Westinghouse Electric Corporation **Energy Systems**

Box 355
Pittsburgh Pennsylvania 15230-0355

AW-95-912

December 11, 1995

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: MR. T. R. QUAY

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: PRESENTATION MATERIALS FROM THE DECEMBER 6, 1995 MEETING ON AP600 CONTAINMENT TEST AND ANALYSIS PROGRAM

Dear Mr. Quay:

The application for withholding is submitted by Westinghouse Electric Corporation ("Westinghouse") pursuant to the provisions of paragraph (b)(1) of Section 2.790 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10CFR Section 2.790, Affidavit AW-95-912 accompanies this application for withholding setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10CFR Section 2.790 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-95-912 and should be addressed to the undersigned.

Very truly yours,

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

/nja

cc: Kevin Bohrer NRC 12H5

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A PDR

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

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COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Brian A. McIntyre, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Corporation ("Westinghouse") and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

Sworn to and subscribed
before me this 12th day
of December, 1995

Lorraine M. Piplica
Notary Public

2640A

Notarial Seal
Lorraine M. Piplica, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Dec. 14, 1995
Member, Pennsylvania Association of Notaries

(1) I am Manager, Advanced Plant Safety And Licensing, in the Advanced Technology Business Area, of the Westinghouse Electric Corporation and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Energy Systems Business Unit.

(2) I am making this Affidavit in conformance with the provisions of 10CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by the Westinghouse Energy Systems Business Unit in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

  (i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

  (ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

  Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) Enclosed is Letter NTD-NRC-95-4609, December 11, 1995 being transmitted by Westinghouse Electric Corporation (W) letter and Application for Withholding Proprietary Information from Public Disclosure, Brian A. McIntyre (W), to Mr. T. R. Quay, Office of NRR. The proprietary information as submitted for use by Westinghouse Electric Corporation is in response to questions concerning the AP600 plant and the associated design certification application and is expected to be applicable in other licensee submittals in response to certain NRC requirements for justification of licensing advanced nuclear power plant designs.

This information is part of that which will enable Westinghouse to:

(a) Demonstrate the design and safety of the AP600 Passive Safety Systems.

(b) Establish applicable verification testing methods.

(c) Design Advanced Nuclear Power Plants that meet NRC requirements.

(d) Establish technical and licensing approaches for the AP600 that will ultimately result in a certified design.

(e) Assist customers in obtaining NRC approval for future plants.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of similar information to its customers for purposes of meeting NRC requirements for advanced plant licenses.

(b) Westinghouse can sell support and defense of the technology to its customers in the licensing process.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar advanced nuclear power designs and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended for developing analytical methods and receiving NRC approval for those methods.

Further the deponent sayeth not.

Enclosure 2 to Westinghouse Letter NTD-NRC-95-4609

AP600 Testing Program

F. Integral Effects Testing

December 6, 1995

D. R. Spencer, Principal Engineer
Containment and Radiological Analysis

Contact: John Butler
Phone: 412-374-5268

Westinghouse Electric Corporation

Integral Effects Tests: (Large Scale Tests)

Outline

Objectives

Test Facility Description

Primary Test Variables

Instrumentation

Test Matrices

Observations

Conclusions

LST Overview

OBJECTIVES

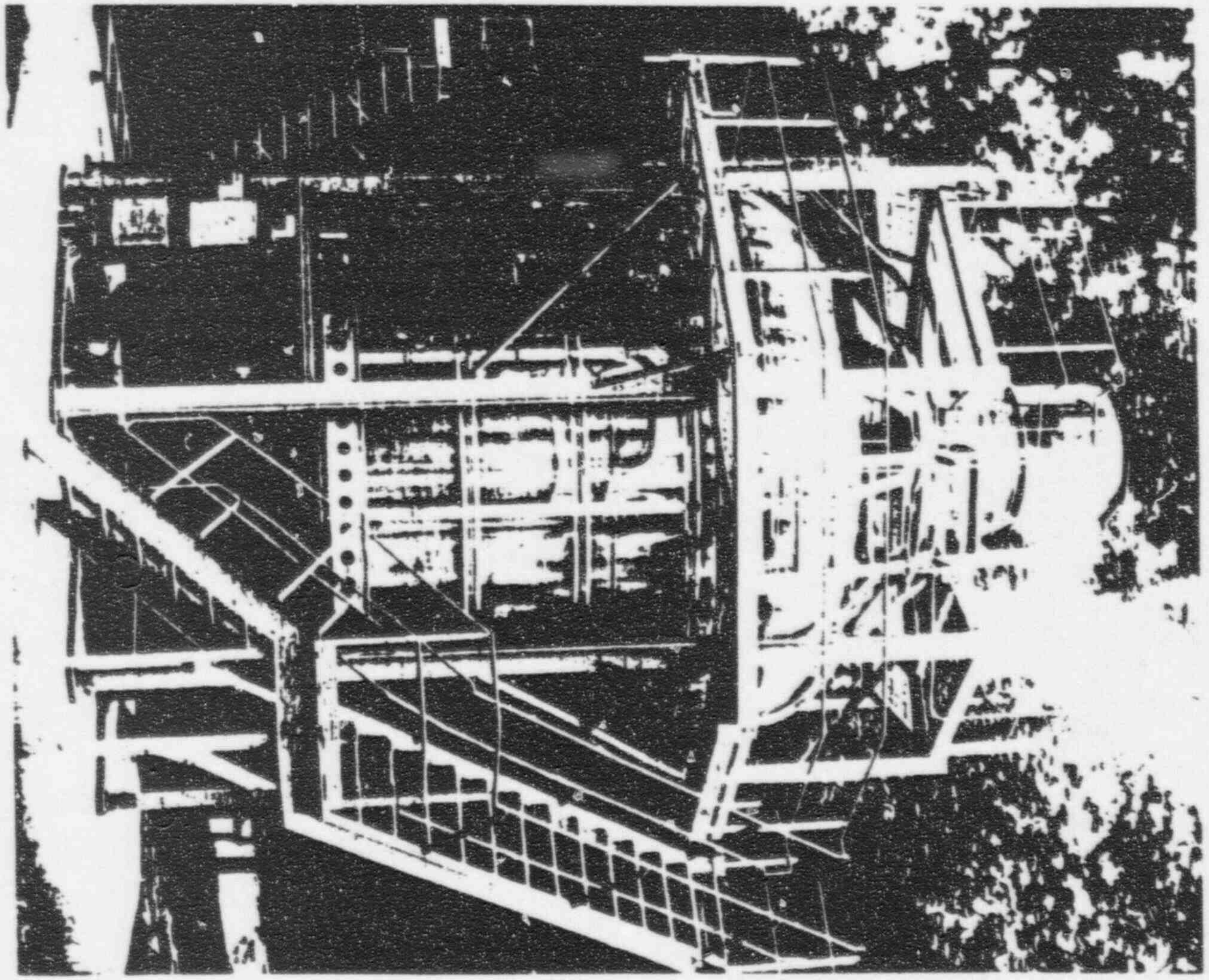
Examine, on a large scale integral test, the parameters that control containment heat and mass transfer:

- Steam condensation on the interior of the containment
- Water evaporation into the external riser air

The data are used for:

- Validation of containment analysis phenomenological models
- Validation of computer codes
- Development of Evaluation Model

Large Scale PCS Test Apparatus



LST Overview

TEST FACILITY

- 1/8th scale AP600 instrumented test vessel

- Instrumented to measure
  - Containment Pressure
  - Wall temperature and heat flux
  - Containment gas temperatures
  - Containment gas steam/air/helium concentrations
  - Containment gas velocities near walls
  - Riser air temperature
  - Riser air velocity
  - External water on and off
  - Internal condensation rate and distribution
  - Boundary and ambient conditions

- 400 channel data acquisition system, (26 channel per sec max)

