Westinghouse Electric Corporation
Energy Systems

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ET-NRC-93-3834
NSRA-APSL-93-0065
Docket No.: STN-52-003

March 9, 1993

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

ATTENTION: R. W. BORCHARDT

SUBJECT: PRESENTATION MATERIAL FROM THE MARCH 9-10, 1993 MEETING ON THE AP600 TESTING PROGRAM

Dear Mr. Borchardt:

Attached is the presentation material used during the Westinghouse AP600 presentations on March 9 and 10, 1993 to the U.S. Nuclear Regulatory Commission. The purpose of this meeting was to review and discuss the testing program for the AP600 design.

The Westinghouse Electric Corporation copyright notice is also attached.

Please contact Brian A. McIntyre on (412) 374-4334 if you have any questions concerning this transmittal.

N. J. Liparulo, Manager
Nuclear Safety & Regulatory Activities

/nja

Attachment

cc: R. Hasselberg, NRC
T. Kenyon, NRC (w/o attachments)
B. McIntyre, Westinghouse

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AP600

WESTINGHOUSE ELECTRIC CORPORATION

PRESENTATION

TO

UNITED STATES

NUCLEAR REGULATORY COMMISSION

WESTINGHOUSE ENERGY CENTER

MARCH 9-10, 1993

AGENDA

AP600

WESTINGHOUSE/NRC MEETING
AP600 DESIGN CERTIFICATION TESTING PROGRAM OVERVIEW

MARCH 9, 1993

9:00	INTRODUCTION	B. A. McINTYRE
9:15	AP600 OVERVIEW	T. L. SCHULZ
10:00	BASIS FOR AP600 TEST AND ANALYSIS PROGRAM	L. E. HOCHREITER
11:00	AP600 TESTING PROGRAMS	E. J. PIPLICA
12:30	LUNCH	
1:30	AP600 TEST ANALYSIS PLAN	L. E. HOCHREITER
2:00	W/NRC INTERFACE, INFORMATION FLOW	J. C. BUTLER
2:30	DRIVE TO W SCIENCE & TECHNOLOGY CENTER	
3:00	TEST FACILITY TOUR	ALL

MARCH 10, 1993

9:00	CMT & PCCS WATER DISTRIBUTION FACILITY TOUR	ALL

INTRODUCTION

B. A. McINTYRE, MANAGER
ADVANCED PLANT SAFETY AND LICENSING

AP600 OVERVIEW

T. L. SCHULZ, FELLOW ENGINEER

SYSTEMS AND EQUIPMENT ENGINEERING

AP600 Safety Systems

- **Provide Passive Safety Systems**
  - Greatly simplified considering construction, maintenance, operation, ISI/IST
  - Mitigate design basis accidents without use of NNS systems
  - Meet NRC safety goals without NNS systems (EPRI)
  - Meet EPRI safety goals with NNS systems
- **Safety Systems Design Features**
  - Only passive processes; no "active" equipment
  - Significant design margins
  - Redundancy to meet single failure criteria
  - PRA based redundancy / diversity
  - Greatly reduced need for operator actions
- **Safety Equipment Design Features**
  - Reliable / experience based equipment
  - Improved inservice testing / inspection
  - Reg. Guide 1.26 Quality Group A, B, or C
  - Seismic I design
  - Qualified Equipment
  - Availability controlled by Technical Specifications with shutdown requirements
  - Reliability Assurance Program
  - Tier I description and ITAAC

AP600 Non-Safety Systems

- **Provide Non-Safety Systems**
  - Reliably support normal operation
  - Minimize challenges to passive safety systems
  - Not required to mitigate design basis accidents
  - Not required to meet NRC safety goals
  - Used to meet EPRI safety goals
- **Non-Safety Systems Design Features**
  - Redundancy for more probable failures
  - Connections to the non-safety diesels
  - Automatic actuation and controls
  - Separated from safety systems
  - Separation within NNS systems not required
- **Non-Safety Equipment Design Features**
  - Reliable / experienced based equipment
  - Use Reg. Guide 1.26 Quality Group D
  - Uniform Building Code, not seismic 1
  - Availability controlled by plant procedures (50.59) without shutdown requirements
  - Reliability Assurance Program
  - Less detailed Tier 1 description and ITAAC

AP600 Decay Heat Removal

o Startup Feedwater System

- Non-Safety feedwater for normal shutdowns and transients
- Two motor driven pumps feed all SGs
- Water supplied from deaerating heater or CST
- Automatic start and flow control
- Automatic load on NNS diesels

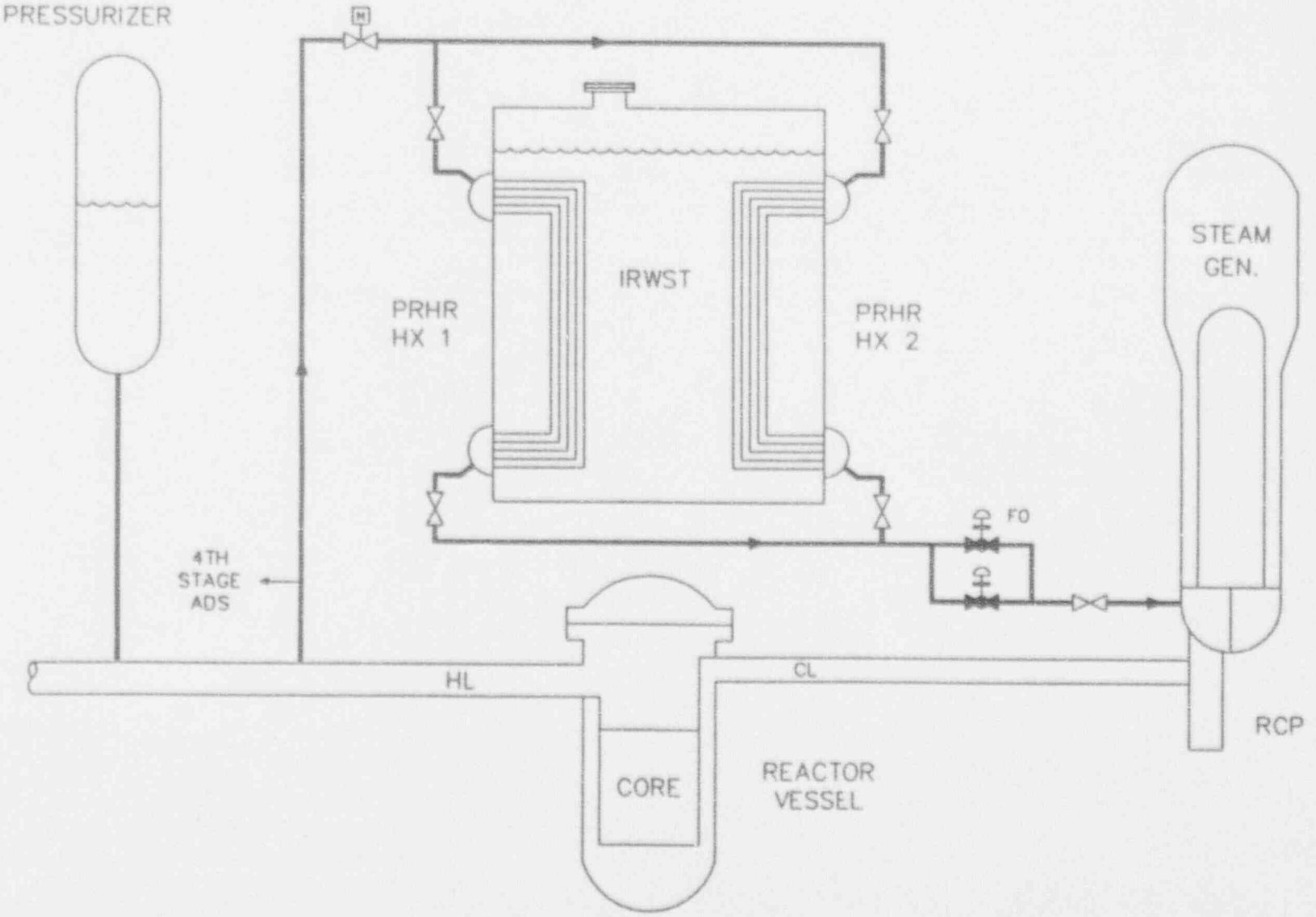
o Passive RHR Heat Exchanger

- Safety cooling for events where SFW is unavailable and during non-LOCA accidents
- Two heat exchangers connected directly to RCS
- Forced flow with RCP; natural circulation without RCP
- Automatic actuation; two fail-open valves
- PRHR HX, located in IRWST, provides heat sink
- IRWST remains subcooled for 2-3 hours
- Passive containment cooling provides ultimate heat sink

o RCS Feed and Bleed

- Provides backup to SFW and to PRHR HX for PRA multiple failure events
- Feed from CMT/Accumulator/IRWST, bleed from ADS
- Automatic actuation of CMT on high RCS temperature with low SG level

AP600 - Passive RHR Heat Exchanger



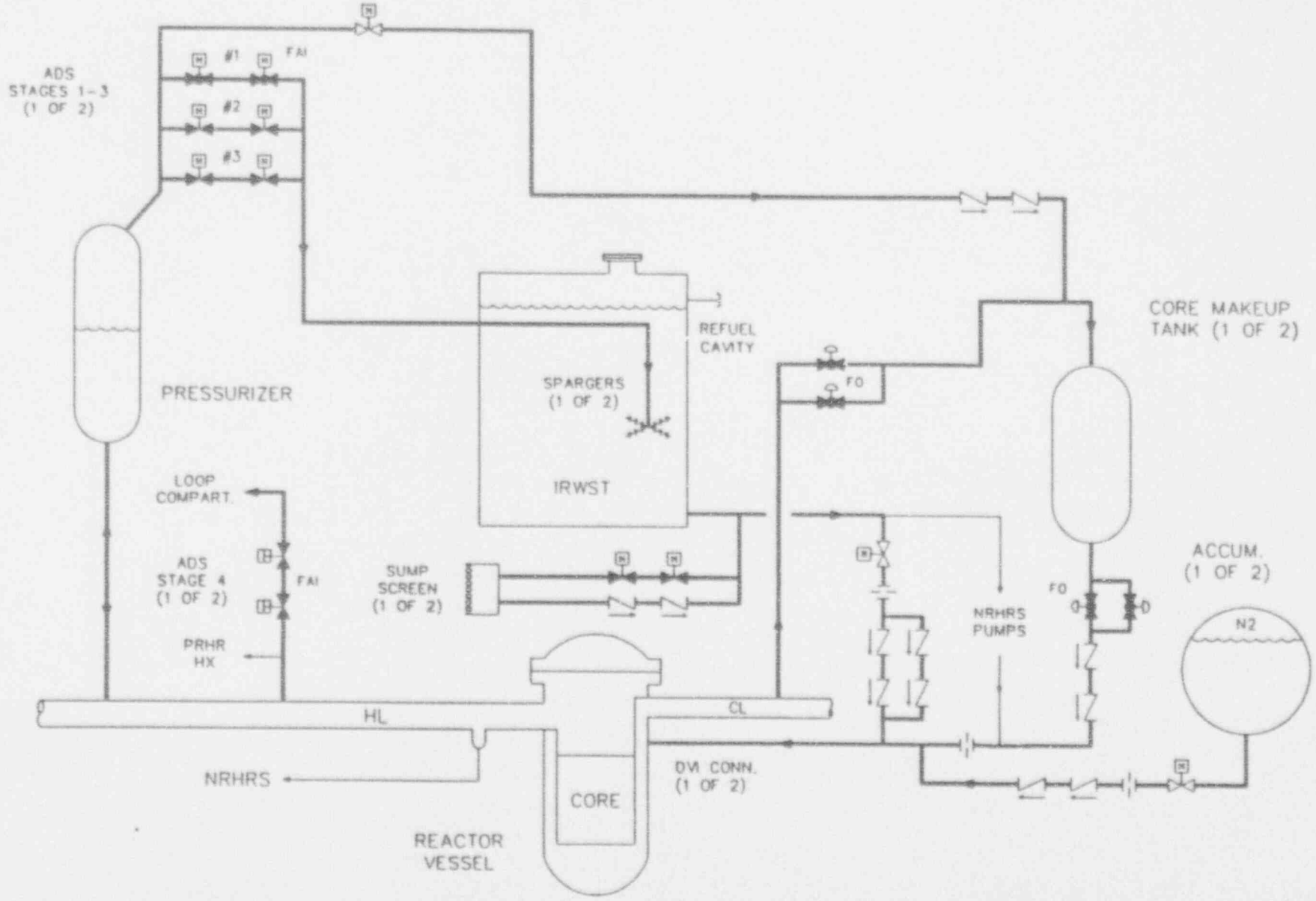
AP600 RCS Makeup

- **CVS Makeup Pumps**
  - Non-Safety makeup for normal plant operation
  - Can accomodate 3/8" break without SI
  - Two motor driven centrifugal pumps
  - Automatic start and connection to diesel

- **Core Makeup Tanks**
  - Safety makeup to the RCS when CVS unavailable or during larger breaks
  - Two tanks provide makeup by gravity at any RCS pressure
  - Automatic actuation by opening redundant air operated valves, fail open, for each CMT
  - Provides significant makeup before ADS actuation; 3 gpm leak for 40 hours

- **PXS Tanks and ADS**
  - Safety injection for LOCA
  - Also PRA backup to CMT & CVS
  - Two CMT, two Accumulators and one IRWST provide makeup
  - Four stages of ADS provide controlled depressurization of RCS

AP600 Passive Safety Injection



AP600 ADS Reliability

o ADS Capacity

- Can tolerate single failure and achieve IRWST gravity injection with conservative analysis
- Can tolerate multiple failures (CCF) and achieve IRWST gravity injection with best estimate analysis

o ADS Testing

- Certification testing
  - full scale ADS testing provides system testing (stages 1-3) and valve feasibility testing
  - OSU and SPES provide scaled testing of integrated plant / systems
- FOAKE testing
  - equipment qualification testing to be performed
- In-plant startup testing
- Operation testing

AP600 Check Valves

- Current PWRs Use Similar Check Valves In Similar Conditions
  - Simple swing disk valve design
  - RCS chemistry
  - Stainless steel with stellite seats
  - Infrequent use, normally closed
- Well Designed, Simple Check Valves Are Reliable In NPP Service
  - Search of NPRDS failure records (1984 to 1990) indicate 4500 check valve failures
  - Of these only 87 were failures to open
  - None of the failures was for a check valve with similar conditions to the IRWST valves
  - No indication of boric acid corrosion or self welding / corrosion was found
- Check Valve Testing
  - Performance tests show AP600 IRWST injection and recirculation check valves perform well
  - Further testing is being discussed
    - In-plant testing / inspections
    - Investigate corrosive bonding and other sticking failure mechanisms

AP600 Passive Capability During Shutdowns

- **Passive Safety Functions Provided During All Shutdown Modes**

- **Hot Shutdown / Hot Standby / Cold Shutdown**
  - Technical Specifications require PRHR HX, CMT, IRWST, and ADS to be available

- **Cold Shutdown Mid-Loop**
  - PRHR HX ineffective (RCS open)
  - CMT / accumulator unnecessary
  - Technical Specifications require:
    - Containment integrity
    - ADS stages 1, 2, and 3 open
    - IRWST MOV available

- **Refueling Shutdown**
  - Refueling cavity provides >72 hours with equipment hatch open
  - Refueling cavity takes >6 hours to boil

AP600 Post 72 Hour Actions

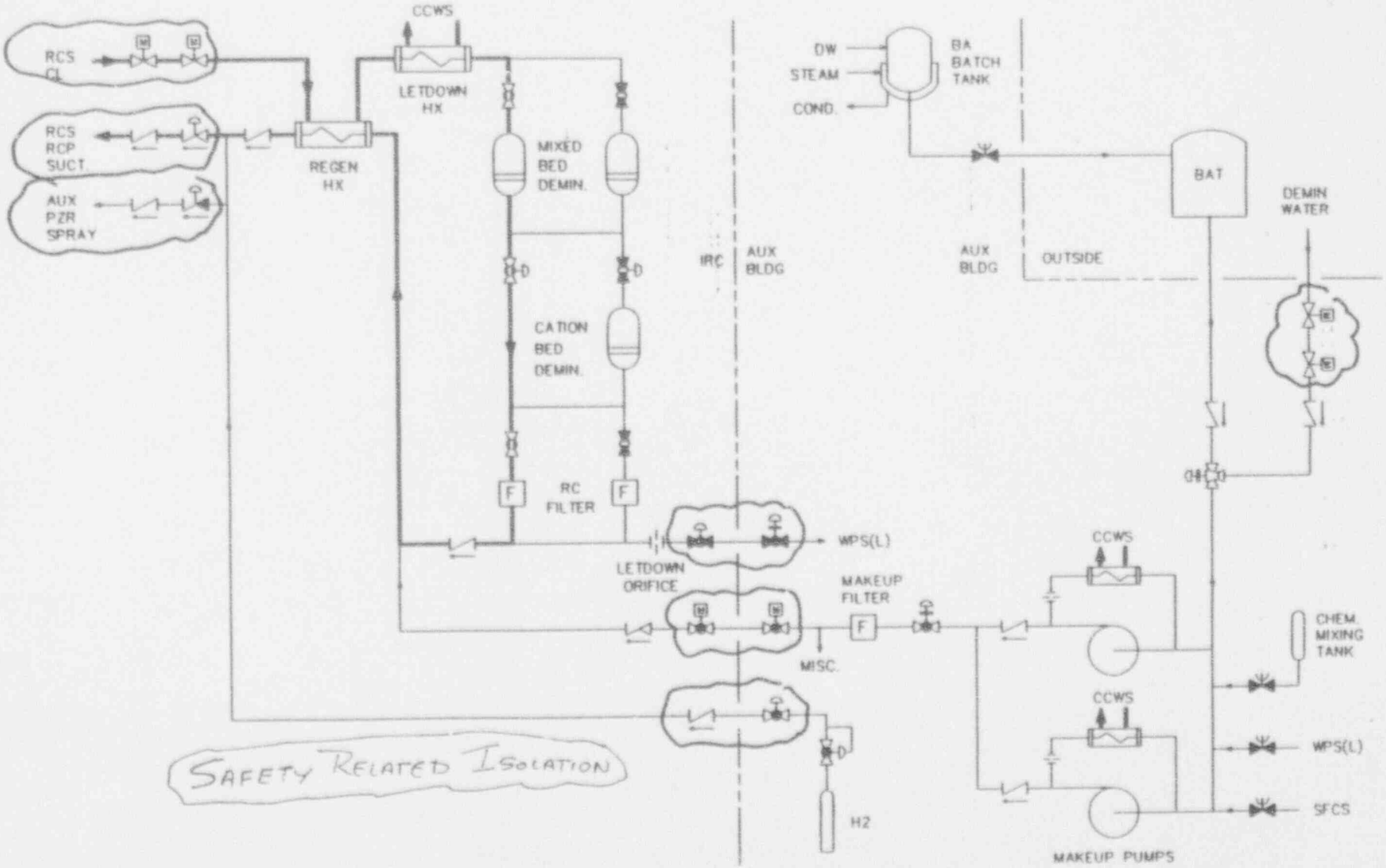
- Long Term Passive Safety System Operation
  - Core cooling and ultimate heat sink remain available indefinitely (>>72 hours) without operator action or offsite support
  - Other safety functions require limited offsite support after 72 hours
  - Limited offsite support after 72 hours
    - Uses readily accessible and transportable equipment and supplies from offsite
    - Safety related connections provided to engage offsite support equipment
  - Installed nonsafety systems NOT required to sustain safety system functions
    - Recovery to cold conditions accomplished when non-safety systems are made available

