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October 25, 1983

NUCLEAR PRODUCTION DEPARTMENT

U. S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
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-83/0659

References:
1. Letter from Mr. A. Schwencer to Mr. J. P. McGaughy, dated July 22, 1983
2. Letter AECM-83/0479, from Mr. L. F. Dale to Mr. H. R. Denton, dated August 23, 1983

Reference 2 transmitted a discussion on the estimated effect of sprays on the containment thermal environment during hydrogen combustion. A request for clarification was made by members of your staff. This clarification is provided in the attached assessment of potential effects of containment sprays on equipment survivability. Resolution of the actual spray effectiveness issue will come through testing at the 1/4 scale HCOG facility.

Yours truly,

Sam H Hobbs

for L. F. Dale
Manager of Nuclear Services

JRH/SHH:rg

Attachment

cc: See next page

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MISSISSIPPI POWER & LIGHT COMPANY

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ASSESSMENT OF POTENTIAL EFFECTS OF CONTAINMENT SPRAYS ON EQUIPMENT SURVIVABILITY

Background

On August 23, 1983, MP&L submitted an evaluation of the thermal environment expected in the Grand Gulf containment during H_2 combustion as a standing flame with sprays in operation (Reference 1). In summary, that evaluation postulated that the gas temperature measured near the HCU floor early in the 1/20th scale tests (before significant heating of the upper containment air) could be used as an estimate of expected gas temperature with sprays in operation. This was based on the assumption that the increase in gas temperature with time observed in the model was primarily due to the recirculation of heated upper containment gas to the flame base. In the actual plant the sprays were assumed to cool this air back to spray temperature leading to minimal heatup of the recirculated air.

It has been pointed out by NRC consultants (Sandia) that the gas temperature observed in the upper portion of the "hot" chimney at the 312° azimuth location in the 1/20th scale test was only 270°F. Therefore, the maximum effect on temperature of the recirculating gas due to spray operation would be to decrease this temperature from 270°F to the spray temperature (90°-185°F depending on the scenario). Assuming that this Δ T would correspond to the Δ T at the HCU floor, a benefit of between 85° and 180°F might be expected due to spray cooling of the recirculated air.

This discussion responds to the Sandia concern relative to the initial estimate of gas temperature as a characterization of spray effectiveness.

Response

The 1/20th scale tests were conducted to obtain:

1. A visual record of global hydrogen combustion behavior in a full 360° model of a Mark III Containment.

2. Data to estimate thermal environment due to combustion of a continuous flame.

The instrumentation in the 1/20th scale test facility was limited. therefore, one must take caution in drawing conclusions based solely upon this data. The observations made by Sandia would be correct if the 270°F observation were the upper containment ambient temperature, i.e., if the air were circulated and cooled in a "slug flow" pattern as shown in Figure 1. However, the conditions observed in the 1/20th scale tests were more complicated than simple "slug flow".

In the 1/20th scale tests there were 3 mechanisms for cooling the heated air due to hydrogen combustion. These were:

1. Mixing with the cooler ambient air.

2. Convective heat transfer from the heated gases to surfaces within the containment.

3. Radiant heat transfer from the flame and hot combustion products to surfaces within the containment.

The effects of these three mechanisms were readily observed even in the limited instrumented results of the 1/20th scale tests as shown in Figure 2. When one compares the measured temperatures shown in Figure 2 with the actual structures in Figure 3, one can readily see the effect of mixing with cooler ambient air each time the heated gases rise through a restricted opening such as the HCU floor. This type of flow is shown in Figure 4, and one can see that it can not be represented as a "slug" flow as was suggested by Sandia.

Also one should note that the effect of the containment sprays are not limited to cooling the air itself but will provide additional cooling through all of the following mechanisms:

1. Cool the containment air directly and increase the relative humidity to 100% and thereby increasing the heat capacity of the air.

2. Promote mixing. Spray effectiveness tests for containments sprays were conducted on plants such as Zion. These tests were to measure spray coverage and what they observed was that the sprays promoted such turbulent mixing that all surfaces were thoroughly wetted and individual spray patterns were nonexistent. Individuals who entered the containment under the protection of umbrellas to inspect for dry spots observed that due to the violent turbulence promoted by the sprays that their umbrellas were instantly destroyed and they were throughly drenched requiring a quick exit from the containment.

