H_2 COMBUSTION TESTING IN A 1/20TH SCALE MODEL OF A BWR MARK III CONTAINMENT

BY

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PRESENTATION TO

U.S. NUCLEAR REGULATORY COMMISSION
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H_2 COMBUSTION TESTING IN A 1/20TH SCALE MODEL A BWR MARK III CONTAINMENT

- OBJECTIVE/SCOPE
- SCALING LAWS APPLIED
- TEST FACILITY DESCRIPTION
- TEST RESULTS
- SUMMARY

H_2 COMBUSTION TESTING IN A 1/20TH - SCALE MODEL OF A MARK III CONTAINMENT

- CONTRACTOR
  - ACUREX CORPORATION
- OBJECTIVES
  - PROVIDE A VISUAL RECORD OF GLOBAL H_2 COMBUSTION BEHAVIOR IN A FULL 360° MODEL OF A MK III CONTAINMENT
  - PROVIDE DATA TO ESTIMATE THERMAL ENVIRONMENT (TEMPERATURES, RADIANT HEAT FLUX) DUE TO H_2 COMBUSTION AS A CONTINOUS FLAME
- SCOPE
  - 41 TESTS PERFORMED INCLUDING TESTS TO ASSSESS THE EFFECTS OF VARIATIONS IN:
    - TOTAL H_2 RELEASE RATE
    - BLOCKAGES/IN WETWELL ANNULUS
    - SPARGER VS. VENT RELEASE
    - NUMBER/LOCATION OF ACTIVE SPARGERS
    - POOL TEMP
    - HEAT LOSS FROM OUTER CONT. SHELL
- STATUS
  - TESTING COMPLETED 6/23/83
  - TEST REPORT BY 10/1/83

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SCALING LAWS APPLIED

- FROUDE MODELLING
  - APPLICABLE TO TURBULENT BUOYANTLY CONTROLLED DIFFUSION FLAMES
- RESULTING SCALING RELATIONS

LENGTH	$(S)^1$
H_2 RELEASE RATE	$(S)^{5/2}$
TIME	$(S)^{1/2}$
VELOCITY	$(S)^{1/2}$
TEMPERATURE	$(S)^0$
CONCENTRATION	$(S)^0$

WHERE S = 1/20 FOR A 1/20TH SCALE MODEL

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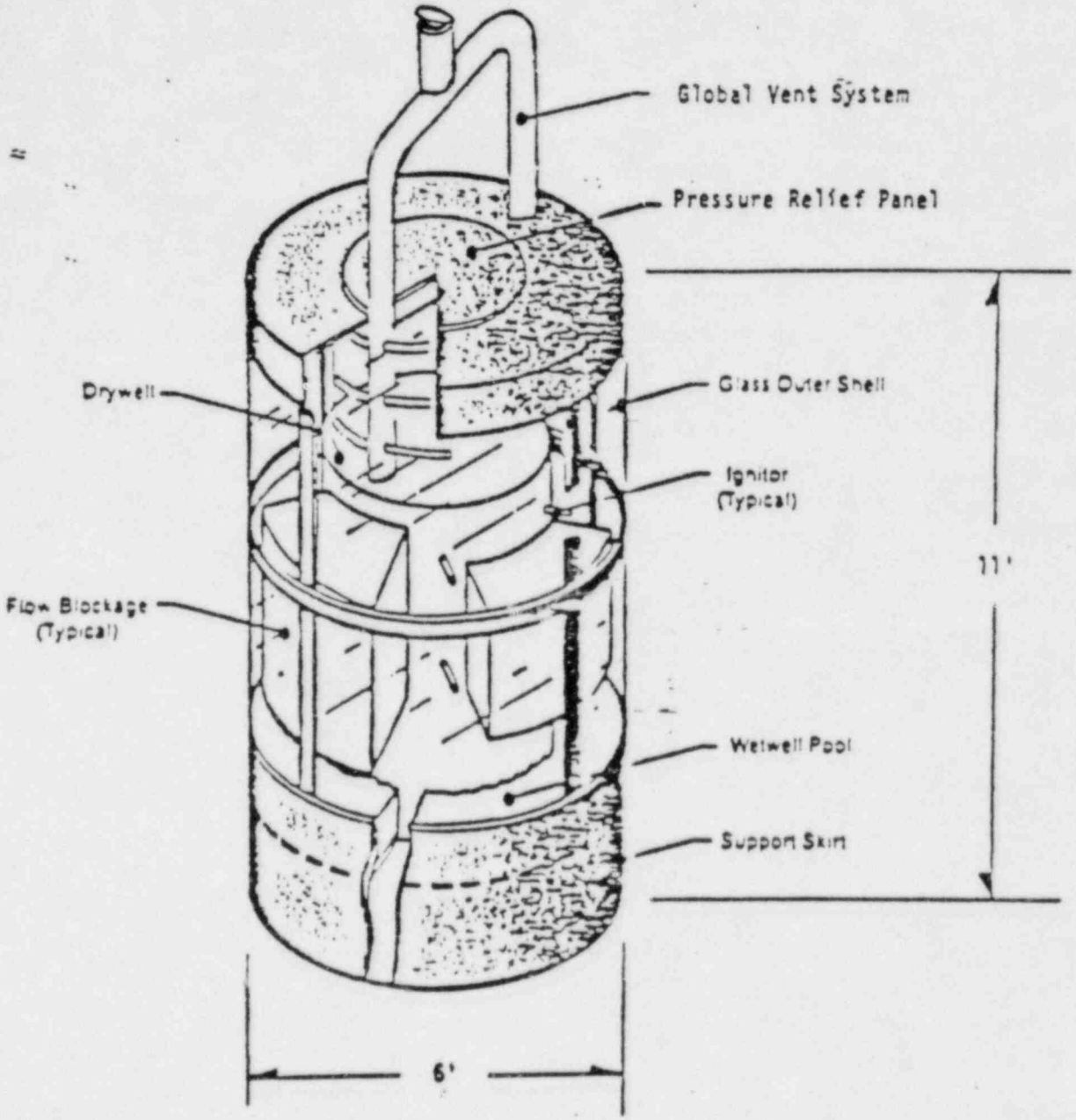

