Westinghouse Non-Proprietary Class 3

Westinghouse Energy Systems

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WCAP-13234
Revision 2

WCAP-13283, Revision 1
is superceded by the
issuance of this WCAP.

TEST SPECIFICATION
FOR
LONG-TERM COOLING TEST

AP600 TEST PROGRAM
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Reviewed by: L. V. Tanto for LKL
L. K. Lau,
OSU Facility Project

Approved by: E. J. Piplica 9/2/94
E. J. Piplica, Manager
Test Engineering

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1.0 PURPOSE

To design and construct a test facility to provide valid thermal hydraulic data to verify the AP600 thermal hydraulic computer codes. The data shall capture key AP600 phenomena such as gravity injection, natural convection and post-accident long-term core cooling behavior at various modes of operations.

To validate the AP600 thermal hydraulic computer codes, the following features shall be incorporated in the test:

- The AP600 Reactor Coolant System including the reactor vessel and internals, two steam generators, four reactor coolant pumps, one pressurizer and the surge line and the connecting two hot legs and four cold legs.

- AP600 passive safety features including the steam generator system (SGS), the passive core cooling systems (PXS) and the automatic depressurization system (ADS) shall be simulated in the test.

- The non-safety systems connecting to the passive safety systems also shall be simulated. These non-safety systems include normal residual heat removal system (RNS) and chemical and volume control system (CVS). However, heat exchangers for these systems are not required.

  The interaction between the passive safety features and the non-safety systems shall be investigated.

- The AP600 containment sump and floodup volume shall be simulated in the test to investigate sump recirculation behavior.

- Small break loss-of-coolant-accidents (SBLOCA) and inadvertent ADS operation shall be simulated in the test to investigate the operation process of the AP600 passive safety features. Each of these accidents shall be simulated from the onset of the accident to the final long-term core cooling mode operation.

Each operation shall provide data to characterize the cooling flow paths into the simulated reactor, through the core, to and out the ADS valves, steam generators, the ADS valves on the hot legs and the break in the loop piping, and other loops in the test facility.

2.0 TEST OBJECTIVES

The overall objective of the test program is to obtain test data at various modes of operations of a 1/4 height scale model of the AP600 Reactor Coolant System (RCS) and applicable portions of the AP600 PXS, Steam Generator System, ADS, Chemical and Volume Control System (CVS) and Normal Residual Heat Removal System (NRS). The test is designed to operate at maximum pressure of 400 psia and maximum temperature of 450°F.

This scaled test facility shall be made of stainless steel material. The RCS model shall include the reactor vessel (RV) and the internals, a pressurizer and the associated surge line, two (2) steam generators (SG), two (2) hot legs, four (4) cold legs, four (4) simulated reactor coolant pumps (RCP) and the associated valves and pipes. The normally flooded portion of the lower containment in AP600 shall be modeled with a tank called the primary sump tank; and the normally non-flooded portion of the lower containment in AP600 shall be modeled with another tank called the secondary sump tank. The primary sump recirculation process shall be modeled. It should be noted that modeling of the control rods and the control rod drive mechanisms at the upper head region of the AP600 reactor vessel are not required. The portions of the PXS to be modeled shall include the ADS, two (2) accumulators, two (2) core makeup tanks (CMTs), one (1) passive RHR heat exchanger, and one (1) incontainment reactor water storage tank (IRWST) as well as all interconnecting valves and piping. One (1) makeup pump and the associated makeup piping loop of the CVS and one (1) normal residual heat removal pump and the associated pipe from the IRWST to RCS cold leg also shall be modeled.

AP600 ADS consists of two trains of ADS 1-3 and two trains of ADS 4 (fourth stage ADS). The test facility shall use one train of ADS 1-3 to simulate flow area for either one train or two trains of AP600 ADS 1-3. The test model shall also use two trains of ADS 4 with each train capable of modeling various flow areas. The ADS 1-3 in the test model shall consist of three (3) parallel lines, with each line properly scaled. The locations of all ADS shall be properly modeled in the test.

Demineralized water will be used as the working fluid and the reactor core will be simulated with electric heater rods scaled to match AP600 core decay heat during the long-term cooling mode. Break locations on both the hot and cold leg loop piping, direct vessel injection (DVI) lines and CMT balance line to the cold leg, will be simulated.

Specific objectives are to:

- Design and construct a scale model which will provide valid thermal hydraulic data including the long-term cooling mode for the AP600.

