Department of Energy
Washington, D.C. 20545
Docket No. 50-537
HQ:S:82:123

NOV 12 1982

Mr. Paul S. Check, Director
CRBR Program Office
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Check:

SUMMARY OF THE SEPTEMBER 15, 1982, MEETING ON THERMAL MARGIN BEYOND THE DESIGN BASE (TMBDB)

On September 15, 1982, the project and the NRC met to discuss selected topics on TMBDB. Enclosure 1 is a summary of the meeting, Enclosure 2 is the meeting agenda, Enclosure 3 includes the view-graphs used, and Enclosure 4 lists the meeting attendees.

Sincerely,

John R. Longenecker

John R. Longenecker
Acting Director, Office of the
Clinch River Breeder Reactor
Plant Project
Office of Nuclear Energy

4 Enclosures

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Enclosure 1

TMBDB MEETING SUMMARY

On September 15, 1982 the Project and NRC met to discuss the agenda topics in Enclosure 2 concerning TMBDB. A copy of the viewgraphs presented are in Enclosure 3 and the attendees are listed in Enclosure 4.

The Project's presentation of two sensitivity studies of sodium-concrete penetration rates was presented. These two studies were a "Margin Assessment Case"[1] and a "Realistic Upper Bound Case."[2] The "margin assessment case" is an artifically contrived case to bound all existing data on sodium-concrete testing and to determine the margin in the existing design for TMBDB. The analysis of this artificial case results in a need to vent the containment building at 10 hours and indicates a need for minor redesign in the reactor cavity.

The analysis of the "Realistic Upper Bound Case" results in a need to vent the containment at 22 hours with no redesign needed.

Also, the Project presented results to NRC that the vent lines from the RCB to the containment-cleanup system may need to be increased to 3 feet diameter from 2 feet diameter to prevent plugging from the sodium aerosols during venting.

During the meeting the Project accepted the following action items in response to NRC questions:

(1) Provide a reference for sodium aerosols not being transported thru the sodium pool to the RC vents.

(2) Evaluate the effects of nonaxisymmetric convection currents on the containment shell integrity.

(3) Provide information on the location of the purge and vent lines and evaluate the possibility of short circuiting.

(4) Provide the reference of the Hydrogen Non-Stratification tests at HEDL.

(5) Forward to NRC a date by which the test results on the Hydrogen Monitor Filter will be available.

(6) Docket the "Margin Assessment Case" in TMBDB in the near future.

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1 7"/hr for 3 hrs then 1"/hr until Sodium Bolidry

2 7"/hr for 20 milutes then 1"/hr until Sodium Bolidry

ENCLOSURE 2

BRIEFING ON CRBRP
THERMAL MARGINS BEYOND THE DESIGN BASIS
FOR THE
NUCLEAR REGULATORY COMMISSION—CRBRP PROGRAM OFFICE
BETHESDA, MARYLAND
SEPTEMBER15, 1982

AGENDA

- INTRODUCTION — N. KAUSHAL
- DISCUSSION OF OPEN ISSUES
  - DESIGN MARGINS TO ACCOMMODATE EXTREME SODIUM-CONCRETE PENETRATIONS DURING TMBDB
    - SUMMARY REVIEW OF TMBDB ANALYSES VIS A VIS SODIUM-CONCRETE REACTION — P. BRADBURY
    - ASSESSMENT OF STRUCTURAL CAPABILITY FOR THE EXTREME PENETRATION CASE — G. FRESKAKIS
  - CONTAINMENT EFFECTS DURING RC /ENTING TO RCB
    - POTENTIAL FOR PLUGGING DURING RC VENTING TO RCB — T. BALL
    - ASYMMETRY EFFECTS OF SODIUM BURNING — T. BALL
    - BASIS FOR NON-STRATIFICATION OF HYDROGEN — T. BALL
    - HYDROGEN AUTO-IGNITION CRITERIA — T. BALL
    - SODIUM AEROSOL DEPLETION CALCULATIONS — J. GROSS
    - SURVIVABILITY OF TMBDB INSTRUMENTATION — M. McKEOWN

2079-11

BRIEFING ON CRBRP
THERMAL MARGINS BEYOND THE DESIGN BASIS
FOR THE
NUCLEAR REGULATORY COMMISSION—CRBRP PROGRAM OFFICE
BETHESDA, MARYLAND
SEPTEMBER 15, 1982

AGENDA (CONT.)

- DISCUSSION OF OPEN ISSUES, CONTINUED
  - OPERABILITY AND ACCESSIBILITY OF VENT, PURGE, AND CLEAN-UP SYSTEMS — P. FAZEKAS
    - CONTAINMENT CLEAN-UP SYSTEM DESCRIPTION
      - VENT SYSTEM DESCRIPTION
      - CLEAN-UP SYSTEM DESCRIPTION
    - CONTAINMENT CLEAN-UP SYSTEM TEST RESULTS
    - DYNAMIC ANALYSIS OF CONTAINMENT CLEAN-UP SYSTEM
  - DISCUSSION OF OPEN ISSUES IDENTIFIED IN AUGUST 17, 1982 MEETING — OPEN
- CLOSING DISCUSSION — N. KAUSHAL
  - CLOSING SUMMARY AND CONCLUSIONS
  - SUMMARY OF NRC STAFF POSITION

2-1973-13

ENCLOSURE 3

CLINCH RIVER BREEDER REACTOR PLANT

CRBRP PROJECT

BRIEFING FOR

NUCLEAR REGULATORY COMMISSION
CRBRP PROGRAM OFFICE

THERMAL MARGINS BEYOND THE DESIGN BASIS (TMBDB)

SEPTEMBER 15, 1982

BRIEFING ON CRBRP
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THERMAL MARGINS BEYOND THE DESIGN BASIS
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CRBRP THERMAL MARGINS BEYOND THE DESIGN BASIS

BRIEFING FOR

NUCLEAR REGULATORY COMMISSION
CRBRP PROGRAM OFFICE

SUMMARY REVIEW OF TMBDB ANALYSES VIS A VIS SODIUM-CONCRETE REACTION

PRESENTED BY:

PHILL BRADBURY
SYSTEMS INTEGRATION, MANAGER
WESTINGHOUSE-OR
CRBRP PROJECT

SEPTEMBER 15, 1982

ROLE OF EXTREME PENETRATION CASE

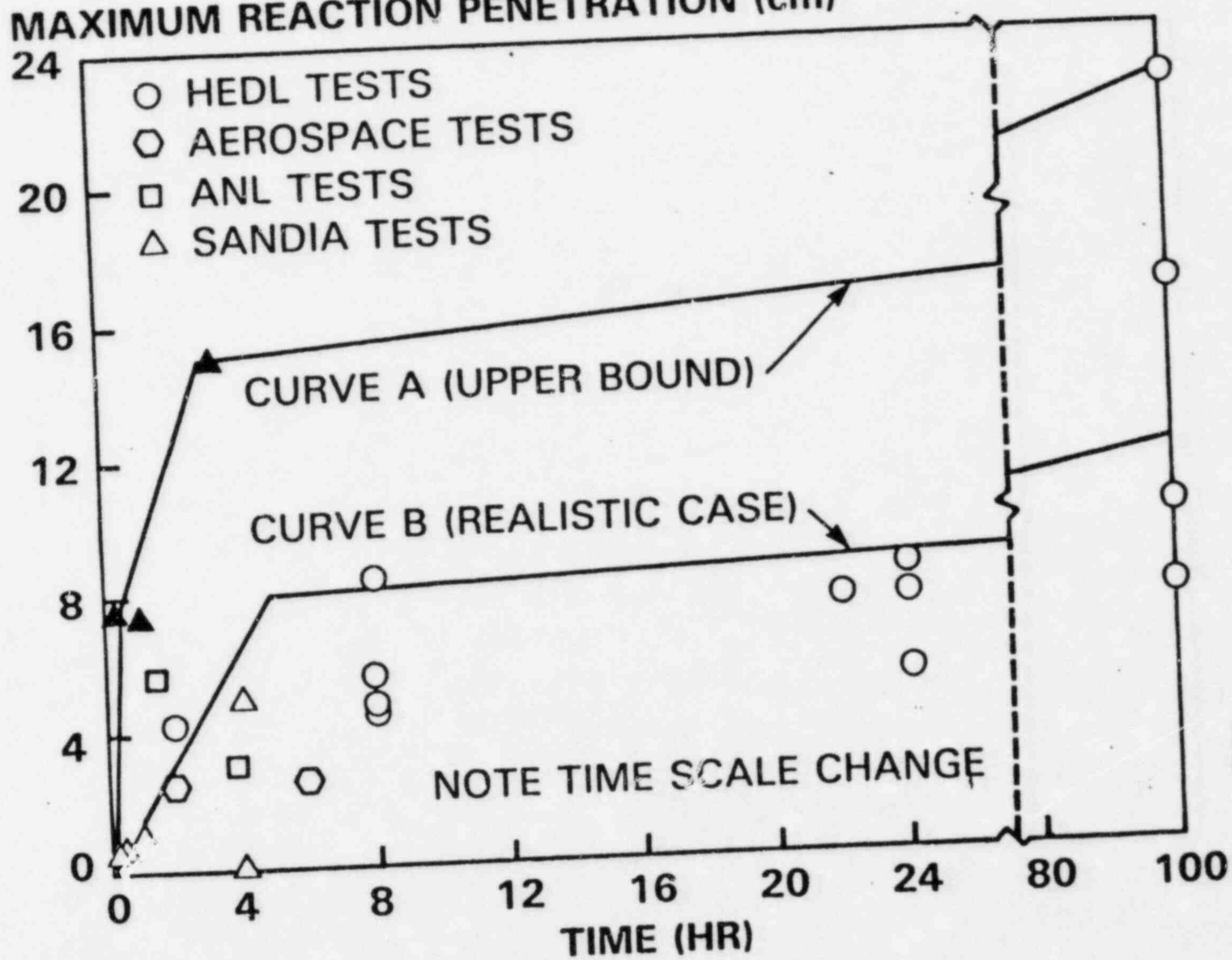
MARGIN ASSESSMENT CASE

- THE CONCRETE PENETRATION RATES CHOSEN FOR THE EXTREME PENETRATION CASE WERE **NOT** DERIVED FROM TEST DATA.
- THE EXTREME PENETRATION CASE **WAS** ARTIFICALLY CONTRIVED AS THAT CASE WHICH WOULD RESULT IN A NEED TO VENT AT 10 HOURS IF 6% HYDROGEN CONCENTRATION MUST NOT BE EXCEEDED.
- THIS CASE HAS BEEN USED **SOLELY** AS A TEST OF THE MARGIN AVAILABLE IN THE DESIGN.

HENCE, WE WILL CALL IT THE 'MARGIN ASSESSMENT CASE'

COMPARISON OF UPPER BOUND AND REALISTIC CASE TO TEST DATA

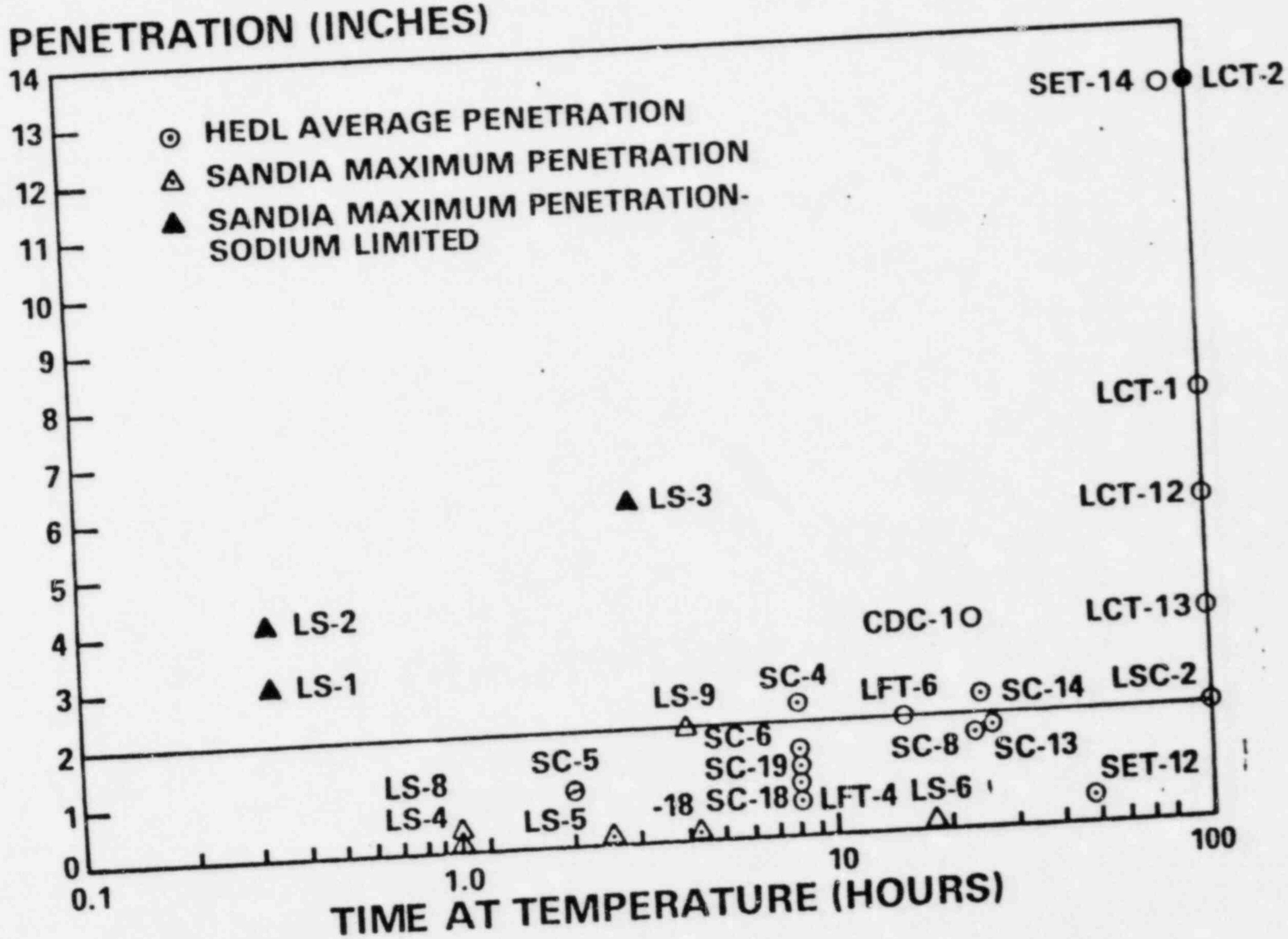
FROM HEDL-TME 82-15



UPPER BOUND OF TEST DATA

- THE UPPER BOUND OF TEST DATA IS
  - 18 cm/HR (7 INS/HR) FOR 20 MINS
  - 2.57 cm/HR (1 IN/HR) FROM 20 MINS TO 3 HRS
  - 0.08 cm/HR (0.03 IN/HR) BEYOND 3 HRS
  - THIS IS JUSTIFIED IN HEDL-TME-82-15.
- THIS UPPER BOUND RESULTS IN TOTAL PENETRATION OF
  - 5.6 INS IN 24 HRS
  - 6.4 INS IN 50 HRS

SODIUM-LIMESTONE CONCRETE REACTION PENETRATION SUMMARY



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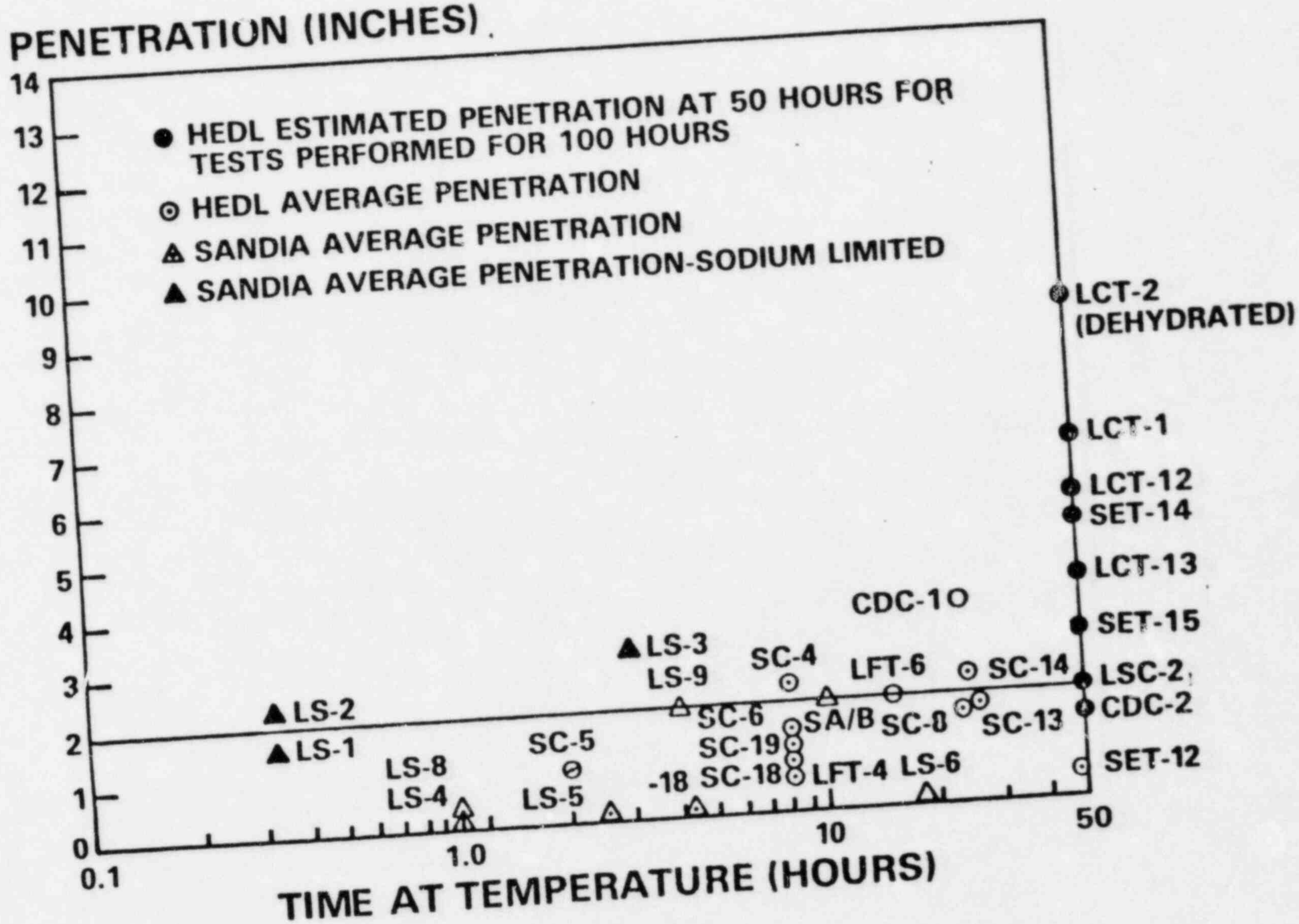
SODIUM-LIMESTONE CONCRETE REACTION PENETRATION SUMMARY FOR TIME PERIOD OF INTEREST (50 HOURS)



REASONABLE UPPER BOUND INCLUDING CORE DEBRIS

- IF CORE DEBRIS IS PRESUMED AS CONTINUALLY BREAKING UP THE REACTION PRODUCT LAYER (A CONSERVATIVE ASSUMPTION) THEN THE REASONABLE UPPER BOUND PENETRATION IS
  - 7 INS/HR FOR 20 MINS
  - 1 IN/HR FROM 20 MINS TO BOIL-DRY
- THIS RESULTS IN TOTAL PENETRATION OF
  - 3 INS IN 1 HOUR
  - 18 INS IN 16 HOURS
  - 26 INS IN 24 HOURS
- EXPECTED VENT TIME TO PREVENT 6% HYDROGEN CONCENTRATION WOULD BE ABOUT 22 HOURS

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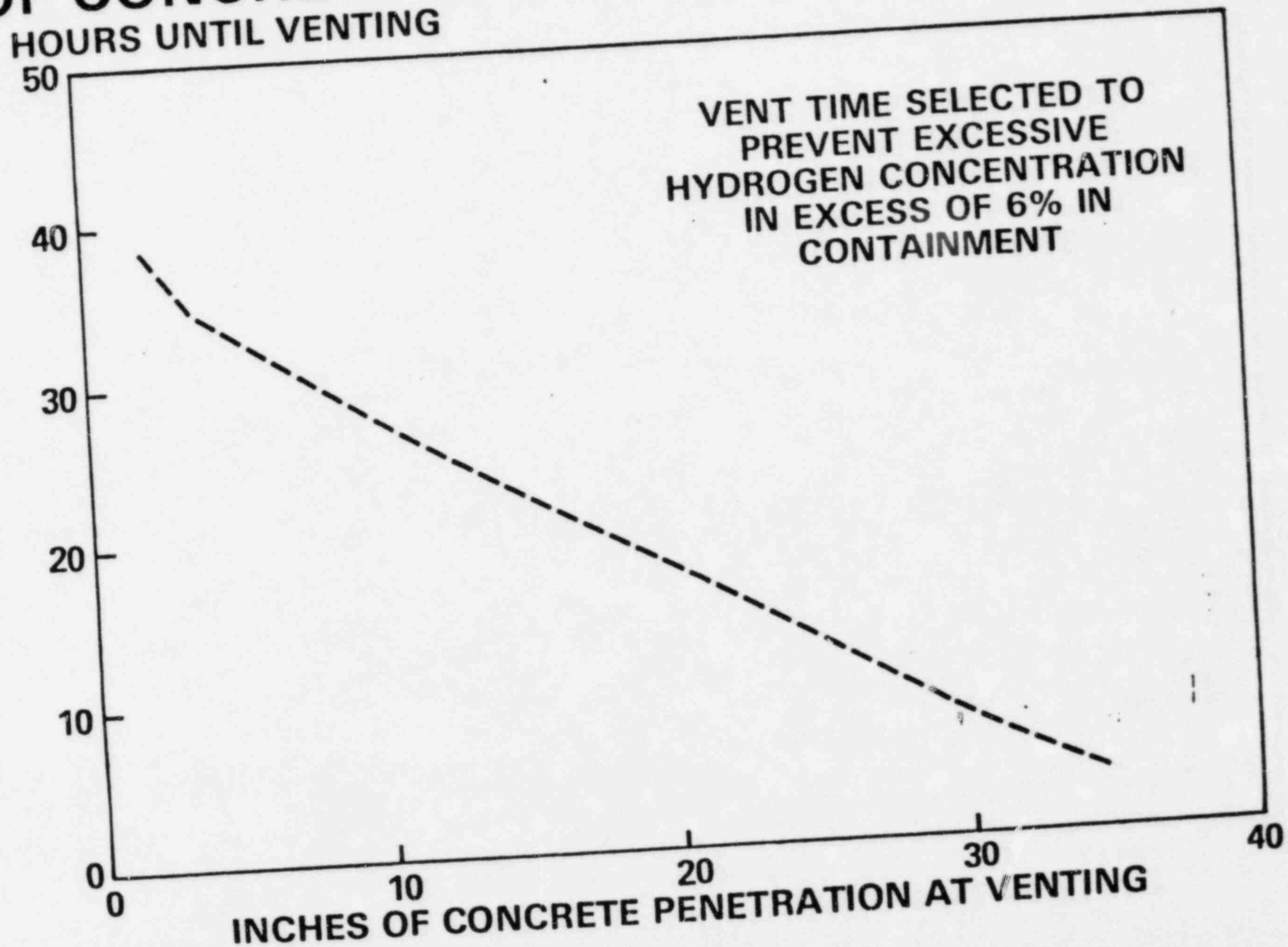
TIME TO VENTING AS A FUNCTION OF CONCRETE PENETRATION AT VENTING



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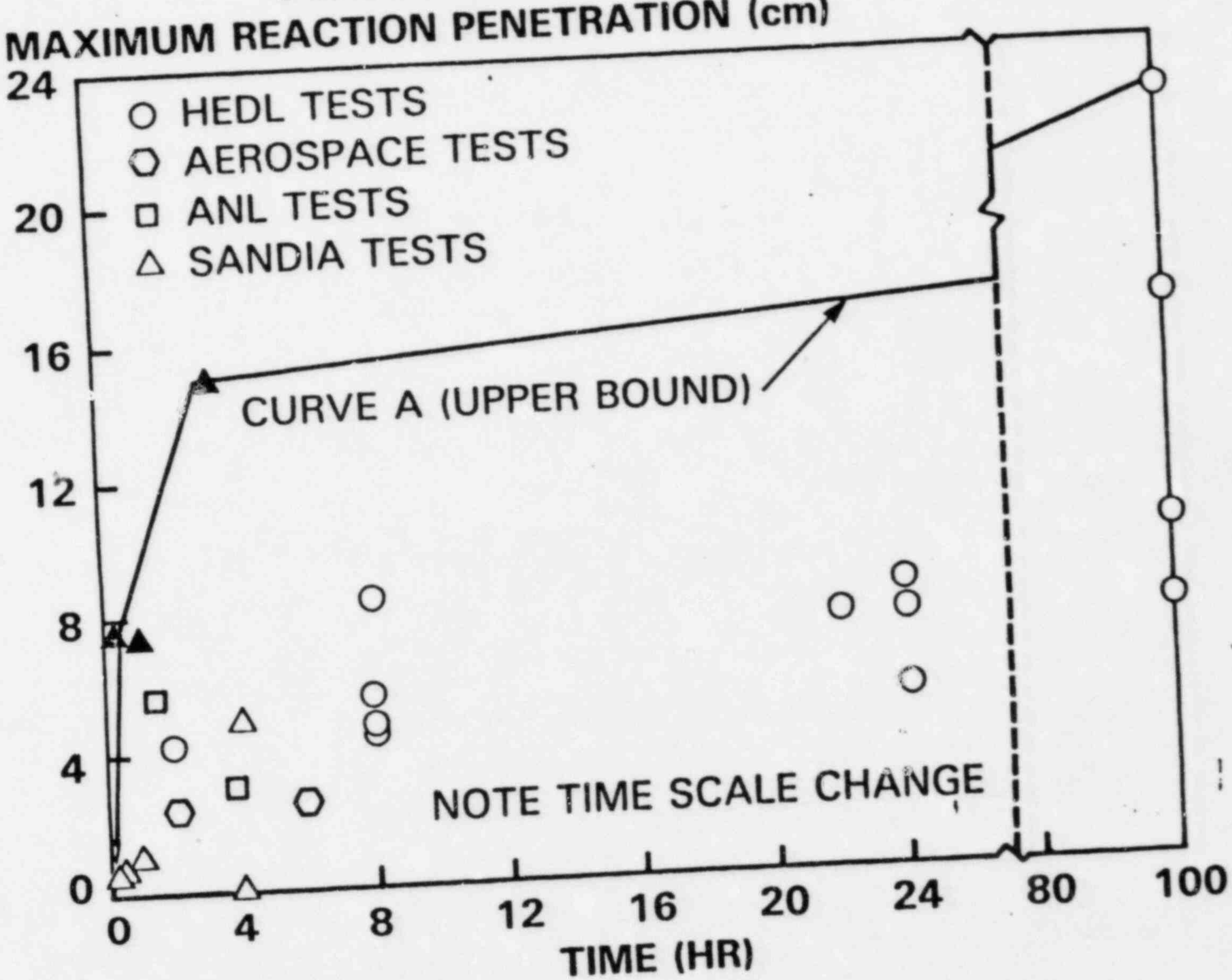
CONCLUSION

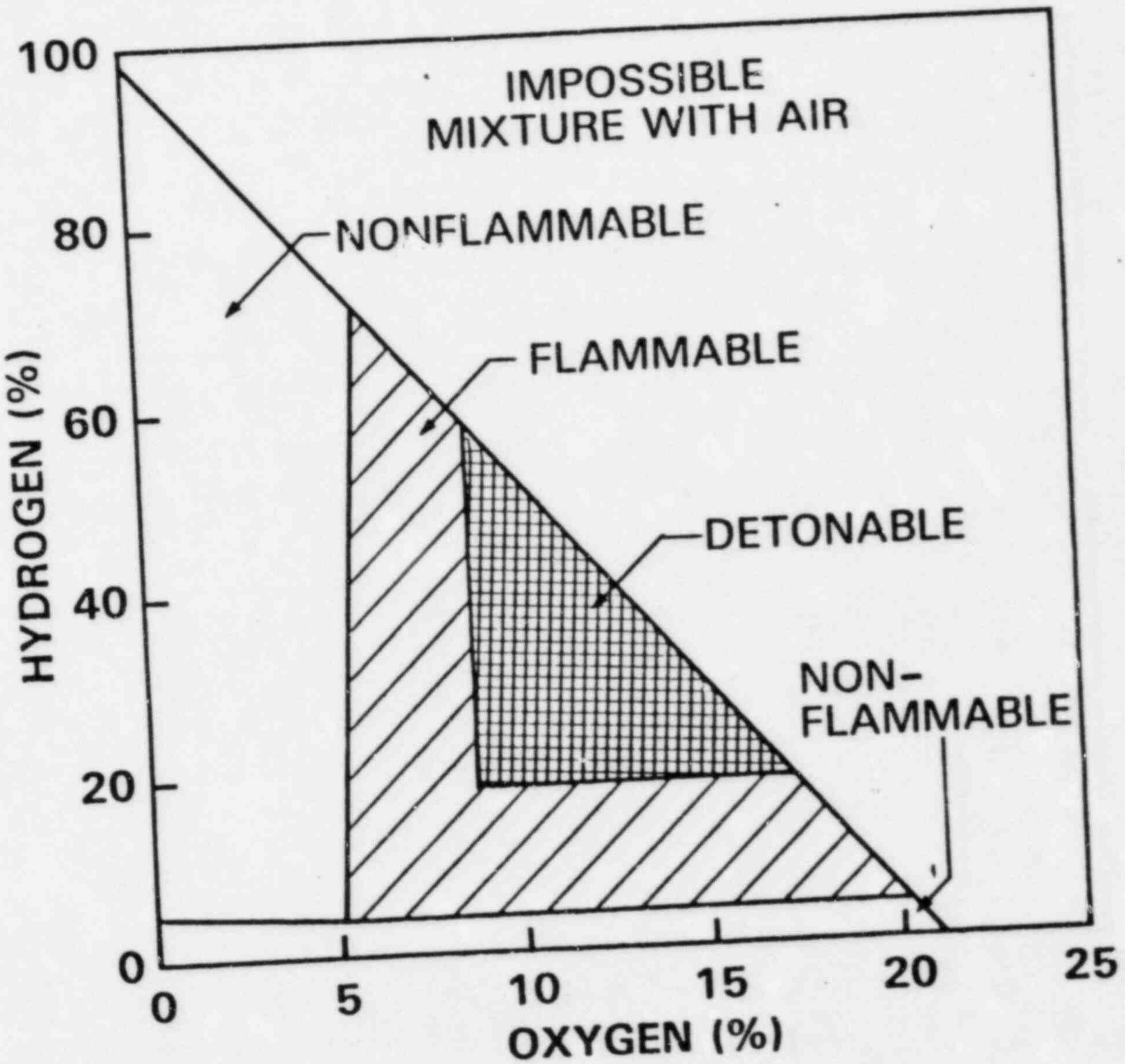
- THE CRBRP DESIGN HAS SUFFICIENT MARGIN TO ACCOMMODATE THE CONSEQUENCES OF SODIUM/CONCRETE REACTIONS WHICH BOUND ALL THOSE OBSERVED IN TESTS TO DATE
- THE MARGIN IS SUFFICIENT TO ACCOMMODATE A CONSERVATIVE PREDICTION OF THE EFFECTS OF CORE DEBRIS ON SODIUM/CONCRETE REACTIONS.
- WITH ALL THESE EFFECTS INCLUDED, IT WOULD NOT BE NECESSARY TO VENT CONTAINMENT IN LESS THAN 22 HOURS.

