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DCP/NRC0885
Docket No.: STN-52-003

May 23, 1997

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

ATTENTION: MR. T. R. QUAY

SUBJECT: AP600 DESIGN CHANGES TO ADDRESS POST 72-HOUR ACTIONS

Dear Mr. Quay:

In Westinghouse letter, Brian McIntyre to T. R. Quay, dated March 14, 1997, Westinghouse indicated additional design changes were being implemented to address containment cooling in the post 72-hour to 7 day time frame after an event. Westinghouse also indicated that WGOTHIC containment pressure analyses with appropriate input were being performed. The attachments provide additional information related to these items as follows:

Attachment 1 - SSAR markup indicating additional changes to the passive containment cooling system.

Attachment 2 - Description of method to account for circumferential (2-dimensional) conduction through the steel containment shell for containment pressure analyses.

Attachment 3 - Revised SSAR figures indicating the results of the revised WGOTHIC containment pressure analyses.

The SSAR markups in Attachments 1 and 3 will be incorporated in Revision 13 to the AP600 SSAR.

The NRC is requested to review the attached material and provide any further comments to Westinghouse by June 16, 1997. Please contact Mr. Ron Vijuk on (412) 374-4728 if you have any questions concerning this transmittal.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

jml

Attachments

cc: W. C. Huffman, NRC (w/Attachments)
J. M. Sebrosky, NRC (w/Attachments)
N. J. Liparulo, Westinghouse (w/o Attachments)

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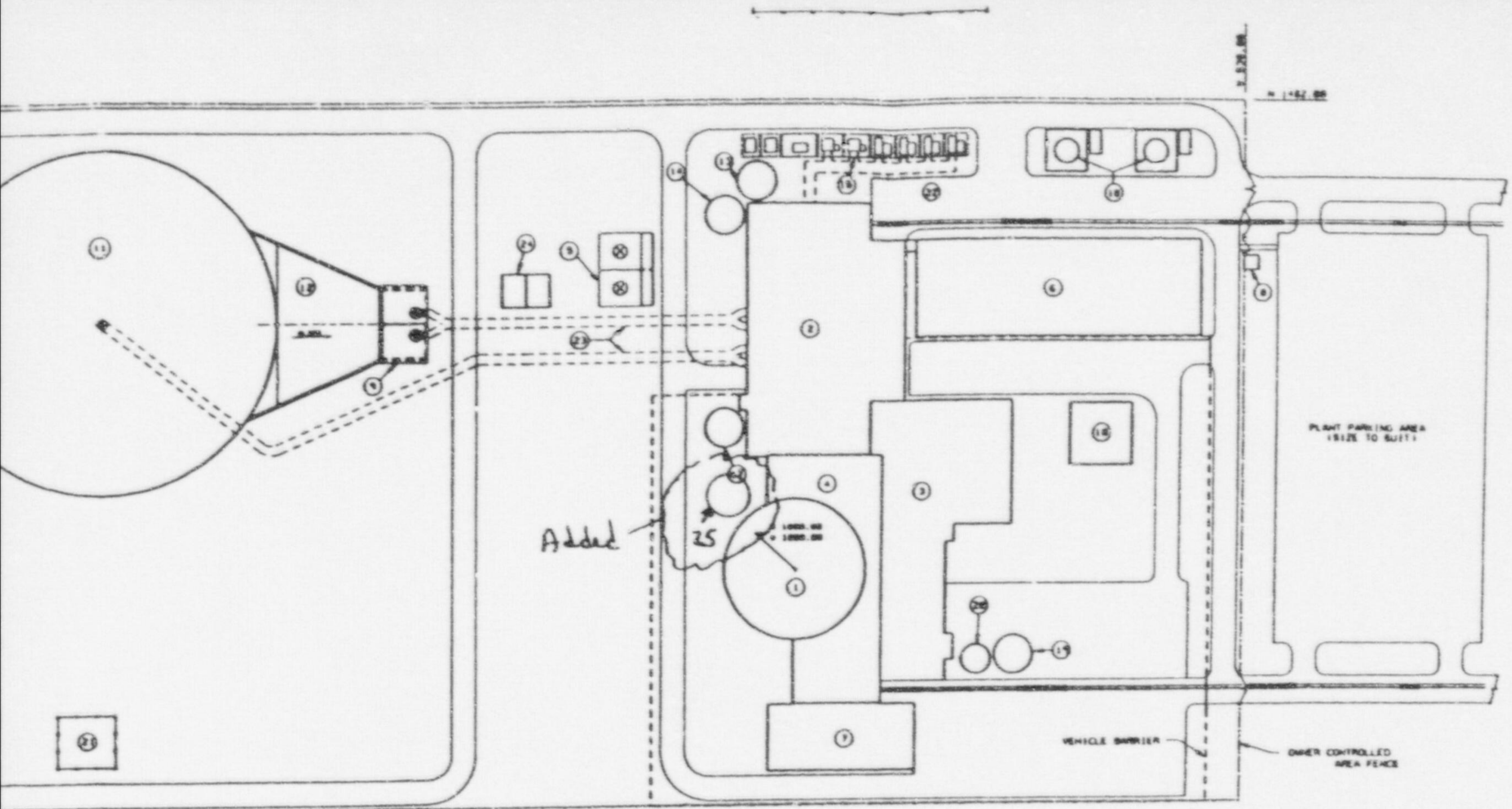
ATTACHMENT 1

SSAR MARKUP INDICATING ADDITIONAL CHANGES
TO THE PASSIVE CONTAINMENT COOLING SYSTEM



LEGEND

CONTAINMENT/SHIELD BUILDING
TURBINE BUILDING
ANNEX BUILDING
AUXILIARY BUILDING
SWS COOLING TOWERS
ADMINISTRATION BUILDING
RADWASTE BUILDING
8. PLANT ENTRANCE
9. CIRCULATING WATER
PUMP INTAKE STRUCTURE
10. DIESEL GENERATOR BUILDING
11. CWS COOLING TOWER
12. CWS INTAKE CANAL
13. FIRE WATER/CLEARWELL STORAGE TANK
14. FIRE WATER STORAGE TANK
15. TRANSFORMER AREA
16. SWITCHYARD
17. CONDENSATE STORAGE TANK
18. DIESEL GENERATOR FUEL OIL
STORAGE TANKS
19. DEMINERALIZED WATER
STORAGE TANK
20. BORIC ACID STORAGE TANK
21. HYDROGEN STORAGE TANK AREA
22. TURBINE BUILDING LAYDOWN AREA
23. CIRCULATING WATER PIPE
24. WASTE WATER RETENTION BASIN

25 Passive Containment Cooling
Ancillary Water Storage Tank

Figure 1.2-2

Site Plan

Table 3.2-3 (Sheet 8 of 64)

AP600 CLASSIFICATION OF MECHANICAL AND FLUID SYSTEMS, COMPONENTS, AND EQUIPMENT

Tag Number	Description	AP600 Class	Seismic Category	Principal Construction Code	Comments
Main Turbine and Generator Lube Oil System (LOS)					Location: Turbine Building
System components are Class E					
Mechanical Handling System (MHS)					Location: Various
MHS-MH-01	Containment Polar Crane	C	I	ASME NOG-1	
MHS-MH-05	Equipment Hatch Hoist	C	I	Manufacturer Std.	
Balance of system components are Class E					
Main Steam System (MSS)					Location: Turbine Building
System components are Class E					
Main Turbine System (MTS)					Location: Turbine Building
System components are Class E					
Passive Containment Cooling System (PCS)			Location: Containment Shield Building and Auxiliary building		
PCS-MT-01	Passive Containment Cooling Water Storage Tank	C	I	ACI 349	See subsection 6.2.2.2.3 for additional design requirements
PCS-MT-03	Water Distribution Bucket	C	I	Manufacturer Std.	See subsection 6.2.2.2.3 for additional design requirements
PCS-MT-04	Water Collection Troughs	C	I	Manufacturer Std.	See subsection 6.2.2.2.3 for additional design requirements
X PCS-MT-05	Passive Containment Cooling Ancillary Water Storage Tank	D	NS	ASME VIII	
PCS-PL-V001A	PCCWST Isolation	C	I	ASME III-3	
PCS-PL-V001B	PCCWST Isolation	C	I	ASME III-3	
PCS-MP-01A	PCS Recirculation Pump	D	NS	Hydraulic Institute Standards	
PCS-MP-01B	"	"	"	"	

Table 3.2-3 (Sheet 10 of 62)

AP600 CLASSIFICATION OF MECHANICAL AND FLUID SYSTEMS, COMPONENTS, AND EQUIPMENT

Tag Number	Description	AP600 Class	Seismic Category	Principal Construction Code	Comments
Passive Containment Cooling System (Continued)					
PCS-PL-V018	Recirculation Pump Throttle Valve	D	NS	ANSI 16.34	
PCS-PL-V021	Recirculation Suction Isolation Valve	D	NS	ANSI 16.34	
PCS-PL-V023	PCS Recirculation Return Isolation	C	I	ASME III-3	
PCS-PL-V029	PCCWST Isolation Valve Leakage Detection Drain	C	I	ASME III-3	
PCS-PL-V032A	Recirculation Pump Suction Isolation Valve	D	NS	ANSI 16.34	
PCS-PL-V032B	Recirculation Pump Suction Isolation Valve	D	NS	ANSI 16.34	
PCS-PL-V033	Recirculation Pump Post-Accident Makeup Isolation	C	I	ASME III-3	
PCS-PL-V034	Recirculation Pump Post-Accident Discharge Isolation	D	NS	ANSI 16.34	
PCS-PL-V035	PCCWST/Fire Protection Root Valve	C	I	ASME III-3	
PCS-PY-B01	Spent Fuel Pool Emergency Makeup Isolation	C	I	ASME III-3	

Balance of system components are Class E

Insert from following page

Table 3.2-3 (Sheet 10) additions

PCS-PL-V036A/B	Recirculation Pump Discharge Check Valve	D	NS	ANSI 16.34
PCS-PL-V037	PCCAWST Discharge Isolation Valve	D	NS	ANSI 16.34
PCS-PL-V038	PCCAWST ~~Discharge~~ Drain Isolation Valve	D	NS	ANSI 16.34
PCS-PL-V040	PCCAWST Discharge Isolation Valve	C	I	ASME III-3
PCS-PL-V042	PCCWST ~~Temporary~~ Long-Term Makeup Isolation Drain Valve	C	I	ASME III-3
PCS-PL-V044	PCCWST ~~Temporary~~ Long-Term Makeup Isolation Valve	C	I	ASME III-3
PCS-PL-V045	PCCWST Drain Isolation Valve	C	I	ASME III-3
PCS-PL-V046	Post-72 Hour Water Source Isolation Bypass Valve	C	I	ASME III-3
PCS-PL-V047	PCCWST Discharge Line Cross-connect Isolation Valve	C	I	ASME III-3

6.2.2 Passive Containment Cooling System

The passive containment cooling system (PCS) is an engineered safety features system. Its functional objective is to reduce the containment temperature and pressure following a loss of coolant accident (LOCA) or main steam line break (MSLB) accident inside the containment by removing thermal energy from the containment atmosphere. The passive containment cooling system also serves as the means of transferring heat to the safety-related ultimate heat sink for other events resulting in a significant increase in containment pressure and temperature.

The passive containment cooling system limits releases of radioactivity (post-accident) by reducing the pressure differential between the containment atmosphere and the external environment, thereby diminishing the driving force for leakage of fission products from the containment to the atmosphere. This subsection describes the safety design bases of the safety-related containment cooling function. Nonsafety-related containment cooling, a function of the containment recirculation cooling system, is described in subsection 9.4.6.

