Westinghouse
Electric Corporation

Energy Systems

Box 355
Pittsburgh Pennsylvania 15230-0355

AW-93-535

October 15, 1993

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

ATTENTION: MR. R. W. BORCHARDT

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: PRESENTATION MATERIALS FROM THE SEPTEMBER 20, 1993 MEETING ON AP600 LOW PRESSURE INTEGRAL SYSTEMS TESTS AT OREGON STATE UNIVERSITY

Dear Mr. Borchardt:

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-93-535 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-93-535 and should be addressed to the undersigned.

Very truly yours,

N. J. Liparulo Manager
Nuclear Safety And Regulatory Activities

/nja

cc: Kevin Bohrer NRC 12H5

1296A

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant specific review and approval.

In order to conform to the requirements of 10 CFR 2.790 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) contained within parentheses located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Section (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying thi: transmittal pursuant to 10 CFR2.790(b)(1).

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

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

Brian A. McIntyre, Manager
Advanced Plant Safety & Licensing

Sworn to and subscribed
before me this 15 day
of October, 1993

Rose Marie Payne

Notary Public

Notarial Seal
Rose Marie Payne, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Nov. 4, 1996
Member, Pennsylvania Association of Notaries

(1) I am Manager, Advanced Plant Safety and Licensing, in the Nuclear and Advanced Technology Divisions, 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 ET-NRC-93-3993, October 15, 1993, being transmitted by Westinghouse Electric Corporation (W) letter and Application for Withholding Proprietary Information from Public Disclosure, N. J. Liparulo (W), to Mr. R. W. Borchardt, 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.

ATTACHMENT 1

Westinghouse/NRC Meeting on
AP600 Low Pressure 1/4 Height Integral Systems Tests

September 20, 1993

Oregon State University
LaSells Stewart Center, Agricultural Science Room

1.	Welcome	J. N. Reyes, Jr.	8:15 (:10)
2.	Introduction/Background/Objectives	E. J. Piplica	8:25 (:15)
3.	OSU Facility Design Update		8:40 (1:30)
	- Final Design	L. K. Lau	
	- Break/Separator System	J. T. Groome	
	- DAS/Control Room	J. T. Groome	
	BREAK		10:10 (:20)
4.	OSU Instrumentation Design	J. T. Groome	10:30 (1:30)
	- Introduction	L. E. Hochreiter	
	- Walk Through Design and Logic	J. T. Groome	
	LUNCH (Valley Footbal Center)		12:00 (1:00)
5.	Facility Tour	OSU/W	1:00 (1:30)
	BREAK (return to meeting room)		2:30 (:15)
6.	OSU Scaling Analysis	J. N. Reyes, Jr.	2:45 (1:30)
	- Brief Review of Chapters 1-4		
	- Depressurization Scaling, Chapter 5		
	- CMT, Accumulator, IRWST, Chapter 6		
	- Long Term Cooling, Chapter 7		
	- Scaling Distortions		
7.	Test Matrix	L. E. Hochreiter	4:15 (:30)
8.	Schedule	E. J. Piplica	4:45 (:15)
9.	Adjourn		5:00

ATTACHMENT 3

WELCOME AND INTRODUCTION

E.J. Piplica, Manager

AP600 Test Engineering

INTRODUCTION

- Background Information

- Objectives of OSU Program

- Purpose/Objectives of this Meeting

BACKGROUND INFORMATION

- Westinghouse visited OSU in 1990 to investigate the possibility of performing long-term cooling tests in a transparent vessel.

- Westinghouse/OSU/PGE agreed to a program that would cover both AP600 and Trojan designs.

- Westinghouse instructed OSU to perform scaling studies for 1/4, 1/6, 1/8 height scale and decided on 1/4 height scale.

- In August 1991 the facility was changed from a transparent glass/quartz facility to stainless steel, because of safety, and the desirability to increase the design pressure of the facility.

- The current design allows us to initiate transients from approximate 400 psia

OBJECTIVES OF OSU PROGRAM

- Simulate gravity injection and natural convection in the small break and long-term cooling mode

- Provide data on the passive safety system performance

- Provide data to characterize the cooling flow paths and behavior

- Provide data to be used to develop and validate computational methods for analyzing small break/LOCA/long-term cooling conditions

OBJECTIVES OF OSU PROGRAM *(continued)*

To meet the objectives of the OSU program, the OSU test facility incorporates:

- All RCS, PXS, and NSS components modeled according to the scaling analysis to minimize geometric atypicalities

- All interconnecting piping and pipe routing to more accurately represent form losses

- A unique break and ADS measurement system to determine mass and energy releases

- Extensive instrumentation (~750 channels) to provide the data needed to valid computational models

- Feedback on the overall facility design from the staff, the ACRS consultants and sub-committee, and the EPRI ~~unity~~ representatives
  utility

OBJECTIVES OF OSU PROGRAM *(continued)*

Changes made to the OSU program based on feedback from the staff and others:

- Broadened scaling report, made it more comprehensive, addressed atypicalities

- Increased OSU model pressure from 200 psia to 400 psia and temperature to 450°F to accommodate broader operating range to address NRC questions

- Added non-safety system to test; CVS, SFW, NRHR

- Added ability to simulate containment backpressure

- Added more ΔP cells in vessel to address 2D/3D effects in downcomer

- Added extra instrumentation in PRHR to provide additional data in C-tube design, and performance

- Comments on the break configuration were factored into the break design for OSU

PURPOSE OF MEETING

- Purpose of this meeting is to:
  - Present the final scaling analysis for the facility
  - Provide a test facility design update and status, particularly for the break system
  - Provide an updated instrumentation list and the drawings detailing instrumentation locations
  - Provide an updated test matrix which has been modified to include NRC comments
  - Provide response to NRC/INEL questions on OSU

OSU FACILITY DESIGN UPDATE

L.K. Lau, Westinghouse

J.T. Groome, OSU

OREGON STATE UNIVERSITY (OSU)
LOW PRESSURE INTEGRAL SYSTEMS TEST

- Design Test Pressure is 400 psia and 450°F

- 1/4 Linear Scale

- Sizes are determined by scaling analysis performed by OSU and based on H2TS (NUREG/CR-5809)