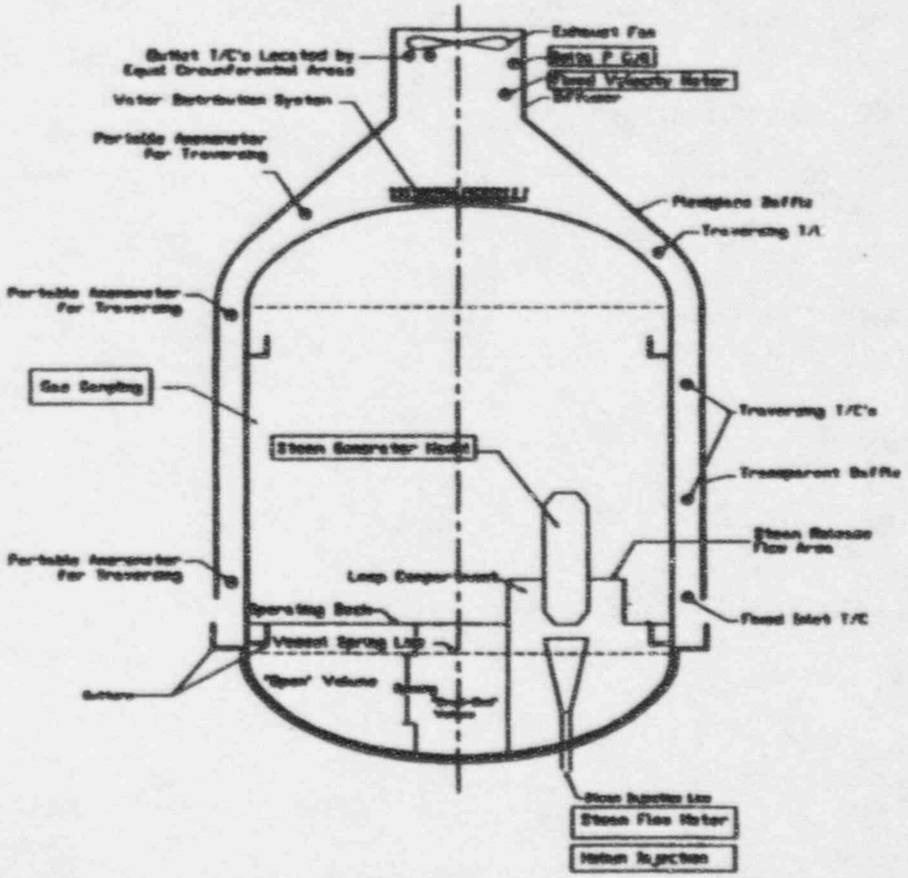
PRIMARY TEST VARIABLES

Values of the primary test variables

- 1.6 lbm/sec steady state and 6.0 lbm/sec peak transient steam supply system
- Natural convection air cooling to 16 ft/sec forced air
- 0 to 3.3 lbm/sec exterior water film supply
- 8 to 22 volume percent helium

LST Overview

Test Facility Configuration



LST Overview

Instrumentation and Measurement Locations

- Wall TC/Heat Flux and Fluid TC - See Figure
- Instrument Tree Fluid TC - See Figure
- Concentrations[ ]^{a,b,c} from wall: Dome-[ ]^{a,b,c}, A at[ ]^{a,b,c}, E at[ ]^{a,b,c} F at[ ]^{a,b,c}
- Velocity sensors mounted in vertical plane, parallel to wall
  - 2.75" throat,[ ]^{a,b,c} from wall; E at[ ]^{a,b,c}, D at[ ]^{a,b,c}, Dome-[ ]^{a,b,c}
  - 1.0" throat,[ ] from wall; Dome-[ ]^{a,b,c}, A at[ ]^{a,b,c}

Water Source Location

- 8 at a radius of[ ]^{a,b,c}
- 56 at a radius of[ ]^{a,b,c}

LST Wall and Fluid TC Locations

a,b,c

Instrument Tree Fluid TC Locations

a,b,c

⊠ Fluid TC

LST Overview

BASELINE TESTS

Steady state heat transfer tests, simplified internals

- Steam flow rate
- Air flow rate
- Water coverage

PHASE 2 TESTS - EXTEND DATA BASE

Steady state and transient simulations, simulated internals

- Steam flow rate
- Air flow rate
- Water coverage
- Effect of light noncondensables
- Internal heat sinks
- Blind blowdown test

LST Overview

PRE-TESTS

- Cold helium distribution
- Video tape delayed water distribution
- Air flow vessel cold (~100°F)
- Establish water distribution control levels

PHASE 3 TESTS - FOLLOW-ON

Steady state and transient heat transfer, simulated internals

- Stepped blowdown steam discharge
- Alternate steam discharge (MSLB)
- Vacuum
- Pressurized vessel

LST Overview

PCCS BASELINE TEST MATRIX

TEST NUMBER	STEAM SUPPLY PRESSURE	WATER COVERAGE	ANNULUS AIR FLOW
	(PSIG)		(FT/SEC)
BASELINE TEST NO INTERNALS:			
L-201.1	10	100%	9
L-202.1	30	100%	9
L-203.1	40	100%	9
L-207.1	30	75% QUADRANTS	9
L-207.2	30	75%	9
BASELINE TEST WITH INTERNALS (NO STEAM GENERATOR MODEL):			
L-201.2	10	100%	12
L-202.2	30	100%	12
L-203.2	40	100%	12
L-204.1	30	100%	16
L-205.1	30	100%	8
L-206.1	30	100%	FREE
L-207.3	30	75 QUADRANTS	12
L-208.1	30	50 QUADRANTS	12
L-207.4	30	75%	12
L-210.1	40	100%	12
L-211.1	40	100%	FREE

LST Overview

PCCS PHASE 2 TEST MATRIX

TEST NUMBER	STEAM CONTROL		AIR FLOW	WATER COVERAGE	LONG TERM HEAT SINKS	HELIUM	SAMPLING
	PRESSURE (PSIG)	FLOW (LB/SEC)	(FT/SEC)				
202.3	30	-	12	100 %	NO	NO	NO
203.3	40	-	12	100%	NO	NO	NO
212.1		0.25/0.5/0.75	12	75 % STRIPED	NO	NO	YES
213.1		0.25/0.5/0.75	12	25 % STRIPED	NO	NO	NO
214.1	-	1.	FREE/12	75 % STRIPED	NO	NO	NO
215.1	-	1.	FREE/12 1/2 AIR BLOCKAGE	75 % STRIPED	NO	NO	NO
216.1	-	0.5	12	75%/25 % QUADRANTS	NO	NO	NO
217.1	-	1	12	75 % STRIPED	NO	17 MOLE %	YES
218.1	-	1.	12	75 % STRIPED	YES	17 MOLE %	YES
219.1	-	0.2	12	DRY/50 % STRIPED	YES	17 MOLE %	YES
220.1 (Blind Test)	-	BLOWDOWN	12	75 % STRIPED	YES	NO	YES
221.1	-	BLOWDOWN	12	50 % STRIPED/DRY	YES	25 MOLE %	YES

LST Overview

PHASE 3 - PCCS FOLLOW-ON TEST MATRIX

TEST NUMBER	STEAM CONTROL		AIR FLOW	WATER COVERAGE	LONG TERM HEAT SINKS	HELIUM	SAMPLING	NOTES
	PRESSURE (PSIG)	FLOW (LB/SEC)	(FT/SEC)					
222.1	-	6/3/0.5	12	75 % STRIPED	YES	NO	YES	Diffuser under SG
222.2	-	6/3/0.5	12	75 % STRIPED	YES	NO	YES	Diffuser 6 feet above deck, pointed up
222.3	-	6/3/0.5	12	75 % STRIPED	YES	NO	YES	3" steam source, 6' above deck, jet pointed at near wall
222.4	-	6/3/0.5	12	75 % STRIPED	YES	NO	YES	3" steam source, 6' above deck, jet pointed up
223.1	-	2.0	12	100%	YES	NO	YES	Vacuum
224.1	-	0.25	12	100%	YES	NO	YES	2 atmospheres air pressure
224.2	-	0.5	12	100%	YES	NO	YES	2 atmospheres air pressure

LST Overview - Observations

Containment Pressure a primary function of:

- Steam source flow rate
- External water flow evaporation rate
- Steam and noncondensable partial pressures
- Internal gas velocities

Containment Pressure a secondary function of:

- External air flow rate
- 50% inlet blockage

LST Overview - Observations

Condensate:

- Approximately 95% of the condensate is collected from the vessel dome and sidewall
- 5% is collected from the open, closed, and steam generator areas
- Condensate approximately equally divided between dome and side wall
- No observable rainfall (below detection limits)

LST Overview - Observations

Internal Velocities and Air/Steam Concentrations

- Under post blowdown LOCA configurations velocities are low (0 to 5 ft/sec) and steam concentrations are high above deck
- Under MSLB configurations velocities are higher and air/steam concentrations are uniform above and below deck

External

- Vessel at 100°F shows strong turbulent upward air flow in annulus
- Dry vessel at 250°F wets readily

LST Overview - Conclusions

The LST measurements provided scalable data to validate

- The PIRT phenomena selection
- The convection heat and mass transfer models
- The subcooled heat transfer model
- The wetting model
- WGOTHIC

G. WATER COVERAGE

December 7, 1995

J. Woodcock, Principal Engineer
Containment and Radiological Analysis

Contact: John Butler
Phone: 412-374-5268

Westinghouse Electric Corporation

Water Coverage

Objectives:

1. Describe the PCS test program to determine how wetting and film coverage change as a function of the film and surface properties
    a. Film flowrate, distribution and temperature
    b. Surface heat flux and temperature
    c. Surface geometry (height, and angle of inclination)
    d. Age of surface coating
    e. Contamination of surface
    f. Manufacturing tolerances

2. Show how transient and steady state film coverage for AP600 are predicted (phenomenological model development and validation)

3. Show how the bounding film coverage input is determined for the evaluation model

PCS Test Program

1. Water Film Formation Tests
2. Water Distribution Tests
3. STC Wet Flat Plate Tests
4. Small-Scale Tests
5. Large-Scale Tests

Water Film Formation Tests (WCAP-13884)

Purpose of Tests

1. To show the wettability of the selected exterior coating for the AP600 containment shell.
2. To characterize the general requirements for forming a water film over a large surface.

Apparatus

The test section is an 8-ft long, 4-ft wide steel plate on a pivoting frame. The plate was coated with the selected inorganic-zinc coating.