COMPARISON OF UPPER BOUND AND REALISTIC CASE TO TEST DATA

FROM HEDL-TME 82-15



FLAMMABILITY/DETONATION LIMITS FOR HYDROGEN AND OXYGEN MIXTURES



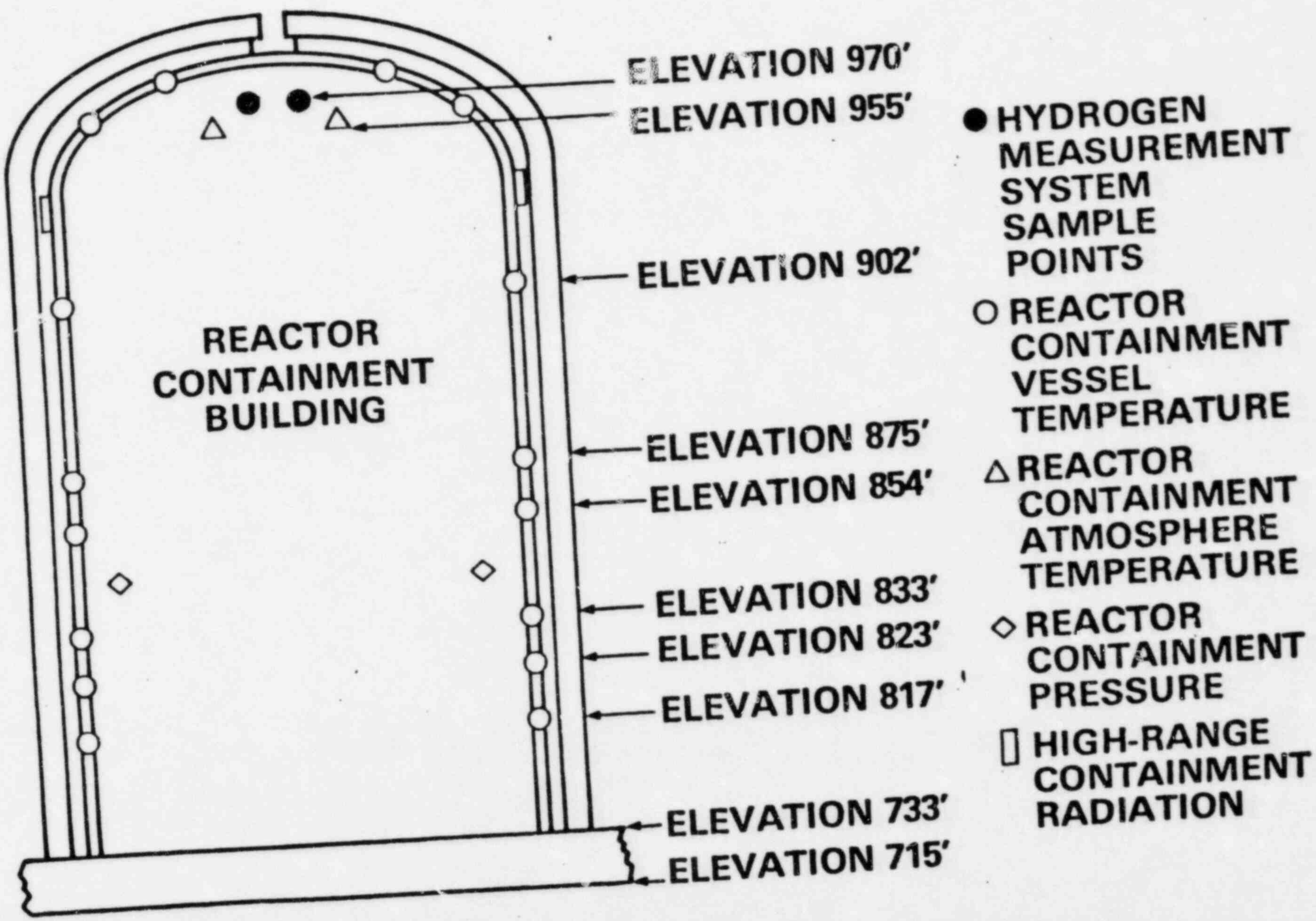
REVIEW OF VENTING CRITERIA

- THE 6% HYDROGEN LIMIT WAS SET CONSERVATIVELY IN 1977. IT HAS RECENTLY BEEN RE-EXAMINED, SINCE IT WAS RECOGNIZED THAT ADDITIONAL MARGIN COULD BE OBTAINED BY UTILIZING MORE REALISTIC LIMITS.
- IN THE MARGIN ASSESSMENT SCENARIO, HYDROGEN CONCENTRATION NEVER EXCEEDS 6% UNLESS OXYGEN CONCENTRATION IS VERY LOW.
- A MORE REALISTIC CRITERION FOR VENTING WOULD INCLUDE CONSIDERATION OF OXYGEN CONCENTRATION.

SURVIVABILITY OF TMBDB INSTRUMENTS

- TMBDB INSTRUMENTATION MONITORS
  - CONTAINMENT ATMOSPHERE TEMPERATURE
  - CONTAINMENT SHELL TEMPERATURES
  - CONTAINMENT PRESSURE
  - CONTAINMENT HYDROGEN CONCENTRATION
  - CONTAINMENT RADIATION
- ALL SIGNAL CONDITIONING EQUIPMENT WILL BE LOCATED IN AREAS THAT WILL NOT BE EXPOSED TO SEVERE TMBDB ENVIRONMENTS.
- INSTRUMENT SENSORS TO BE QUALIFIED FOR CONTAINMENT CONDITIONS ARE THE CONTAINMENT ATMOSPHERIC TEMPERATURE THERMOCOUPLES, THE CONTAINMENT PRESSURE SENSORS, AND THE FILTERS FOR THE HYDROGEN MONITORING EQUIPMENT.
- SENSORS SIMILAR TO THESE SENSORS HAVE BEEN UTILIZED SUCCESSFULLY IN SODIUM-AEROSOL TESTING. ANALYSIS AND TESTING IS UNDERWAY TO DETERMINE IF MODIFICATION TO THE INSTRUMENT DESIGN WILL BE NECESSARY FOR THE TMBDB CONDITIONS.

CRBRP CONTAINMENT TMBDB INSTRUMENTATION



SUMMARY OF HYDROGEN MONITOR FILTER TESTS

	NUMBER OF TESTS	AEROSOL CONCENTRATION GM/M3	ATMOSPHERIC TEMPERATURE °C	AEROSOL LOADING OF FILTERS GM/M22	TIME OF EXPOSURE TO AEROSOL HRS
• SCOPING TESTS	6	6 - 40	100 - 190	35 - 5600 (5,000G TOTAL)	50
• HYDROGEN FILTER TESTS	9	20 - 190	75 - 660	880 - 6110	10
• TMBDB CONDITIONS	—	46	590	(1,400G TOTAL)	132

HYDROGEN SAMPLING SYSTEM REQUIREMENTS

• SAMPLE SYSTEM DELAY TIME*	10 MINUTES (MAX)
• SAMPLE LINE SIZE*	61 M (200 FT) LONG 6.3 mm (0.25-IN) ID
• FILTER PRESSURE DROP, MAX*	34 kPa (5 psi)
• CONTAINMENT TEMPERATURE	16°C TO 593°C (60°F TO 1100°F)
• CONTAINMENT ATMOSPHERE	0-10 v/o H_2O, 0-6 v/o CO_2
• OPERATION DURATION	500 HRS (WITH AEROSOL) 8000 HR TOTAL
• AEROSOL CONCENTRATION	46 g/m^3 (AT CV CONDITIONS)
• AEROSOL COMPOSITION	Na_2O_2, NaOH, AND Na_2CO_3
• AEROSOL SIZE	AERODYNAMIC MASS MEDIAN DIAMETER (AMMD) = 5 μm, σ_g = 3.0
• REQUIRED INSTRUMENT FLOW*	150 cc/MIN (MINIMUM) AT 150°C (300°F)
• FILTER EFFICIENCY*	SUFFICIENT TO PROTECT SYSTEM

* ADAPTED FROM CRBRP-3, VOL. 2

2280-1

TYPICAL DESIGN REQUIREMENTS

TMBDB INSTRUMENT REQUIREMENTS:

INSTRUMENT	UNITS	RANGE	% ACCURACY % OF MAX VALUE
• CONTAINMENT ATMOSPHERE TEMPERATURE	°F	60-1100	± 5
• CONTAINMENT STEEL DOME TEMPERATURE	°F	40-700	± 5
• CONTAINMENT ATMOSPHERE PRESSURE	psia	14.7-55	± 5
• CONTAINMENT HYDROGEN CONCENTRATION	VOLUME %	0-8	± 5

REQUIREMENTS ALSO SPECIFIED FOR:

- RESPONSE TIME
- DURATION
- CHEMICAL ENVIRONMENT
- RADIATION ENVIRONMENT
- ENVIRONMENTAL TEMP. AND PRESSURE

BRIEF DESCRIPTION OF TMBDB INSTRUMENTATION PLANNED FOR USE IN CONTAINMENT

HYDROGEN MONITORS

- PROTOTYPE DESIGN CONSISTS OF FILTERING THE SAMPLE LINES IN-CONTAINMENT. THE MONITORS ARE LOCATED IN THE REACTOR SERVICE BUILDING.
- THE PROTOTYPE FILTER DESIGN HAS BEEN DEVELOPED FOLLOWING 6 SCOPING TESTS AND 9 FILTER TESTS.
- THE CHOSEN PROTOTYPE FILTER DESIGN CONSISTS OF A NICKEL POWDER FILTER AND SETTLING CHAMBER.
- A "BACKFLOW" CAPABILITY MAY BE PROVIDED TO CLEAN THE FILTERS DURING OPERATION.
- FURTHER TESTING TO TMBDB ENVIRONMENTAL CONDITIONS IS PLANNED.

BRIEF DESCRIPTION OF TMBDB INSTRUMENTATION PLANNED FOR USE IN CONTAINMENT (CONT.)

ATMOSPHERIC TEMPERATURE SENSORS

- CURRENT PLANS ARE TO UTILIZE SEAMLESS, STAINLESS STEEL SHEATHED, 1/8'' OR 1/16'' OD, MgO INSULATED, TYPE K, UNGROUNDED THERMOCOUPLES WITH NO CONNECTORS IN CONTAINMENT.
- SIMILAR 1/8'' THERMOCOUPLES HAVE OPERATED 100 HOURS IN SODIUM TESTS WITH AVERAGE TEMPERATURES BETWEEN 800-900°F AND PEAKS UP TO 1200°F.
- NO FAILURES HAVE BEEN OBSERVED IN TESTS TO DATE.

BRIEF DESCRIPTION OF TMBDB INSTRUMENTATION PLANNED FOR USE IN CONTAINMENT (CONT.)

PRESSURE SENSORS

- THE CURRENT DESIGN UTILIZES DIAPHRAGM GAUGES CONNECTED TO THE CONTAINMENT VESSEL WITH 1/4" OR 1/2" STAINLESS STEEL TUBING.
- NO ACTIVE FLOW IS REQUIRED THROUGH THE TUBING DURING OPERATION OF THE SENSORS.
- SIMILAR DESIGNS HAVE BEEN UTILIZED IN PREVIOUS SODIUM TESTS WITH UP TO 50 FT. OF TUBING AND NO PROBLEMS HAVE BEEN ENCOUNTERED.

HAA-3 APPLICATION TO HCDA AEROSOL ANALYSIS

J. F. GROSS

WESTINGHOUSE ADVANCED REACTORS DIVISION

SEPTEMBER 15, 1982

HAA-3 APPLICATION TO HCDA AEROSOL ANALYSES

A. What Is The HAA-3 Code And How Is It Used?

B. How Does HAA-3 Work?

C. What Assumptions Are Implicit In The HAA-3 Calculational Techniques?

D. What Assumptions Are Implicit In The HAA-3 Input Data For HCDA Analyses?

E. Why Is HAA-3 Acceptable And Valid For HCDA Aerosol Analyses?

WHAT IS THE HAA-3 CODE AND HOW IS IT USED?

1. HAA-3 Is A Heterogeneous Aerosol Agglomeration Code Which Predicts Aerosol Behavior And Transport Following Hypothetical LMFBR Accidents.

2. The Code Is Used to Calculate Distribution Of Aerosols In The RCB From HCDA's. Leakage Of The Suspended Aerosols Provides An Input To The Dose Calculations.

HOW DOES HAA-3 WORK?

1. Calculates Number Density Of Suspended Aerosol (Particles/cc).

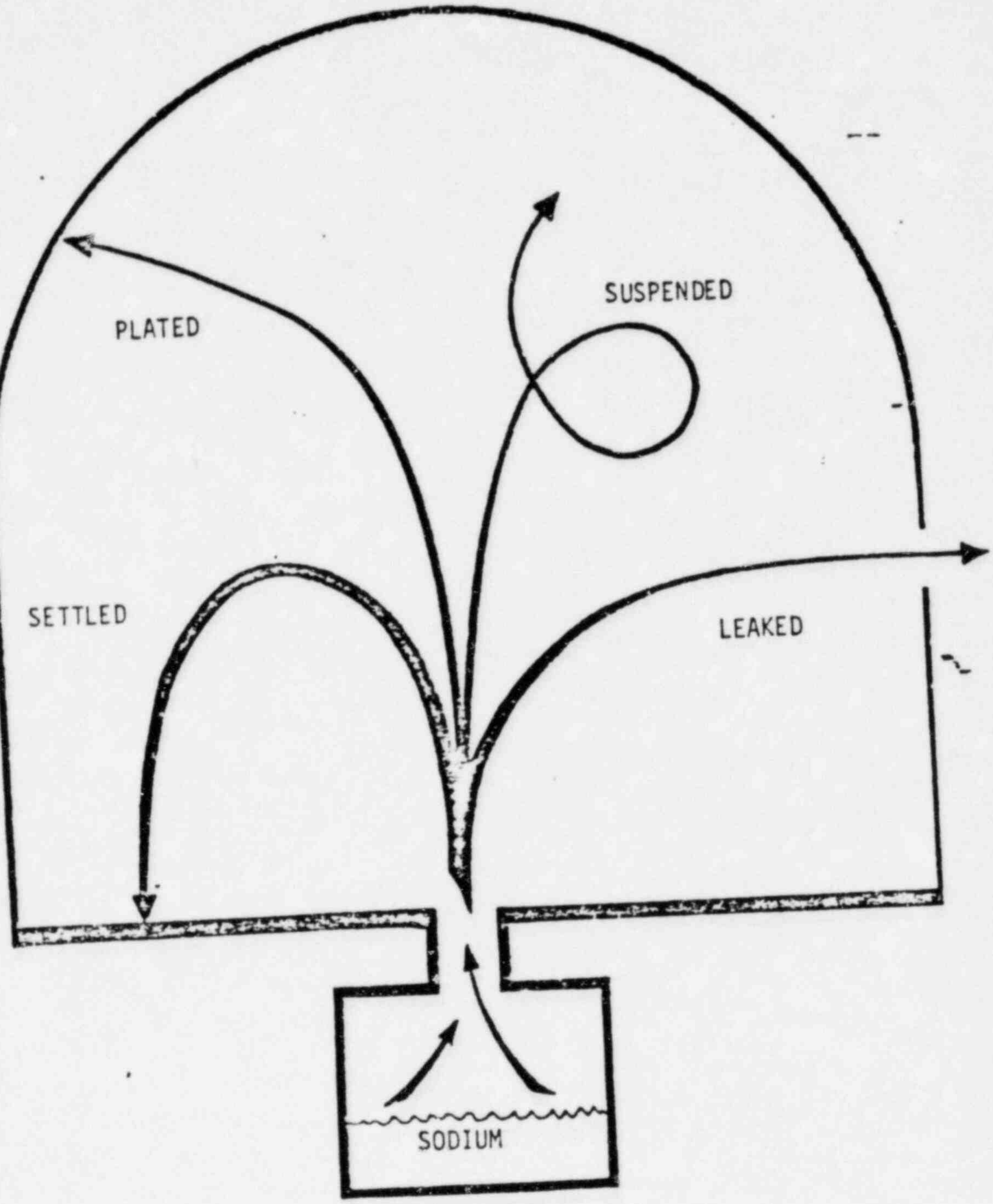
2. The Source Of Suspended Mass Is The Source Generation Rate Calculated From The CACECO Sodium-In Rate To The RCB.

3. Mass Is Distributed To 4 Different Regions: Plated, Settled, Leaked And Suspended.

4. The Amount Of Plated Mass Is Determined By The Experimentally Determined Wall Plating Parameter, Δ.

5. The Settling Rate Of The Aerosol Is Determined By The Size Of The Particles Which Grow Through Agglomeration.

6. The Source Of Leaked Mass Is The Suspended Aerosol. Leakrate Is An Input Parameter.



HAA-3 DISTRIBUTION MODEL

WHAT ASSUMPTIONS ARE IMPLICIT IN THE HAA-3 CALCULATIONAL TECHNIQUES?

1. Homogeneous And Instantaneous Distribution Of Suspended Aerosol.

2. Aerosol Particle Size Distribution Function Is Log-Normal.

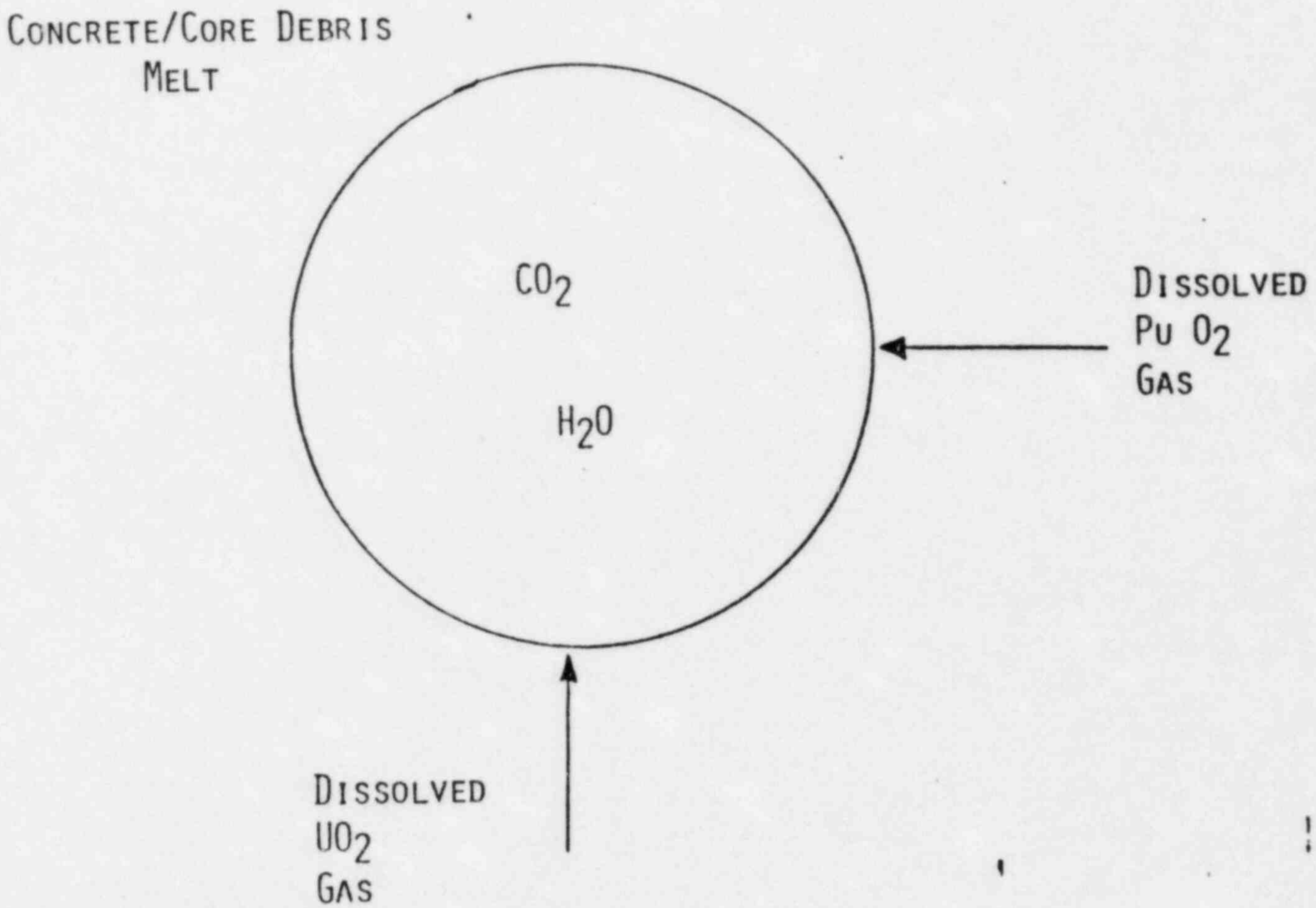
3. Ignores Agglomeration Caused By Aerosol Turbulence.

4. Ignores Plating Caused By Thermophoresis.

WHAT ASSUMPTIONS ARE IMPLICIT IN THE HAA-3 INPUT DATA FOR HCDA ANALYSIS?

1. 100% Of The Sodium Aerosol Produced Becomes Airborne In The RCB.
2. Rate That Sodium Enters RCB Is Calculated By The CACECO Code.
3. Sodium Aerosol Production Ceases At Boil-dry (133 hrs.)
4. Sodium Aerosol Is 45% Sodium Hydroxide And 55% Sodium Monoxide As Determined By CACECO.
5. Plutonium and Uranium Aerosol Production, Resulting From Gas Sparging, Begins At Initiation Of The HCDA.
6. Quantity Of Plutonium And Uranium Released By Sparging is Calculated Using The Technique Of WASH-1400, Appendix G To Appendix VII.
7. Leakrate From The RCB, Prior To Venting At 36 hrs, Is Proportional To The $\sqrt{\Delta P}$ Such That The Rate Is .1% Vol/Day At 10 PSIG.
8. Leakrate During RCB Venting, From 36 hrs. to 39 hrs, Is The RCB Blowdown Rate From 15 PSIG.
9. Leakrate After RCB Purging Is Initiated At 39 hrs. Is 8000 scfm Continuously.

GAS SPARGING



WHY IS HAA-3 ACCEPTABLE AND VALID FOR HCDA AEROSOL ANALYSES?

1. Scenario Specific Aerosol And Environment Parameters (Aerosol Density, Particle Size, Air Temperature, Etc.) Are Part Of Input Data.

2. No Internally Coded Data Base.

3. Effect Of Depletion Mechanisms Is Calculated Using Equations Derived From Classic Particle Kinetics Considerations Which Are Independent Of Chemical Composition.

4. HAA-3 Has Been Verified With Experimental Data In AI-AEC-12977.

5. Input Data Used For HCDA Analysis Is Within The Range Of Input Parameter Verification.

INPUT PARAMETER VERIFICATION RANGE FOR HAA-3 HCDA ANALYSIS

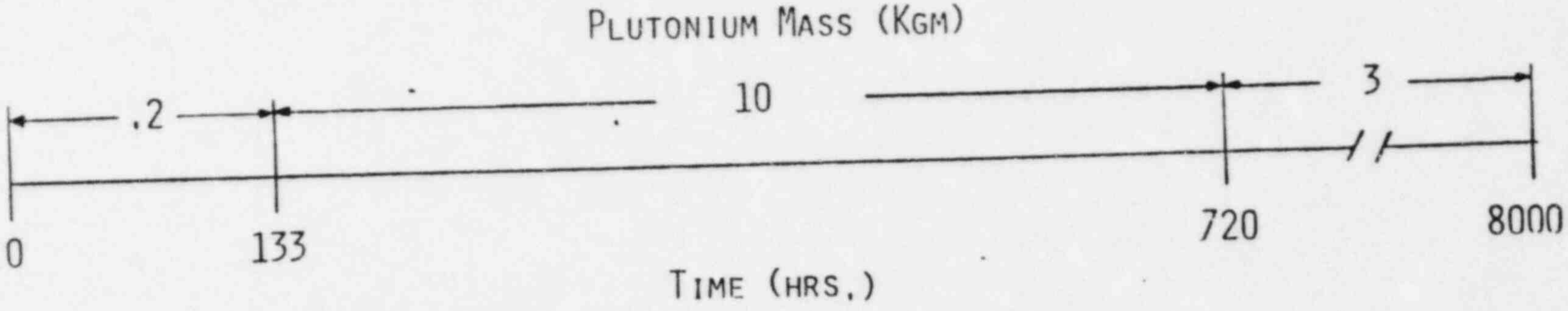
PARAMETER	RANGE OF VALUES*	VALUE USED IN CRBRP-3 BASE CASE	
		SODIUM AEROSOL	FUEL AEROSOL
AEROSOL R_{50} (μ)	.05 - 5.5	.3	.1
σ OF R_{50}	1.0 - 3.0	2	2
INITIAL CONCENTRATION (μGM/CC)	0.0 - 135	6.18	0.0
DENSITY OF AEROSOL (GM/CC)	.05 - 10.97	2.21	10.97
AIR TEMPERATURE (^{O}K)	300 - 811	765	366
WALL PLATING PARAMETER, Δ	$1X10^{-5}$ - $5X10^{-4}$	$4.0X10^{-5}$	$4.0X10^{-5}$
CHAMBER VOLUME (CC)	UP TO $8.5X10^{8}$	$9.9X10^{10}$	$9.9X10^{10}$
GRAVITATIONAL AGGLOMERATION EFFICIENCY, α	0.0 - 1.0	1.0	1.0
DENSITY MODIFICATION FACTOR, ε	.05 - 1.0	.1	.1

*SOURCE OF DATA:

1. AI-AEC-12977, "AEROSOL MODELING OF HYPOTHETICAL LMFBR ACCIDENTS"
2. GEAP-14054, "REVIEW AND EVALUATION OF CURRENT AEROSOL MODELS FOR LMFBR SAFETY ANALYSIS"
3. HEDL-TME 79-28, "AEROSOL BEHAVIOR DURING SODIUM POOL FIRES IN A LARGE VESSEL-CSTF TESTS AB1 AND AB2"
4. AI-AEC-13038, "HAA-3 USER REPORT"

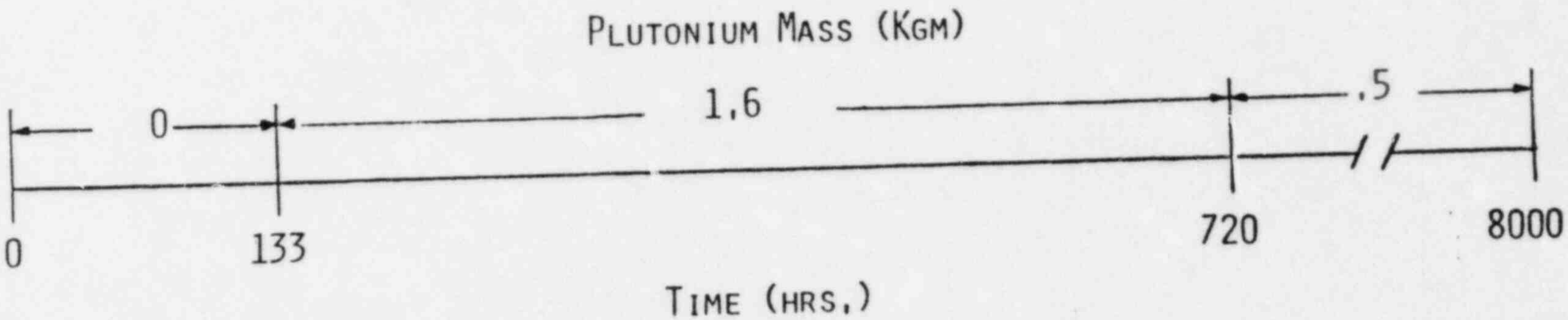
CALCULATED PLUTONIUM SPARGED DURING HCDA ANALYSIS

CONSERVATIVELY RELEASED TO RCB FOR DOSE CALCULATION:



CLEAN-UP SYSTEM LOADING - 7.7 KGM PU
DISTRIBUTION COEFFICIENT BASED ON 5000°F

MORE REALISTIC RELEASE TO RCB:



CLEAN-UP SYSTEM LOADING - 1.2 KGM PU
DISTRIBUTION COEFFICIENT BASED ON 4500°F

PLUTONIUM LOADING OF TMBDB CLEAN-UP SYSTEM

1. Ignores Aerosol Depletion In The Reactor Cavity And During Transport to RCB.

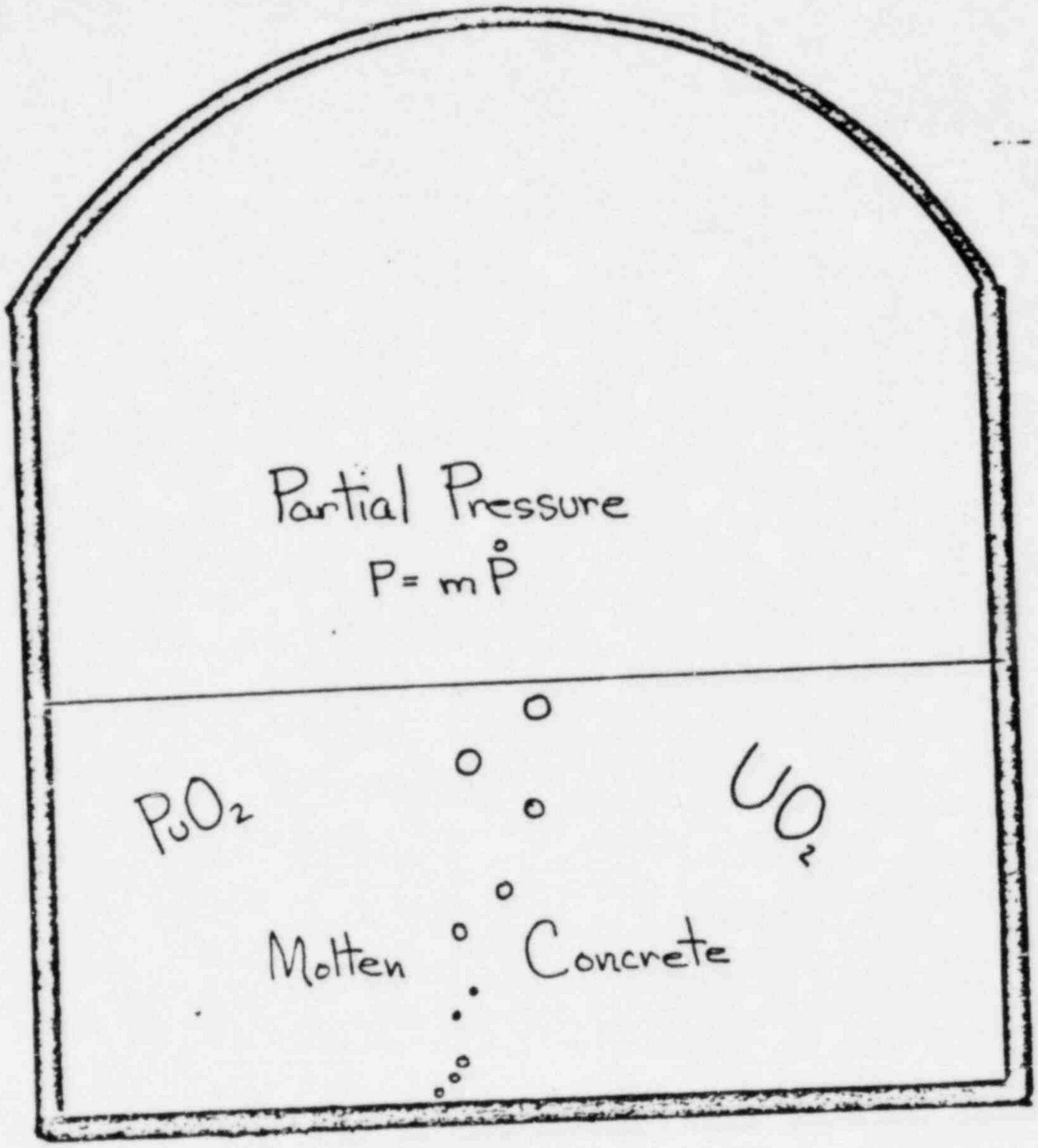
2. Ignores Factor Of ~50 Reduction In Sparged Plutonium From Vapor Pressure Reduction In Dilute Solution.