- Major Components:

  - Simulated reactor vessel and internals

  - 2 simulated loops each with 2 cold legs, 1 hot leg, and 1 SG

  - Simulated pressurizer and associated lines

  - 2 simulated CMTs and 2 simulated accumulators with associated lines

  - Simulated IRWST with associated lines and a sparger

OREGON STATE UNIVERSITY (OSU)
LOW PRESSURE INTEGRAL SYSTEMS TEST
(continued)

- Simulated containment sump and the normally non-flooded compartments and associated lines

- Simulated ADS 1-4 stages

- Simulated DVI lines and pressure balance lines

- 1 simulated PRHR Hx and associated loop

- Simulated RNS RHR pump and lines from IRWST to reactor vessel

- 1 Simulated CVS makeup pump and line to SG channel head

- 4 simulated RCPs

- 48 heater rods simulating approximately 2% decay heat

* - Simulated passive containment cooling condensate return process

OREGON STATE UNIVERSITY (OSU) LOW PRESSURE INTEGRAL SYSTEMS TEST
(continued)

- Simulation Capability of Test Model
  - Simulated CMT injection
  - Simulated accumulator injection
  - Simulated IRWST injection
  - Simulated sump injection at containment pressure in long-term cooling mode
  - Simulated ADS valves and operations
  - Simulated PRHR Hx operations
  - * Break simulation at hot leg, cold leg, CMT-cold leg pressure balance lines, CMT-pressurizer pressure balance line and DVI injection line.
  - Long-term cooling, post-LOCA simulation

OREGON STATE UNIVERSITY (OSU) LOW PRESSURE INTEGRAL SYSTEMS TEST

(continued)

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* • Instrumentation - Over 750 Channels

- Over 118 DP and level cells
- Over 380 thermocouples for fluid temperature, component wall temperature measurement
- Over 50 heat flux metes for component or pipe wall heat loss measurement
- Over 35 pressure transducers for absolute pressure measurements and pressure monitoring
- 4 separators for ADS and break flow measurement
- Over 60 flow meters such as magnetic flow meter, turbine flow meter, and flow orifice
- Over 12 OSU/Westinghouse developed heated thermocouples for fluid phase change detection

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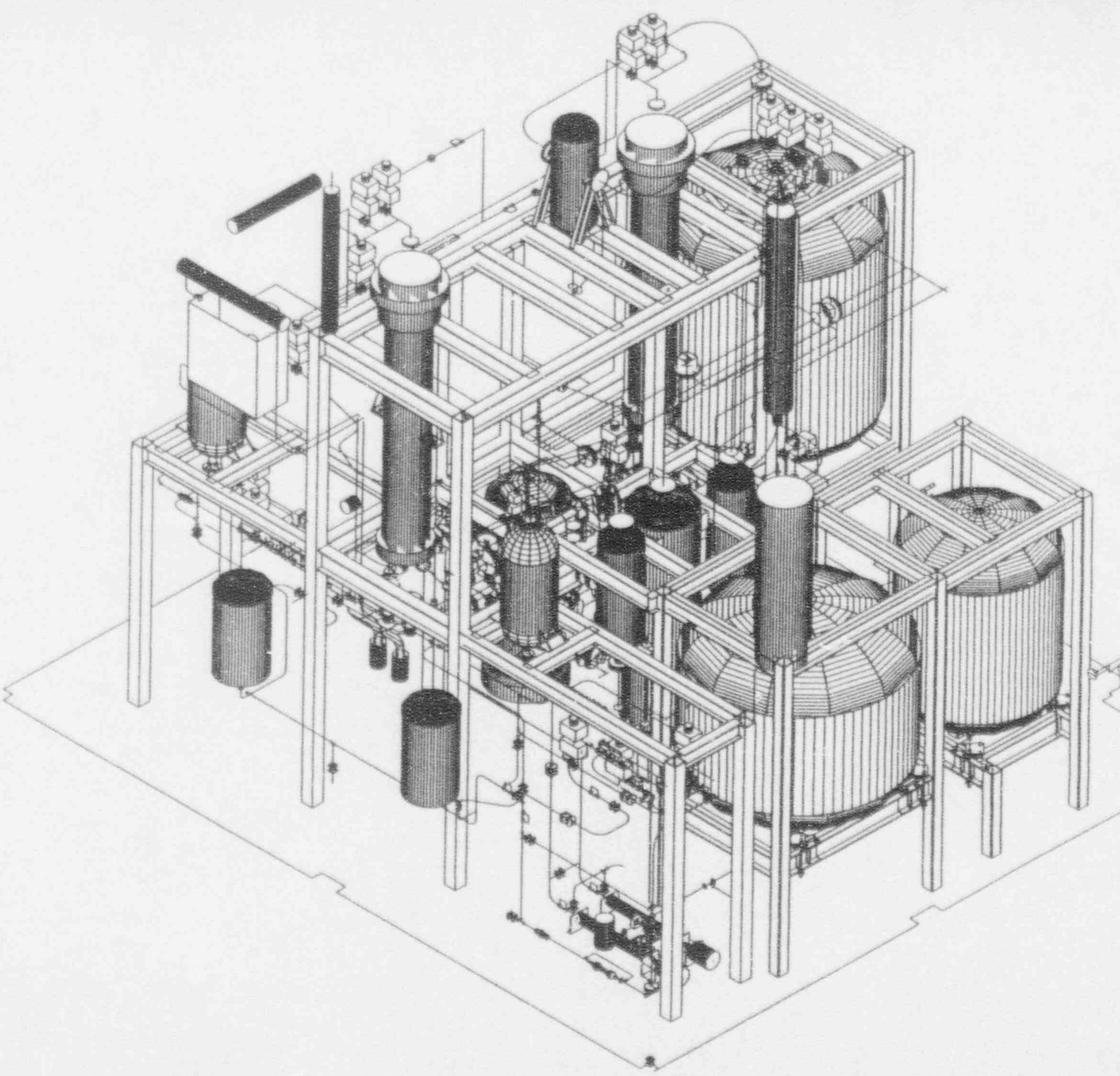