1/20TH SCALE MK III CONTAINMENT COMBUSTION
VISUALIZATION TEST FACILITY

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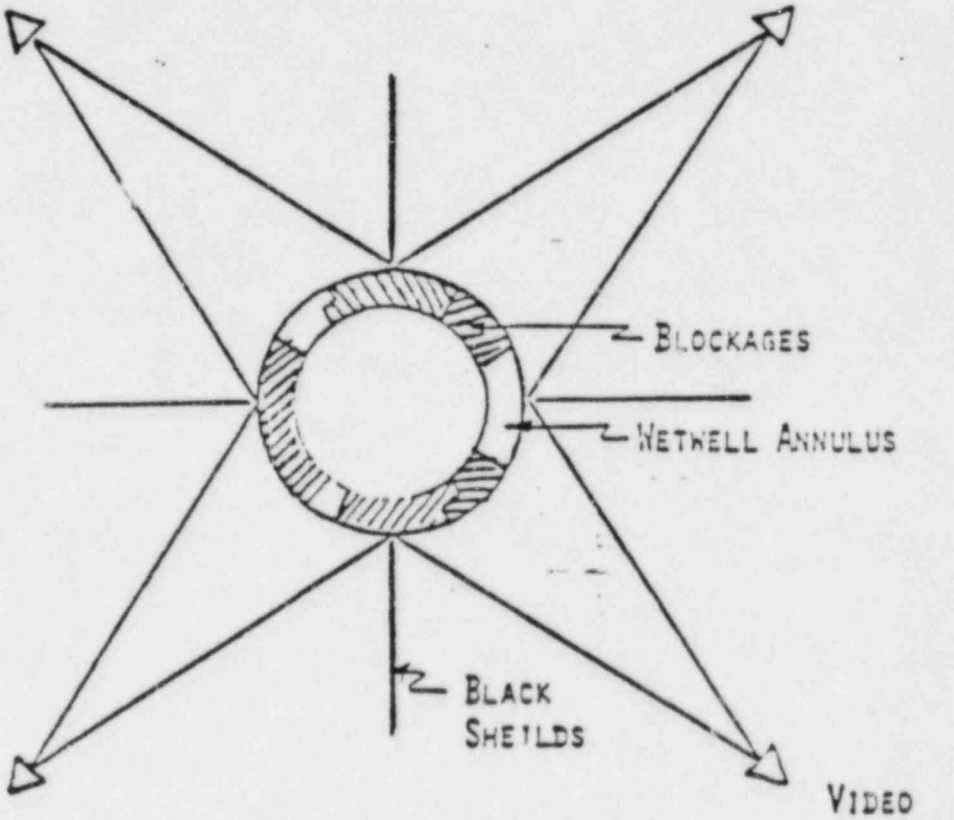
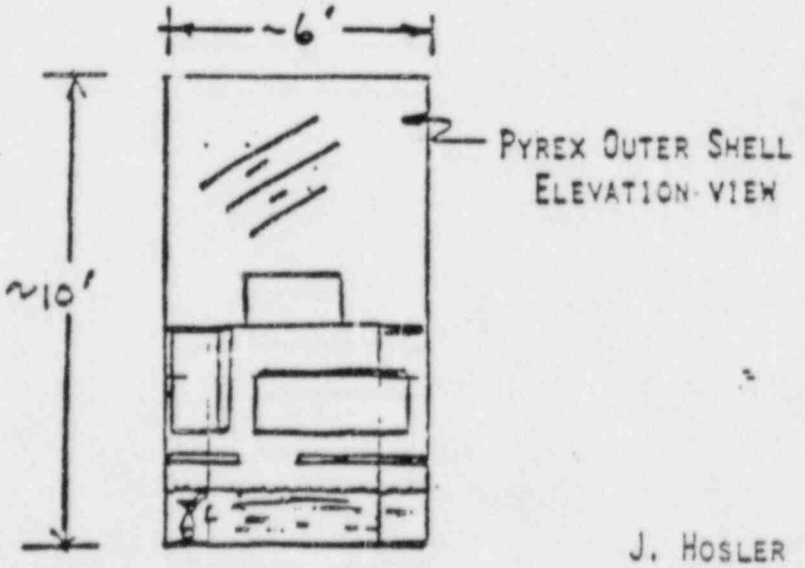
PLAN VIEW OF 1/20TH
SCALE VISUALIZATION FACILITY





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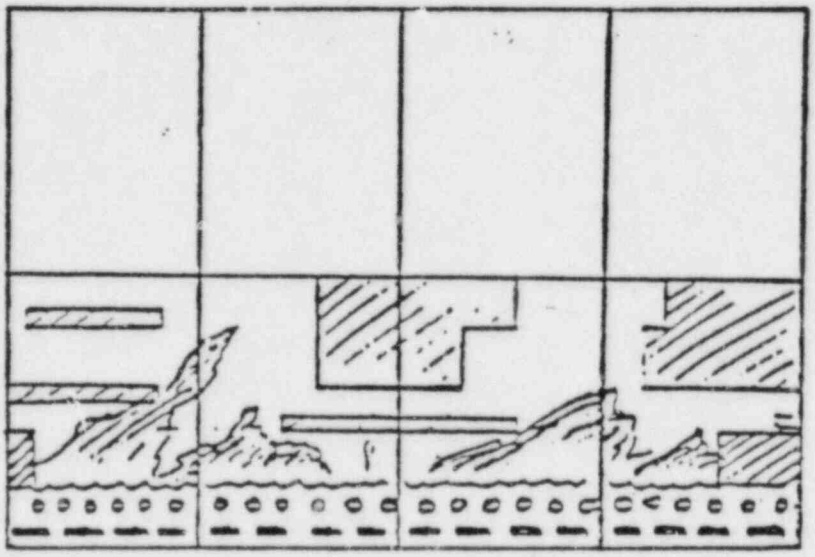

- MIXING OF VIDEO FROM EACH OF THE 4 CAMERAS ON A SINGLE TAPE WILL ALLOW CONTINUOUS VIEWING OF THE FULL 360° SIMULTANEOUSLY

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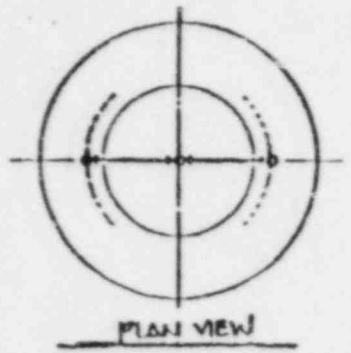
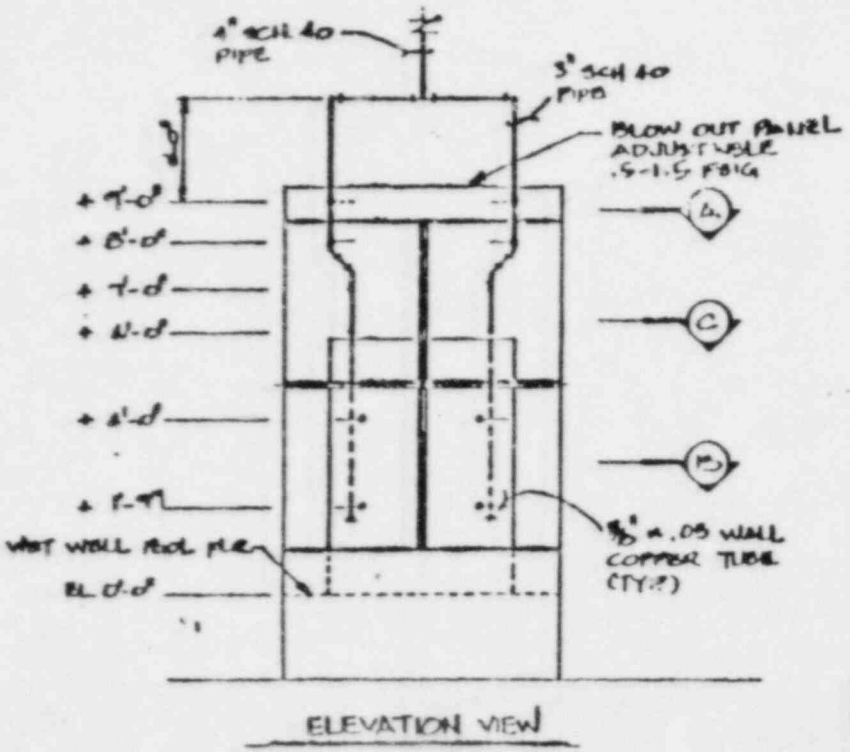
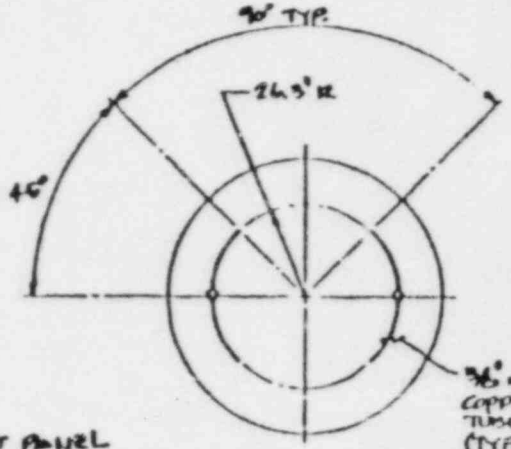