Non-Safety System Isolation Functions

AP600

- Non-Safety Systems Provide Some Safety Related Isolation Functions
  - RCS pressure boundary isolation
  - Containment isolation
  - Other isolation functions provided to mitigate DBA's
- These Isolation Capabilities Are Fully Safety Related
  - Single failure capability
  - Reg. Guide 1.26 quality group A, B, or C
  - Seismic I
  - Technical Specification controls
  - Described in SSAR and ITAAC

AP600 Chemical and Volume Control System



AP600 PRA Activities

- PRA Has Been Used As Design Tool
  - Five major PRA quantifications / design iterations
  - Heavy interaction between plant designers and risk analysis
  - Initial PRA study done in 1987
  - Latest PRA submitted to NRC in June 1992
  - Each PRA included:
    - Plant design input, PRA model development
    - Quantification, sensitivity studies
    - Review, understanding of results
    - Development of ideas to improve plant; analysis, procedures, and design
  - Successive PRA studies became more detailed

- PRA Has Shown That AP600:
  - Meets NRC and EPRI PRA goals (CDF & SRF)
  - Results not overly dependent on
    - Operator actions
    - Non-safety systems
    - Any one passive system

AP600 Core Melt Frequency

Internal Events at Power	AP600	Current Plants	Reduction
Transients	7.1E-8	1.3E-5	180
Blackout	2.9E-9	6.6E-6	230
SG Tube Rupture	2.6E-9	1.7E-6	650
LOCA - Small	7.7E-8	8.0E-6	100
LOCA - Medium	8.8E-8	5.0E-6	60
LOCA - Large	1.6E-8	8.0E-7	50
ATWT	4.5E-8	2.2E-6	50
Loss of Cooling	1.6E-9	1.1E-5	6800
Interfacing LOCA	< E-9	1.0E-6	1000
Vessel Rupture	3.0E-8	3.0E-7	10
	---	---	---
Total	3.3E-7/yr	5.0E-5/yr	150
Without Nonsafety Systems (1)	2.6E-6/yr	~1 E-3/yr	380

Note (1) Without CVS, RNS, SFW, and AC power

Nonsafety Systems Roles In Initiating Event Frequency

Events At Power	NNS System	DID System
Transients	yes	no
Loss of Cooling	no	yes
Blackout	yes	no
SG Line Breaks	no	no
SG Tube Rupture	no	no
LOCA - Very Small	no	yes
LOCA - Small	no	no
LOCA - Medium	no	no
LOCA - Large	no	no
ATWT	yes	no
Interfacing LOCA	no	no
Vessel Rupture	no	no

Core Melt Increase When A System Is Unavailable

System	CMF	Increase
IRWST injection	3.5E-4/yr	1100
PRHR HX & CMT	1.8E-4	550
PRHR HX	4.0E-5	120
Accumulators	3.9E-6	12
ADS stages 1,2,3	3.8E-6	12
ADS stage 4	2.1E-6	6
Containment integrity	1.1E-6	3
Normal RHR	6.6E-7	2
CVCS	5.9E-7	2
Startup Feedwater	4.8E-7	2
Diesel generators	3.7E-7	1
All Systems Available	3.3E-7/yr	

Core Melt Increase When A System Is Unavailable

System	CMF	Increase
IRWST injection	3.6E-4/yr	4000
ADS stages 1,2,3	1.0E-6	11
PRHR HX & CMT	9.2E-7	10
PRHR HX	7.1E-7	8
Normal RHR	4.6E-7	5
Diesel generators	2.3E-7	3
ADS stage 4	1.1E-7	1
Accumulators	8.9E-8	1
Containment integrity	8.9E-8	1
CVCS	8.9E-8	1
Startup Feedwater	8.9E-8	1
All Systems Available	8.9E-8/yr	

Defense-In-Depth System Importance

	Core Damage Frequency	Release Frequency
Base Case, All Systems		
- Internal at Power	3.3E-7/yr	2.1E-8/yr
- Internal at Shutdown	8.9E-8/yr	1.0E-9/yr
- Total Internal Events	4.3E-7/yr	2.2E-8/yr
Sensitivity Case (1)		
- Internal at Power	2.6E-6/yr	2.2E-7/yr
- Internal at Shutdown	5.4E-7/yr	7.0E-8/yr
- Total Internal Events	3.1E-6/yr	2.9E-7/yr
NRC Goal		
- Internal / External Events	1.0E-4/yr	1.0E-6/yr

Notes:

(1) Sensitivity case retains same IE frequencies and removes all mitigation credit for CVS, SFW, RNS and onsite / offsite AC power

BASIS FOR AP600 TEST AND ANALYSIS PROGRAM

L. E. HOCHREITER, CONSULTING ENGINEER
NUCLEAR SAFETY ANALYSIS AND STRATEGIC DEVELOPMENT

Basis for AP600 Test and Analysis Program

Things We Considered When Structuring the AP600 Test Program

- What systems are different?
- What design information is needed to evaluate performance?
- What phenomena would be important for safety analysis assessment?
- What data are needed for modeling?
- What data exist for code validation?
- Which codes or models should we use?

Basis for AP600 Test and Analysis Program

- We examined the key phenomena for
  - Large break LOCA
  - Small break LOCA
  - Transient analysis
  - Containment analysis
  - Long-term cooling
- Assessed the new features
- Determined if data existed for code validation
- If no data was available or if was insufficient, a specific test was developed

Small Break LOCA

AP600

LOCA Process	AP600 Uniqueness w.r.t. W Plants	SBLOCA Model Validation - Does It Exist?	AP600 Specific Validation Needed	Comments
ADS Blowdown Process	Yes	No	ADS tests, modeled with SBLOCA code to develop/verify model	Critical item for AP600
Pressurizer Model to Handle ADS	Yes	Yes, LOFT	May need to verify pressurizer model to be consistent with ADS	Pressurizer model has to be verified to accommodate larger breaks
Core H.T.	No	Yes	None	
Structure H.T.	Yes, Reflector	Yes, not specific to AP600	None	
HHSI Delivery, Signal, Behavior, Delivery rate	Yes	No	CMT component test, along with ADS tests should show signal generation and flow rates	
Two phase loop ΔP's	No	Yes	None	
Loop Seal Behavior	Yes, no loop seals	Yes	None	
HHSI Delivery Location	Yes, delivery in downcomer	No	CMT tests, UPTF, CCTF downcomer	CCTF, UPTF data should be available. Model these tests with WCFT

Small Break LOCA (continued)

LOCA Process	AP600 Uniqueness w.r.t. W Plants	SBLOCA Model Validation - Does It Exist?	AP600 Specific Validation Needed	Comments
Critical Flow	Yes, ADS valves	No	ADS tests will test actual valves, sparger	Need to develop valve critical flow model, sparger model
Loop Draining Behavior	Yes, 2HL, 4CL	Not directly	None, code can handle (licensed NOTRUMP for CE 2x4 design)	
SB SG Behavior	No	Yes	None	
Cooldown with PRHR	Yes	No	PRHR Tests	Examine PRHR effect on system response

Containment Analysis

Containment Behavior	AP600 Uniqueness w.r.t. W Plants	Cont. Validation - Does It Exist?	AP600 Specific Validation Needed	Comments
Evaporative Film Cooling	Yes	No	PCCS Tests, 1/8 Scale Tests, Heated Plate Tests	Currently Planned Tests Will Meet Needs
Condensation, with Non-Condensibles	No	Yes, not AP600 Specific	Same as above, plus other data, CVTR, U. of Wisconsin	Same as above
Air Cooling of Steel Shell	Yes	No	Same as above	Same as above
Internal Circulation Patterns in Containment	No	Yes, not AP600 Specific	Same as above	Same as above
Effect of Hydrogen on Containment Heat Transfer	No	Yes, not AP600 Specific	Same as above	Same as above
Liquid Film Distribution on Containment	Yes	No	Film Flow Experiments Will Design the Water Distribution o Plate Tests o Large Scale Film Flow Tests	Prototypical System Will be Tested
Effects of Buildings and Wind Velocity on Air Flow over Steel Shell	Yes	No	Small Scale Wind Tunnel Data Exists, Additional Tests are Planned	Goal is to make design Wind Neutral

Basis for AP600 Test and Analysis Program

This Process Led Us To:

- Perform Scaled - Full Scale Design Verification Tests of New Critical Components
- Perform Separate-effects Tests on Large - Full Scale Hardware to Reduce Scaling Concerns
- Perform Low Pressure Integral Systems Test at Reduced Scale to Verify Safety Analysis Codes for Gravity Drain/Core Cooling System Behavior when Passive Systems would be most challenged (OSU)
- Emphasize containment performance using small scale tests for model development and two larger scale systems tests for model verification
- Use best estimate thermal-hydraulic system codes
- After discussions with the NRC staff and the ACRS; Westinghouse proposed to perform full height, full pressure integral systems tests to remove any residual doubt on passive safety system performance (SPES-2)

Tests on Passive Core Cooling Systems

- Used to verify computer models
  - Passive Residual Heat Removal System Heat Exchanger tests to obtain heat transfer data for PRHR performance
  - Core Makeup Tank test to verify condensation and gravity drain models
  - Automatic Depressurization System tests
  - OSU Integral Systems tests will verify long-term cooling flow path with gravity feed at medium-to-low pressures
  - SPES Integral Systems tests will examine high pressure integral systems effects for SBLOCA, SGTR and MSLB situations

Tests on Passive Containment Cooling Systems

- Used to assess and verify safety analysis methods
  - Develop/confirm evaporative heat transfer tests for interior of containment
  - Containment wind tunnel tests
  - Full scale segment of the containment dome to investigate water distribution
  - Passive containment cooling tests, 3 ft. diameter by 25 ft. high vessel
  - 1/8 th scale containment cooling tests, 15 ft. diameter by 25 ft. high vessel which simulates AP600 containment, used for code verification at larger scale

AP600 TESTING PROGRAMS

E. J. PIPLICA, MANAGER

TEST ENGINEERING

Summary

- The test program is extensive
- Many successful results to date confirm design features
- Test data has been/will be incorporated into analysis codes which in turn confirm plant performance
- Program includes two integral tests at high and low pressure
- Test program is highly responsive to USNRC and the Utilities

Test Categories

- Safety Related Tests
- Non-Safety Related Equipment Tests
- Basic Research Tests

Safety Related Tests

- Provide data for computer codes used for SSAR analysis:
  - Models
  - Correlations
  - Verification

- Generally, a thermal-hydraulic test
  - Performed to understand and explain T/H phenomena
  - Can be system or separate effects test

- Highest quality assurance pedigree
  - NQA-1 applies, 10CFR21 applies
  - Test specification required
  - Test operating procedures required
  - Test facility design documentation required
  - Quality records required

- Examples
  - Large Scale PCCS Heat Transfer tests
  - Integral Systems tests (SPES-2, OSU)
  - Separate Effect Tests (ADS, CMT)

Non-Safety Related Equipment Tests

AP600

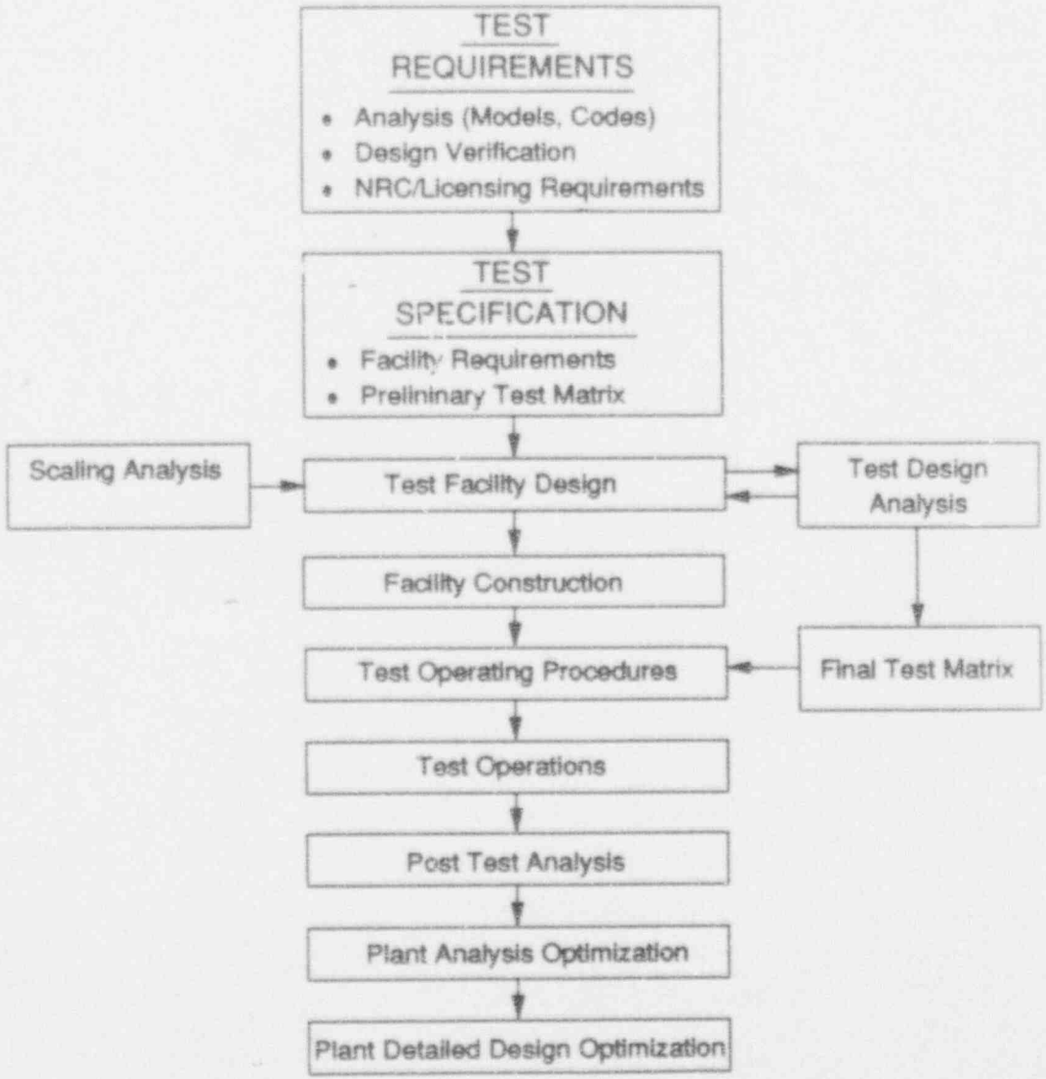
- Provide design information on specific components
  - Feasibility of design
  - Manufacturability
  - Verify component performance
- Generally mechanical tests
  - Performance data
  - Wear data
- High quality assurance standards
  - NQA-1 applies
  - Test specification optional
  - Test operating procedures required
  - Test facility design documentation required
  - Quality records required
- Examples
  - High Inertia Rotor tests
  - RCP Flow tests (air & water)
  - Check Valve tests

Basic Research Tests

AP600

- Experimental in nature
- Generally bench tests performed at universities
  - Investigate specific phenomena in detail
  - Answer specific questions of performance or feasibility
  - Provide guidance for further testing
- Quality requirements
  - Test plan required
  - Test facility design documents required
- Examples
  - University of Wisconsin condensation tests
  - University of Tennessee Reactor Vessel Air Visualization tests
  - Bench Wind Tunnel test

AP600 Test, Analysis & Design Process



AP600 Testing Programs

- Design Certification Tests
  - Passive Core Cooling System Tests
  - Passive Containment Cooling System (PCCS) Tests
- Engineering Tests
  - Component Design Verification Tests

PASSIVE CORE COOLING SYSTEM TESTS

AP600 Passive Core Cooling System Tests

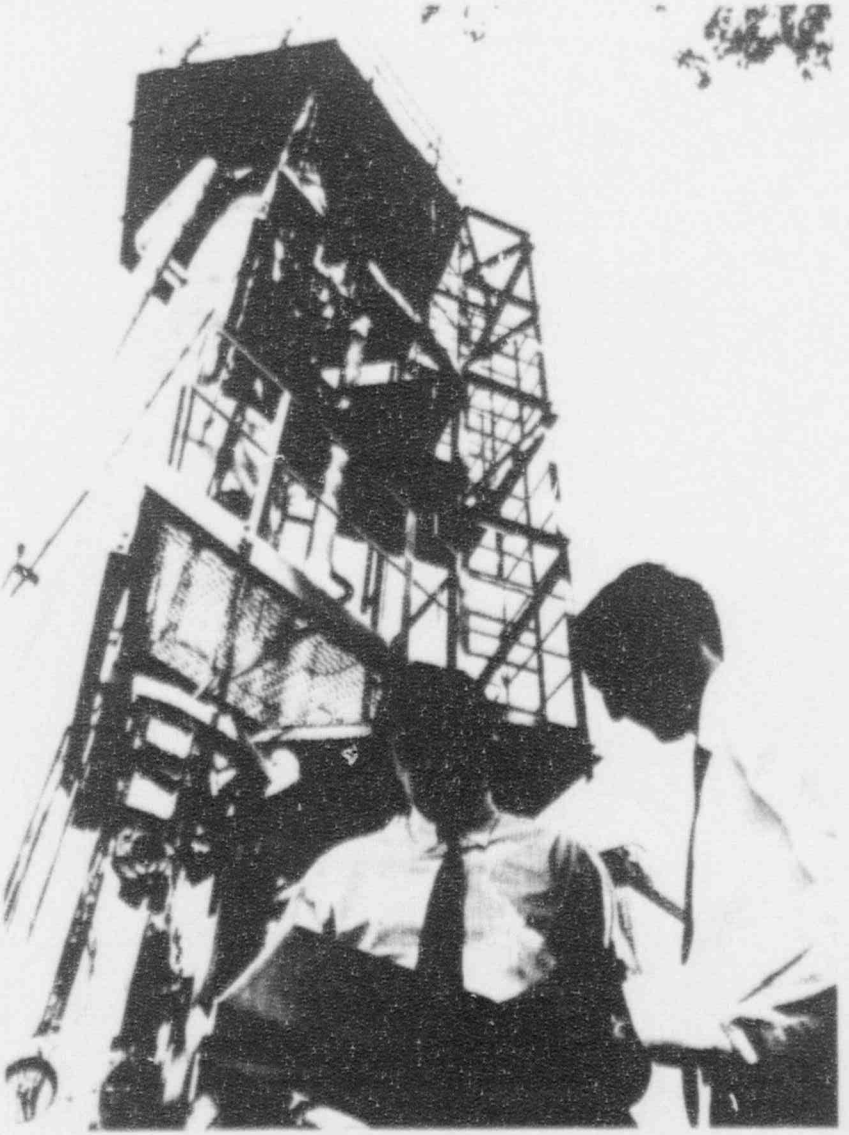
- Passive Residual Heat Removal Heat Exchanger Tests
- Automatic Depressurization System Phase A Tests
- Integral Systems Tests
- Departure from Nucleate Boiling Tests
- Core Makeup Tank Tests
- Automatic Depressurization System Phase B Tests

