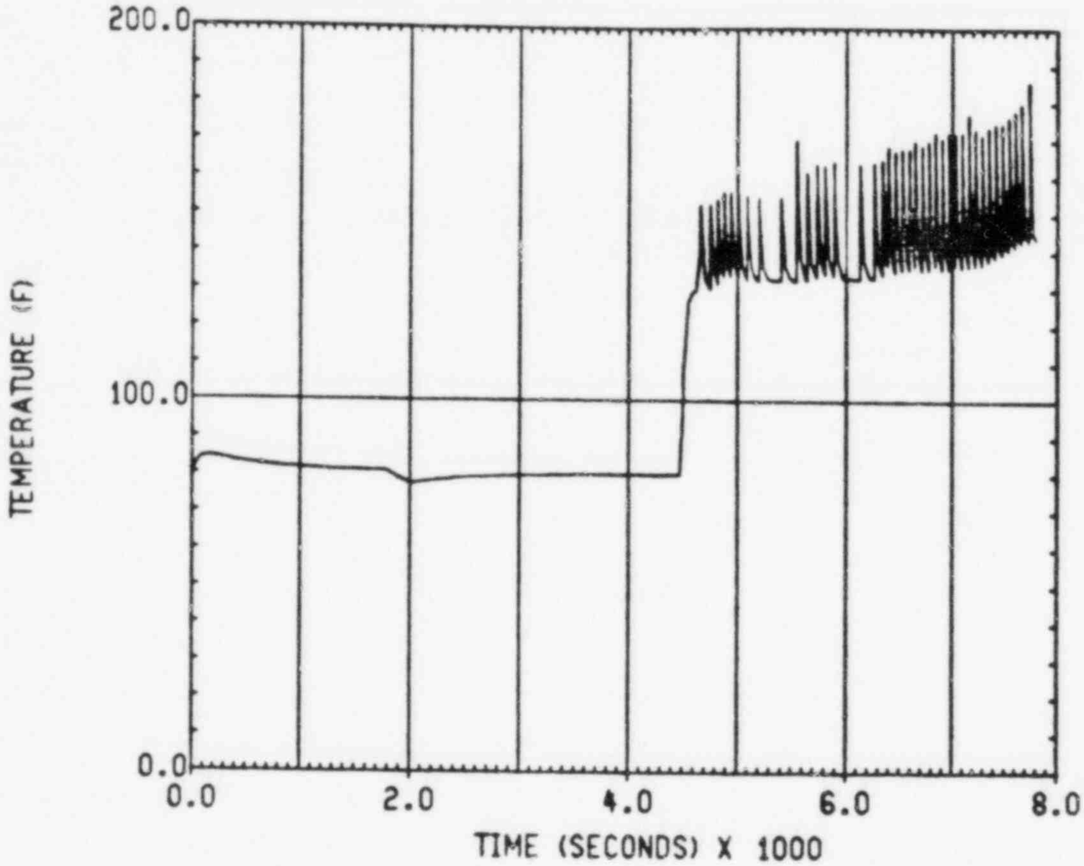
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
DRYWELL TEMPERATURE

FIGURE 13



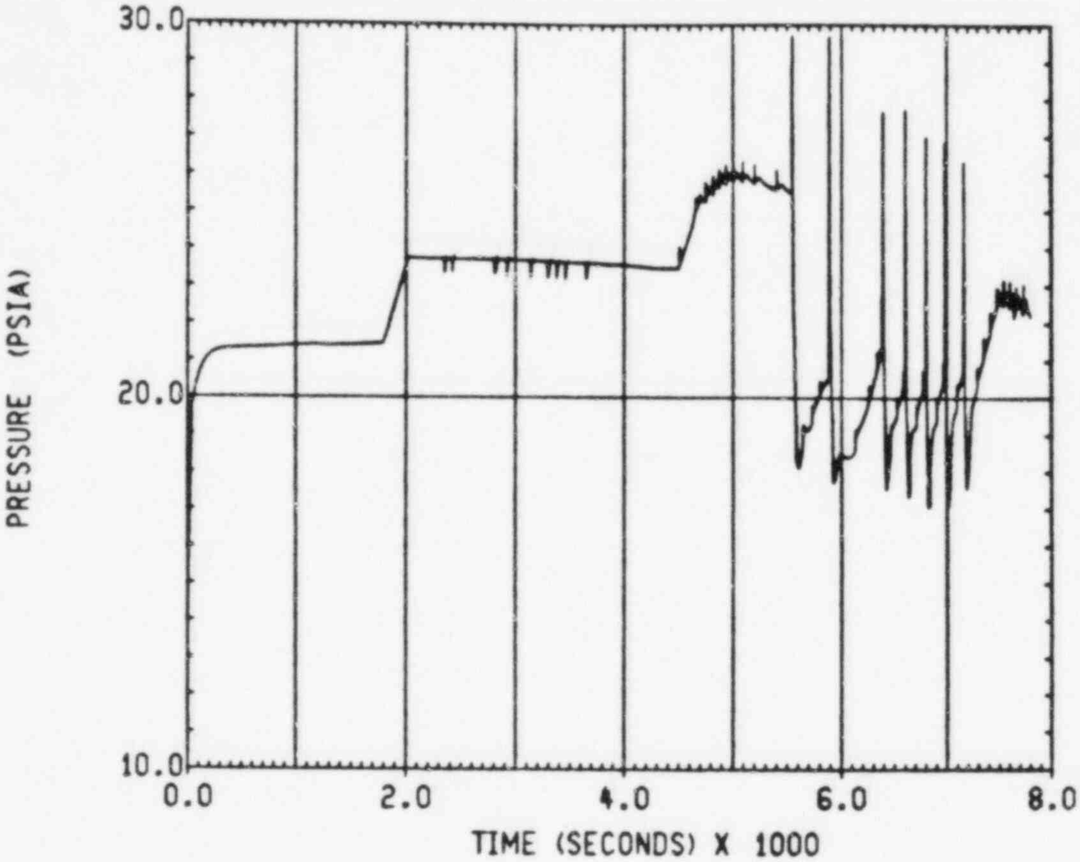
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
WETWELL TEMPERATURE

FIGURE 14



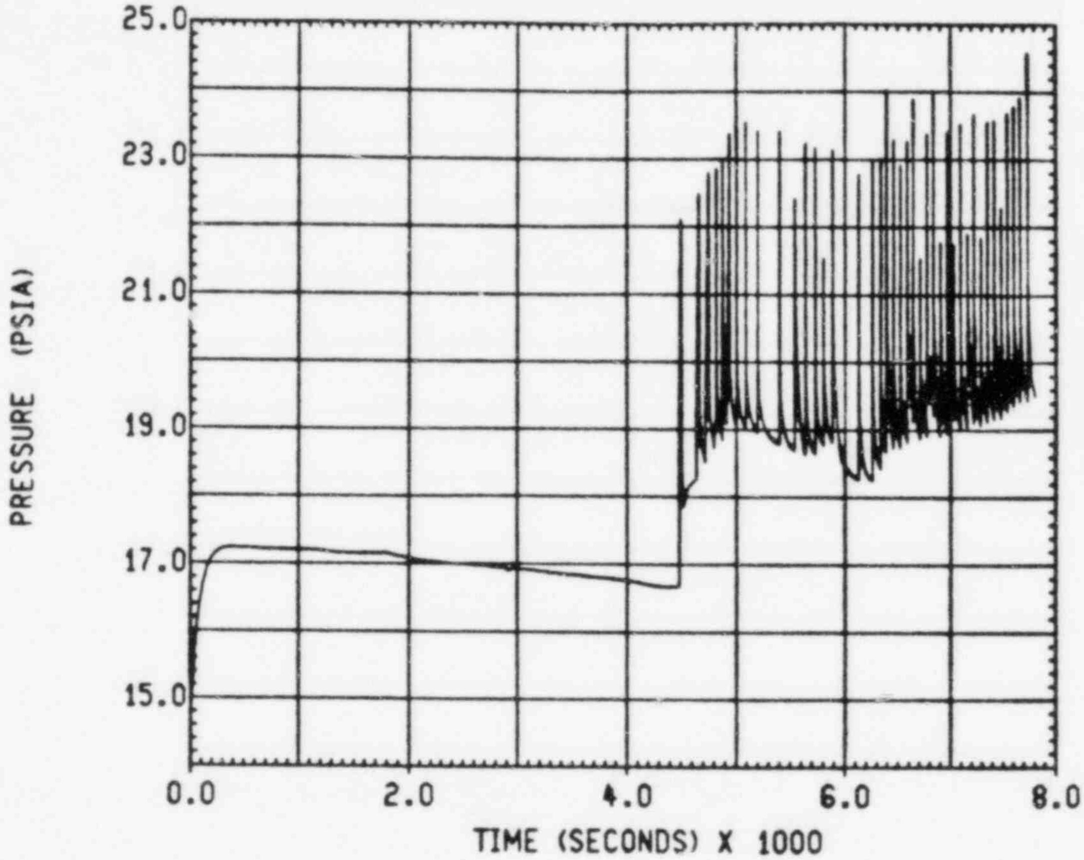
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
CONTAINMENT TEMPERATURE

FIGURE 15



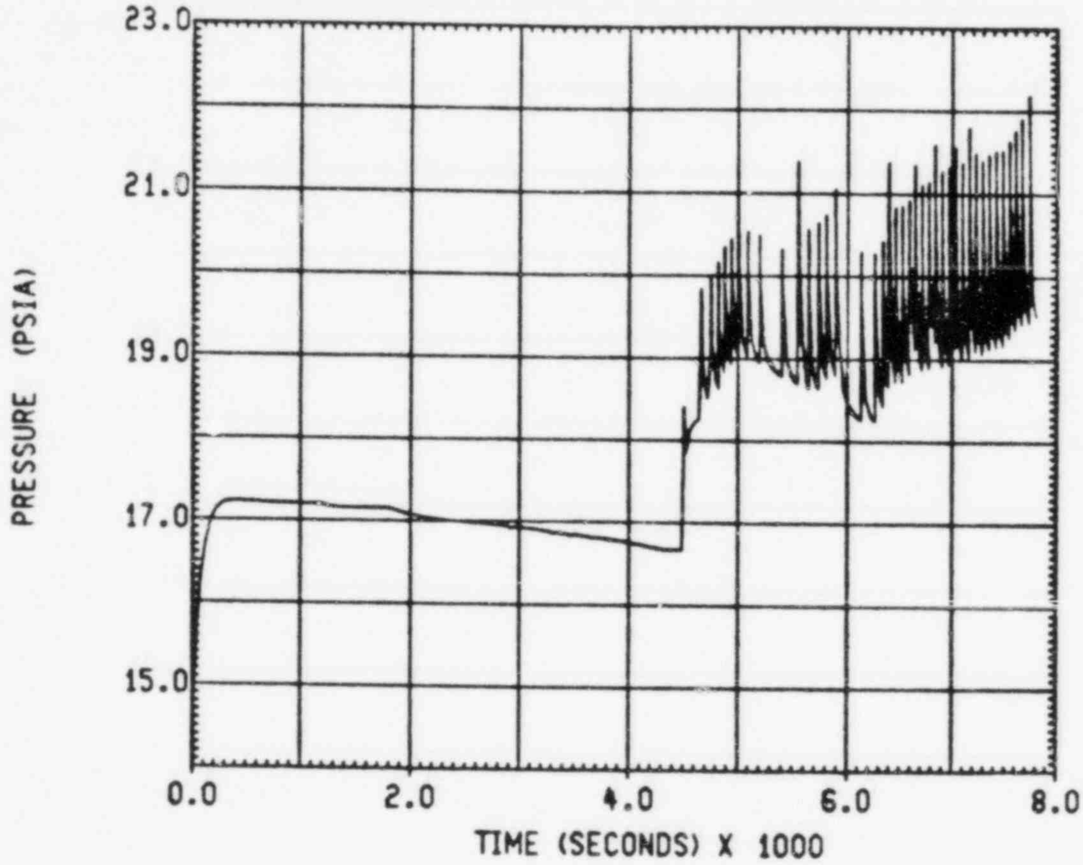
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
DRYWELL PRESSURE