PLAN VIEW

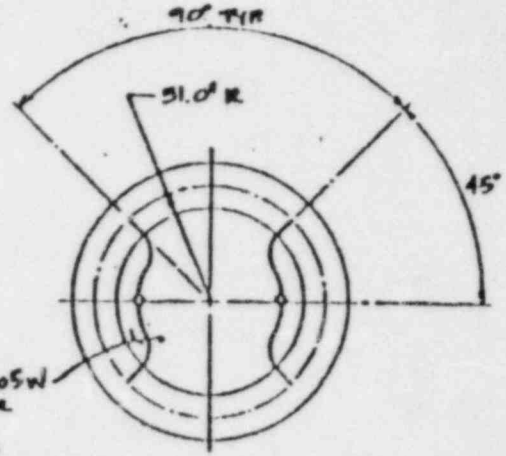


ELEVATION VIEW



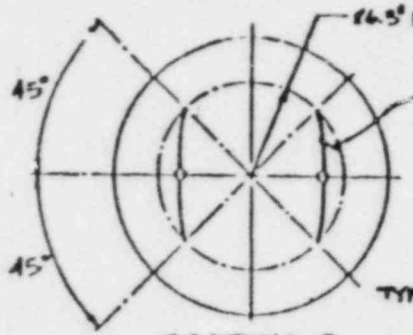
SECTION A

TYP. STATION +9'-0" & +8'-0"



SECTION B

TYP. STATION +4'-0" & +8'-0"



TYP. STATION +9'-0" & +4'-0"