- Measure flows, pressure drops and temperatures as a function of transient time in all loop flow paths and the simulated reactor vessel to characterize the operation of the AP600 during the long-term cooling mode to obtain a mass and energy balance on the system.

- Provide supplemental information such as phase changes during transient to aid mass and energy balance analysis.

- Provide valid thermal/hydraulic data on the core flow behavior on a scaled basis for each of the different injection modes: accumulators, CMT, IRWST and the lower containment sump recirculation.

- Investigate a wide range of test conditions to examine the limits of core coolability for the post-accident period. These test conditions range from small break simulation with single failure to double-ended break with multiple failures.

- Provide data on the interfacing effect from CVS makeup pump and RNS RHR pump on long-term core cooling.

- Provide a basis to scale the test result to high pressure core cooling transients.

- Measure flows at the ADS and the breaks as well as other loop flow paths. These flow measurements shall aid in the estimation of boron buildup in AP600.

- Provide capability to simulate the injection of nitrogen gas in PXS from accumulators and to cold leg / core makeup tank balance lines.

3.0 REFERENCES

A. AP600 Plant Description Document, December, 1990

B. FLECHT SEASET Program: Final Report, EPRI NP-4112, Project 959-1, September, 1986

C. AP600 Reactor Coolant System (RCS) SSD, NSE-92-0081

D. AP600 Passive Core Cooling System (PXS) SSD, NSE-92-0034

E. AP600 Steam Generator System (SGS) SSD, NSE-92-0036

F. AP600 Normal Residual Heat Removal System (RNS) SSD, NSE-92-0031

G. AP600 Chemical & Volume Control System (CVS) SSD, NSE-92-0082

H. Reactor Vessel and Internals Drawings:

- MV01 V1 001, Rev 1
- MV01 V2 001, Rev 1
- RXS V2 001, Rev 2
- MI01 V1 001, Rev 2

I. Steam Generator and Pressurizer Drawings:

- MB01 V2 101, Rev 3
- MB01 V1 001, Rev 2
- MB01 V2 001

J. Primary Loop Layout Drawings:

- PL01 V2 001, Rev 3

K. NSSS Systems Drawings:

- RCS M6 001, Rev 6
- SGS M6 001, Rev 4
- PXS M6 001, Rev 4
- CVS M6 001, Rev 5
- RNS M6 001, Rev 3

L. IMP THRIVE Data, MED-RPV-3403

M. AP600 Design Parameter List, NSE-90-0334

N. PRHR HX Design Document, SEE-FS(91)-0179

O. AP600 General Arrangement Drawings for Reactor Floodup Volume:

- 1010 P2 001, Rev 1
- 1020 P2 001, Rev 1
- 1020 P2 002, Rev 1
- 1030 P2 001, Rev 1
- 1040 P2 001, Rev 1
- 1000 P2 901, Rev 1
- 1000 P2 902, Rev 1
- 1000 P2 907, Rev 1

P. Containment Volumes and Heat Sinks Calculations ,1100 SOC 001, Rev. 0

4.0 TEST FACILITY REQUIREMENTS

The test facility for the AP600 Long-Term Cooling Test shall model the AP600 RCS, PXS, ADS, portion of SGS, CVS and RNS and lower containment structures. The test facility shall have the following capabilities:

A. Provide adequate space for all test components and supporting systems such that the test can be constructed and operated with ease, efficiency and safety. The facility shall be constructed indoors. Large tanks, if required, may be placed outdoors if adequate protection from freezing or other environmental damage is provided. All test components shall be situated at scaled heights as determined form a scaling study based on prototypical AP600 dimensions.

B. A controlled electrical supply system estimated to be at least 720 kilowatts must be provided to power the electrical heater rods in the reactor core model in order to simulate the core decay heat during long-term cooling operation. Controls must be such that the decay heat transient can be simulated automatically.

C. A cold water supply and a demineralized water system capable of providing demineralized cold water at adequate rates for system and equipment fill, CVS makeup, condensate return (makeup) simulating passive containment cooling process and SG feedwater supply must be provided. Pumped fill and drain capability must be installed.

D. Adequate drainage systems must be provided to remove water from the test loop as well as any spillages or overflows such that the test facility will not be adversely affected.

E. A two-phase flow separation system to separate two-phase mixture into single-phase steam and liquid from selected discharge pipes and simulated breaks must be provided. Flow rate, pressure, and temperature measurements at selected locations must be provided.

F. Adequate ventilation must be provided to remove steam or water vapor discharged from the test facility and to control test facility temperature to protect sensors.