Results

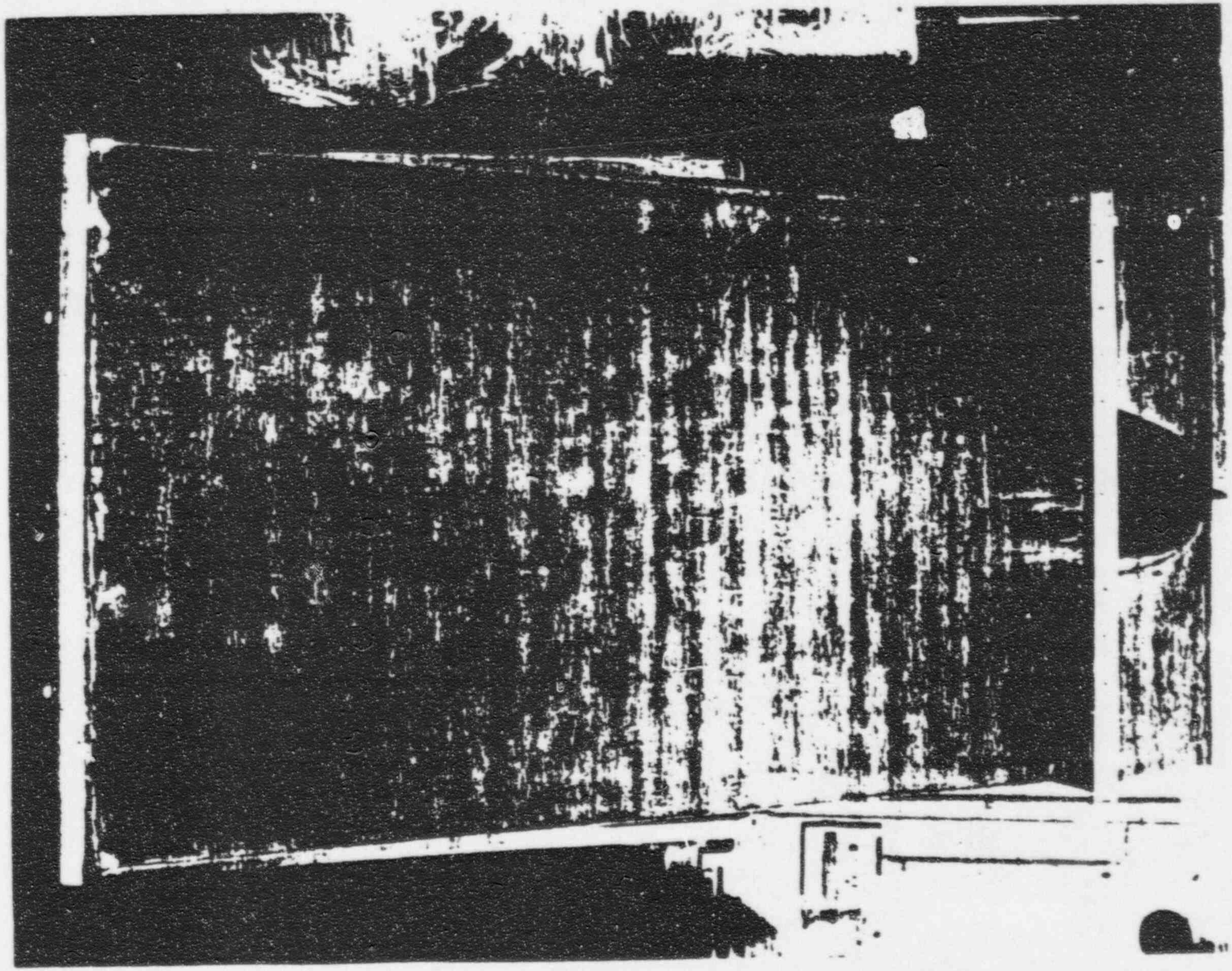
The selected coating wetted readily.

A point source flowrate of 1 gpm produced a 1-ft wide stripe, independent of the inclination angle.

No rivulet formation was observed even at high point source flow rates and with vertical orientation.

Various methods were tried to enhance the spreading across the entire width of the plate. Once formed, the film was stable, did not form into rivulets, and wetted the entire length of the plate.

Water Film Formation Tests



Water Distribution Tests (WCAP-13292, WCAP-13816, WCAP-13960)

Purpose of Tests

To provide a full-scale demonstration of the capability to distribute water on the steel containment dome outer surface and top of the containment sidewall with worst case manufacturing tolerances.

Apparatus

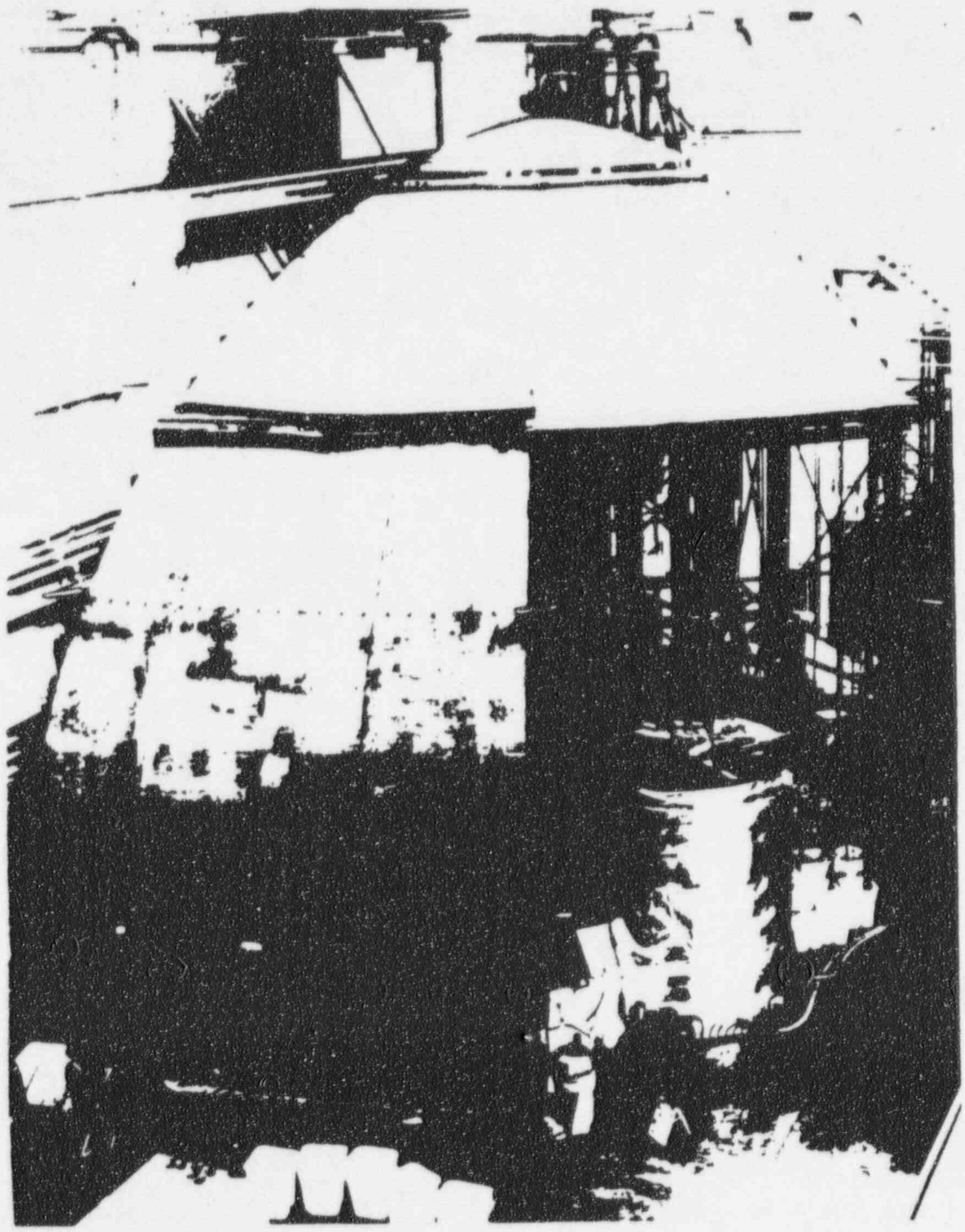
The test section is a 1/8 sector of the full-scale dome. The test section was built with maximum allowable weld tolerances between the steel plates and was coated with the selected inorganic zinc coating.