SECTION C

ITEM NO	PART NO	DESCRIPTION	QTY REQD

LIST OF MATERIALS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

REVISIONS

NEXT ASSY	QTY	USED ON	QTY

APPLICATION

DRAWN H. JUL

CHECKED

ENGINEER

APPROVED

MATERIAL

FINISH

ACUREX Aerotherm

FACILITY VENT LOCATIONS

MARK III CONTAINMENT MODEL

SIZE	C.M. ASSEMBLY NO	DRAWING NO	REV.
C	50726	7104-1030	

SCALE NONE WT SHEET 1 OF 1

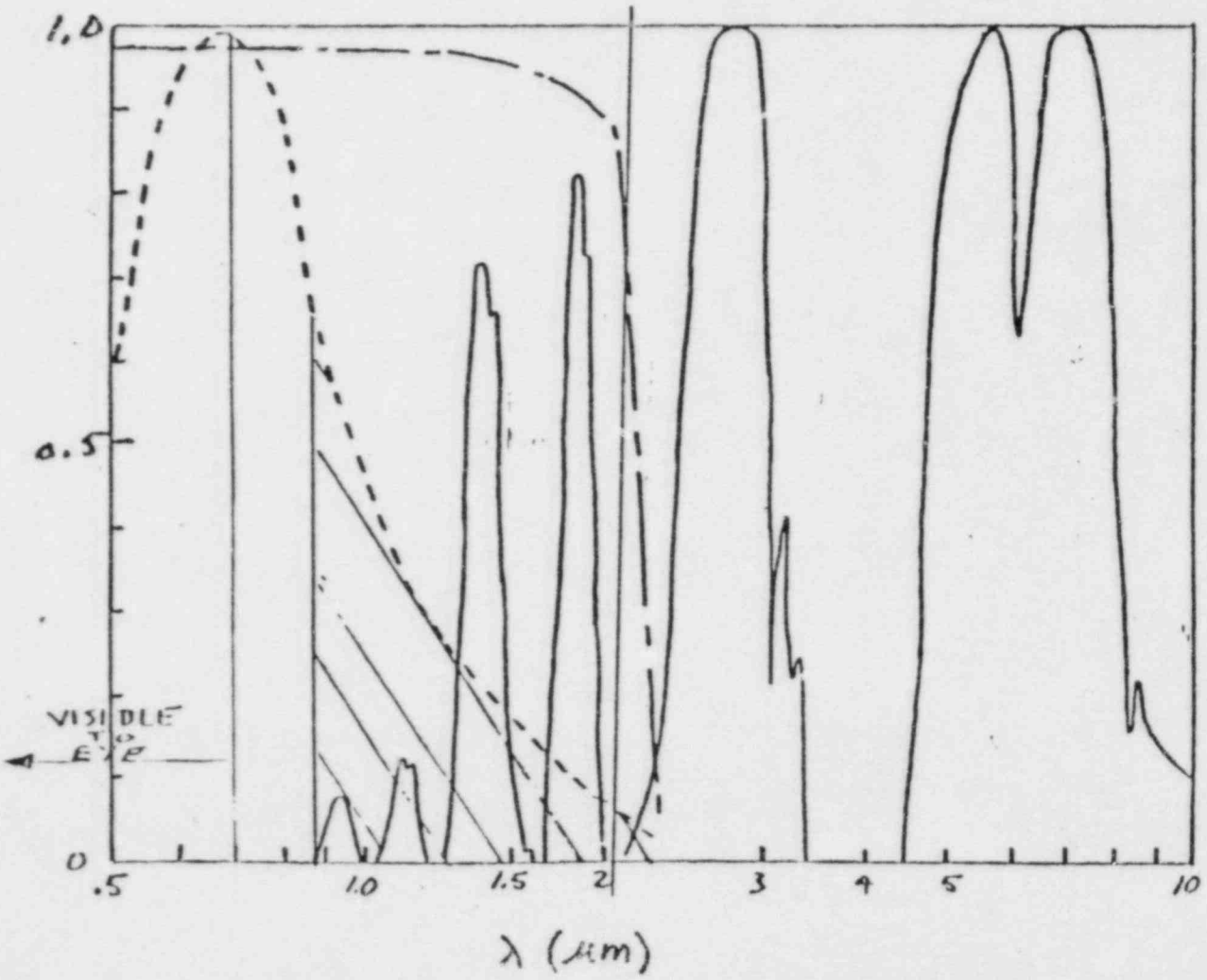
7104-1030

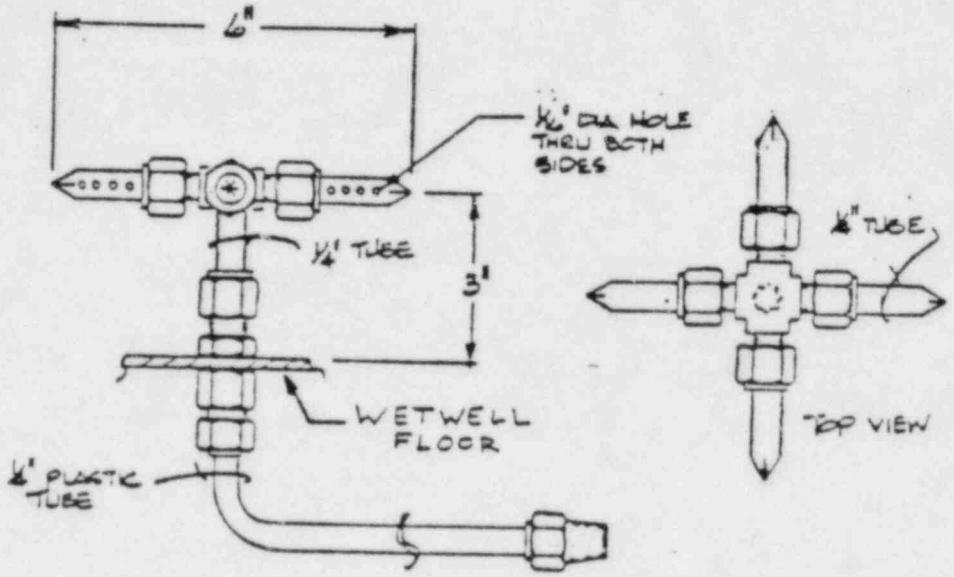
HOW H_2 COMBUSTION IS VISUALIZED

—— PYREX TRANSMITTANCE

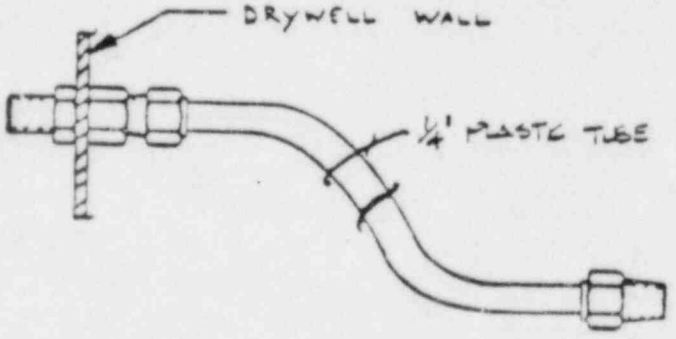
- - - - - CAMERA ACCEPTANCE

——— H_2O EMISSIVITY

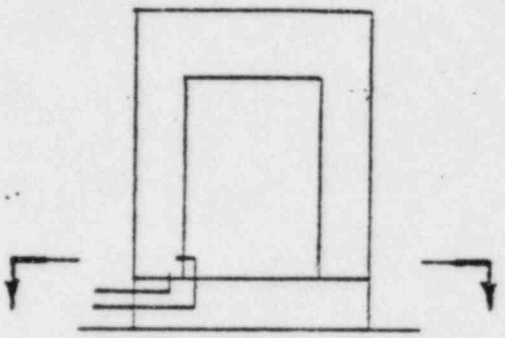


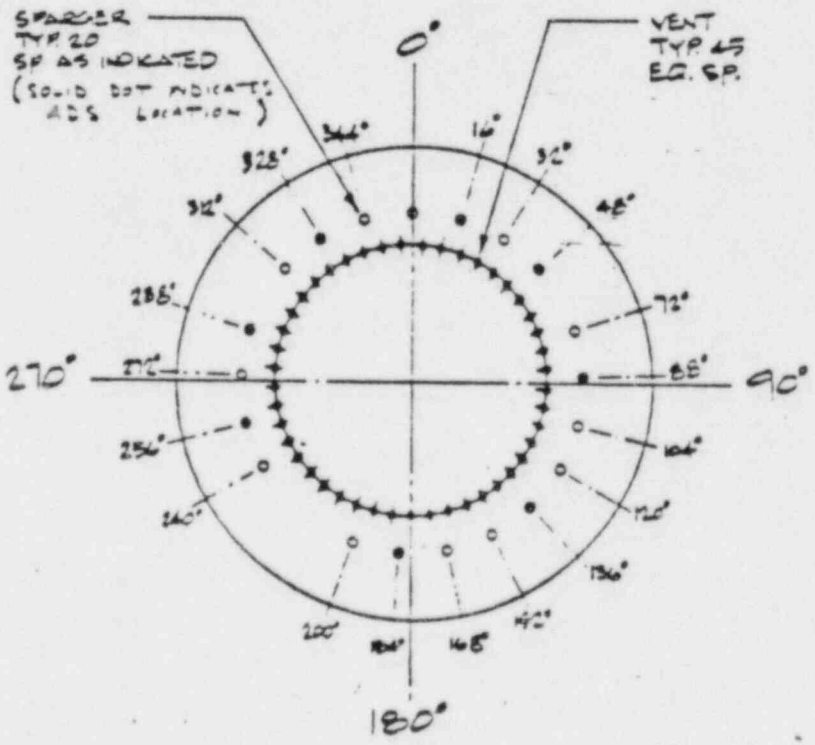


SPARGER DETAIL



VENT DETAIL

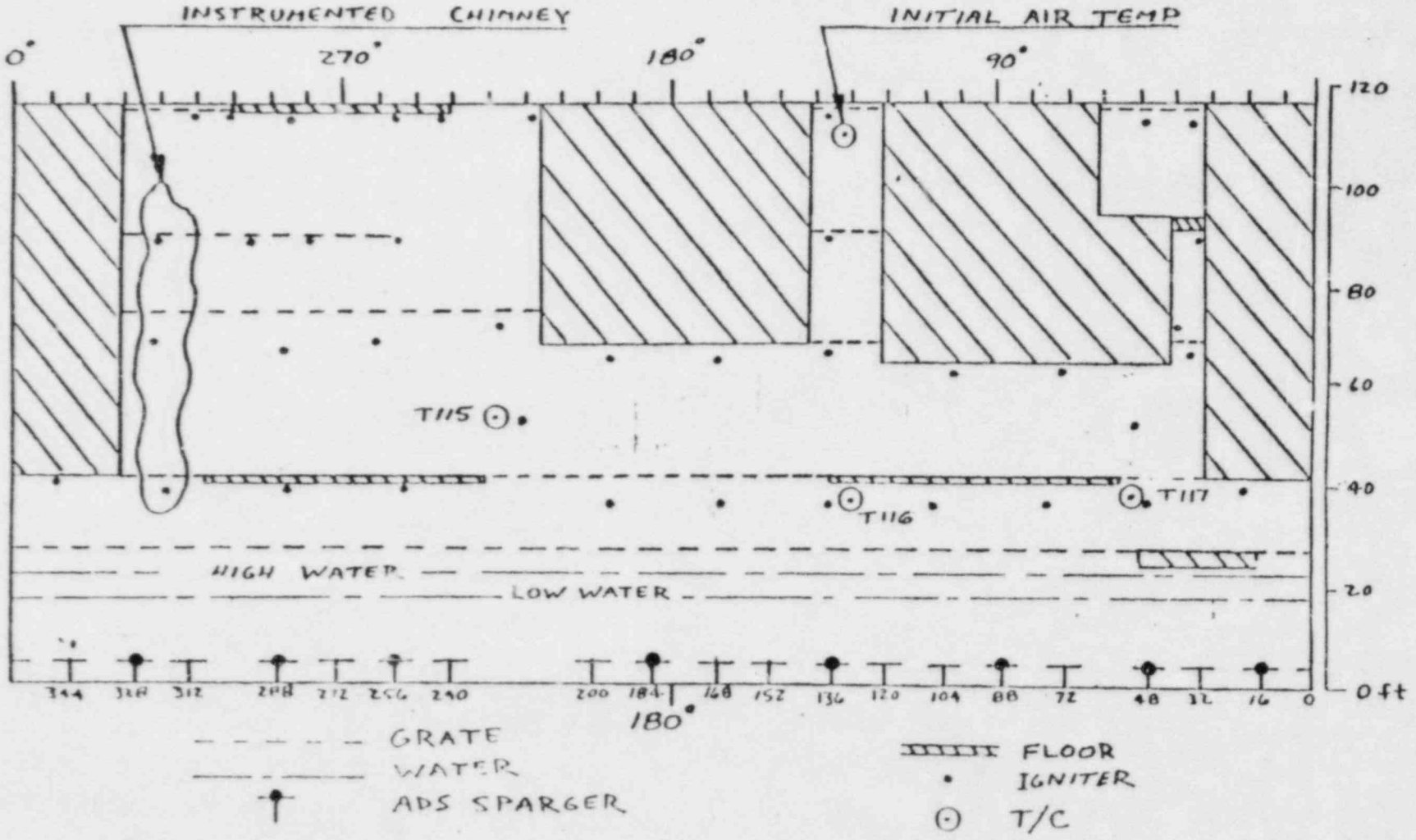




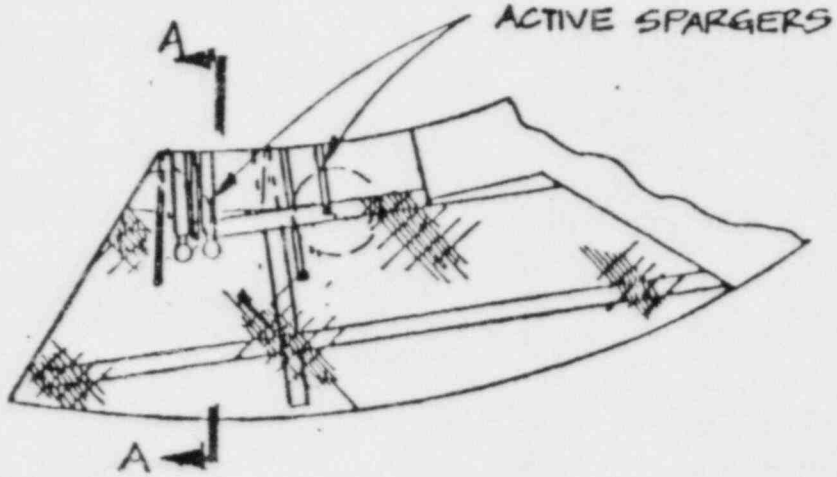
VENT & SPARGER

LOCATIONS

ROLL-OUT OF 1/20th SCALE DRYWELL

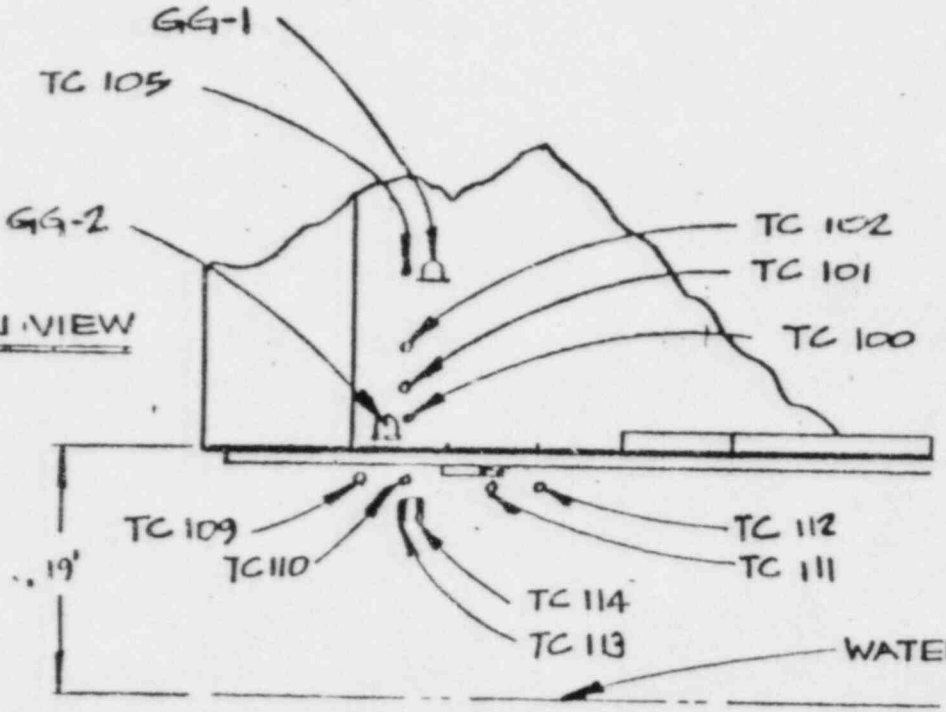


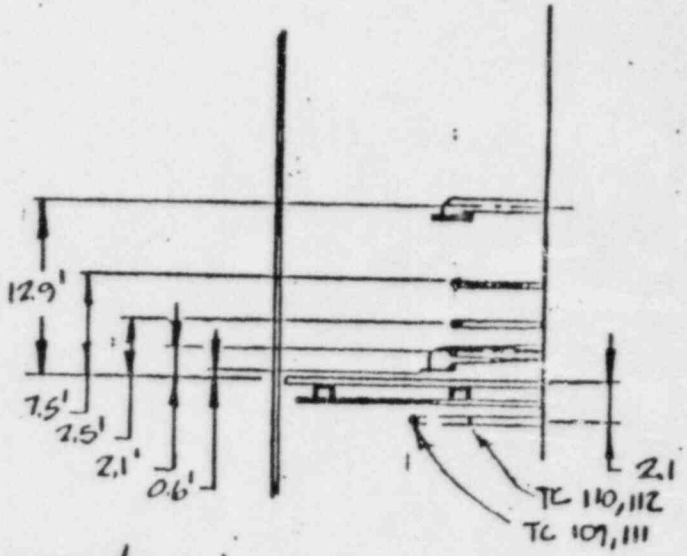
PLAN VIEW



PHASE II

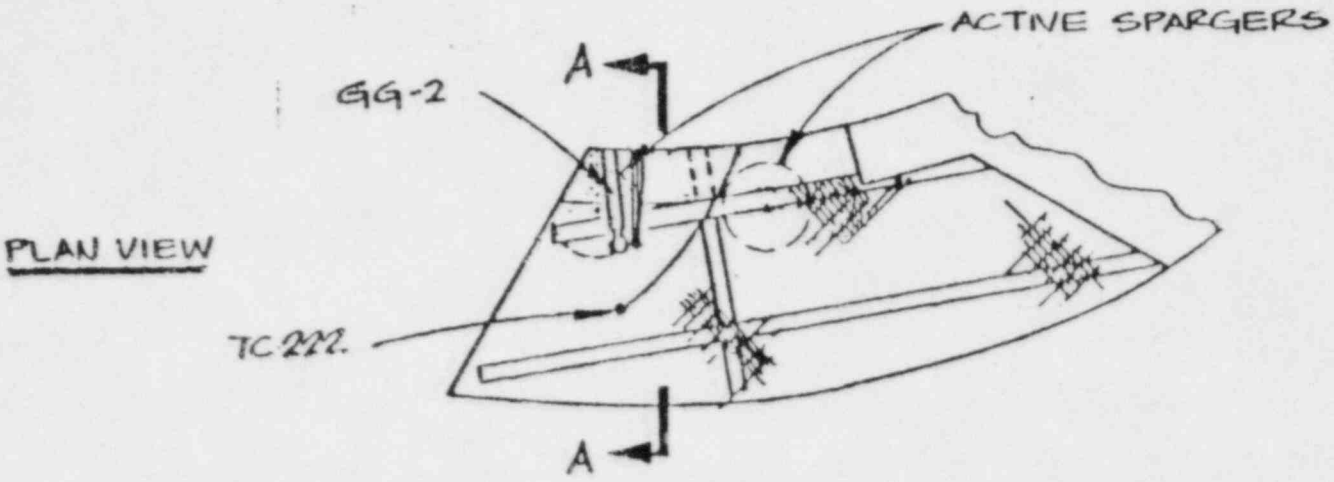