G. A data collection system (DAS) to record up to 1000 channels from various sources such as thermocouples, pressure sensors, flow meters, shall be provided. All data shall be permanently recorded on an acceptable electronic media (such as CDs) for transmission to Westinghouse. (See Section 7.0.)

H. Major operating parameters such as system pressure and temperature shall be visually displayed independent to the DAS system, for safe operation of the test facility consideration.

I. An instrumentation plan shall be developed and used which will permit accurate calculations of transient mass and energy balances for the systems.

J. The facility shall be capable of performing steady-state experiments as well as transient blowdown tests.

K. Provide a system to simulate the AP600 containment pressure at a controllable fashion and automatically.

L. Provide a condensate makeup system to simulate the condensation return process in AP600 Passive Containment Cooling System (PCCS).

M. The facility shall be flexible to perform break simulation transients at different locations without major modification.

N. The facility shall be capable of changing ADS from single train simulation to two train simulation with minimum effort, and vice versa.

The vendor is to supply all consumables including power, water, compressed air, cables, etc.

The test vendor is to perform detail scaling analysis of the Long-Term Cooling Test Facility and to provide steam generator design, PRHR HX design, control room design, supporting structure design, HVAC system design, and to operate the test facility. The vendor is also responsible to satisfy all local zoning requirements, OSHA requirements and to obtain proper operating permits. Westinghouse is to supply the test facility design, instrumentation design and the reactor vessel and internals design. The vendor has the responsibility of procurement and fabrication of the test facility components which includes instrumentation and calibration.

5.0 TEST ARTICLES

All test articles and interconnecting piping shall be sized and located at the proper elevations based on the scaling study using prototypical AP600 dimensions to the maximum extent possible. The following major test articles are to be provided for the AP600 Long-Term Cooling Test:

A. Reactor Vessel

The RV shall be constructed of stainless steel material and include a model representation of the upper and lower reactor internals, the core barrel and core reflector and downcomer, the reactor core (using electrically heated rods) and the upper head region. Connections for the hot and cold legs and PXS injection nozzles shall be provided. Heat losses from the vessel shall be minimized. Control rods and control rod drive mechanisms are not included. Westinghouse is to provide the design of the reactor vessel and internals. The vendor is to fabricate and assemble it.

B. Reactor Coolant Loop Piping

Both the hot and cold leg (of the RCS) pipes shall be made of stainless steel material. Heat losses from the loop piping shall be minimized.

Valved tees shall be installed to exit off one (1) hot leg and two (2) cold legs to simulate pipe breaks of various size. The discharge from these simulated breaks shall be allowed to expand freely in an expansion chamber with minimum resistance. The expanded two-phase flow shall then be directed to the two-phase flow separation system with proper temperature, pressure and flow rate measurement to characterize the break flow. The liquid shall be drained to the primary sump tank at properly scaled elevation, and the steam shall be measured and vented out of the test facility building.

Westinghouse is to provide the design of the reactor coolant loop piping including pipe routing and pipe break spools. The vendor is responsible for the actual fabrication of the loop.

C. Steam Generator

The two steam generators shall be made of stainless steel. While the SG channelhead shall be sized according to the scaling study from prototypical AP600 dimensions, the upper body of the SG need not be of prototypical scale but shall approximate the AP600 to the maximum extent possible. A heat exchanger shall be provided to remove the heat from the secondary side of each steam generator or dump the steam directly to an existing steam line. Although steam generator tube rupture (SGTR) is not tested at this time, the SG design must incorporate provisions to allow testing of SGTR conditions. The vendor is to design and construct the steam generators. Westinghouse will review and approve the design prior to actual fabrication.

D. Pressurizer (PZR)

One (1) pressurizer with pressurizer over-pressure protection device shall be used in the test. It shall be made of stainless steel material. A heater shall be used for level and pressure control. Westinghouse is to provide design specifications. Vendor is to perform detail design and fabrication. Westinghouse shall review and approve the design.

E. Automatic Depressurization System (ADS)

Valves and pipes shall be provided off the top of the PZR and to the simulated sparger in IRWST to simulate the first three stages of AP600 ADS. One train of ADS 1-3 shall be used in the test. This train shall consist of three parallel lines, each simulating stage 1, 2 or 3, and each includes an isolation valve and flow nozzle. Also, each parallel line shall be able to simulate either single train or two train AP600 ADS arrangement. Therefore, line size and flow nozzle size in each stage in the test shall be properly scaled and designed.