Results

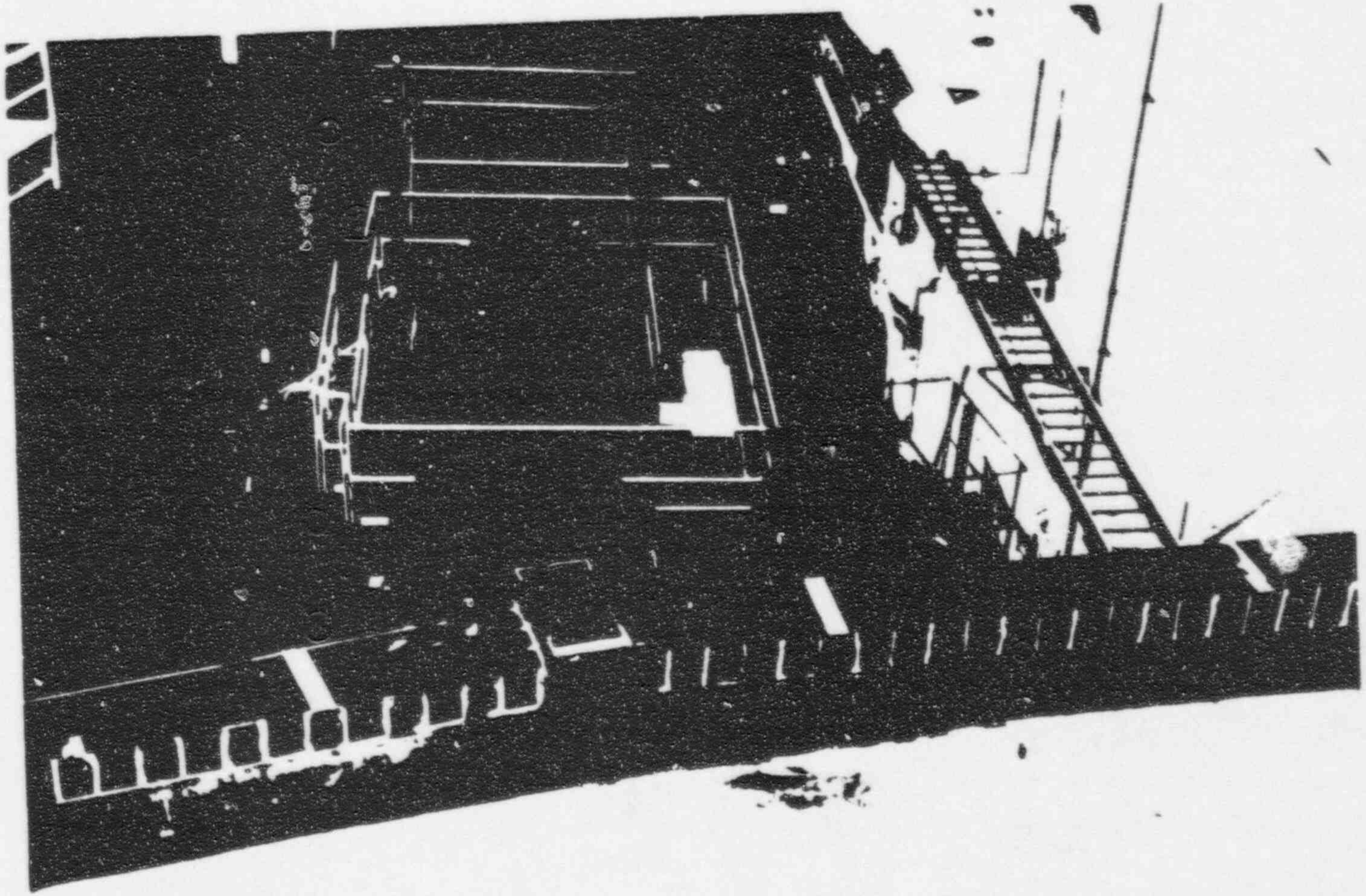
Time to fill weirs and reach a steady state coverage at 220 gpm equivalent flowrate was about 10 minutes.

The film coverage and thickness was measured as a function of flowrate at the springline on the full-scale test section.