The passive containment cooling system also provides a source of makeup water to the spent fuel pool in the event of a prolonged loss of normal spent fuel pool cooling.

6.2.2.1 Safety Design Basis

- The passive containment cooling system is designed to withstand the effects of natural phenomena such as ambient temperature extremes, earthquakes, winds, tornadoes, or floods.

- Passive containment cooling system operation is automatically initiated upon receipt of a Hi-2 containment pressure signal.

- The passive containment cooling system is designed so that a single failure of an active component, assuming loss of offsite or onsite ac power sources, will not impair the capability of the system to perform its safety-related function.

- Active components of the passive containment cooling system are capable of being tested during plant operation. Provisions are made for inspection of major components in accordance with the intervals specified in the ASME Code, Section XI.

- The passive containment cooling system components required to mitigate the consequences of an accident are designed to remain functional in the accident environment and to withstand the dynamic effects of the accident.

- The passive containment cooling system is capable of removing sufficient thermal energy including subsequent decay heat from the containment atmosphere following a design basis event resulting in containment pressurization such that the containment pressure remains below the design value with no operator action required for ~~seven days~~72 hours. The passive containment cooling system is designed to reduce containment pressure to less than one-half its design pressure within 24 hours following a postulated loss of coolant accident.

- The passive containment cooling system is designed and fabricated to appropriate codes consistent with Regulatory Guides 1.26 and 1.32 and in accordance with Regulatory Guide 1.29 as described in Section 1.9.

6.2.2.2 System Design

6.2.2.2.1 General Description

The passive containment cooling system and components are designed to the codes and standards identified in Section 3.2; flood design is described in Section 3.4; missile protection is described in Section 3.5. Protection against dynamic effects associated with the postulated rupture of piping is described in Section 3.6. Seismic and environmental design and equipment qualification are described in Sections 3.10 and 3.11. The actuation system is described in Section 7.3.

6.2.2.2.2 System Description

The passive containment cooling system is a safety-related system which is capable of transferring heat directly from the steel containment vessel to the environment. This transfer of heat prevents the containment from exceeding the design pressure and temperature following a postulated design basis accident, as identified in Chapters 6 and 15. Containment pressure is further reduced to one-half the design pressure within 24 hours following the worst postulated loss of coolant accident. The passive containment cooling system makes use of the steel containment vessel and the concrete shield building surrounding the containment. The major components of the passive containment cooling system are: the passive containment cooling water storage tank (PCCWST) which is incorporated into the shield building structure above the containment; an air baffle, located between the steel containment vessel and the concrete shield building, which defines the cooling air flowpath; air inlets and an air exhaust, also incorporated into the shield building structure; and a water distribution system, mounted on the outside surface of the steel containment vessel, which functions to distribute water flow on the containment. A passive containment cooling ancillary water storage tank and two recirculation pumps are provided for onsite storage of additional PCS cooling water and to transfer the inventory to the PCCWST.

A normally isolated, manually-opened flow path is available between the passive containment cooling system water storage tank and the spent fuel pool.

A recirculation path is provided to control the passive containment cooling water storage tank water chemistry and to provide heating for freeze protection. Passive containment cooling water storage tank filling operations and normal makeup needs are provided by the demineralized water transfer and storage system discussed in subsection 9.2.4.

The system piping and instrumentation diagram is shown in Figure 6.2.2-1. System parameters are shown in Table 6.2.2-1. A simplified system sketch is included as Figure 6.2.2-2.

6.2.2.2.3 Component Description

The mechanical components of the passive containment cooling system are described in this subsection. Table 6.2.2-2 provides the component design parameters.

Passive Containment Cooling ~~System~~ Water Storage Tank - The passive containment cooling

~~system~~ water storage tank is incorporated into the shield building structure above the containment vessel. The inside wetted walls of the tank are lined with stainless steel plate. It is filled with demineralized water and has a useable volume of greater than ~~400,000~~ 531,000 gallons for passive containment cooling functions. The passive containment cooling system functions as the safety-related ultimate heat sink. The passive containment cooling water storage tank is seismically designed and missile protected.

The surrounding reinforced concrete supporting structure is designed to ACI 349 as described in subsection 3.8.4.3. The welded seams of the plates forming part of the leak tight boundary are examined by liquid penetrant after fabrication to confirm that the boundary does not leak.

The tank also has redundant level measurement channels and alarms for monitoring the tank water level and redundant temperature measurement channels to monitor and alarm for potential freezing. To maintain system operability, a recirculation loop that provides chemistry and temperature control is connected to the tank.

The tank is constructed to provide sufficient thermal inertia and insulation such that draindown can be accomplished without heater operation.

In addition to its containment heat removal function, the passive containment cooling ~~system~~ water storage tank also serves as a source of makeup water to the spent fuel pool and a seismic Category I water storage reservoir for fire protection following a safe shutdown earthquake.

The PCCWST suction pipe for the fire protection system (FPS) is configured so that actuation of the FPS will not infringe on the ~~550,000~~ 531,000 gallons volume allocated to the passive containment cooling function. Additionally actuation of the passive containment cooling system will not infringe on the 18,000 gallon volume allocated to the fire protection system.

Passive Containment Cooling ~~System~~ Water Storage Tank Isolation Valves - The passive containment cooling system water storage tank outlet piping is equipped with two sets of redundant isolation valves. The air-operated butterfly valves are normally closed and open upon receipt of a Hi-2 containment pressure signal. These valves fail-open, providing a fail-safe position, on the loss of air or loss of 1E dc power. The normally-open motor-operated gate valves are located upstream of the butterfly valves. They are provided to allow for testing or maintenance of the butterfly valves.

The storage tank isolation valves, along with the passive containment cooling water storage tank discharge piping and associated instrumentation between the passive containment cooling water storage tank and the downstream side of the isolation valves, are contained within a temperature-controlled valve room to prevent freezing. Valve room heating is provided to maintain the room temperature above 50°F.

Flow Control Orifices - Orifices are installed in each of the four passive containment cooling ~~system~~ water storage tank outlet pipes. They are used, along with the different elevations of the outlet pipes, to control the flow of water from the passive containment cooling ~~system~~ water storage tank as a function of water level. The orifices are located within the temperature-controlled valve room.

Water Distribution Bucket - A water distribution bucket is provided to deliver water to the outer surface of the containment dome. The redundant passive containment cooling water delivery pipes and auxiliary water source piping discharge into the bucket, below its operational water level, to prevent excessive splashing. A set of circumferentially spaced distribution slots are included around the top of the bucket. The bucket is hung from the shield building roof and suspended just above the containment dome for optimum water delivery. The structural requirements for safety-related structural steel identified in subsection 3.8.4 apply to the water distribution bucket. ANSI/ASCE-8-90 (Reference 24) is used for design and analysis of stainless steel cold formed parts. The water distribution bucket is fabricated from one or more of the materials included in Table 3.8.4-6, ASTM-A240 austenitic stainless steel, or ASTM-A276 austenitic stainless steel.

Water Distribution Weir System - A weir-type water delivery system is provided to wet the containment shell during passive containment cooling system operation. The system includes channeling walls and collection troughs, equipped with distribution weirs. The distribution system is capable of functioning during extreme low- or high-ambient temperature conditions. The structural requirements for safety-related structural steel and cold formed steel structures identified in subsection 3.8.4 apply to the water distribution weir system. ANSI/ASCE-8-90, (Reference 24) is used for design and analysis of stainless steel cold formed parts. The water distribution weir system is fabricated from one or more of the materials included in Table 3.8.4-6, ASTM-A240 austenitic stainless steel, or ASTM-A276 austenitic stainless steel.

Air Flow Path - An air flow path is provided to direct air along the outside of the containment shell to provide containment cooling. The air flow path includes a screened shield building inlet, an air baffle that divides the outer and inner flow annuli, and a chimney to increase buoyancy. Subsection 3.8.4.1.3 includes information regarding the air baffle. The general arrangement drawings provided in Section 1.2 provide layout information of the air flow path.

Passive Containment Cooling Ancillary Water Storage Tank - The passive containment cooling ~~system~~ ancillary water storage tank is a cylindrical steel tank located at ground level near the auxiliary building. It is filled with demineralized water and has a useable volume of greater than 400,000 gallons for makeup to the passive containment coolling water storage tank. The tank is designed as an ASME section VIII component and to withstand seismic (SSE) conditions and a 145 mph wind.

The tank has a level measurement and an alarm for monitoring the tank water level and a temperature measurement channel to monitor and alarm for potential freezing. To maintain system operability, an internal heater, controlled by the temperature instrument is provided to maintain water contents above freezing and chemistry can be adjusted by PCCWST recirculation loop.

The tank is insulated to assure sufficient thermal inertia of the contents is available to prevent freezing for 7 days without heater operation. The transfer piping is maintained dry also to preclude freezing.

Chemical Addition Tank - The chemical addition tank is a small, vertical, cylindrical tank that is sized to inject a solution of hydrogen peroxide to maintain a passive containment cooling water storage tank concentration for control of algae growth.

Recirculation Pumps - Each recirculation pump is a 100 percent capacity centrifugal pump with wetted components made of austenitic stainless steel. The pump is sized to recirculate the entire volume of tank water once every week.

Recirculation Heater - The recirculation heater is provided for freeze protection. The heater is sized based on heat losses from the passive containment cooling ~~system~~ water storage tank and recirculation piping at the minimum site temperature, as defined in Section 2.3.

6.2.2.2.4 System Operation

Operation of the passive containment cooling system is initiated upon receipt of two out of four Hi-2 containment pressure signals. Manual actuation by the operator is also possible from either the main control room or remote shutdown workstation. System actuation consists of opening the passive containment cooling ~~system~~ water storage tank isolation valves. This allows the passive containment cooling ~~system~~ water storage tank water to be delivered to the top, external surface of the steel containment shell. The flow of water, provided entirely by the force of gravity, forms a water film over the dome and side walls of the containment structure.

The flow of water to the containment outer surface is initially established at approximately 440 gpm for short-term containment cooling following a design basis loss of coolant accident. The flow rate is reduced over a period of 72 hours to a value of approximately ~~55~~ 63 gpm. ~~and finally to approximately 15 gpm at seven days.~~ This flow provides the desired reduction in containment pressure over time and removes decay heat. The flow rate change is dependent only upon the decreasing water level in the passive containment cooling water storage tank. Prior to 72 hours after the event operator actions are taken to align the passive containment cooling ancillary water storage tank to the suction of the PCS recirculation pumps to replenish the cooling water supply to the PCCWST. Sufficient inventory is available within the PCCAWST to maintain the 63 gpm flow rate for an additional 4 days.

To adequately wet the containment surface, the water is delivered to the distribution bucket above the center of the containment dome which subsequently delivers the water to the containment surface. A weir-type water distribution system is used on the dome surface to distribute the water for effective wetting of the dome and vertical sides of the containment shell. The weir system contains radial arms and weirs located considering the effects of tolerances of the containment vessel design and construction. A corrosion-resistant paint or coating for the containment vessel is specified to enhance surface wetability and film formation.

The cooling water not evaporated from the vessel wall flows down to the bottom of the inner containment annulus into floor drains. The redundant floor drains route the excess water to storm drains. The drain lines are always open (without isolation valves) and each is sized to accept maximum passive containment cooling system flow. The interface with the storm drain system is an open connection such that any blockage in the storm drains would result in the annulus drains overflowing the connection draining the annulus independently of the storm drain system.