The fourth stage of the ADS shall be represented by two lines, each with one valve and one flow nozzle. Each line is located off a hot leg and discharges into an expansion chamber where the ADS 4 flow expands freely. The expanded ADS 4 flow shall then be directed to the two-phase flow separation system with proper pressure, temperature and flow measurements. Westinghouse is to design the ADS, including pipe routing, and the vendor is to fabricate and assemble the ADS.

F. Core Makeup Tank

Two (2) closed vessels made of stainless steel material shall be provided to gravity drain into the RV through the safety injection nozzles. Water level and flow rates shall be measured. Control logic shall be provided to actuate ADS valves via the CMT levels. Westinghouse is to provide CMT design, piping design and control logic design for fabrication by the vendor.

G. In-Containment Refueling Water Storage Tank (IRWST)

A closed vessel shall be provided to simulate the IRWST. This vessel shall be capable of venting to atmospheric pressure or pressurized to a given pressure simulating containment pressure in AP600. This tank shall be equipped with sufficient venting capacity to prevent over-pressurization. The vent/relief valves shall be capable of maintaining a desired pressure ranging from atmospheric pressure to 40 psig (containment pressure). The discharge line from the first three stages of ADS valves located on top of the PZR shall lead to a simulated sparger located in the IRWST. The sparger shall be properly scaled and designed such that one sparger in the test can be used to simulate either single or two trains in AP600. The sparger design must be flexible such that different sparger arms can be used without major facility modifications.

Westinghouse is to provide design specifications. Vendor is to provide detail design and fabrication. The final design must be approved by Westinghouse.

H. Lower Containment Structure

Two stainless steel vessels shall be provided to simulate the AP600 lower containment—one simulates the normally flooded area (called the primary sump tank) and the other simulates the normally non-flooded area (called the secondary sump tank). The primary sump tank shall be sized to simulate normally flooded volume in the AP600 lower containment structure; and the secondary sump tank shall be sized to simulate normally non-flooded volume in the AP600 lower containment structure. These tanks shall be located at properly scaled elevations. The inlet and outlet piping connections shall be properly scaled and located also. These vessels shall be able to operate at atmospheric pressure or be pressurized to simulate AP600 containment pressure. Venting and pressure control device shall be used to prevent over-pressurization or vacuum. Westinghouse shall design and provide specifications for these vessels. Vendor shall perform detail drawings and fabrication. .

I. Accumulators

Two (2) water tanks representing the AP600 accumulators shall be designed and made of stainless steel material and will be designed to full system pressure and will be pressurized with nitrogen. Westinghouse is to provide design specifications. Vendor is to perform detail design and fabrication. Westinghouse shall approve the design prior to fabrication.

J. Passive RHR Heat Exchanger (PRHR HX)

One (1) 100% capacity of AP600 PRHR HX shall be modeled in the test. The PRHR HX shall be made of stainless steel material and of C-tube type. The heat transfer shall be properly modeled. Westinghouse shall supply information for vendor to design and fabricate the PRHR HX.

K. Normal RHR System

Part of the normal RHR system shall be modeled in this facility. Specifically, one (1) RHR pump and lines connecting from IRWST to DVI shall be modeled. Westinghouse is to provide the design for fabrication by vendor.

L. Chemical and Volume Control System (CVS)

Portion of the CVS shall be modeled. Specifically, the CVS makeup pump and the associated lines to the steam generator channelhead (cold leg side) shall be modeled with stainless steel material. Westinghouse is to provide detail design and the vendor is to fabricate it.

M. Condensate Makeup Tank with Electrical Heater

One stainless steel tank shall be used in this facility. This tank with an electrical heater inside is part of the condensate return system which simulates the AP600 passive containment cooling process. The tank shall be located at a convenient place to supply condensate makeup to either IRWST or the primary sump tank automatically and programmably. This tank shall also provide pre-heated water to the two-phase flow separation system to prevent unnecessary condensation of the steam flow from various sources such as a break or ADS 4. Westinghouse is to provide design specifications and automatic control logics. Vendor is to perform detail design and fabrication. Westinghouse shall approve the design prior to fabrication.

N. Interconnecting Piping Simulating AP600 Piping

All interconnecting piping shall be designed to be of proper size based on the scaling analysis. Adequate pipe strength, support and flexibility shall be provided to insure the integrity of the system. All pipe lines shall be designed and routed to avoid water hammer and shall be capable of being completely drained and cleared. Injection lines and vent lines shall contain replaceable orifices for simulating the effective pipe sizes. Westinghouse is to provide detail design of the piping for fabrication and installation by the vendor. Westinghouse shall perform piping analysis.