AP600 Low Pressure Integral System Test Isometric

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OREGON STATE UNIVERSITY (OSU)
LOW PRESSURE INTEGRAL SYSTEMS TEST
(continued)

Facility Construction Update -- Almost completed

- All major supporting structures installed
- Primary loop installed

  includes: Reactor vessel/internals
  Hot legs and cold legs and RCPs
  Steam generators
  Pressurizer and surge line and spray line
  DVI injection lines

- IRWST and associated injection line installed
- CMTs and CMT injection lines installed
- ACCs and injection lines installed
- Primary sump tank and secondary sump tanks installed
- Sump recirculation lines approximately 98% installed
- Fill and drain system installed
- Normal RH pump and associated lines installed

OREGON STATE UNIVERSITY (OSU)
LOW PRESSURE INTEGRAL SYSTEMS TEST
(continued)

- CVS makeup pump and steam generator feed pump installed
- PZR to CMT pressure balance lines to be fabricated
- CMT to cold leg balance lines installed, except connection at top of CMTs
- ADS 1-3 lines from PZR up to and including ADS 1-3 separator installed
- Two ADS 4 separators installed, connecting lines to be installed with the break and ADS flow measurement system
- Sparger fabrication complete and installation in progress

OREGON STATE UNIVERSITY (OSU)
LOW PRESSURE INTEGRAL SYSTEMS TEST
(continued)

Control Room and DAS Construction Update

- Control panel completed
- 60% field instruments loaded in the control panel
- 90% instrument wiring to hand switches, PLC controllers, etc., completed
- 90% wiring from operating panel to DAS system completed
- 50% wiring from field instruments to DAS panel completed

Outstanding Issues

- Break and ADS flow measurement system design
- CMT top end steam distributor design
- Order instrumentation for break and ADS flow measurement system

BREAK & ADS FLOW MEASUREMENT SYSTEM (BAMS)

DESIGNED TO:

- SEPARATE 2 PHASE FLOW INTO STEAM AND LIQUID FOR DIRECT MEASUREMENT
- SIMULATE CONTAINMENT PRESSURE INCREASE OVER TIME
- PROVIDE FOR HEATED CONDENSATE RETURN TO IRWST AND PRIMARY SUMP
- REDUNDANT/CONFIRMATORY STEAM FLOW MEASUREMENT
- ALL STEAM PIPING AND MOISTURE SEPARATORS WILL BE HEATED
- ONE ADS 4 SEPARATOR WILL BE USED FOR DOUBLE-ENDED BREAKS

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OSU INSTRUMENTATION DESIGN

J. T. Groome, OSU

L.E. Hochreiter, W

INSTRUMENTATION PLAN

- System wide treatment mass/energy balance can be achieved
- Individual component mass/energy balances can be directly measured or calculated from the data
  - Rod bundle heat transfer measured
  - Accumulator, CMT, IRWST, Sump flows are measured
  - PRHR flow measured when single-phase
  - Balance line flow measured when single-phase liquid or single-phase steam
  - PRHR heat transfer measured

- Steam generator steam/feed flows measured

- Steam generator heat transfer measured

- All break steam flows, break liquid flows measured

- All ADS steam flows, ADS single-phase liquid flows measured

- CMT heat transfer, (wall, liquid) measured

- IRWST pool heat transfer measured

- System heat loss measured

- Stratified flow regimes can be obtained in hot/cold legs and pressurizer surge line

PHILOSOPHY

- Use conventional, more reliable, instrumentation, arranged to maximize knowledge
- Supply redundant measurement when possible
- Design instrumentation to obtain system wide, and where possible, component mass/energy balances
- Control process instrumentation separated from data acquisition system
- Instrumentation was designed with computer code validation in mind

OSU APEX INSTRUMENTATION

- OVER 750 INSTRUMENTS MEASURING FLOW, DIFFERENTIAL PRESS DROPS, LEVEL, HEAT FLUX, PHASE, POWER, AND TEMPERATURE
- 118 DIFFERENTIAL PRESSURE DETECTORS
- 33 PRESSURE DETECTORS
- 20 MAGNETIC FLOW METERS
- 5 TURBINE FLOW METERS
- 6 VORTEX FLOW METERS
- 6 HEATED T/C FLOW METERS
- 3 TRUE RMS POWER METERS
- 12 LOAD CELLS
- 12 OSU/WESTINGHOUSE DESIGNED HEATED PHASE SWITCHES
- 51 HEAT FLUX METERS
- 424 THERMOCOUPLES
- BREAK AND ADS FLOW MEASUREMENT SYSTEM INSTRUMENTATION BEING DESIGN

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Scaling Analysis for the OSU AP600 (APEX) Low Pressure Integral System Test

José N. Reyes, Jr.
Department of Nuclear Engineering
Oregon State University

OSU/AP600 (APEX) Scaling Analysis

General Program Objectives and Scaling Objectives

General Scaling Methodology

H2TS Analysis Method

Chapter 4: Closed Loop Natural Circulation Scaling Analysis

Chapter 5: Depressurization Scaling Analysis

Chapter 6: Venting, Draining, and Injection Scaling Analysis

Chapter 7: LCS Recirculation Cooling Scaling Analysis

Chapter 8: Summary of Results, and Critical Attributes

GENERAL PROGRAM OBJECTIVES

- Design, construct and operate a 1/4 length scale test facility to examine AP600 integral system behavior, gravity driven injection and natural convection, long term cooling.

- Obtain experimental data to assess the computational methods that will be used to analyze the core cooling capability of the AP600.