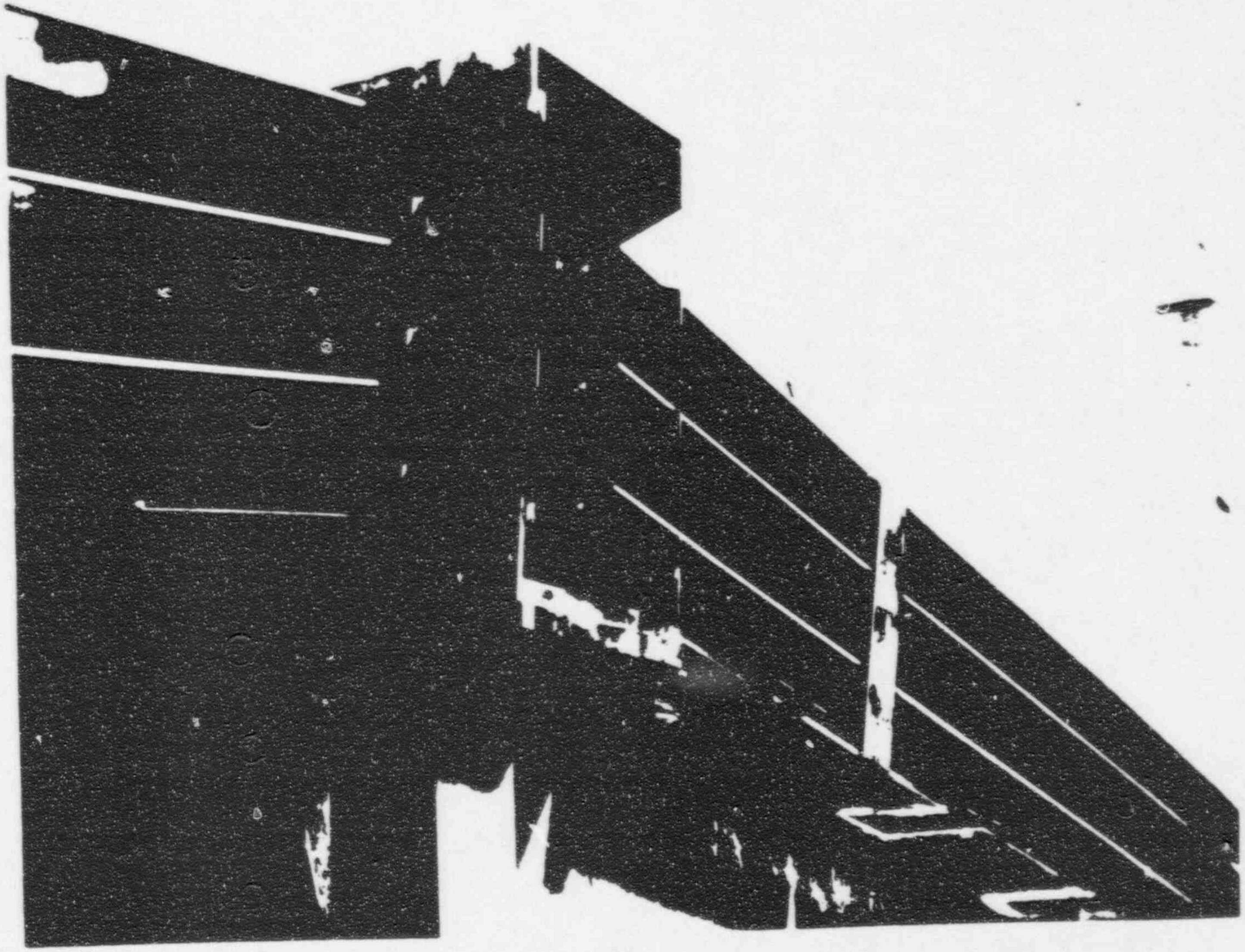
Full Scale Water Distribution Tests



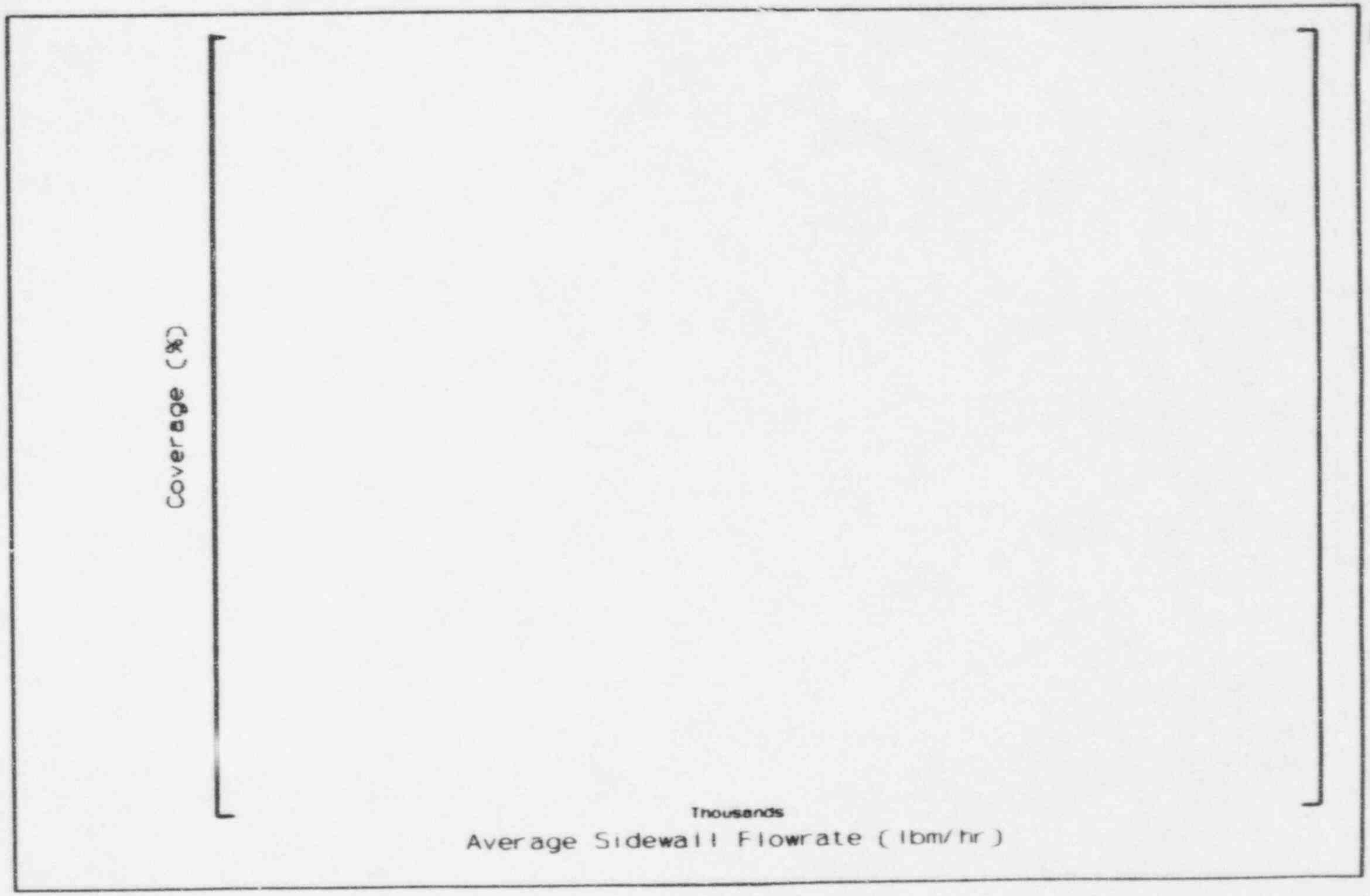
Full Scale Water Distribution Tests



Full Scale Water Distribution Tests



Coverage Data From Phase 3 Water Distribution Tests



(a,c)

STC Wet Flat Plate Tests (WCAP-12665 rev. 1)

Purpose of Tests

1. To obtain data on evaporative heat and mass transfer.
2. To observe film hydrodynamics including possible formation of dry patches due to surface tension instabilities.

Apparatus

The test section is a heated, 6-ft long, 2-ft wide steel plate. The plate was coated with the selected inorganic zinc coating. An air duct was formed with a clear Plexiglas cover to allow film flow visualization.

Results

A wavy laminar water film was formed easily, even in the vertical orientation and showed no instability or tendency to form rivulets.

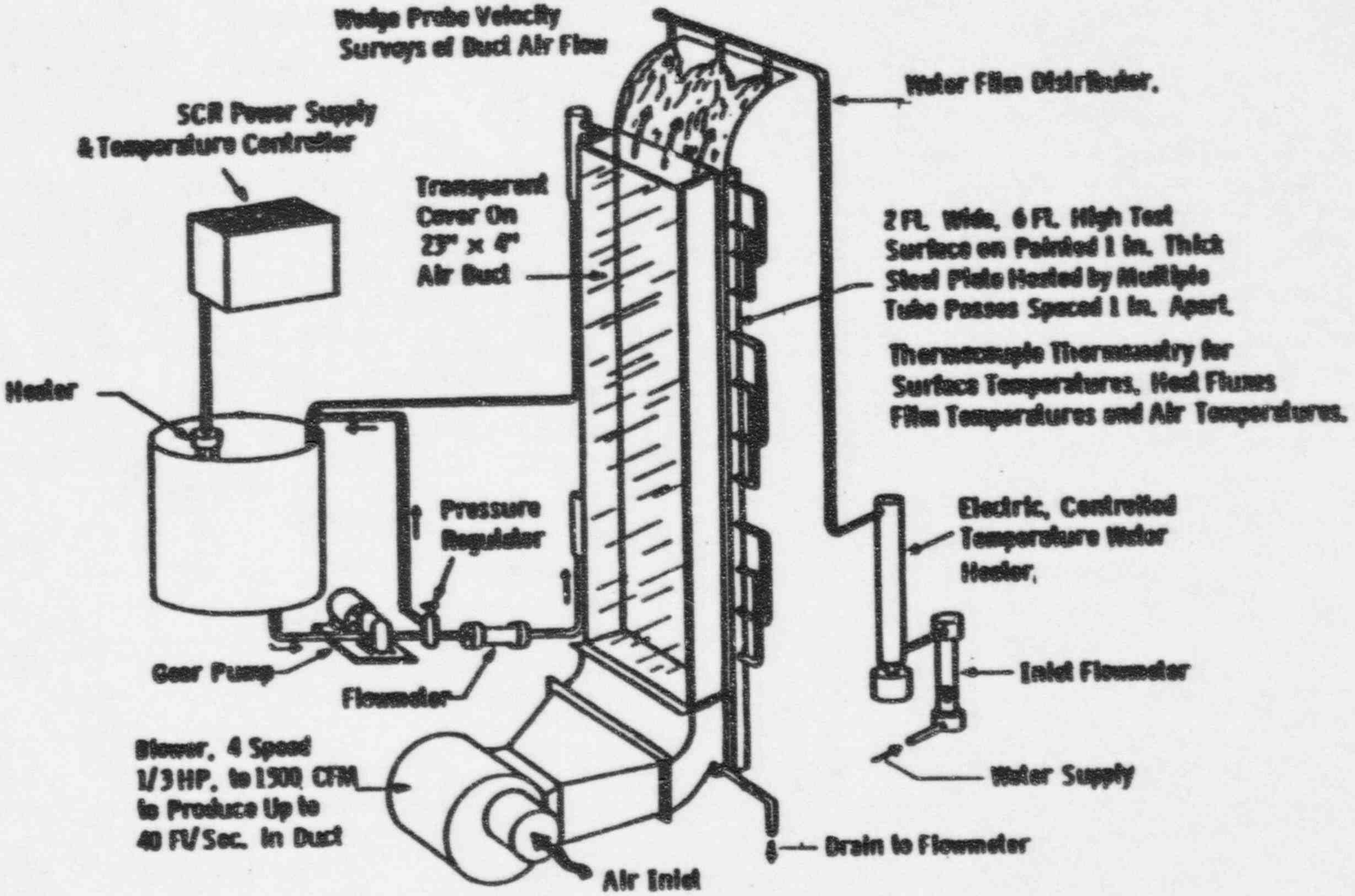
The film was not susceptible to instabilities that lead to dry patch formation at any heat flux density or plate surface temperature encountered.

The film was not adversely affected by the countercurrent cooling air flow.

Range of STC Flat Plate Test Parameters

	Minimum	**Maximum**	
Air Flow	5.9	38.7	ft/s
Film Flow	0	318	lbm/hr-ft
Avg. Heat Flux	680	3700	BTU/hr-ft^2

STC Heated Flat Plate Test Apparatus



Small-Scale Integral Tests (WCAP-14134)

Purpose of Tests

1. To obtain heat and mass transfer data in an integral setting over an increased range of operating conditions, including postulated severe accident conditions.

2. To evaluate the impact of low environmental temperatures on the containment and air baffle structures.

Apparatus

The test facility consisted of a 24-ft tall, 3-ft diameter pressure vessel surrounded by a transparent baffle enclosing an air annulus.

Results

A uniform water film was easily formed using simple weirs.