O. Two-Phase Flow Measurement System

A two-phase flow measurement system shall be used to measure two-phase flow from various sources such as a break or ADS 4. This system shall use four (4) separators, each capable of separating two-phase mixture into single-phase steam and single-phase liquid. Four separators shall be used—one for ADS 1-3 flow measurement, two for ADS 4 flow measurement and one for break flow measurement. The interconnecting pipes shall be provided for proper single-phase flow measurement. Proper instrumentation shall be provided to characterize the two-phase flow. Westinghouse shall provide detail design of the separators and connecting pipings. Westinghouse shall also provide instrumentation specifications. Vendor is to procure, fabricate and install the system.

P. Break Simulation Arrangements

Break simulations at one (1) hot leg, two (2) cold legs, one (1) direct vessel injection line and one (1) cold leg to CMT balance line shall be provided in this test. Breaks of different sizes shall be used, ranging from 1/2" to double-end DVI break. Westinghouse shall provide design on these break spools and piping arrangements. Vendor is to fabricate and install them.

Q. Fill and Drain System

There shall be a fill and drain system (including a feedwater tank) used in this test. The vendor is to design, fabricate and install the system and associated pipes and valves.

R. Demineralized Water System

A demineralized water system shall be provided to ensure proper conductivity in the water for proper functioning of some of the instrumentation used in this test. This system shall be able to provide pure water to minimize scale formation on the electrical heater rods located in the reactor vessel. Adequate spare parts shall be provided to ensure continued operation of the test facility. Vendor is to design, fabricate, and install this system. Westinghouse shall approve the system design prior to actual installation.

S. Support Structures and Miscellaneous Piping

All support structures and non-AP600 piping required for this test facility shall be designed, fabricated and installed by the vendor. Westinghouse shall agree on the design either verbally or in writing.

6.0 INSTRUMENTATION AND CONTROL REQUIREMENTS

This test shall simulate proper AP600 control logics and shall provide adequate information to perform an overall mass/energy balance of AP600 loops during both transient and steady-state conditions. To achieve this goal, control logics shall be designed and used in this test and redundant instrumentation shall be used and located at properly selected locations. The following subsections provide a basis for instrumentation selection. Actual quantity and type of instrumentation can only be finalized during the actual design stage. Approximately 1,000 shall be planned for.

A. Types of Instrumentation

It is important to define all the instrumentation that may be required to obtain a mass/energy balance in the test facility prior to construction of the loop. Allowances for installation of instrumentation, such as taps for differential pressure transducers, can then be installed during construction in the event they are required in the future.

The following types of instrumentation are to be provided for the AP600 Long-Term Cooling Test:

- Thermocouples (T/Cs) shall be used to measure the temperature of the coolant in the primary and secondary systems as well as any supply or component cooling water. They also measure selected component wall and insulation temperature in order to complete mass/energy balance on the component.

  T/Cs shall also be used to measure the temperature distribution in the heater core. Locations shall be chosen within selected heater rods to obtain both the axial and radial temperature distribution within the heater core. Premium grade thermocouples shall be used and connected through controlled purity extension wire to a low level volt meter and analog-to-digital conversion circuit in the data acquisition system (DAS).

- Recording flow meters shall be used to measure all single phase water mass flow rates. The range of these meters must be carefully selected to minimize error.

- Pressure transducers shall record the absolute pressures within various tanks and at selected locations in the test loops.

- Differential pressure transducers shall be used to record pressure drops and liquid levels in various tanks and vessels in the test loops as well as the liquid inventory in various pipes in the primary loop.

- Two-phase flow can be directed to moisture separators to provide for quality measurement. The proposed method is to separate the steam and water and measure over time the steam, the water flow rate, the pressure and temperature.

- Vortex meters can be used to measure single phase steam flow. For low rate liquid flow, a magnetic flow meter, turbine meter or other applicable flow meter can be used.

- Instrumentation is required to measure and record the ambient air conditions including barometric pressure, temperature and humidity.

B. Types of Controls

The test shall model the AP600 process control wherever necessary. Controls shall be utilized in the test facility to aid the smooth operation of test runs. Following is a preliminary list of process controls to be used in the test. Additional controls may be added as required.

- Steam Generator Level Control
  Water level in the steam generator shall be controlled. This is performed by monitoring the steam generator level which is interlocking with the feed water control valve. A Programmable Logic Controller (PLC) can be used for this purpose.

- Steam Generator Main Steam Throttle Control
  Main steam flow shall be controlled with throttle valve and PLC. This controls the simulated SG pressure.