A path for the natural circulation of air upward along the outside walls of the containment structure is always open. The natural circulation air flow path begins at the shield building inlet, where atmospheric air enters horizontally through openings in the concrete structure. Air flows past a set of fixed louvers and is forced to turn 90 degrees downward into an outer annulus. This outer shield building annulus is encompassed by the concrete shield building on the outside and a removable baffle on the inside. At the bottom of the baffle wall, curved vanes aid in turning the flow upward 180 degrees into the inner containment annulus. This inner annulus is encompassed by the baffle wall on the outside and the steel containment vessel on the inside. Air flows up through the inner annulus to the top of the containment vessel and then exhausts through the shield building chimney.

As the containment structure heats up in response to high containment temperature, heat is removed from within the containment via conduction through the steel containment vessel, convection from the containment surface to the water film, convection and evaporation from the water film to the air, and radiation from the water film to the air baffle. As heat and water vapor are transferred to the air space between the containment structure and air baffle, the air becomes less dense than the air in the outer annulus. This density difference causes an increase in the natural circulation of the air upward between the containment structure and the air baffle, with the air finally exiting at the top center of the shield building.

The passive containment cooling ~~system~~ water storage tank provides water for containment wetting for ~~seven days~~72 hours following system actuation. Operator action can be taken to replenish this water supply from the PCCAWST or to provide an alternate water source directly to the containment shell through an installed safety-related seismic piping connection. In addition, water sources used for normal filling operations can be used to replenish the water supply.

The arrangement of the air inlet and air exhaust in the shield building structure has been selected so that wind effects aids the natural air circulation. The air inlets are placed at the top, outside of the shield building, providing a symmetrical air inlet that reduces the effect of wind speed and direction or adjacent structures. The air/water vapor exhaust structure is elevated above the air inlet to provide additional buoyancy and reduces the potential of exhaust air being drawn into the air inlet. The air flow inlet and chimney regions are both designed to protect against ice or snow buildup and to prevent foreign objects from entering the air flow path.

Inadvertent actuation of the passive containment cooling system is terminated through operator action by closing either of the series isolation valves from the main control room. Subsection 6.2.1.1.4 provides a discussion of the effects of inadvertent system actuation.

6.2.2.3 Safety Evaluation

The safety-related portions of the passive containment cooling system are located within the shield building structure. This building (including the safety-related portions of the passive containment cooling system) is designed to withstand the effects of natural phenomena such as earthquakes, winds, tornadoes, or floods. Components of the passive containment cooling system are designed to withstand the effects of ambient temperature extremes.

Operation of the containment cooling system is initiated automatically following the receipt of a Hi-2 containment pressure signal. The use of this signal provides for system actuation during transients, resulting in mass and energy releases to containment, while avoiding unnecessary actuations. System actuation requires the opening of either isolation valve, with no other actions required to initiate the post-accident heat removal function since the cooling air flow path is always open. Operation of the passive containment cooling system may also be initiated from the main control room and from the remote shutdown work station. A description of the actuation system is contained in Section 7.3.

The active components of the passive containment cooling system, the isolation valves, are located in two redundant pipe lines. Failure of a component in one train does not affect the operability of the other mechanical train or the overall system performance. The fail-open, air-operated valves require no electrical power to move to their safe (open) position. The normally open motor-operated valves are powered from separate redundant Class 1E dc power sources. Table 6.2.2-3 presents a failure modes and effects analysis of the passive containment cooling system.

Capability is provided to periodically test actuation of the passive containment cooling system. Active components can be tested periodically during plant operation to verify operability. The system can be inspected during unit shutdown. Additional information is contained in subsections 3.9.6 and 6.2.2.4, as well as in the Technical Specifications.

The passive containment cooling system components located inside containment, the containment pressure sensors, are tested and qualified to perform in a simulated design basis accident environment. These components are protected from effects of postulated jet impingement and pipe whip in case of a high-energy line break.

~~The containment pressure analyses demonstrate that the passive containment cooling system is capable of removing sufficient heat energy including subsequent decay heat from the containment atmosphere so that the peak pressure following the worst postulated loss of coolant accident is below the containment design pressure with no operator action to replenish the tank for at least seven days.~~ Analyses ~~also~~ show that the containment pressure is reduced to below one-half of the design pressure within 24 hours following the most limiting design basis loss of coolant accident.

The containment pressure analyses are based on an ambient air temperature of 115°F dry bulb and 80°F coincident wet bulb. The passive containment cooling system water storage tank water temperature basis is 120°F. Results of the analyses are provided in subsection 6.2.1.

6.2.2.4 Testing and Inspection

6.2.2.4.1 Inspections

The passive containment cooling system is designed to permit periodic testing of system readiness as specified in the Technical Specifications.

The portions of the passive containment cooling system from the isolation valves to the passive containment cooling ~~system~~ water storage tank are accessible and can be inspected during power operation or shutdown for leaktightness. Examination and inspection of the pressure retaining piping welds is performed in accordance with ASME Code, Section XI. The design of the containment vessel and air baffle retains provisions for the inspection of the vessel during plant shutdowns.

6.2.2.4.2 Preoperational Testing

Preoperation testing for the passive containment cooling system is addressed in Chapter 14.

6.2.2.4.3 Operational Testing

Operational testing is performed to:

- Demonstrate that the sequencing of valves occurs on the initiation of Hi-2 containment pressure and demonstrate the proper operation of remotely operated valves.

- Verify valve operation during plant operation. The normally open motor-operated valves, in series with each normally closed air-operated isolation valve, are temporarily closed. This closing permits isolation valve stroke testing without actuation of the passive containment cooling system.

- Verify water flow delivery, consistent with the accident analysis.

- Verify visually that the path for containment cooling air flow is not obstructed by debris or foreign objects.

- Test frequency is consistent with the plant technical specifications (Section 16.3.6) and inservice testing program (Section 3.9.6).

6.2.2.5 Instrumentation Requirements

The status of the passive containment cooling system is displayed in the main control room. The operator is alerted to problems with the operation of the equipment within this system during both normal and post-accident conditions.

Normal operation of the passive containment cooling system is demonstrated by monitoring the recirculation pump discharge pressure, flow rate, passive containment cooling ~~system~~ water storage tank level and temperature, passive containment cooling ancillary water storage tank level and temperature, and valve room temperature. Post-accident operation of the passive containment cooling system is demonstrated by monitoring the passive containment cooling ~~system~~ water storage tank level, passive containment cooling ~~system~~ ~~cooling~~ water flow rate, containment pressure and external cooling air discharge temperature.

The information on the activation signal-generating equipment is found in Chapter 7.

The protection and safety monitoring system providing system actuation is discussed in Chapter 7.

Table 6.2.2-1

PASSIVE CONTAINMENT COOLING SYSTEM PERFORMANCE PARAMETERS

PCCWST[1] useable capacity for PCS (gal) - Minimum	~~550,000~~ 531,000
PCCWST useable capacity for FPS[2] (gal) - Minimum	18,000
Injection flow rate (gpm) - Initial - Minimum	440
Injection flow rate (gpm) - Flow at 72 hours - Minimum	~~55~~ 63
Injection flow rate (gpm) - Final at 7 days - Minimum	~~1458~~ 63X
Injection duration (days) - Minimum	7
PCCWST minimum temperature (°F)	40
PCCWST maximum temperature (°F)	120

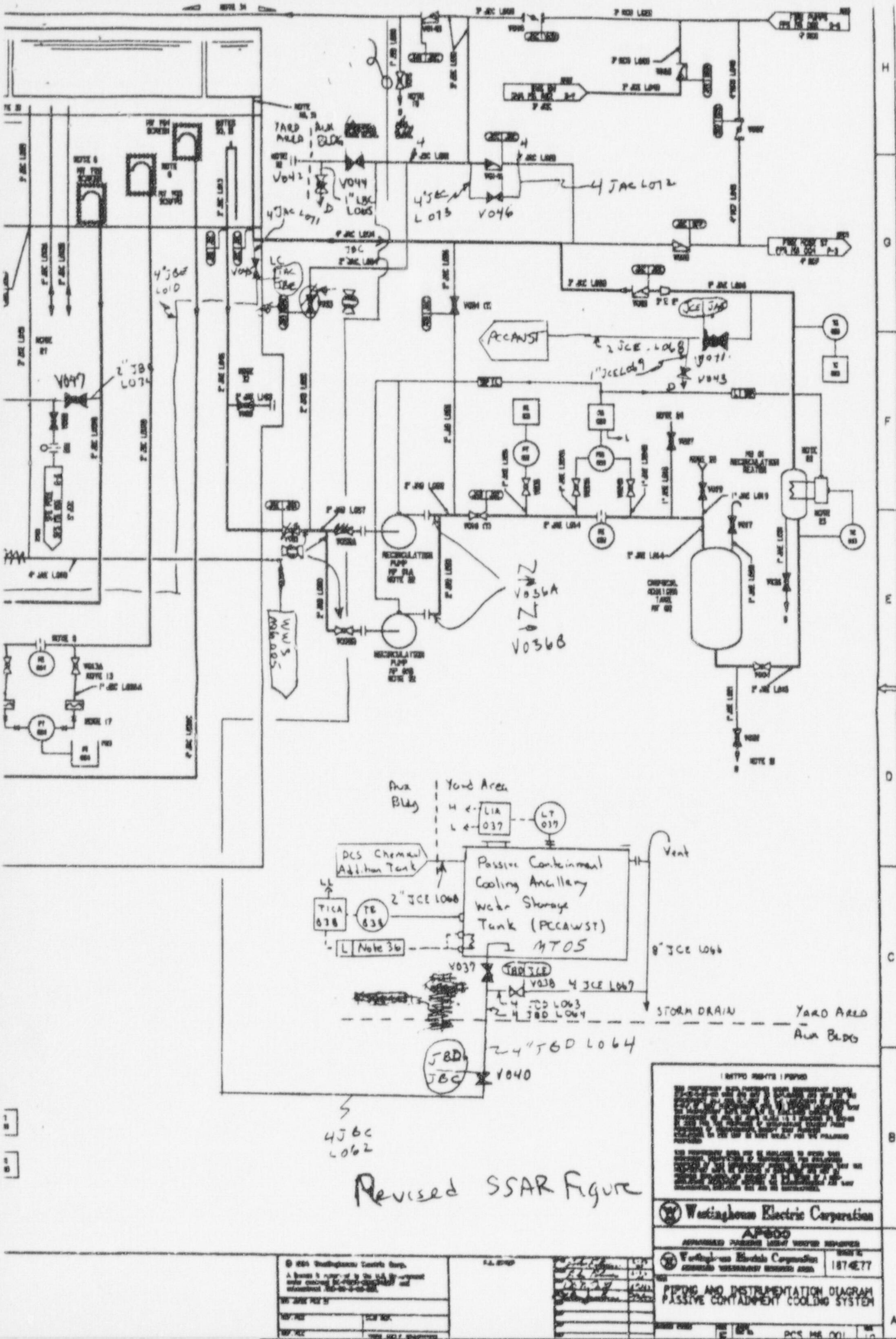
Notes:

1. PCCWST = passive containment cooling water storage tank
2. FPS = fire protection system

Table 6.2.2-2

COMPONENT DATA
PASSIVE CONTAINMENT COOLING SYSTEM
(Nominal)