SCALING OBJECTIVES

A. Obtain the similarity groups that should be preserved between the test facility and the full-scale prototype,

B. Establish priorities for preserving similarity groups,

C. Assure that important processes have been identified and addressed,

D. Provide specifications for test facility design, and

E. Quantify biases due to scaling distortions.

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HIERARCHICAL TWO-TIERED SCALING ANALYSIS METHOD

- Developed by USNRC
- Documented in NUREG/CR-5809
- Comprehensive scaling methodology
- Ishii-Kataoka similarity criteria can be developed using H2TS method

- The basic objective of the H2TS method is to develop sets of characteristic time ratios for the transfer processes of interest.

- Control volume balance equation for constituent "k"

$$\frac{dV_k \psi_k}{dt} = \Delta \, [Q_k \psi_k] \pm \Sigma j_{km} A_{km} \qquad (1.1)$$

where

$$\Delta \, [Q_k \psi_k] = [Q_k \psi_k]_{in} - [Q_k \psi_k]_{out} \qquad (1.2)$$

- In equation (1.1) the ψ_k term represents the conserved property; $\psi_k = \rho$, ρu, or $\rho \epsilon$ (mass momentum or energy per unit volume), V_k is the control volume, Q_k is the volumetric flow rate, j_{km} is the flux of property ψ_k transferred from constituent "k" to "m" across the transfer area A_{km}.

- Dimensionless initial conditions and boundary conditions

$$V_k^+ = \frac{V_k}{V_{k,0}}, \psi_k^+ = \frac{\psi_k}{\psi_{k,0}}, Q_k^+ = \frac{Q_k}{Q_{k,0}},$$

$$j_{km}^+ = \frac{j_{km}}{j_{km,0}}, A_{km}^+ = \frac{A_{km}}{A_{km,0}} \tag{1.3}$$

Substituting these groups into equation (1.1) yields:

$$V_{k,0}\psi_{k,0} \frac{dV_k^+ \psi_k^+}{dt} = Q_{k,0}\psi_{k,0}\, \Delta \left[Q_k^+ \psi_k^+\right] \pm \Sigma \left(j_{km,0} A_{km.0}\right) j_{km}^+ A_{km}^+ \tag{1.4}$$

Dividing both sides of this equation by $Q_{k,0}\ \psi_{k,0}$ yields:

$$\tau_k \ \frac{dV_k^+ \psi_k^+}{dt} = \Delta\left[Q_k^+ \psi_k^+\right] \pm \Sigma \Pi_{km} j_{km}^+ A_{km}^+ \qquad (1.5)$$

where the residence time of constituent "k" is

$$\tau_k = \frac{V_{k,0}}{Q_{k,0}} \qquad (1.6)$$

and the characteristic time ratio for a transfer process between constituents "k" and "m" is given by:

$$\Pi_m = \frac{j_{km,0} A_{km,0}}{Q_{k,0} \psi_{k,0}} \qquad (1.7)$$

CHAPTER 4, CLOSED LOOP NATURAL CIRCULATION SCALING ANALYSIS

- Rationale for selection of length scale and diameter scale
- Phenomena examined:
  - Single-phase natural circulation
  - Two-phase natural circulation
  - Core heat transfer
  - Flow regime transitions
  - Critical heat flux
- Parameters scaled
  - Time
  - Length
  - Primary system volume
  - Core geometry, flow area, length, power
  - Hot leg diameter, flow area, length, power
  - Cold leg diameter, length and geometry
  - Pressurizer surge line diameter, length and geometry
  - All components relative elevations

Chapter 4 Scaling Results

- Ishii-Kataoka Scaling Ratios were obtained using H2TS methodology.

- Analysis revealed the importance of satisfying the two-phase scaling criteria as a "set" in order to achieve properly scaled loop flow rates.

- When fluid property similitude exists, the core Π groups are unity.

Chapter 4 Additions

- Include section on single-phase forced and mixed convection heat transfer.

  For the AP600 cases of interest:

$$\frac{G_{rL}}{R_{eL}^2} >> 1$$

  This indicates free-convection turbulent flow along a heated vertical surface (Chen, 1986)

However, using the criterion of Metais and Eckert, 1964 for flow inside vertical tubes, $G_{rD}\ P_r\ L/D$ versus R_{eD} , indicates that forced convection turbulent flow behavior can be expected for portions of the transients.

- Effect of heat transfer regime during single-phase natural circulation transients is not significant as long as core power is being effectively removed.

- Use additional CHF correlations to examine Π_{CHF} distortions.

CHAPTER 5, DEPRESSURIZATION SCALING ANALYSIS

- Phenomena examined:
  - System depressurization rate
  - Fluid property scaling
  - Critical flow
  - Core decay power
  - Components stored energy
  - Steam generator dryout
  - Pressurizer stored energy
  - PRHR mass flow rate
- Parameters scaled:
  - Pressure setpoints
  - Core power
  - ADS/break sizes
  - Steam generator tube size, number, and shell side liquid level
  - PRHR tube size and number

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Table 5.2

System Level Scaling Analysis: Control Volume Balance Equations for System Depressurization (with Simplifying Assumptions)

System Fluid Mass:

$$\frac{d}{dt}\left(\rho_{sys} V_{sys}\right) = \Sigma \dot{m}_{in} - \Sigma \dot{m}_{out} \qquad (5.10)$$

System Fluid Energy:

$$\frac{d}{dt}(\rho_{sys} h_{sys}) = \frac{dP_{sys}}{dt} + \frac{1}{V_{sys}}\left[\Sigma(\dot{m}h)_{in} - h_{sys}\Sigma \dot{m}_{out} + q_{sys}\right] \qquad (5.18)$$

Solid Structure Energy:

$$\frac{d}{dt}(\rho_s V_s C_{vs} T_s) = -H_{sf}(T_s - T_f) A_{si} - \frac{(T_s - T_{amb})}{R_{th}} \qquad (5.5)$$