FIGURE 16



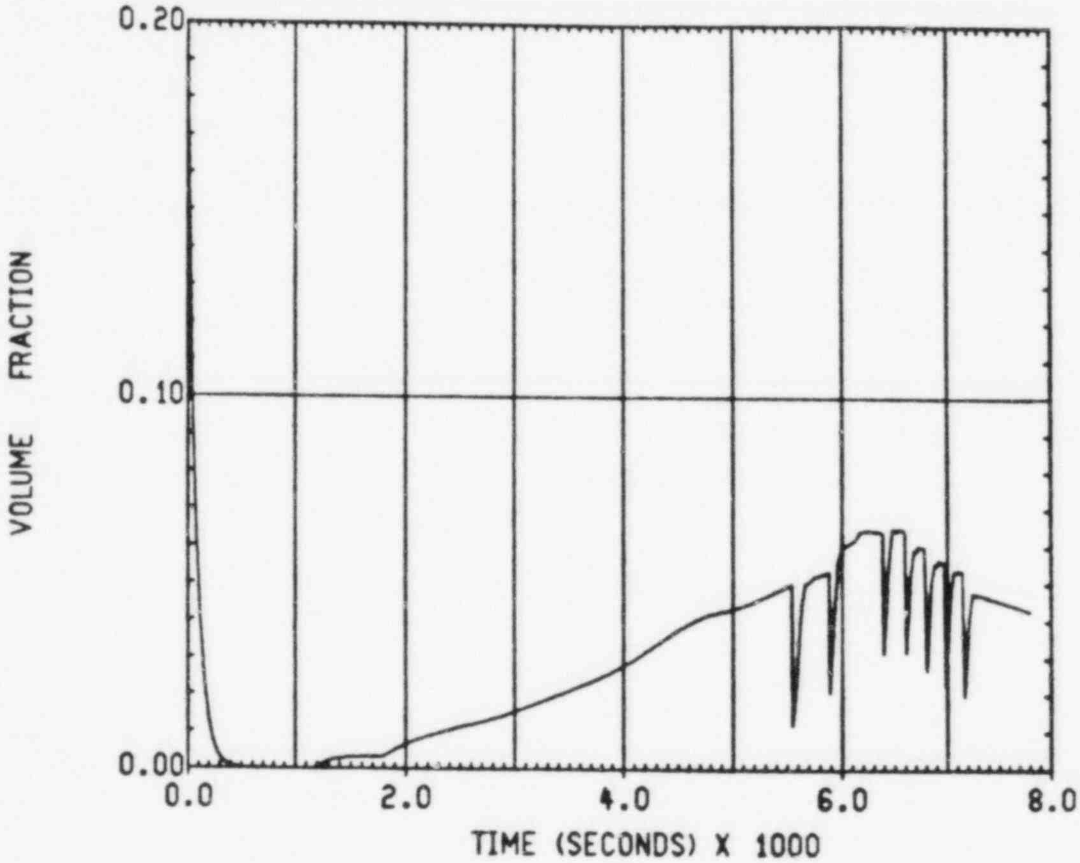
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
WETWELL PRESSURE

FIGURE 17



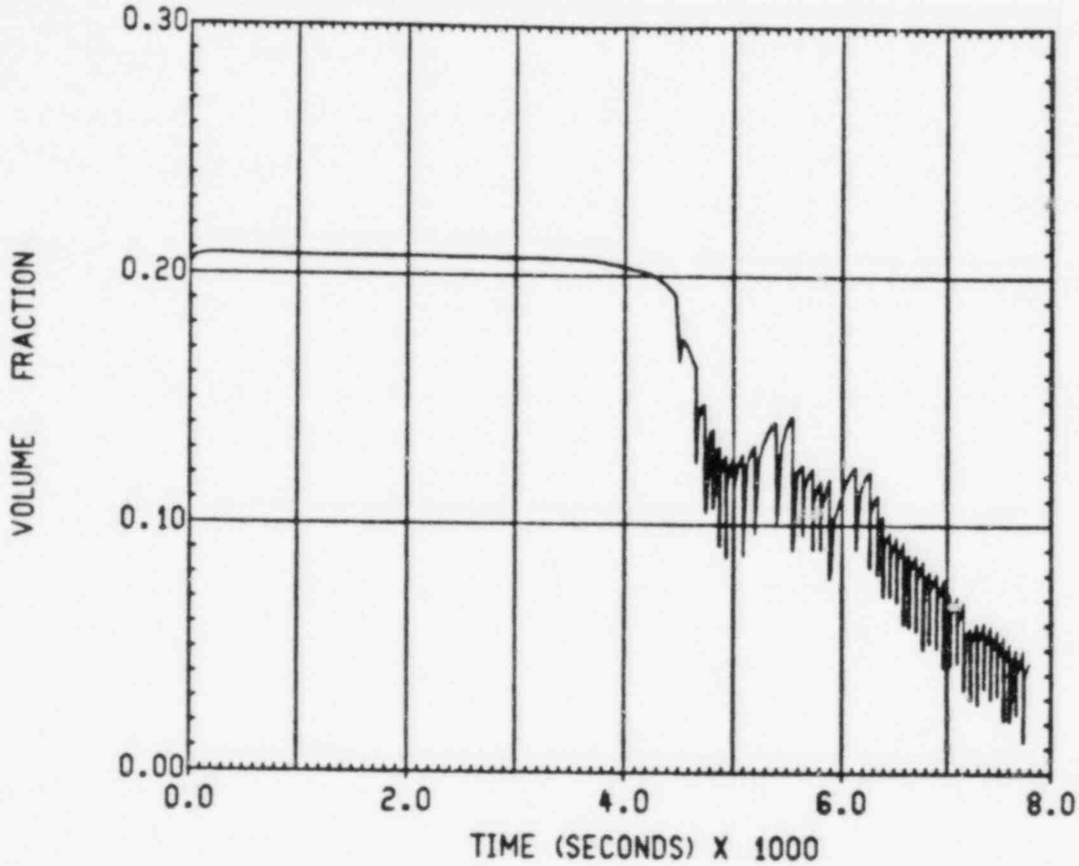
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
CONTAINMENT PRESSURE

FIGURE 18



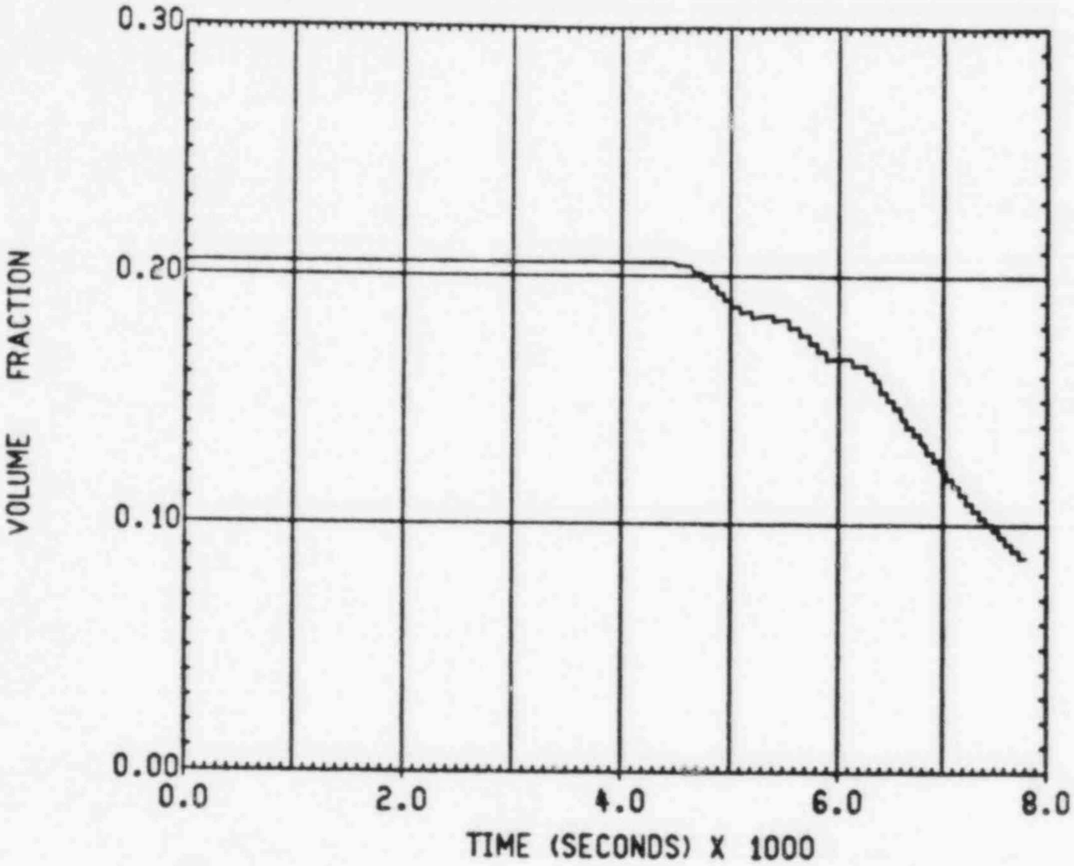
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
DRYWELL O2 GAS CONCENTRATION

FIGURE 19



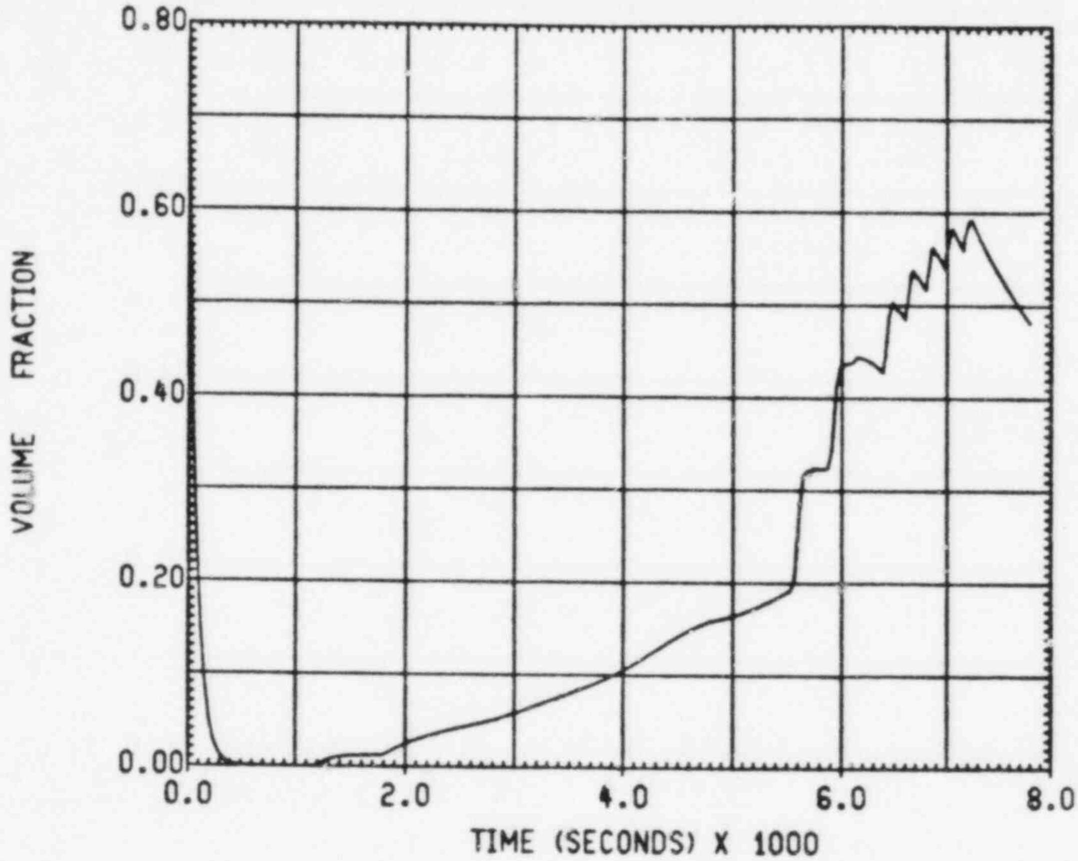
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
WETWELL O2 GAS CONCENTRATION