Passive Containment Cooling ~~System~~ Water Storage Tank	
Volume (gal) - Nominal)	~~540,000~~ 531,000
Design temperature (°F)	125
Design pressure (psig)	Atmospheric
Material	Concrete with stainless steel liner
Passive Containment Ancillary Cooling ~~System~~ Water Storage Tank	
Volume (gal) - Nominal)	425,000
Design temperature (°F)	125
Design pressure (psig)	Atmospheric
Material	Carbon Steel
Water Distribution Bucket	
Volume (gal) - Nominal	42
Design temperature (°F)	150
Design pressure (psig)	Atmospheric
Material	Stainless steel
Water Distribution Collection Troughs and Weirs	
Design temperature (°F)	N/A
Design pressure (psig)	Atmospheric
Material	Stainless steel
Passive Containment Cooling Recirculation Pump	
Quantity	2
Type	Centrifugal
Design Capacity (gpm)	100
Design total differential head (ft)	300



Revised SSAR Figure

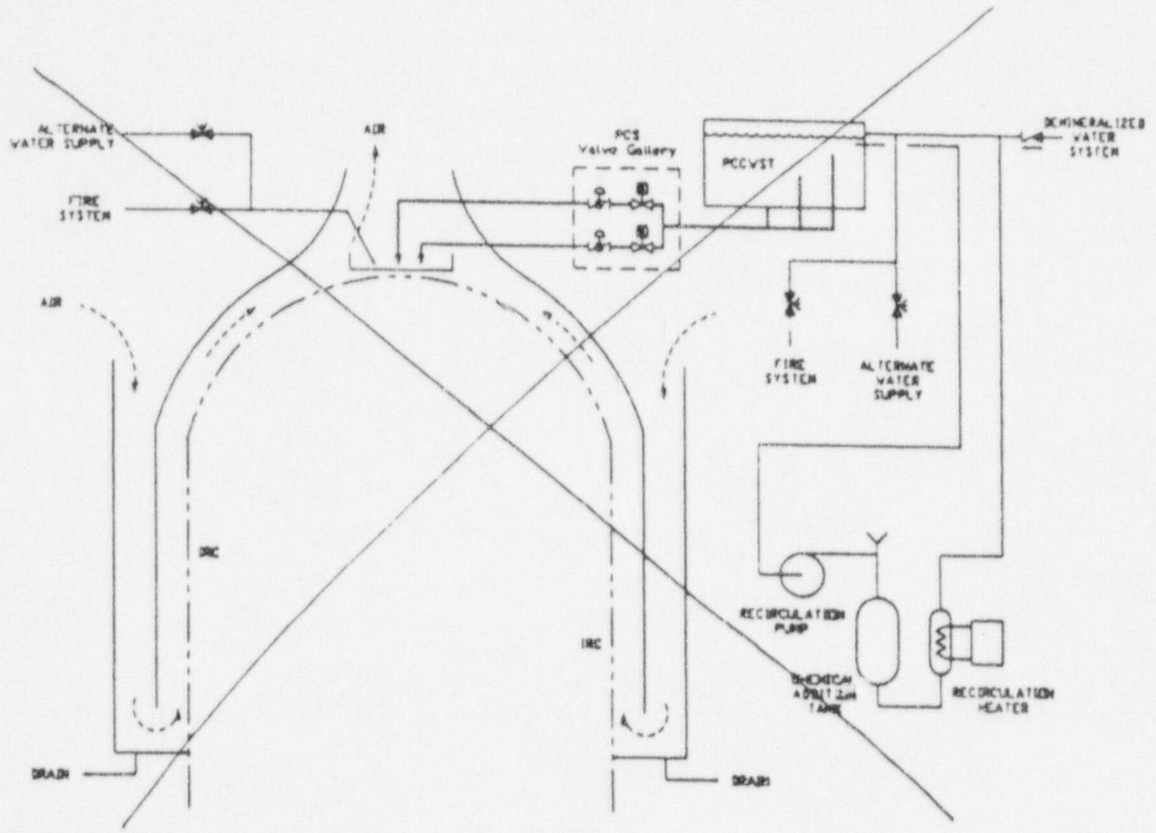


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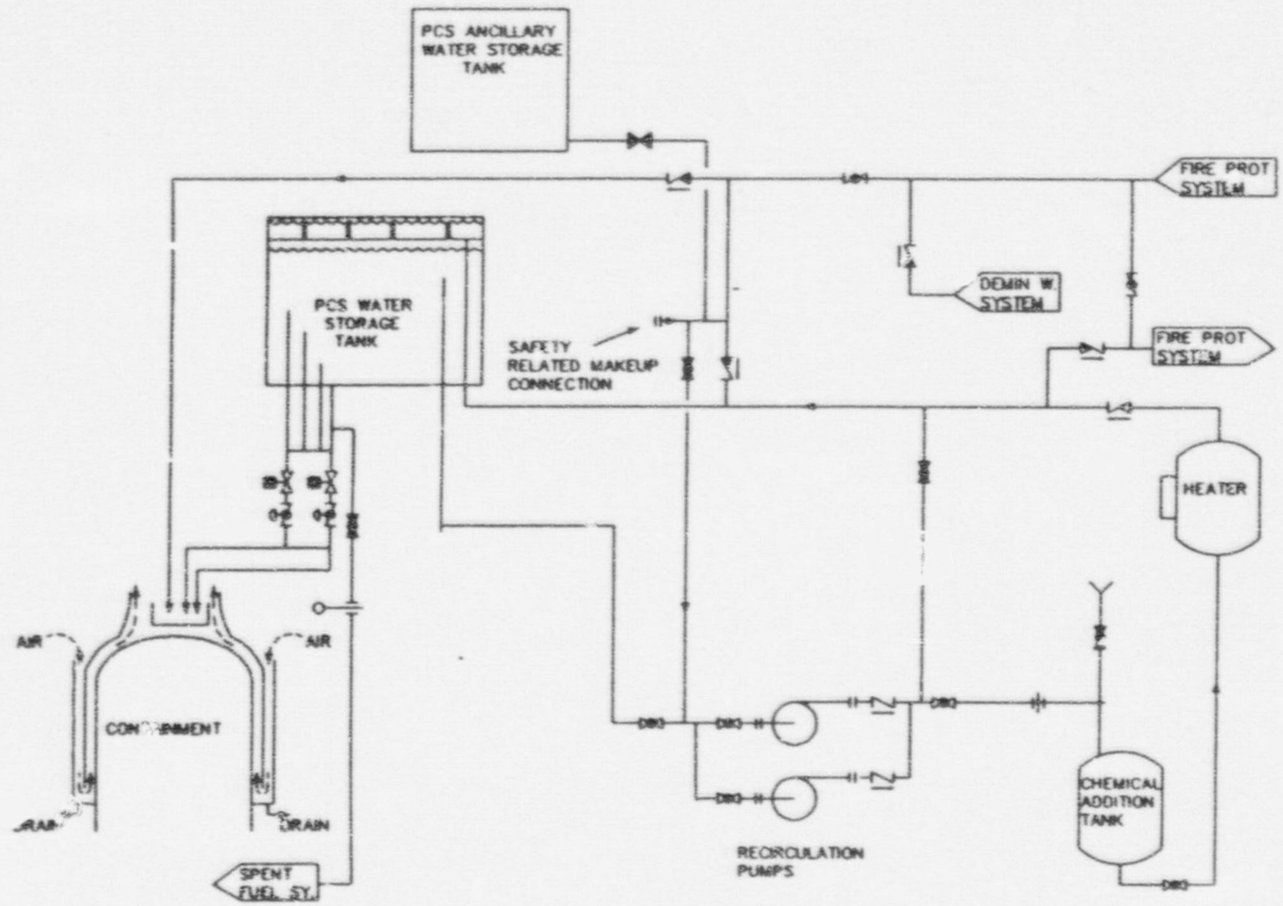
Figure 6.2.2-2

Simplified Sketch of Passive Containment Cooling System



PCS ANCILLARY WATER STORAGE TANK
FIRE PROT SYSTEM
DEMIN W. SYSTEM
FIRE PROT SYSTEM
PCS WATER STORAGE TANK
SAFETY RELATED MAKEUP CONNECTION
HEATER
AIR
AIR
DRAIN
SPENT FUEL SY.
RECIRCULATION PUMPS
CHEMICAL ADDITION TANK

ACTIONS (continued)

CONDITION	REQUIRED ACTION	COMPLETION TIME
D. Required Action and associated Completion Time of Conditions A, B, or C not met. OR LCO not met for reasons other than A, B, or C.	D.1 Be in MODE 3. AND D.2 Be in MODE 4.	8 hours 72 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.6.6.1	Verify the water storage tank temperature ≥ 40 °F and ≤ 120°F.	---NOTE---- Only required when the ambient temperature is ≤ 32°F or ≥ 100°F ------------ 24 hours
SR 3.6.6.2	Verify the water storage tank volume ≥ 400,000 gallons.	24 hours
SR 3.6.6.3	Verify each passive containment cooling system, power operated, and automatic valve in each flow path that is not locked, sealed, or otherwise secured in position, is in the correct position.	24 hours

(continued)

B 3.6 CONTAINMENT SYSTEMS

B 3.6.6 Passive Containment Cooling System (PCS) - Operating

BASES

BACKGROUND

The PCS provides containment cooling to limit post accident pressure and temperature in containment to less than the design values. Reduction of containment pressure reduces the release of fission product radioactivity from containment to the environment, in the event of a Design Basis Accident (DBA). The Passive Containment Cooling System is designed to meet the requirements of GDC 38 "Containment Heat Removal" and GDC 40 "Testing of Containment Heat Removal Systems" (Ref. 1).

The PCS consists of a 400,000 gal cooling water tank, ~~three~~ four headered tank discharge lines with flow restricting orifices, and two separate full capacity discharge flow paths to the containment vessel with isolation valves, each capable of meeting the design bases. The isolation valves on each flow path are powered from a separate Division.

Upon actuation of the isolation valves, gravity flow of water from the cooling water tank (contained in the shield building structure above the containment) onto the upper portion of the containment shell reduces the containment pressure and temperature following a DBA. The flow of water to the containment shell surface is initially established to assure that the required short term containment cooling requirements following the postulated worst case LOCA are achieved. As the decay heat from the core becomes less with time, the water flow to the containment shell is reduced in two steps. The change in flow rate is attained without active components in the system and is dependent only on the decreasing water level in the elevated storage tank. In order to ensure the containment surface is adequately and effectively wetted, the water is introduced at the center of the containment dome and flows outward. Weirs are placed on the dome surface to distribute the water and ensure effective wetting of the dome and vertical sides of the containment shell.

The path for the natural circulation of air is from the air intakes in the shield building, down the outside of the baffle, up along the containment shell to the top, center

(continued)

ATTACHMENT 2

DESCRIPTION OF METHOD TO ACCOUNT FOR
CIRCUMFERENTIAL (2-DIMENSIONAL) CONDUCTION
THROUGH THE STEEL CONTAINMENT SHELL
FOR CONTAINMENT PRESSURE ANALYSES.

TWO-DIMENSIONAL CONDUCTION THROUGH THE AP600 CONTAINMENT SHELL FOR THE AP600 CONTAINMENT EVALUATION MODEL

1.0 INTRODUCTION

The AP600 Passive Containment Cooling System transfers heat from the containment atmosphere to the outside environment. For the first seven days following a postulated accident, cooling water is applied to the outside surface of the shell to facilitate the heat removal process by evaporation of the applied water. Early in the postulated event, the water applied to the shell exterior provides at least 90% coverage of the external surface. As the transient progresses, the applied flow rate is reduced and the water coverage of the external surface area of the shell is reduced.