   The water that falls onto intermediate floors and into the upper pool will eventually cascade down the walls and floors until it reaches the wetwell area.

   The turbulent mixing caused by the containment sprays will help cool local areas and will distribute the heat produced by the flames throughout the entire volume.

3. Maintain suspended water droplets in the containment free volume. It is estimated that there will be a minimum of 1700 gallons of water continuously suspended in the containment free volume. These suspended water droplets have a significant impact of increasing the heat capacity above that of air alone. For example, the ratio of heat capacities of the air-water mixture vs. air alone is as follows:

Temperatures	Ratio of Heat Capacities
$T < 212°F$	1.5
$T = 212°F$	480

   The increase of heat capacity alone without allowing for the effect of vaporization would result in a 33% reduction of temperatures, and when one takes into account the vaporization of water together with more turbulent mixing the effects on measured temperatures will be dramatic and it is expected that any temperatures above 212°F will be in close proximity to the flames themselves. (More is said on this in items 4 and 5 below.)

4. Cool equipment directly. All equipment wetted by the containment sprays directly or wetted due to the turbulent mixing will be cooled. The upper limit to this effect is easy to quantify (i.e., any equipment which is wetted will not be heated above saturation temperature).

5. Direct cooling of the flame and combustion gases due to vaporization of entrained water droplets.

   Observation of the leaning of flames in the 1/20th scale tests indicates that strong global recirculation flows are established up some "chimneys", down others, and horizontally above the pool. Depending on the total heat released, the upward velocity in the "hot" chimneys may be sufficient to partially block downward flow of spray-droplets. However, spray flow down the "cold" chimneys will be relatively unimpeded and a significant fraction of those droplets would be expected to be entrained in the horizontal flow above the pool. These droplets would flow into the flames and their hot plumes and would be available as a significant heat sink as they vaporize. A conservative estimate of the heat sink capacity of such droplets can be made as follows:

   a. There were 1 cold and 3 hot chimneys as observed in the 1/20th scale facility.

   b. No droplets are assumed to enter the hot chimneys due to upward flow of the hot gases.

   c. Of the droplets entering the cold chimney 75% is assumed to fall into the pool and 25% is assumed to be carried by the air into the flames.

   d. A single spray train is in operation.

Analysis:

Total spray water flow available for vaporization in the hot chimneys

$$M_w = \frac{A_c}{A_T} \times 5500 \text{ GPM} \times \frac{1}{60}\,\frac{\text{min}}{\text{sec}} \times 8\ \frac{\text{lbm}}{\text{gallon}} \times 0.25$$

where A_c = Flow area of cold chimney
A_T = Total cross section area of upper containment
5500 GPM = Spray flow of a single train.

$$M_w = \frac{530 \text{ ft}^2}{11304 \text{ ft}^2} \times 5500 \text{ GPM} \times 1/60 \times 8 \times 0.25 = 8.6 \text{ lbm/sec}$$

The heat sink capacity of this water is

$$Q_s = (1000 \text{ Btu/lbm})_{\text{heat of vaporization}} \times 8.6 \text{ lbm/sec} = 8600 \text{ Btu/sec}$$

The total energy released for a total H_2 flow of 0.8 lbm/sec =

$$Q_R = 61{,}500 \text{ Btu/lbm} \times 0.8 \text{ lbm/sec} = 49{,}200 \text{ Btu/sec}$$

The fraction of energy released which could then be absorbed by the entrained water droplets = $\frac{8600}{49,200} = 0.17$

In terms of the effect on the ΔT (ambient prior to combustion to that after) this corresponds to a 17 percent decrease for this effect alone or:

the Δ T due to spray vaporization = 0.17 x 560°F* = 95°F

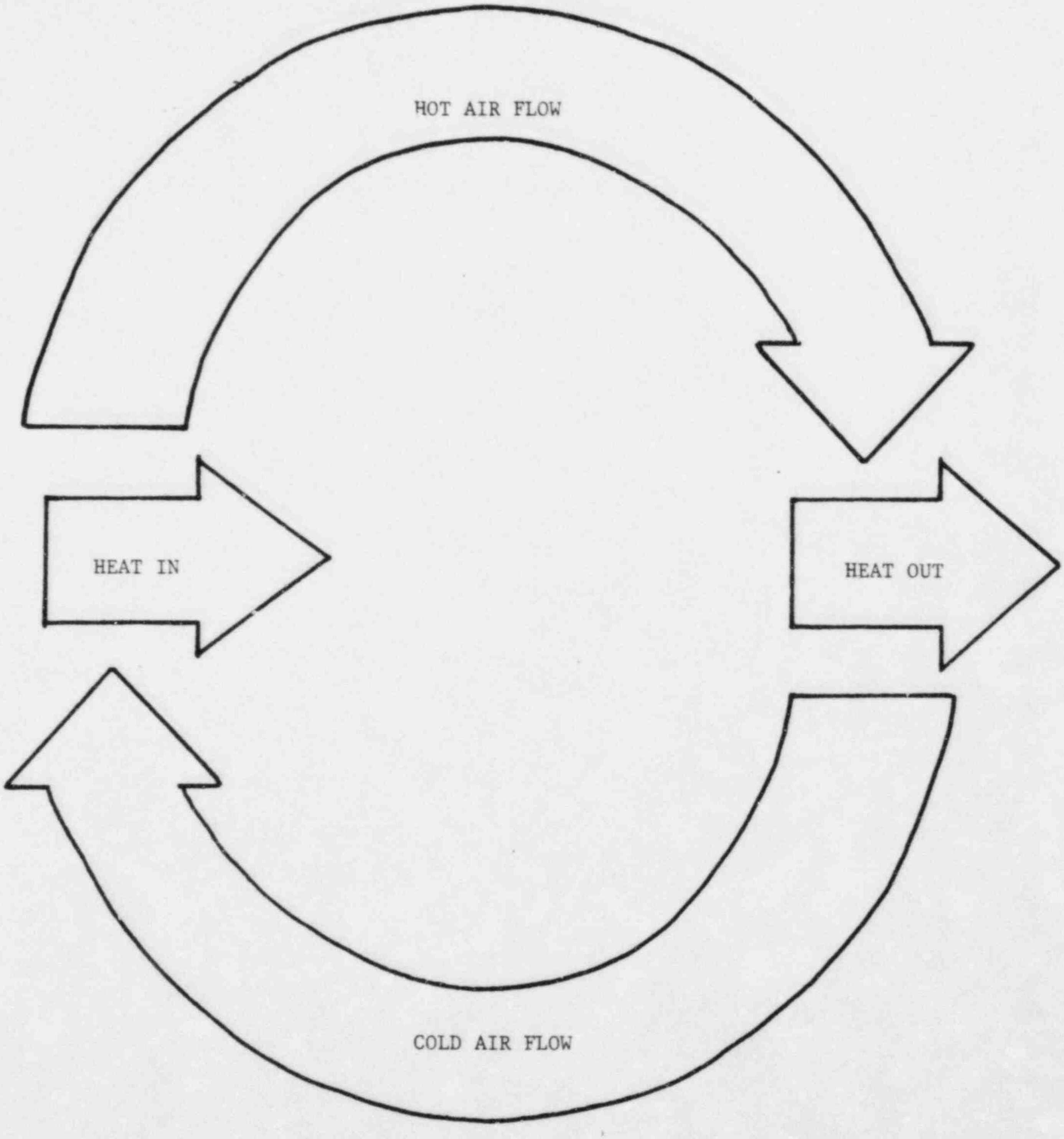
Summary

Due to the above described mechanisms, we anticipate that the containment sprays will have a major effect on cooling the containment and equipment after combustion of hydrogen. This effect will be measured in the ¼ scale tests, and will be factored into the equipment survivability analysis.