Completed Tests

- Passive Residual Heat Removal Heat Exchanger Test
  - Confirmed heat transfer performance
- Automatic Depressurization System (ADS) Phase A Test
  - Sparger blowdown characteristics have been tested

Passive RHR Heat Exchanger Test

AP600



Passive RHR Heat Exchanger Test

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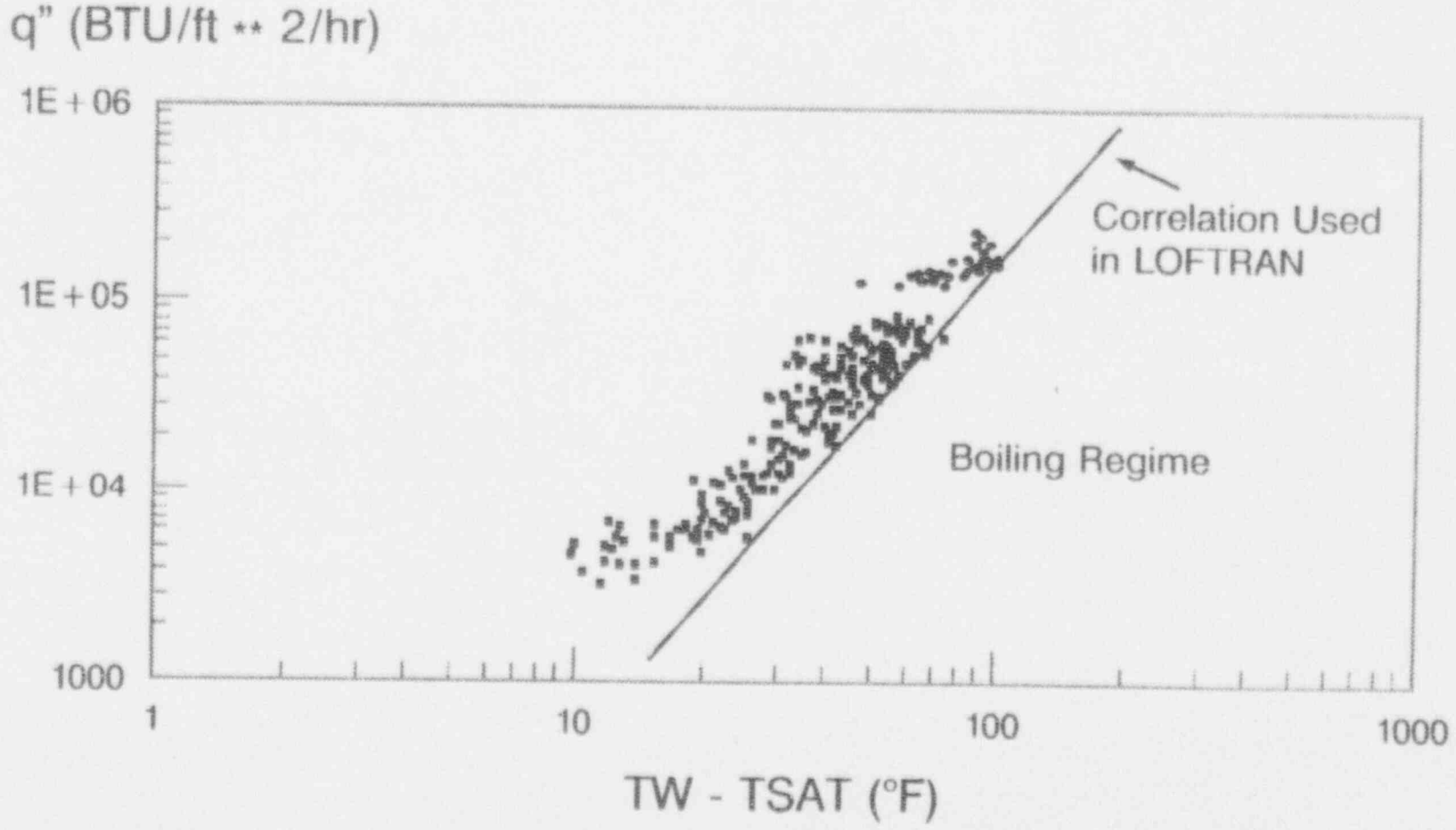
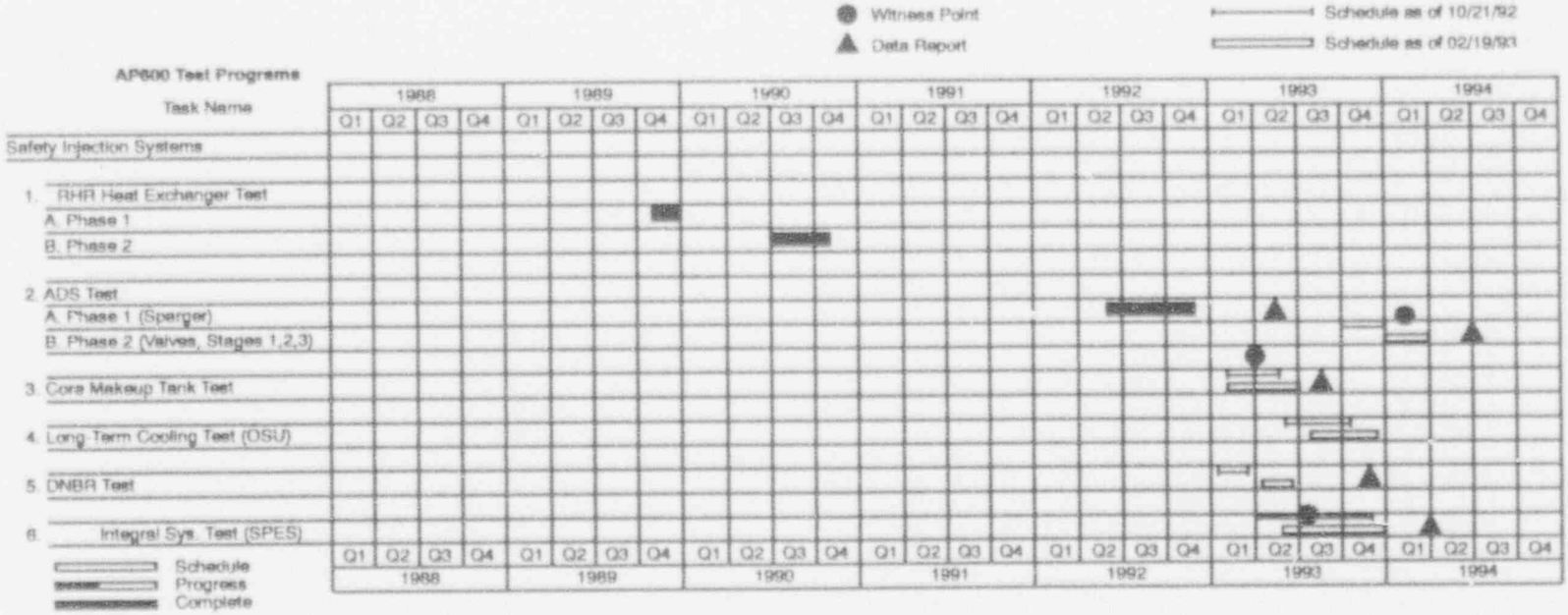
PRHR Data and Correlation Used in LOFTRAN Computer Code



Ongoing and Planned Tests

- Two separate Integral System Tests examine the behavior of the plant and interconnected systems
  - Full-height, full-pressure test at SPES facility in Italy models two AP600 loops with CMTs, accumulators, passive heat exchanger, IRWST, and automatic depressurization system
  - A quarter-scale lower pressure (~400 psig) test at Oregon State University will model the NSSS, passive safety features, and important non-safety features
- Departure from Nucleate Boiling (DNB) Test
  - The AP600 pump design includes a high inertia rotor to control flow coastdown
  - Ample margin to DNB eliminates design impact
- Core Makeup Tank Test
- ADS Phase B Test

AP600 Passive Core Cooling System Test Schedule



Passive Containment Cooling System Tests

AP600 Passive Containment Cooling System Tests

- Feasibility Tests
- Condensation Tests
- Heat Transfer Tests
- Water Distribution Tests
- Wind Tunnel Tests

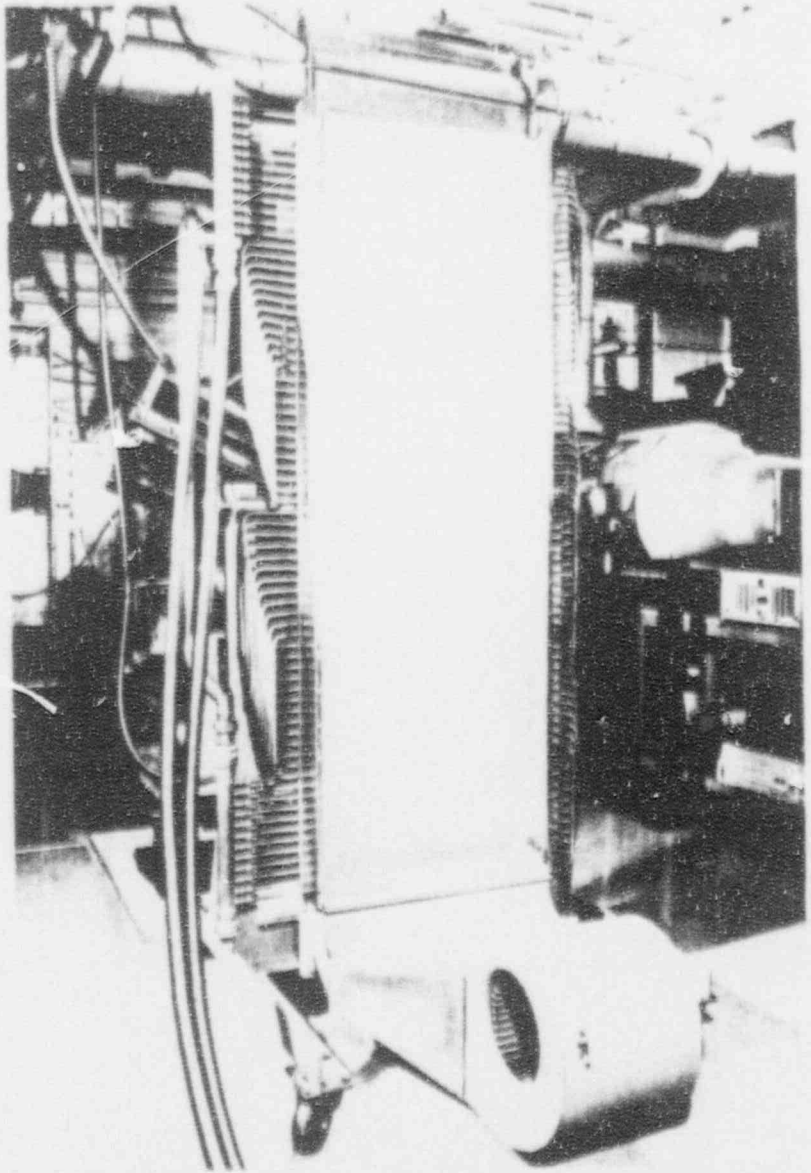
Completed Tests

- Bench Wind Tunnel Experiment
  - Assessed effects of wind on shield building design (inlet/outlet location)
- Air Flowpath Pressure Drop Test
  - Obtained pressure drop data through the downcomer and annulus
- Water Film Formation Test
  - Confirmed wettability of a coated steel surface

Completed Tests (continued)

- Heated Plate and Integral PCCS Tests
  - Confirmed heat transfer capability
- Large - 1/8th scale PCCS Heat Transfer Tests
  - Detailed interior/exterior heat transfer performance characteristics
- Water Distribution Tests
  - Measured prototypical water coverage
- Wind Tunnel Test
  - Confirmed natural circulation with site wind conditions present
  - Optimized air inlet and exhaust arrangements