As evidenced by test data, the flow distribution weirs develop alternating wetted and dry, vertical "stripes" of containment surface areas. These stripes become clearly segregated as the applied water flow rate is reduced. Heat removal from the wetted areas is greater than from the dry areas; evaporative cooling in the wetted area is much greater than convection from the dry surface. This difference in heat removal capability results in a two-dimensional heat transfer through the thickness of the containment shell. Thermal energy is conducted from the hotter dry stripe areas into the adjacent portions of the containment shell cooled by a wetted stripe. The transfer of additional thermal energy to the wetted stripe increases the water evaporation rate, the containment heat removal rate, and the use of applied flow to cool the containment.

2.0 EFFECT OF CIRCUMFERENTIAL (2-D) CONDUCTION THROUGH THE STEEL CONTAINMENT SHELL ON THE EVAPORATION OF WATER BY THE AP600 PASSIVE CONTAINMENT COOLING SYSTEM (PCS)

The AP600 water distribution testing, performed as part of the AP600 design certification program, showed that the outside surface of the containment shell will be partially wetted when the applied water flowrate is reduced below the high initial flowrate. At cold, unheated conditions, the observed side wall wetting was 47% with 110 gpm and 24% with 55 gpm equivalent applied flows for the AP600. The limited percentages of wetted area were a consequence of cold water being applied to the cold surface at discretely spaced locations and the fact that the cold water spread to a stream width that resulted in a Γ_{DIST} of ~290 lb/hr-$ft_{Wet\ Per}$. Therefore, the observed stream width and wetted surface areas were directly proportional to the water flow rate. At the flow rates given above, the stream widths were observed to be less than the distance between weir slots and alternating, vertical, dry and wetted stripes formed down the containment below the lower distribution weir.

Since the rate of evaporation of water from the containment shell is largely a function of the water film temperature, heat transfer from the dry surface areas to the wetted surface areas will result in a significant enhancement to the currently calculated evaporation rates. The currently calculated evaporation rates are based on one dimensional, radial conduction through the containment steel shell. As the PCS flows are reduced and wetted areas decrease, a significant amount of heat will be conducted circumferentially through the steel shell from adjacent hotter dry vertical stripes to the cooler wetted vertical stripes. Following is a description of the method used to calculate the effect of circumferential 2-dimensional heat conduction on the water evaporation and resulting containment pressure for the AP600 passive containment cooling system.

2.1 Geometry of the Wet and Dry Vertical Stripes on the Containment Outside Steel Surface

The occurrence of alternating wet and dry vertical stripes on the containment outside surface has been documented both on a cold, full scale model of 1/16th of the containment dome and top portion of the containment sidewall, in the AP600 Water Distribution Test (Ref. 1 and Figure 1), and on a hot surface with evaporation in progress in the PCS Large Scale Test (Ref. 2). In the water distribution test, it was demonstrated that water applied by the second (lower) set of weirs on the significantly downward sloped portion of the containment dome follows the natural fall line; resulting in wetted stripes at a spacing on the vertical sidewall that is equal to the spacing of applied water streams at the weir, multiplied by the ratio of the containment radius at the sidewall and the radius at the weir. For example, the 6-inch weir slot spacing at the ~50-foot radius of the dome produced stripes at a spacing of ~8-inches at the sidewall radius of 65-feet, and the stripes remained separated at low applied flowrates. In the Large Scale Test, with heat transfer occurring, the wet stripes were observed to flow vertically to the bottom of the sidewall until almost all of the applied water was evaporated.

This evaluation of the effects of 2-dimensional conduction on the wetted steel surface temperature and resulting water evaporation rate was based on the same alternating wet and dry stripe pattern and spacing produced by the water distribution weir(s) observed in the water distribution test. Namely, an 8.35 inch center-line to center-line stripe spacing was used. This corresponded to the lower weir position and weir notch spacing to be used in the plant. In addition, a wider dry stripe directly under the 16 weir collection boxes was taken into account.

2.2 Inside and Outside Heat Transfer Boundary Conditions for the Conduction Model

The boundary conditions used in the 2-dimensional conduction model were established by a series of 1-dimensional steady state calculations of the PCS heat transfer process performed at steady state containment pressures ranging from 10 psig to 65 psig (24.7 to 79.7 psia). These calculations were done using the same heat and mass transfer methodology as used in WGOTHIC and provided the heat transfer and the temperature differences from the steam/air mixture inside containment to the inside surface of the containment shell, through the steel shell, and from the wet and dry outside containment surface to the air. The heat transfer and temperature differences were used to establish boundary condition heat transfer coefficients for each containment pressure condition. The outside heat transfer coefficients vs. the outside steel shell temperature obtained for each pressure condition for the wetted surface, were fitted using a second degree polynomial for use in the conduction model. These boundary conditions were reviewed to assure that the heat transfer rates at all containment pressure/temperature conditions were higher than the corresponding heat transfer calculated by WGOTHIC in the containment analysis. This assures that any increase in heat transfer, as compared to the heat transfer with radial conduction through the containment steel shell, is underpredicted.

2.3 Conduction (ANSYS) Model Description

The effect of circumferential conduction through the AP600 steel containment shell on the shell surface temperatures and the resulting effects on the condensing heat transfer on the inside surface, the evaporative heat transfer on outside wetted surfaces, and the convective heat transfer from the dry outside surface; were quantified using the ANSYS computer code. The ANSYS computer code is a multi-purpose, finite element program which has been commercially used since 1970. For this calculation ANSYS revision 5.3 was used.

The ANSYS calculation was a two dimensional thermal steady state analysis of a periodic half-cell (cross section) that consisted of a two-dimensional block that was 0.1354 feet (1.625 inches) thick and 0.3479 feet (4.174 inches) wide; corresponding to the AP600 containment steel shell thickness and the spacing of water streams at the containment sidewall perimeter imposed by the PCS water distribution weirs. The half-cell had a length of one unit (1-ft.). A conductivity of 24 Btu/hr-ft-°F was assigned for the steel material. Adiabatic boundary conditions were used for the right and left side of the half-cell model to represent symmetry and periodicity of the cell.

The inside containment bulk temperature and a steam/air mixture heat transfer coefficient to the inside steel surface were input for each containment inside pressure condition analyzed. The outside heat transfer coefficient vs. the wetted steel outside surface temperature and a constant dry surface heat transfer coefficient (with a fixed outside cooling air temperature) conservatively bounding the pressure conditions analyzed, established the outside heat transfer boundary conditions.

2.4 Conduction (ANSYS) Model Results

The heat flux from the wetted portion of the half-cell model were compared with the wetted heat flux that occurs when radial heat conduction (1-dimensional conduction) is assumed. Figure 2 shows the water evaporation rate with 2-dimensional conduction vs. the fraction of wetted area, normalized to the evaporation rate calculated with radial heat conduction (1-dimensional) outward through the steel shell, for containment pressures of 10, 15, 20, and 25 psig. Several additional plots to illustrate the effect of 2-dimensional conduction on the PCS heat transfer process are provided for the 20 psig containment pressure , 25% wetted case. A temperature distribution contour plot is shown for the ANSYS half-cell model in Figure 3, with the surface inside containment at the top of the page. Figure 4 shows the thermal flux from the inside to outside surface (-y direction), perpendicular to the containment shell. Figures 5 and 6 show the thermal flux distribution on the outside and inside surface of the wall respectively.

2.5 Insights from the PCS Large Scale Testing

Although the large scale PCS heat transfer testing was largely conducted with very high water coverage fractions, that minimize the effect of circumferential conduction on the water evaporation rate; a clear indication of this effect is demonstrated by comparing the results from test run RC048C of test matrix 212.1 and test run RC050C of test matrix 213.1. In these tests, the containment pressure and other boundary conditions were essentially the same with the exception that the amount of water applied to the external surface of the test vessel was 17.4 gpm in test RC048C and 6 gpm in test RC050C.

The reduced water flow rate in test RC050C resulted in a significant reduction in the wetted area observed at the bottom of the test vessel sidewall, 52% for test RC050C vs. 95% for test RC048C. In spite of the reduced wetted area in test RC050C, the total heat removed from the test vessel and the amount of water evaporated in this test was equal to test RC048C. A re-examination of this test data is underway, however it can be stated that the inside/outside thermocouple pairs (used as local heat flux meters) where dry/wet stripes occur, demonstrate the following:

- Elevated wet surface temperatures and enhanced water evaporation occurs at wetted locations adjacent to dry stripes.
- Large measured through wall temperature differences occur at dry locations adjacent to wet stripes, as would be expected with skewed isotherms similar to that shown in Figure 3.
- Expected temperature differences and heat fluxes occur on both wet and dry surface locations not adjacent to the edges of stripes.

3.0 APPLICATION TO AP600 CONTAINMENT EVALUATION MODEL

The AP600 PCS heat removal at a given containment pressure is determined largely by how much of the applied water is evaporated. The heat removal or cooling effectiveness of the cooling water applied to the containment shell is maximized if all the water applied evaporates. Consequently, the determination of how much water, if any, runs off the containment shell is necessary in determining the effectiveness of the applied cooling water.

The current containment analysis approach calculates the effective PCS flow rate for input to the WGOTHIC code. The PCS flow is limited to only that flow which is calculated to be evaporated. This is done so that the code is not required to determine wetted area as a function of time. The applied PCS flow defined in this manner is called the "evaporation limited flow" in the AP600 WGOTHIC Applications Report, Reference 3. The use of "evaporation limited flow" for the containment evaluation model is conservative because it accounts for only evaporated water and discounts sensible heating of any runoff flow.

In the AP600 plant, as the water coverage of the containment shell decreases due to decreases in PCS flow rates, alternate wet and dry stripes are formed on the containment shell exterior surface and 2-dimensional (radial and circumferential) heat conduction is established in the containment shell. Initial calculations of "evaporation limited flow" accounted for only 1-dimensional (radial) conduction through the containment shell.

Accounting for 2-dimensional conduction increases the temperature of the wetted steel surface, and therefore also increases the temperature of the liquid film, over what is calculated for 1-dimensional (radial) conduction only. The increase in the temperature of the liquid film, in turn, results in the evaporation of more water, reducing the calculated runoff from the shell. The following is a description of how the increase in water evaporation effectiveness of the PCS when both radial and circumferential heat conduction through the steel containment is accounted for in the AP600 containment evaluation model.

3.1 Calculating Fraction of PCS Water that Does Not Evaporate

The amount of water runoff from the containment shell utilizes the simple relationship between the total film flow rate, $\dot{m}$; the total circumference, or width of the wetted surface, W; and the film flow per unit width, Γ. The equation is;

$$\dot{m} = \Gamma \cdot W \qquad (1)$$

and its derivative with respect to vertical distance is;

$$\frac{d\,\dot{m}}{dz} = W\frac{d\,\Gamma}{dz} + \Gamma\frac{dW}{dz} \qquad (2)$$

The wetted coverage and runoff flow rate are calculated based on the following assumptions;

1) The initial film flow rate per unit width, Γ_{DIST}, is determined in part by the distribution system and the ability of cold water to spread on the cold containment surface.

2) The water flows in constant width stripes below each weir slot while the flow rate (water film thickness) decreases due to evaporation for $\Gamma_{DIST} > \Gamma > \Gamma_{MIN}$. The distance the stripe travels down the containment sidewall is bounded $0 < Z < Z_{MIN}$, where Z_{MIN}

is the distance down the containment wall where $\Gamma = \Gamma_{MIN}$.

3) At $\Gamma = \Gamma_{MIN}$, evaporation causes the film stripe to narrow while Γ remains constant at Γ_{MIN}.

Initial Coverage

The wetted coverage on AP600 containment with cold water was characterized in the Water Distribution Tests. The initial film flow per unit width at the 65 ft radius, Γ_{DIST}, is presented in Table 7-2 of Reference 3. The film flow rate per unit width at the spring line is related to the wetted primeter, W_{SPRING} and the applied flow rate, $\dot{m}$, by Equation 1, $\dot{m}_{ON} = W_{SPRING} \Gamma_{DIST}$ where $\Gamma_{DIST} = 293\ lb_m/hr\text{-}ft$.