- Steam Generator Steam Isolation Valve Control
  On/off control of each steam generator steam line isolation valve. Vale is normally open and is interlocked to close, if necessary.

- ADS Actuation
  The ADS valves shall be interlocked to open at selected CMT water levels. Valves included in this operation are 1-3 stage ADS valves and two fourth stage ADS valves.

- CMT Actuation
  The CMT to cold leg balance line isolation valves are normally open. The normally closed isolation valve in the DVI line shall be controlled by PLC to open at simulated "S" signal or low pressurizer water level.

- Reactor Vessel Heater Rod Control
  Power to heater rods is interlocked to shut off at high heater and sheath temperature, high reactor vessel pressure or low reactor vessel water level.

- PRHR HX Discharge Line On/Off Control
  PRHR HX discharge line isolation valve is interlocked to open at the actuation of the first stage ADS valve, or at a time delay after "S" signal which is a signal to actuate safety features.

- Other on/off valves are CVS and RNS pump discharge isolation valves.

- Programmable control of CVS pump and/or RNS pump discharge flow rate.

Westinghouse shall provide control logic diagrams. Vender is to procure, fabricate and install them.

7.0 DATA ACQUISITION

The data acquisition system shall include the equipment necessary to receive, transmit, process and record the voltage or current signals output from the individual sensing instruments including amplifiers, signal conditioners, transmitters, interconnecting wiring, analog-to-digital converters, interfacing boards, switching panels, computers, displays and other recording devices as needed.

A. Input Channels

The ability to receive up to 1,000 analog signals from the various thermocouples, pressure sensors, flow meters and other instrumentation, and record them digitally will be required. Shielded leads shall be used for all signal input leads to minimize noise.

B. Sampling Rates

Total system input for the required data acquisition system shall be a minimum of 70 channels scanned per second. Higher input rates are allowable.

C. System Accuracy

Digitizing errors for the various channels from sensor to DAS shall meet or exceed the following requirements:

• Thermocouples	±2% full scale
• Flow Meters	±2% full scale
• Pressure Transducers	±2% full scale
• All Other Instrumentation	±2%

Note: These are total errors from sensing source to the DAS. Accuracy of the sensor itself can be better.

D. Signal Input Levels

The data acquisition system must be capable of processing the following signal levels for the various instrumentation channels:

• Thermocouples	5-12 Millivolts DC
• Flow Meters	4-20 Milliamps DC
• Pressure Transducers	4-20 Milliamps DC
• All Other Instrumentation	As Required

E. On-Line Data Storage

The capacity of the data acquisition system must be capable of storing and maintaining all data retrieved and recorded during a single test. Steady-state tests are expected to run for up to three hours or longer. Transient tests may run for up to eight hours or longer.

F. On-Line Monitoring

The data acquisition system must have the capability of validating test signals while testing is in operation. For example, dynamic strip chart displays, CRT displays, channel snapshots or other acceptable displays shall be available for verification. In addition, the DAS shall be able to log the sequence of events automatically, e.g., opening and closing time of a valve.

G. Post-Test Requirements

Permanent storage of all test data shall be on electronic media such as computer diskettes, magnetic tapes or CD ROMS to be delivered to Westinghouse Electric Corporation following each series of tests. Within a reasonable time after the completion of a test, the site operation team shall produce "day-of-test" report to be transmitted to Westinghouse. This day-of-test report shall include data plots, test log and any unusual observations during or after the test.

8.0 TEST OPERATION

The operation of the test facility shall be established and documented in the Test Operating Procedures. These operating procedures shall include, but not be limited to:

A. Facility Shakedown

A series of pre-operational tests will be performed to assure that the model has been built to the specifications defined herein and that the facility can be operated safely and reliably. As a minimum, the following types of Pre-Operational Tests shall be performed:

Cold Pre-Operational Tests

- Instrumentation calibration, check and verification
- Process and control instrumentation calibration, check and verification
- Measure CMT gravity flow rate, injection line pressure drop
- Measure ACC flow rate, injection line pressure drop
- Measure IRWST gravity flow rate, injection line pressure drop
- Measure or obtain charging pump injection rate as a function of pressure
- Measure or obtain NRHRS pump injection rate as a function of pressure
- Measure ADS line pressure drop
- Measure or obtain steam generator feedwater pump flow as a function of pressure
- Measure primary loop flows and component pressure drops
- Hydrotest primary system, including safety injection tanks
- Perform loop drain test to check total system volume
- Hydrotest containment sump tank and IRWST

Hot Pre-Operational Tests

- Measure primary loop flows and loop pressure drops
- Measure component heat loss
- Calibrate core power (full and decay power vs. time)
- Measure steam generator energy removal (full and decay power)
- Characterize PRHR natural circulation flow and heat removal
- Measure CMT drain rate via CL/CMT steam balance line
- Depressurization test for system checkout

Detailed Shakedown Test Operation Procedures shall be developed and approved by Westinghouse in advance of the tests.