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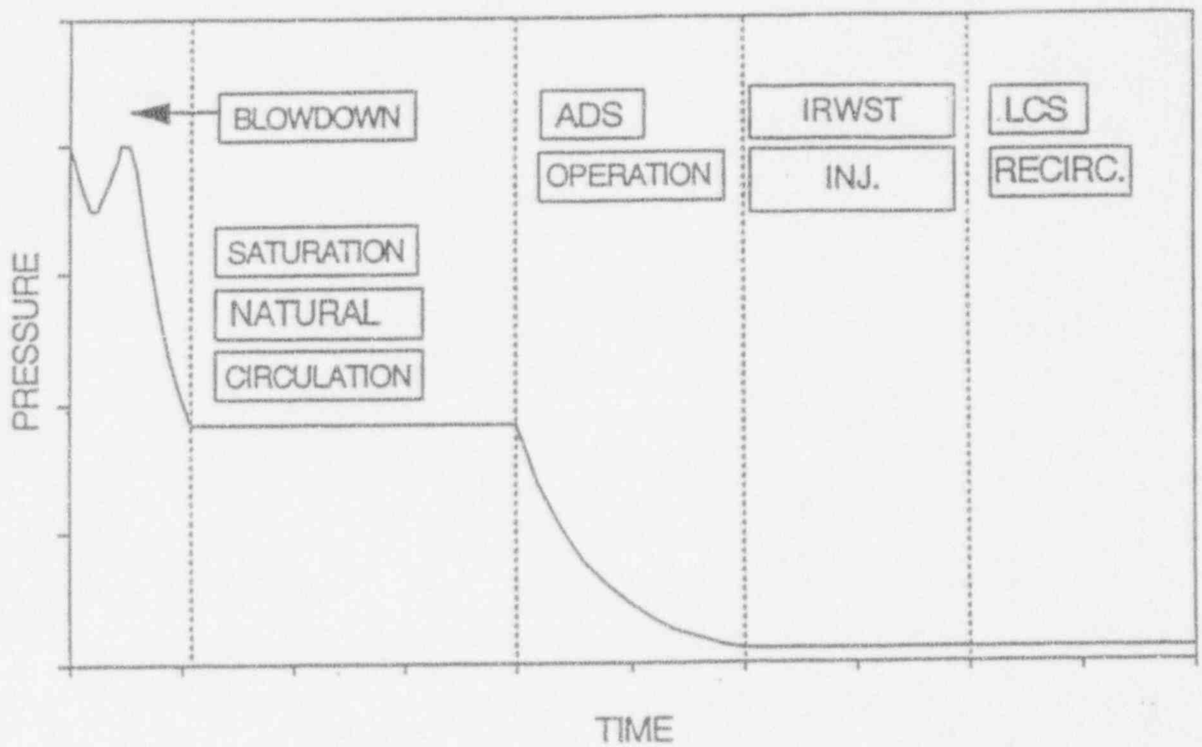
AP600 SBLOCA SCENARIO



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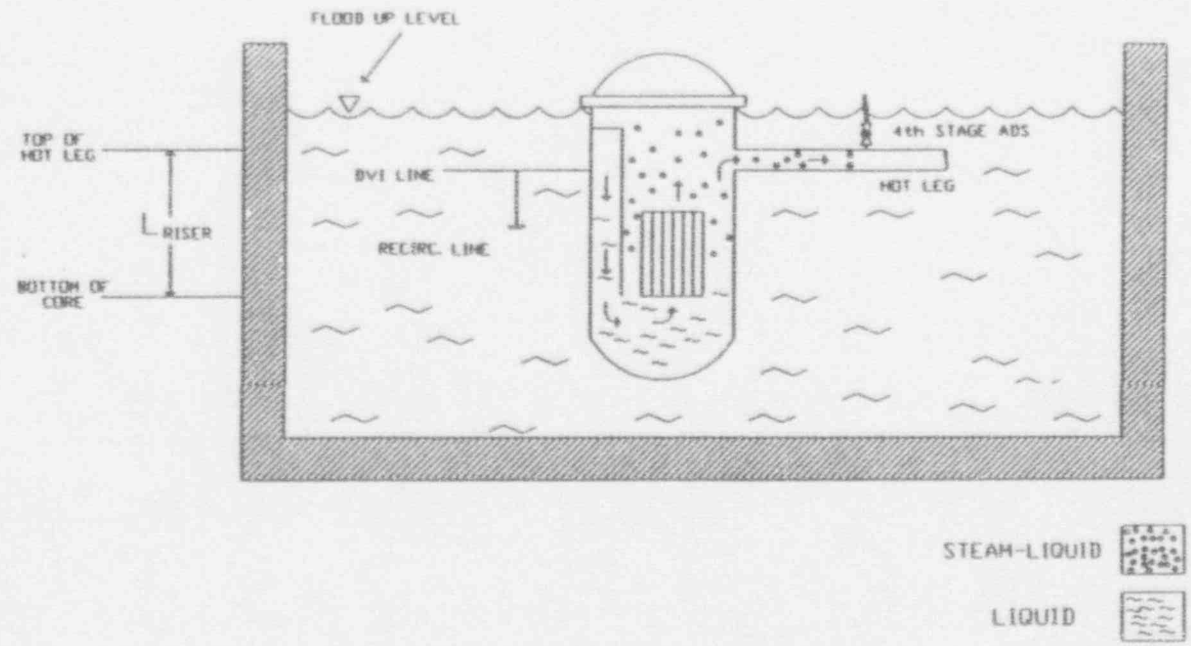
CONTAINMENT SUMP



CHAPTER 8: SUMMARY OF RESULTS AND CRITICAL ATTRIBUTES

- Sixty-three Π group ratios have been developed to scale the following processes of importance to AP600 SBLOCA and long-term cooling:

  - Natural circulation and recirculation flow phenomena
  - Depressurization phenomena
  - Venting, draining, and injection phenomena

- Upper and lower values have been calculated for each Π group ratio to assess the degree of distortion introduced because exact similitude is not achieved.

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Results of Π Group Ratio Evaluation:

- Two-phase natural circulation processes during long-term cooling will be adequately modeled in the test facility. Π_{CHF} will be examined further.