FIGURE 20



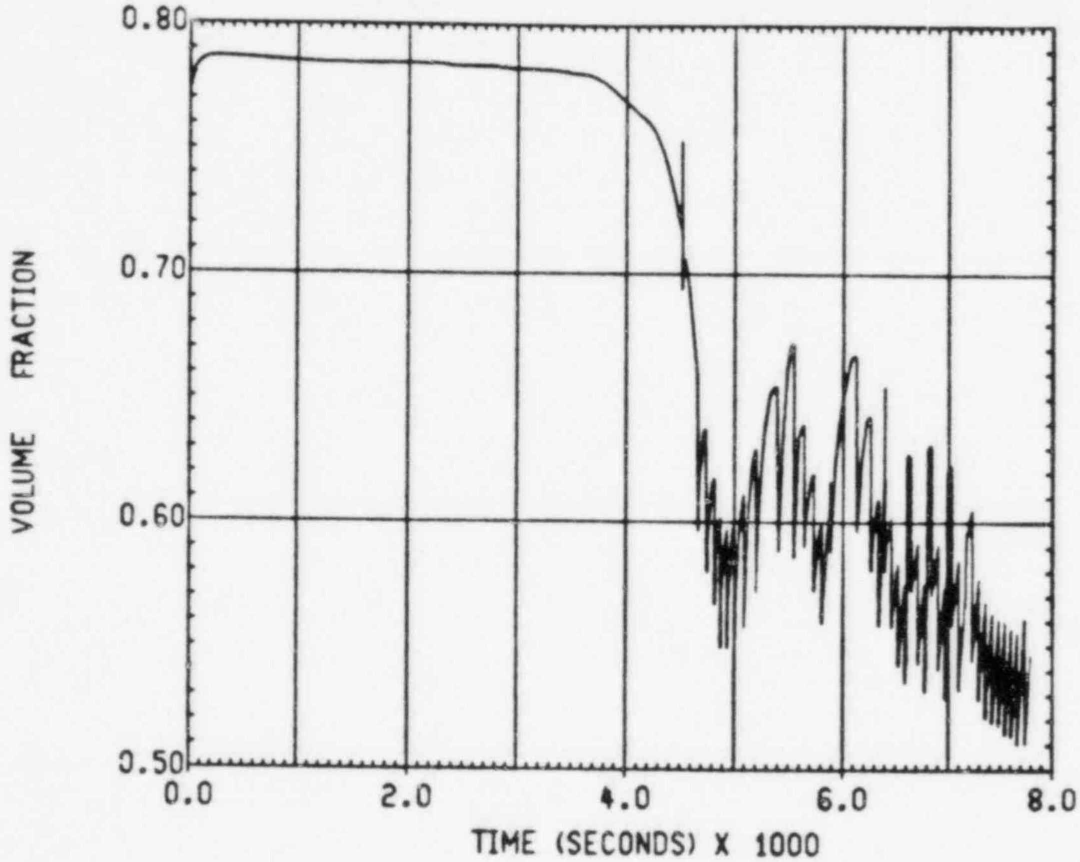
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
CONTAINMENT 02 GAS CONCENTRATION

FIGURE 21



70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
DRYWELL N2 GAS CONCENTRATION

FIGURE 22



70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
WETWELL N2 GAS CONCENTRATION

FIGURE 23

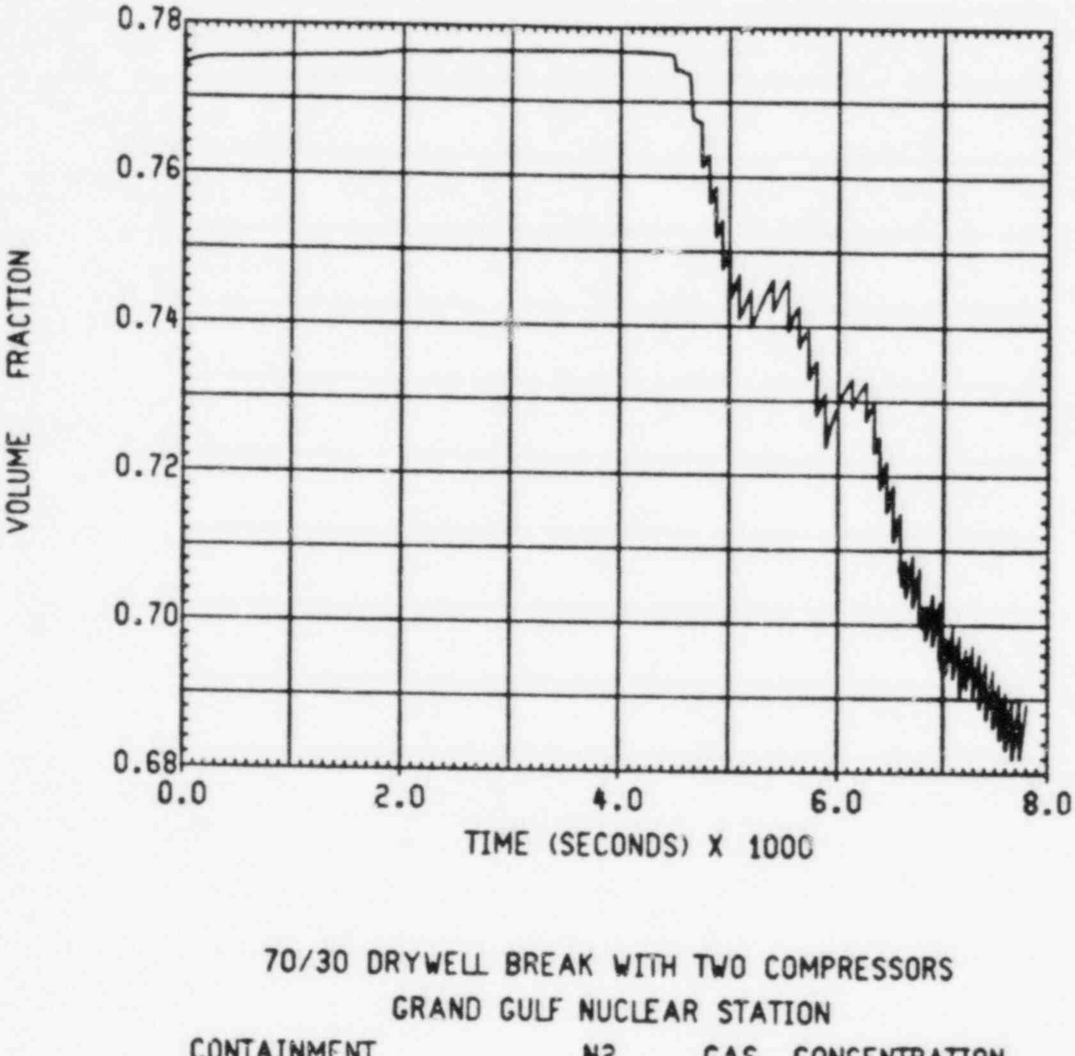
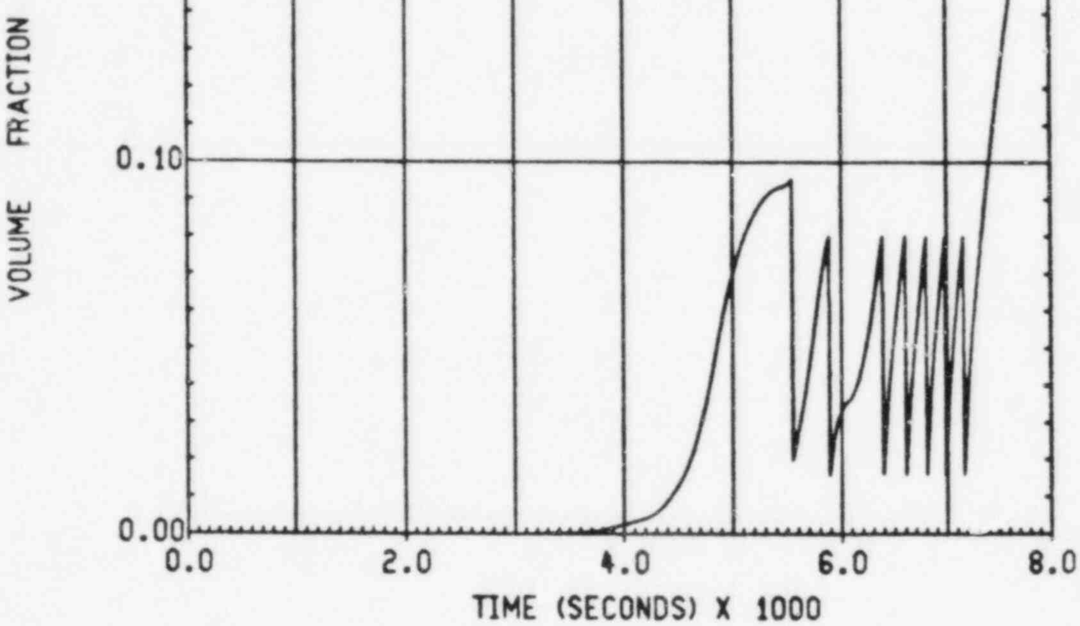
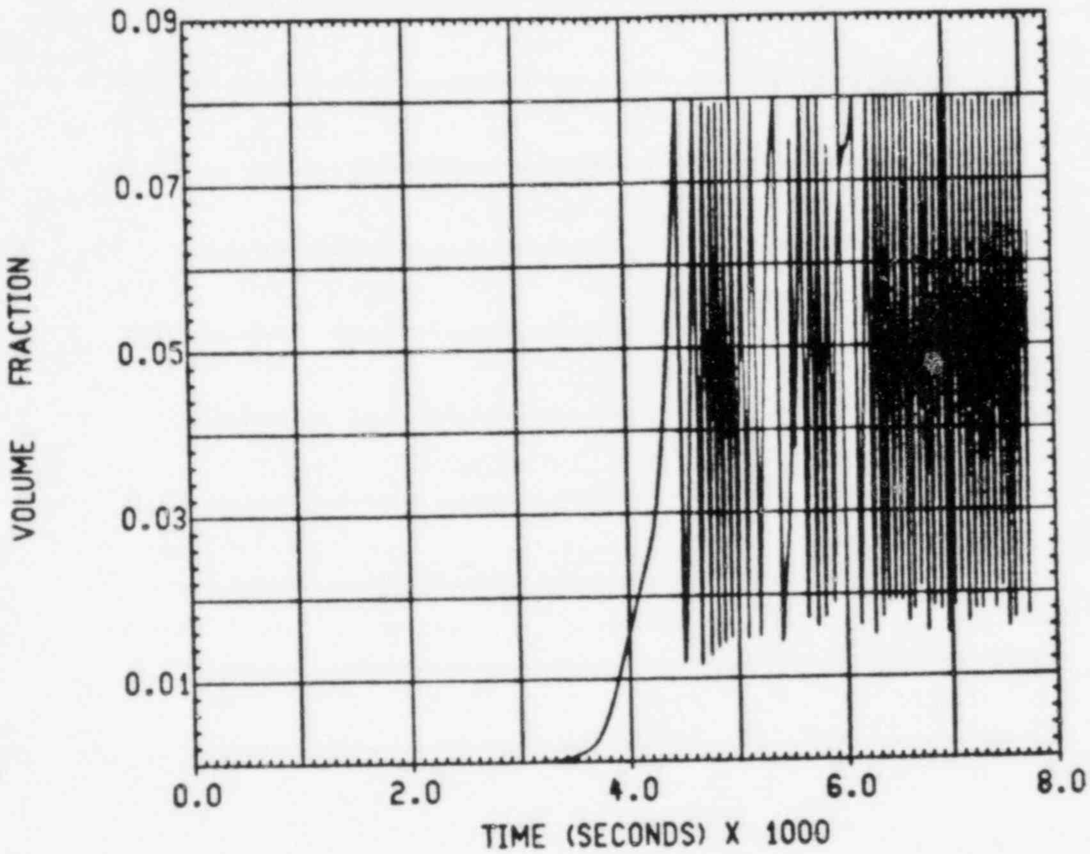

0.78
0.76
0.74
0.72
0.70
0.68
VOLUME FRACTION
0.0
2.0
4.0
6.0
8.0
TIME (SECONDS) X 1000
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
CONTAINMENT N2 GAS CONCENTRATION