Constant Width Coverage

After the water distribution is established, the film evaporates at mass flux, ϕ_M, as it flows down the shell in stripes having parallel sides. Since the stripes are parallel sided, W is constant at W_{SPRING}. For a constant width stripe, $d\Gamma/dz = -\phi_M$. The change equations for $\dot{m}$, Γ, and W for the constant width portion of the stripe are:

$$\frac{d\,\dot{m}}{dZ} = \phi_M \cdot W \qquad (3)$$

$$\frac{d\,\Gamma}{dZ} = \phi_M \qquad (4)$$

$$\frac{d\,W}{dZ} = 0 \qquad (5)$$

With the three equations listed above, the film mass flow rate, $\dot{m}$; and the flow rate per unit width, Γ; can be calculated for the constant width evaporation portion of the coverage. For the case with ϕ_M = constant and W = constant as is assumed for $\Gamma_{DIST} > \Gamma > \Gamma_{MIN}$ and $0 < Z < Z_{MIN}$, the analytical expression for the mass flow rate is:

$$\dot{m} = \dot{m}_{ON} - \phi_M \cdot W_{DIST} \cdot Z \qquad (6)$$

Equation 6 can be written in terms of difference equations for a numerical solution where $\Delta\dot{m} = \dot{m}_2 - \dot{m}_1$ and $\Delta Z = Z_2 - Z_1$

$$\Delta \dot{m} = - W_{SPRING} \cdot \phi_M \cdot \Delta z \tag{7}$$

$$\dot{m}_2 = \dot{m}_1 - W_{SPRING} \cdot \phi_M \cdot (Z_2 - Z_1) \tag{8}$$

Knowing $\dot{m}$, the film flow rate per unit width is determined from Equation (1) where Γ is $\Gamma_{DIST} = \dot{m}/W$. The value of Z when Γ reduces to Γ_{MIN} is Z_{MIN}. The value of Z_{MIN} can be determined from Equation 6. That is,

$$Z_{MIN} = \frac{\dot{m}_{ON} / W_{DIST} - \Gamma_{MIN}}{\phi_M} \tag{9}$$

Constant Γ_{MIN} Coverage

When $\Gamma = \Gamma_{MIN}$, the stripe width, W, begins to narrow while Γ_{MIN} is maintained at a constant value. The resulting change equations for $\dot{m}$, Γ, and W for this portion of the stripe are:

$$\frac{d\dot{m}}{dZ} = \phi_M \cdot W \tag{10}$$

$$\frac{d\Gamma}{dZ} = 0 \tag{11}$$

$$\frac{dW}{dZ} = - \frac{\phi_M W}{\Gamma} \tag{12}$$

When ϕ_M = constant and $\Gamma = \Gamma_{MIN}$ = constant, the solution to the dW/dZ expression is the simple exponential function:

$$W = W_{DIST} \cdot \exp^{\phi_M \cdot (Z_2 - Z_1) / \Gamma_{MIN}} \tag{13}$$

When ϕ_M is not constant with height the analytical expression for W depends on the functional form of ϕ_M and is not necessarily a simple expressicn. However, a general expression is written for numerical integration:

Knowing W from equation 13, 14 or 15, the mass flow rate at any Z is simply calculated

$$\Delta W = - \frac{W \cdot \phi_M \cdot \Delta Z}{\Gamma_{MIN}} \qquad (14)$$

$$W_2 = W_1 - \frac{W_1 \cdot \phi_M \cdot (Z_2 - Z_1)}{\Gamma_{MIN}} \qquad (15)$$

from Equation (1). The runoff flow rate is $\dot{m}_{OFF} = W\Gamma_{MIN}$, where W is the value at the bottom of the containment shell, $Z = Z_{MAX}$.

Source for Γ_{DIST} and Γ_{MIN}

The constant input values for the minimum stable film flow per unit width, Γ_{MIN} and the source film, Γ_{DIST} are listed in Section 7 of Reference 3. It is assumed that the film thins while the film width, W, remains constant, until Γ_{MIN} is reached. The value for Γ_{DIST} is based on observations from the PCS Water Distribution Test. The thinning of the liquid film until Γ_{MIN} is reached and narrowing afterwards is consistent with observations from the Large Scale Test, and the value of Γ_{MIN} is based on test and analytical results, Reference 3.

3.2 Evaporation Limited Flow Calculation

By inspection of equation 13, it is noted that W, the film flow per unit width, is always greater than zero. Thus, for constant values of ϕ and Γ_{MIN}, equation 13 will always predict some water will run off the wall without evaporating. However, from calculations performed with the WGOTHIC code and experimental observations, all the water applied to the containment shell can be evaporated for some transient conditions. Thus, the preceding calculation method is conservative in its execution. This calculational method is applied to WGOTHIC code calculations by reducing the PCS source flow used as an input to the calculations by the amount the water film model predicts to run off the containment shell based on an assumed ϕ as discussed below. This reduced flow is defined as the "evaporation limited flow." Using this "evaporation limited flow" as an input to the WGOTHIC code, the WGOTHIC code will calculate the applied flow to completely evaporate.

Basic Methodology

The input to the calculational scheme to calculate the input film flow rate to WGOTHIC such that the total evaporation is consistent with the preceding simple model is determined as follows;

1. An average evaporation heat flux, ϕ_H, at selected time(s) is determined for the wet WGOTHIC climes below the lower weir. The evaporation mass flux is $\phi_M = \phi_H/h_{fg}$.

2. The runoff, $\dot{m}_{OFF}$ is calculated for each time using Equations 6 and 13 for problems with constant evaporation mass flux, or Equations 7 and 14 for problems with variable

evaporation flux.

3. The runoff, m_{OFF}, is subtracted from the water source, m_{ON}, and the difference is available for input to WGOTHIC, thereby assuring that WGOTHIC predicts limited evaporation of PCS water.

4. WGOTHIC is then run with the modified source input and the calculated results are used to define ϕ_H for input to Step 1 to recalculate runoff.

When the WGOTHIC calculated values of ϕ_H are consistent with and slightly higher than the values assumed for input under Step 1, the solution is converged.

Inclusion of 2-Dimensional Conduction Effects

At a given containment pressure, the benefit (increased evaporation of applied PCS flow from the outside surface of the containment shell) calculated for inclusion of 2-dimensional heat conduction is dependent upon the wetted width of the regularly spaced vertical stripes created by the water distribution system at reduced PCS flow rates. Consequentially, the film evaporation rate is also a function of the stripe width. Thus, the calculation of the width of the film stripe is accomplished by iteration.

Accounting for 2-dimensional conduction through the containment shell increases the evaporation at a given containment pressure. The change in evaporation with change in wetted region has been expressed as the ratio of the evaporation rate for a wet stripe versus the wetted fraction of the sidewall (W/W_O), where W_O is the containment sidewall perimeter, compared to the evaporation rate with only radial heat conduction. The function is:

$$M = 2.6694 - 5.6293\frac{W}{W_O} + 8.9047\left(\frac{W}{W_O}\right)^2 - 7.0263\left(\frac{W}{W_O}\right)^3 + 2.0785\left(\frac{W}{W_O}\right)^4 \qquad (16)$$

where M is a multiplier applied to the one-dimensional calculations. The value, M, for a given containment wetted fraction represents the increase in evaporation rate per unit area resulting from accounting from 2-dimensional (radial and circumferential) heat transfer over that calculated for the one-dimensional (radial only) case.

The function defined in equation 16 has been evaluated to be applicable over a containment pressure range of 10 to 25 psig.

Application of Evaporation Multipliers

During the initial high-flow PCS period, water coverage is high (~90% coverage) and two-dimensional effects are small. However, when PCS flow is initially reduced from the high flow value of 442 gpm to 123-110 gpm, coverage of the containment shell is predicted to be reduced to about 50%. Thus, it is from this time forward that the multiplier for two-dimensional conduction is first applied to evaporation rates.

4.0 SUMMARY

The method used to account for two dimensional heat conduction in the containment shell to liquid stripes and the methodology used to calculate the evaporation limited PCS flow at a fixed evaporation rate, ϕ_M, have been described. The two-dimensional conduction through the containment shell provides for increased evaporation rate of the PCS applied liquid, resulting in an overall benefit to the predicted heat rejection rate of the PCS.

5.0 REFERENCES

1) WCAP-13960; AP600 Doc. No. PCS-T2R-019, Rev. 0, 12/93; PCS Water Distribution Phase 3 Test Data Report, by J. Gilmore.

2) WCAP-14135; AP600 Doc. No. PCS-T2R-032, Rev. 1, 4/97; Final Data Report for Large Scale Tests, Phase 2 and Phase 3, by F. E. Peters.

3) A. Forgie, J. Narula, R. Ofstun, D. L. Paulsen, S. K. Slabaugh, M. Sredzinski, D. R. Spencer, J. Woodcock, "WGOTHIC Application to AP600", WCAP 14407, Westinghouse Electric Corporation.