- Depressurization:

  - Dominant Π group ratios are represented by Π_7 through Π_{10} and Π_{25} through Π_{36} (break mass and energy flow rate ratios). Distortions are due to the effect of pressure scaled fluid properties on critical flow ratios. The break mass flow and energy flow rates cannot both be ideally scaled under reduced pressure conditions with the same fluid.

  - Although the values for Π_{19} through Π_{24} (SBLOCA power ratios) exceed 1.5, Table 5.16 indicates that these Π groups are not important to depressurization.

Results of Π Group Ratio Evaluations (continued):

- Depressurization (continued):

  - Because fluid property similitude will exit during ADS 4 operation, depressurization from ADS 4 conditions will be simulated quite well. (See Π_{11}, Π_{29}, and Π_{35})

- Venting, Draining, and Injection:

  - The dominant Π groups for the CMT phenomena are Π_{37} through Π_{39}. The distortions in Π_{37} (CMT steam condensation rate) is due to the reduced CMT surface area and effects of pressure scaling on fluid properties.

- Evaluate the importance of the distortions on the data.

Conclusions:

- Assessment of Π groups indicates that pressure scaled phenomena in the model will be representative of phenomena expected in the full-scale AP600.

- Long-term cooling behavior will occur when fluid property similitude exists. Π group assessment indicates that ADS 4 depressurization process through long-term cooling will be modeled well in APEX.

- The APEX facility data will provide sufficient data to benchmark the codes.

OSU AP600 LOW PRESSURE INTEGRAL SYSTEMS EFFECTS TESTS - TEST MATRIX

L.E. Hochreiter

Westinghouse Electric Corporation

- Approach

  - OSU test matrix consists of two types of experiments

    - Cold and hot pre-operational tests used to characterize the system and components of the facility

      - For computer code input to reduce uncertainty

      - To provide additional data on components with controlled boundary conditions

    - Matrix tests with one-at-a-time parameter variations

OSU

COLD PRE-OPERATIONAL TESTS - (Revised 9/14/93)

TEST	DATA	HOW USED IN CODE
CMT Gravity Drain	Flow versus line ΔP, CMT volume versus height	Verify the line resistance form and frictional losses of the CMT injection lines, CMT volume
Accumulator Drain	Flow versus line ΔP, volume versus height	Same as above but for accumulator
IRWST Drain	Flow versus line ΔP, volume versus height	Same as above but for IRWST
Sump Drain to RCS	Flow versus line ΔP, volume versus height	Same as above but for sump
Charging Pump Flow vs. Pressure	Flow versus pressure table	Used as a boundary condition in the code
NRHRS Pump Flow vs. Pressure	Flow versus pressure table	Same
Primary Flows and ΔP's	Loop pressure drop for a given flow	Used to adjust the form losses in the code to match ΔP's for a given flow
Vessel Bypass Determination	Determination the vessel bypass to upper head	Set bypass flow
Pressurizer and CMT balance line ΔPs	Flow versus ΔP for balance lines	Confirm line resistance, set orifice as needed
Loop Drain for Volume Check	System volume versus height	Confirm OSU model volumes

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HOT PRE-OPERATIONAL TESTS - (Revised 9/14/93)

TEST	DATA	HOW USED IN CODE
Steady-State Forced Flow Test Heat Losses, and Calometric Balance	Flow rate, pressure drop, and temperature distributions, pipe metal temperatures rod bundle, PRHR, steam generator temperatures	Verify the loop form and frictional resistances, heat loss, system heat balance, heat transfer in bundle steam generator, PRHR
Primary system heat capacity test	Cool down rate of the system wall, fluid temperatures, pressure	Verify the structural models in the code
Secondary Side Performance	Heat transfer versus power level, verify the steam generator control system	Verify steam generator model in codes
PRHR Natural Circ Tests	PRHR temperatures, IRWST temperatures, PRHR flow	Confirm PRHR flow, heat transfer, for code
Primary Side Natural Circ Flow	Primary system, pressure, temperature, ΔP distribution Rod bundle, PRHR, steam generator temperatures	Confirm the natural circulation behavior of code for primary, flows, temperatures, core, steam generator, heat transfer.
CMT Recirculation Behavior	CMT balance line flows, CMT wall fluid temperatures, pressures	Confirm CMT recirculation behavior, flows, and temperatures, mixing effects
CMT Draindown via Pressurizer Balance Line	CMT fluid and wall temperature distribution; pressurizer balance line, temperature, pressure distribution; system pressures, pressure drops, pressurizer pressure	Verify CMT draining behavior, heat transfer, heat up, CMT condensation behavior, mixing effects to develop/verify CMT model
CMT Draindown via Cold Leg Balance Line	Same except use cold leg balance line as steam supply from rod bundle	Same, except examine CMT behavior with larger cold leg balance line flows
Low Pressure Depressurization Checkout	Full compliment of data on system	Verify break flows, system transient behavior, pressures, pressure drops, temperatures and break flows

OSU TEXT MATRIX - Revision 3 9/14/93

TEST NO.	TEST TYPE	TEST DESCRIPTION	PRHR STATUS	NSS STATUS	SINGLE FAILURE	COMMENTS
SB1	SBLOCA	2" CLB, bottom of pipe, Loop A,**	On	Off	1 of 2 4th stage ADS	Reference cold leg break
SB2	SBLOCA	2" CLB, bottom of pipe, Loop B	On	Same	Same	Break on opposite side of plant
SB3	SBLOCA	2" CLB, top of pipe, Loop A	On	Same	Same	Break orientation
SB4	SBLOCA	2" CLB, bottom of pipe, Loop A	Off	On	Same	Safety/non-safety system interaction, prevent 4th stage ADS
SB5*	SBLOCA	~1" CLB, bottom of pipe, Loop A	On	Off	Same	Break size effect
SB6	SBLOCA	4" CLB, bottom of pipe, Loop A	On	Off	Same	Break size effect
SB7	SBLOCA	2" CLB, bottom of pipe, Loop A	On	Off	Fail complete train 1-4	Beyond design basis. ADS performance
SB8	SBLOCA	2" CLB, bottom of pipe, Loop A	On	Off	Fail stages 1,3	ADS performance