Reference

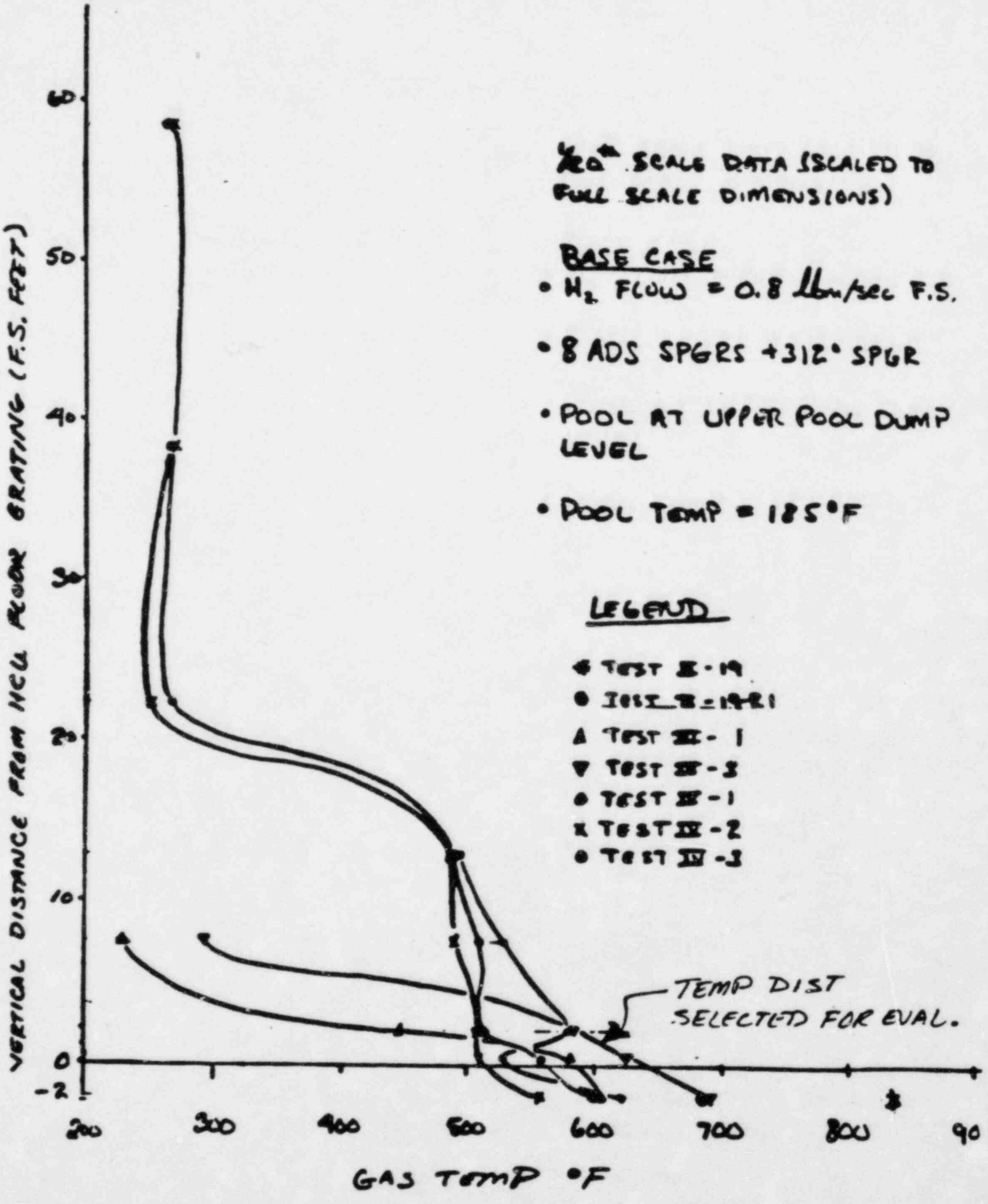
1. Letter L. F. Dale (MP&L) to H. Denton (U.S.NRC), Supplementary Response to NRC Letter on H_2 Control, 8/23/83 (AECM-83/0479).

* Observed ΔT at HCU floor (700°F - 140°F) w/o sprays.