FIGURE 24



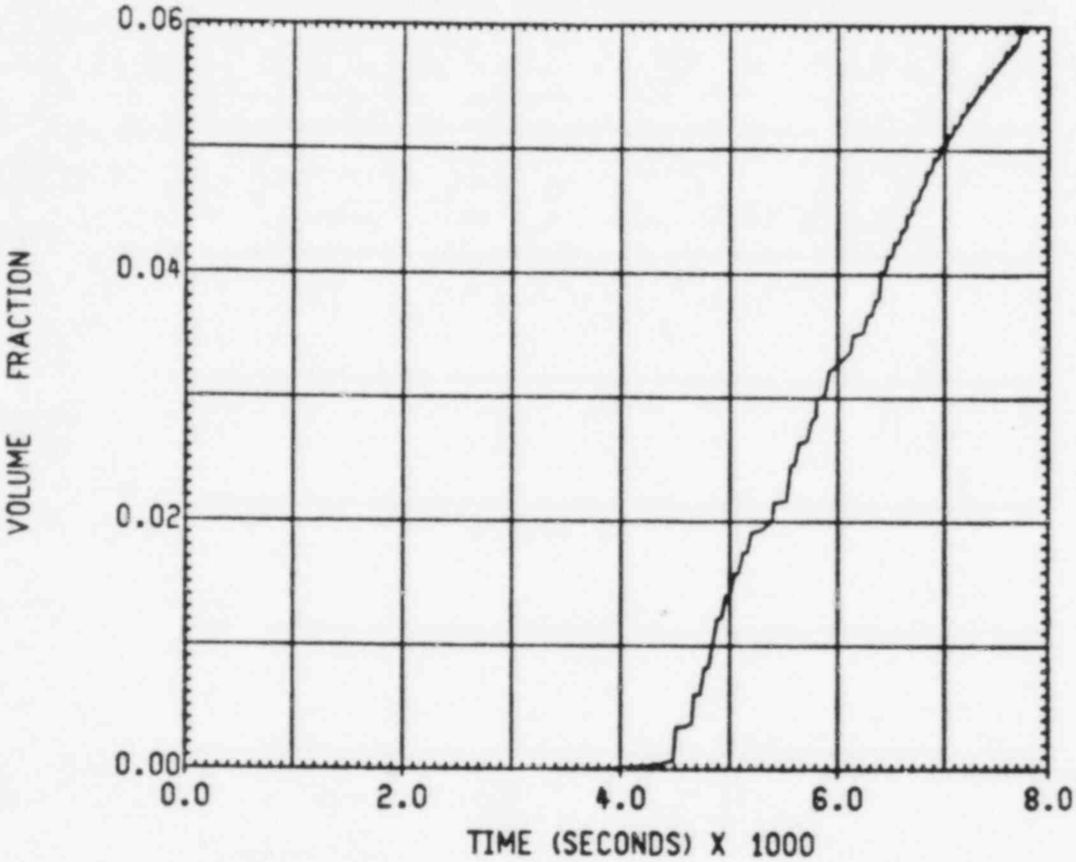
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
DRYWELL H2 GAS CONCENTRATION

FIGURE 25



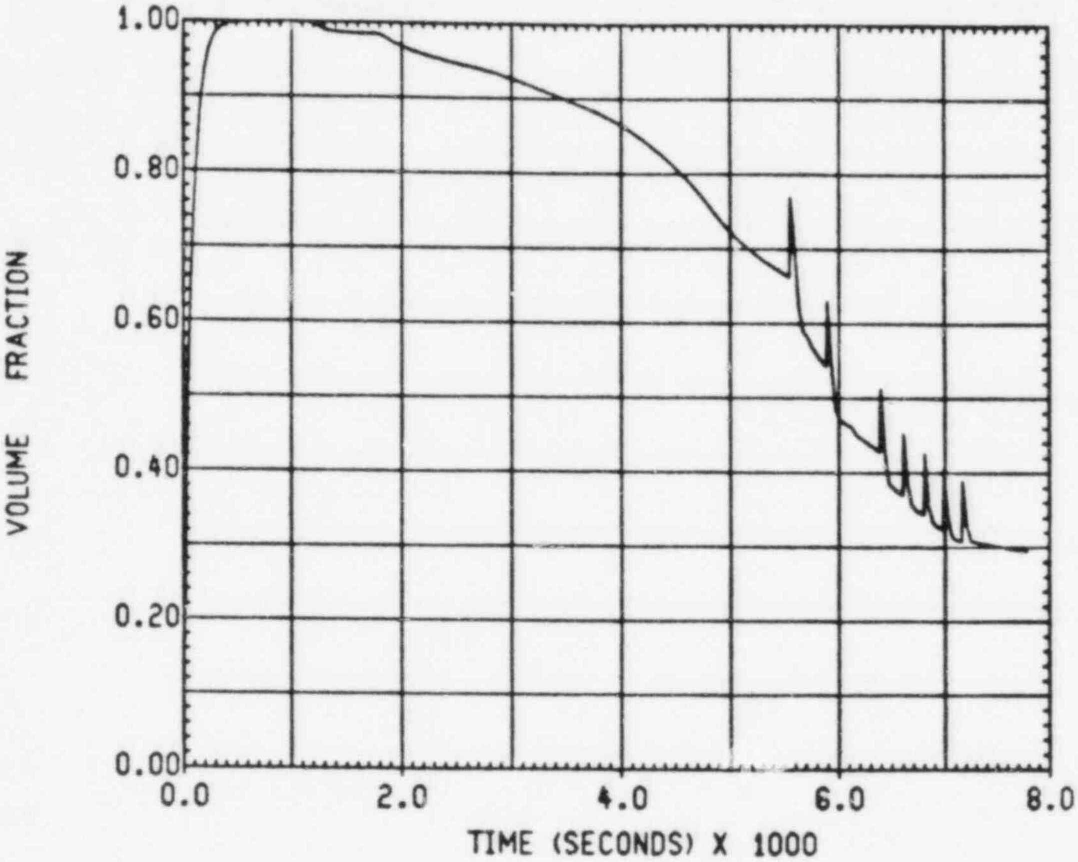
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
WETWELL H2 GAS CONCENTRATION

FIGURE 26



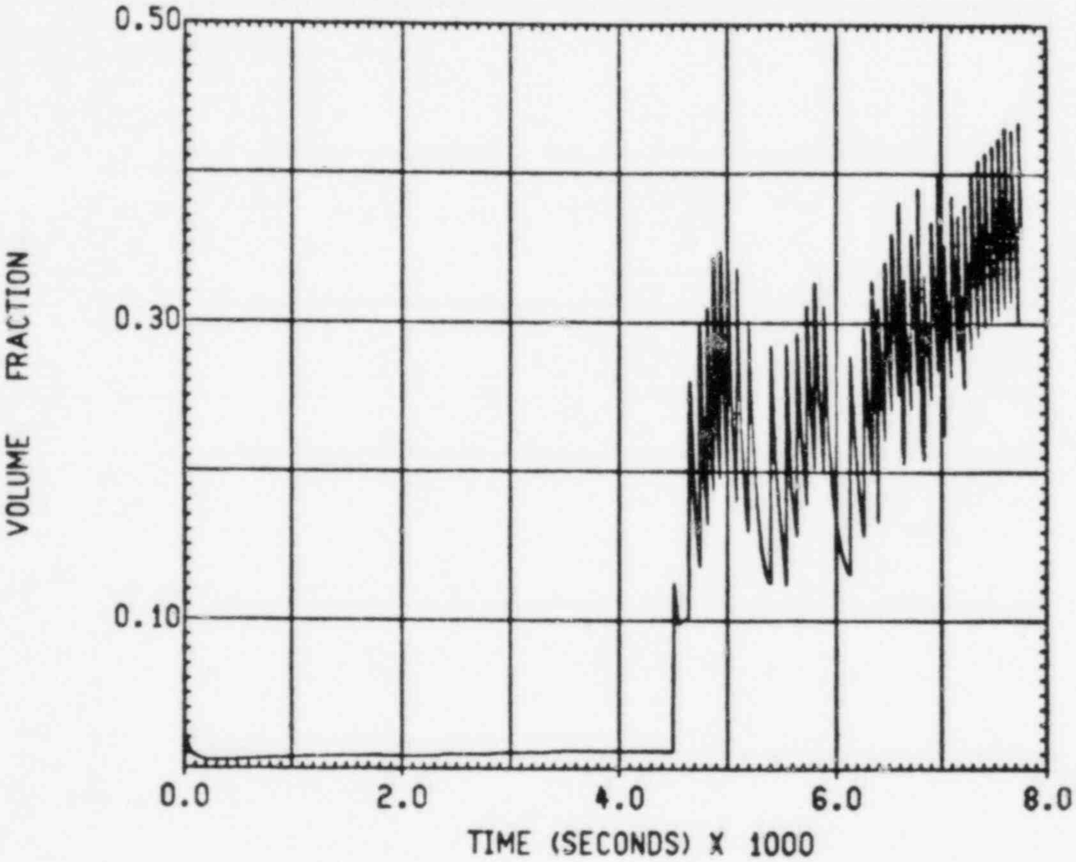
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
CONTAINMENT H2 GAS CONCENTRATION

FIGURE 27



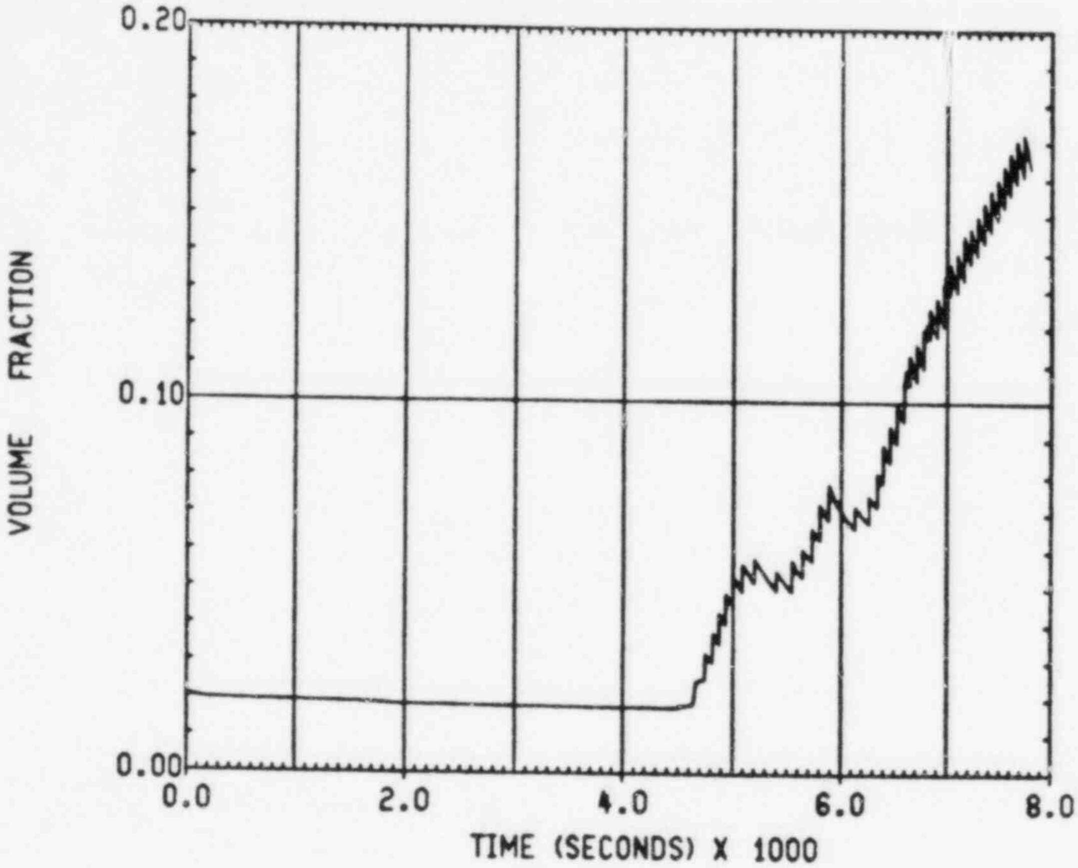
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
DRYWELL STEAM GAS CONCENTRATION