ELEVATION VIEW



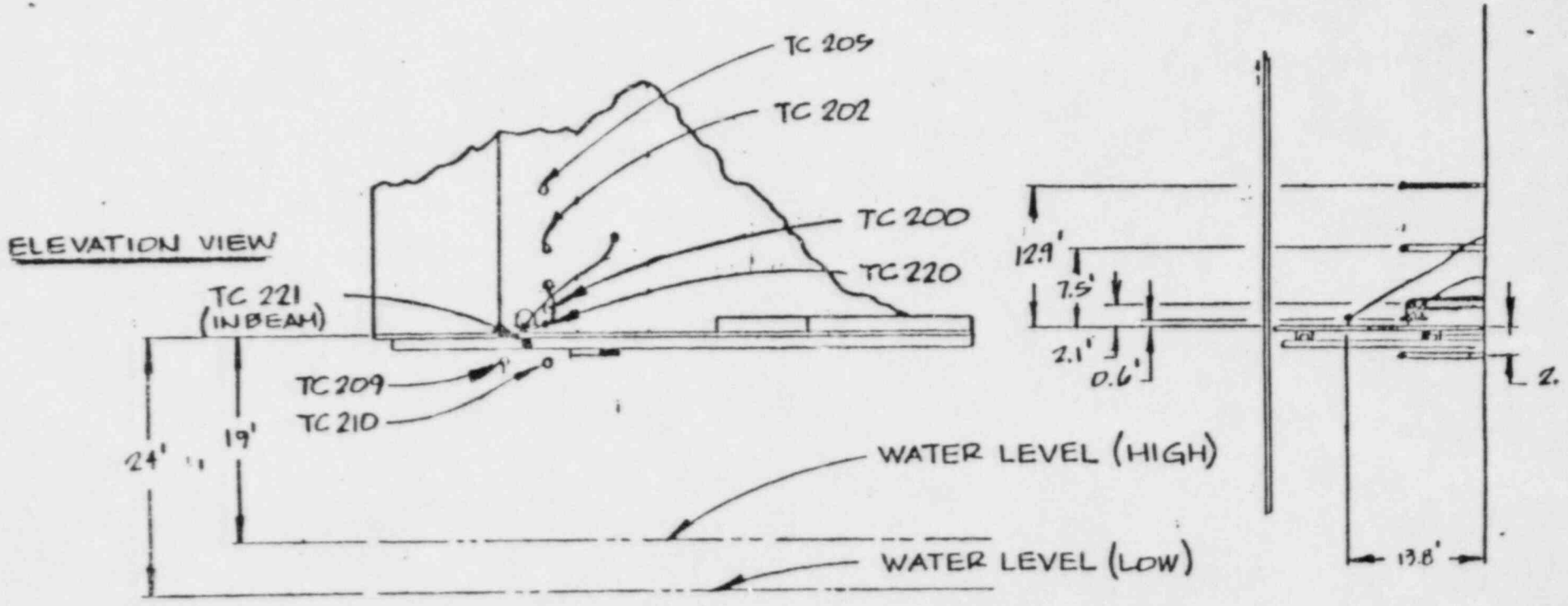


"FULL SCALE (IN PLANT) DIMENSIONS (FT) SHOWN"

PHASE III

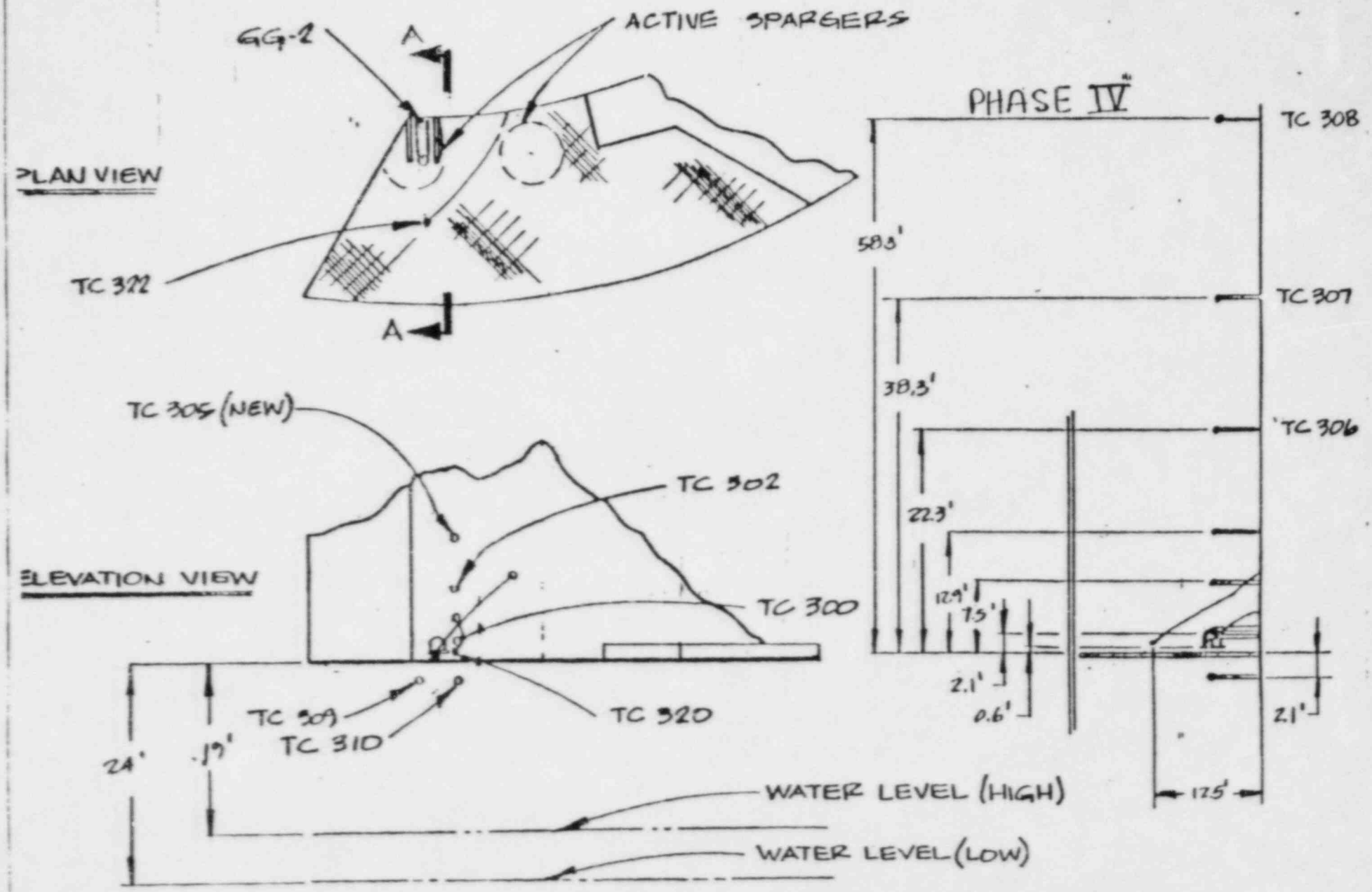


PLAN VIEW



ELEVATION VIEW

"FULL SCALE (IN PLANT) DIMENSIONS (FT) SHOWN"



"FULL SCALE (IN PLANT) DIMENSIONS (FT) SHOWN"

TESTS PERFORMED

- PHASE II
- PHASE III
- PHASE IV

- NOTE PHASE I WAS FACILITY SHAKEDOWN

1/20th Scale Phase II Test Matrix

Test #	Total H_2 Flow (Full Scale) lbm/sec	Pool Temp °F	Gas Temp °F	Pool Water Level	H_2 Release Locations	Insul.	40° Floor
II-1	1.0	185	140	UPD*	8 ADS + 312°	No	In
II-2	2.0	↓	↓				
II-3	1.0	125	90				
II-4	2.0						
II-5	1.0				9SPGRS + VENTS		
II-6	2.0						
II-7	1.0				8 ADS + 312°	Yes	
II-8	2.0						
II-9	1.0	185	140				
II-10	2.0						
II-11	1.0						
II-12	2.0						
II-13	1.0	125	90				
II-14	2.0						
II-15	1.0					No	Out
II-16	2.0						
II-17	1.0				312° SPGR ONLY		
II-18	2.0						
II-19	0.8	185	140		8 ADS + 312°		In
II-21**	0.8	125	90				
II-22	0.6						
II-23	0.4						
II-24	0.6	185	140				