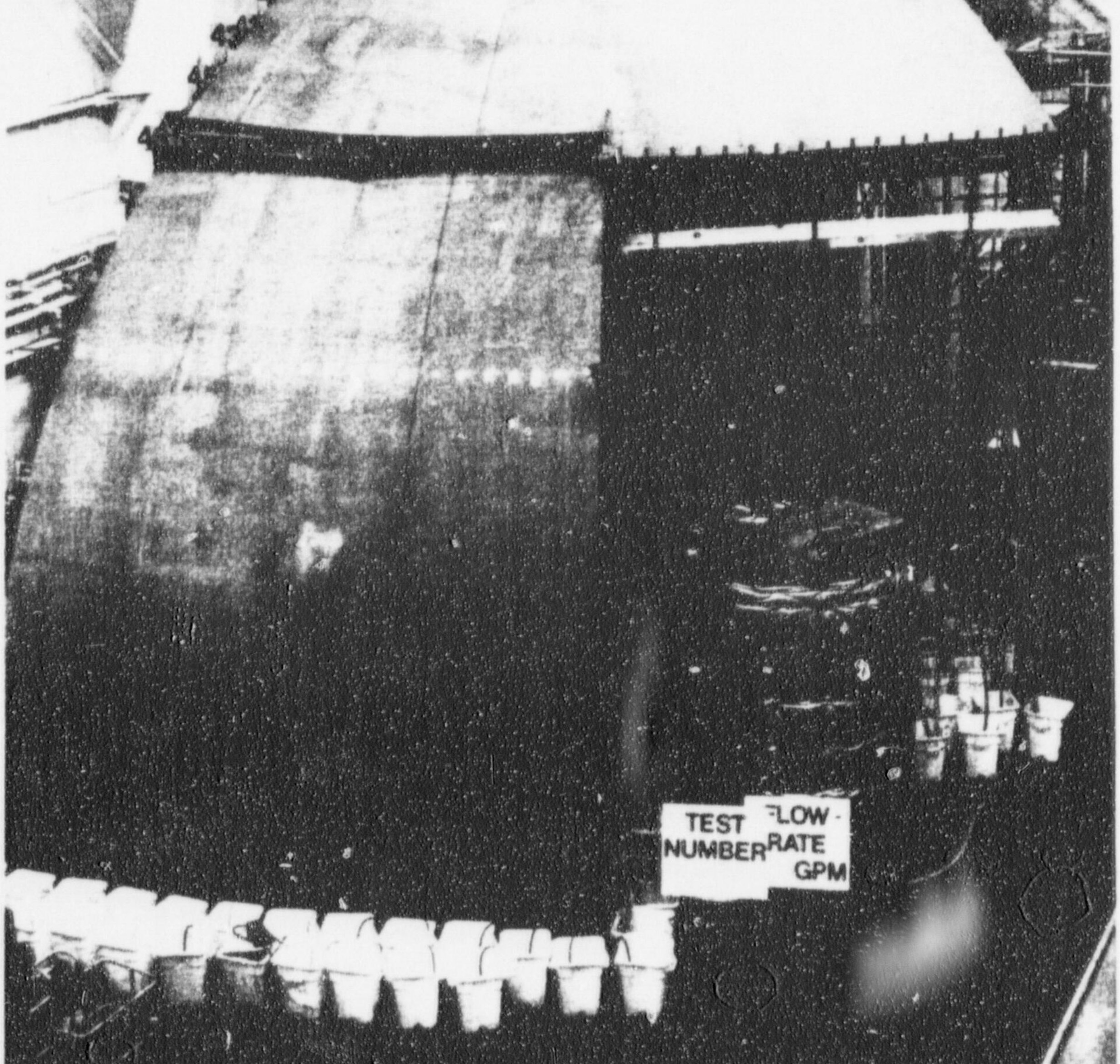


Figure 1, AP600 Water Distribution Test Facility

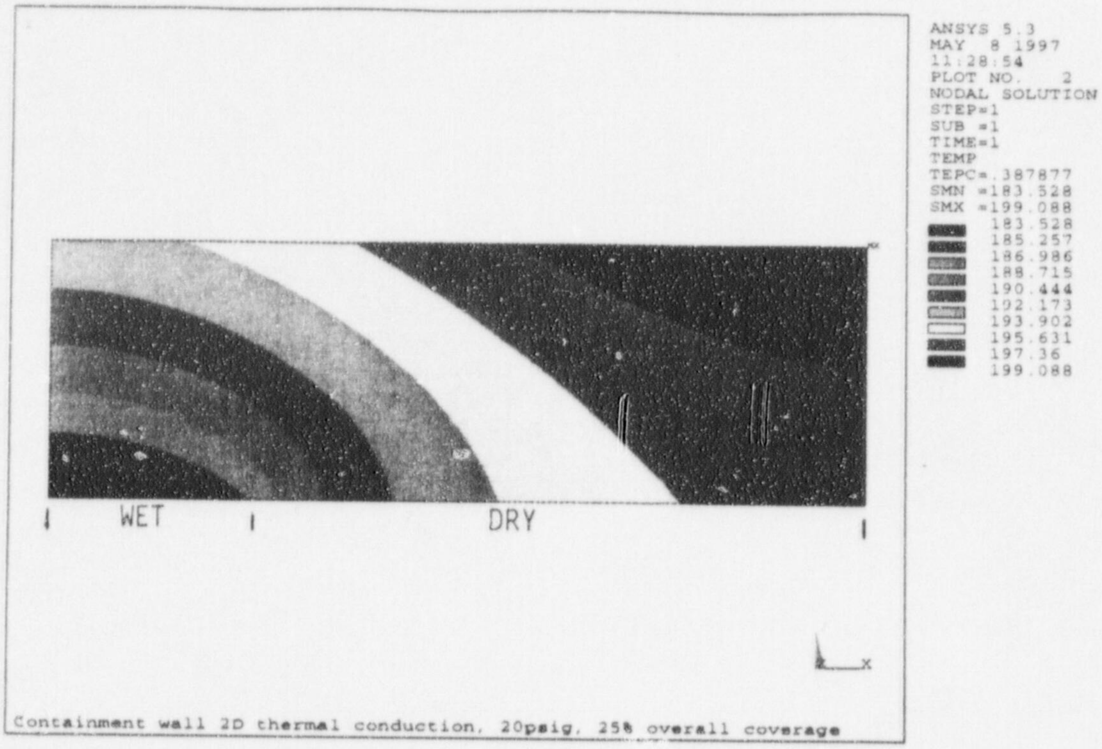


Figure 3, Temperature Distribution through Containment Shell Steel Wall (Top-inside surface, Bottom-outside Surface

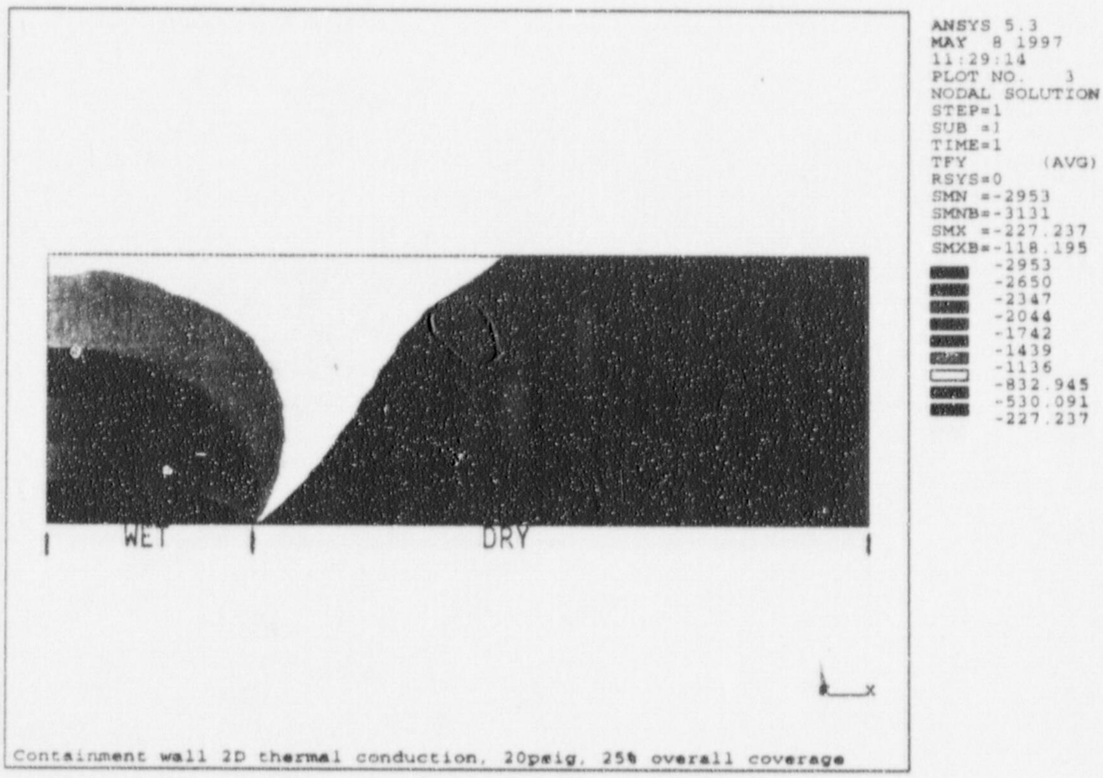
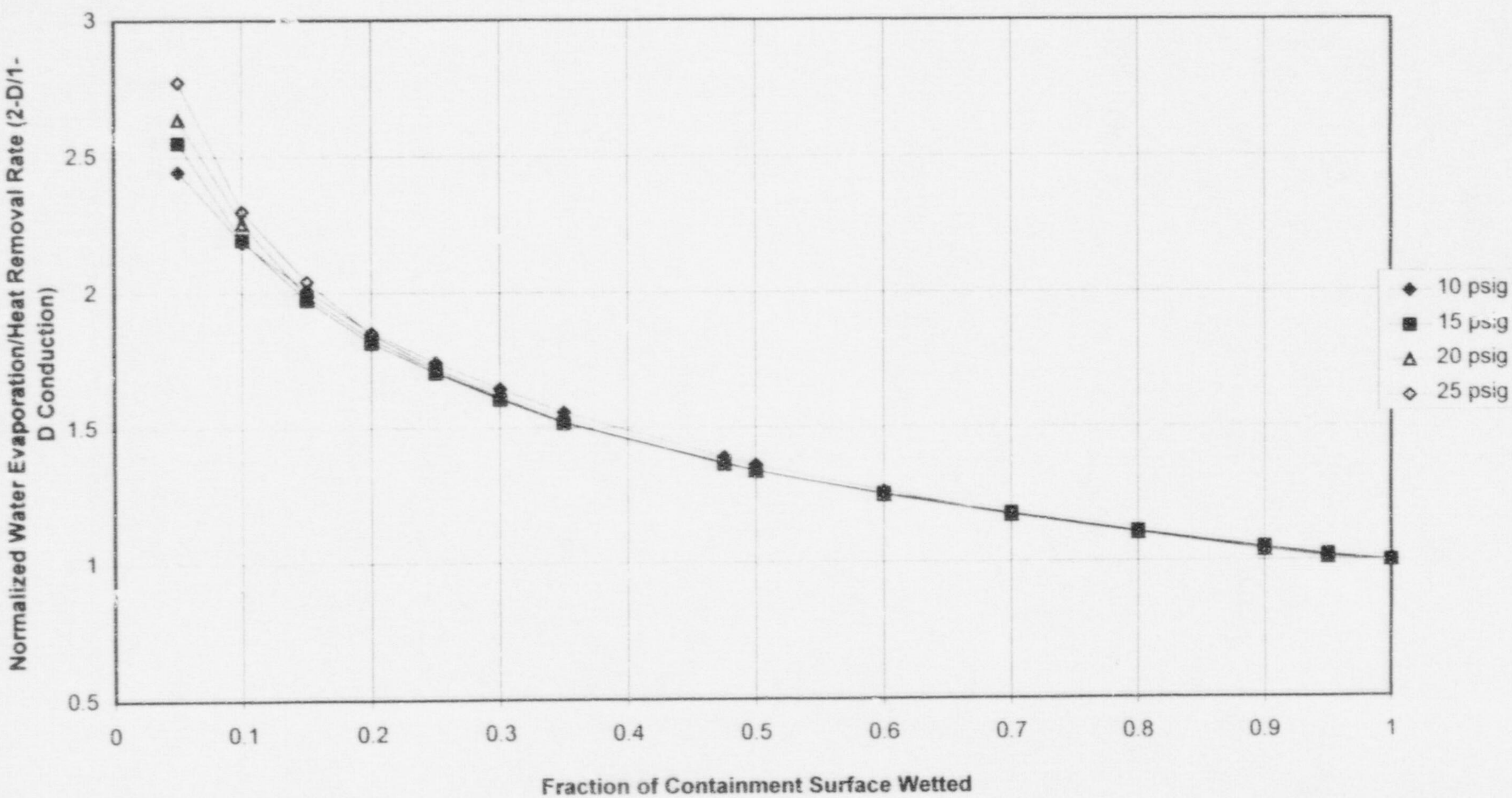


Figure 4, Total Thermal Flux [Btu/hr-ft^2]

Figure 2, Normalized Water Evaporation Rate (2-D/1-D Conduction) vs. the Overall Containment Wetted Fraction