B. Calibration

All instrumentation and the DAS shall be calibrated to traceable national standards under controlled conditions to assure their operability and accuracy. A series of instrumentation readings under controlled conditions shall be documented.

C. Matrix Testing

Steady-state and transient matrix tests shall be performed to examine:

- the operation of the long-term gravity makeup path from the in-containment refueling water storage tank (IRWST).
- the long-term core cooling via gravity makeup and the natural circulation flow path from the flooded reactor vessel cavity, i.e., the primary sump tank and
- the operation of the ACCs and CMTs during different types of SBLOCAs combined with:
  - Single failures of ADS valves
  - Active or inactive PRHR
  - Active or inactive non-safety RHR or CVS systems
  - Other single or multiple failures, as required

The tests shall provide data to characterize the cooling flow paths into the reactor, throughout the core, into and out of the Automatic Depressurization System (ADS) valves, steam generators (SG), the ADS valves on the hot leg and the break in the reactor coolant system piping. These tests shall be defined and delineated in a test matrix to be provided by AP600 Test Engineering. Attention shall be given to the initial conditions of the test loop prior to initiation of the test. This includes initial system inventory, power, pressure, flows and temperatures. In addition, each matrix test requires a reviewed and signed test procedure prior to actual testing. Westinghouse shall provide all matrix test procedures.

Two main categories of tests shall be performed in the OSU AP600 Test Facility:

- Small Break LOCA Tests
- Long-Term Cooling Tests

These tests shall be grouped into series as follows:

Series 1: Cold Leg SBLOCA

These tests shall be initiated by "opening" a break on the cold leg spool piece while at known initial conditions. The parameters that shall be varied are break size, break location and orientation, PRHR status, non-safety system status and ADS valve status.

Series 2: CMT – Cold Leg Balance Line SBLOCA

These tests shall be initiated by "opening" a break on the cold leg balance line (at the horizontal run) to the CMT while at known initial conditions. The PRHR shall be active and the non-safety system shall be inactive. One fourth stage ADS valve shall be failed closed.

Series 3: DVI Injection Line SBLOCA

These tests shall be initiated by "opening" a break on the DVI spool piece while at known initial conditions. The parameters that shall be varied are PRHR status, non-safety system status and ADS valve status.

Series 4: Inadvertent First Stage ADS Operation

These tests shall be initiated by opening the first stage of the ADS while at a known initial condition. The parameters that shall be varied are PRHR status, non-safety system status and fourth stage ADS status.

Series 5: Hot Leg SBLOCA

These tests shall be initiated by "opening" a break on the hot leg spool piece while at known initial conditions. The parameters that shall be varied are PRHR status, non-safety system status and ADS valve status.

All above tests will run into long-term cooling mode, unless specified otherwise. Most tests require PRHR be active and the non-safety RHR system be inactive. ADS spargers shall be simulated and IRWST injection shall be permitted following system depressurization. IRWST and sump recirculation operation and long-term cooling stability shall be examined.

The planned matrix tests are listed in Table 9-1.

9.0 TEST REPORTS AND DATA REQUIREMENTS

All test data shall be the property of Westinghouse Electric Corporation. A series of reports and procedures shall be submitted as deliverables in order to properly document the test facility design, operation and data reporting.

A. Facility Description Report

A facility design report describing the facility, test articles, instrumentation and data acquisition system used to meet the requirements of this specification shall be prepared by Westinghouse with the help of the Test Vendor.

B. Bench Test Report

A summary report shall be provided by the vendor if bench testing of certain types of equipment or instrumentation is necessary. The vendor shall consult with Westinghouse Test Engineering on instrumentation selection for the test program.

C. Facility Operating Procedures

A series of Facility Operating Procedures describing the operation of the facility shall be prepared by the test vendor in accordance with the applicable QA requirements of Section 10.0 and shall be submitted for review and approval by Westinghouse prior to the start of testing.

D. Matrix Test Procedures

Matrix test procedures shall be prepared by Westinghouse. Instrumentation check shall be included in the procedures prior to the start of each test. The procedures shall be reviewed by the vendor. Selected pre-test predictions shall be provided by Westinghouse to aid the testing operations.