*UPD - Upper Pool Dump Water Level

**No. II-20 Data Recorded.

1/20th Scale Phase III Test Matrix

Test	Total H_2 Flow (Full Scale lbm/sec	Pool Temp °F	Gas Temp °F	Pool Water Level	H_2 Release Locations	Heat Flux Meas.	Insul.	40° Floor
III-1	0.8	185	140	UPD*	8 ADS + 312°	Total	No	In
III-2	2.0	↓	↓	↓	↓	↓	↓	↓
III-3	0.8	↓	↓	↓	↓	Convective	↓	↓
III-4	2.0	↓	↓	↓	↓	↓	↓	↓
III-5	0.8	↓	↓	↓	8 ADS	↓	↓	↓
III-6	2.0	↓	↓	↓	↓	↓	↓	↓
III-7	0.8	↓	↓	NWL**	8 ADS + 312°	↓	↓	↓
III-8	2.0	↓	↓	↓	↓	↓	↓	↓
III-9	0.8	↓	↓	↓	↓	↓	↓	↓
III-10	1.0	↓	↓	↓	↓	↓	↓	↓
III-11	1.0	↓	↓	UPD	↓	↓	↓	↓
III-12	0.8	↓	↓	NWL	8 ADS	Total	↓	↓
III-13	1.0	↓	↓	↓	↓	↓	↓	↓

*UPD - Upper Pool Dump Water Level

**NWL - Normal Operation Water Level.

1/20th Scale Phase IV Test Matrix

Test	Total H_2 Flow (Full Scale) lbm/sec	Pool Temp °F	Gas Temp °F	Pool Water Level	H_2 Release Locations	Heat Flux Meas.	Insul.	40° Floor
IV-1	0.8	185	140	UPD*	8 ADS + 312°	Total	No	In
IV-2	↓	↓	↓	↓	↓	↓	↓	↓
IV-3	↓	↓	↓	↓	↓	↓	↓	↓
IV-4	↓	↓	↓	NWL**	↓	↓	↓	↓

*UPD - Upper Pool Dump Water Level.