3. Sparged Plutonium Does Not Have Time To Achieve Equilibrium Vapor Condition.

4. Completely Molten Core Scenario Required Essentially Zero Heat Transfer To Reactor Cavity Area Above Pool Surface.

5. RCB Aerosol Depletion Ignores Effect Of Sparged U238 Blankets And Molten Concrete From Debris Bed.

VAPOR PRESSURE REDUCTION IN DILUTE SOLUTION



Melt Composition

Conservative	More Realistic
100% Pu & U	98% Concrete
	2% Pu & U

Vapor Pressure Reduction = 100/2 = 50

CONTAINMENT EFFECTS DURING

REACTOR CAVITY VENTING

T. W. BALL

SEPTEMBER 15, 1982

1. POTENTIAL FOR RC VENT PLUGGING.
2. ASYMMETRY EFFECTS FOR SODIUM BURNING.
3. BASIS FOR NON-STRATIFICATION OF HYDROGEN.
4. HYDROGEN AUTO-IGNITION CRITERIA.

POTENTIAL FOR REACTOR CAVITY VENT PLUGGING

DESIGN REQUIREMENTS (CRBRP-3, VOL. 2):

THE VENT SYSTEM SHALL HAVE A PRESSURE DROP OF LESS THAN 0.1 PSI WITH A FLOW RATE OF 4000 LB/HR OF GASES, A DENSITY OF 0.03 LB/FT^3, AND A VISCOSITY OF 0.05 LB/FT-HR. IT SHALL REMAIN FUNCTIONAL IF UP TO 450 LBS OF SODIUM OXIDE AEROSOL ENTER THE VENT AT A MAXIMUM RATE OF 8000 LB/HR.

BASES FOR REQUIREMENTS:

1. PRESSURE DROP 0.1 PSI - ARBITRARY LOW VALUE TO ASSURE ~PRESSURE EQUALIZATION.
2. FLOW RATE, DENSITY, VISCOSITY - AVG. OVER FIRST 24 HOURS.
   - 1. & 2. PROVIDE BASIS FOR SIZING PIPE.
3. 450 LBS SODIUM OXIDE, 8000 LBS/HR - INITIAL BLOWTHROUGH OF R.C. ATMOSPHERE UPON RUPTURE DISK BREAKING. 450 LBS OF NA_2O RESULTS FROM BURNING INITIAL 2% OXYGEN IN THE R.C. AND PIPEWAY CELLS.

ASYMMETRY EFFECTS OF SODIUM BURNING

(QUESTION CS760.144)

ALTHOUGH THE RC VENT WILL BE OFF-CENTER IN THE RCB, IT WILL STILL BE ABOUT 55 FEET FROM THE STEEL SHELL WALL.

THE ASSUMPTION OF AXISYMMETRIC TEMPERATURES IN THE STEEL SHELL IS A VALID ASSUMPTION FOR THE FOLLOWING REASONS:

- ONLY SIGNIFICANT HEAT TRANSFER IS CONVECTION (RADIATION WOULD BE BLOCKED BY DENSE SODIUM OXIDE SMOKE)
- STRONG CONVECTIVE MIXING OF RCB ATMOSPHERE BY FLAME
- NOZZLE SIZED TO PRECLUDE DIRECT FLAME CONTACT WITH STEEL SHELL ($<$80 FT FLAME - 180 FT TOP OF RCB)
- CRITICAL AREA OF STEEL SHELL (816 FT EL.) PROTECTED BY INSULATION

MAXIMUM TEMPERATURE 220°F
∴ AZIMUTHAL GRADIENTS SMALL

BASIS FOR HYDROGEN NON-STRATIFICATION

(CRBRP-3, VOL. 2, APPX. H.3)

1. PRE-HYDROGEN IGNITION PERIOD

   - COMBINED MOLECULAR DIFFUSION, NATURAL CONVECTION AND FORCED CONVECTION - MORE THAN ADEQUATE TO CAUSE UNIFORM MIXING
   - THIS WAS CONFIRMED BY HEDL TESTS ATM-1 THROUGH ATM-4

2. HYDROGEN BURN TO SODIUM BOILDRY PERIOD

   - CONVECTION FROM FLAME AND VENT/PURGE MIXING

3. POST-BOILDRY

   - SLOW ADDITION RATES
   - H_2-CO MIXTURE DENSITY APPROXIMATELY EQUAL TO AIR DENSITY
   - VENT/PURGE MIXING ADEQUATE TO PREVENT STRATIFICATION

HYDROGEN AUTO-CATALYTIC RECOMBINATION

Objectives:

- Determine conditions for ignition
- Determine conditions for extinguishment

Description:

- Controlled hydrogen jet ignition and extinguishment tests (3.5 ft.^3 chamber)

  Effects of: Hydrogen, nitrogen, sodium, water vapor in jet
  Oxygen depletion in chamber
  Water vapor in chamber - hydrogen generation
  Jet temperature
  Jet velocity

- Confirmatory tests during large scale sodium-concrete interactions testing (3800 ft.^3 chamber)

8064-51

HYDROGEN AUTO-CATALYTIC RECOMBINATION
(Continued)

Results/Status:

- Program has been completed
- Hydrogen burning criteria incorporated into CACECO:
  - Upon reaching containment, hydrogen will burn when either criterion (A) or (B) is met in combination with criterion (C)
    - (A) The hydrogen-nitrogen mixture entering containment is above 1450°F
    - (B) The hydrogen-sodium-nitrogen mixture entering containment contains at least 6 G/M^3 of sodium at temperatures above 500°F
    - (C) The oxygen concentration is above 8%. With the oxygen concentration above 5% and the hydrogen concentration above 4%, the hydrogen in excess of 4% would burn

8054-82

HYDROGEN AUTO-IGNITION DATA

(HEDL-TME 78-80)

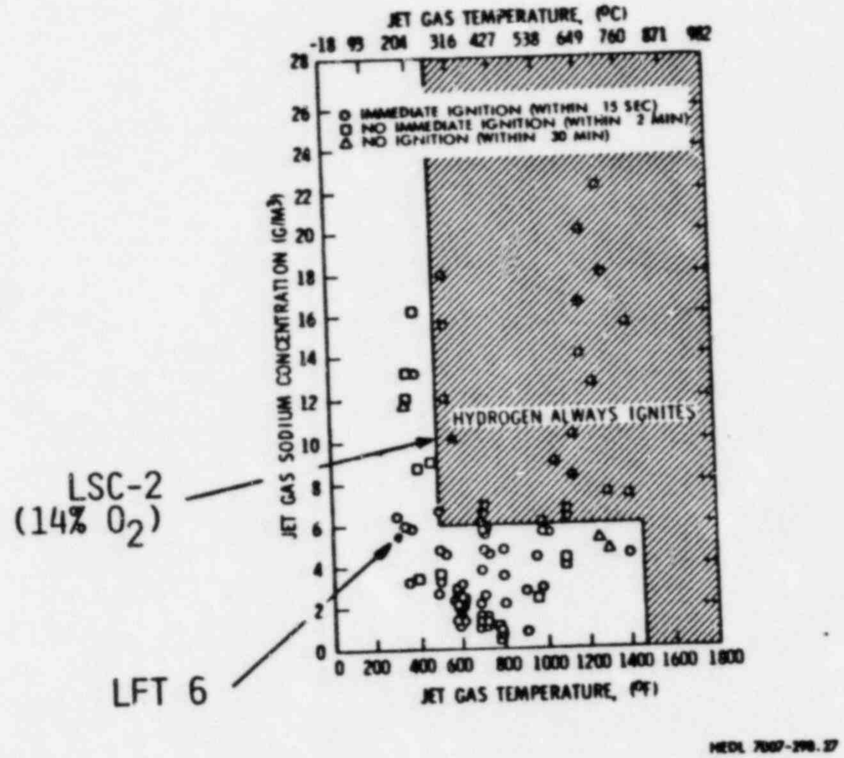


FIGURE 6. Conservative Limits for Hydrogen-Sodium Jet Ignition.

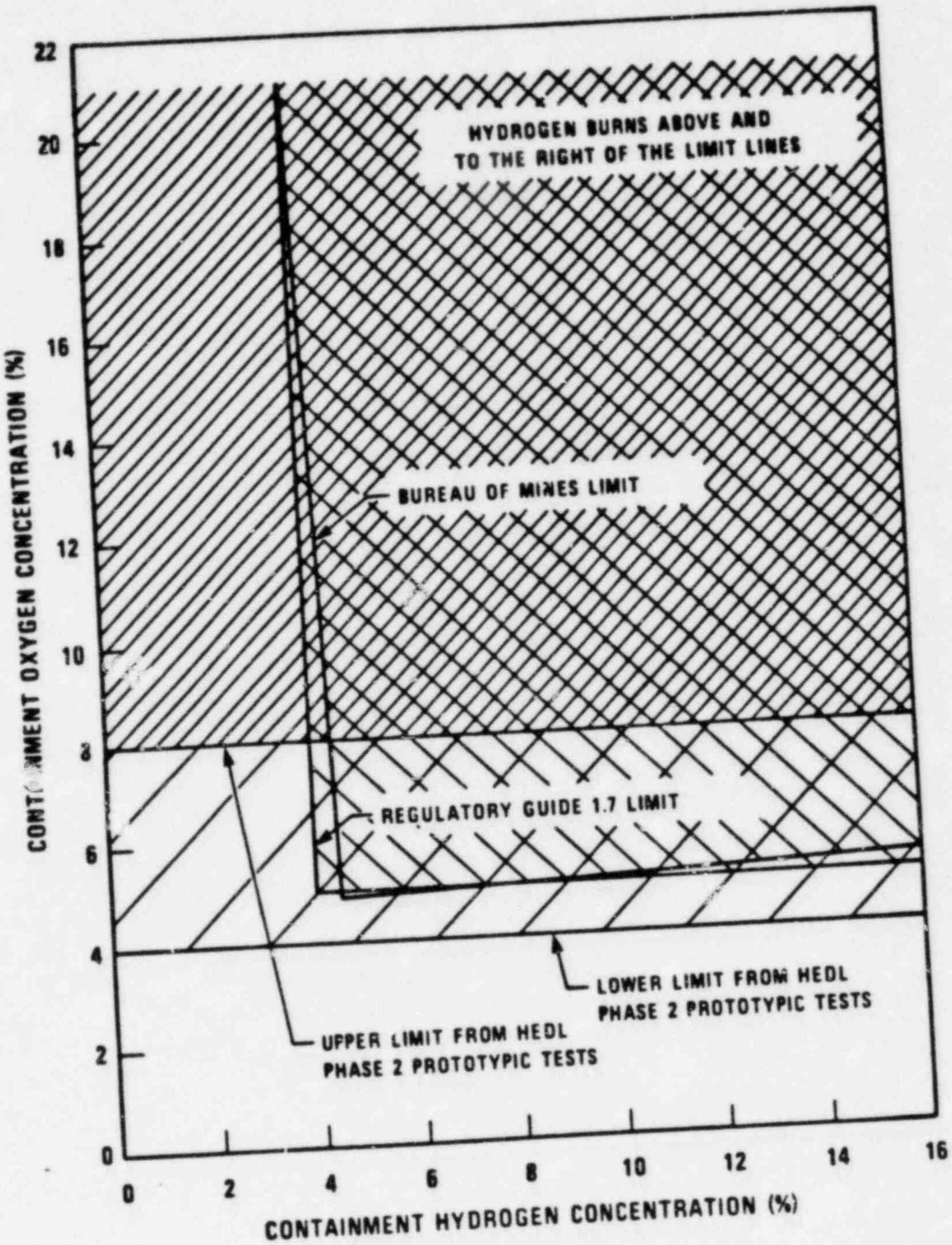


Figure H.1-5 Containment Hydrogen Flammability Limits

1966-174

EVALUATION OF STRUCTURES FOR MARGIN ASSESSMENT CASE

SUMMARY OF DISCUSSION

- STRUCTURAL REQUIREMENTS
- SCOPE OF EVALUATION
- STRUCTURAL EVALUATIONS
- DESIGN MODIFICATIONS

Presentation to NRC
by G. N. Freskakis
Sept. 15, 1982
Bethesda

TMBDB STRUCTURAL EVALUATIONS

- STRUCTURAL EVALUATIONS HAVE BEEN CONDUCTED FOR THE FOLLOWING CASES:

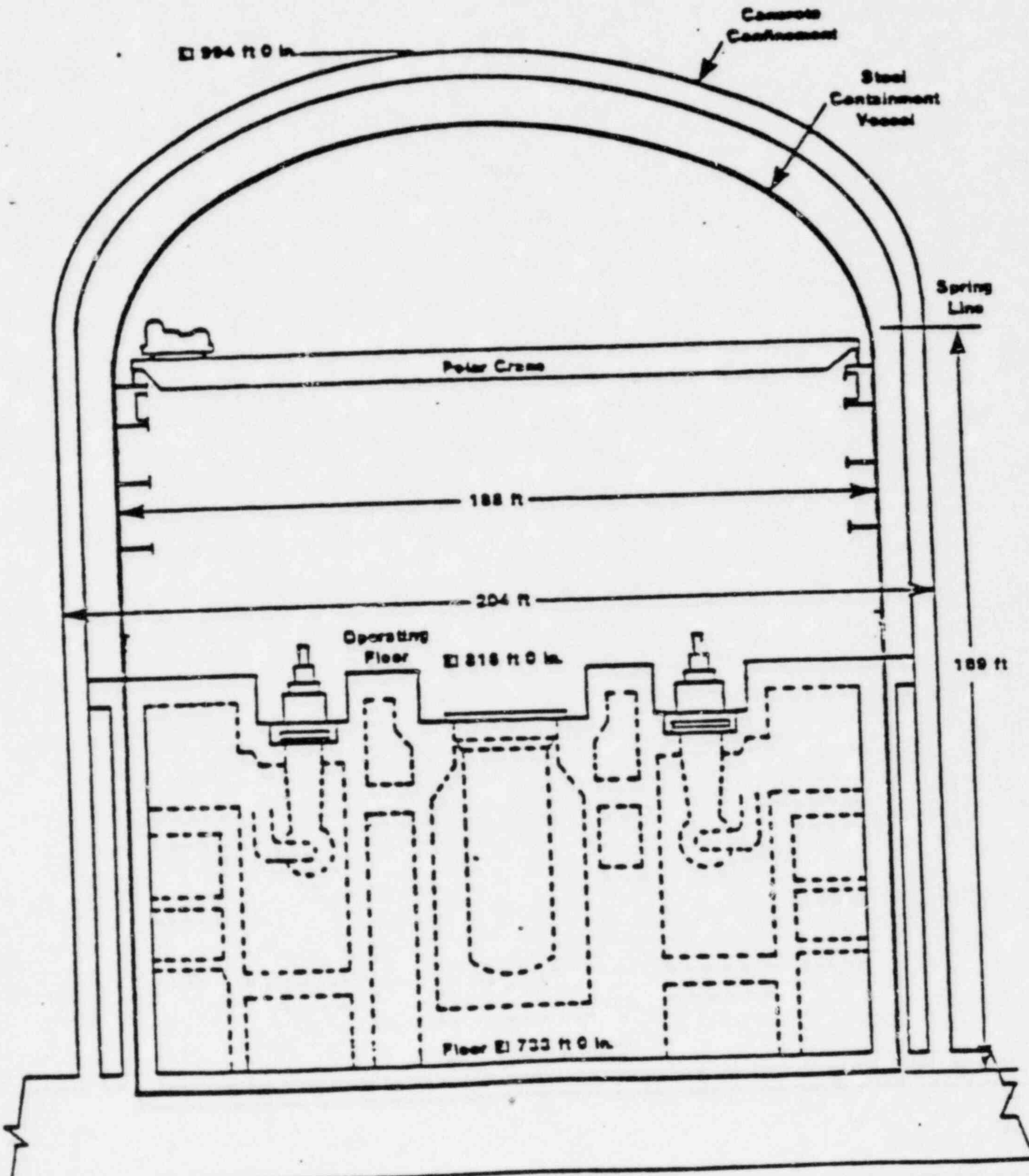
  A. BASE CASE - LIMITED SODIUM PENETRATION INTO RC FLOOR

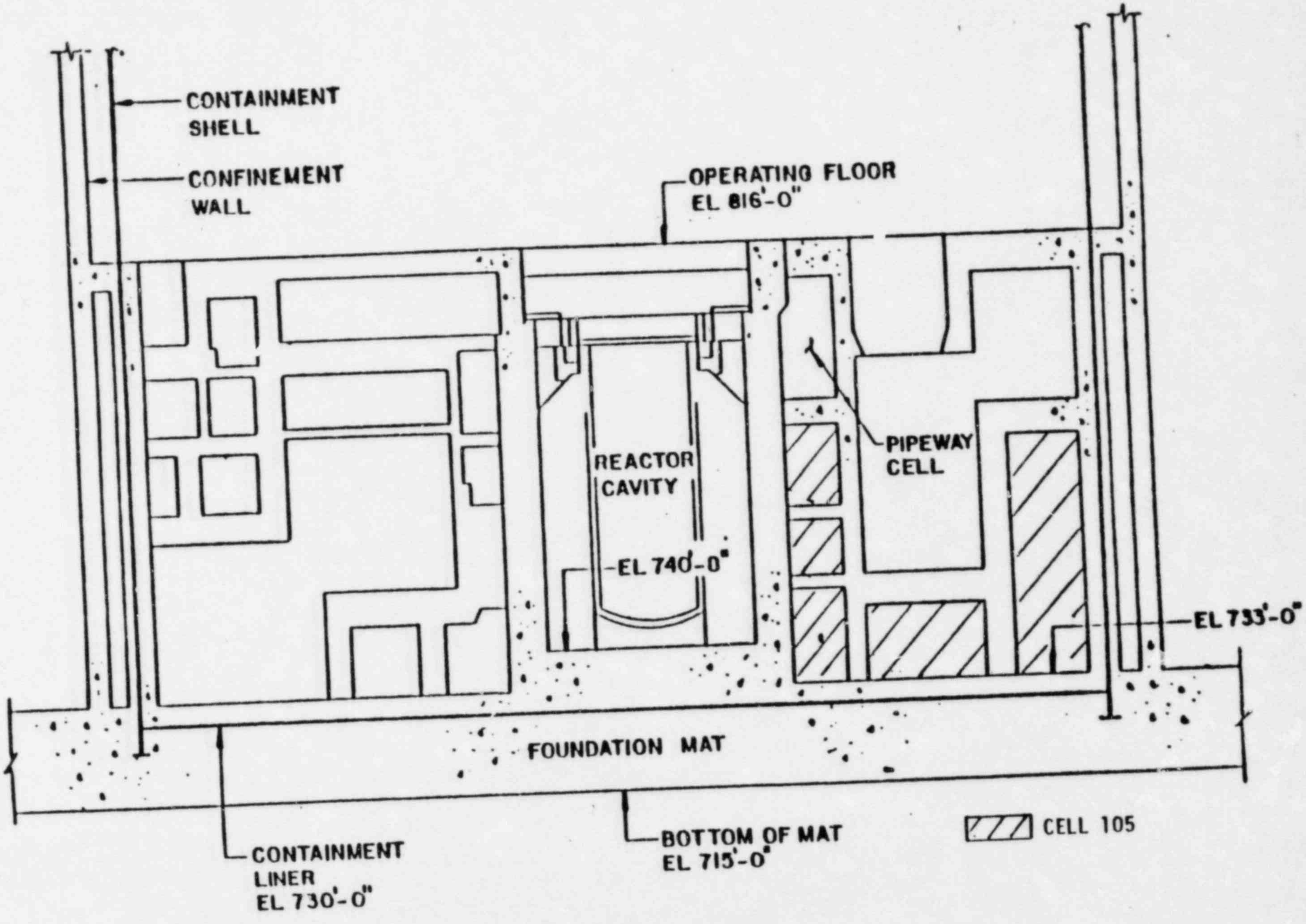
  B. MARGIN ASSESSMENT CASE - EXTREME SODIUM PENETRATION INTO RC FLOOR

- TWO CASES ENVELOPE INTERMEDIATE PENETRATIONS INTO RC FLOOR

- THE MARGIN ASSESSMENT SCENARIO IS NOT TREATED AS A DESIGN CASE. ANY IDENTIFIED MODIFICATIONS TO THE DESIGN ARE INTRODUCED FOR ILLUSTRATIVE PURPOSES ONLY

CONTAINMENT/CONFINEMENT





RCB CROSS SECTION

STRUCTURAL EVALUATION OF MARGIN ASSESSMENT CASE

- Sodium Concrete Reaction Rate:

  7 inch per hour for first 3 hours

  1 inch per hour after 3 hours to boil dry

- Boil Dry Time - 50 hours

- Structural Evaluation Criteria

  - Wall liner in Reactor Cavity to maintain integrity until boil dry time
  - Reactor Cavity Floor and Pipeway Cell Floors to prevent sodium leakage to cell 105 (Air Filled Cell) until boil dry time
  - Containment and Confinement integrity to be maintained for long term (8000 hours)
  - Pipeway cell wall liner integrity to be maintained as follows:

    Wall liner between reactor cavity and pipeway cell - 50 hrs

    Others - 30 hrs

(CONTINUED)

STRUCTURAL EVALUATION OF MARGIN ASSESSMENT CASE

- SCOPE OF EVALUATION

  - DETERMINE WHETHER STRUCTURES, AS DESIGNED, CAN WITHSTAND IMPOSED EXTREME PENETRATION CONDITIONS

  - DETERMINE NECESSARY DESIGN MODIFICATIONS SO STRUCTURES CAN WITHSTAND IMPOSED CONDITIONS

  - SCOPING EVALUATIONS

    DEMONSTRATE INTEGRITY BY COMPARISON WITH BASE CASE (WHENEVER POSSIBLE)

    OR

    PERFORM ANALYSIS USING SIMPLIFIED MODELS AND COMPARISON WITH BASE CASE. MATERIAL PROPERTIES AND CRITERIA SAME AS IN BASE CASE (CRBRP-3)

STRUCTURAL EVALUATION OF MARGIN ASSESSMENT CASE

- STRUCTURES OF PARTICULAR CONCERN:
  - REACTOR CAVITY
  - PIPEWAY CELLS
  - CONFINEMENT STRUCTURE
  - CONTAINMENT SHELL

RESULTS OF REACTOR CAVITY WALL AND LINER EVALUATION

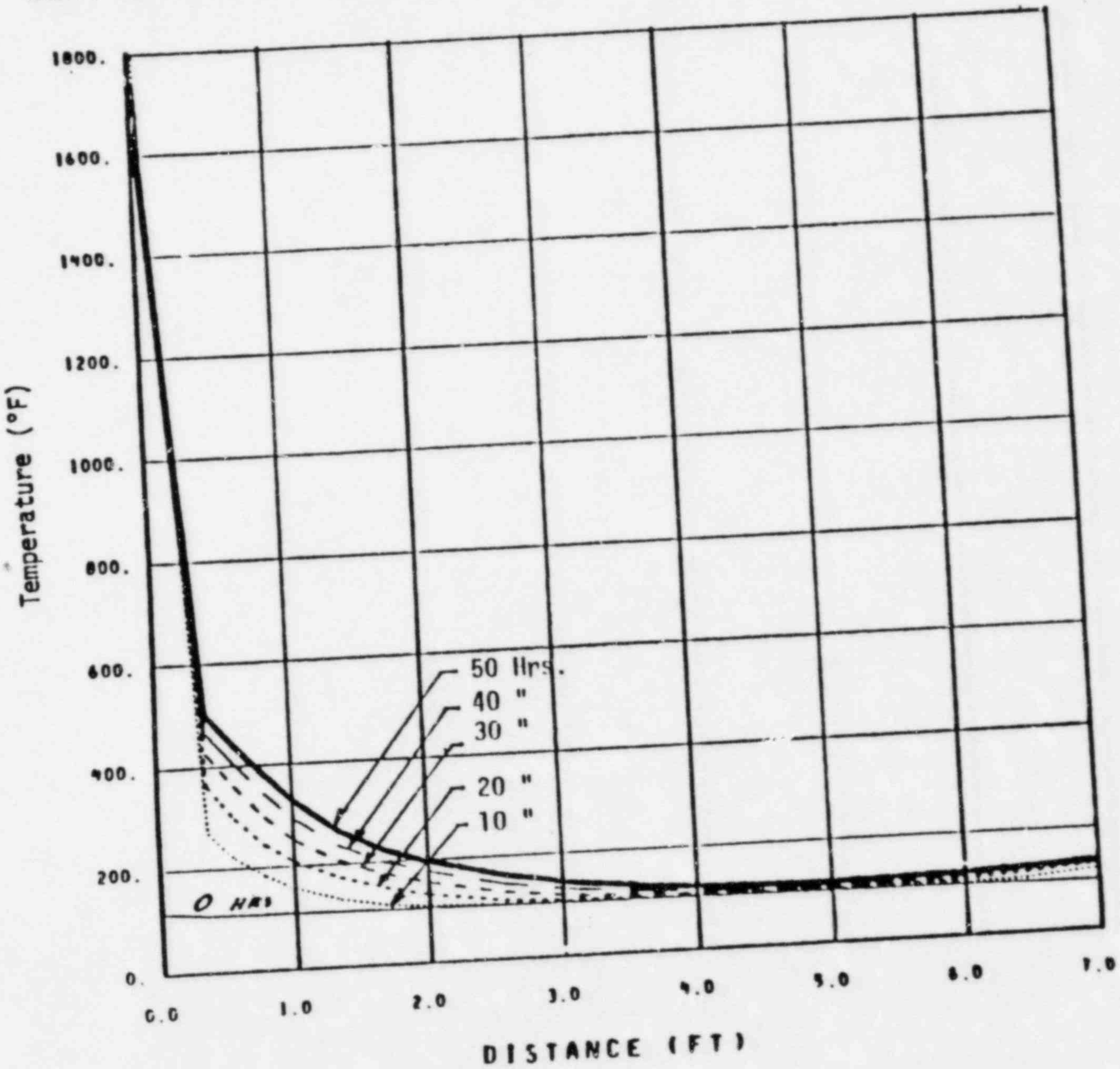
- IN MARGIN ASSESSMENT CASE, WALL LINER IS SUBJECTED TO SAME TEMPERATURES AS IN BASE CASE
- MARGIN ASSESSMENT TEMPERATURE GRADIENTS AT 50 HOURS ABOUT THE SAME AS BASE CASE 50 HR. GRADIENTS OF BASE CASE
- FOR BASE CASE CONDITIONS INTEGRITY HAS BEEN DEMONSTRATED AS FOLLOWS:

LOWER SUBMERGED LINER	50 HRS
UPPER SUBMERGED LINER	70 HRS
NON-SUBMERGED LINER	80 HRS
CONCRETE WALL	> 132 HRS

- BASED ON ABOVE, RC LINER AND WALL ABOVE FLOOR ARE EXPECTED TO MAINTAIN INTEGRITY FOR 50 HRS. (BOIL DRY TIME) AND BEYOND

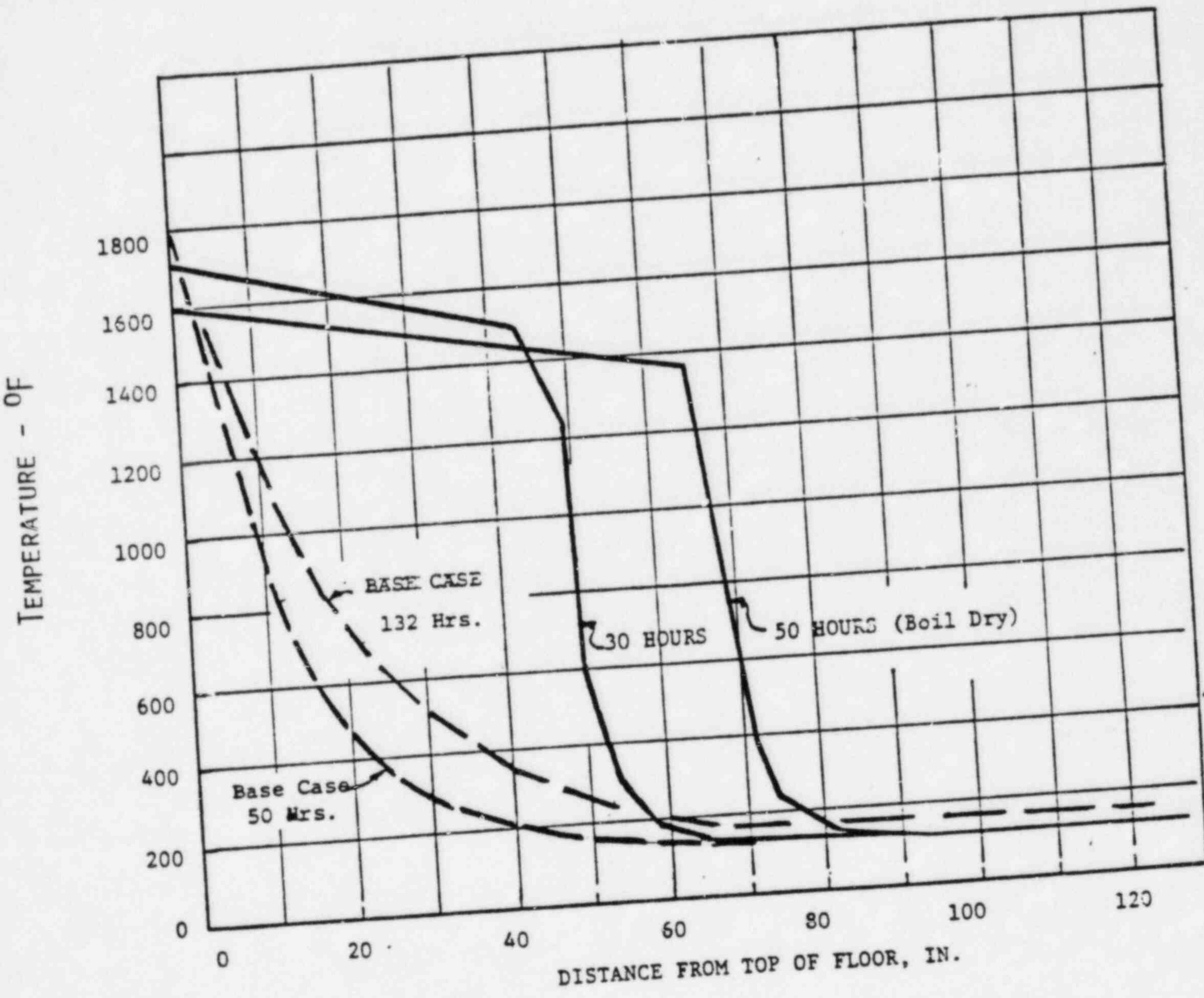
MARGIN ASSESSMENT CASE

REACTOR CAVITY LOWER SUBMERGED WALL



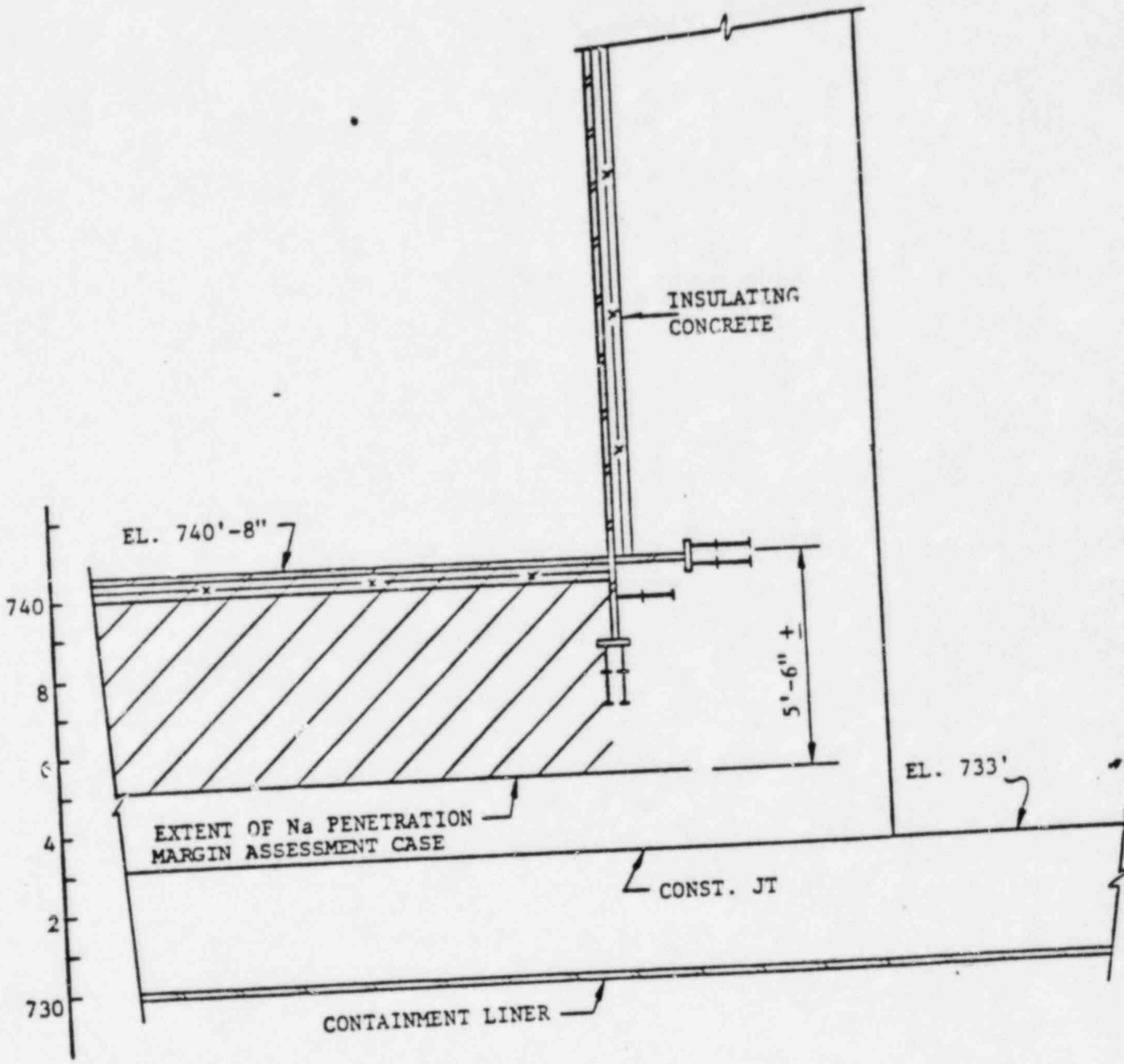
STRUCTURAL EVALUATION OF REACTOR CAVITY FLOOR UNDER MARGIN ASSESSMENT CASE CONDITIONS