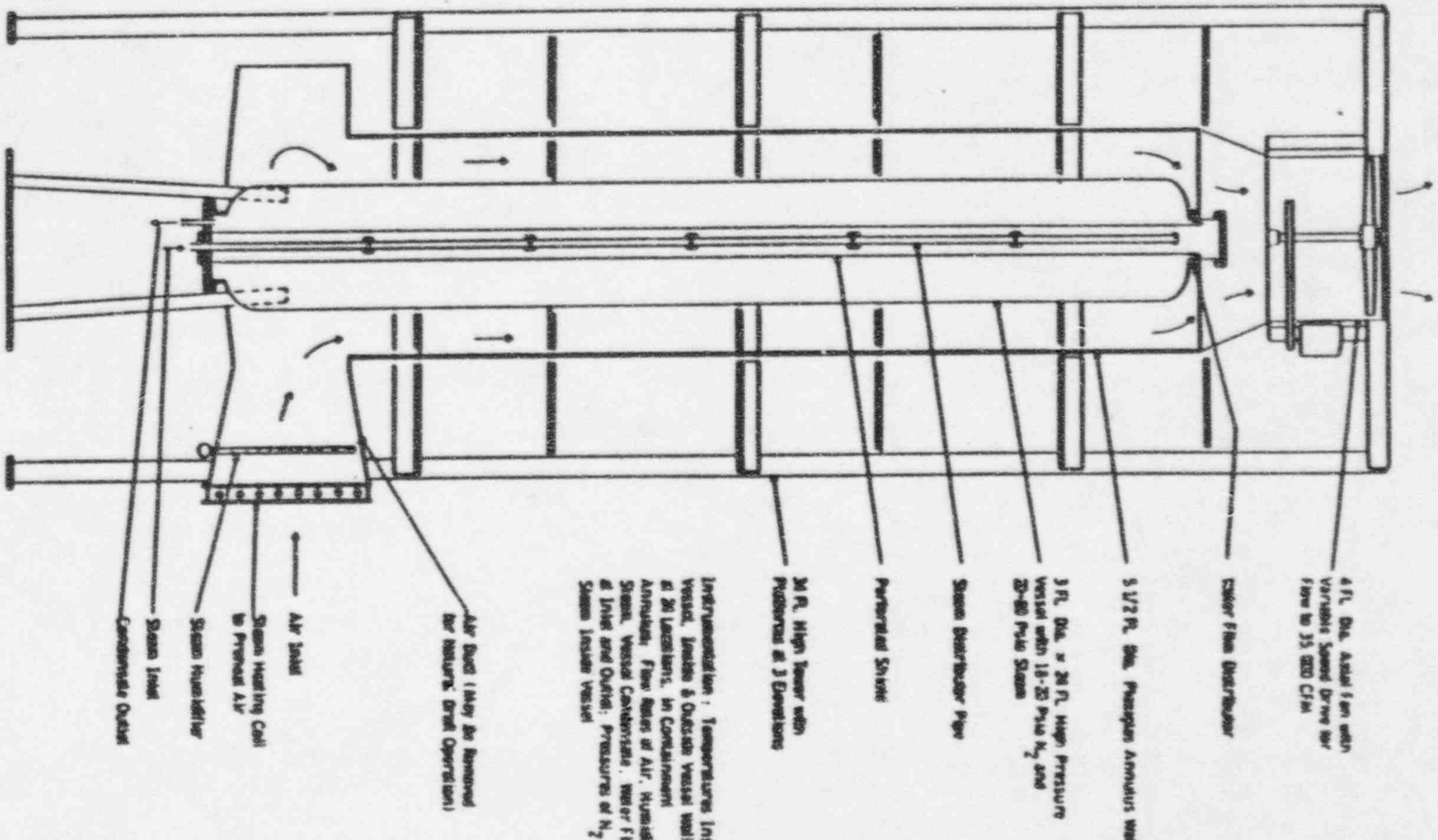
The water film was stable, even at evaporating heat fluxes 3 times higher than is likely to be encountered in the AP600.

The film had no tendency to become less uniform or form rivulets on the cylindrical wall.

Range of Small-Scale Test Parameters

	Minimum	Maximum
Air Flow	8	20 ft/s
Film Flow	0	2.6 gpm
Steam Flow	100	1637 lbm/hr
Avg. Heat Flux	95	7600 BTU/hr-ft^2

Section View of AP600 Integral Small-Scale Test



Large-Scale Integral Tests (WCAP-14135, PCS-T2R-050)

Purpose of Tests

To obtain heat and mass transfer data in an integral setting, including the effects of natural convection and steam condensation on the interior of a 1/8 scale vessel.

Apparatus

The test facility consisted of a 1/8 scale pressure vessel surrounded by a transparent baffle enclosing a 3-in wide air annulus.

Results

As the heat flux was increased (or film flow rate was decreased), dry stripes were produced near the water stream impact site on the dome.

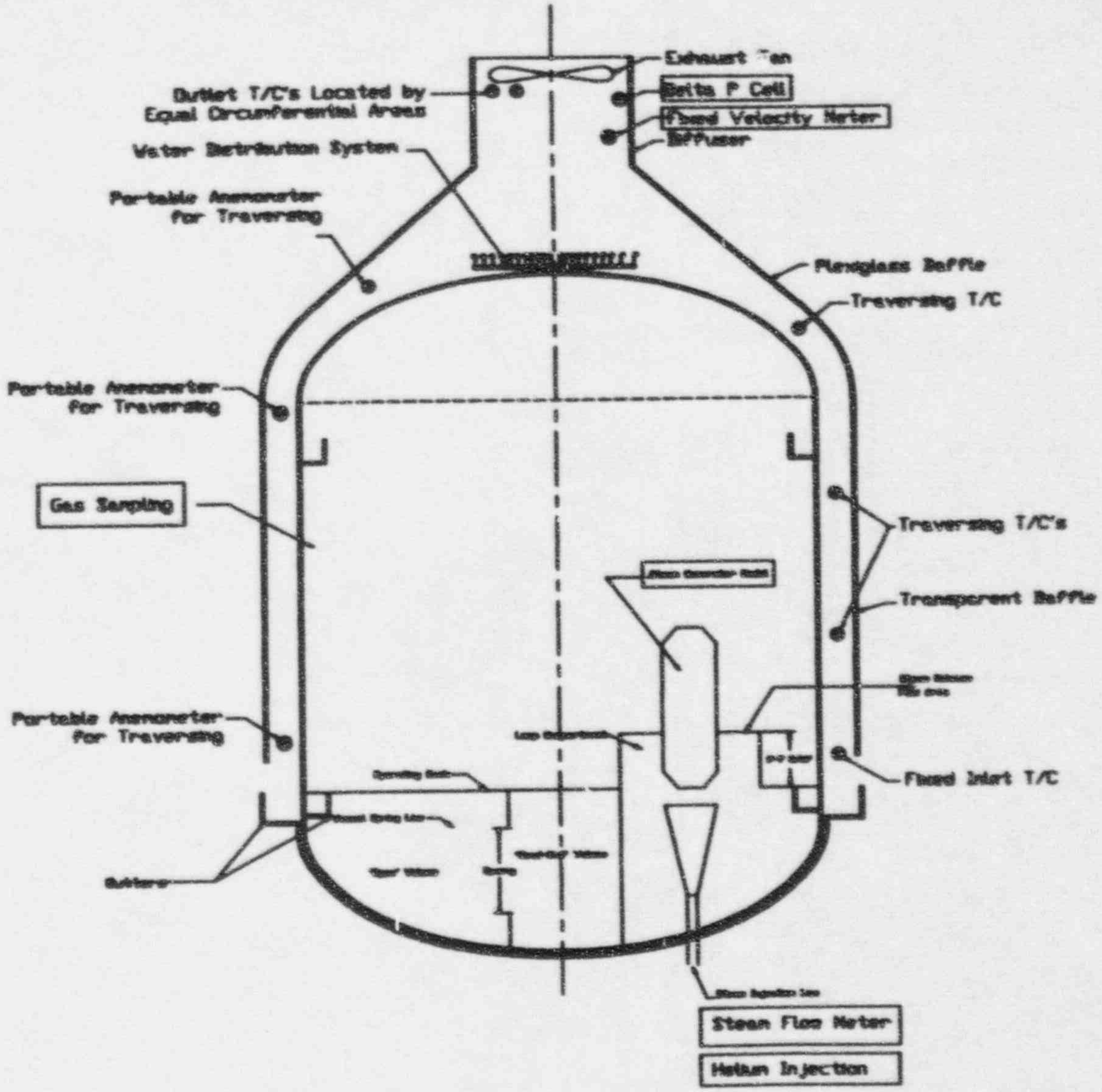
The width of the dry stripes increased with increasing heat flux or decreasing water flowrate.

A hot, dry vessel was easily wetted without forming rivulets or causing the film to leave the surface.

Range of Large-Scale Test Parameters

	Minimum	Maximum	
Air Flow	FREE	16	ft/s
Film Flow	0	317	lbm/hr-ft
Steam Flow	450	5900	lbm/hr
Avg. Heat Flux	600	7700	BTU/hr-ft^2

AP600 Large-Scale PCS Test



Video Tape Presentation

Key Observations from Videotapes:

- Water Distribution Test
  - The weir system creates stripes of film on the vessel that cover about 90% of the surface below the weirs
- Large-Scale Test (wetting of a hot, dry vessel)
  - The coated surface wets and re-wets readily
- STC Flat Plate (dryout and re-wetting of surface)
  - Water film remains thin to complete evaporation, consistent with a receding contact angle near zero

Analytical Water Coverage Model

- Need to analytically predict how a film stripe behaves as it evaporates.

- Available models were examined and a modified form of the Zuber-Staub Model was developed and validated with test data.

Modifed Zuber-Staub Model

- Predicts the occurance of a stable dry stripe within a flowing film by performing a force balance at the tip of a dry stripe.

$$\frac{\rho}{15}\left[g\sin\beta\,\frac{\rho}{\mu}\right]^2\delta^4 + \rho g\cos\beta\,\frac{\delta}{2} = \frac{\sigma(1-\cos\theta)}{\delta} + \frac{d\sigma}{dT}\frac{\dot{q}''}{k}\cos\theta + \rho_v\left(\frac{\dot{q}''}{\rho_v h_{fg}}\right)^2\frac{\Delta\rho}{\rho_l}\cos^2\theta$$

- Stagnation Force + Body Force = Surface Tension+Thermocapillary Force+Vapor Thrust

- The vapor thrust component is small except at very high heat fluxes (>10^6 BTU/hr-ft^2) and can be neglected for AP600.