FIGURE 28



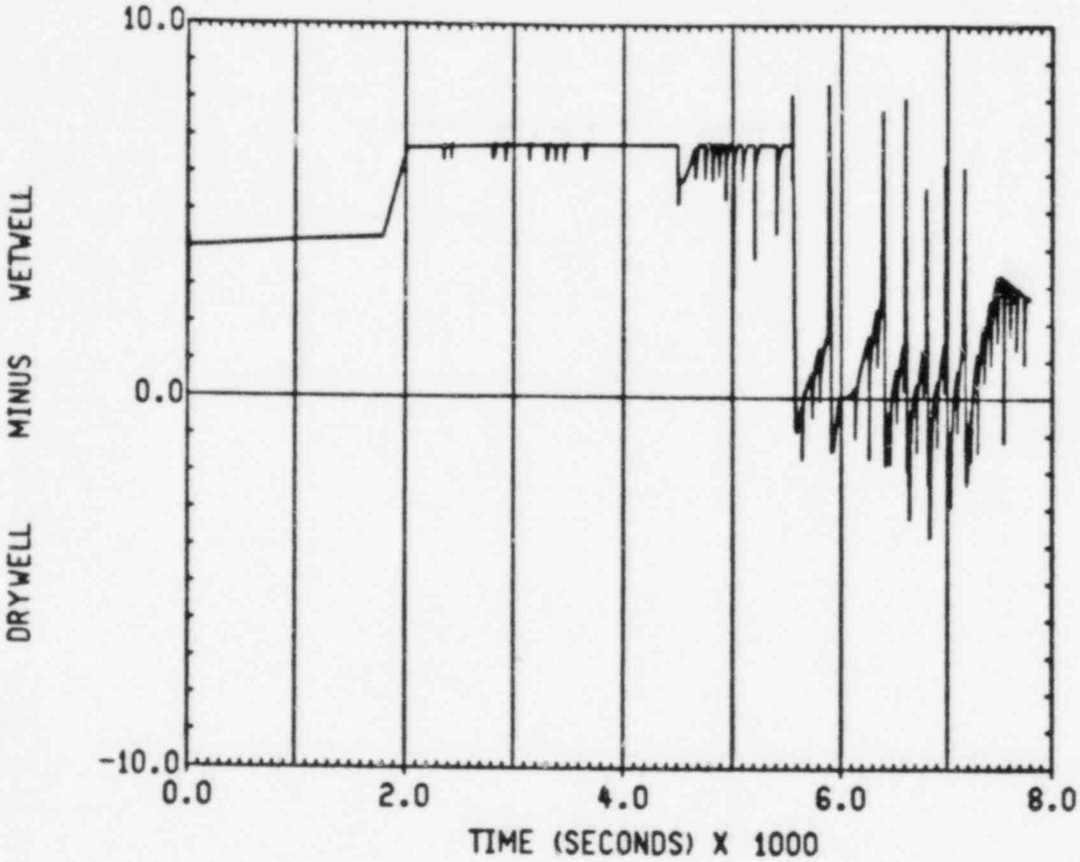
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
WETWELL STEAM GAS CONCENTRATION

FIGURE 29



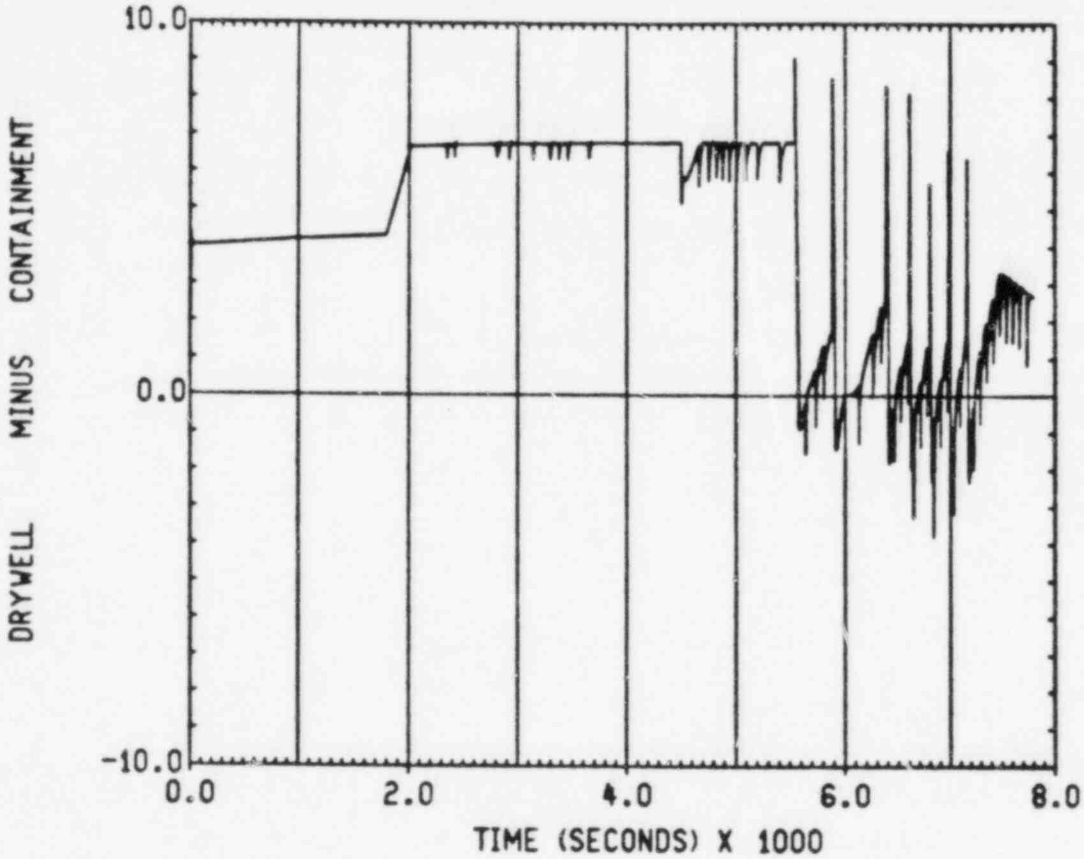
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
CONTAINMENT STEAM GAS CONCENTRATION

FIGURE 30



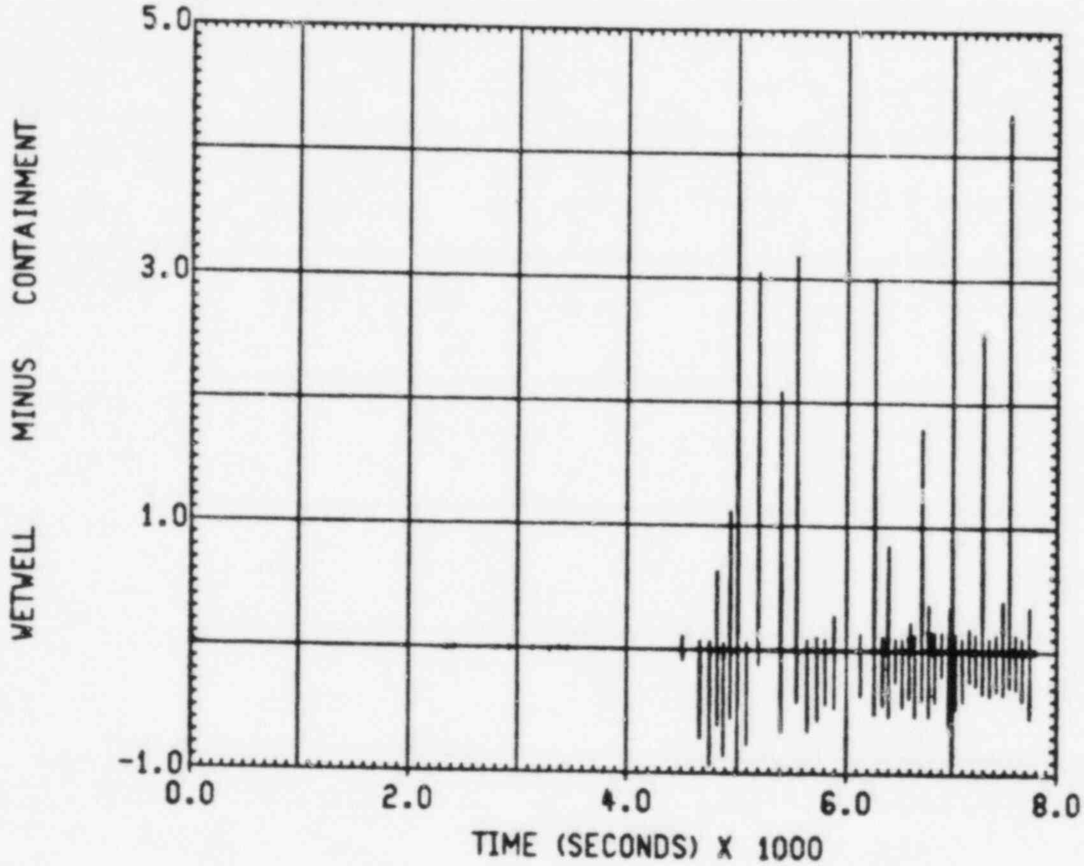
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
DIFFERENTIAL PRESSURE

FIGURE 31



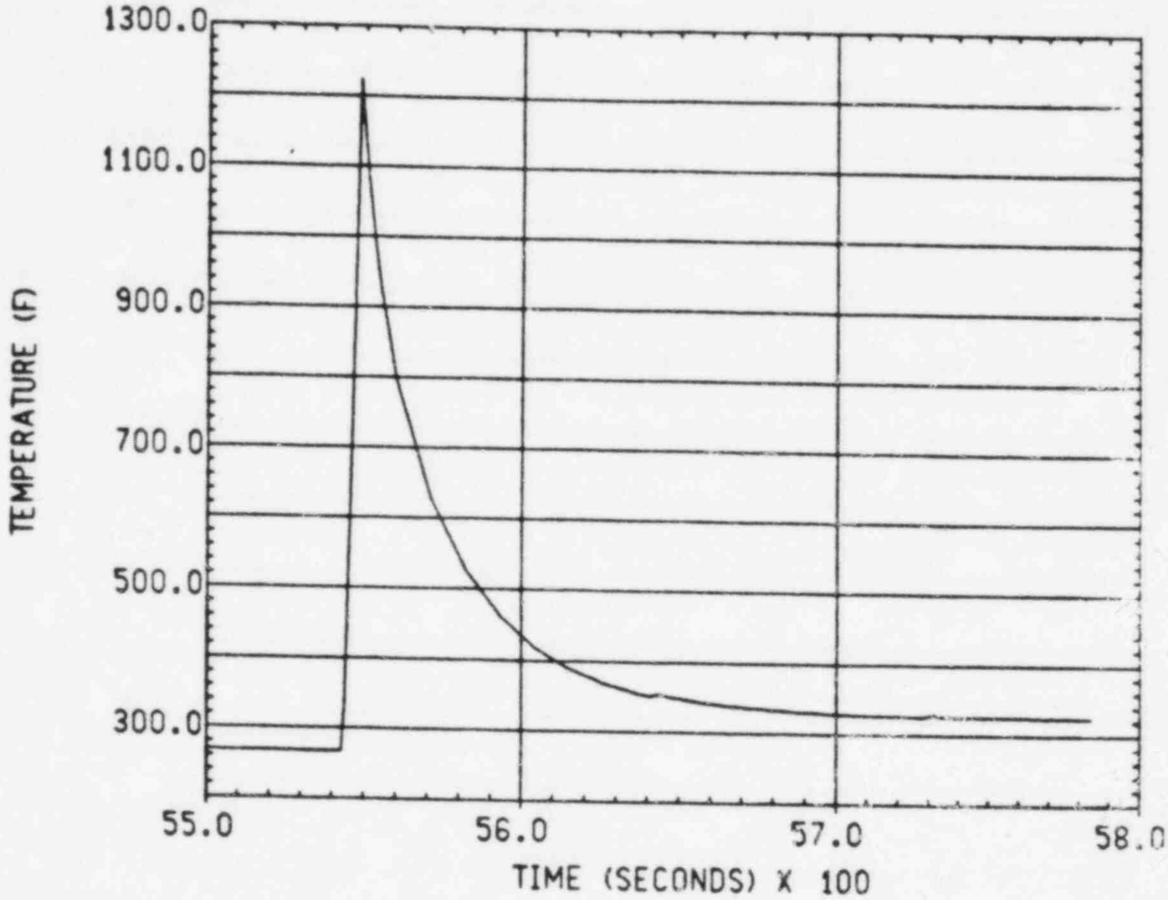
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
DIFFERENTIAL PRESSURE