- ASSUMPTIONS
  - FLOOR LINER ASSUMED TO FAIL AT ONSET OF SPILL
  - APPROXIMATELY 5.5 FEET OF FLOOR CONCRETE PENETRATED BY SODIUM



REACTOR CAVITY FLOOR - TEMPERATURE TRANSIENTS

MARGIN ASSESSMENT CASE



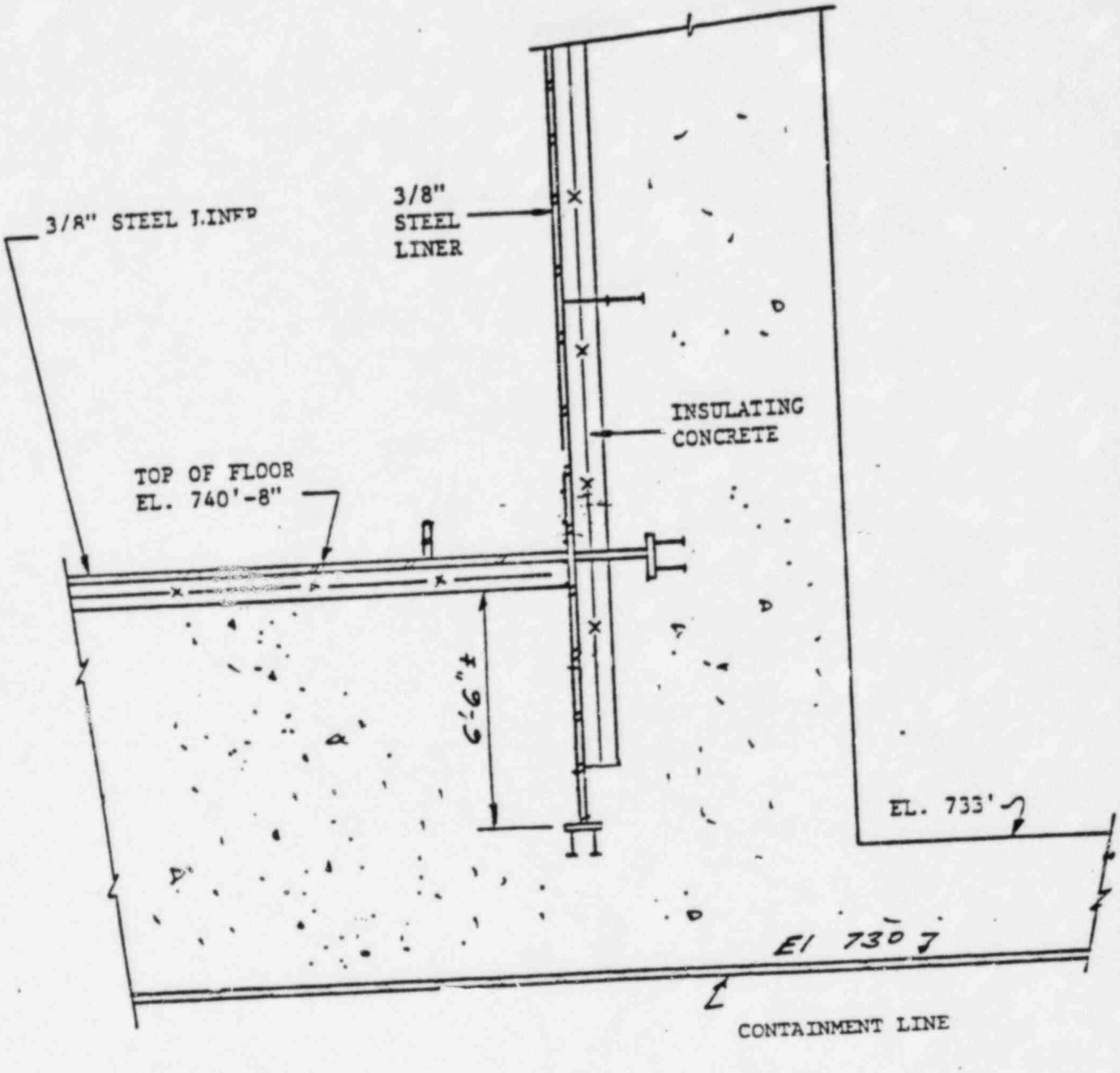
SECTION - REACTOR CAVITY AND WALL
CURRENT DESIGN AND EXTENT OF Na PENETRATION

CONCLUSIONS OF RC FLOOR EVALUATION

- CURRENT DESIGN DOES NOT MEET MARGIN ASSESSMENT EVALUATION CRITERIA. POTENTIAL LEAKAGE TO CELL 105
- MINOR MODIFICATIONS TO THE FLOOR SYSTEM WOULD BE NECESSARY TO MEET MARGIN ASSESSMENT EVALUATION CRITERIA

RC FLOOR DESIGN MODIFICATIONS NEEDED FOR MARGIN ASSESSMENT CASE

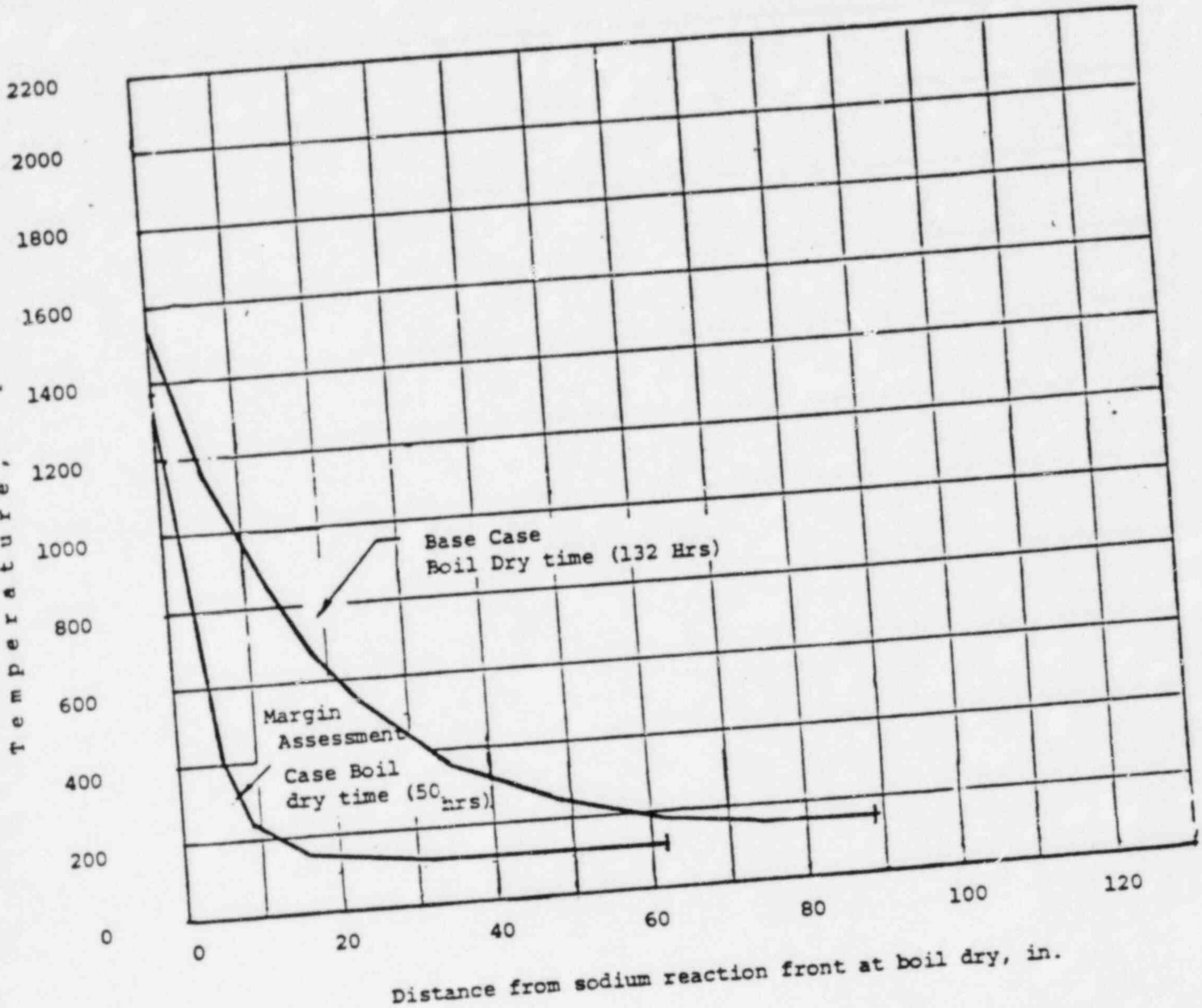
- Remove construction joint at elevation 733 and rearrange Re-bar
- Extend wall liner to 6.5± ft. into structural concrete
- Provide circumferential vertical plate on top of floor liner near wall to inhibit spreading of fuel debris to region of floor-wall junction



SECTION - REACTOR CAVITY FLOOR AND WALL

MODIFIED DESIGN

TO ACCOMMODATE MARGIN ASSESSMENT CASE



RC FLOOR - COMPARISON OF BASE CASE
AND MARGIN ASSESSMENT CASE TRANSIENTS

REACTOR CAVITY FLOOR ASSESSMENT

- FLOOR DESIGN EVALUATED USING MODEL OF AXISYMMETRIC RESTRAINED SECTION AND ELASTIC PLASTIC FINITE ELEMENT ANALYSIS WITH COMPUTER PROGRAM ANSYS. CAPACITY DETERMINED FROM M-Ø RELATIONS OBTAINED WITH COMPUTER PROGRAM MPHI

- RESULTS INDICATE THAT DESIGN MEETS SCENARIO REQUIREMENTS WITH SUBSTANTIAL MARGIN

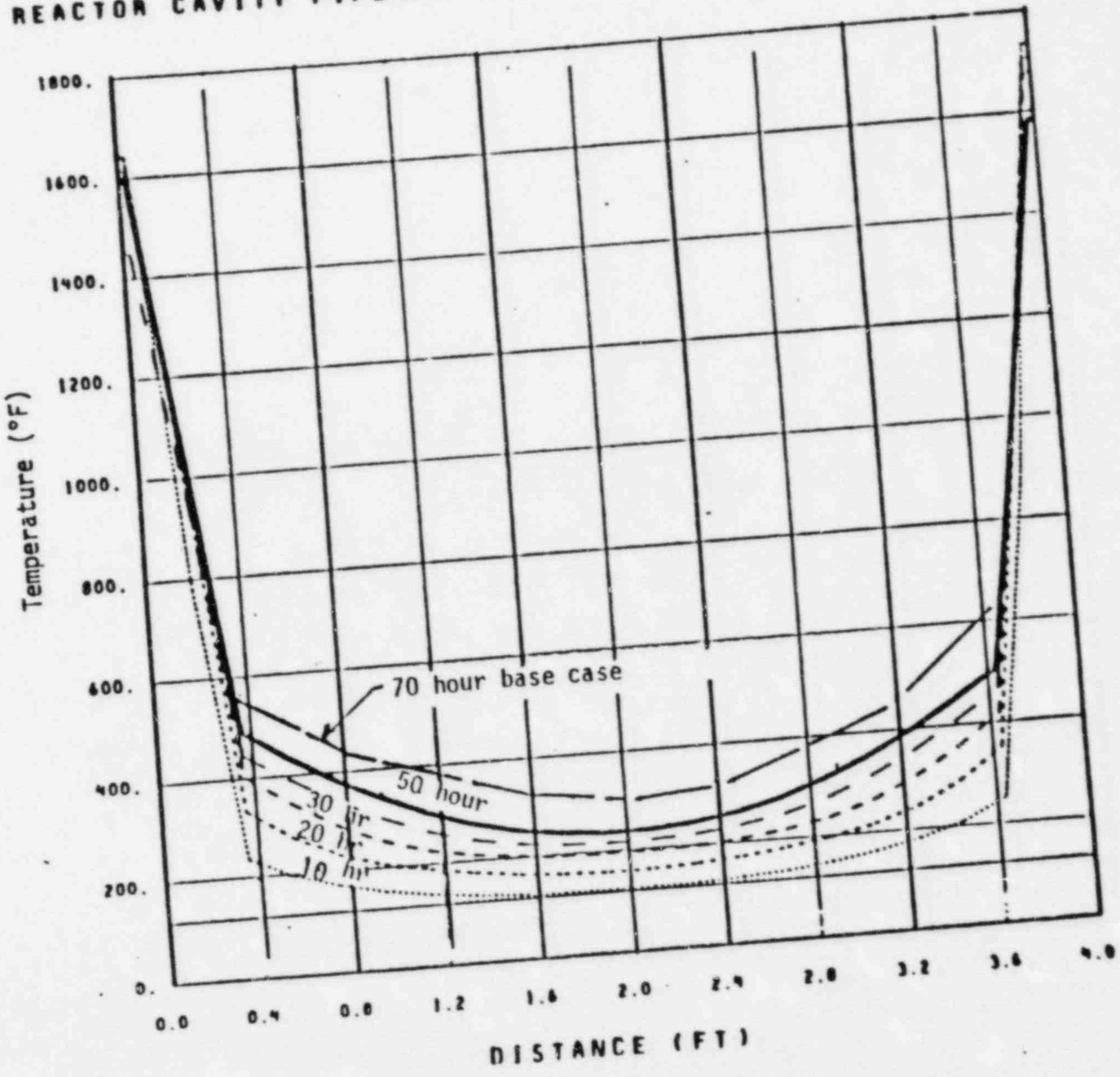
STRUCTURAL EVALUATION OF PIPEWAY CELL WALLS AND LINERS UNDER MARGIN ASSESSMENT CASE CONDITIONS

- WALL BETWEEN RC AND PIPEWAY CELL
  - IN MARGIN ASSESSMENT CASE, WALL LINER TEMPERATURES SAME AS IN BASE CASE
  - IN MARGIN ASSESSMENT CASE, 50 HOUR WALL TEMPERATURE LOWER THAN BASE CASE, 70 HOURS
  - IN BASE CASE WALL LINER INTEGRITY DEMONSTRATED FOR 70 HOURS, CONCRETE WALL WILL NOT COLLAPSE BEFORE 132 HOURS

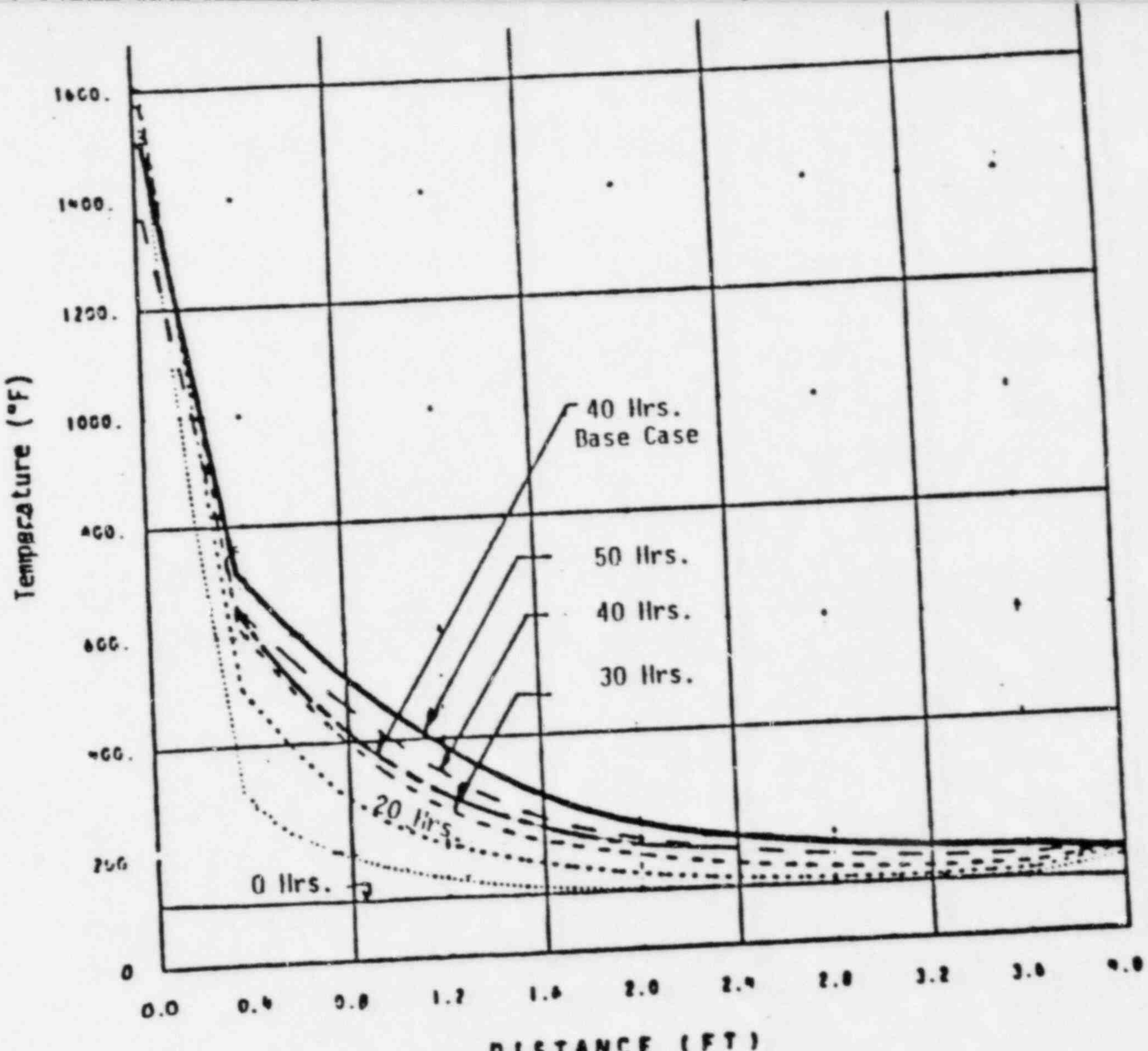
- OTHER WALLS
  - IN MARGIN ASSESSMENT CASE, WALL LINER TEMPERATURES SAME AS IN BASE CASE
  - IN MARGIN ASSESSMENT CASE, 30 HOUR TEMPERATURE TRANSIENT SAME AS 40 HOUR BASE CASE TEMPERATURE
  - IN BASE CASE, WALL LINER INTEGRITY DEMONSTRATED FOR 40 HOURS, CONCRETE WALL WILL NOT COLLAPSE BEFORE 132 HOURS

MARGIN ASSESSMENT CASE

REACTOR CAVITY PIPEWAY CELL DOUBLE HEATED WALL



NOTE: MARGIN ASSESSMENT TRANSIENTS UNLESS OTHERWISE NOTED



NOTE: MARGIN ASSESSMENT CASE TRANSIENTS UNLESS NOTED OTHERWISE

PIPEWAY CELL WALL TEMPERATURES - MARGIN ASSESSMENT CASE

RESULTS OF PIPEWAY CELL WALL AND LINER EVALUATION

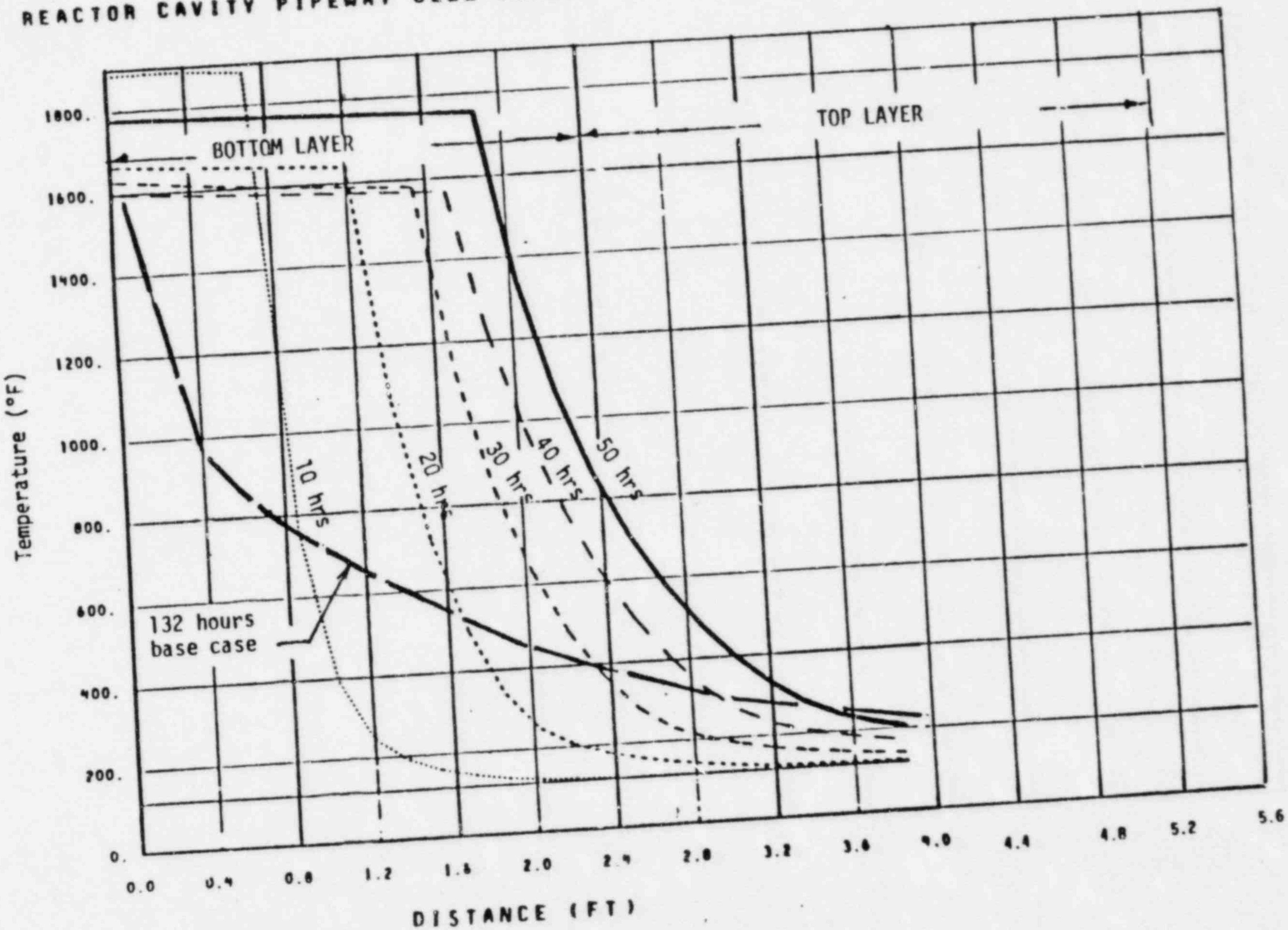
- CONCRETE WALLS AND WALL LINERS MEET MARGIN ASSESSMENT STRUCTURAL EVALUATION CRITERIA

STRUCTURAL EVALUATION OF PIPEWAY CELL FLOOR UNDER MARGIN ASSESSMENT CASE CONDITIONS

- Floor Liner assumed to fail at 0 hours
- Approximately 2.5 feet penetrated by sodium

MARGIN ASSESSMENT CASE

REACTOR CAVITY PIPEWAY CELL FLOOR



CONCLUSIONS OF PIPEWAY CELL FLOOR EVALUATION

- CURRENT DESIGN DOES NOT MEET MARGIN ASSESSMENT STRUCTURAL EVALUATION CRITERIA

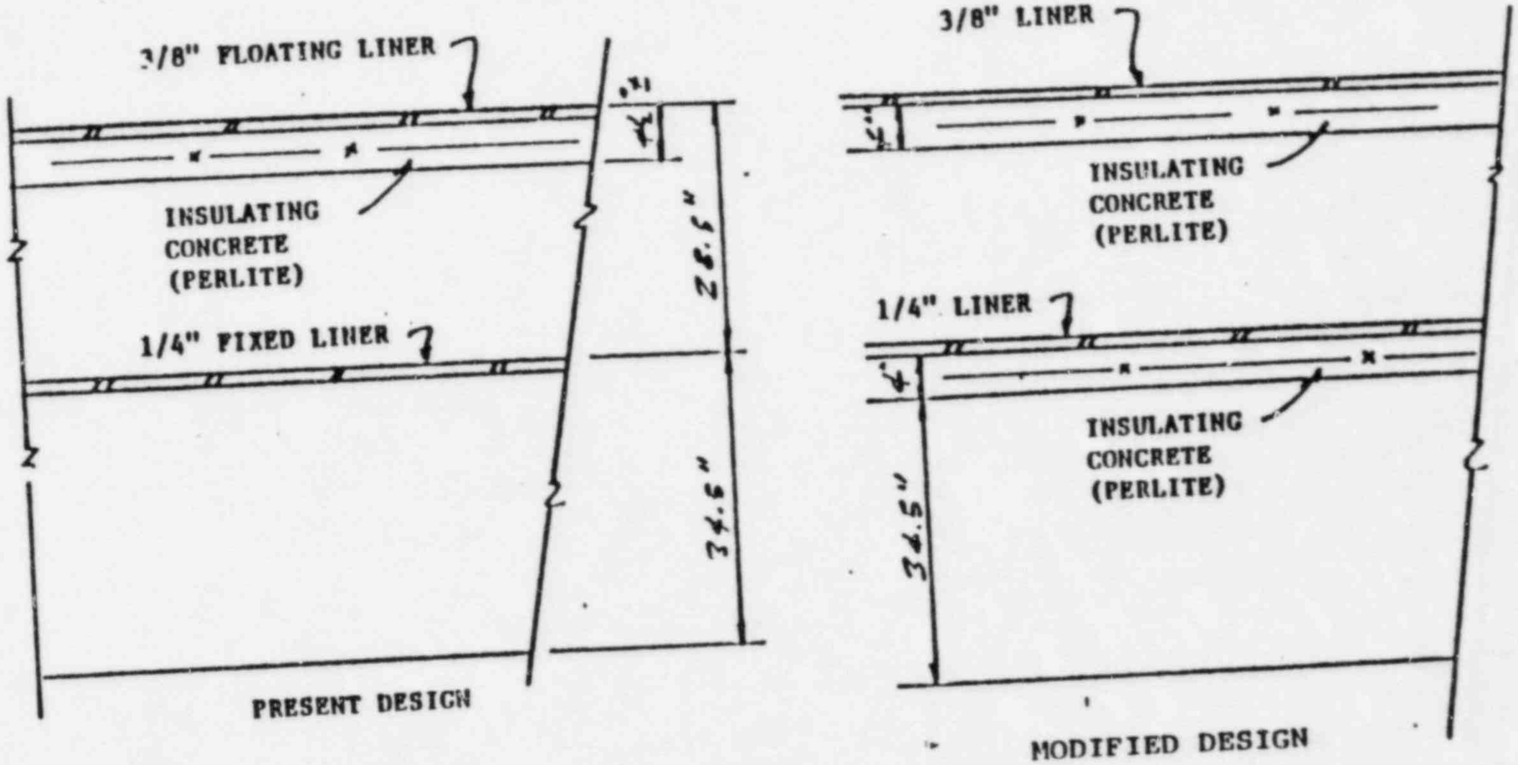
- MINOR MODIFICATIONS TO THE PIPEWAY FLOOR WOULD BE NECESSARY TO MEET THE MARGIN ASSESSMENT SCENARIO REQUIREMENTS