E. Test Data Reduction

Following each completed set of tests, data is to be transferred to a suitable electronic media and forwarded to Westinghouse Test Engineering. The data shall include conversion from electrical signals to engineering units and provide clear identification and headings such as test number, date of test, etc.

F. Day of Test Reports

Following the completion of each test series defined in Section 8.0, data is to be collected, verified and transmitted to Westinghouse Test Engineering as a day of test report by Westinghouse site team. This report is to include all test calibration data, a verified data reduction calculation and an error analysis of the instrumentation. All data stored electronically (CD) and all video tapes shall be provided to Westinghouse Test Engineering.

Table 9-1
OSU TEST MATRIX

Series	Test Title	Break location and size	Single Failure Assumed
1, 7	SB1	2-inch break on bottom of cold leg #3 with continuation into long-term cooling	Fail 1 of 2 lines in 1 ADS-4 train
1	SB3	2-inch break on top of cold leg #3	Fail 1 of 2 lines in 1 ADS-4 train
1	SB4	2-inch break on bottom of cold leg #3 with non-safety systems on and long-term cooling	Fail 1 of 2 lines in 1 ADS-4 train
1, 7	SB5	1-inch break on bottom of cold leg #3 with continuation into long-term cooling	Fail 1 of 2 lines in 1 ADS-4 train
2	SB7	2-inch break on bottom of cold leg #3 without long-term cooling	Fail 1 of 2 trains of ADS stages 1 through 4
2	SB9	2-inch break on CMT balance line (horizontal) without long-term cooling	Fail 1 of 2 lines in 1 ADS-4 train
2, 7	SB10	DEG break on CMT balance line (horizontal) with continuation into long-term cooling	Fail 1 of 2 lines in 1 ADS-4 train
3, 7	SB11	DEG DVI line break with continuation into long-term cooling	Fail 1 of 2 lines in 1 ADS-4 train
3, 7	SB12	DEG DVI line break with continuation into long-term cooling	Fail 1 of 2 trains ADS-1 and ADS-3
3, 7	SB13	2-inch DVI line break with continuation into long-term cooling	Fail 1 of 2 lines in 1 ADS-4 train
4, 7	SB14	Inadvertent ADS 1 opening with continuation into long-term cooling	Fail 1 of 2 lines in 1 ADS-4 train
5	SB15	2-inch break on hot leg #2 without long-term cooling	Fail 1 of 2 lines in 1 ADS-4 train
1, 7	SB19	2-inch break on bottom of cold leg #3 with simulated containment backpressure and continuation into long-term cooling	Fail 1 of 2 lines in 1 ADS-4 train
1, 7	LTC21	4-inch break on bottom and top of cold leg #3 with continuation into long-term cooling	Fail 1 of 2 lines in 1 ADS-4 train

10.0 QUALITY ASSURANCE REQUIREMENTS

Testing quality assurance shall conform to a Project Quality Plan (PQP) specially prepared for this project. The PQP shall include all applicable items listed in ANSI/ASME NQA-1-1986. This test shall conform to the requirements in the Code of Federal Regulations, Title 10, Part 21 (10CFR21). The following measures shall be provided for in the PQP:

1. Provisions for ensuring that those performing the tests are qualified and trained in the quality assurance requirements of the test specification.

2. Provisions for ensuring that changes to the test procedure are reviewed and approved to the same extent as the originals.

3. Provisions for ensuring that the latest approved revision of the test procedure is used.

4. Provision for calibration of test equipment, traceable to recognized national standards. If no such standard exists, a description of the calibration method shall be included.

5. Provisions for verification and configuration control of computer software (if any) used to collect or reduce data.

6. Provision for reporting and reconciling deviations from the approved test procedure.

7. Provisions (such as a signed checklist) for ensuring that test prerequisites are met. Test prerequisites include calibrated instrumentation, appropriate equipment, trained personnel, condition of test equipment and item(s) to be tested, suitable environmental conditions, and provisions for data acquisition.

8. Provisions for ensuring that necessary monitoring is performed and that the test conditions are maintained. (A test log containing periodic signed entries that include any pertinent observations or information not captured elsewhere is recommended.)

9. Documented evaluation of test results by the test sponsor to ensure that test requirements were met.

10. Identification in the test records of items tested, date of the test, instrumentation and data recorders, type of observation, results and acceptability, action taken in connection with noted deviations, and person who evaluates the test results.