FIGURE 32



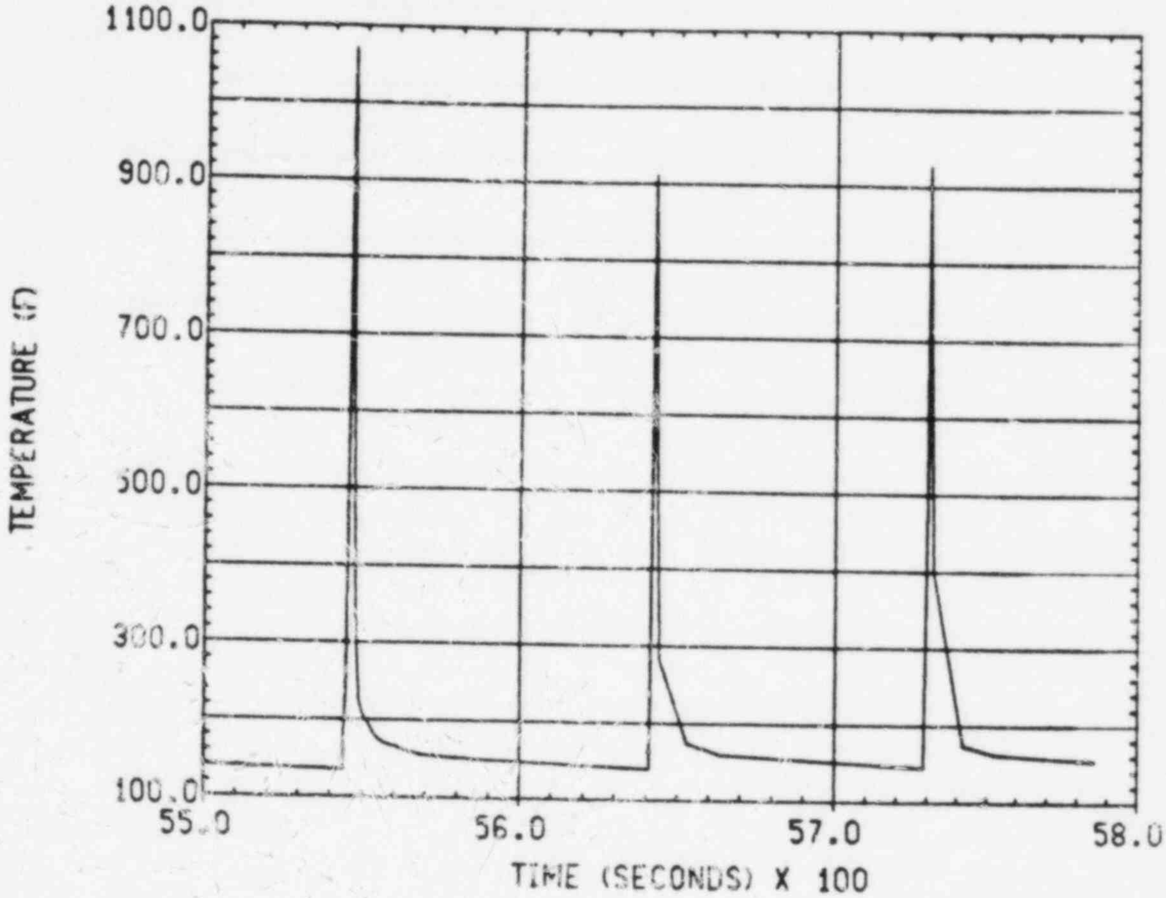
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
DIFFERENTIAL PRESSURE

FIGURE 33



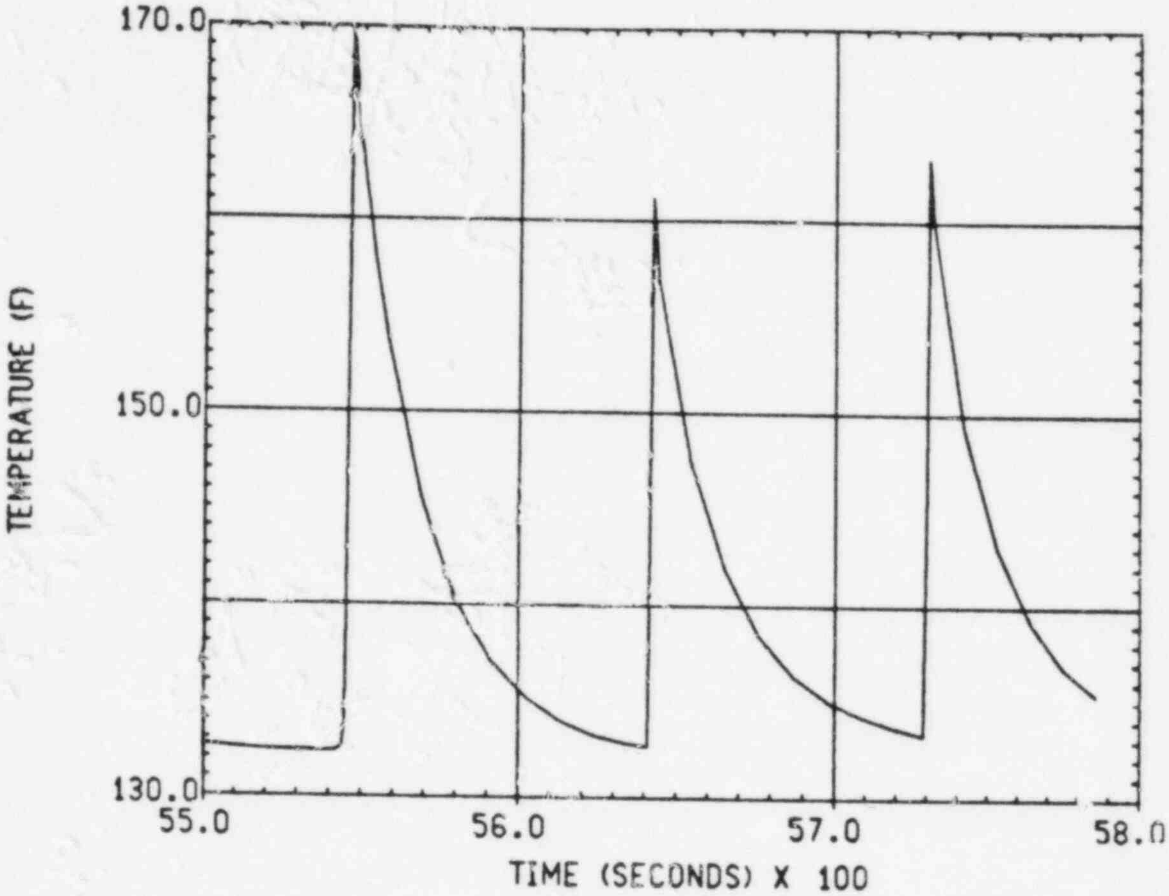
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
DRYWELL TEMPERATURE

FIGURE 34



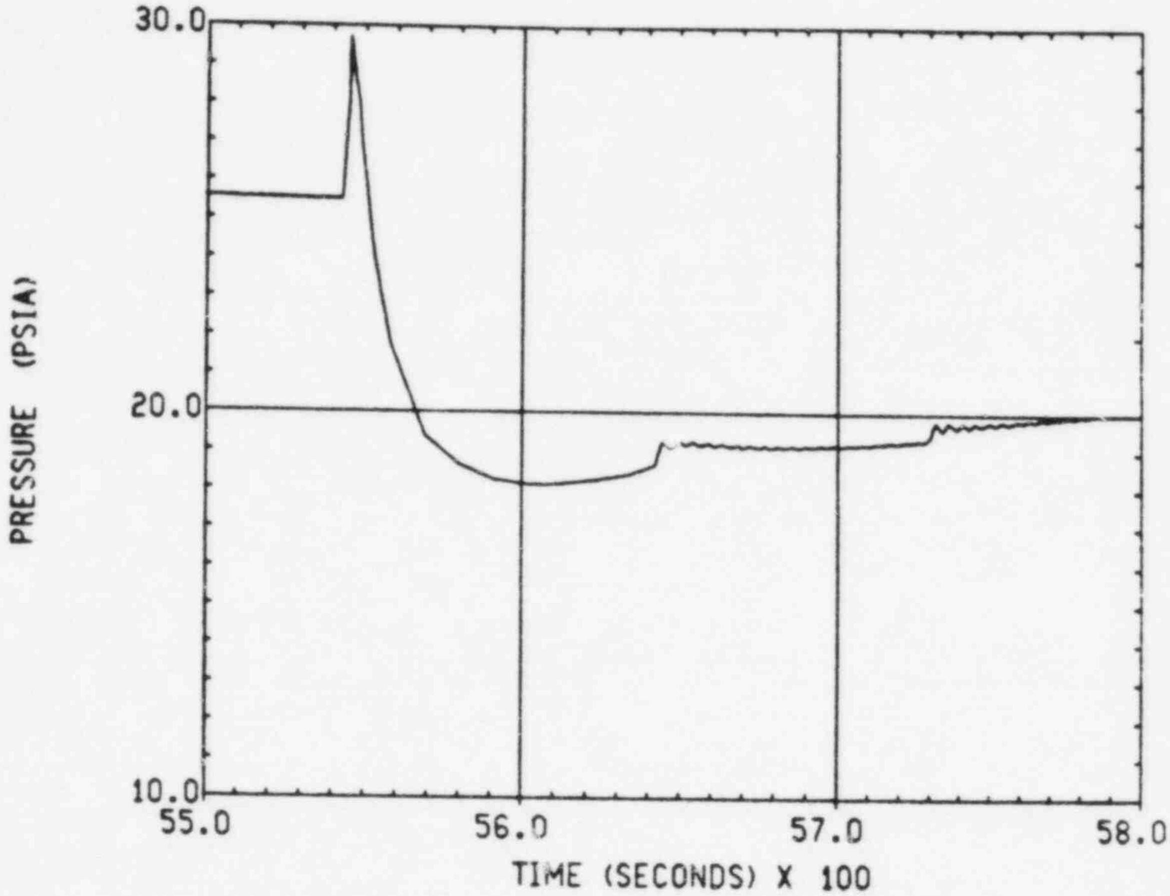
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
WETWELL TEMPERATURE

FIGURE 35



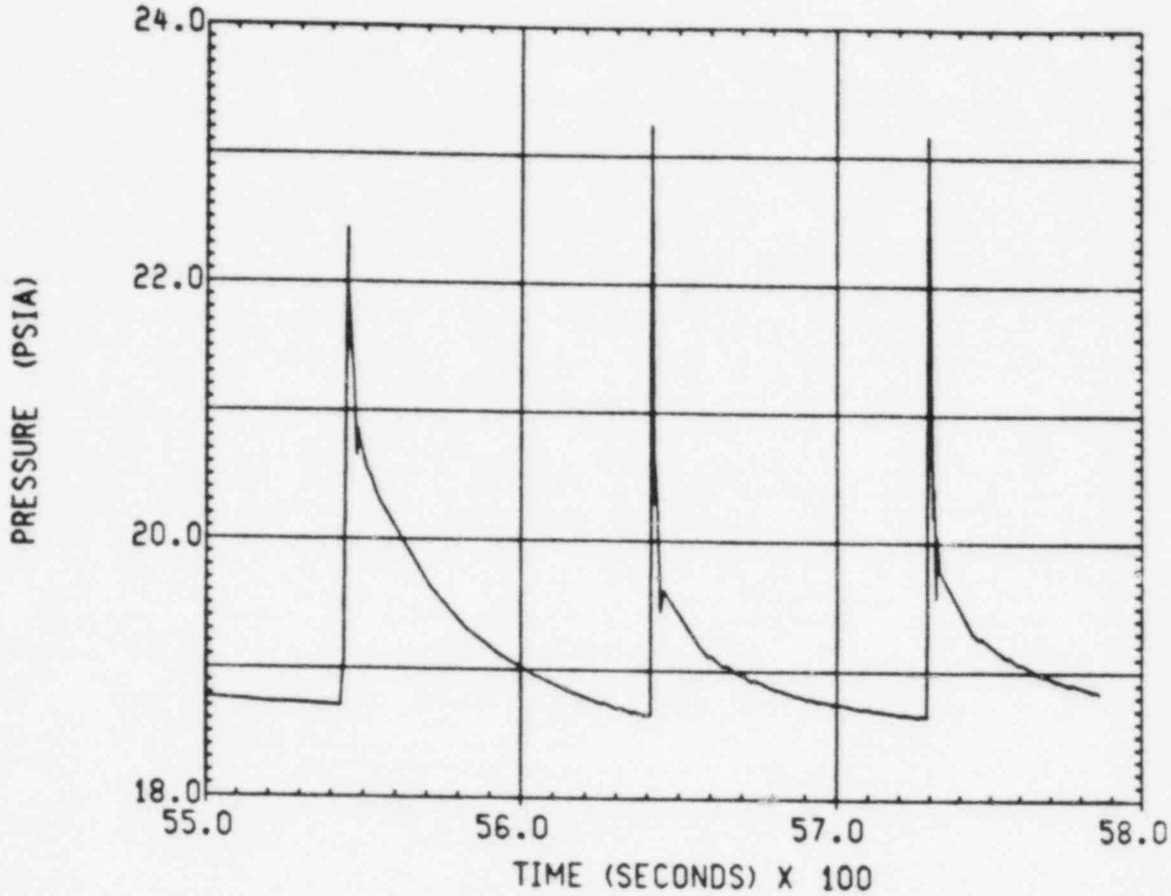
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
CONTAINMENT TEMPERATURE