- Solve for δ and determine Γ_{min} as follows

$$\Gamma_{\min} = \frac{g\sin\beta}{3\mu}\delta^3$$

Model Development

- To Determine the Local Minimum Stable Film Thickness, Must Know
    - Fluid properties: ρ, μ, σ
    - Surface orientation, β
    - Film thickness, δ (or Γ)
    - Heat flux
    - Contact wetting angle for the surface, θ

- Define the Ratio between Flow Rates at the Minimum Film Thickness, Γ_{min}, and the Local Film Thickness, Γ

$$R = \frac{\Gamma}{\Gamma_{min}}$$

- The Zuber-Staub Model for a Smooth Surface Determined that for R>1.0, the Film Would Remain Stable

Model Development

Determination of the Contact Wetting Angle

- Wetting angle measured using an optical comparator
  - Heated and unheated surface
  - Weathered and unweathered surface
- All measurements indicate that a contact wetting angle for weathered surfaces ranging from θ = [ ]^{a,c} should be used in the film stability analysis.
- The evaluation model bounds the effects of wetting angle

Model Development

Contact Wetting Angle

TEST RESULTS

Description of Test	Contact Angle Weathered Sample	Contact Angle Unweathered Sample
2. Room Temperature, T=80°F		
3. Heated, T=110°F		
4. Heated, T=180°F t=0 sec.		
t=15 sec.		
t=30 sec.		
t=60 sec.		

(a,c)

Model Development

- To Use this Model for AP600 Wetted Coverage it was Necessary to:
  - Determine the value of R at which the flow becomes unstable for a rough surface with welds and other imperfections, R_{ref}.
  - Once the film becomes unstable it continues at incipient stability

For incipient stability:

$$\Gamma = R_{ref} \, \Gamma_{min}$$

- Thus, for an Unstable Evaporating Film, the Coverage Fraction Decreases Continually
- Sixteen Large-Scale Heat Transfer Tests are Predicted Using Various Values of R_{ref}
- R_{ref} = 1.75 Conservatively Predicts the LST Coverage Results

Model Validation

a,c

Application to AP600

Test Data Show:

1. The shell will be covered with a large number of film stripes instead of a continuous sheet of film.
2. About 10 minutes is required to establish steady state coverage at the 220 gpm PCS film flow rate.
3. Water coverage will decrease as the PCS film flow rate decreases with time.
4. Film continues to thin until completely evaporated.

Analytical Model Predicts:

The film stripes will thin and split, causing the coverage to decrease from top to bottom of the vessel as the water evaporates.

WGOTHIC AP600 Clime Model

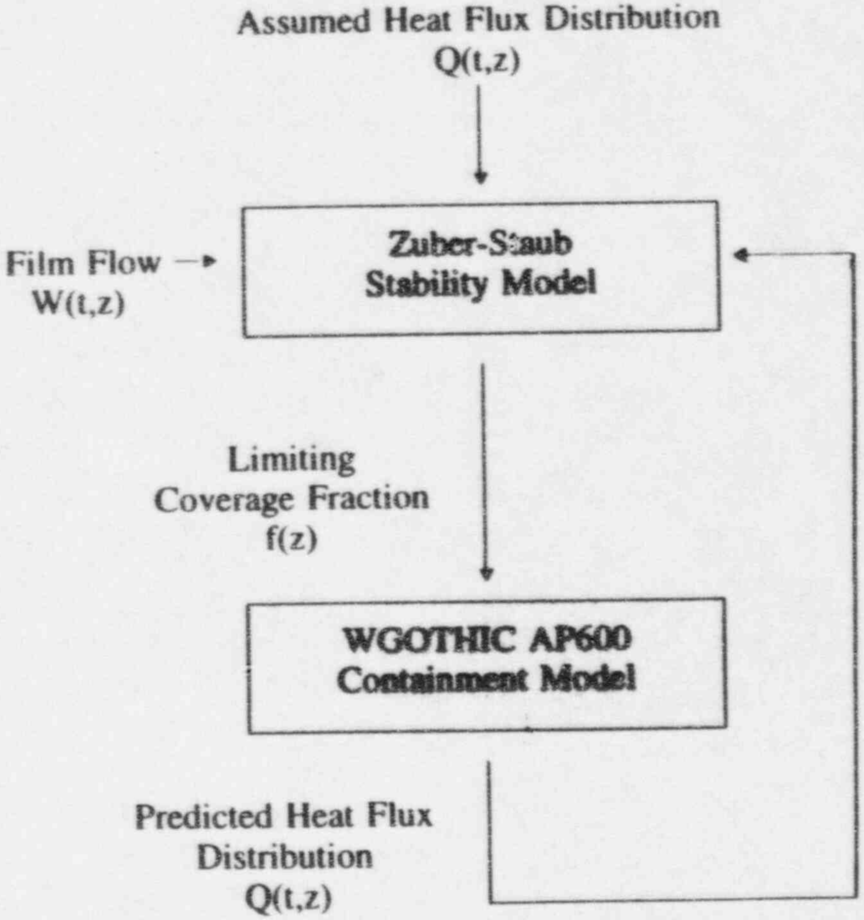
- The shell is divided into 7 elevation planes (3 on the dome and 4 on the vertical sidewall).

- The modified Zuber-Staub model is used to determine a bounding value for film flow and coverage (area and wetted perimeter) for each elevation plane for all times.

- The surface of each shell elevation is divided into wet and dry sections based on the film coverage.

- Although water is available for cooling the dome within a minute, a conservative 11 minute delay is assumed before any water begins to flow onto the shell surface.

Assumed Heat Flux Distribution



Assumed Heat Flux Distribution
Q(t,z)

Film Flow
W(t,z)

Zuber-Staub
Stability Model

Limiting
Coverage Fraction
f(z)

WGOTHIC AP600
Containment Model

Predicted Heat Flux
Distribution
Q(t,z)

Process for Determining Water Coverage Fraction for AP600

Film Coverage Chronology (220 gpm)

- Chronology for AP600

Time (s)	Event
0.0	Large, double ended cold leg LOCA occurs
10.0	PCS AOV strokes open
30.0	PCS piping is filled
33.0	Water begins to flow onto dome
183.0	First weir is filled and begins to spill
333.0	Second weir is filled and begins to spill
600.0	Steady state coverage on dome

- Evaluation model conservatively assumes no water on the shell until after steady state water coverage is established

Time (s)	Event
0.0	Large, double ended cold leg LOCA occurs
660.0	PCS water applied over the shell in evaluation model

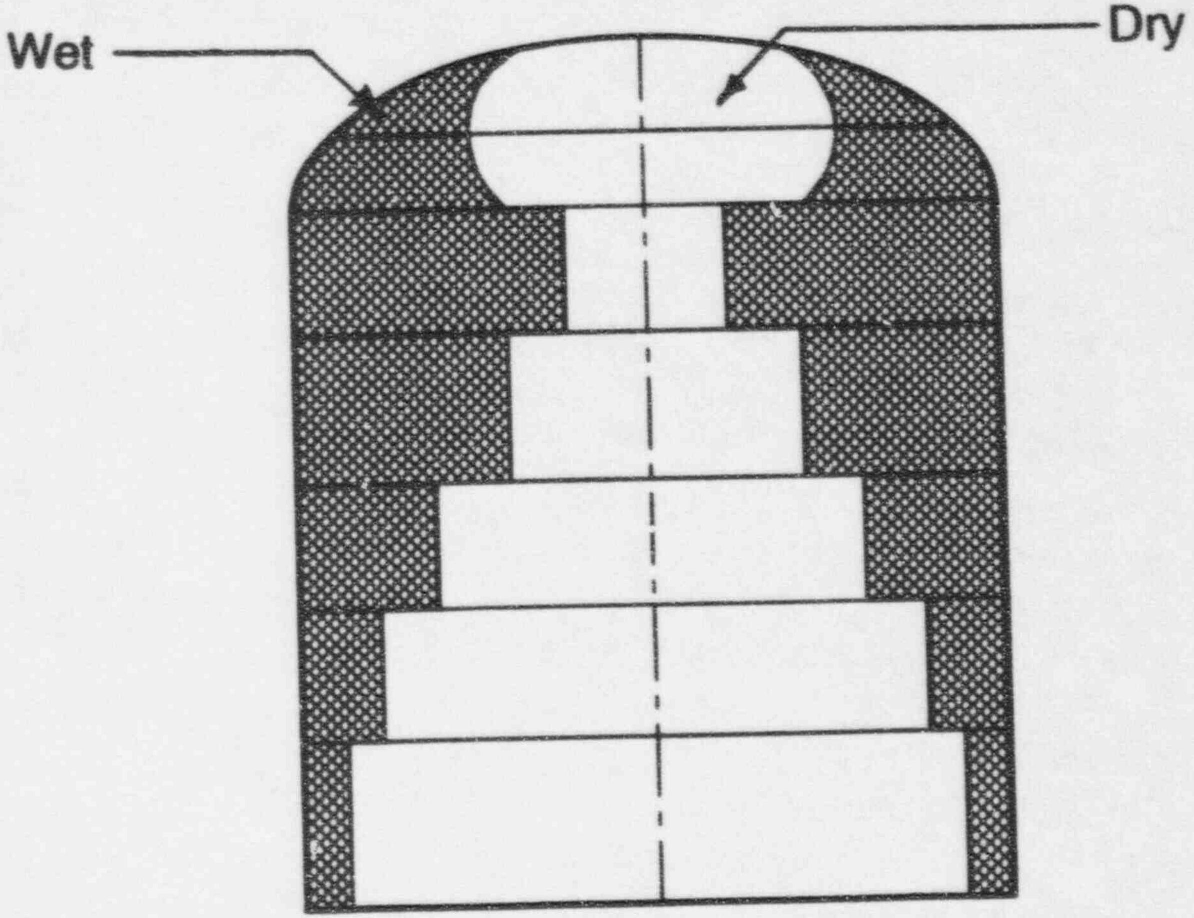
Description of Climes

- A special conductor (Clime) is used in WGOTHIC to calculate the mass and energy transfer for each section of the shell. (condensation, conduction, evaporation convection and radiation)

- Stacks of climes are created to track the films.