PIPEWAY CELL FLOOR MODIFICATIONS

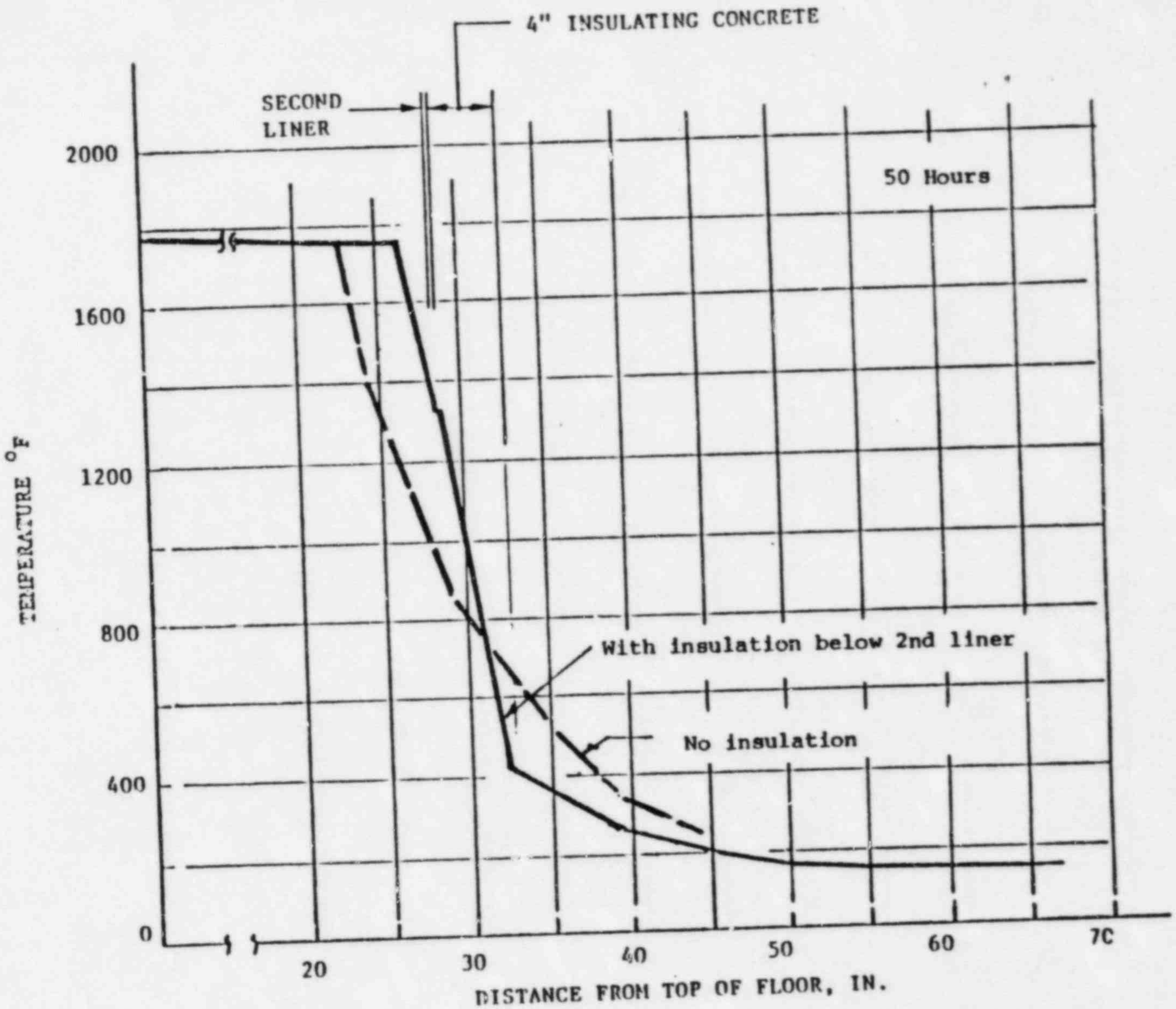
NEEDED FOR MARGIN ASSESSMENT CASE

- PROVIDE 4 IN. OF INSULATING CONCRETE BELOW SECOND LINER SEPARATING TWO LAYERS OF STRUCTURAL CONCRETE

- LOWER FLOOR BOTTOM BY 4 IN. TO MAINTAIN 35 IN. THICKNESS OF BOTTOM LAYER

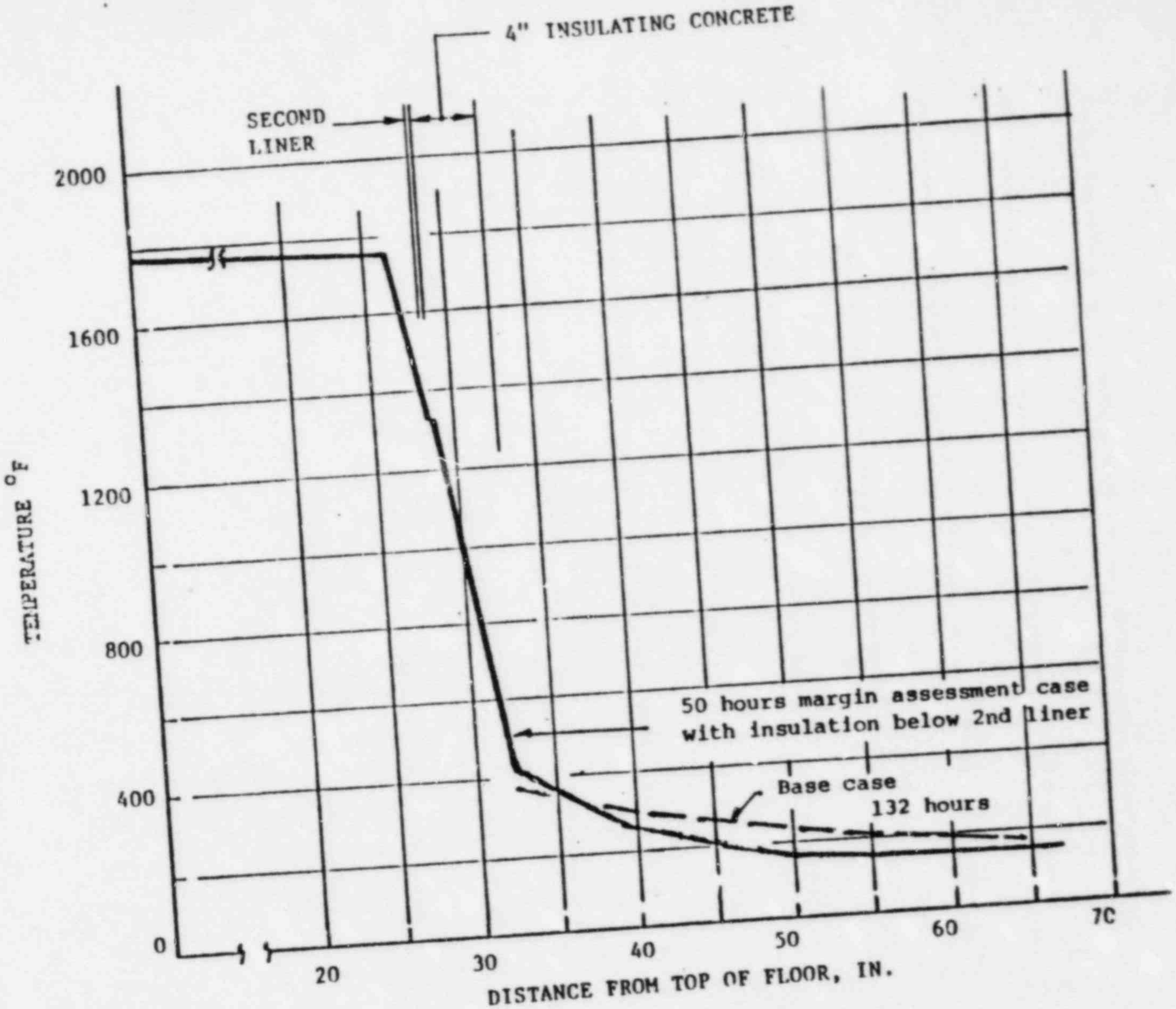


PIPEWAY CELL FLOOR CROSS SECTION



PIPEWAY CELL FLOOR - THERMAL TRANSIENTS

MARGIN ASSESSMENT CASE



PIPEWAY CELL FLOOR - THERMAL TRANSIENTS

MARGIN ASSESSMENT CASE

PIPEWAY CELL FLOOR ASSESSMENT

- FLOOR DESIGN EVALUATED USING MODEL OF RESTRAINED SECTION AND ELASTIC PLASTIC FINITE ELEMENT ANALYSIS WITH COMPUTER PROGRAM ANSYS. CAPACITY DETERMINED FROM $M-\phi$ RELATIONS OBTAINED WITH COMPUTER PROGRAM MPHI

- RESULTS INDICATE THAT DESIGN MEETS SCENARIO REQUIREMENTS

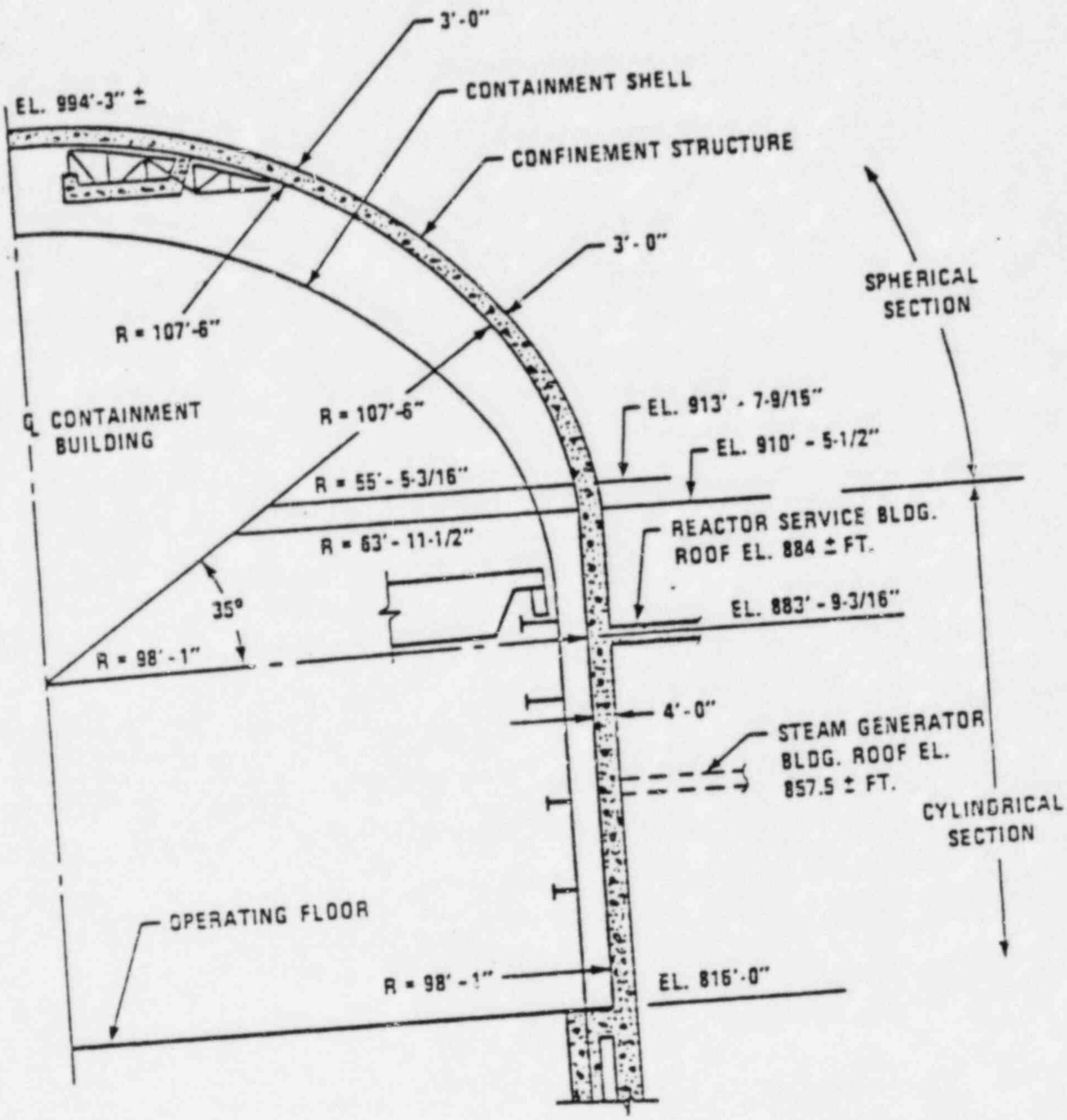
STRUCTURAL EVALUATION OF CONFINEMENT STRUCTURE FOR MARGIN ASSESSMENT CASE

- IN BASE CASE INTEGRITY DEMONSTRATED FOR 140 HOURS, COOLING DOWN BEYOND 140 HOURS

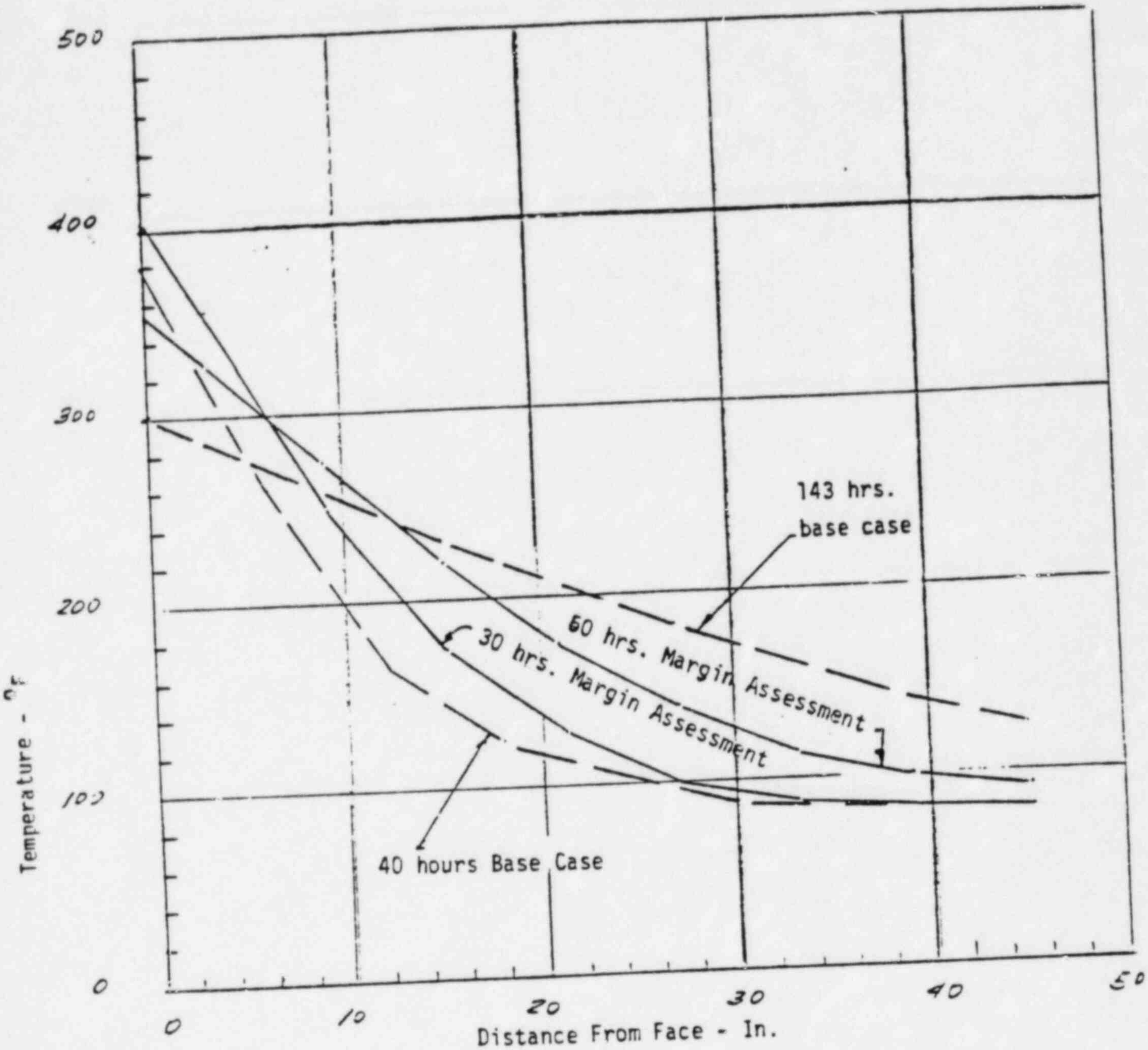
- DIRECT COMPARISON OF MARGIN ASSESSMENT CASE TRANSIENTS WITH BASE CASE TRANSIENTS NOT CONCLUSIVE

- EVALUATION USING SIMPLIFIED COMPUTER MODELS

  - BASE CASE CONSIDERED AXISYMMETRIC MODEL FULL HEIGHT, FACTORS ESTABLISHED FOR RATIO OF FORCES AND MOMENTS IN FULL MODEL TO THOSE IN RESTRAINED SECTION MODELS.
  - COMPUTER ANALYSIS (USING ANSYS) CARRIED OUT FOR RESTRAINED SECTION MODELS UNDER MARGIN ASSESSMENT CASE TRANSIENTS
  - FORCES AND MOMENTS ADJUSTED BY FACTORS FOR FULL MODEL EFFECT. CAPACITY OF SECTIONS DETERMINED FROM M-0 RELATIONS OBTAINED WITH COMPUTER PROGRAM MPIII.
  - CRITICAL TIME 30-50 HOURS, THEN COOLING TAKES PLACE



CONFINEMENT STRUCTURE



CONFINEMENT WALL TEMPERATURE AT EL. 900'

RESULTS OF CONFINEMENT STRUCTURE EVALUATION

- RESULTS DEMONSTRATE THAT CONFINEMENT STRUCTURE WILL MAINTAIN LONG-TERM INTEGRITY UNDER MARGIN ASSESSMENT CONDITIONS

STRUCTURAL EVALUATION FOR MARGIN ASSESSMENT CONDITIONS
SUMMARY AND CONCLUSION

- REACTOR CAVITY WALL AND WALL LINER MEET MARGIN ASSESSMENT STRUCTURAL EVALUATION CRITERIA
- WITH MINOR MODIFICATIONS REACTOR CAVITY FLOOR WOULD MEET MARGIN ASSESSMENT EVALUATION CRITERIA
- PIPEWAY CELL WALLS AND WALL LINERS MEET MARGIN ASSESSMENT EVALUATION CRITERIA
- WITH MINOR MODIFICATIONS, PIPEWAY CELL FLOOR WOULD MEET MARGIN ASSESSMENT EVALUATION CRITERIA
- CONFINEMENT STRUCTURE AND CONTAINMENT SHELL MEET MARGIN ASSESSMENT EVALUATION CRITERIA

CRBPR OVERVIEW BRIEFING

FOR

NUCLEAR REGULATORY COMMISSION
CRBPR PROGRAM OFFICE

CONTAINMENT VENT AND CLEANUP SYSTEM

PRESENTED BY

PETER FAZEKAS

MANAGER, AUXILIARY SYSTEMS ENGINEERING

BURNS AND ROE, INC.

CONTAINMENT CLEANUP SYSTEM
DESIGN DEVELOPMENT

- EVALUATION OF ALTERNATIVE CONCEPTS
- SELECTION OF THREE-STAGE WET SCRUBBER
- TESTING OF THE SELECTED CONCEPT
- DYNAMIC ANALYSIS OF THE SYSTEM ON BASIS OF TEST RESULTS

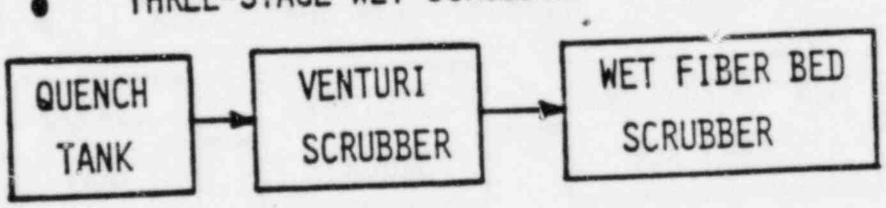
CONTAINMENT CLEANUP SYSTEM
EVALUATION OF ALTERNATIVE CONCEPTS
(HEDL REPORT TC-836)

MAJOR ALTERNATES CONSIDERED:

- HIGH EFFICIENCY SYSTEMS (99% EFF.)
  - BAG + HEPA + CHARCOAL
  - CYCLONE + HEPA + CHARCOAL
  - SAND AND GRAVEL + HEPA + CHARCOAL
  - WET FIBER BED + HEPA + CHARCOAL
- MEDIUM EFFICIENCY SYSTEMS (90% EFF.)
  - VENTURI SCRUBBER
  - SPRAY CHAMBER (QUENCH TANK)
  - WET FIBER BED

SELECTED SYSTEM DESIGN:

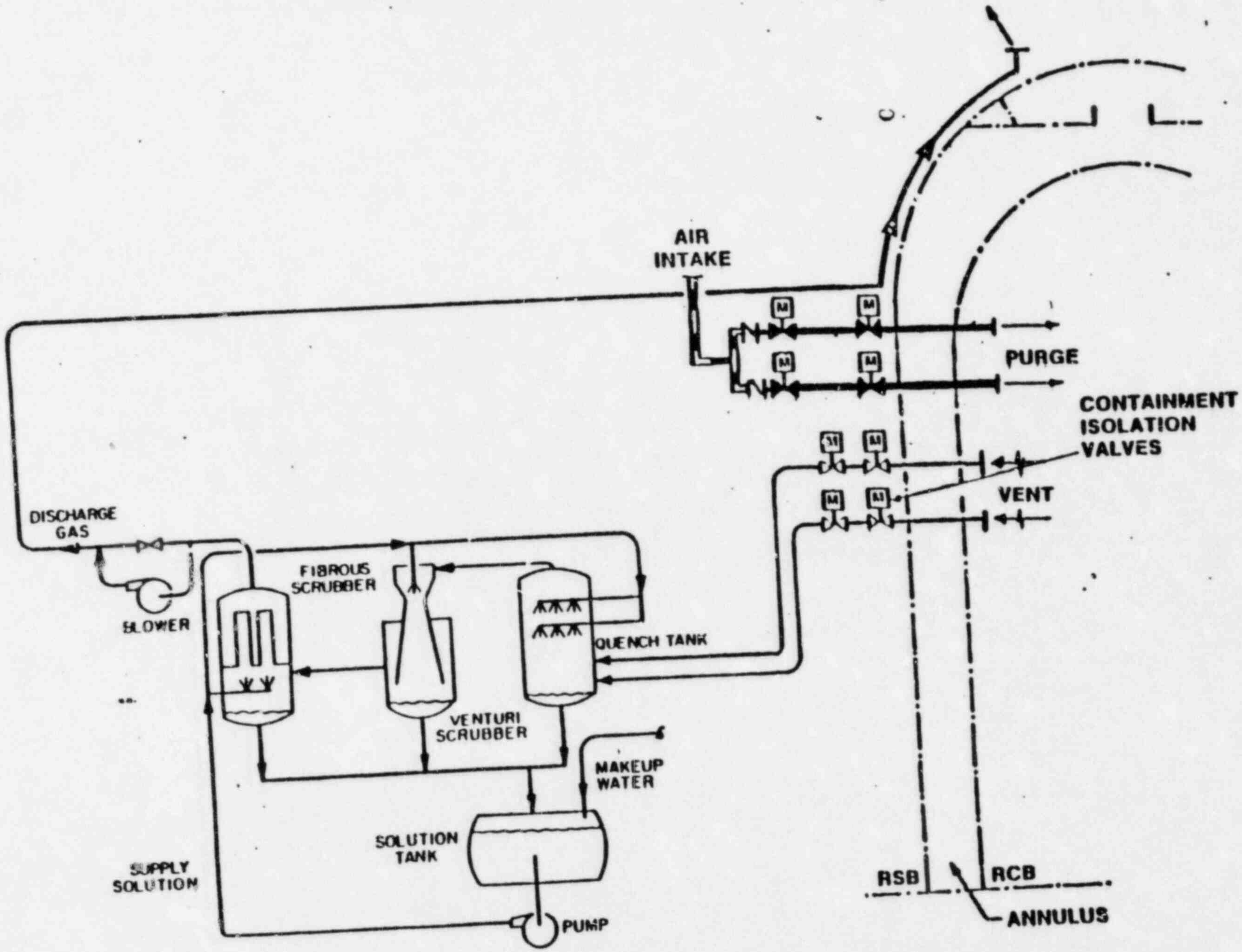
- HIGH EFFICIENCY PERFORMANCE (99% EFF.)
- HIGH MASS LOADING CAPABILITY
- THREE-STAGE WET SCRUBBER



CONTAINMENT VENT AND CLEANUP SYSTEM DESIGN DESCRIPTION

- VENT SYSTEM DESIGN
  - DESIGN REQUIREMENTS
  - SYSTEM DESCRIPTION
  - SYSTEM OPERATION
- CLEANUP SYSTEM DESIGN
  - DESIGN REQUIREMENTS
  - SYSTEM/COMPONENT DESCRIPTION
  - SYSTEM OPERATION

CONTAINMENT VENT, PURGE AND CLEANUP SYSTEMS



CONTAINMENT VENT SYSTEM

REQUIREMENTS:

- CAPACITY TO RELIEVE CONTAINMENT PRESSURE
- REMAIN FUNCTIONAL WITH SODIUM AEROSOLS ENTERING SYSTEM
- DESIGN FOR CALCULATED TEMPERATURES AND PRESSURES
- REMOTE MANUAL ACTUATION FROM THE CONTROL ROOM

DESCRIPTION/OPERATION:

- CONNECTED TO THE TMBDB CLEANUP SYSTEM THROUGH REDUNDANT PIPES
- REDUNDANT ISOLATION VALVES ON EACH VENT LINE
- FEATURES TO PREVENT INADVERTENT ACTUATION
  - NO LOCAL VALVE OPERATORS
  - ACTIVATION ONLY FROM NORMALLY LOCKED TMBDB PANEL IN CONTROL ROOM

CONTAINMENT CLEANUP SYSTEM

REQUIREMENTS:

- 99% EFFICIENCY FOR SOLID AND/OR LIQUID RADIOACTIVE MATERIALS
- 97% EFFICIENCY FOR VAPORS (NaI, SeO_2, Sb_2O_3)
- REMAIN FUNCTIONAL WITH CALCULATED SODIUM AEROSOL INGESTION
- REMAIN FUNCTIONAL WITH CONTAINED RADIOACTIVITY AND HEAT GENERATION FROM FISSION PRODUCTS
- REMOTE MANUAL ACTUATION FROM THE CONTROL ROOM

DESCRIPTION OPERATION:

- WET SCRUBBER FILTRATION SYSTEM
- DISCHARGE AT TOP OF THE CONFINEMENT DOME
- 24,000 NOMINAL ACFM CAPACITY
- WATER SYSTEM DESIGNED FOR pH OF 13
- SYSTEM LOCATED IN THE REACTOR SERVICE BUILDING
- ALL ACTIVE COMPONENTS REDUNDANT

CONTAINMENT VENT AND CLEANUP SYSTEM
SPECIAL CONSIDERATIONS

- CONTAINMENT VENT SYSTEM
  - CONTAINMENT ISOLATION VALVE OPERABILITY
  - CONTAINMENT PENETRATION DESIGN
  - VENT PIPE PLUGGING
- CONTAINMENT CLEANUP SYSTEM
  - POTENTIAL HYDROGEN EXPLOSION
  - WATER OVERFLOW INTO CONTAINMENT
  - MATERIAL SELECTION/COMPATIBILITY

CONTAINMENT VENT SYSTEM
VALVE OPERABILITY

- REDUNDANT VENT LINES WITH DOUBLE ISOLATION VALVES
- VALVES LOCATED IN AREAS NOT AFFECTED BY TMBDB CONTAINMENT ENVIRONMENT
- REMOTE OPERATION FROM CONTROL ROOM
- NO MANUAL OVERRIDE CAPABILITY

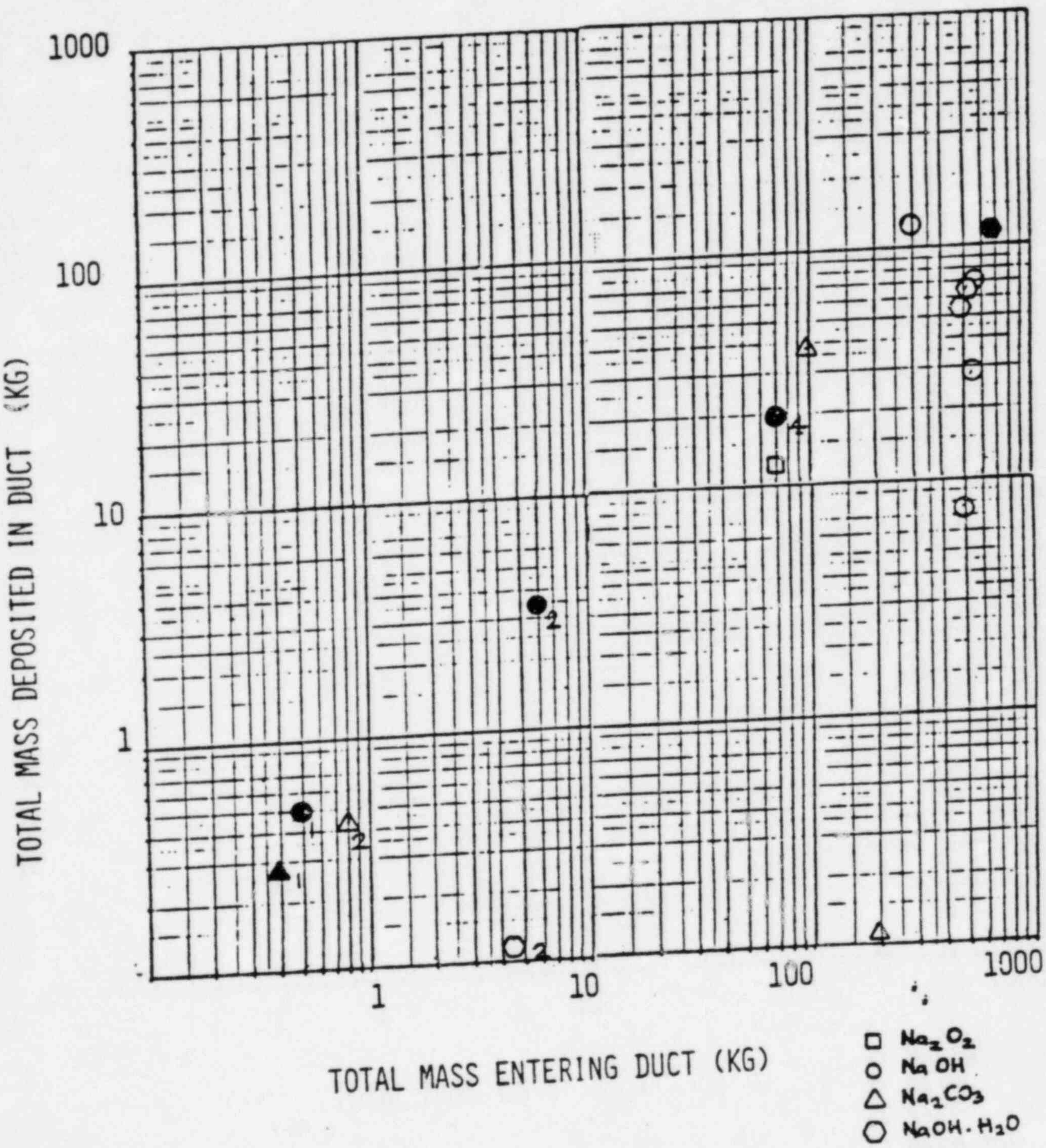
CONTAINMENT VENT SYSTEM
PENETRATION DESIGN

- CURRENT CONFIGURATION SIMPLE "PIPE THRU" PENETRATION
- THERMAL ANALYSIS TO DETERMINE CONTAINMENT VESSEL TEMPERATURE DISTRIBUTION AT PENETRATION VICINITY
- STRESS ANALYSIS TO DETERMINE CONTAINMENT VESSEL STRESSES
- FALL BACK TO FLUED-HEAD CONFIGURATION IF STRESSES ARE EXCESSIVE

CONTAINMENT VENT SYSTEM
PIPE PLUGGING

- THE CURRENT DESIGN IS BASED ON THE CONVEYING VELOCITY METHOD - RESULTED PIPE SIZE 24"
- HEDL TEST INDICATED PLUGGING OF 10" PIPE
- THE TECHNICAL LITERATURE WAS REVIEWED FOR AEROSOL DEPOSITION IN TURBULENT FLOW
- CONSERVATIVE EQUATION WAS SELECTED FOR PIPE PLUGGING
- SCOPING CALCULATION INDICATED THAT 36" PIPE WILL NOT PLUG UNDER TMBDB CONDITION
- VERIFICATION OF PLUGGING EQUATION WITH TEST RESULTS IS IN PROCESS
- BASED ON TEST EXPERIENCE PIPE ROUTING CRITERIA ESTABLISHED