* Continue into long-term cooling mode

** Loop A is CMT side, Loop B is pressurizer side

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OSU TEXT MATRIX - Revision 3 9/14/93

TEST NO.	TEST TYPE	TEST DESCRIPTION	PRHR STATUS	NSS STATUS	SINGLE FAILURE	COMMENTS
SB9	SBLOCA	2"CL balance line, horizontal loop, Loop A	On	Off	Fail 1 of 2, 4th Stage ADS	Break location asymmetric CMT performance
SB10*	SBLOCA	DEG, CL balance line, horizontal Loop A	On	Off	Same	Break size effect
SB11*	SBLOCA	DEG, DVI line break	On	Off	Same	Break location, loss of on ECCS train
SB12*	SBLOCA	DEG, DVI line break	On	Off	Fail 1,2 ADS Stage	Alternate Single Failure
SB13*	SBLOCA	2" DVI line break	On	Off	1 of 2, 4th stage ADS	Break size, asymmetric CMT behavior
SB14*	SBLOCA	Inadvertent ADS, stage 1 open	On	Off	Same	ADS performance

* Continue into long-term cooling mode

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OSU TEXT MATRIX - Revision 3 9/14/93

TEST NO.	TEST TYPE	TEST DESCRIPTION	PRHR STATUS	NSS STATUS	SINGLE FAILURE	COMMENTS
SB15	SBLOCA	2" HLB bottom of pipe, Loop A	On	Off	1 of 2 4th stage ADS	Break orientation
SB16*	SBLOCA	DEG PRZ/CMT BL break, between check valve/CMT, Loop A	On	Off	Same	Break location
SB17	SBLOCA	DEG, PRZ/CMT BL break between PRZ and check valve	On	Off	Same	Break location
SB18*	SBLOCA	2" CLB, bottom of pipe, Loop A	On	Off	Same	Repeat test
SB19	SBLOCA	2" CLB, bottom of pipe, Loop A with transient containment back pressure	On	Off	1 of 2 4th stage	Effects of transient containment pressure
SB20*	SBLOCA	2" CLB, bottom of pipe, Loop A with revised condensate return	On	Off	1 of 2 4th stage	Effects of reduced condensate return on core cooling
LTC21	LBLOCA	Simulate long-term cooling effects following LBLOCA	On	Off	1 of 2 4th stage	Decay heat removal effects early in transient

* Continue into long-term mode

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- Test matrix

  - Tests have been structured around the SSAR Analysis

  - Tests are planned examining different and more limiting single failures

  - Some NRC comments have been incorporated into matrix, others are under evaluation

  - Overlap tests are planned with SPES to examine scaling behavior.

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- Conclusions

  - Test matrix is sufficiently broad to adequately provide the information to validate the SSAR analysis codes

  - Overlap tests with spes are included to provide a scaling overlap.

OSU PROGRAM SCHEDULE

E.J. Piplica, Manager

AP600 Testing Engineer

CHART 10 - LOW PRESSURE 1/4th HEIGHT INTEGRAL SYSTEMS

(Sheet 1 of 2)