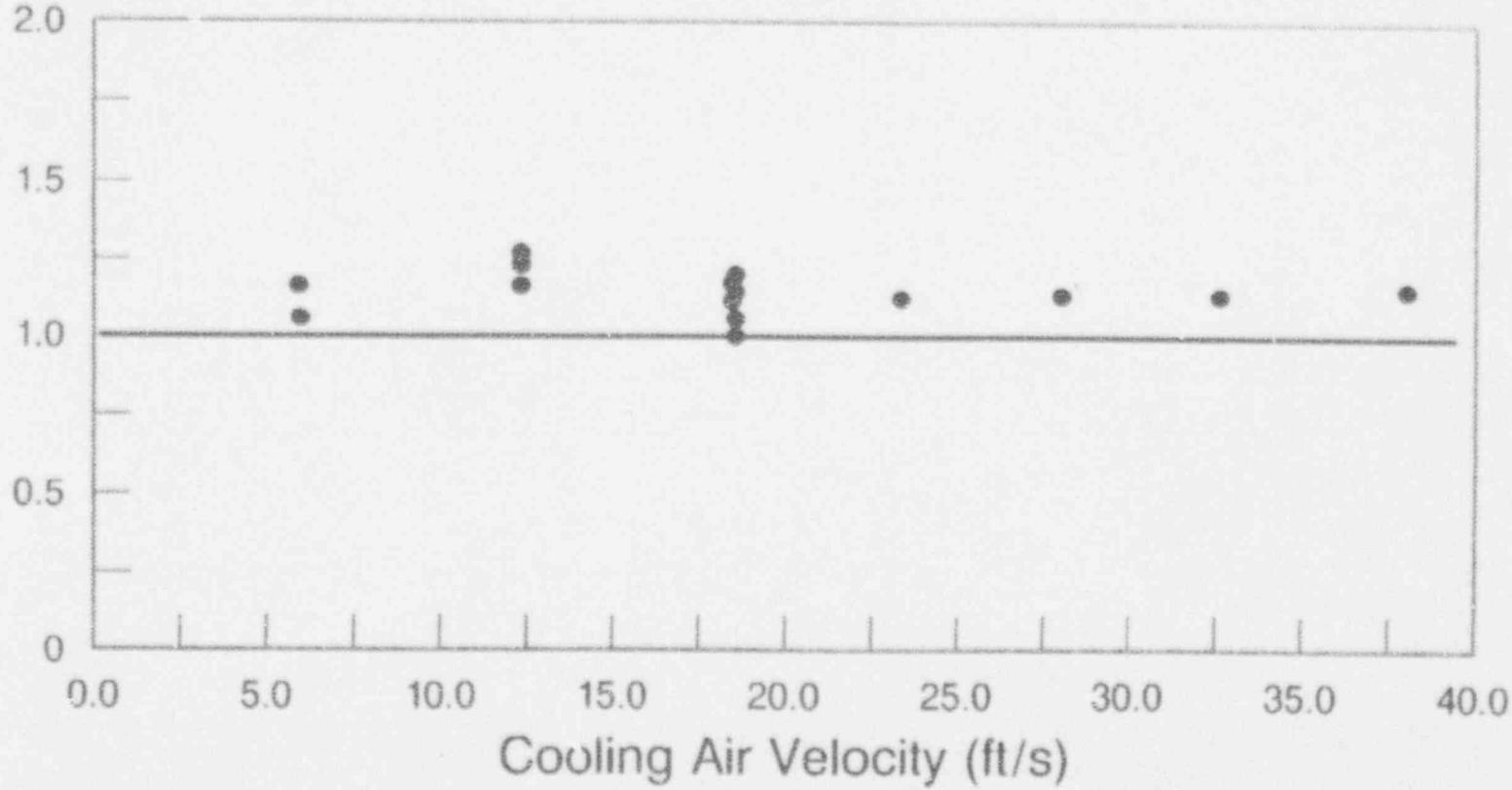
AP600 PCCS Heated Plate Tests

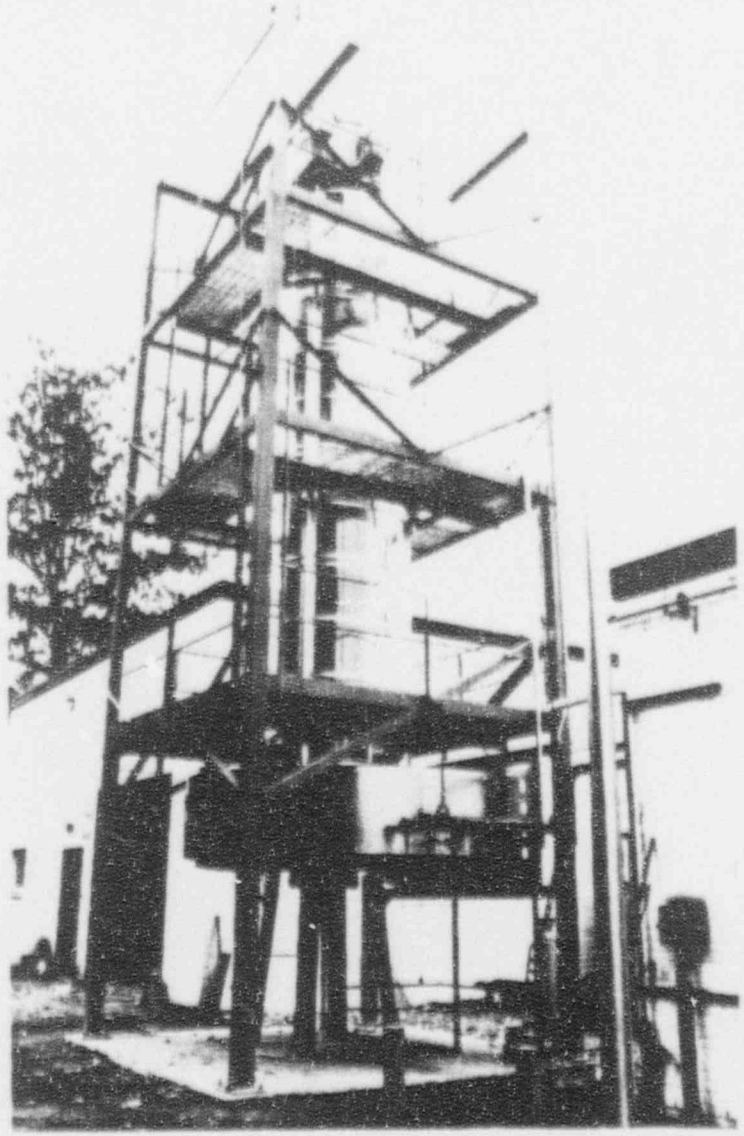


AP600 PCCS Heated Plate Test Results

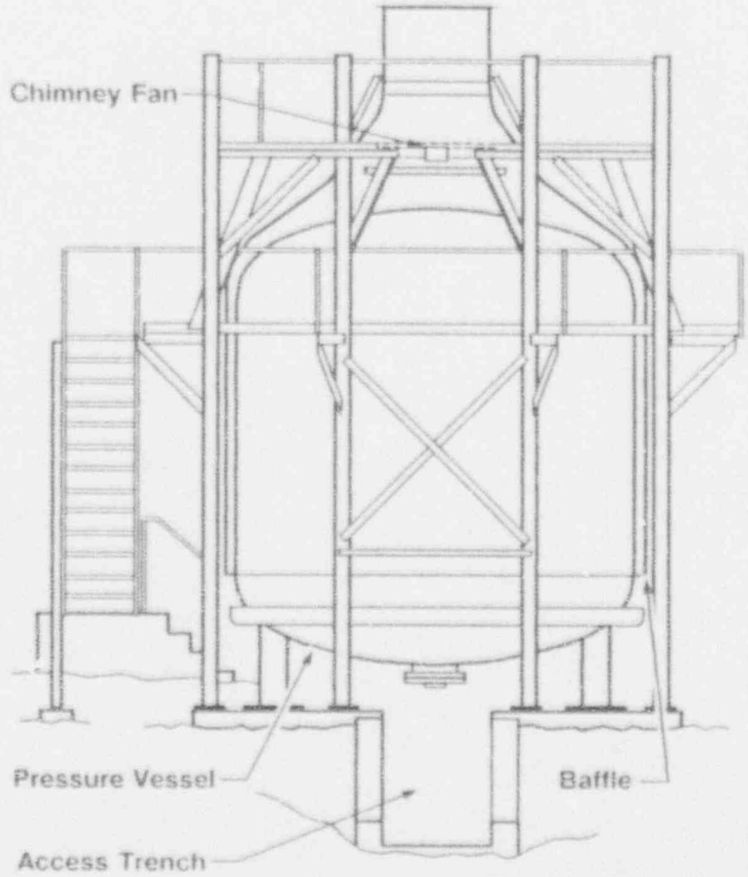
Wetted-Evaporative Cooling over Range of Water Flowrates and Plate Angle

Measured Heat Flux/Calculated Heat Flux

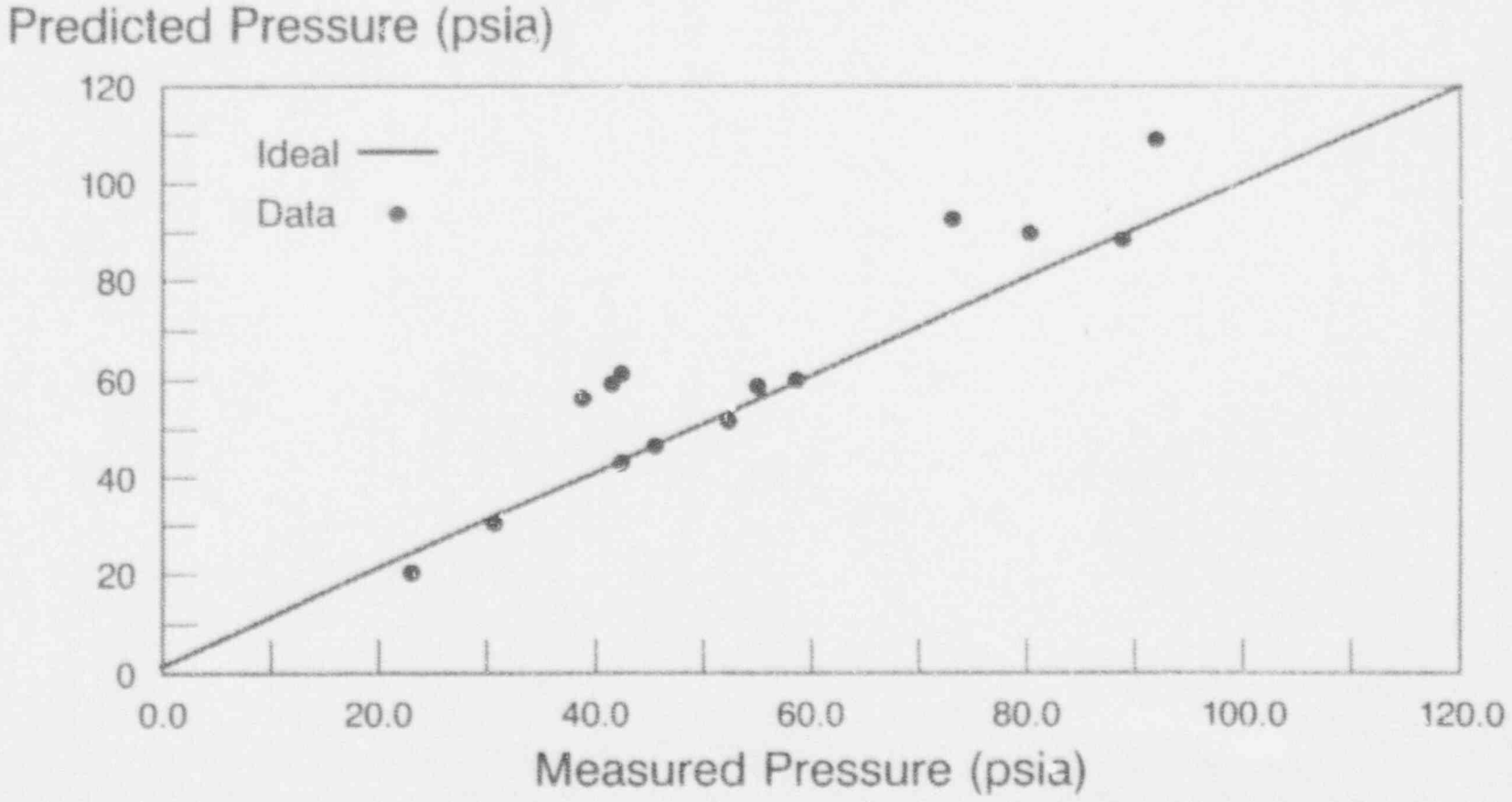




AP600 Large Scale PCCS Heat Transfer Tests

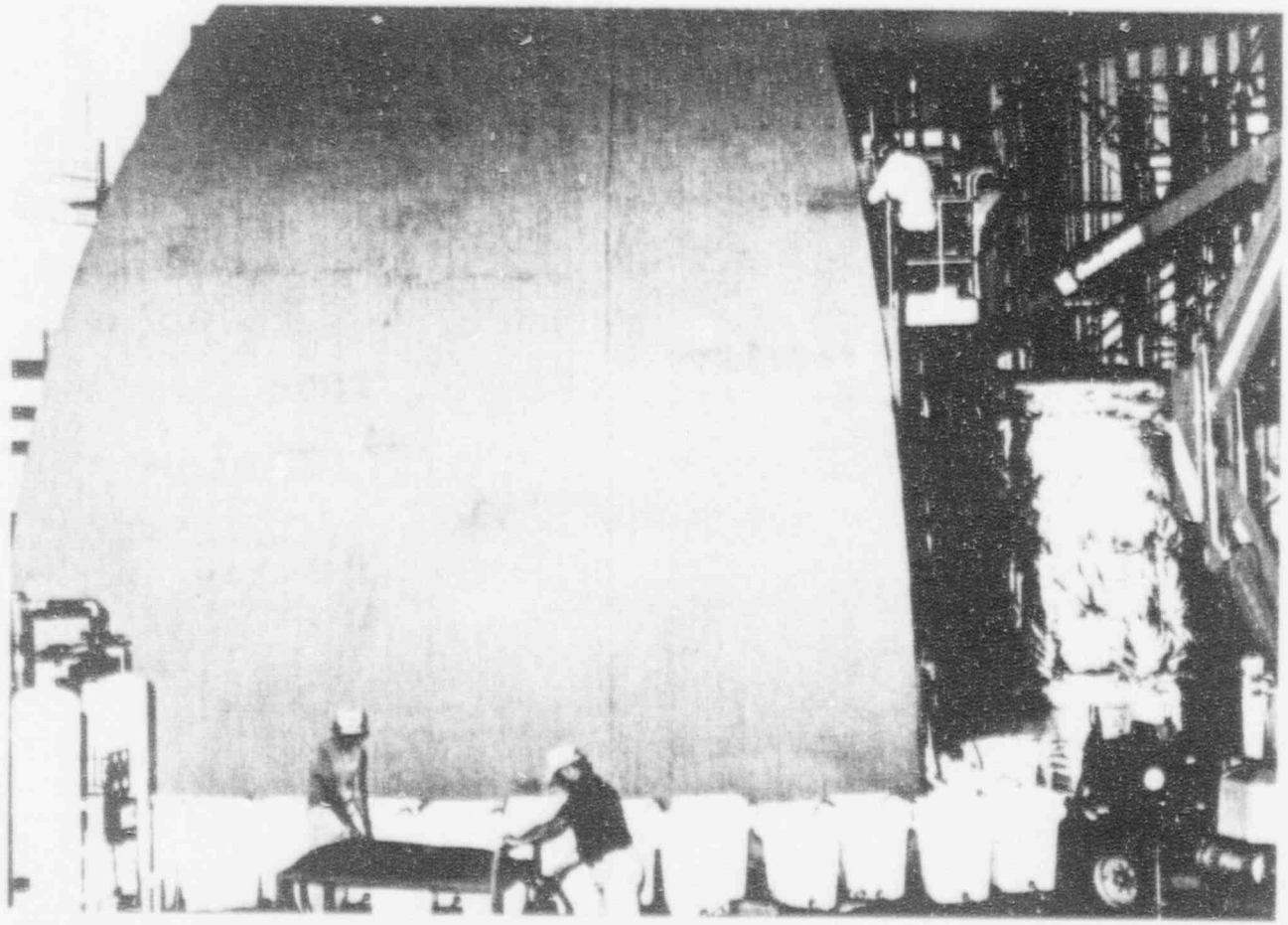


Vessel Pressure Predicted vs. Measured

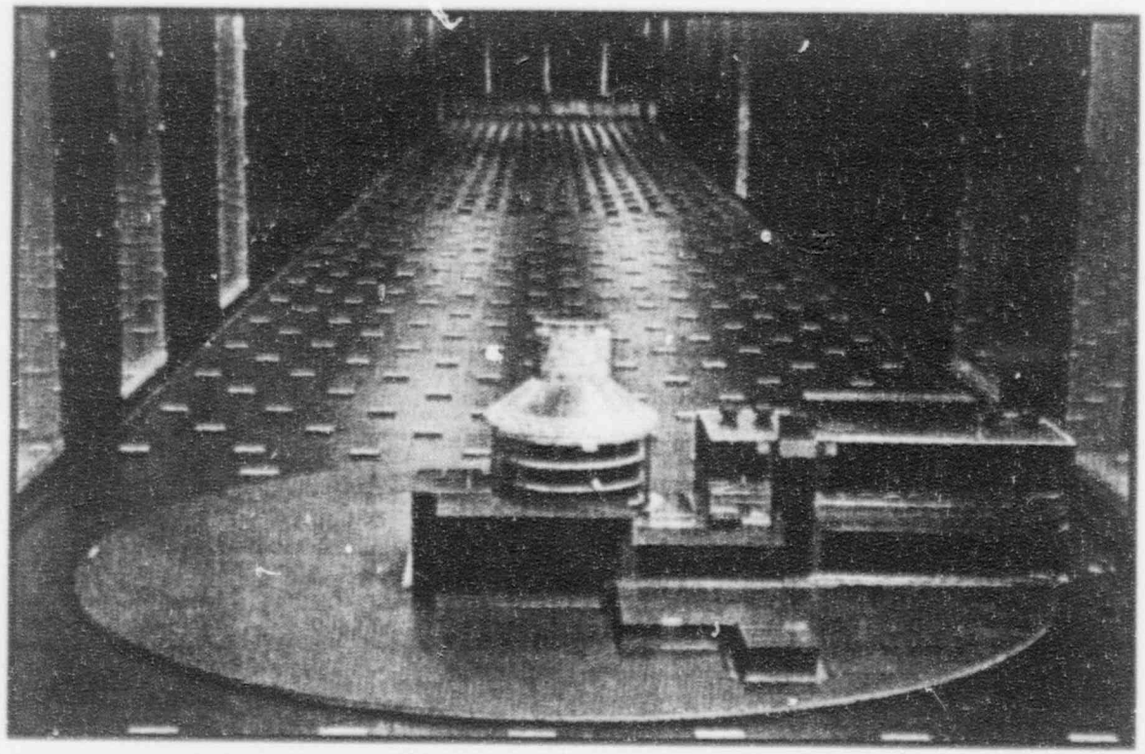


AP600 Water Distribution Tests

Full-Scale Representation of 1/8th Segment of AP600 Containment Dome



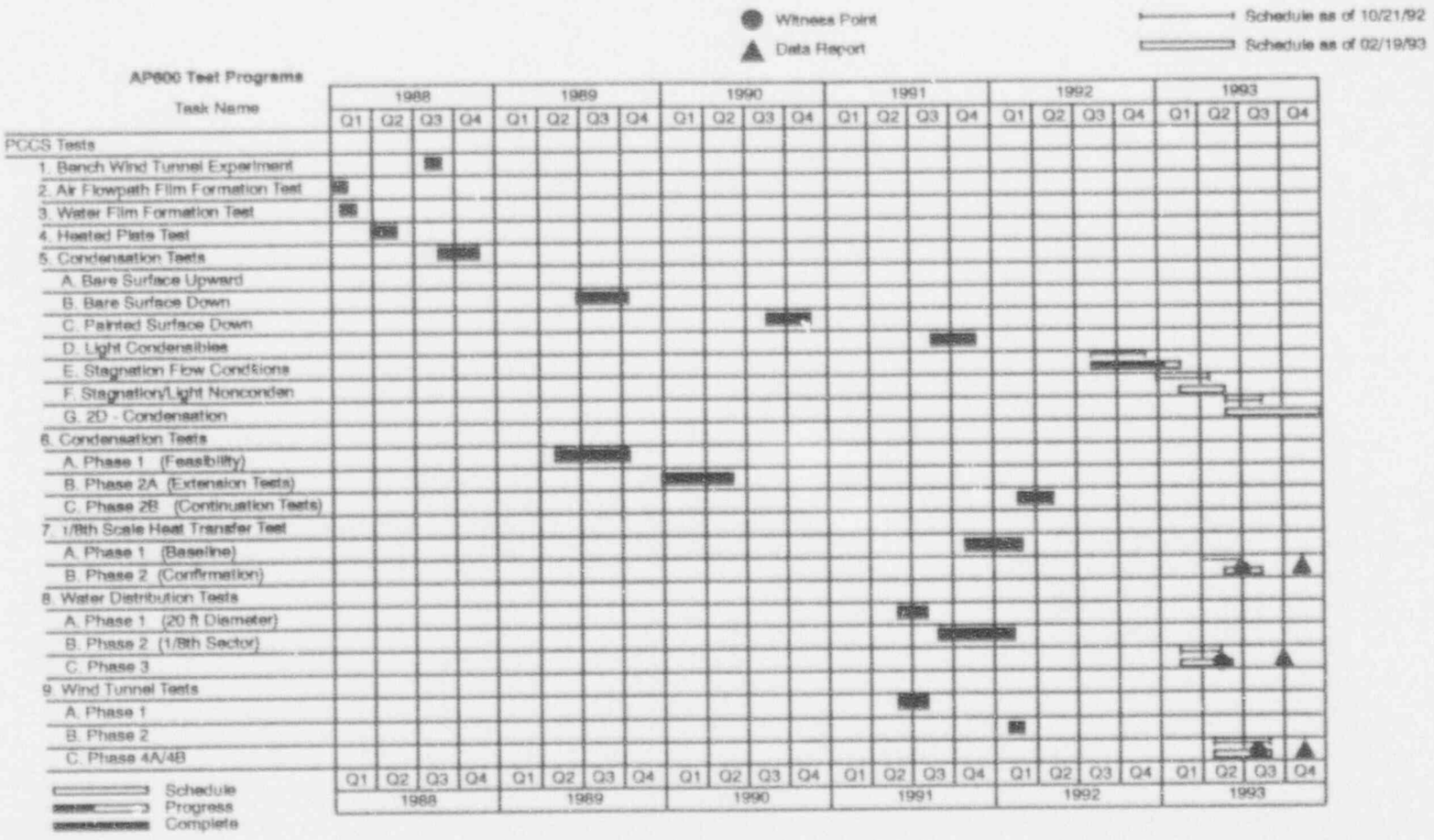
AP600 Wind Tunnel Test



Ongoing and Planned Tests

- Heat Transfer Tests
  - The 1/8th scale facility includes modeling of internal containment structures to assess steam distribution effects
  - Results from completed baseline tests and from previous tests incorporated into WGOTHIC analysis code with excellent results
- Water Distribution Tests
  - Measure water coverage using water distribution system
- Wind Tunnel Tests
  - Repeat at high Reynolds numbers
  - Site geography effects will be assessed with a smaller model which varies site features