AEROSOL DEPOSITION IN DUCTS



EVALUATION OF TECHNICAL LITERATURE AND SELECTION OF EQUATION FOR AEROSOL DEPOSITION IN TURBULENT FLOW

- THE WORK OF THE FOLLOWING AUTHORS WERE EVALUATED:
  - FRIEDLANDER AND JOHNSTONE
  - WELLS AND CHAMBERLAIN
  - DAVIES
  - SEHMEL
  - LIU AND ILORI
  - GIESKE ET. AL.
- SEHMEL'S EMPIRICAL FORMULA WAS SELECTED
  - BASED ON EFFECTIVE PARTICLE DIFFUSITIVITY MODEL AND CORRECTED BY LINEAR REGRESSION METHOD PER AVAILABLE EXPERIMENTAL DATA
  - ASSUMED PERFECT PARTICLE SINK SURFACE
  - GOOD STATISTICAL CORRELATION WITH EXPERIMENTAL RESULTS
  - THE SELECTED FORMULA

$$K^{+} = 1.47 \times 10^{-16} \rho^{1.01} R^{2.10} R_E^{3.02}$$

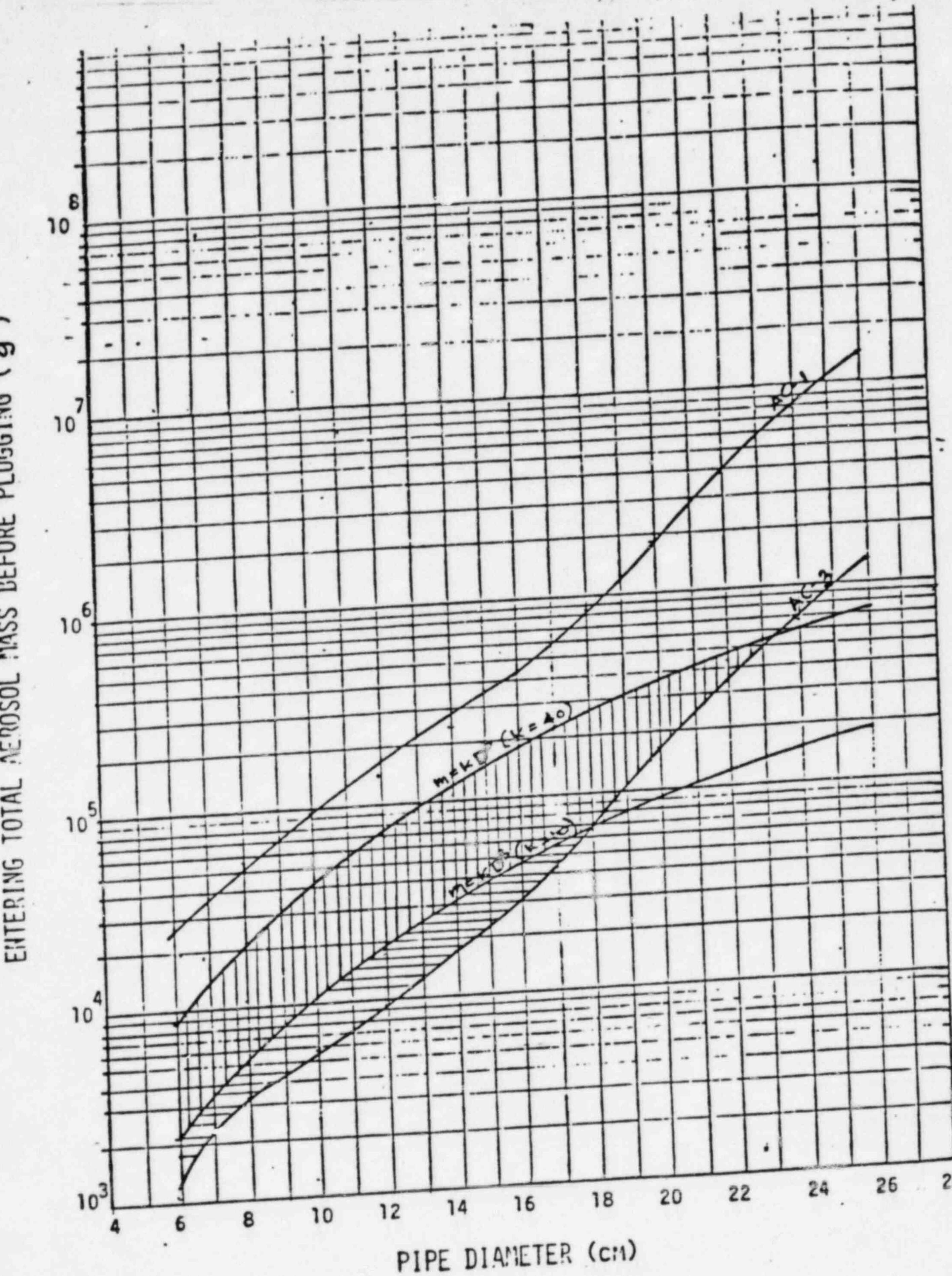
WHERE:

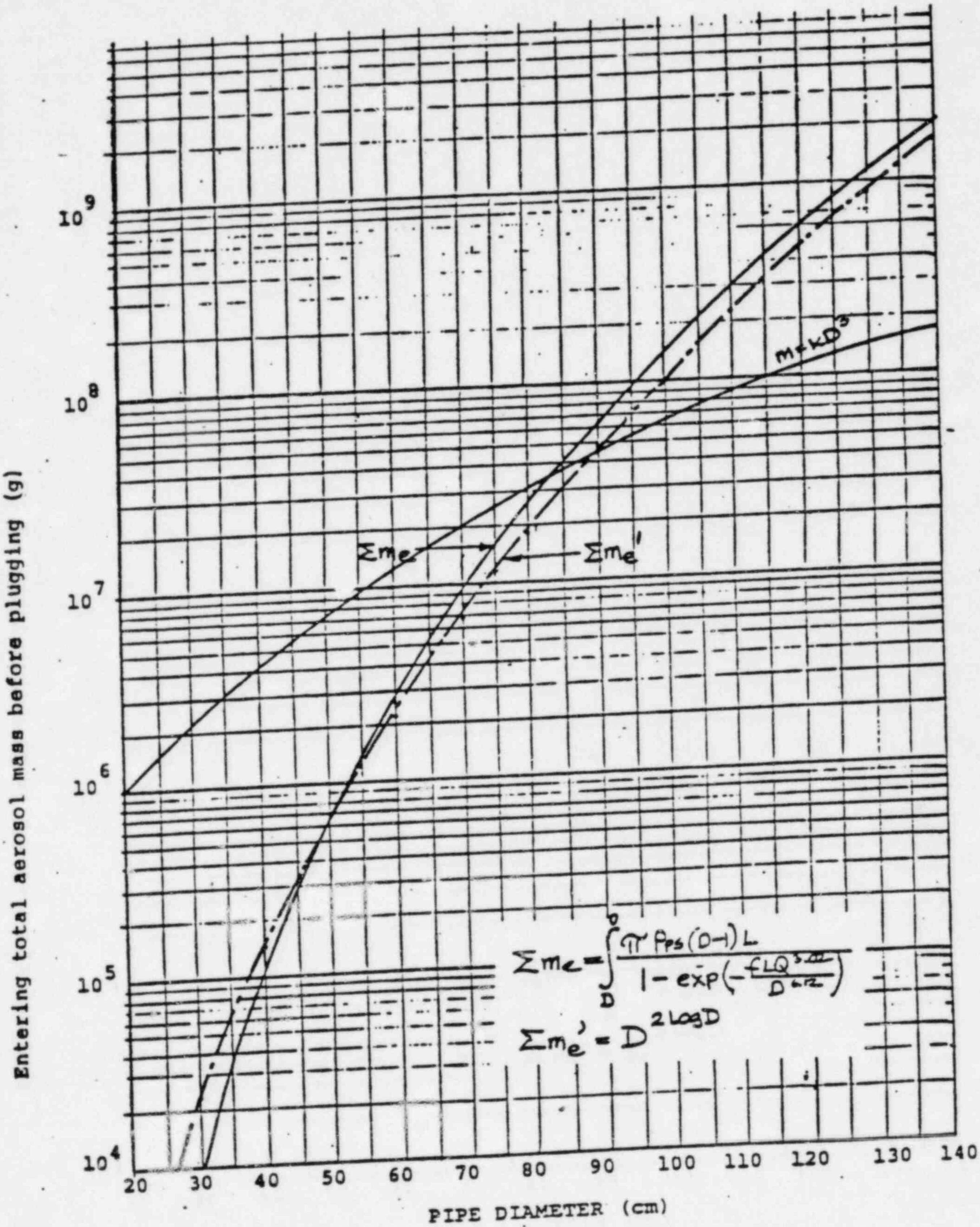
K^{+} = DIMENSIONLESS DEPOSITION VELOCITY

ρ = PARTICLE DENSITY (g/cm^3)

R = RATIO OF PARTICLE DIAMETER (μ) TO PIPE DIAMETER (CM)

R_E = REYNOLDS NUMBER


ENTERING TOTAL AEROSOL MASS BEFORE PLUGGING (g)
PIPE DIAMETER (cm)
AC-1
AC-2
$m = kD^3$ (k = 40)
$m = kD^3$ (k = 10)
10^3
10^4
10^5
10^6
10^7
10^8
4
6
8
10
12
14
16
18
20
22
24
26
28



Entering total aerosol mass before plugging (g)
10^9
10^8
10^7
10^6
10^5
10^4
20
30
40
50
60
70
80
90
100
110
120
130
140
PIPE DIAMETER (cm)
M=KD^3
Σme
Σme'
Σme = ∫ π ρps (D−1) L / 1 − exp(−fLQ / D)
Σme' = D^2 LogD

CONTAINMENT CLEANUP SYSTEM
POTENTIAL HYDROGEN EXPLOSION

- THE VENTED GASES ARE NOT CONTAINING HYDROGEN OXYGEN MIXTURES IN THE EXPLOSIVE RANGE
- HIGH POINTS OF THE COMPONENTS VENTED TO PREVENT STAGNATION
- NON-EXPLOSIVE GAS MIXTURE WILL NOT SEPARATE

CONTAINMENT CLEANUP SYSTEM
WATER OVERFLOW INTO CONTAINMENT

- THE CLEANUP SYSTEM COMPONENTS COULD CONTAIN THE ENTIRE WATER INVENTORY
- THE EXPECTED WATER LEVEL IS BELOW THE VENT PIPE ELEVATION

CONTAINMENT CLEANUP SYSTEM
MATERIAL SELECTION/COMPATIBILITY

- ALL METALLIC COMPONENTS ARE SPECIFIED AS CARBON STEEL OR ARE TO BE COMPATIBLE WITH THE EXPECTED WATER CHEMISTRY

- THE FIBROUS SCRUBBER ELEMENTS SPECIFIED AS POLYPROPYLENE, TEST INDICATED HIGH PH COMPATIBILITY

CONTAINMENT CLEANUP SYSTEM
TESTS

- TEST OBJECTIVES
- TEST DESCRIPTION
- TEST RESULTS

ADD TIME 81-1 80-47 AC-1→4 5 6

CONTAINMENT VENT AND CLEANUP SYSTEM
TEST OBJECTIVES

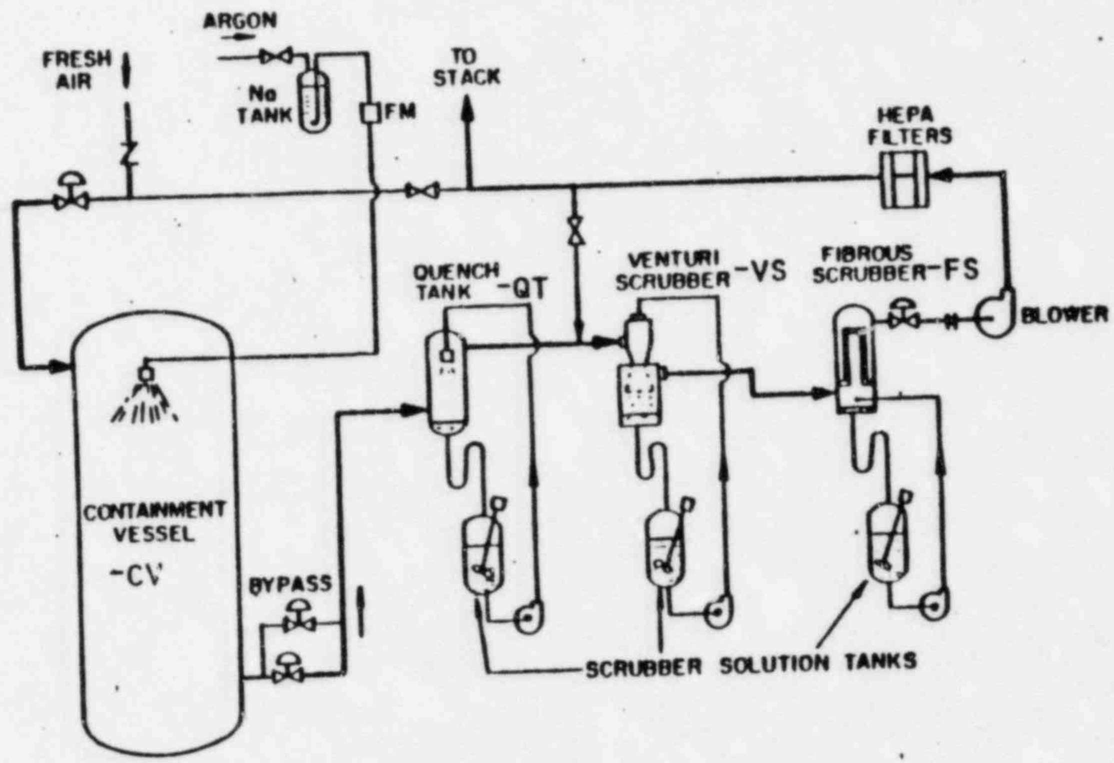
- DETERMINE THE PARTICLE DECONTAMINATION PERFORMANCE OF THE SYSTEM COMPONENTS DURING VARIOUS OPERATING CONDITIONS
- DETERMINE THE CONDENSIBLE DECONTAMINATION PERFORMANCE OF THE SYSTEM
- DETERMINE THE HEAT/REMOVAL CAPABILITY OF THE SYSTEM COMPONENTS
- ESTABLISH THE PRESSURE LOSSES THRU THE SYSTEM COMPONENTS DURING VARIOUS OPERATING CONDITIONS
- DETERMINE THE AEROSOL CHARACTERISTICS IN THE CONTAINMENT
- EVALUATE THE OPERABILITY OF THE SYSTEM COMPONENTS
- DEMONSTRATE THE COMPATIBILITY OF THE SPECIFIED COMPONENT MATERIALS WITH THE SYSTEM ENVIRONMENT
- DETERMINE THE AEROSOL DEPOSITIONS IN THE SYSTEM

CONTAINMENT CLEANUP SYSTEM
TEST DESCRIPTION

- TEST ARTICLE CONFIGURATION
- EXPERIMENTAL MEASUREMENTS
- TEST CONDITIONS

CONTAINMENT CLEANUP SYSTEM

TEST ARTICLE CONFIGURATION



CONTAINMENT CLEANUP SYSTEM TEST
EXPERIMENTAL MEASUREMENTS

- SUSPENDED AEROSOL MASS CONCENTRATION (AT ALL COMPONENTS)
- AEROSOL SIZE DISTRIBUTION (AT ALL COMPONENTS)
- AEROSOL PARTICLE SIZE AND SHAPE (AT ALL COMPONENTS)
- AEROSOL CHEMICAL COMPOSITION (CV & DUCT)
- SETTLED AEROSOL MASS (CV, DUCT)
- SETTLED AEROSOL DENSITY (CV, DUCT)
- SODIUM SPRAY RATE (CV)
- COMPONENT PRESSURE DROPS (ALL COMPONENTS)
- GAS FLOW RATE (FS OUTLET)
- LIQUID FLOW RATE (AT ALL COMPONENTS)
- GAS TEMPERATURE (AT ALL COMPONENTS)
- LIQUID TEMPERATURE (AT ALL COMPONENTS)
- GAS COMPOSITION (O_2, H_2, CO_2, MOISTURE/CV, FS OUTLET)

CONTAINMENT CLEANUP SYSTEM

TEST CONDITIONS

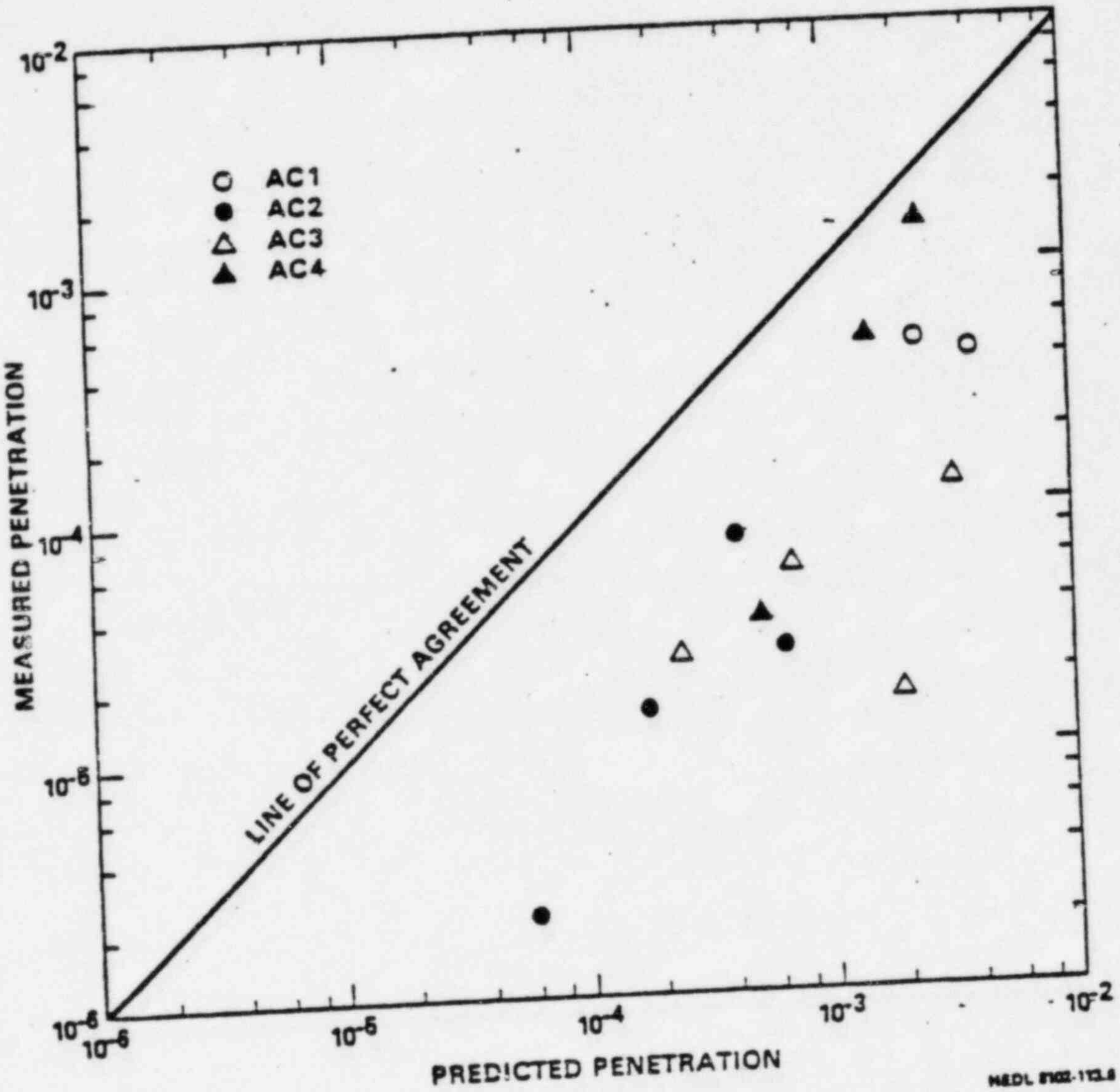
	AC-1	AC-2	AC-3	AC-4	AC-5	AC-6
COMPONENTS						
• QUENCH TANK	YES	YES	YES	YES	NO	NO
• VENTURI SCRUBBER	YES	YES	YES	YES	YES	YES
• WET FIBER SCRUBBER	YES	YES	YES	YES	YES	YES
AEROSOL TYPE	Na_2O_2	NaOH	Na_2CO_3	NaOH.H_2O	NaOH	NaOH.H_2O
INLET CONCENTRATION (g/m^3)	6	11	5	15	13	27
PARTICLE SIZE AMMD (μ)	3.1	3.7	3.6	3.5	3.3	5.5
GEOMETRIC STD. DEVIATION	2.8	2.1	2.8	2.6	2.5	2.5
GAS FLOW RATE (m^3/s)	0.19	0.35	0.27	0.55	0.44	0.54
PRESSURE DROP (kPa)	1.5	1.8	2.1	2.0	5.7	2.1
COLLECTED AEROSOLS (kg)	60.6	151	61.2	342	477	424
MEASURED EFFICIENCY (%)						
QUENCH TANK	79	66	62	62	-	-
VENTURI SCRUBBER	89	88	86	87	81	94.5
WET FIBER SCRUBBER	98.6	99.0	99.2	99.2	99.9	99.4
OVERALL SYSTEM	99.97	99.96	99.95	99.93	99.98	99.96

CONTAINMENT CLEANUP SYSTEM
TEST MAJOR CONCLUSIONS

- PARTICLE DECONTAMINATION PERFORMANCE 99.95%
- NAI DECONTAMINATION PERFORMANCE 99.8%
- AT DESIGN FLOW CONDITIONS VENTURI SCRUBBER LEAVING GAS AND WATER IN THERMAL EQUILIBRIUM
- PRESSURE DROPS VARIED AS PREDICTED ⟶ SYSTEM CAPABLE FOR LARGE AEROSOL LOADINGS
- THE PERFORMANCE OF ALL COMPONENTS IMPROVED WITH REDUCED GAS FLOW
- THE SYSTEM LOADING DEPENDS ON NA_2CO_3 SOLUBILITY, RECOMMENDED LIMIT 115g NA/L
- THE DECONTAMINATION EFFICIENCY IS NOT AFFECTED BY THE CHEMICAL COMPOSITION OF THE AEROSOL
- RECOMMENDED L/G RATIOS

VENTURI SCRUBBER	0.007
WET FIBER SCRUBBER	0.00008

- WET FIBER SCRUBBER MAX. VELOCITY 21 FT/SEC
- SYSTEM OPERATION WAS SATISFACTORY
  - NO SPRAY NOZZLE PLUGGING
  - NO FIBER ELEMENT DETERIORATION
  - NO CARBON STEEL CORROSION
  - TROUBLE FREE FLOW MODULATION



Comparison of Measured and Predicted Sodium Aerosol Penetration by Total System.

NaI MASS BALANCE AND NaI REMOVAL EFFICIENCY FOR TEST AC3

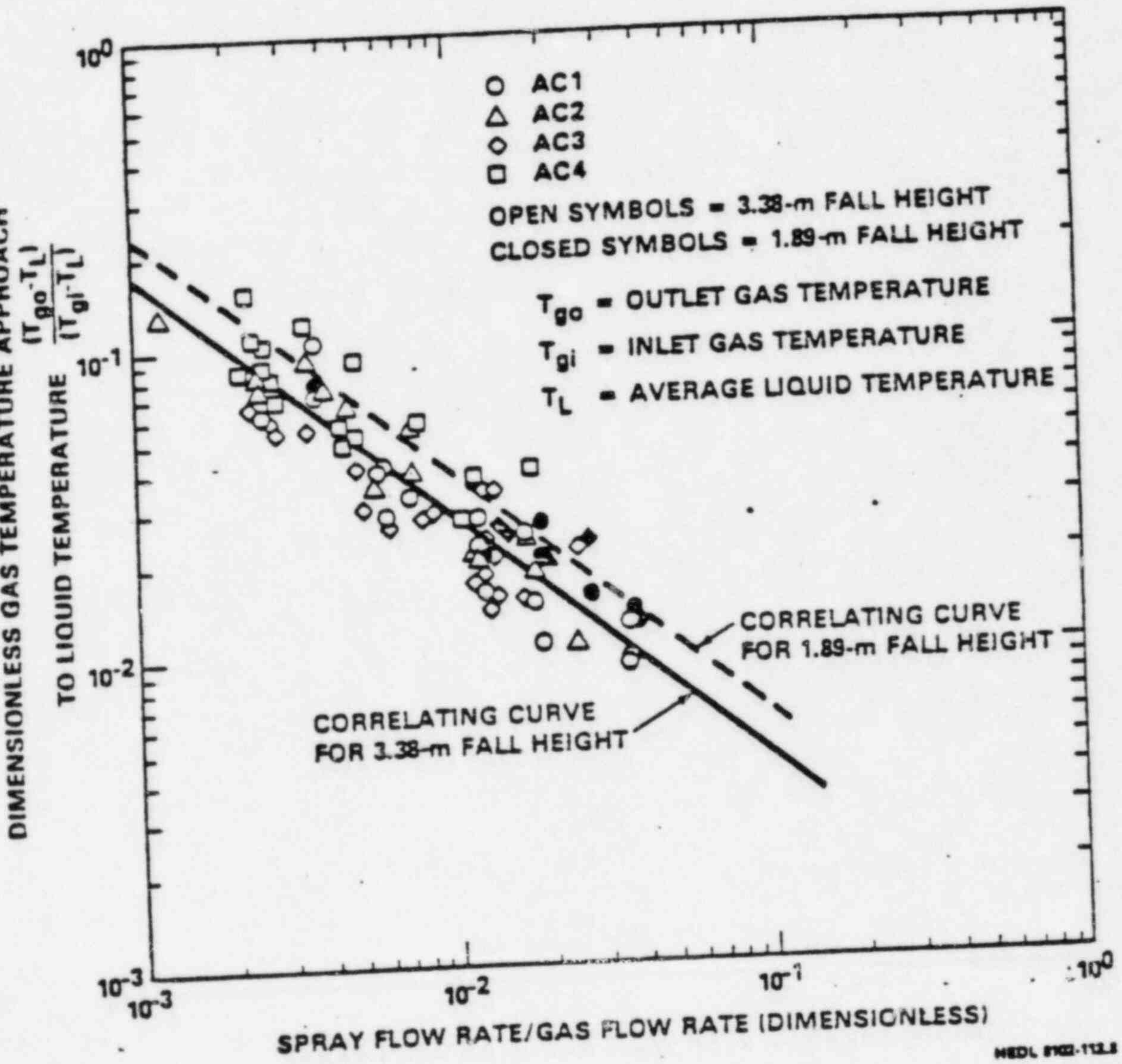
Component	Test AC3	
	Recovered (g NaI)	Removal Efficiency
Quench Tank	205	0.291
Venturi Scrubber	208	0.417
Fibrous Scrubber	289	0.9947
HEPA Filter	1.531	1.000*
Overall System	703.531	0.9978**

*Assumed
**Excluding HEPA filter

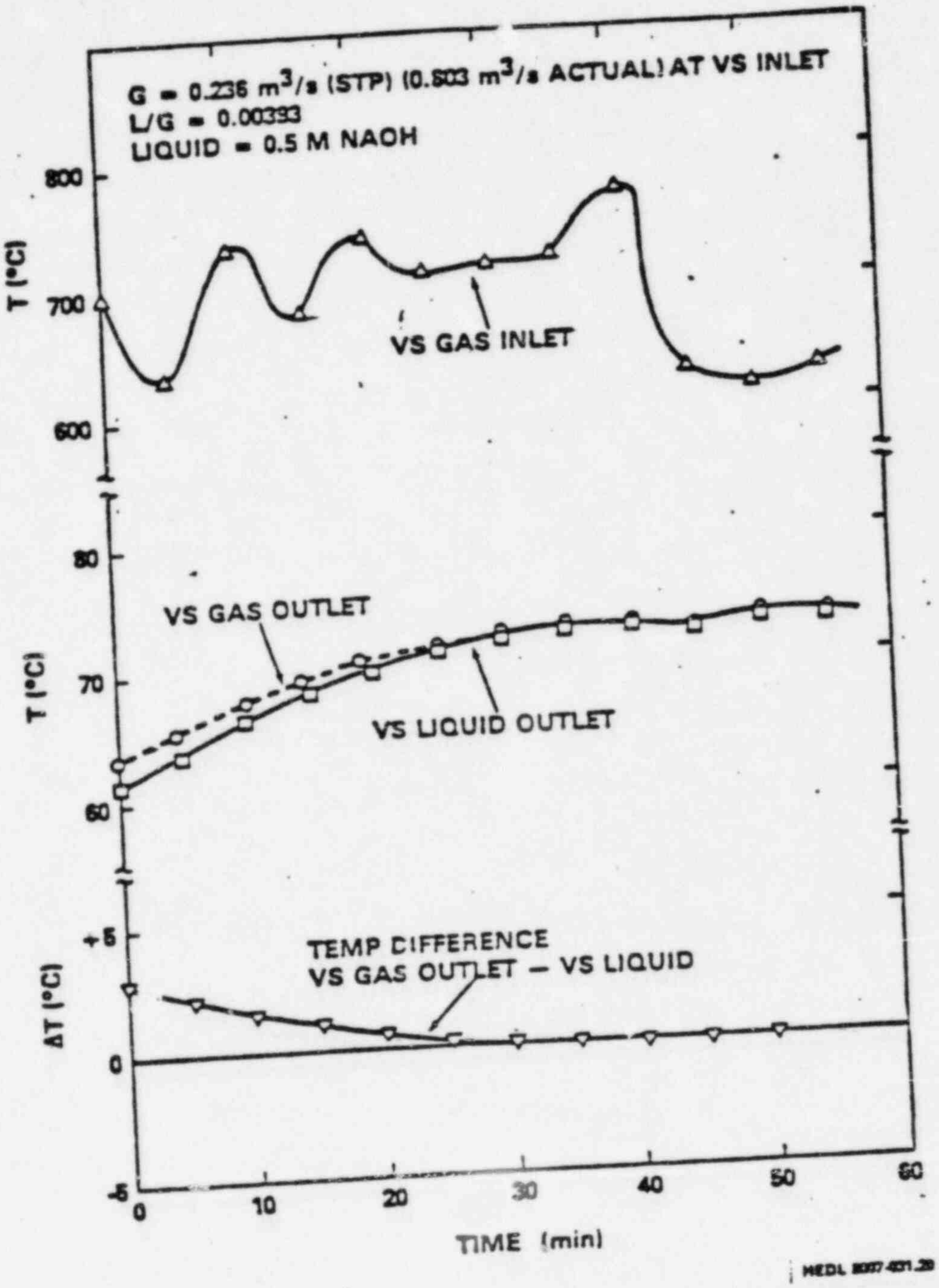
SUMMARY OF NaI EFFICIENCIES DETERMINED BY AEROSOL AND BY LIQUID SAMPLING METHODS

Component	Average Efficiency				
	Test				Average All Tests
	AC3	AC4	NaI-1	NaI-2	
Quench Tank					
Aerosol	*	*	*	*	
Liquid	0.29	*	0.53	0.41	0.33
Venturi Scrubber					
Aerosol	0.57	0.20	0.67	0.21	0.41
Liquid	0.42	*	0.83	0.80	0.68
Fibrous Scrubber					
Aerosol	0.998	0.990	0.997	0.998	0.996
Liquid	0.995	*	**	**	0.990
QT/VS/FS System					
Aerosol	*	~0.992	0.998	0.999	0.9963
Liquid	0.9978	*	**	**	0.9978

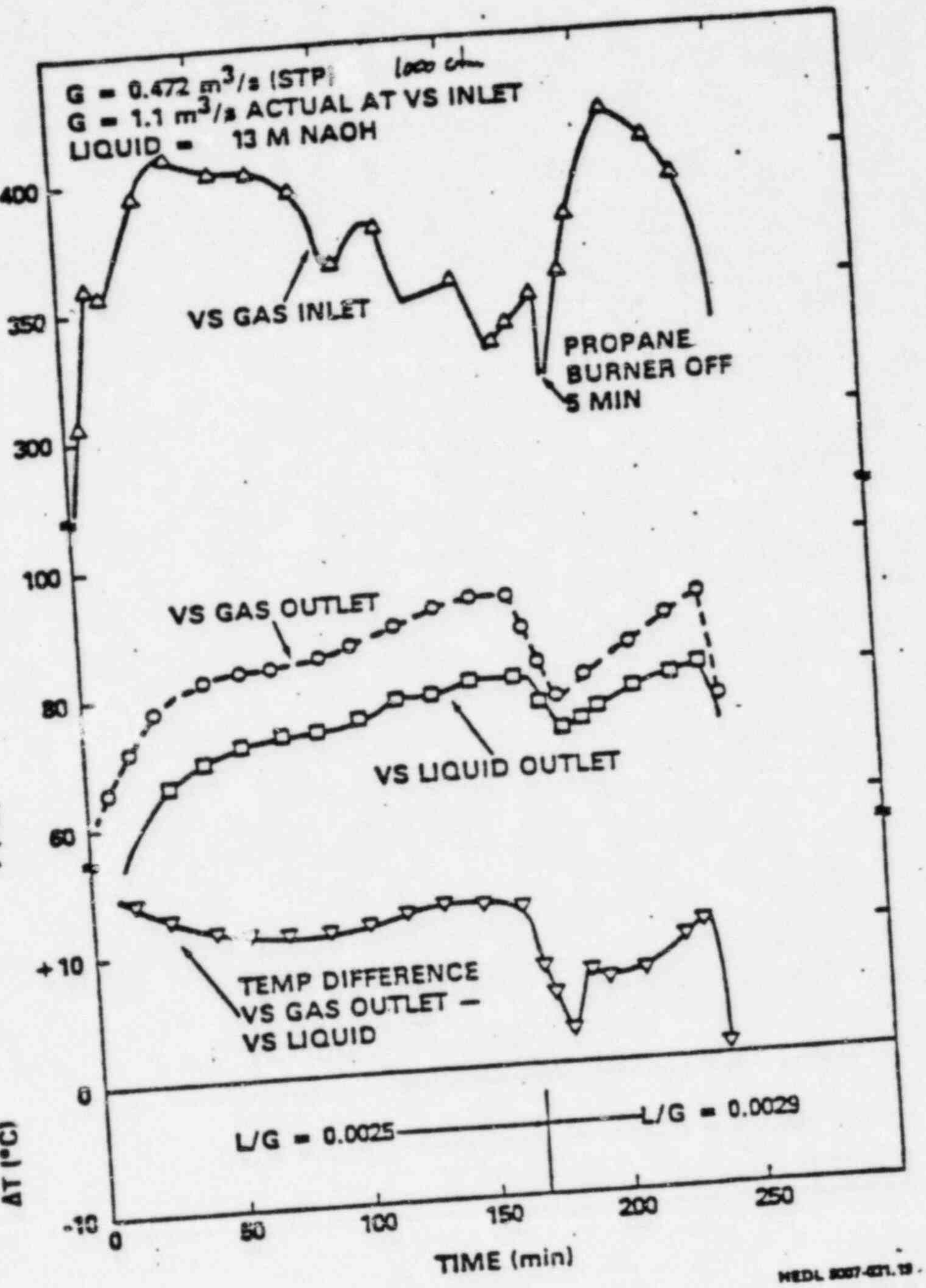
*Not measured; no inlet sample taken
**Not measured; back-up HEPA filter not analyzed