**NWL - Normal Operation Water Level.

SUMMARY OF RESULTS

- STEADY DIFFUSION FLAMES ESTABLISHED ABOVE POOL FOR TOTAL H_2 INJECTION RATES GREATER THAN 0.4 LBM/SEC (FULL SCALE)

- BURNING CHARACTERIZED BY THE FOLLOWING SEQUENCE

  - H_2 INJECTION BEGINS (ADS + 312° (SORV) SPARGERS)

  - WEAK UPWARD FLAME PROPAGATION FROM LOWEST IGNITERS

  - ALMOST IMMEDIATELY A FAST DOWNWARD PROPAGATION TO POOL (MINIMAL PRESSURIZATION <.1 PSIG)

  - IMMEDIATE ESTABLISHMENT OF STEADY FLAMES ANCHORED ABOVE SPARGERS (PRIMARY BURNING)

  - STRONG HORIZONTAL AIR FLOWS ABOVE POOL ESTABLISHED QUICKLY

    - DIRECTION OF FLOWS DEPENDENT ON ANNULAR FLOW BLOCKAGE

  - BURNING MOST INTENSE IN 312° CHIMNEY (GRAND GULF CONFIG.)

  - AS O_2 IS DEPLETED FLAMES WEAKEN, GROW TALLER AND EVENTUALLY MOVE UPWARD AND ANCHOR ON HCU FLOOR GRATING (312° CHIMNEY ONLY) (SECONDARY BURNING)

  - ALL BURNING TERMINATES

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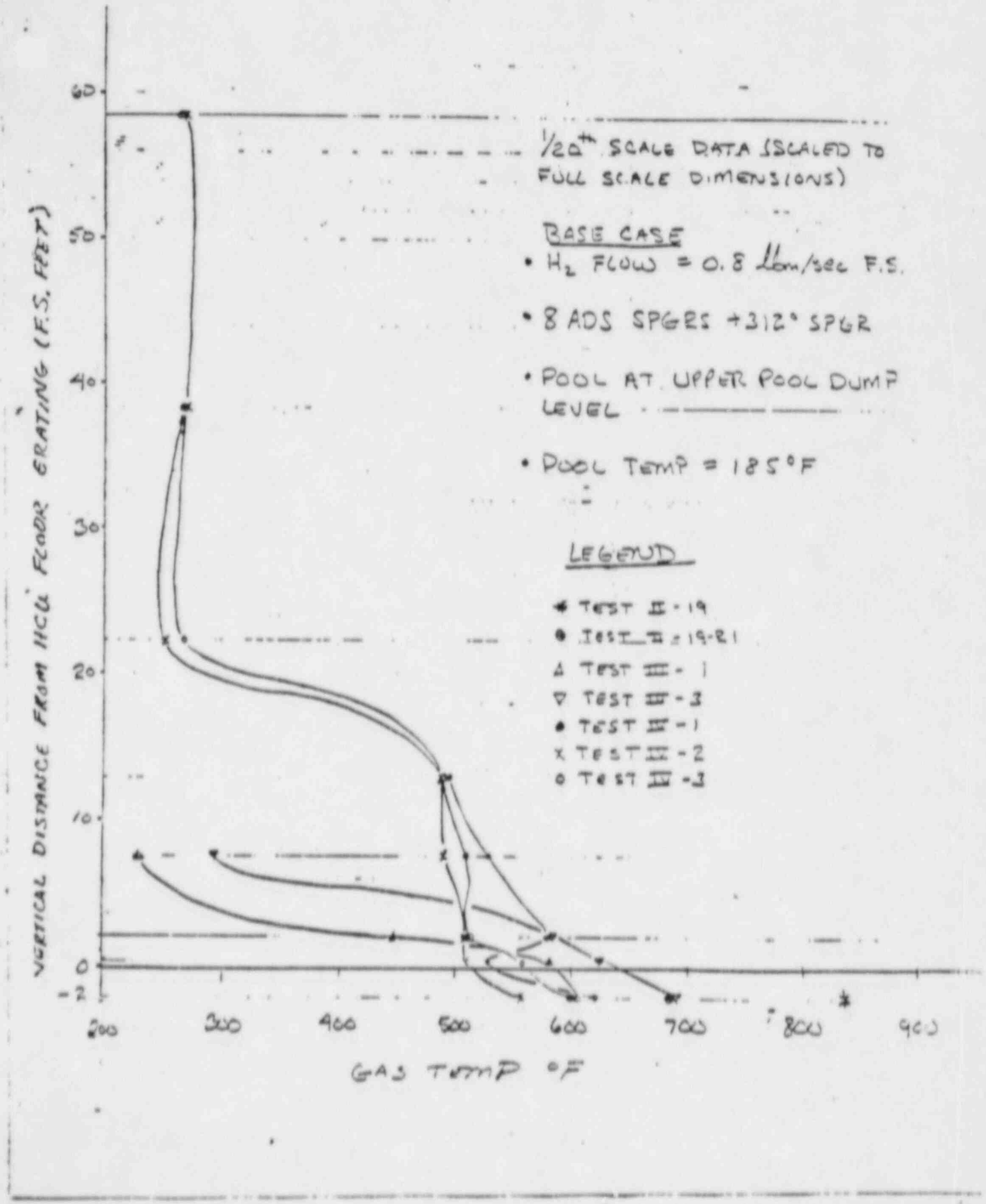
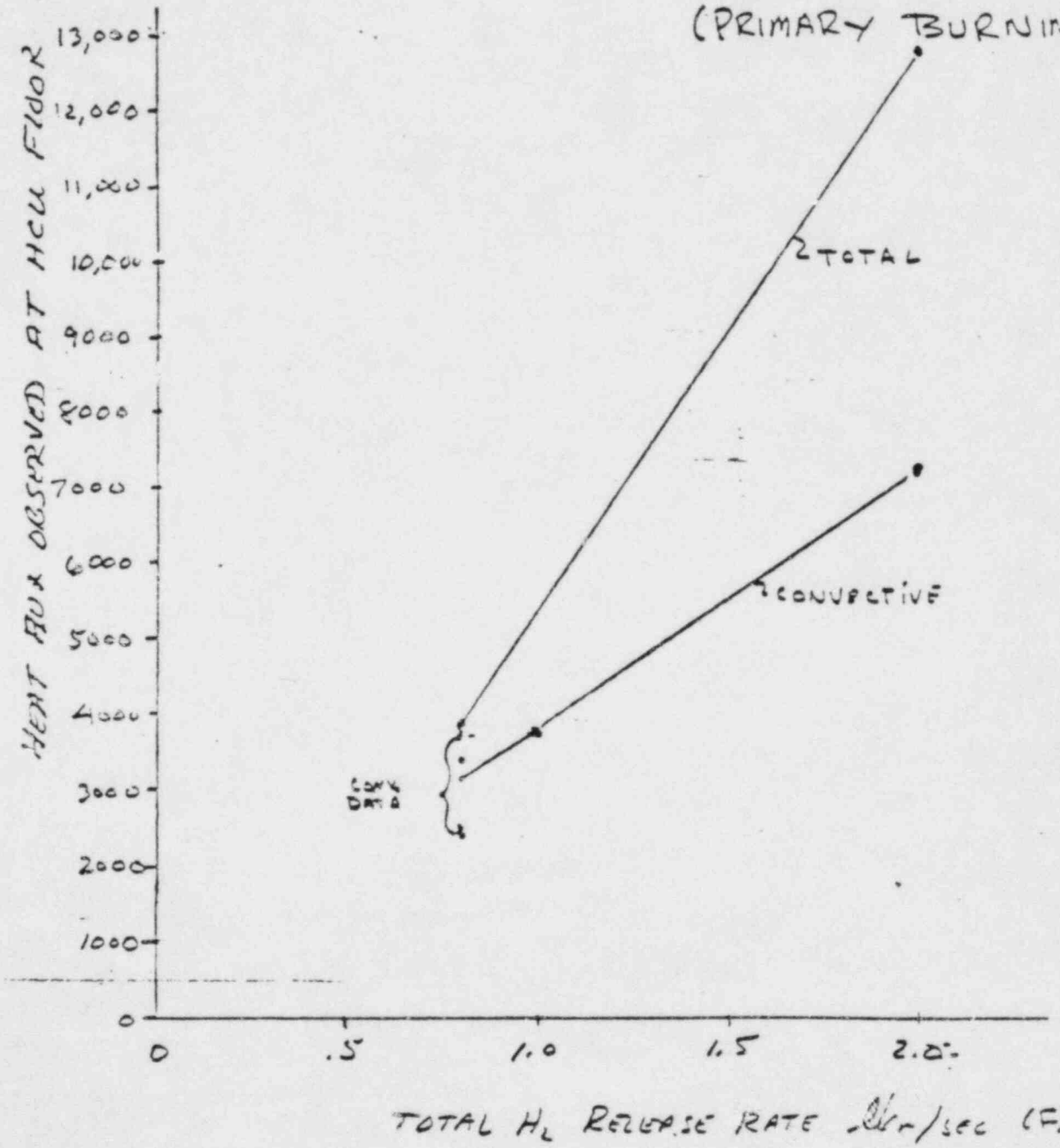