AP600 Passive Containment Cooling System Test Schedule

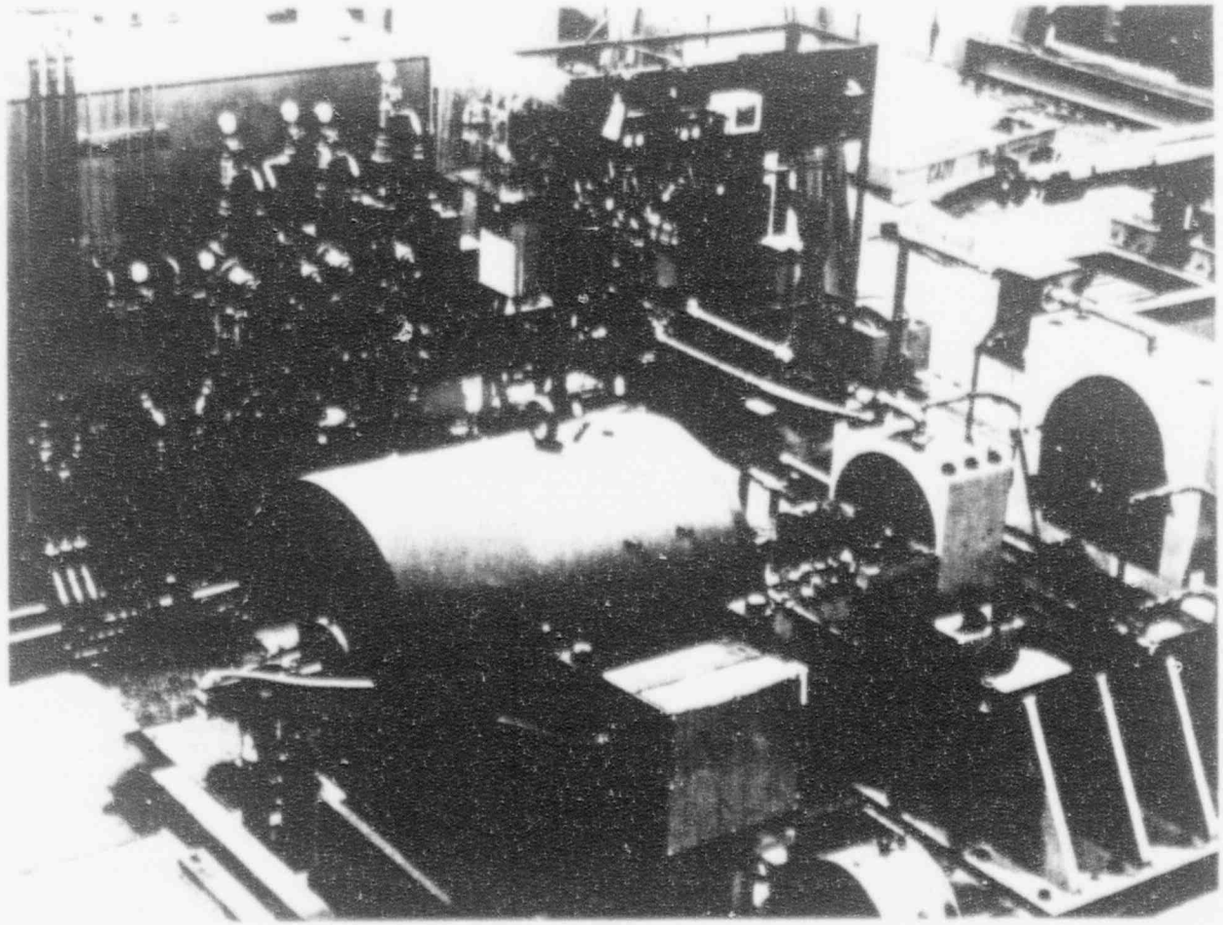


Component Design Verification Tests

Completed Tests

- Reactor coolant pump/steam generator channel head air flow test
  - No flow maldistributions
- Reactor coolant pump journal bearing test
  - Determined dynamic/horsepower characteristics
- Incore Instrumentation System (IIS) Test
  - Demonstrated IIS will not be affected by Control Rod Drive Mechanism (CRDM) electromagnetic interference
- Reactor vessel flow visualization
  - No abnormal flow distribution
- Check Valve Mechanical Test
  - Demonstrated low pressure performance

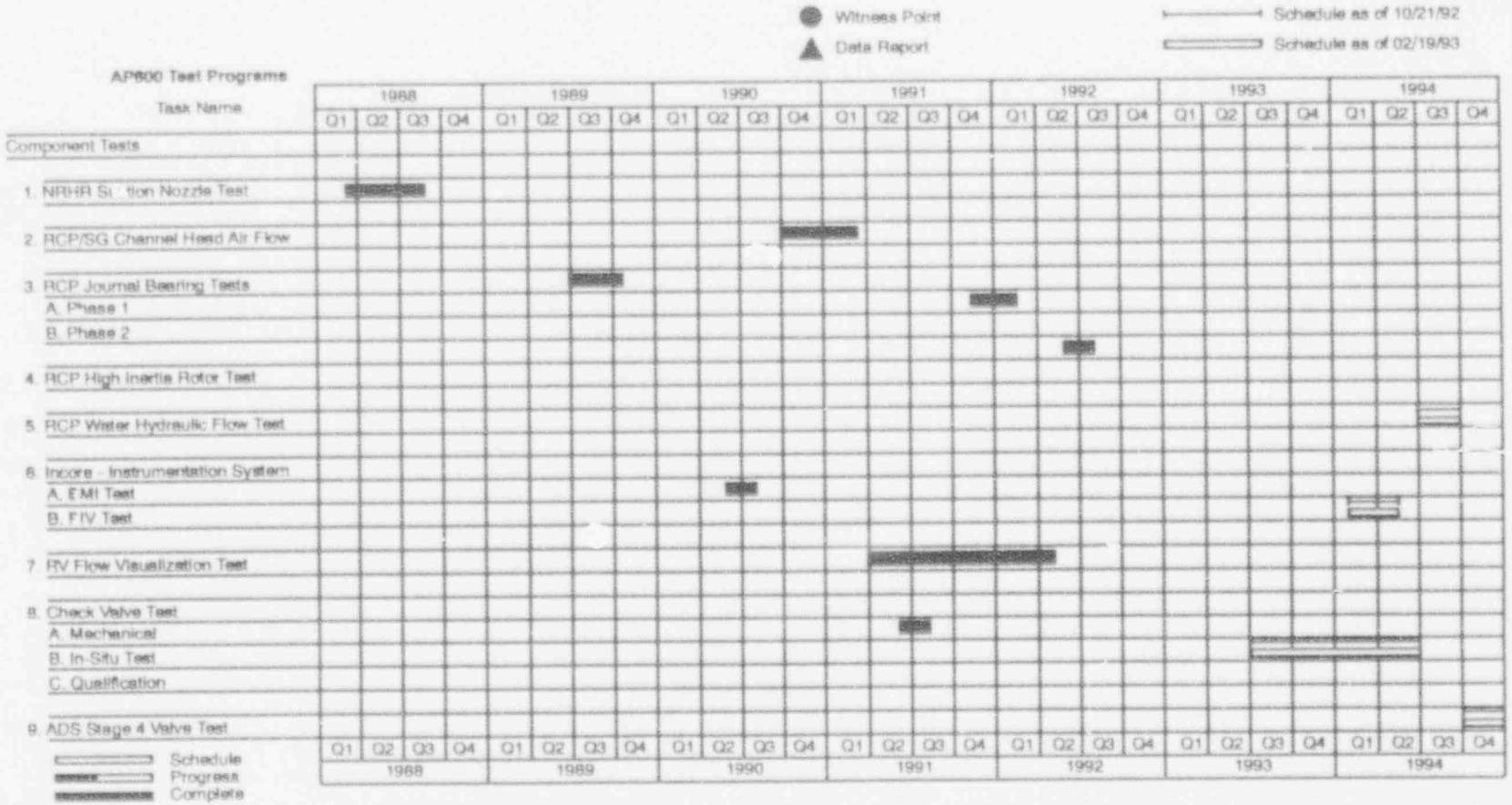
AP600 High Inertia Pump Journal and Bearing Test



Ongoing or Planned Component Tests

- Reactor Coolant Pump Flow Test
- Incore Instrumentation Flow Induced Vibration Test
- Check Valve Tests
- Fourth Stage ADS Valve Test

AP600 Component Design Verification Test Schedules



Key Tests for Design Certification

Key Tests for Design Certification

- Separate Effects Tests
  - Automatic Depressurization Test - Phase B
  - Core Makeup Tank Tests
- Integral Tests
  - OSU 1/4 Height Scaled Pressure Test
  - SPES-2 Full-Height, Full-Pressure Test
  - PCCS Large Scale Heat Transfer Tests

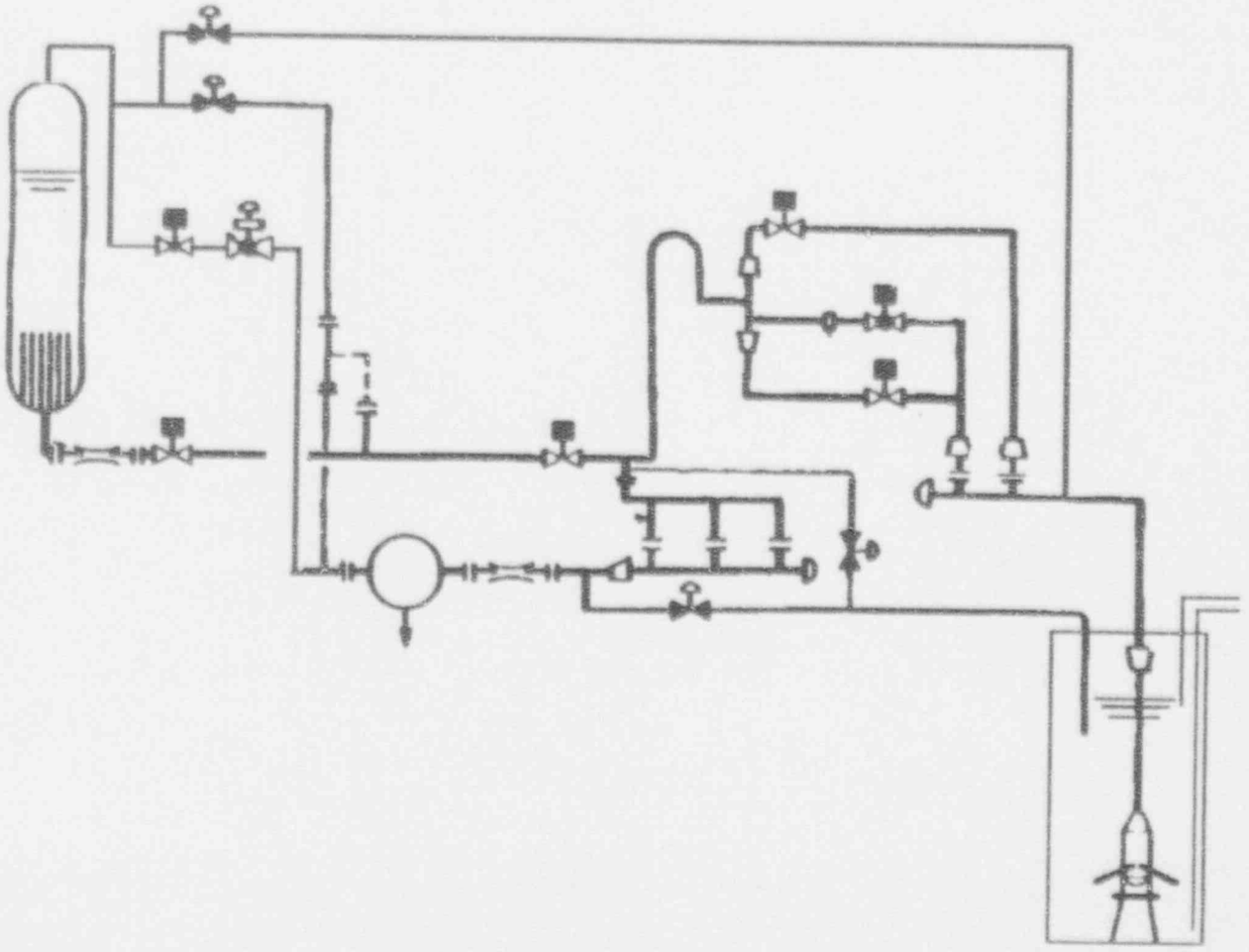
ADS Phase B Test

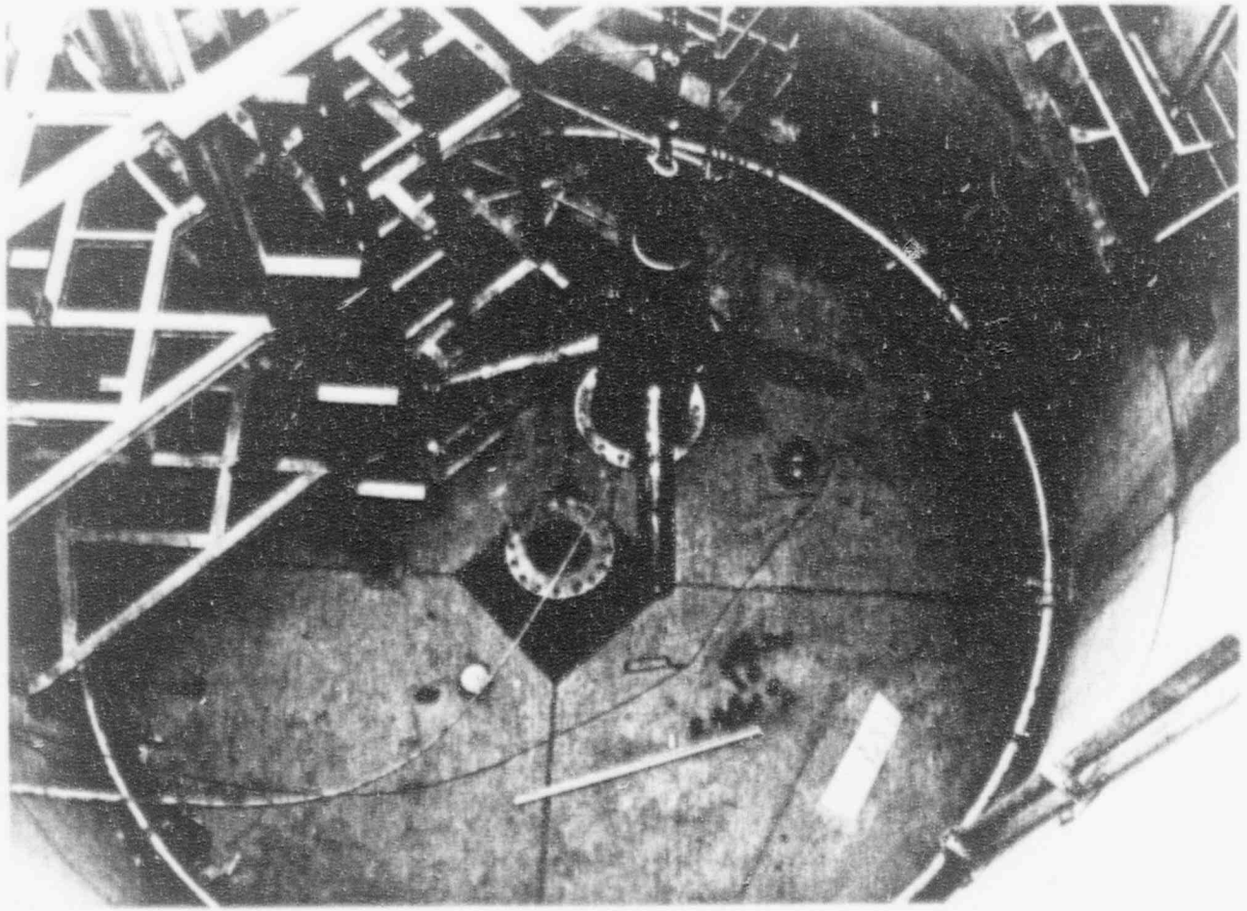
AP600

- Organization - ENEA
- Location - VAPORE Facility, Casaccia, Italy
- Key Features
  - Separate effects test
  - Full scale, prototypic hardware
- Purpose of Tests
  - Evaluate valve performance
  - Obtain piping load data
- Progress
  - Valve procurement underway
  - Preliminary facility design completed
- Tests scheduled to begin January 1994