FIGURE 36



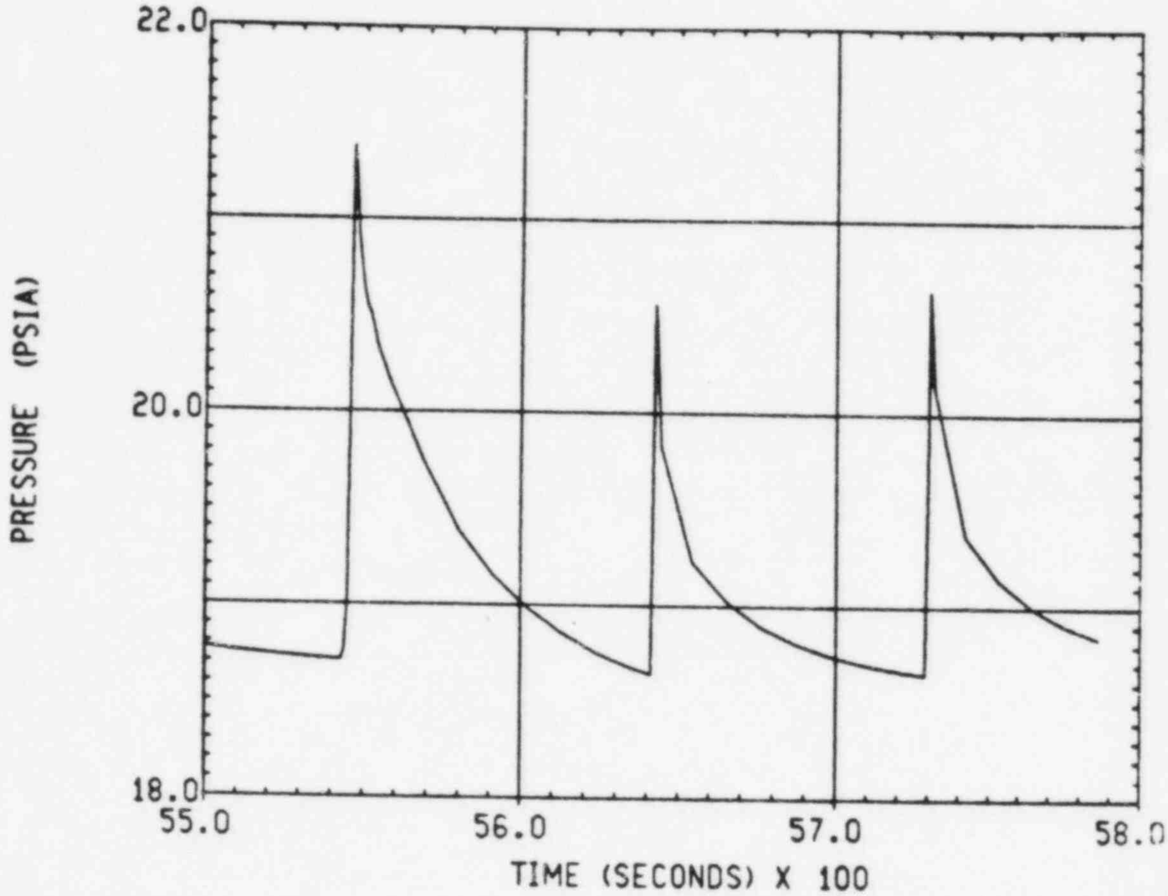
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
DRYWELL PRESSURE

FIGURE 37



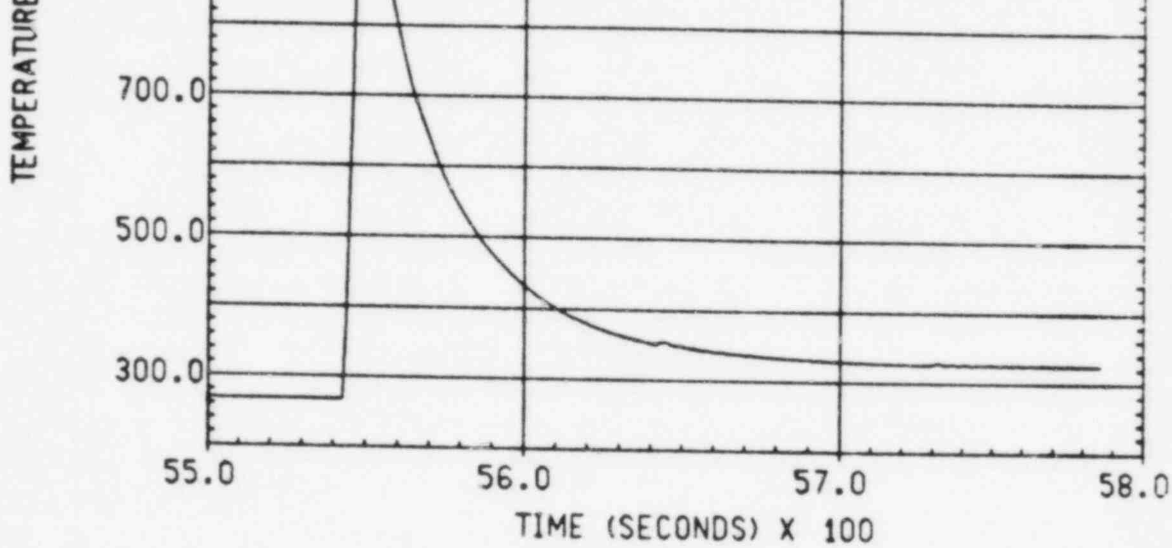
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
WETWELL PRESSURE

FIGURE 38



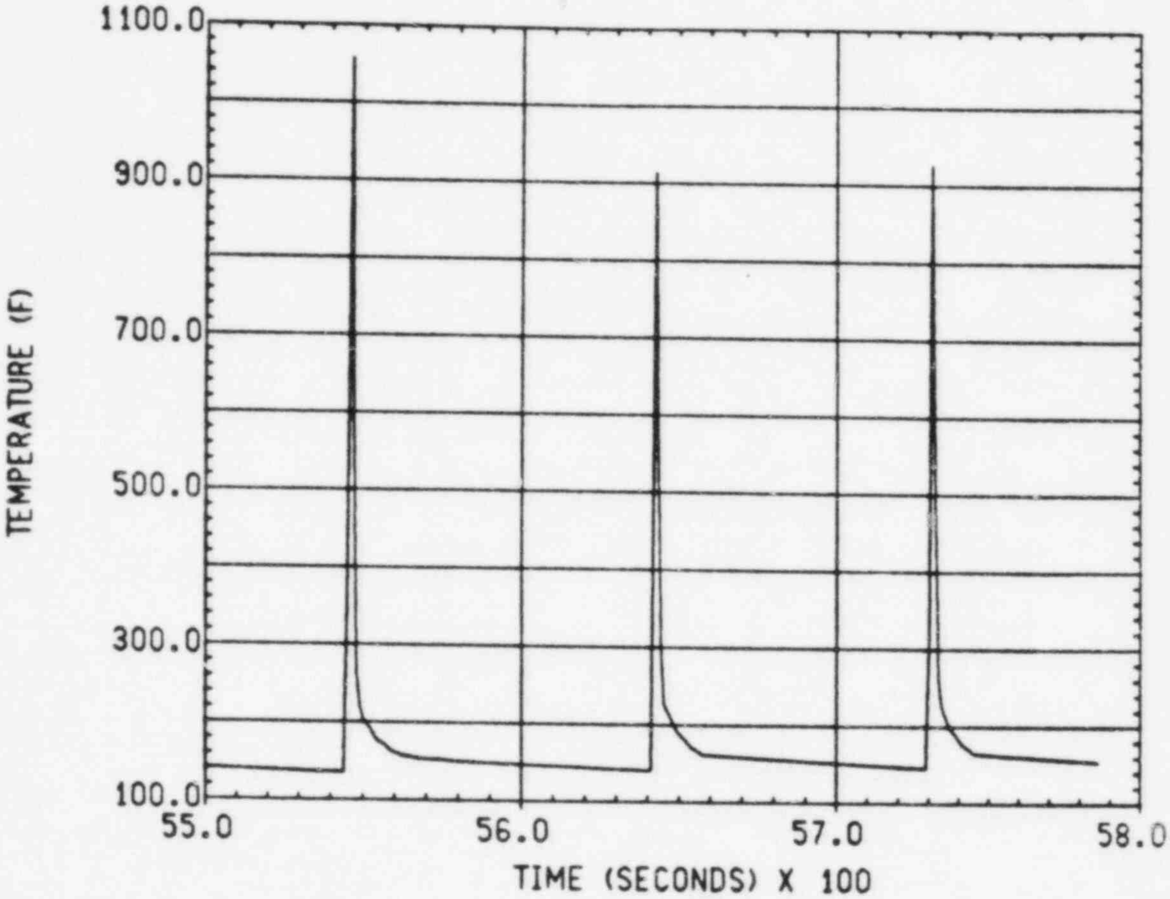
70/30 DRYWELL BREAK WITH TWO COMPRESSORS
GRAND GULF NUCLEAR STATION
CONTAINMENT PRESSURE

FIGURE 39



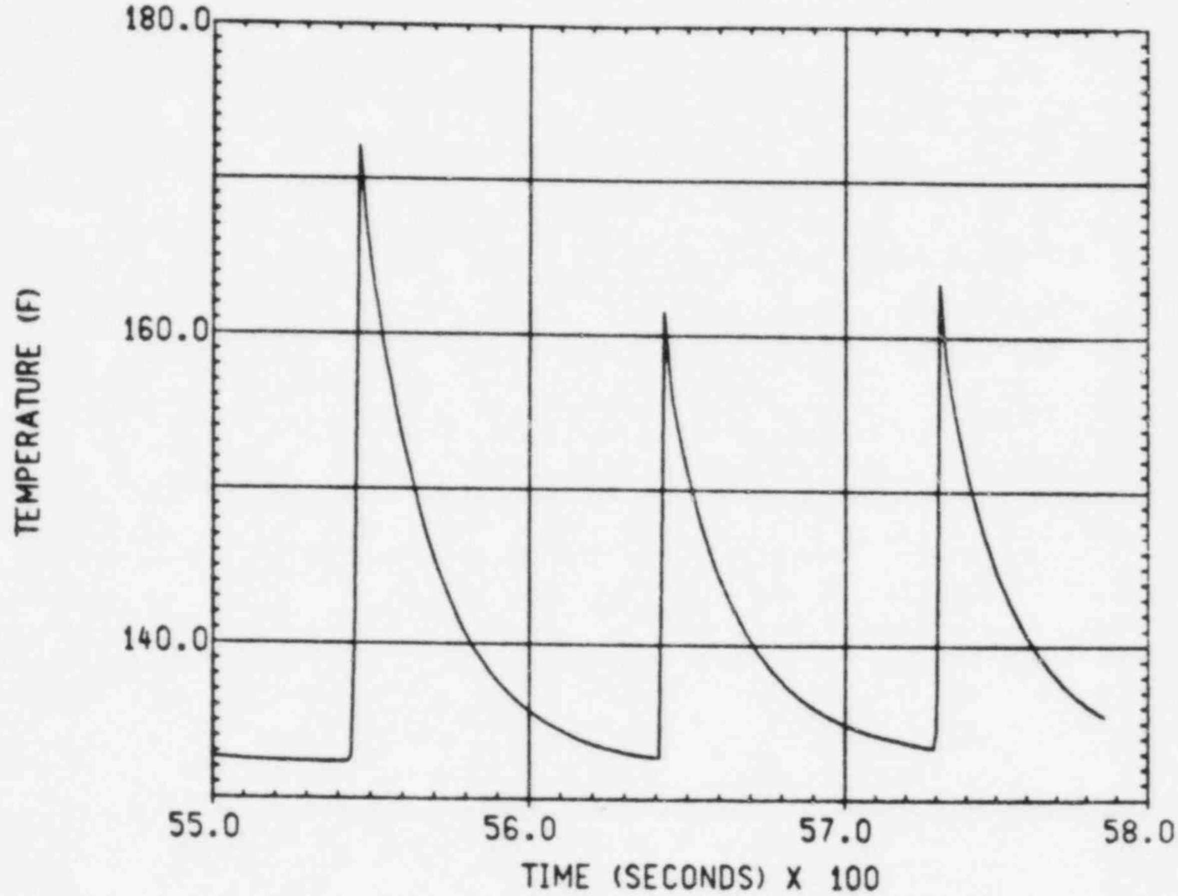
70/30 DRYWELL BREAK TWO COMP NEW BEAM LENGTH
GRAND GULF NUCLEAR STATION
DRYWELL TEMPERATURE