VERTICAL DISTANCE FROM HCU FLOOR GRATING (F.S. FEET)
60
50
40
30
20
10
0
-2
200
300
400
500
600
700
800
900
GAS TEMP °F
1/20th SCALE DATA (SCALED TO FULL SCALE DIMENSIONS)
BASE CASE
• H2 FLOW = 0.8 lbm/sec F.S.
• 8 ADS SPGRS +312° SPGR
• POOL AT UPPER POOL DUMP LEVEL
• POOL TEMP = 185°F
LEGEND
TEST II - 19
TEST II - 19-R1
TEST III - 1
TEST III - 3
TEST III - 1
TEST III - 2
TEST III - 3

HEAT FLUXES OBSERVED AT HCU FLOOR (AT 1/20TH SCALE) VS H_2 RELEASE RATE (PRIMARY BURNING)



EFFECTS OF VARIATIONS IN PARAMETERS ON PEAK GAS TEMP (T_G) JUST BELOW HCU FLOOR

- TOTAL H_2 FLOW RATE ($\dot{Q}$)
  - INCREASING $\dot{Q}$ FROM 0.8 LBM/SEC → 1.0 LBM/SEC INCREASED $T_G \sim 200^{\circ}F$
  - INCREASING $\dot{Q}$ FROM 0.8 LBM/SEC → 2.0 LBM/SEC INCREASED $T_G \sim 450^{\circ}F$

- NUMBER OF ACTIVE SPARGERS
  - DELETION OF ADJACENT SPARGER (9 TO 8 SPARGERS) DECREASES T_G (EFFECT MORE PRONOUNCED AT HIGH H_2 FLOW RATE)
    - T_G DECREASED $\sim 100^{\circ}F$ FOR 0.8 LBM/SEC TESTS
    - T_G DECREASED $\sim 350^{\circ}F$ FOR 2.0 LBM/SEC TESTS
  - RELEASE OF ALL H_2 THROUGH A SINGLE SPARGER INCREASED $T_G \sim 400^{\circ}F$ (RELATIVE TO 9 TOTAL (2 ADJACENT) CASE)

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EFFECTS OF VARIATIONS IN PARAMETERS ON PEAK GAS TEMPERATURE JUST BELOW HCU FLOOR (CONT'D)

- 50-50 SPLIT BETWEEN LOCA VENTS AND SPARGER FLOW
  - DECREASED $T_G \sim 100^{\circ}F$ IN HOTTEST CHIMNEY
  - T_G IN OTHER CHIMNEYS MAY INCREASE SLIGHTLY
- POOL WATER LEVEL
  - LOWERING POOL WATER LEVEL FROM UPPER POOL DUMP LEVEL TO NWL:
    - HAD NO EFFECT IN REGION DIRECTLY ABOVE SPARGER
    - LOWERED $T_G \sim 50^{\circ}$ NEAR CENTER OF HCU FLOOR

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EFFECTS OF VARIATIONS IN PARAMETERS ON PEAK GAS TEMPERATURE JUST BELOW HCU FLOOR (CONT'D)

- INSULATING PYREX OUTER SHELL OF FACILITY
  - NO RESOLVABLE EFFECT

- REMOVAL OF SOLID FLOOR IN WETWELL ANNULUS AT. 40° AZIMUTH
  - $T_{G(MAX)}$ LIKELY UNAFFECTED (FLAMES SHIFTED AWAY FROM INSTRUMENTATION)
  - OVERALL GAS CIRCULATION PATTERNS MODIFIED (FLAMES LEAN RIGHT RATHER THAN LEFT, SOME "UP" CHIMNEY'S BECAUSE "DOWN" CHIMNEY AND VICE-A-VERSA).

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SUMMARY

- 41 TESTS PERFORMED IN A 1/20TH SCALE MODEL OF A MARK III CONTAINMENT
  - OBJECTIVES:
    - OVERALL H_2 COMBUSTION PHENOMENA UNDERSTANDING
    - COMBUSTION VISUALIZATION
    - ASSESSMENT OF THERMAL ENVIRONMENT IN WETWELL RESULTING FROM DIFFUSION FLAMES
  - SCOPE
    - ASSESS EFFECTS OF VARIATIONS IN
      - H_2 FLOW RATE
      - NO. OF ACTIVE SPARGERS
      - VENT VS. SPARGER FLOW
      - POOL WATER LEVEL
      - POOL TEMPERATURE
      - HEAT LOSS FROM OUTER SHELL CONTAINMENT
      - FLOW BLOCKAGE IN WETWELL ANNULUS
- FROUDE SCALING LAWS APPLIED

SUMMARY (CONT'D)

- RESULTS
  - PHENOMENA CHARACTERIZED BY STEADY FLAMES BASED AT POOL SURFACE FOR H_2 RATES ABOVE 0.4 LBM/SEC FULL SCALE
  - FLAMES LIFT TO HCU FLOOR LEVEL LATE IN BURN (O_2 <~ 6%)
    - FOR BASE CASE ($\dot{Q}$ = 0.8 LBM/SEC, 8 ADS + 312° SPRAGER, 185° POOL)
      - PEAK GAS TEMP JUST BELOW HCU FLOOR GENERALLY RANGED FROM 560 TO 700°F (ONE TEST SHOWED TEMP AS HIGH AS 836°F)
      - OBSERVED HEAT FLUX TO HCU FLOOR FROM BELOW:

        TOTAL ~ 4K BTU/HR FT^2
        CONVECTIVE ~ 3.2K BTU/HR FT^2
      - THERMAL ENVIRONMENT INFLUENCED MOST BY H_2 RELEASE RATE AND NUMBER OF RELEASE LOCATIONS

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