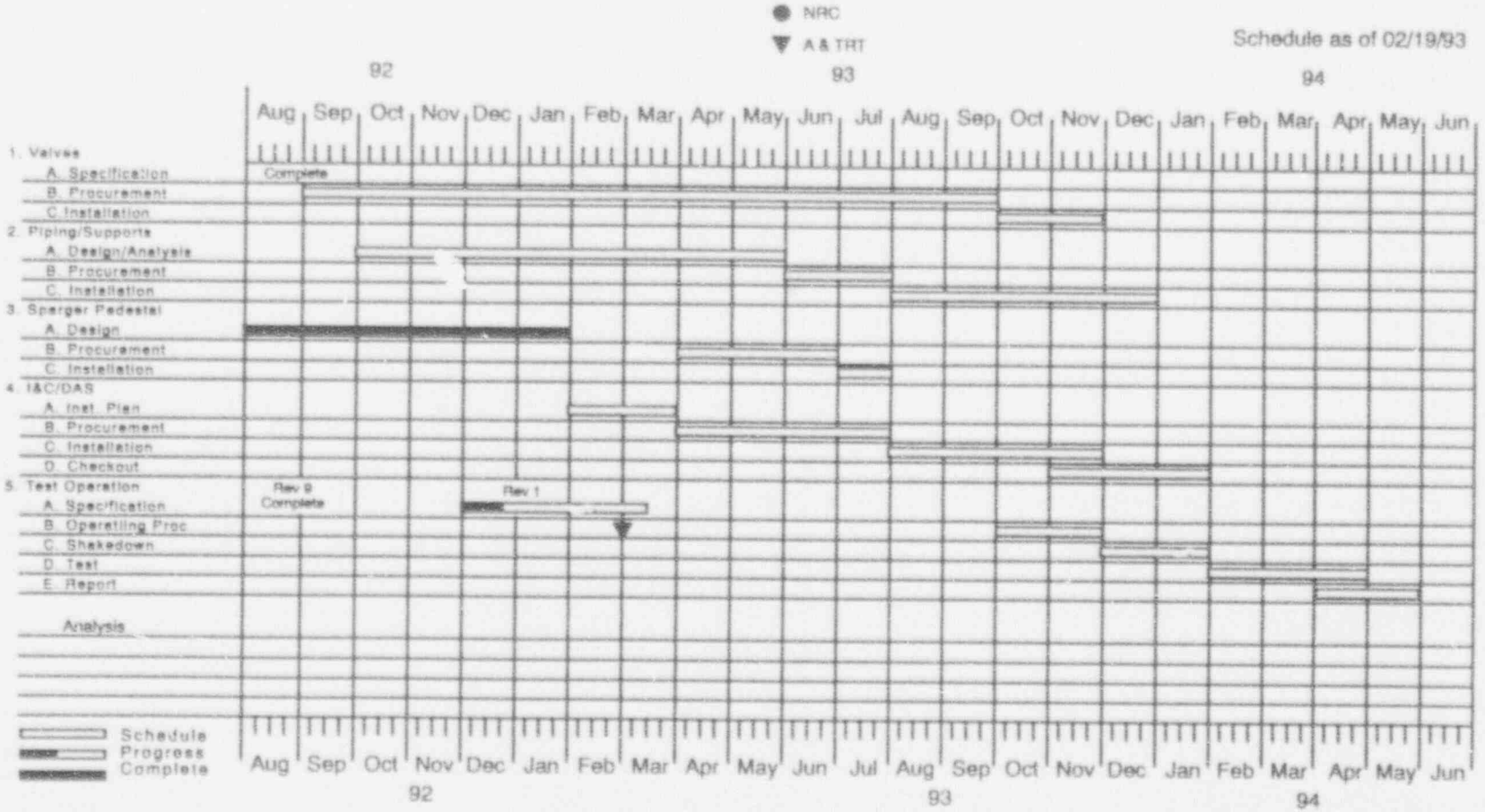
ADS Phase B Test

AP600





ADS Phase B Test Schedule

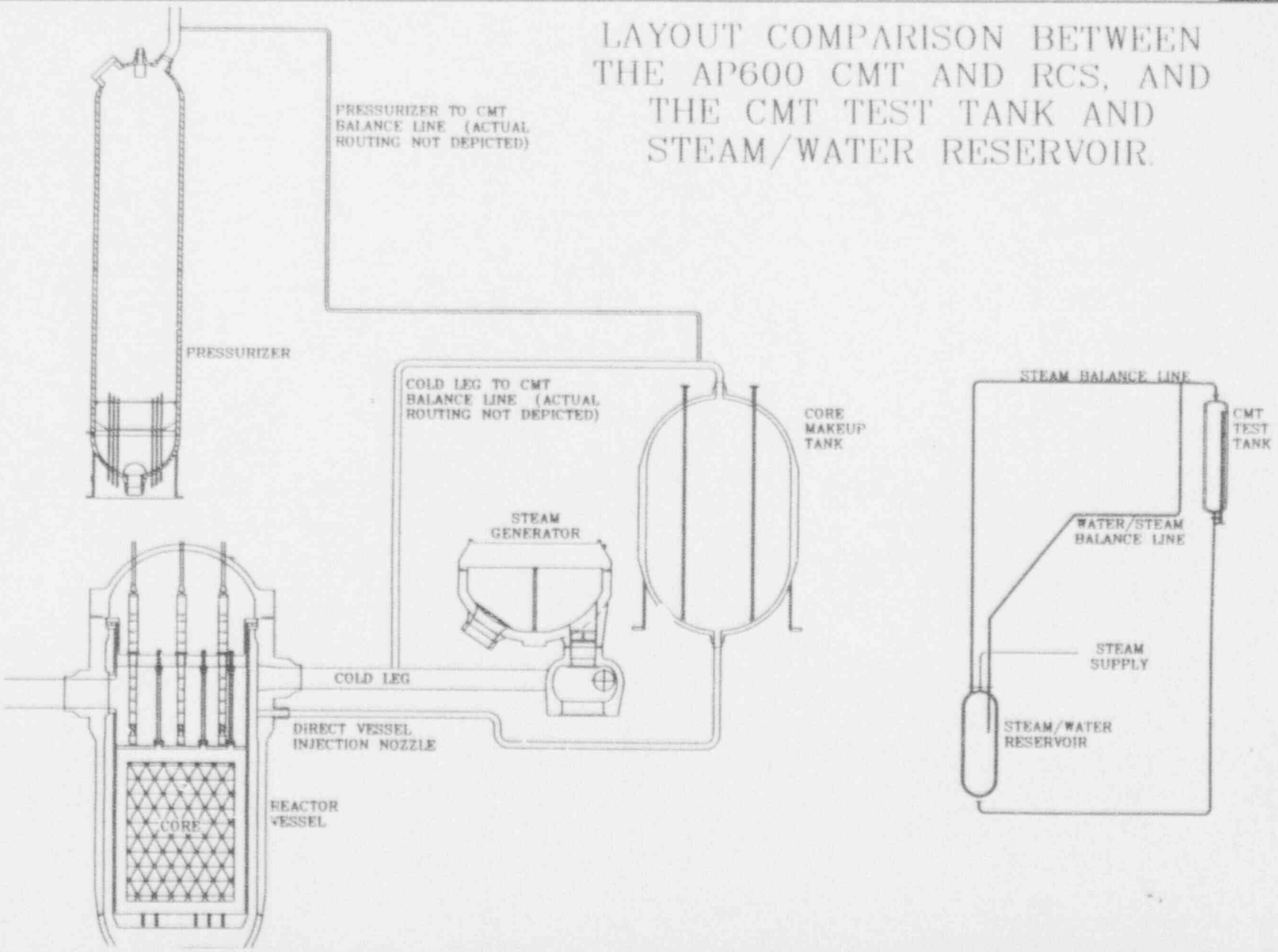


Core Makeup Tank Test

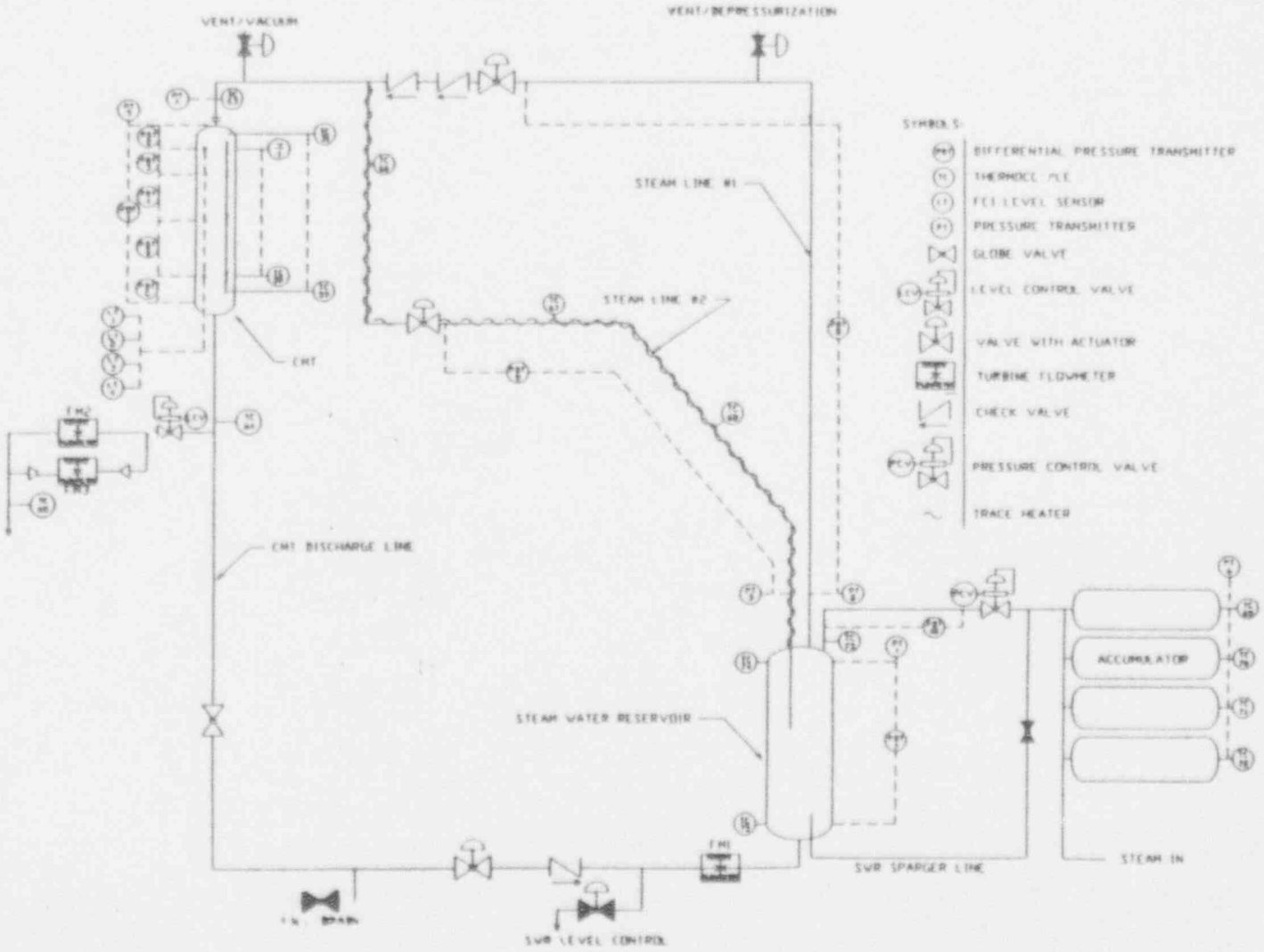
- Organization - Westinghouse
- Location - Waltz Mill Site, Madison, PA
- Key Features
  - Separate effects test at full pressure and temperature
  - Simulated CMT (10 ft high x 2 ft diameter)
  - Simulated cold leg and pressurizer balance lines
- Purpose of Tests
  - Evaluate CMT performance
  - Evaluate CMT level instrumentation
  - Obtain T/H data for code verification
- Progress
  - Facility construction complete
  - Cold shakedown tests underway
- Matrix tests scheduled to begin April, 1993

Core Makeup Tank Test

AP600



Core Makeup Tank Test



REVIEW/WITH

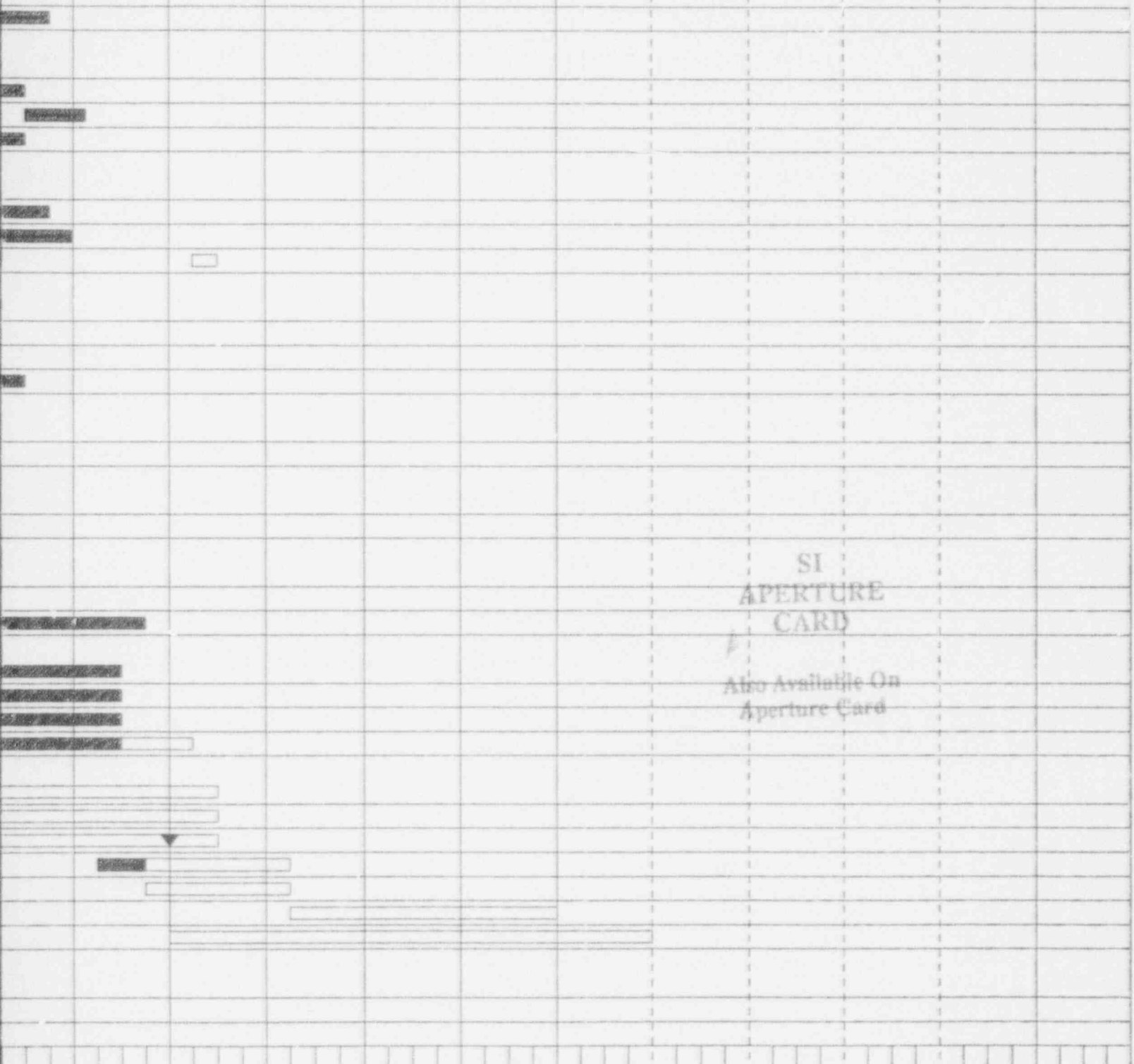
CORE MAKEUP TANK TEST SCHEDULE

ESS POINTS ● - NRC ▼ - A & TRT

SCHEDULE AS OF 02/19/93

93

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC



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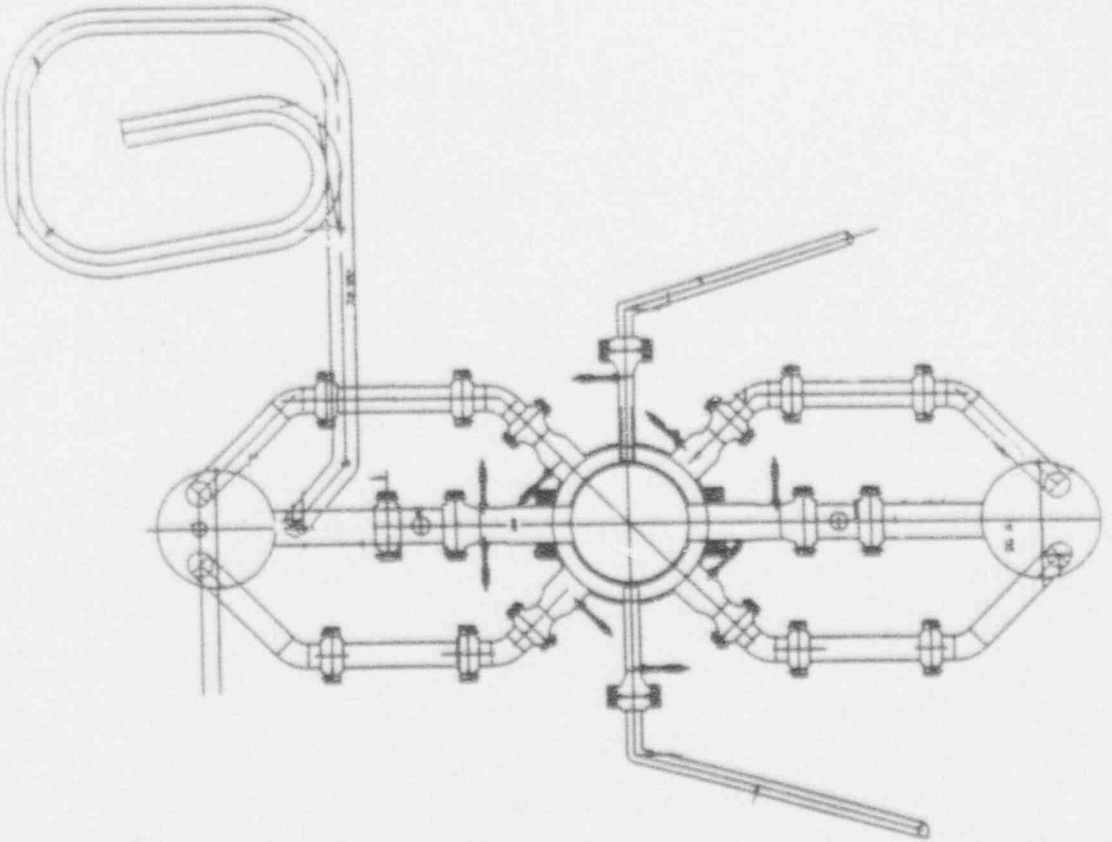
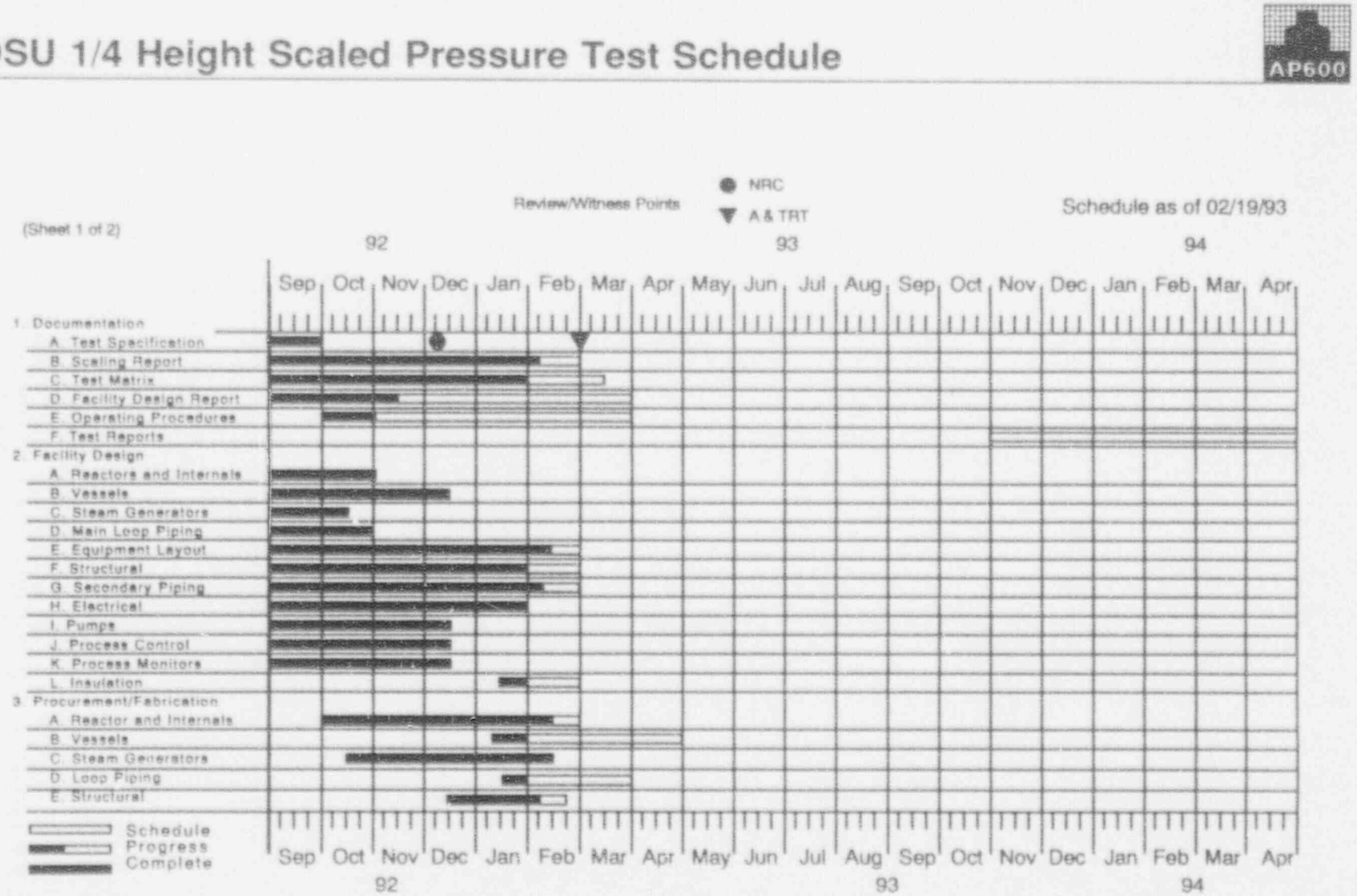
OSU 1/4 Height Scaled Pressure Tests