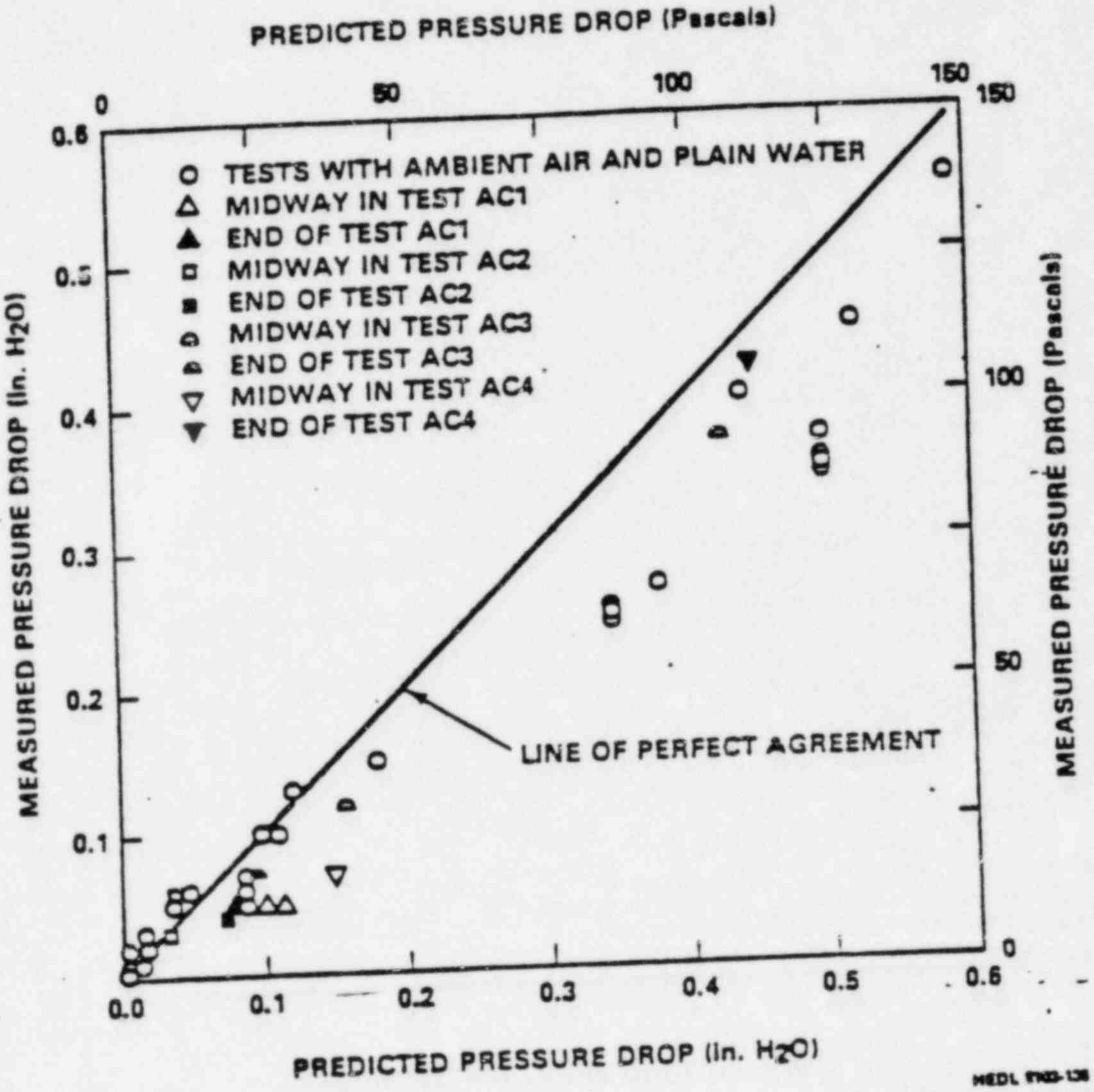
Correlation of Gas Cooling Data for Quench Tank.



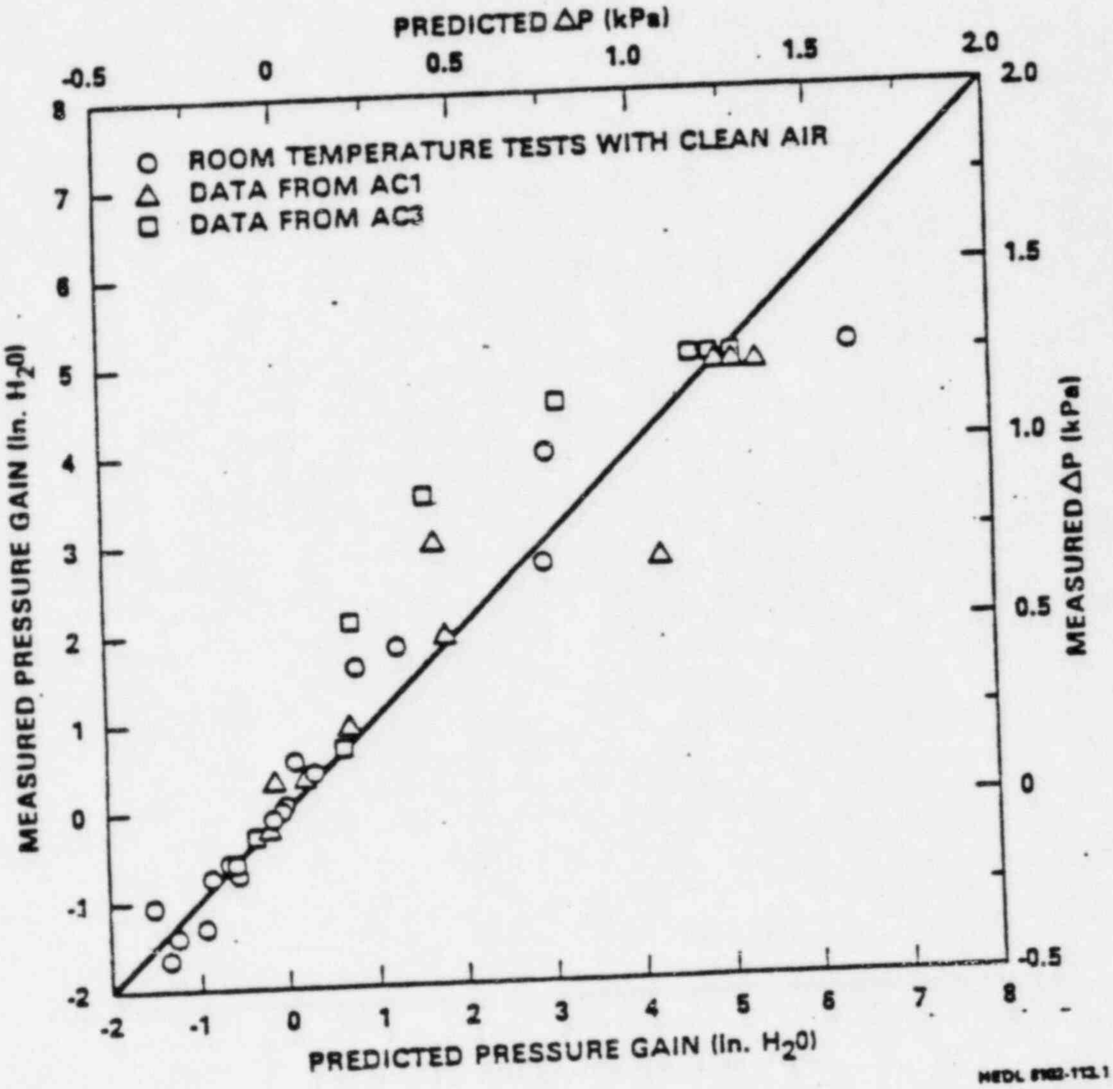
Gas Cooling by Venturi Scrubber at Intermediate Value of L/G.



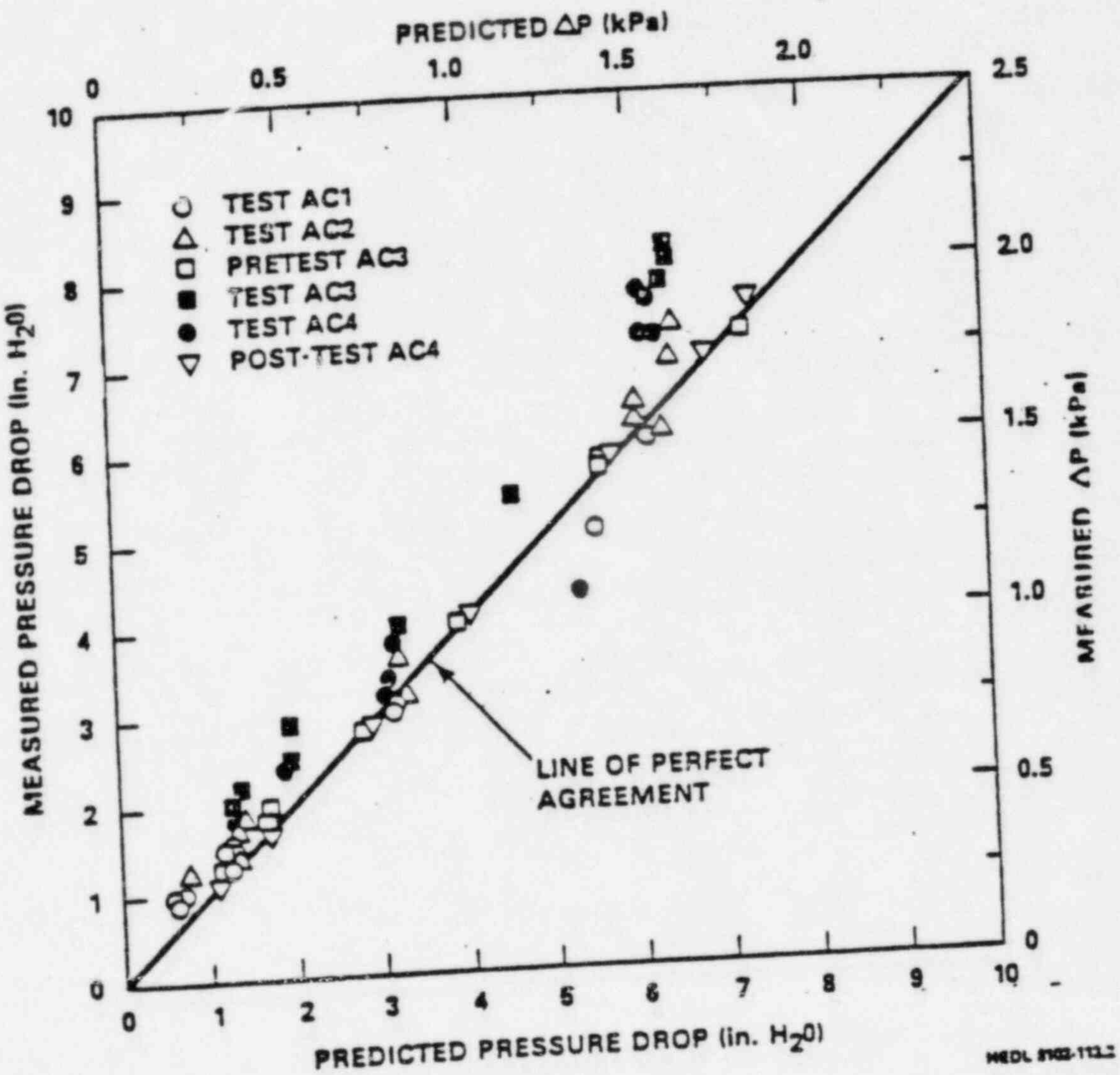
Gas Cooling by Venturi Scrubber at Low L/G Ratios.



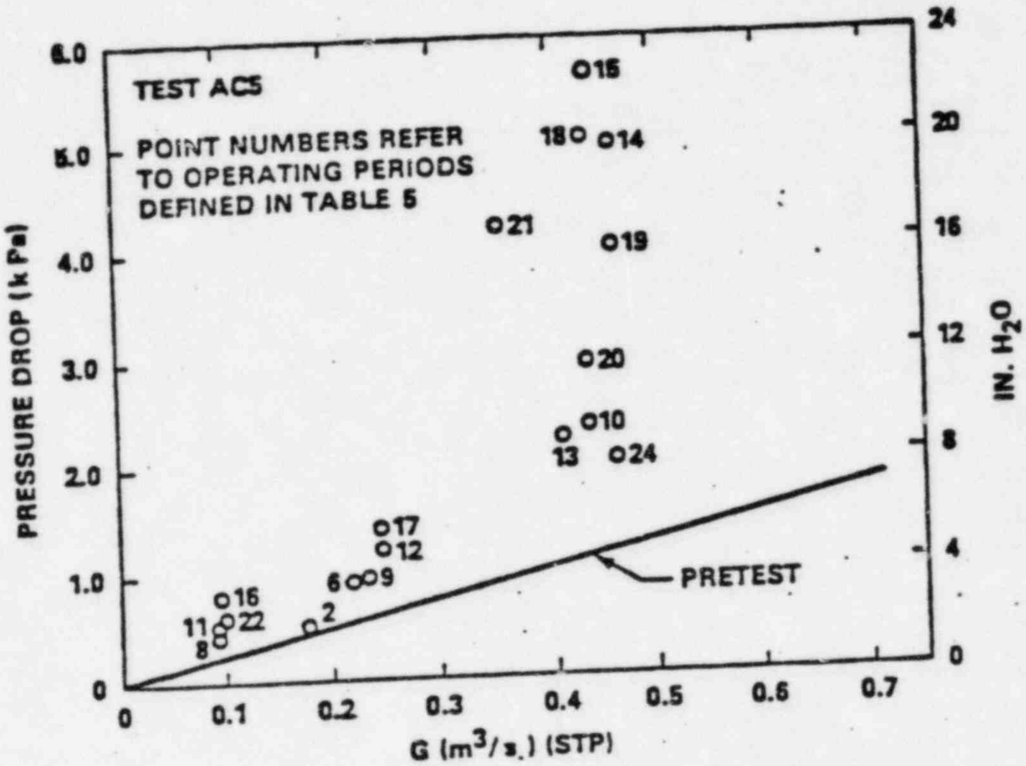
Comparison of Measured and Predicted Pressure Drop Across Quench Tank.



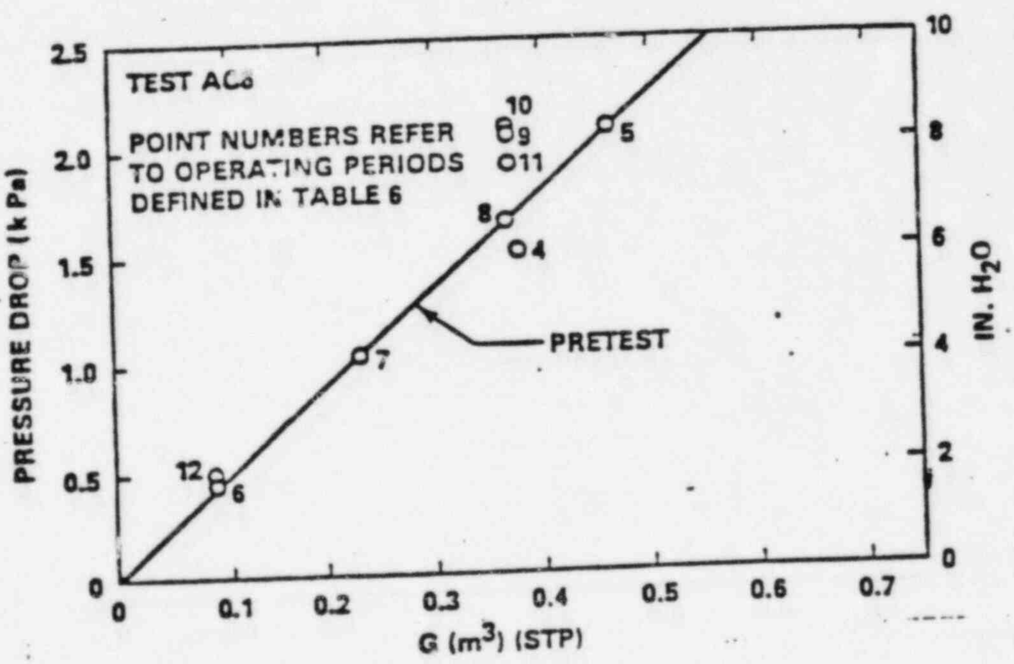
Comparison of Measured and Predicted Pressure Differentials Across Venturi Scrubber.



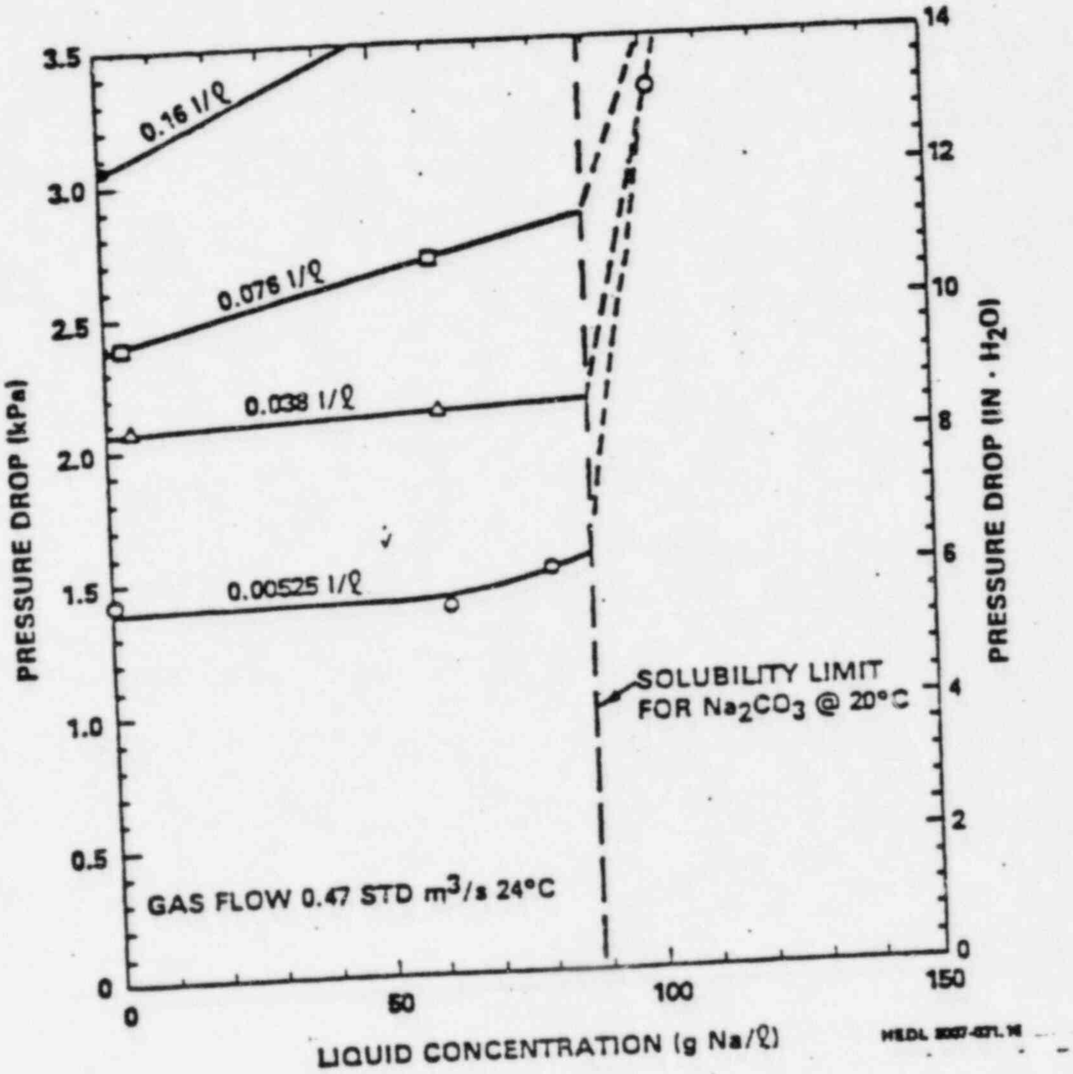
Comparison of Measured and Predicted Pressure Drop Across Fibrous Scrubber.



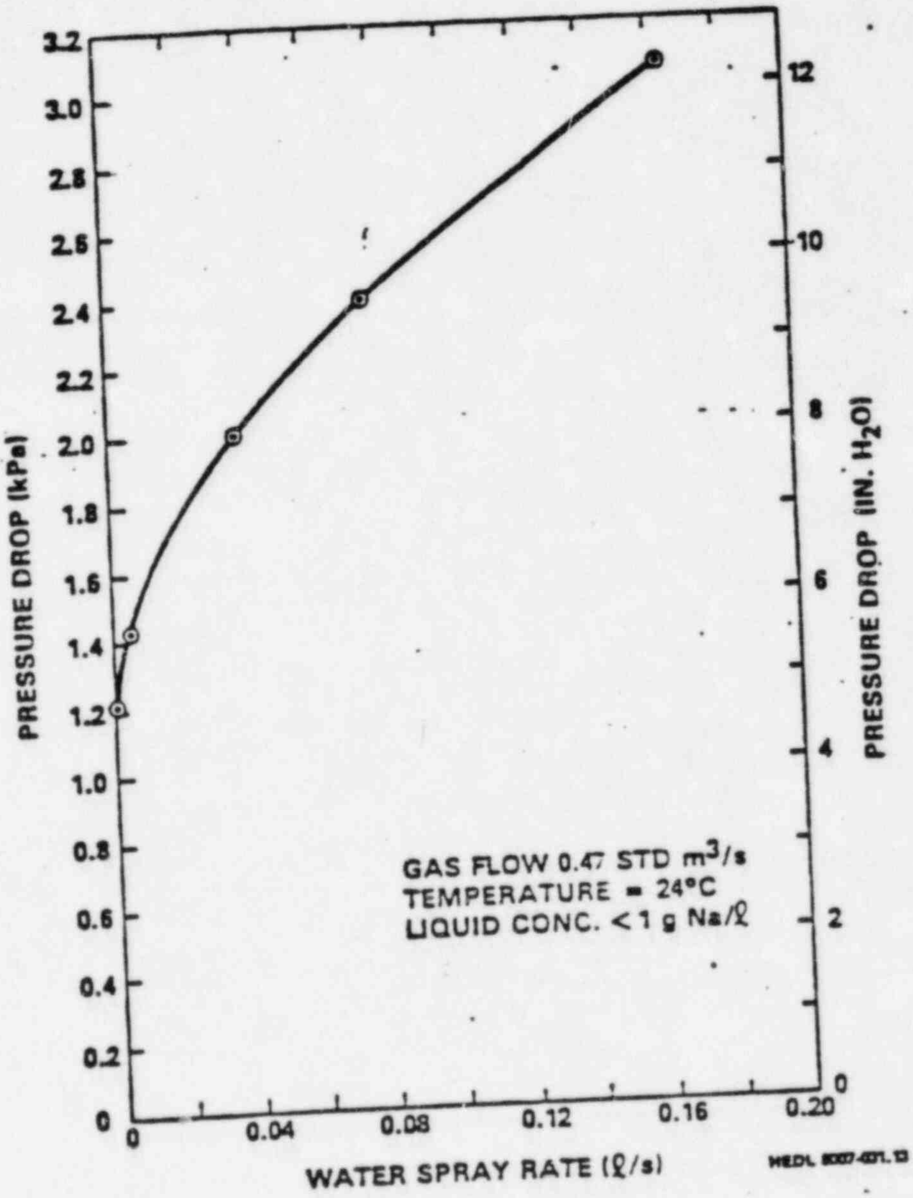
TEST AC5
POINT NUMBERS REFER
TO OPERATING PERIODS
DEFINED IN TABLE 5
PRETEST
PRESSURE DROP (k Pa)
IN. H_2O
G (m^3/s.) (STP)



TEST AC6
POINT NUMBERS REFER
TO OPERATING PERIODS
DEFINED IN TABLE 6
PRETEST
PRESSURE DROP (k Pa)
IN. H_2O
G (m^3) (STP)



Effect of Caustic Spray on Pressure Drop Across Fibrous Scrubber.



Effect of Water Spray Rate on Pressure Drop Across Fibrous Scrubber.

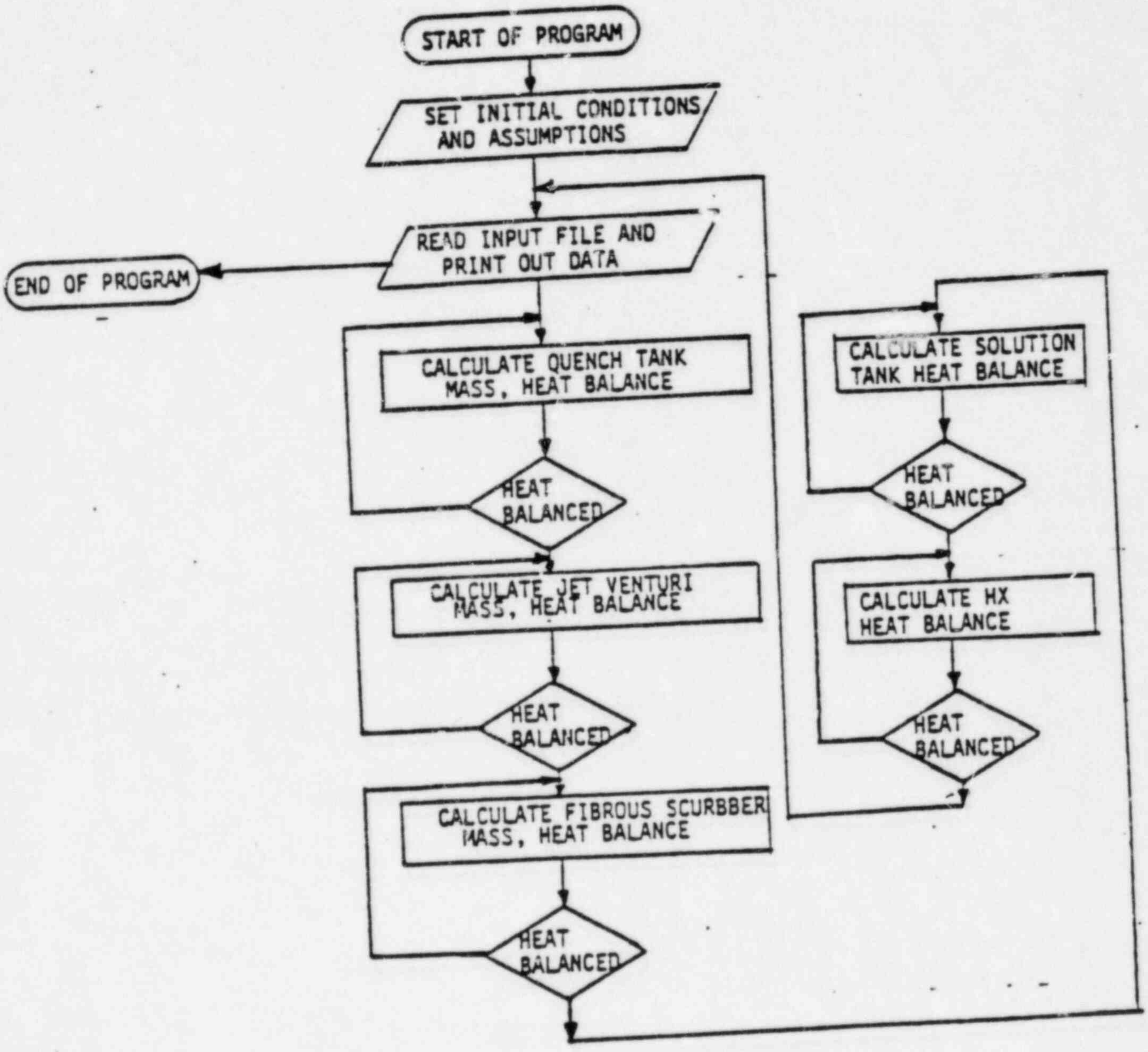
SOLUTION TANK ASSUMPTIONS/INPUTS

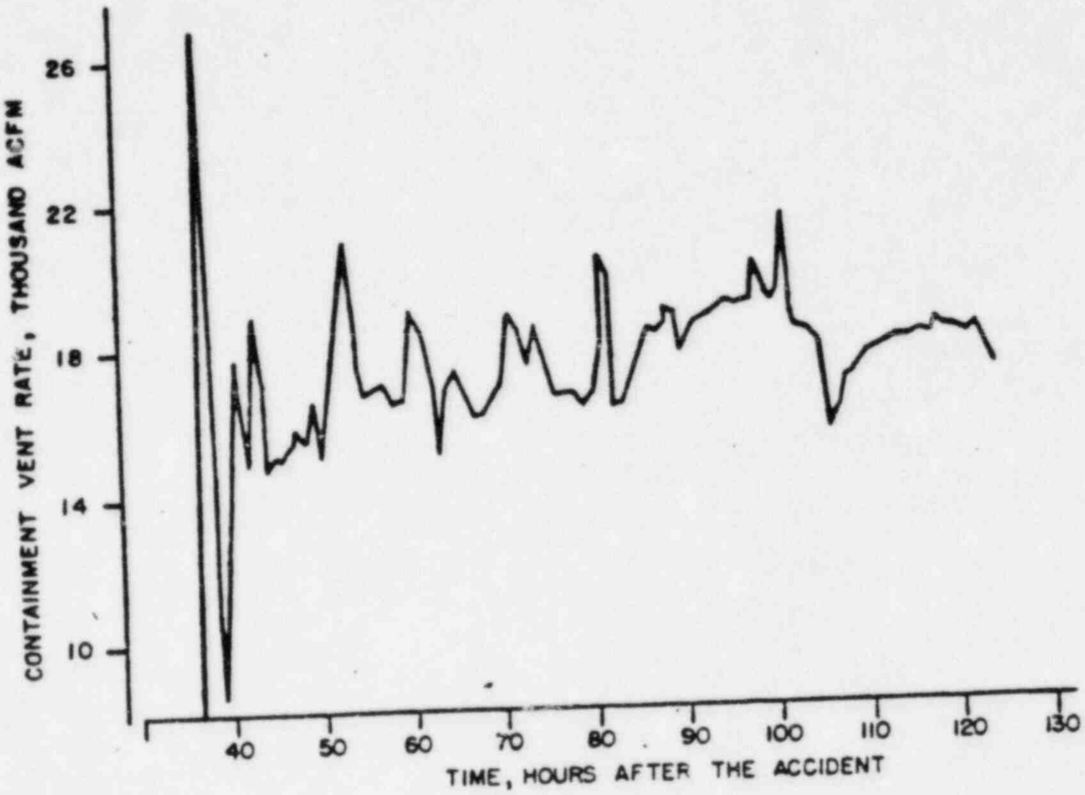
	INPUT	ASSUMPTION	CONSERVATISM
• TANK VOLUME 150,000 GAL	X		
• INITIAL WATER VOLUME 130,000 GAL	X		
• INITIAL WATER TEMPERATURE 60^{o}F		X	
• GOOD TANK MIXING		X	
• NO TANK HEAT LOSS		X	X
• DECAY HEAT REMAINS IN THE TANK		X	