SCHEDULE AS OF 08/13/93

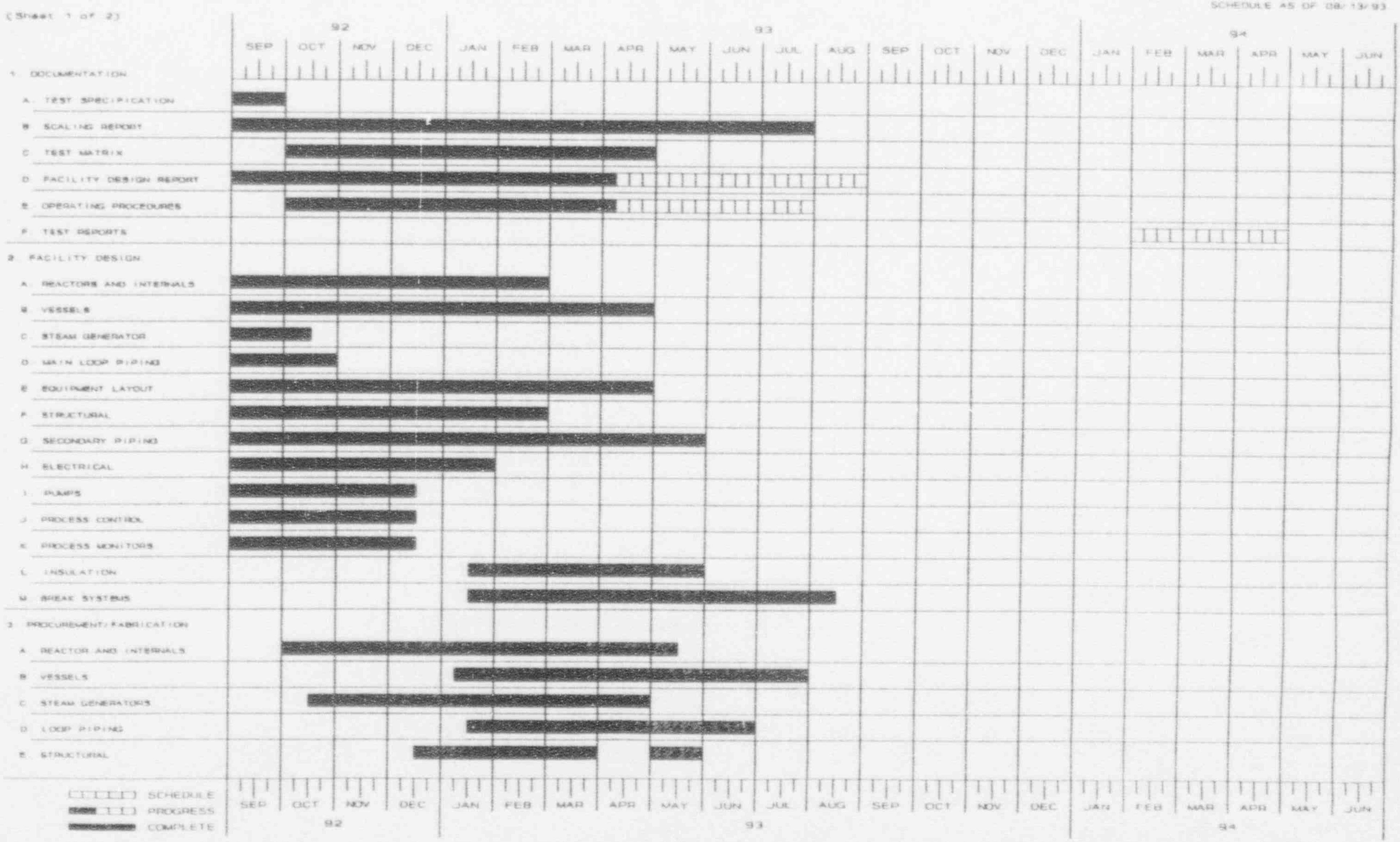
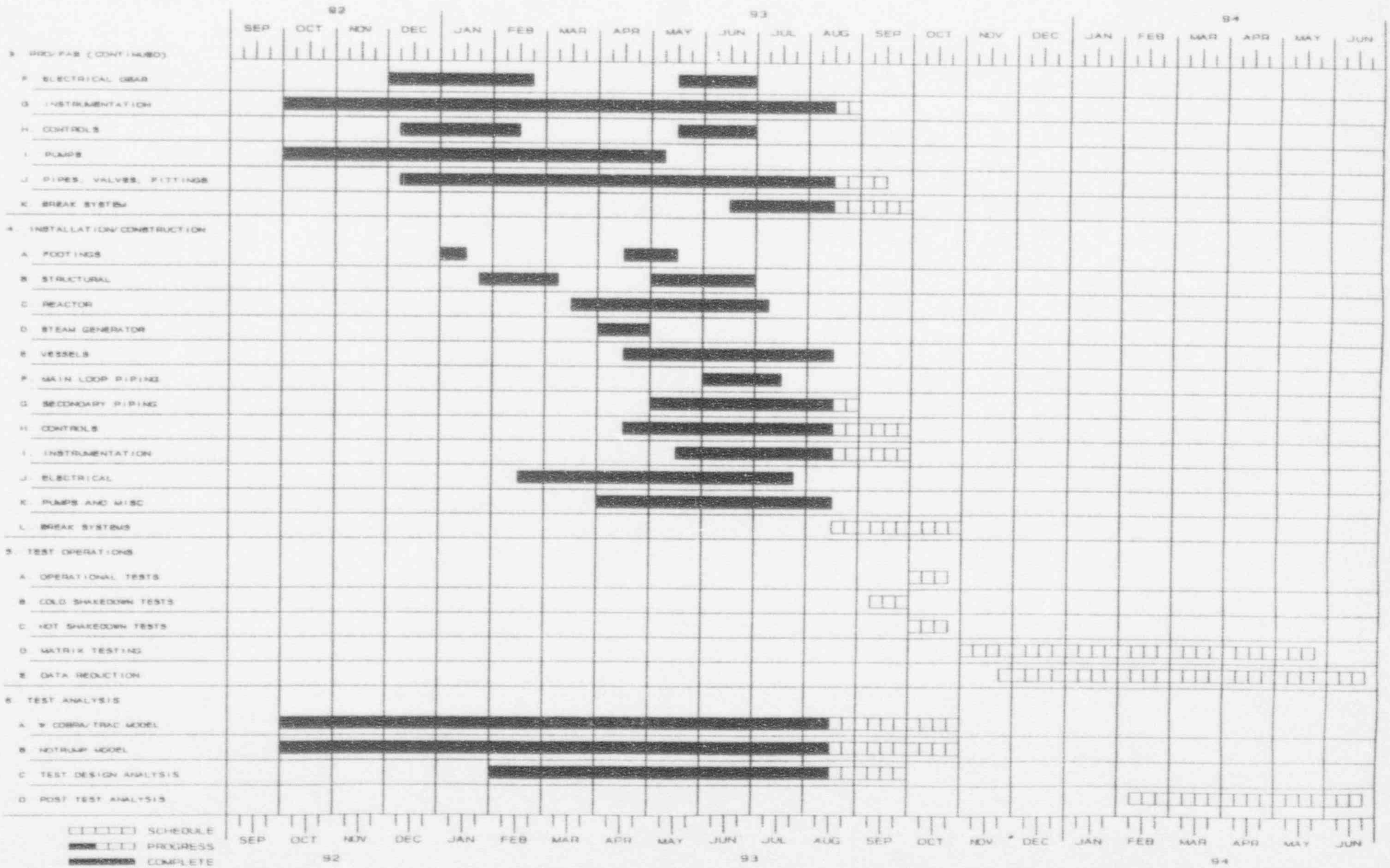


CHART 10 - LOW PRESSURE 1/4th HEIGHT INTEGRAL SYSTEMS

(Sheet 2 of 2)

SCHEDULE AS OF 08/13/93



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SCHEDULE

- Facility construction is about six months behind our FY 93 work plan developed in July 1992

- Original plan for testing was serial:

  - Complete all construction activities

  - Commission facility

  - Perform cold shakedown tests

  - Perform hot shakedown tests

- Delays in the design of the BAMS and its subsequent fabrication and installation threatens to further delay the initiation of testing

- Develop revised construction/testing plan

  - Continue facility construction

  - Perform cold shakedown tests as construction continues

  - Complete BAMS design; procure, fabrication and installation and cold shakedown tests

  - Perform hot shakedown tests

  - Initiate matrix tests

SCHEDULE

- Actions to implement revised plan
  - Develop detailed project schedule
  - Add manpower to identify activities to complete and develop schedule
  - Assign Westinghouse Test Engineer to OSU
  - Construction contractor will support test activities through shakedown testing