- Key Features
  - Low pressure, sealed facility
  - Complete RCS and Passive Core Cooling System model
  - 1/4 scaled height
  - 400 psig maximum pressure
  - Stainless steel components and piping
- Purpose of Tests
  - Provide T/H data for code verification at low pressure operation and during long term cooling
- Progress
  - Scaling analysis of RCS complete
  - Facility design complete
  - Procurement of long-lead components underway
  - Site preparation completed
  - Steam generators set in place
- Matrix tests scheduled for August 1993

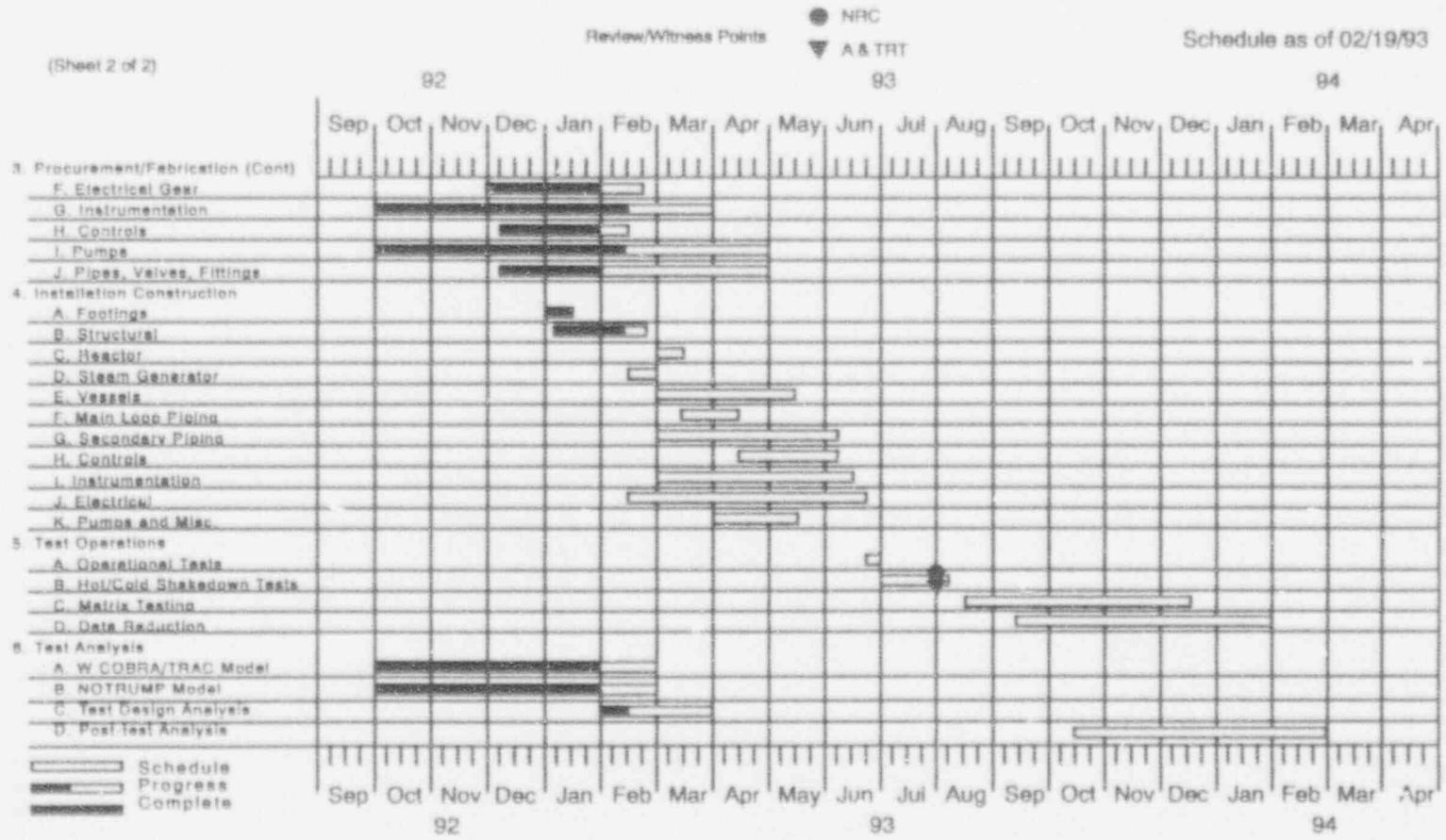
OSU 1/4 Height Scaied Pressure Tests



OSU 1/4 Height Scaled Pressure Test Schedule



OSU 1/4 Height Scaled Pressure Test Schedule (continued)



SPES-2 Full-Height, Full Pressure Tests

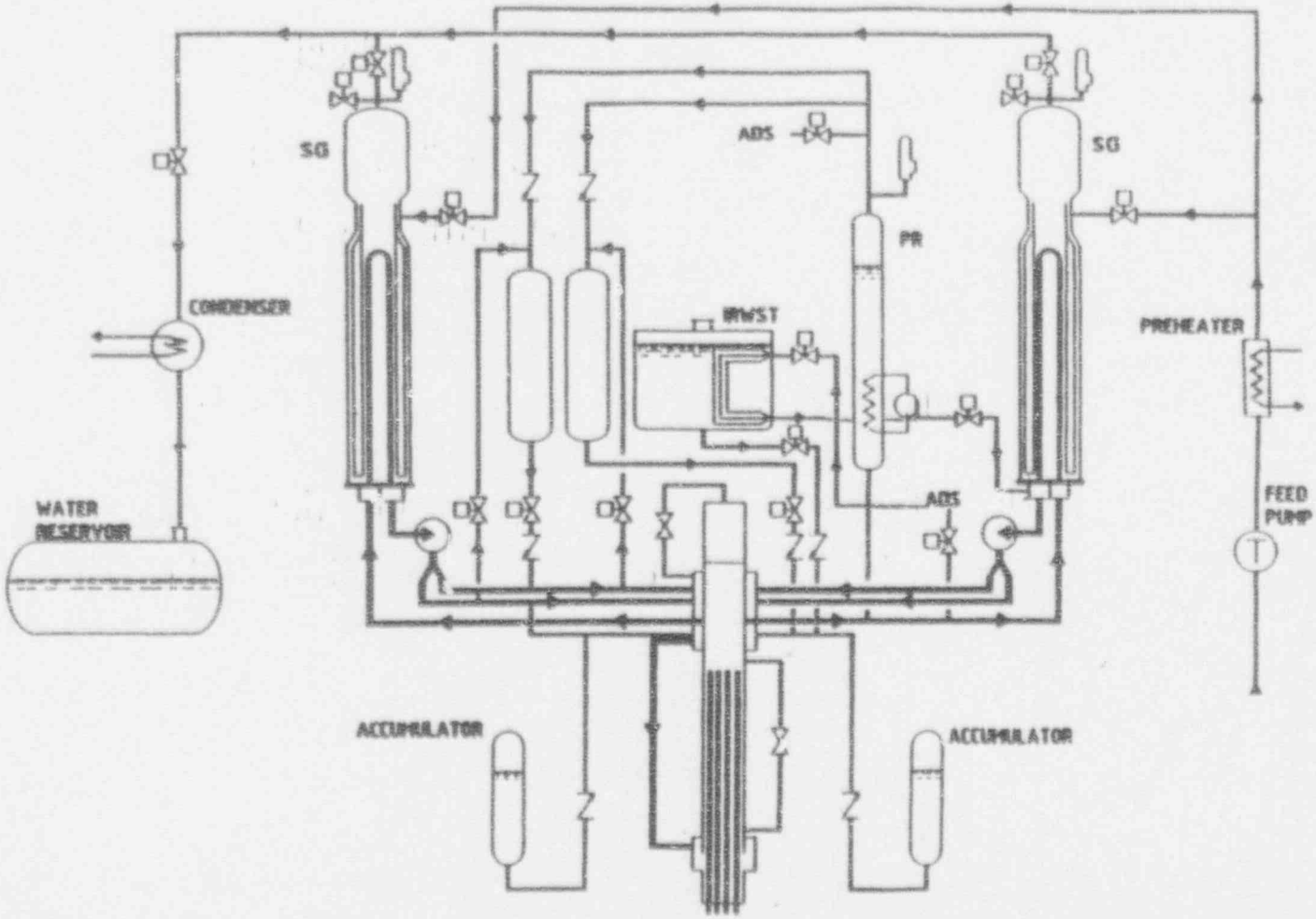
- o Organization - SIET supported by ENEA, ENEL, and Ansaldo
- o Location - SPES Facility, Piacenza, Italy
- o Key Features
  - 1/395 volume scale, full pressure, full height facility
  - 2250 psig, 600°F
  - Full simulation of AP600 features
    - Two cold legs / one hot leg per loop
    - Two CMTs, Two accumulators
    - ADS simulation
    - Two active steam generators
    - Full height heated core
    - PRHR modeled
    - IRWST modeled
    - Direct vessel injection

SPES-2 Full-Height, Full-Pressure Tests

AP600

- Purpose of Tests
  - Obtain T/H data at high pressure for computer code verification
- Progress
  - Scaling analysis complete
  - Facility modifications completed
  - Proposed test matrix prepared and reviewed by NRC
  - Cold shakedown tests underway
- Matrix tests scheduled to begin April 1993
- The SPES-2 test matrix will address:
  - SBLOCA simulations (break size, location, interactions w/ non-safety systems)
  - Steam line break
  - Steam generator tube rupture
    - Design basis with/without active systems to mitigate
    - Beyond design basis events

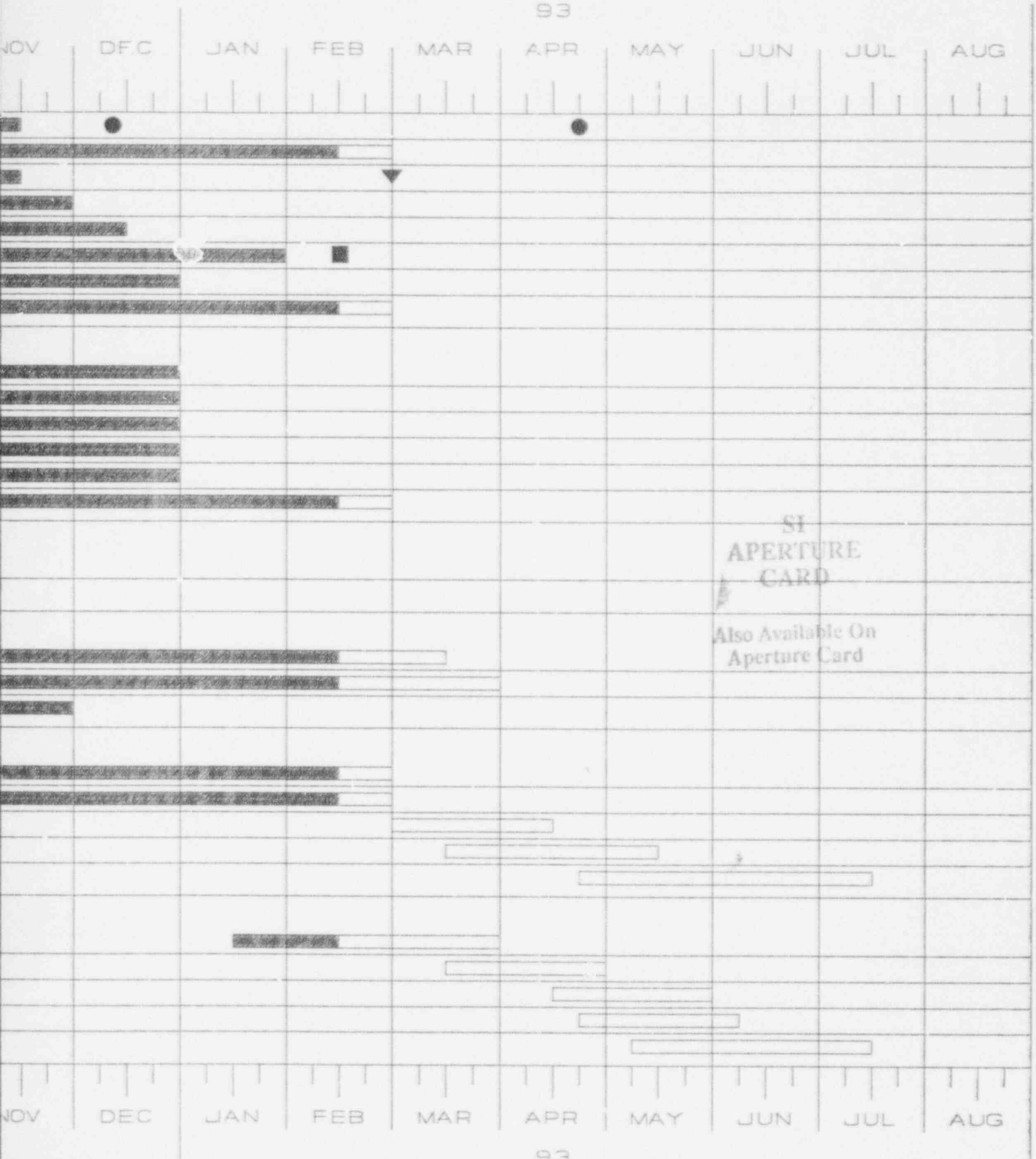
SPES-2 Full-Height, Full-Pressure Tests



SPES-2 TEST SCHEDULE (SHEET 1 OF 2)

● - NRC
▼ - A & TRT
■ - ENEL

SCHEDULE AS OF 02/19/93



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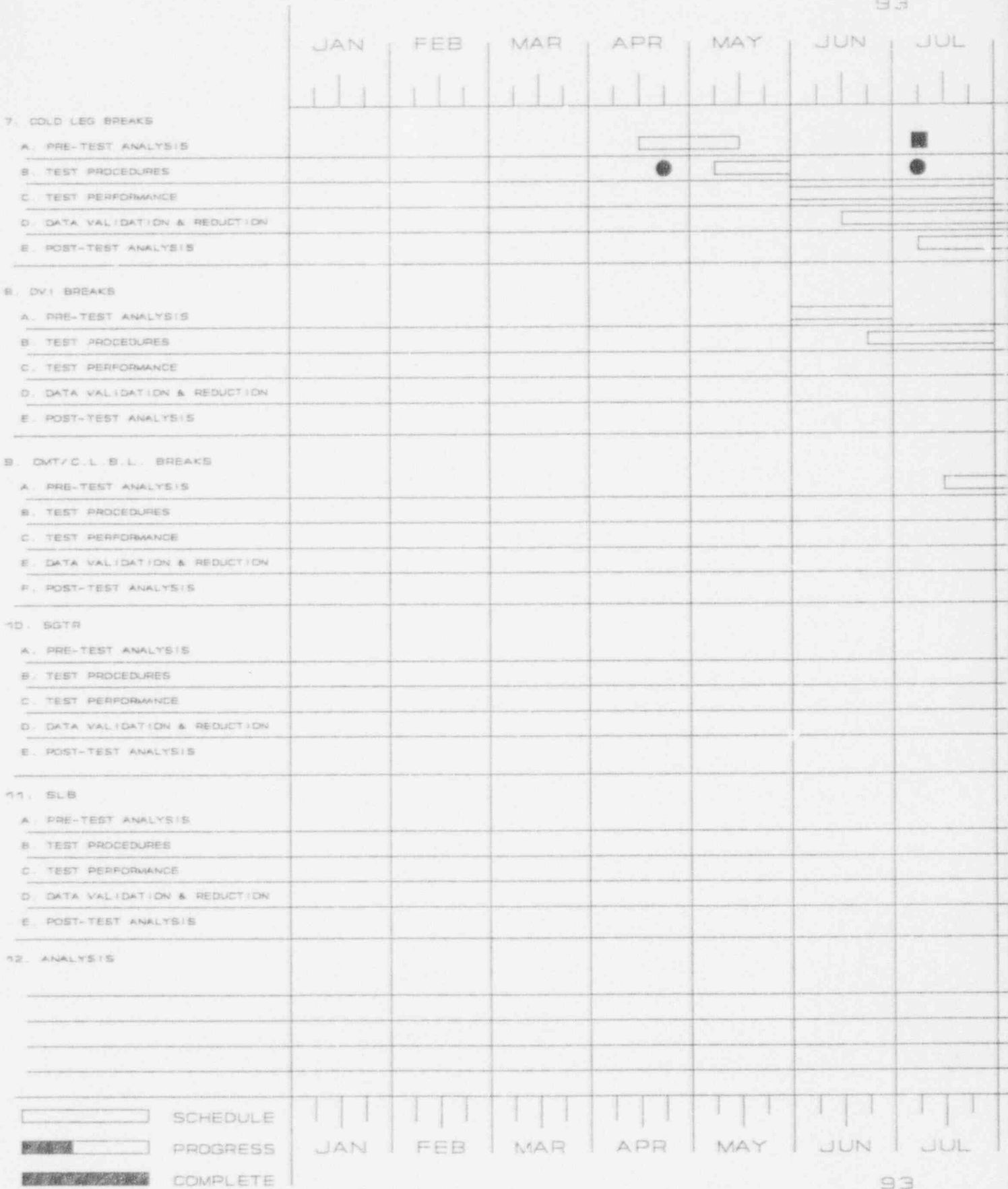
SPES-2 TEST SCHEDULE (SHEET 2 OF 2)