FIGURE 40



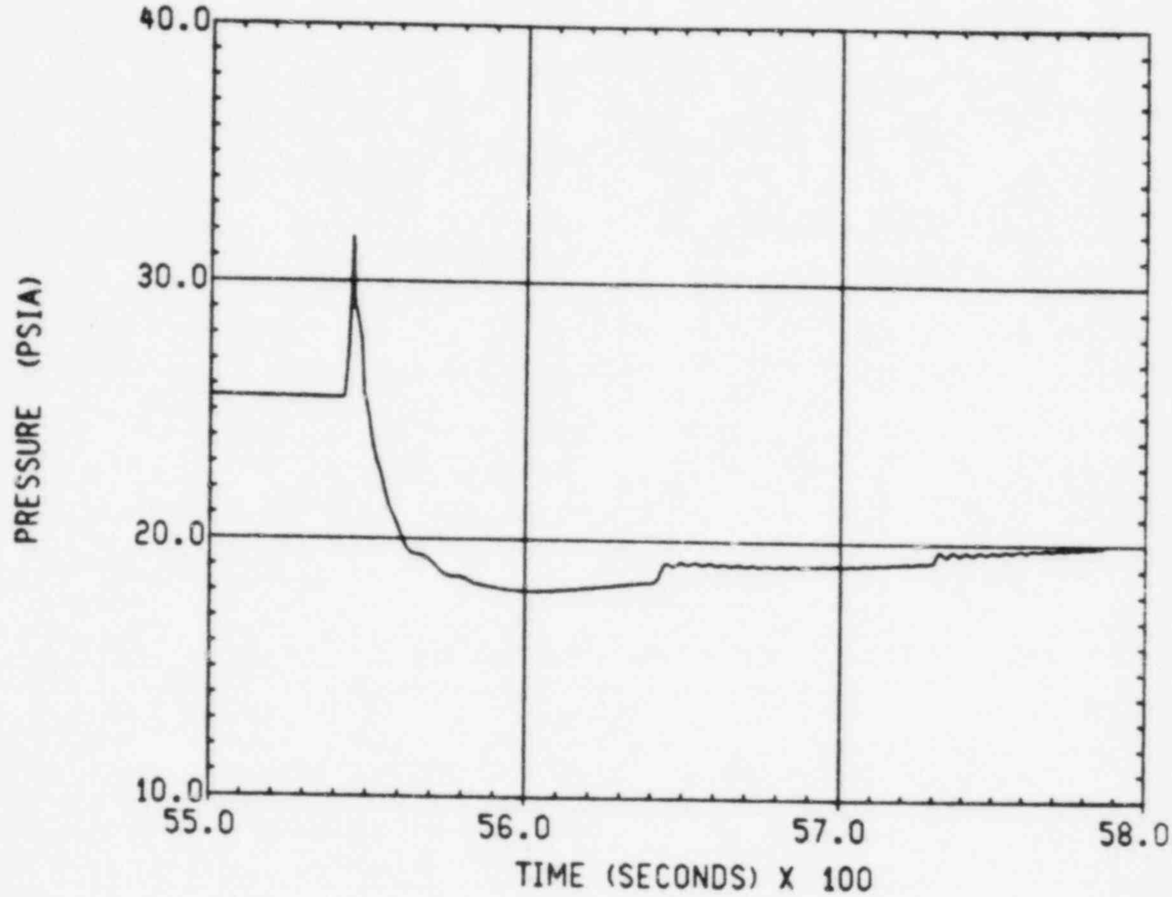
70/30 DRYWELL BREAK TWO COMP NEW BEAM LENGTH
GRAND GULF NUCLEAR STATION
WETWELL TEMPERATURE

FIGURE 41



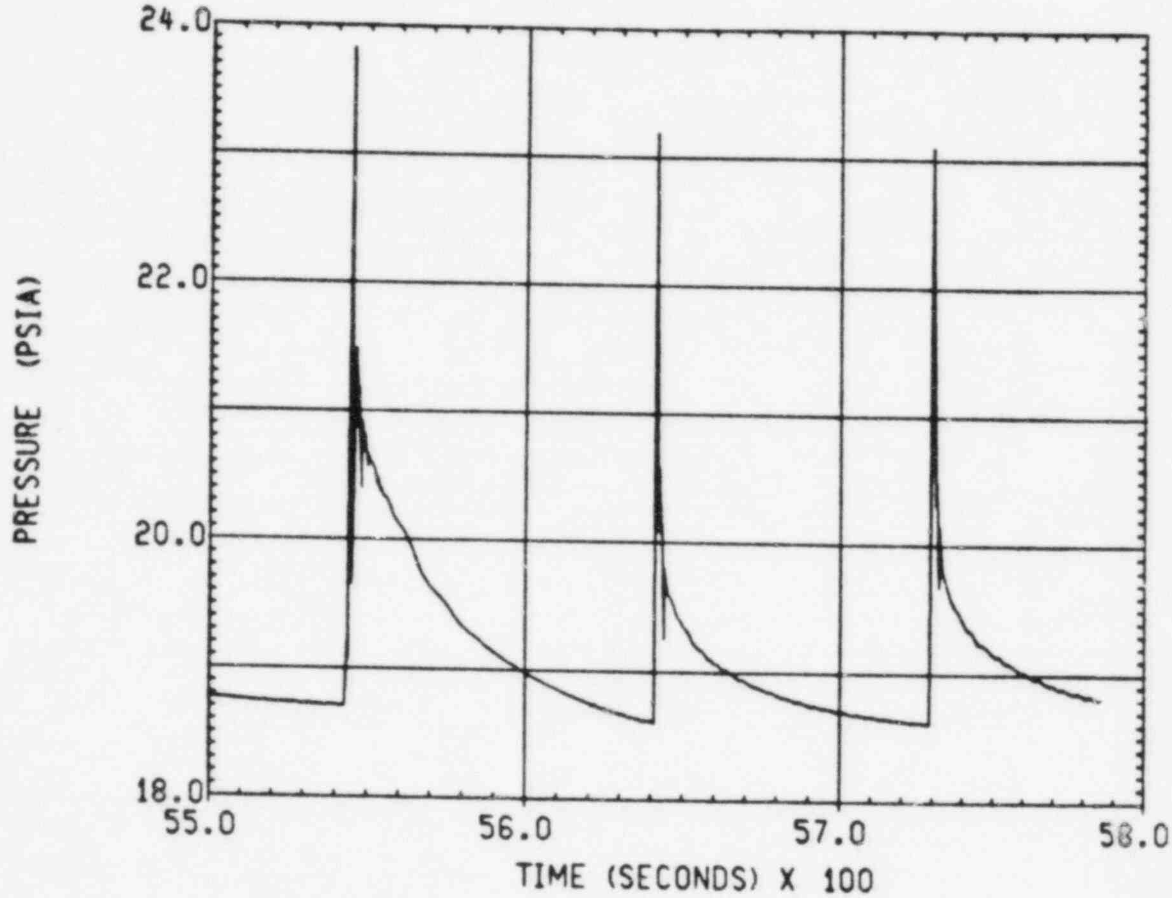
70/30 DRYWELL BREAK TWO COMP NEW BEAM LENGTH
GRAND GULF NUCLEAR STATION
CONTAINMENT TEMPERATURE

FIGURE 42



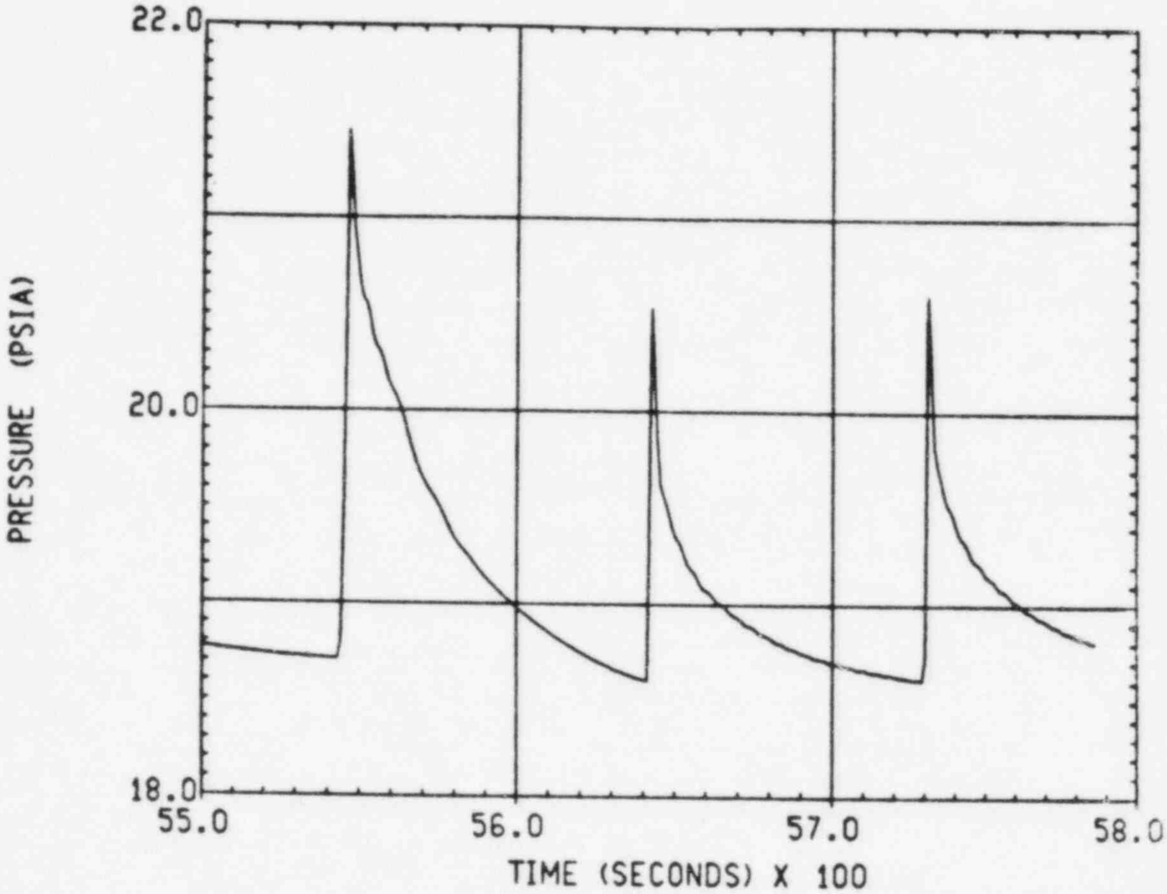
70/30 DRYWELL BREAK TWO COMP NEW BEAM LENGTH
GRAND GULF NUCLEAR STATION
DRYWELL PRESSURE

FIGURE 43



70/30 DRYWELL BREAK TWO COMP NEW BEAM LENGTH
GRAND GULF NUCLEAR STATION
WETWELL PRESSURE

FIGURE 44



70/30 DRYWELL BREAK TWO COMP NEW BEAM LENGTH
GRAND GULF NUCLEAR STATION
CONTAINMENT PRESSURE

FIGURE 45