PUMP, MAKE-UP, ASSUMPTIONS/INPUTS

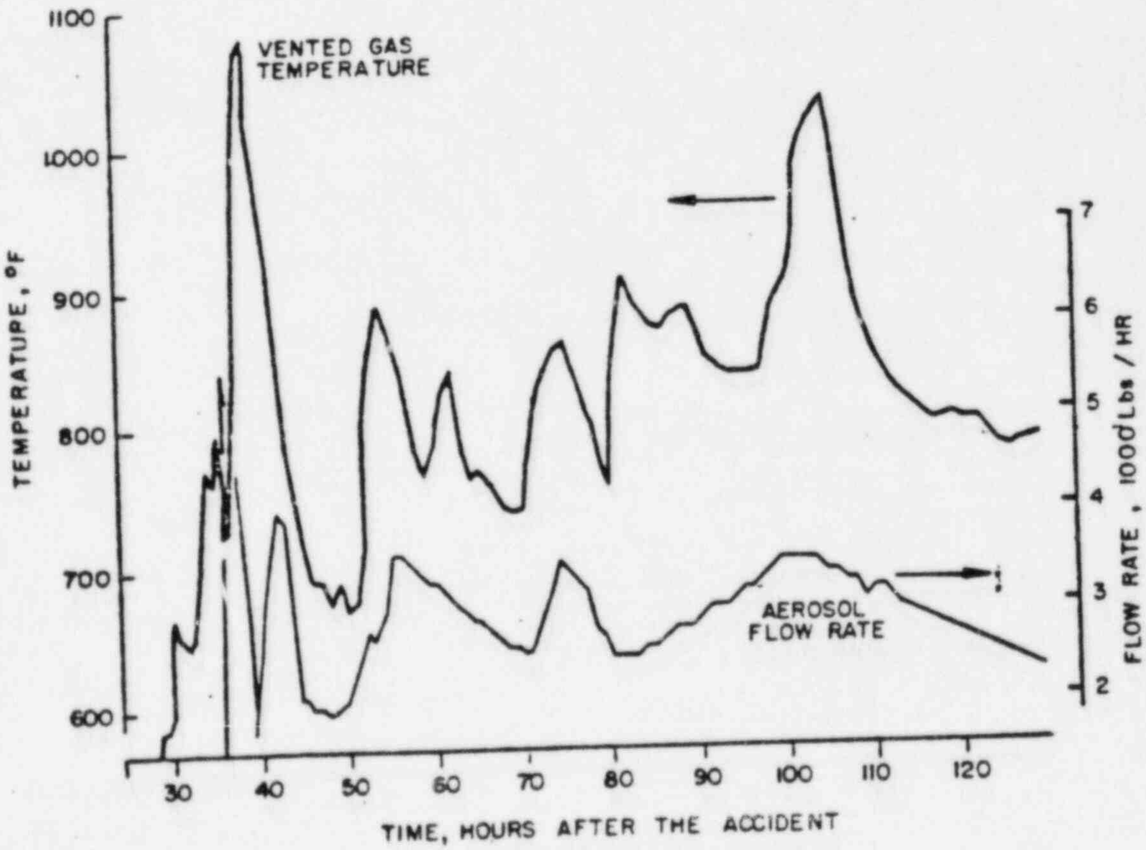
	INPUT	ASSUMPTION	CONSERVATISM
• CONSTANT VOLUME, VARIABLE TEMP, DENSITY	X		
• .5°F ΔT INPUT DUE TO PUMPING ACTION		X	X
• COOLING WATER INLET TEMPERATURE 91°F		X	X
• MAKE-UP RATE 5 GPM	X		
• MAKE-UP TEMPERATURE 91°F		X	X

BASIC PROGRAM LOGIC

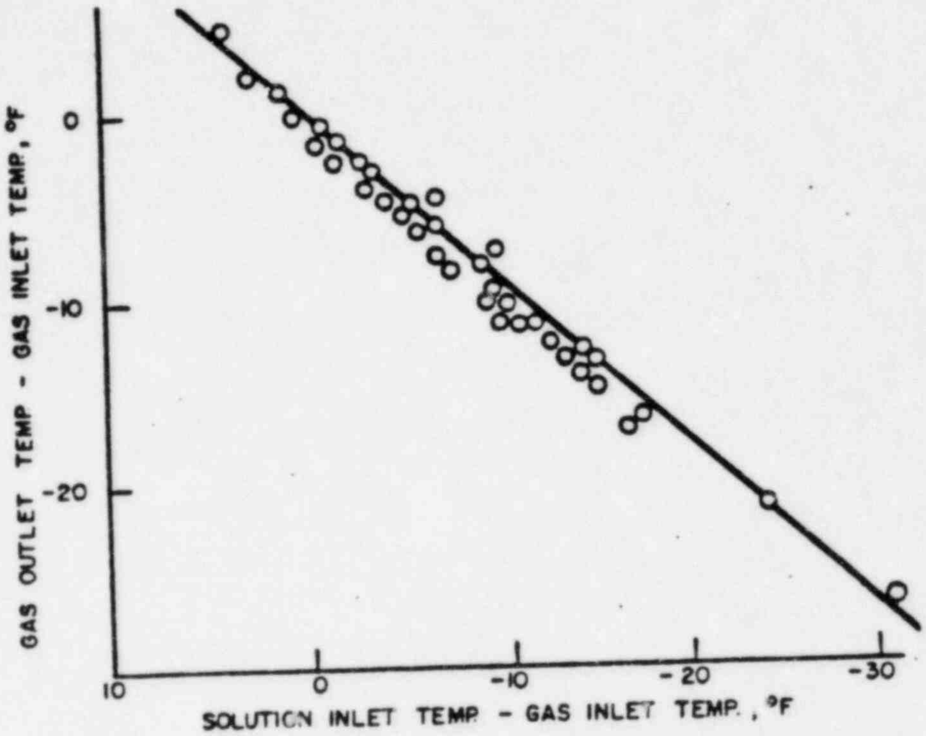




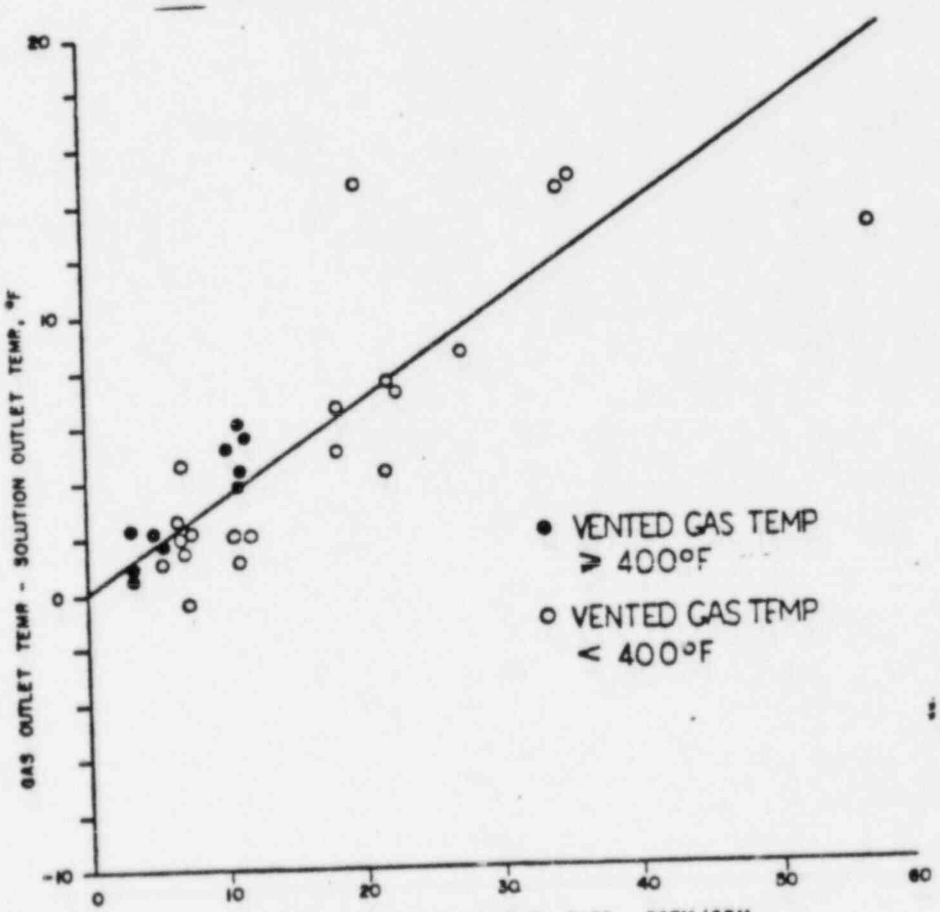
CONTAINMENT VENT RATE



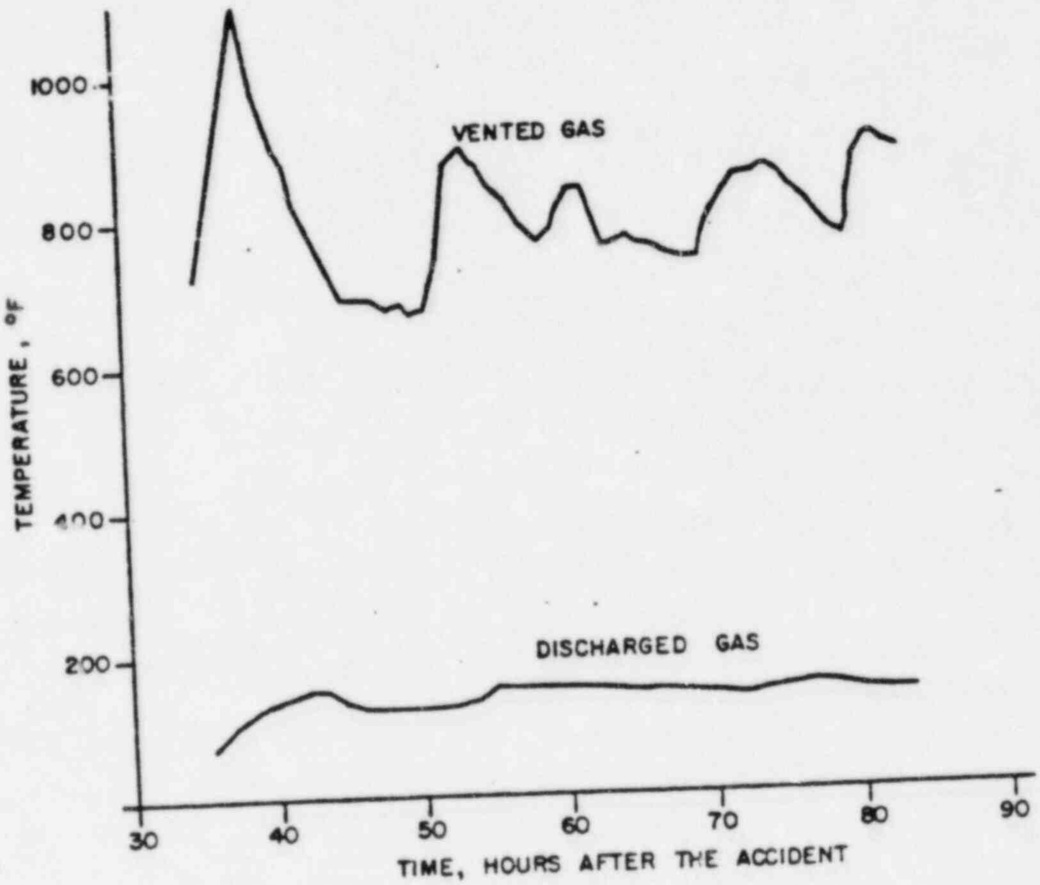
VENTED GAS TEMPERATURE AND AEROSOL FLOW RATE



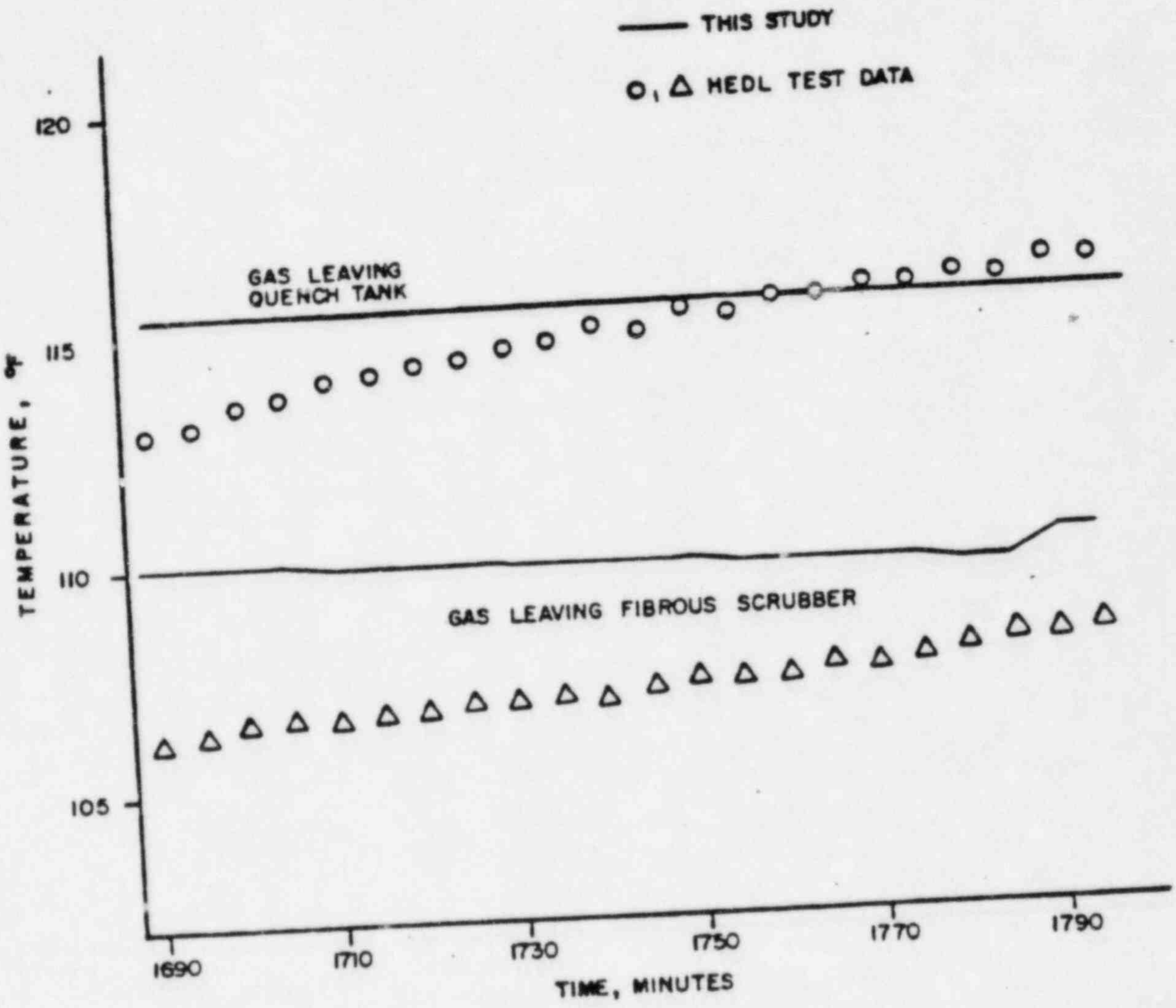
RELATIONSHIP FOR VENTURI SCRUBBER DATA



RELATIONSHIP FOR QUENCH TANK DATA



CALCULATED DISCHARGED GAS TEMPERATURE



COMPARISON OF RESUTS WITH HEDL TEST RUN AC1

SUMMARY

- CONTAINMENT CLEANUP SYSTEM IS USED TO MITIGATE HCDA'S
- HEDL TESTED CONTAINMENT CLEANUP SYSTEM
- BURNS AND ROE ANALYZED CONTAINMENT CLEANUP SYSTEM VIA COMPUTER MODELING
- ANALYTICAL AND TEST RESULTS CORRELATED WELL

SUMMARY OF AEROSOL DEPOSITION IN DUCTS - TESTS AC1 THROUGH AC6

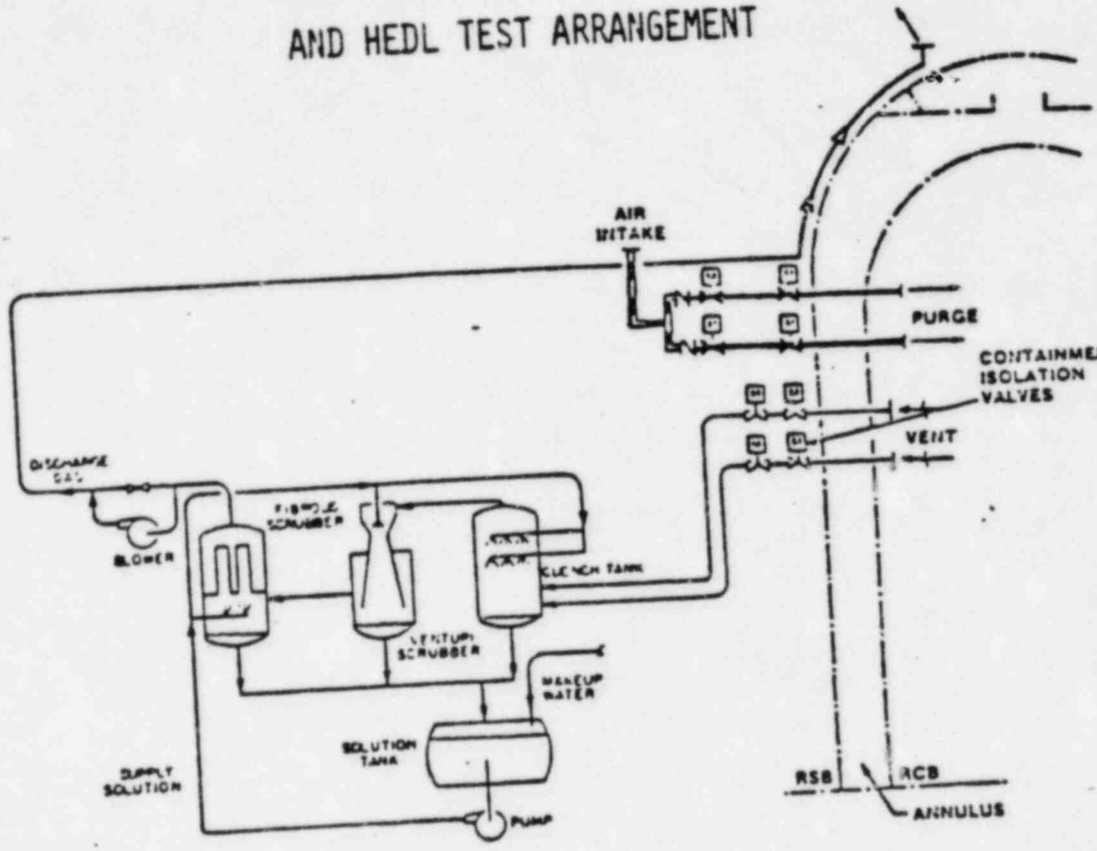
Duct Number	Dimensions I.D. mm	Dimensions Length m	Aerosol Mass, kg[a] Deposit In Duct	Aerosol Mass, kg[a] Penetrated Duct	Aerosol Mass, kg[a] Total	% Pen.	Na Fraction g Na per g Total	Bulk Density g/cm^3	Maximum ΔP kPa	Duct Plugged
AC1-10	265	16.4	12.5	60.8	73.3	82.9	0.515	0.16	0.5	No
AC2-1	22.1	14.6	0.516	0	0.516	0	0.437	~0.5	70	Yes
AC2-10	265	16.4	122	172	294	58.5	0.437	.87	2.8	No[b]
AC3-1	22.1	13.3	0.275	0.110	0.385	28.6	0.434	0.11	70	Yes
AC3-2	52.5	13.5	0.420	0.405	0.825	49.1	0.434	0.11	9.0	No
AC3-10	265	16.4	37.0	61.7	98.7	62.5	0.434	0.11	0.87	No
AC4-2	52.5	13.5	0.137	4.37	4.51	96.9	0.25	~0.6	5.2	No
AC4-10	265	16.4	62.6	455	518	87.8	0.25	~0.6	3.3	No
AC5-2	52.5	17.8	3.56	2.60	6.16	42.2	0.558	~0.5	70	Yes
AC5-4	110	21.3	20.4	50.8	71.2	71.3	0.558	~0.5	7.5	Yes
AC5-10	265	10.7	27.8	541	569	95.1	0.558	~0.5	1.0	No
AC6-10	265	10.7	55.6	424	480	88.3	0.458	0.64	4.2	No

(a) Determined by analyzing for Na and dividing by Na mass fraction
(b) Duct plugged post-test by heating duct walls above NaOH melting point

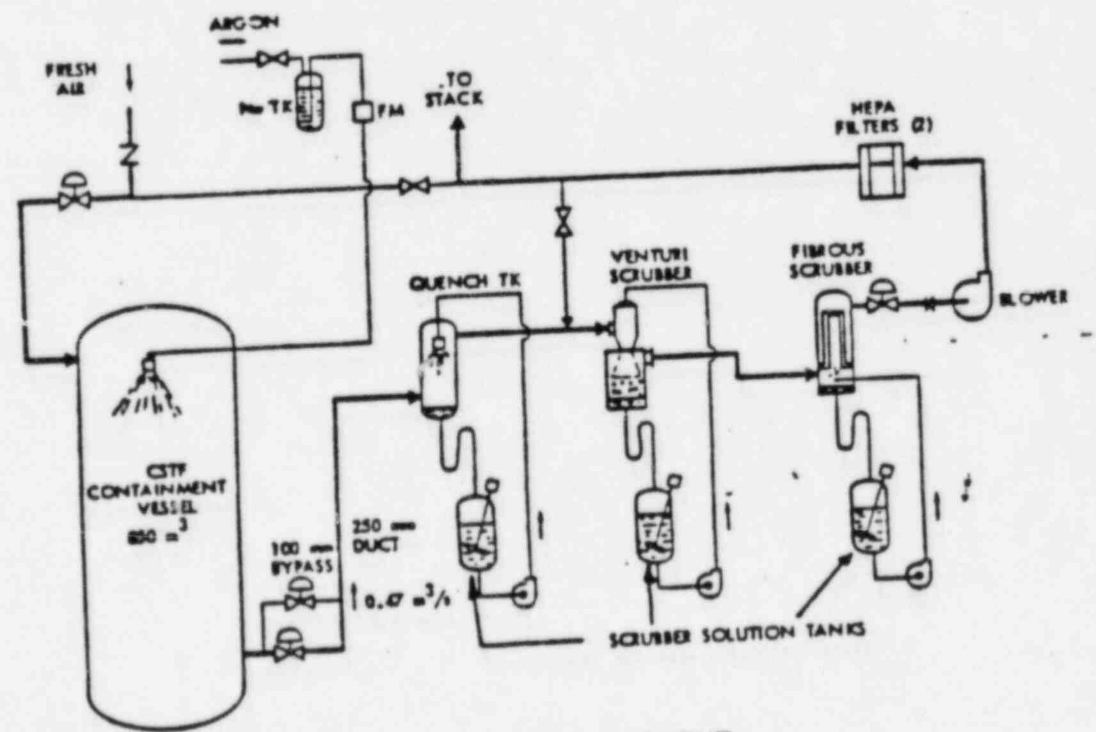
CONTAINMENT CLEANUP SYSTEM
DYNAMIC ANALYSIS

- TO VERIFY THE PERFORMANCE OF THE CONTAINMENT CLEANUP SYSTEM, A TEST PROGRAM WAS INITIATED AT HANFORD ENGINEERING DEVELOPMENT LABORATORY (HEDL)
  - THE PRIMARY GOAL OF THE TEST PROGRAM IS TO VERIFY THE FILTRATION EFFICIENCY OF THE CLEANUP SYSTEM
  - THE TEST COULD NOT FULLY SIMULATE ALL TMBDB CONDITIONS DUE TO LIMITATIONS OF THE TEST FACILITY
- THE FULL SIZE SYSTEM DESIGN REQUIRED A DYNAMIC ANALYSIS OF THE CONTAINMENT CLEANUP SYSTEM
  - THE PURPOSE OF THE DYNAMIC ANALYSIS IS TO SIMULATE THE THERMO-HYDRAULIC BEHAVIOR OF THE SYSTEM
  - THE RESULT OF THE ANALYSIS PROVIDED INPUT TO THE SIZING OF THE COMPONENTS AND SELECTION OF THE COMPONENT MATERIALS
  - THE ANALYSIS UTILIZED THE AVAILABLE TEST DATA FOR EMPERICAL CORRELATIONS AND EXTRAPOLATION
- THE COMPARISON OF TEST RESULTS WITH THE ANALYTICAL RESULTS INDICATED CLOSE CORRELATION

COMPARISON OF THE CRBRP LAYOUT AND HEDL TEST ARRANGEMENT



CRBRP LAYOUT



HEDL TEST ARRANGEMENT

COMPARISON OF THE HEDL AND CRBRP SYSTEM COMPONENT PARAMETERS

	HEDL	CRBRP
MAXIMUM SYSTEM FLOW (SCFM)	1,000*	22,800*
MAXIMUM AEROSOL CONCENTRATION (G/M^3)	35*	50*
MAXIMUM GAS TEMPERATURE (°F)	700*	1,100*
QUENCH TANK		
DIAMETER (FT)	4	18′ 6″
HIGH (FT)	13	25
RESIDENCE TIME (SEC)	6.5*	5.7*
SPRAY FLOW (GPM)	28.5	500
AIR/WATER RATIO ($\frac{CFM}{GPM}$)	35*	46*
JET VENTURI		
THROAT DIAMETER (INCH)	7.5	20
THROAT VELOCITY ($\frac{FT}{SEC}$)	54	198
HIGH (FT)	8.7	24
FLUID FLOW (GPM)	50.6	1,000
AIR/WATER RATIO ($\frac{CFM}{GPM}$)	19.7*	30*
FIBROUS SCRUBBER		
DIAMETER (FT)	2.5	23
HIGH (FT)	13.25	24
ELEMENT NO.	1	38
ELEMENT LENGTH (IN)	24	24
ELEMENT LENGTH (IN)	120	72
TOTAL ELEMENT FACE AREA (FT^2)	63	1,432
ELEMENT FACE VELOCITY ($\frac{FT}{MIN}$)	15.9*	18.1*

* SIGNIFICANT PARAMETERS

CONTAINMENT CLEANUP SYSTEM PROCESS MODEL

- QUENCH TANK

  CHEMICAL CONVERSION OF NA_2O TO NAOH → REACTION HEAT

  SOLUTION OF REMOVED NAOH PARTICLES → SOLUTION HEAT

  COOLING OF VENTED GAS → SENSIBLE HEAT

- JET VENTURI

  SOLUTION OF REMOVED NAOH PARTICLES → SOLUTION HEAT

  COOLING OF VENTED GAS → SENSIBLE/LATENT HEAT

- FIBROUS SCRUBBER

  SOLUTION OF REMOVED NAOH PARTICLES → SOLUTION HEAT

  REMOVAL OF FISSION PRODUCTS → DECAY HEAT

• • •

- SYSTEM INPUT VARIABLES

  VENTED GAS MASS FLOW RATE, TEMPERATURE, PRESSURE, WATER VAPOR CONTENT

  VENTED NA_2O MASS FLOW RATE

  VENTED FISSION PRODUCT DECAY HEAT RATE

  REMOVED FISSION PRODUCT DECAY HEAT RATE

  FLUID FLOW NAOH CONCENTRATION, TEMPERATURE, DENSITY

CONTAINMENT CLEANUP SYSTEM PROCESS MODEL (CONT'D)

- SYSTEM INPUT CONSTANTS

  FLUID VOLUMETRIC FLOW RATE TO COMPONENTS

  FILTRATION EFFICIENCY OF THE COMPONENTS

  HX COOLING WATER FLOW, INLET TEMPERATURE

  MAKE-UP WATER FLOW, TEMPERATURE

  HX SURFACE AREA

- SYSTEM OUTPUT VARIABLES

  GAS FLOW, TEMPERATURE AT VARIOUS STAGES

  FLUID FLOW NaOH CONCENTRATION, TEMPERATURE, VISCOSITY

  HEAT EXCHANGER DUTY

ANALYTICAL PROGRAM ASSUMTPIONS/INPUTS

- GENERAL
- QUENCH TANK
- JET VENTURI
- FIBROUS SCRUBBER
- SOLUTION TANK
- PUMP, MAKE-UP, HEAT EXCHANGER

GENERAL ASSUMPTIONS/INPUTS

	INPUT	ASSUMPTION	CONSERVATISM
• ALL AEROSOL IN THE FORM OF Na_2O		X	X
• NO HEAT LOSS IN VENT PIPE		X	X
• NO AEROSOL REMOVAL IN VENT PIPE		X	X
• PRESSURE REDUCTION IN VENT PIPE	X		

QUENCH TANK ASSUMPTIONS/INPUT

	INPUT	ASSUMPTION	CONSERVATISM
• REMOVAL EFFICIENCY 67%		X	X (T)
• CONVERSION TO NaOH COMPLETE		X (T)	
• $T_{AO} = T_{SOQ} + .3333\ R_{AS}$		X	X (T)
• SOLUTION FLOW = 500 GPM	X		

where:

T_{AO} = AIR OUTLET TEMPERATURE

T_{SOQ} = SOLUTION OUTLET TEMPERATURE QUENCH TANK

R_{AS} = AIR/SOLUTION RATIO $(\frac{SCFM}{GPM})$

(T) = VERIFIED BY TEST

JET VENTURI ASSUMPTIONS/INPUTS

	INPUT	ASSUMPTION	CONSERVATISM
• REMOVAL EFFICIENCY 80%		X	X (T)
• $T_{AO} = T_{SIV}$		X	X (T)
T_{AO} = AIR OUTLET TEMPERATURE			
T_{SIV} = SOLUTION INLET TEMPERATURE VENTURI			
• SOLUTION FLOW 1000 GPM	X		

(T) = VERIFIED BY TEST

FIBROUS SCRUBBER ASSUMPTIONS/INPUTS

	INPUT	ASSUMPTION	CONSERVATISM
• REMOVAL EFFICIENCY 98,8%		X	X (T)
• DECAY HEAT RAISES AIR TEMPERATURE		X	X
• NO WATER EVAPORATION	X		X
• WATER SPRAY FLOW 4 GPM	X		

(T) = VERIFIED BY TEST

ENCLOSURE 4

TMB DR meeting 15 Sept 82

Name	Affiliation
John Perry	NRC/RSB
C J Allen	NRC/CRBRPO
A K Aggrawal	BNL
R. Kuer	SAI
P. FAZEKAS	B&R
Jim ELLWANGER	B&R
S.L. Additon	Westinghouse
[illegible]	CRBRPO
D. [illegible]	CRBRPO
[illegible]	Westinghouse
Dick Becker	NRC/CRBRPO
Tom Butler	Los Alamos
Coyne Prenger	LANL
D. Jensen	Los Alamos
Allen Neuls	Los Alamos
BAHMAN ATEFI	SAI
Louis N. Rib	consultant
Brad Burson	NRC/RES
T. J. Walker	NRC/RES
E. RANDICH	SANDIA
Jerry Swift	CRBRPO, NRC
R. E. [illegible]	Burns & Roe
S. N. [illegible]	Burns & Roe
[illegible] Bice	NRC/ACRS staff
[illegible]	[illegible]
Frank Sciacca	Energy Inc - Sandia
JOHN BROCKMANN	SANDIA
David [illegible]	NRC consultant/ASAI.

see other side ↓

Name	Affiliation
S.Y. Hsieh	BNL
R.D. GASSER	BNL
HB Holz	NRC
L.E. STRAWBRIDGE	W-WM
John F. Gross	W-WM
T. W. Ball	W-WM