93



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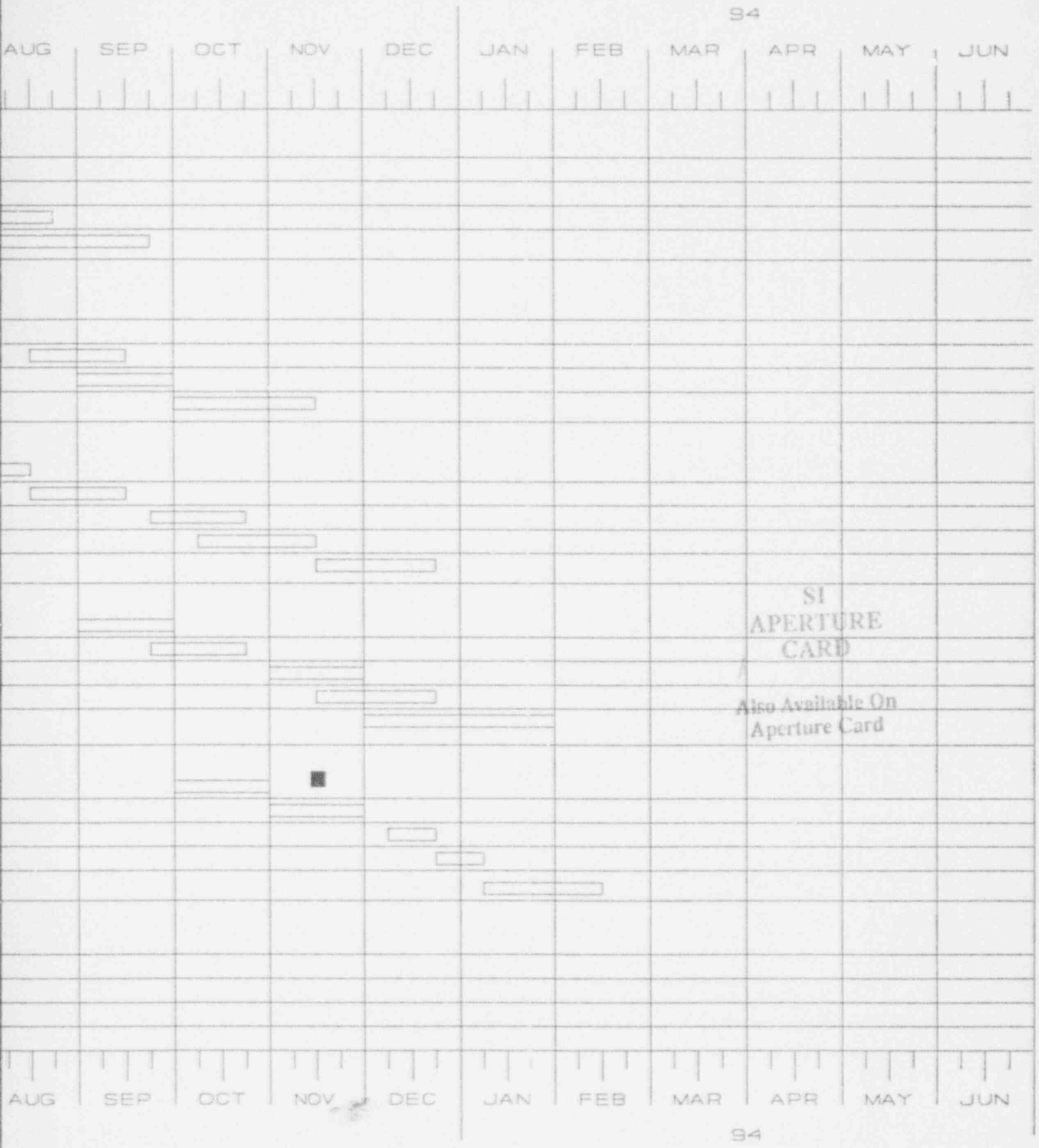
- NRC
- A & TRT
- ENEL

SCHEDULE AS OF 02/19/93



PCCS Large Scale Heat Transfer Tests

AP600

- Organization - Westinghouse

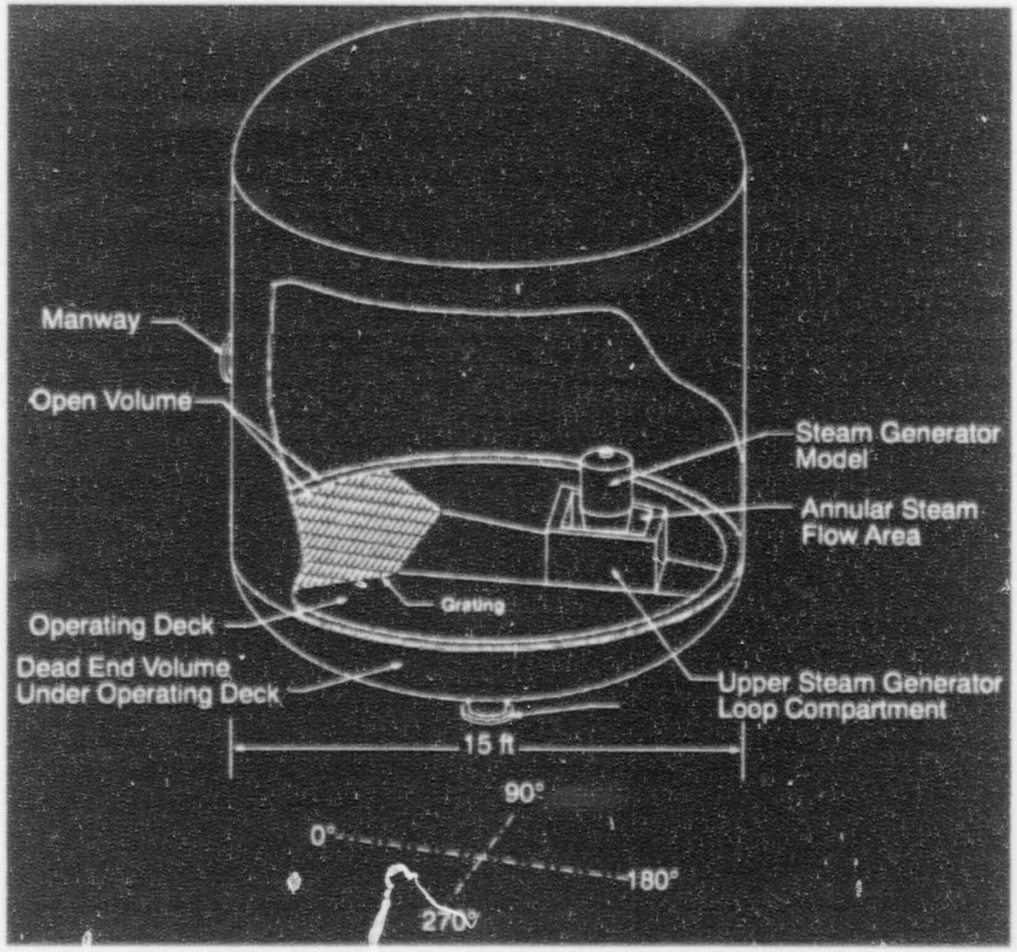
- Location - Science and Technology Center, Churchill, PA

- Key Features
  - 1/8th scale containment vessel
  - 100 psig max pressure
  - 350°F max temperature
  - Interior containment model of operating deck and SG compartment
  - Variable coverage water distribution system
  - Exterior water film and air cooling
  - Three independent methods used to obtain heat balances

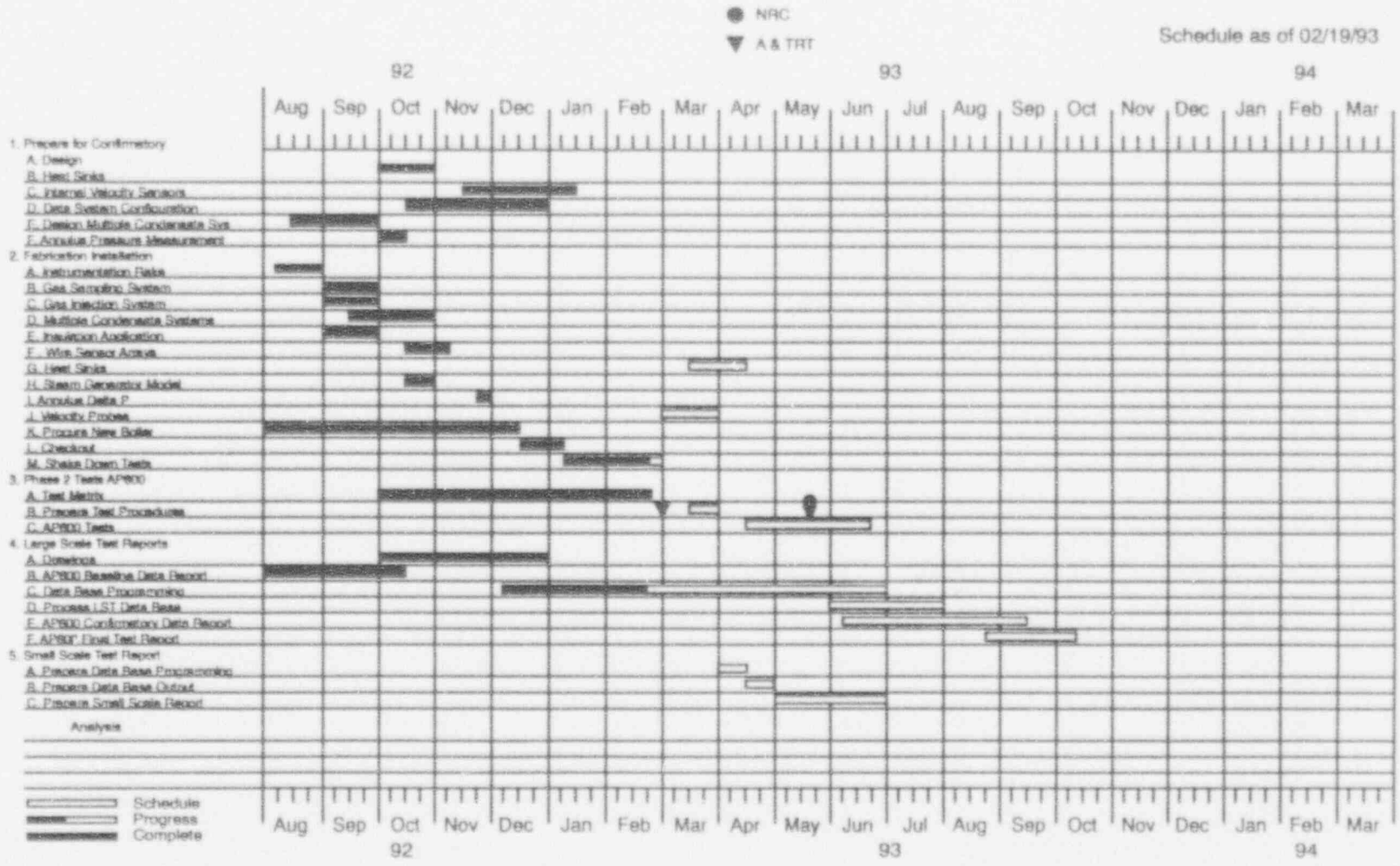
- Purpose
  - Obtain data to verify computer code used to predict containment performance

- Matrix tests scheduled to begin April 1993

PCCS Large Scale Heat Transfer Tests



PCCS Large Scale Heat Transfer Test Schedule



AP600 TEST ANALYSIS PLAN

L. E. HOCHREITER, CONSULTING ENGINEER

NUCLEAR SAFETY ANALYSIS AND STRATEGIC DEVELOPMENT

AP600 Test Analysis Plan

- The AP600 Test Analysis Plan consists of:
  - A scaling logic for the test
  - Engineering analysis with computer codes to support the test design, instrumentation, test procedures, and test operation
  - Test data analysis to help verify tests, derive thermal-hydraulic parameters from the data
  - Post test analysis with SSAR computer codes to verify/improve component models
  - Analysis report

Automatic Depressurization System Tests

- Tests are full scale using full scale valve package, sparger, and pressurizer
- Engineering analysis of the facility has been performed by ENEA with RELAP5 to design the tests
- W is currently analyzing the Phase A tests with WCOBRA/TRAC and has a Phase B model operational
- The ADS Tests will be analyzed to determine
  - Structural loadings on the tank during depressurization
  - Choking behavior of the sparger
  - Critical flow through the ADS valves
  - Two-phase loading on the tank and sparger
  - ADS discharge line pressure drops
- Post test analysis on the ADS tests will be performed using both WCOBRA/TRAC and NOTRUMP. In addition, ENEA will do post test analysis with RELAP5
- WGOTHIC analysis is being performed to examine the tank loading behavior

Core Makeup Tank Test

- Scaling logic will be provided to verify that the key thermal-hydraulic phenomena will be captured in the scaled CMT test

- Engineering analysis of the CMT has been proceeding using WCOBRA/TRAC to help size components, design the tests, place instrumentation as well as to test the code

- The CMT data will be analyzed to determine:
  - Mass/energy balances
  - Wall condensation heat transfer coefficients
  - Interfacial heat transfer
  - Thermal Stratification/Mixing effects
  - Void fraction with depressurization
  - Natural circulation behavior

- SSAR codes (WCOBRA/TRAC and NOTRUMP) will be used to analyze the CMT tests

Oregon State University (OSU) Low Pressure Integral Systems Test

- A detailed scaling analysis has been performed to design the reduced pressure, reduced height facility

- Engineering analysis is being performed with NOTRUMP to help size the components, verify the pressure scaling approach and plan the tests

- The OSU tests will be analyzed to determine:
  - Transient system behavior for different break locations, sizes, and system failures
  - Test facility transient mass/energy balance
  - Flow regime characteristics

- Tests will be analyzed using NOTRUMP and WCOBRA/TRAC

SPES-2 Full Height, Full Pressure Integral Systems Tests

- Scaling analysis has been performed to size loop components
- Engineering analysis of the facility is being performed by Ansaldo using RELAP5/Mod 3, to verify scaling and to establish test operating procedures
- Currently setting up a NOTRUMP model for SPES-2
- SPES-2 tests will be analyzed to determine:
  - Transient system behavior for different SBLOCA break locations, sizes, system failures; Steam generator tube rupture; and Main steam line break
- Tests will be analyzed using NOTRUMP and WCOBRA/TRAC

Large Scale Containment Tests

- Scaling logic presented in WGOTHIC topical report (WCAP-13246)
- Feasibility tests analyzed with WGOTHIC
  - University of Wisconsin condensation tests
  - Heated plate tests
- Integral (small scale) PCCS tests have been analyzed with WGOTHIC and COMPACT
- Engineering analysis of Large Scale tests was down with COMPACT to help place instrumentation, examine flow patterns
- Large scale baseline tests have been analyzed with WGOTHIC
- Currently performing pretest/engineering analysis with WGOTHIC to establish test conditions
- Large scale test data will be analyzed to obtain
  - test mass/energy balances inside and outside of containment
  - local heat flux, heat transfer coefficients
  - non-condensible distribution
- Large scale tests will be analyzed using WGOTHIC

Conclusions

- A comprehensive AP600 test and analysis program has been developed and is in progress
- Key new features are being tested
- Tests will characterize the unique features at large scales so that computer models can be developed or verified
- State-of-the-art safety analysis methods employed
- The combined test and analysis program will meet AP600 licensing needs

W/NRC INTERFACE, INFORMATION FLOW

J. C. BUTLER, PRINCIPAL ENGINEER
ADVANCED PLANT SAFETY AND LICENSING

W/NRC Interface, Information Flow

- Westinghouse is committed to conducting the AP600 test program in an open interactive environment
- The current test program has benefited from comments and discussions with the NRC and Industry
- The test program schedule is demanding and success oriented
- The need for close and frequent interaction is crucial to the success of this schedule.
- The need for ample time to for NRC review of the test programs and test results is recognized

W/NRC Interface, Information Flow

AP600

Steps taken to ensure that high quality information is provided in a timely manner

- Submit all test documents related to tests as they are created
  - e.g., test plans or specifications, scaling rationale, facility description reports, instrumentation plans, facility/component drawings, test data reports, test analysis reports
- Hold joint meetings with NRR, RES, ACRS staff and consultants
  - to discuss test plans, analysis plans, instrumentation requirements, design and schedules
- Provide information in advance of meetings
  - to obtain feedback and comments during the meetings and to allow for more meaningful discussion

W/NRC Interface, Information Flow

AP600

Steps taken to ensure that high quality information is provided in a timely manner (continued)

- Provide test data on an ongoing basis
  - rather than providing solely at the conclusion of the test program
- Provide updated test schedules on a monthly basis
  - to keep the NRC apprised of progress and to assist in plans for test reviews, visits and witness points
- Minimize Proprietary claims on submitted information

W/NRC Interface, Information Flow

AP600

AP600 Testing Program Review Meetings (December '92 - April '93):

December 9, 1992	-	OSU Tests Detailed Review
December 10, 1992	-	SPES-2 Tests Detailed Review
December 14, 1992	-	Testing Program Overview
February 25, 1993	-	CMT Tests Detailed Review & Facility Visit
March 9-10, 1993	-	Test Program Review and Facility Visits
March 23-24, 1993	-	Containment Tests Review and Facility Visits
April 20, 1993	-	ADS Tests Review and Facility Visit
April 22, 1993	-	SPES-2 Tests Review and Facility Visit

FACILITY TOURS