"Slug" Flow Representation

FIGURE 1



1/20th SCALE DATA (SCALED TO FULL SCALE DIMENSIONS)
BASE CASE
• H_2 FLOW = 0.8 lbm/sec F.S.
• 8 ADS SPGRS + 312° SPGR
• POOL AT UPPER POOL DUMP LEVEL
• POOL TEMP = 185°F
LEGEND
TEST II-19
TEST II-19R1
TEST III-1
TEST III-3
TEST IV-1
TEST IV-2
TEST IV-3
TEMP DIST SELECTED FOR EVAL.
VERTICAL DISTANCE FROM HCU FLOOR GRATING (F.S. FEET)
GAS TEMP °F

FIGURE 2

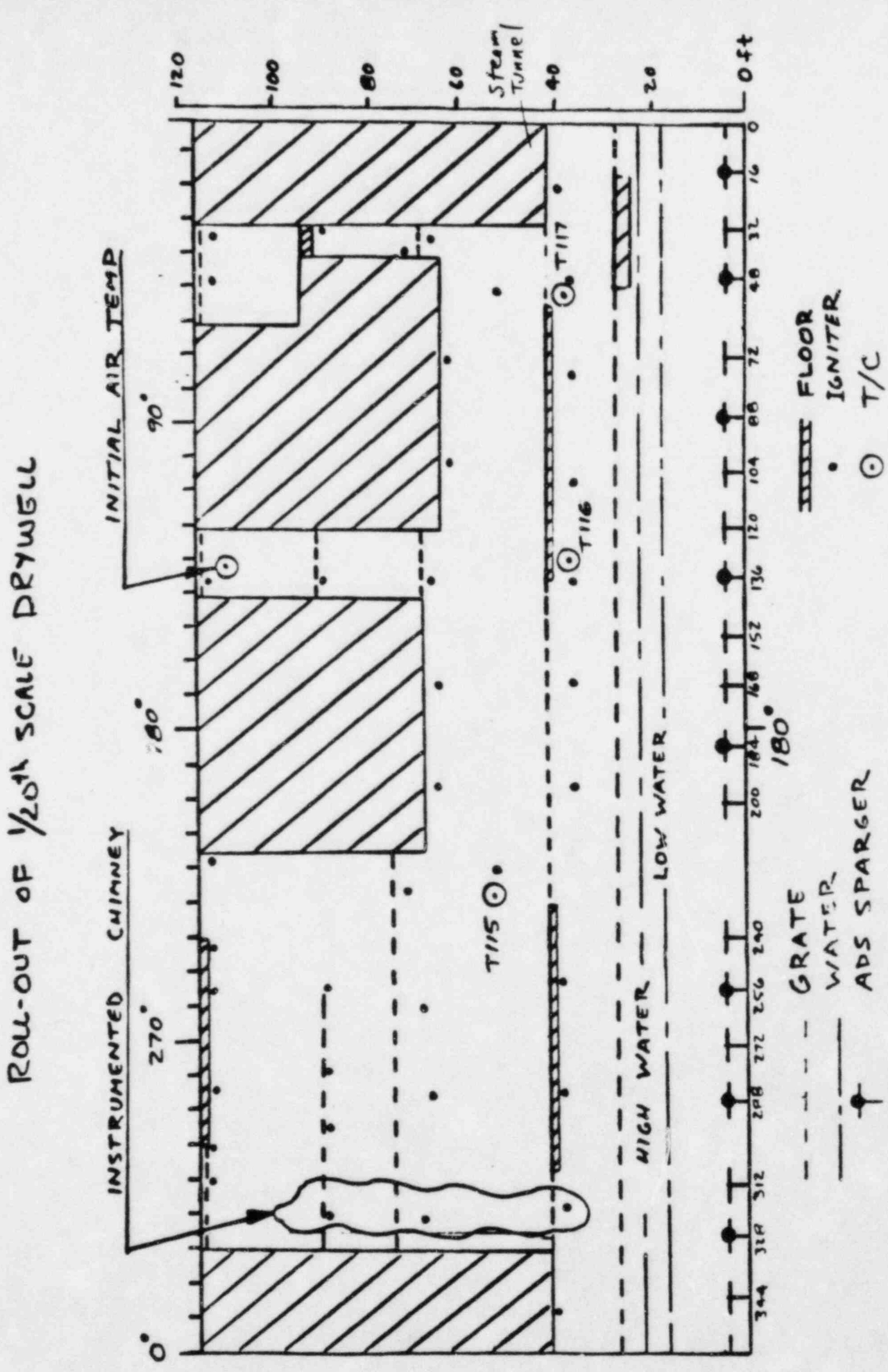
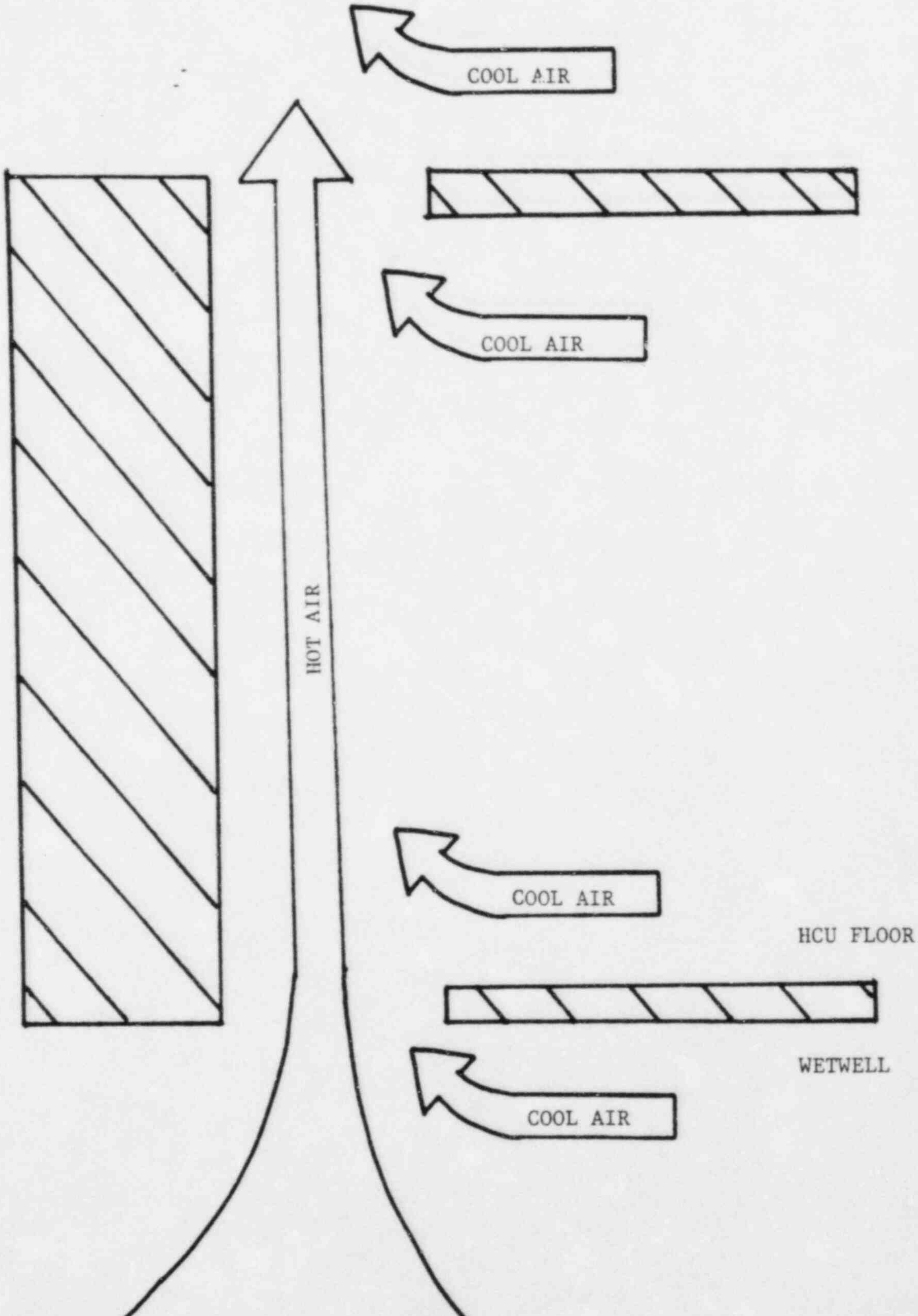

ROLL-OUT OF 1/20th SCALE DRYWELL
INSTRUMENTED CHIMNEY
INITIAL AIR TEMP
Steam Tunnel
T117
T116
T115
0°
90°
180°
270°
120
100
80
60
40
20
0 ft
0
16
32
48
72
88
104
120
136
152
168
184
200
240
256
272
288
312
328
344
HIGH WATER
LOW WATER
GRATE
WATER
ADS SPARGER
FLOOR
IGNITER
T/C

FIGURE 3



AIR FLOW

FIGURE 4