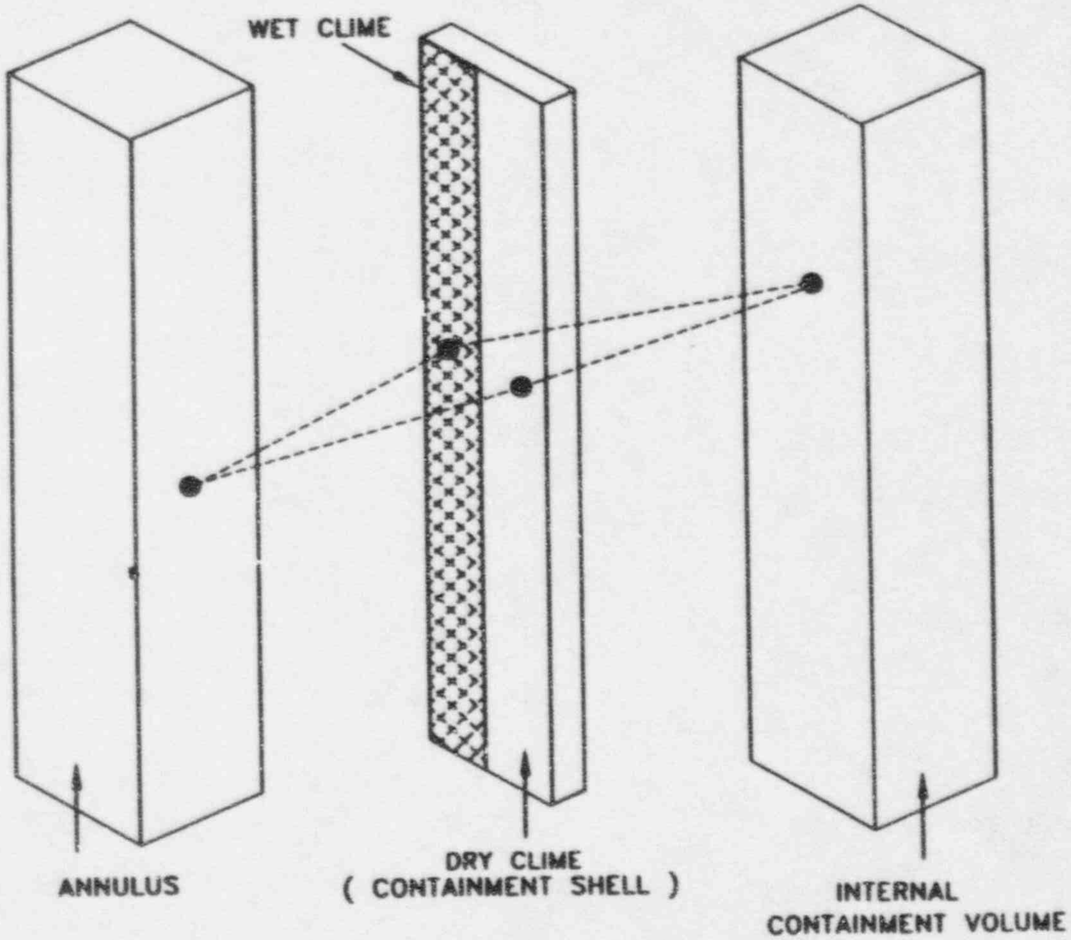
- After condensation or evaporation, the remainder of the film is transported down through the stack of climes.

WGOTHIC Clime Model



Representation of the WGOTHIC Clime Water Coverage Input for Half of the Containment Shell

WGOTHIC Clime Model



WGOTHIC AP600 Water Coverage Sensitivities Completed

Water Coverage Sensitivity

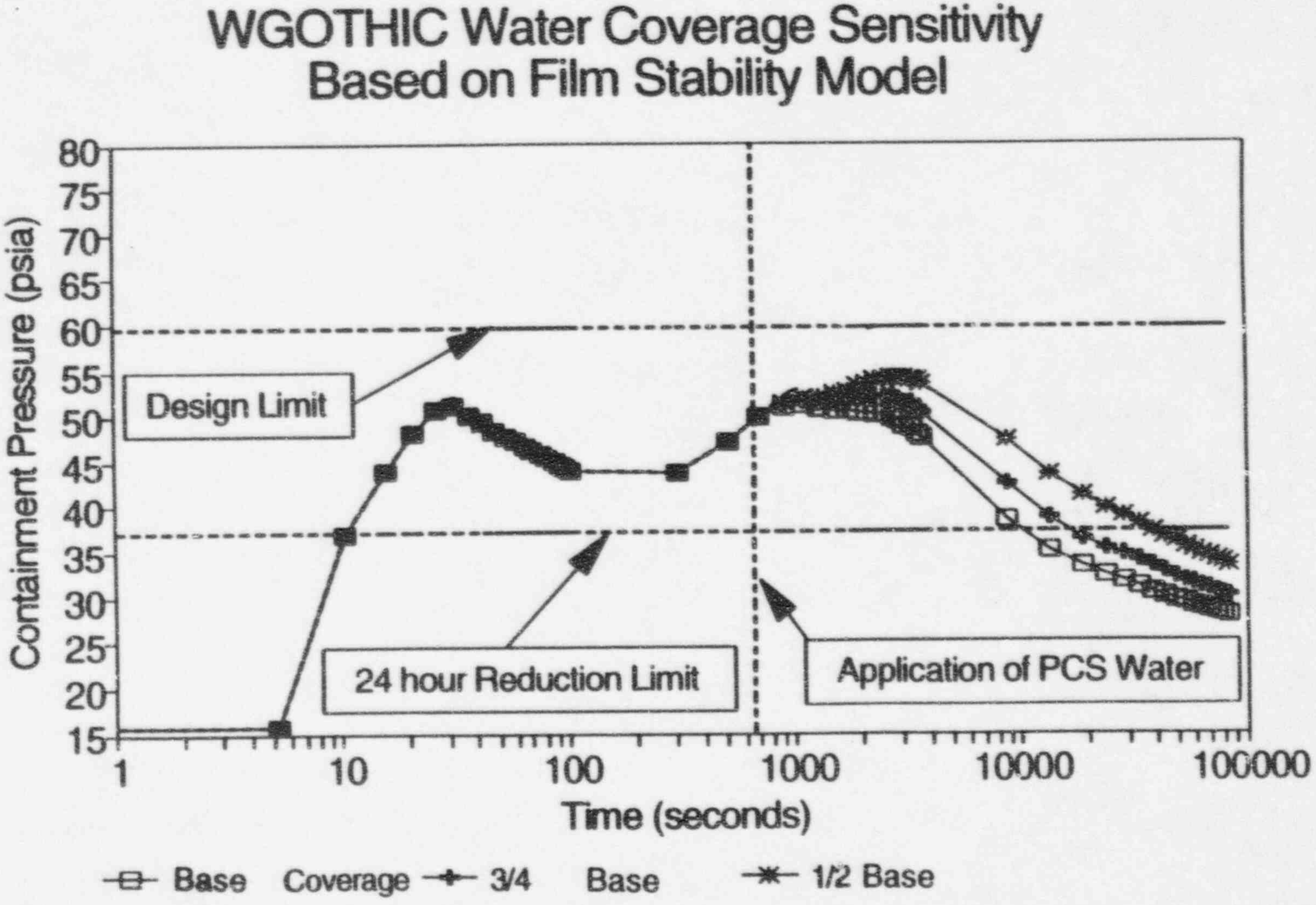
Base case coverage established using modified Zuber-Staub model with a maximum 40% coverage limit assumed for the top 2 climes on the dome.

	Dome Coverage			Sidewall Coverage			
Avg	Top	Mid	Bot	Top	Mid1	Mid2	Bot
48%	40%	40%	66%	55%	43%	34%	30%
36%	40%	40%	48%	36%	31%	28%	26%
24%	40%	40%	37%	19%	18%	17%	16%

Water Coverage
(Fraction of Total Surface Area)

	48%	36%	24%
Peak Pressure	51.2	52.1	54.2 psia
24 hr Pressure	27.9	30.0	33.5 psia

WGOTHIC Water Coverage Model



Conclusions

- The modified Zuber-Staub model for predicting water coverage has been validated and bounds essentially all test data
- The WGOTHIC AP600 containment pressure response model is relatively insensitive to the input water coverage fraction and the bounding DBA coverage is not near any cliffs
- A bounding water coverage is established for input to the WGOTHIC AP600 containment model