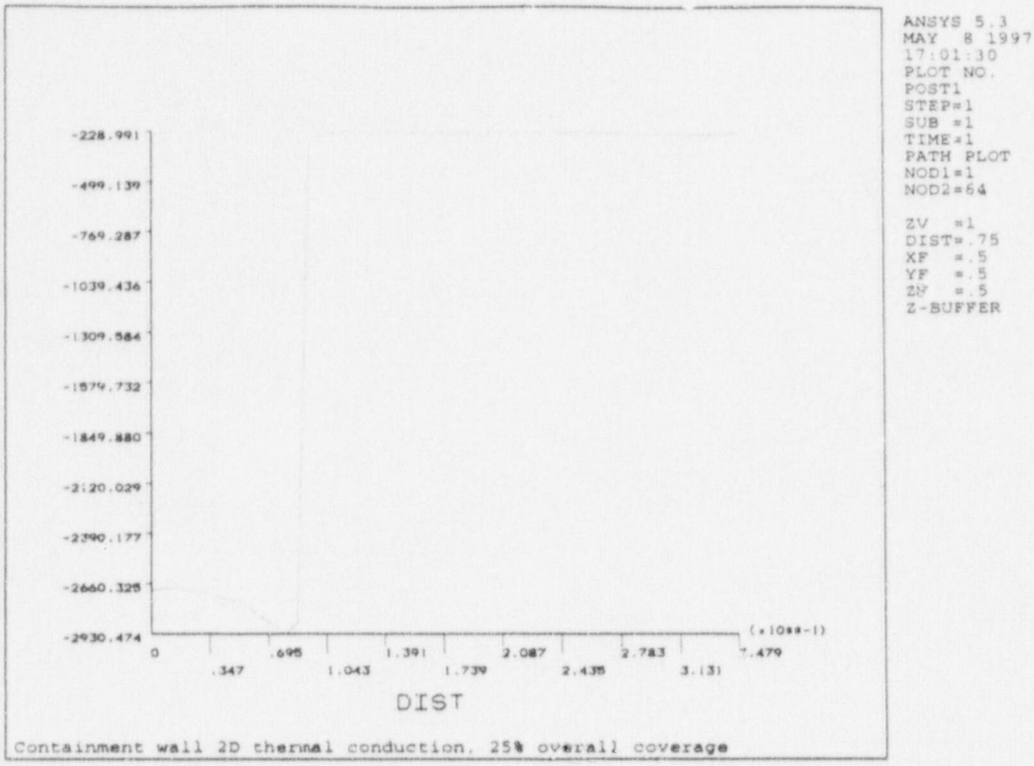


Figure 5, Thermal Flux in Y-direction on Outside Surface of Containment Wall [Btu/hr-ft^2]

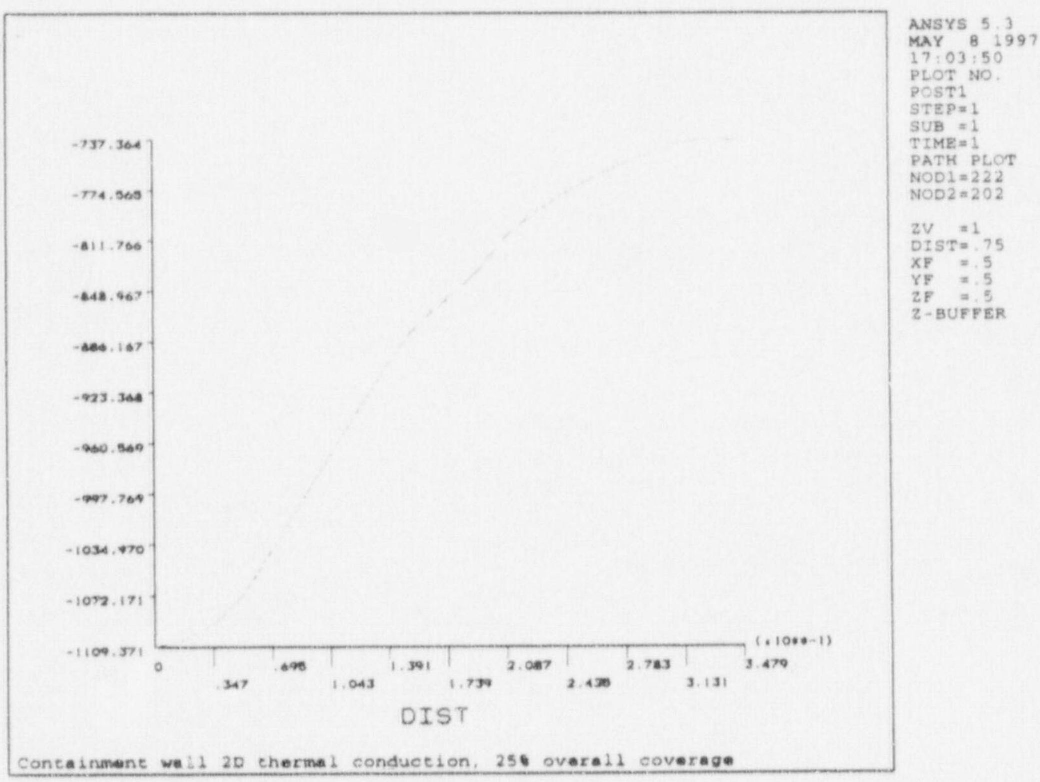


Figure 6, Thermal Flux in Y-direction on Inside Surface of Containment Wall [Btu/hr-ft^2]

ATTACHMENT 3

REVISED SSAR FIGURES INDICATING THE RESULTS OF THE REVISED WGOTHIC CONTAINMENT PRESSURE ANALYSES.

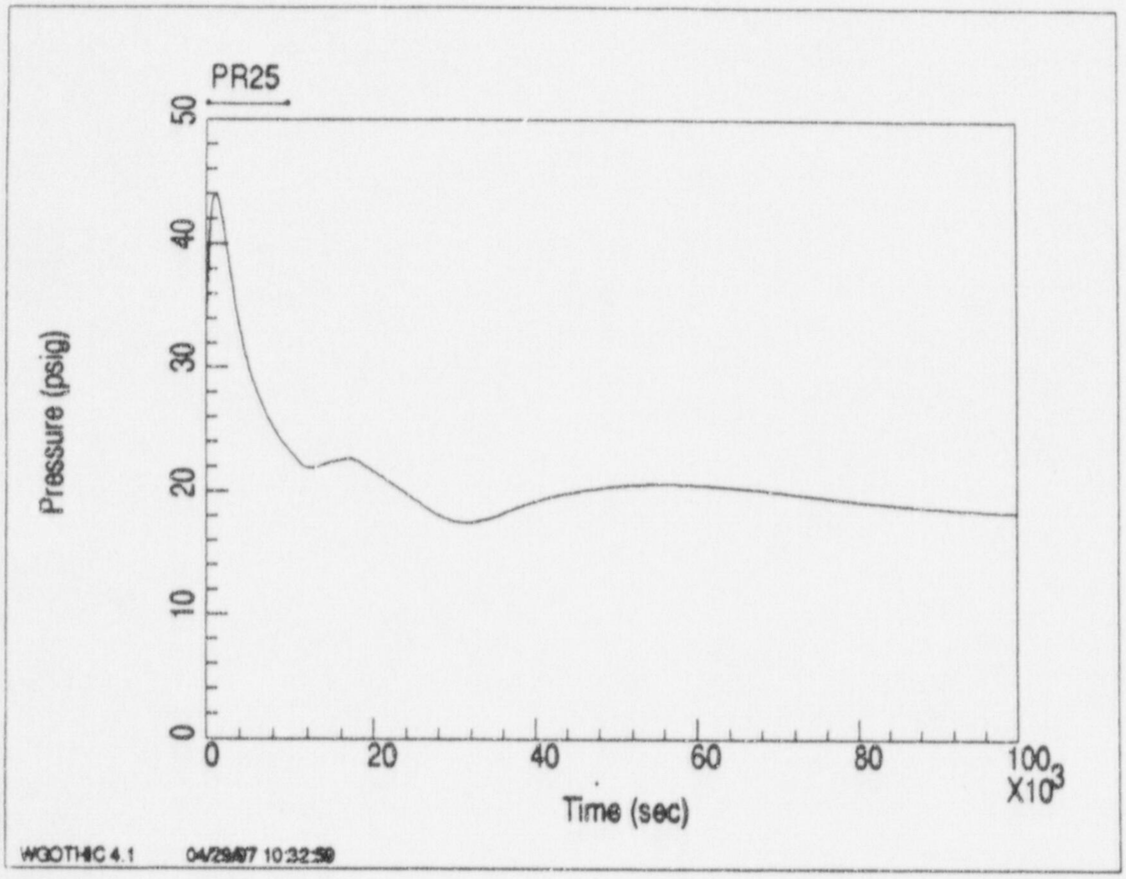


Figure 6.2.1.1-5

DECLG LOCA Case for 24 Hours

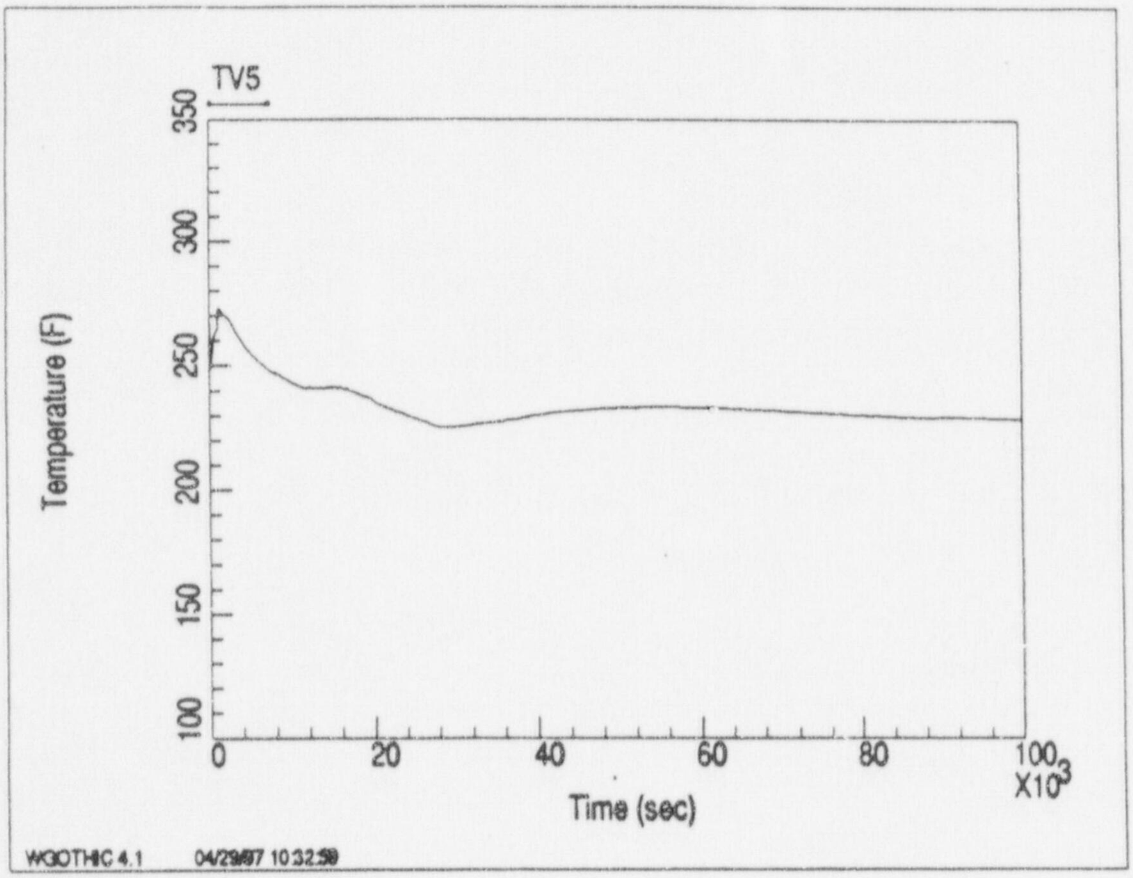


Figure 6.2.1.1-6

DECLG LOCA Case for 24 Hours

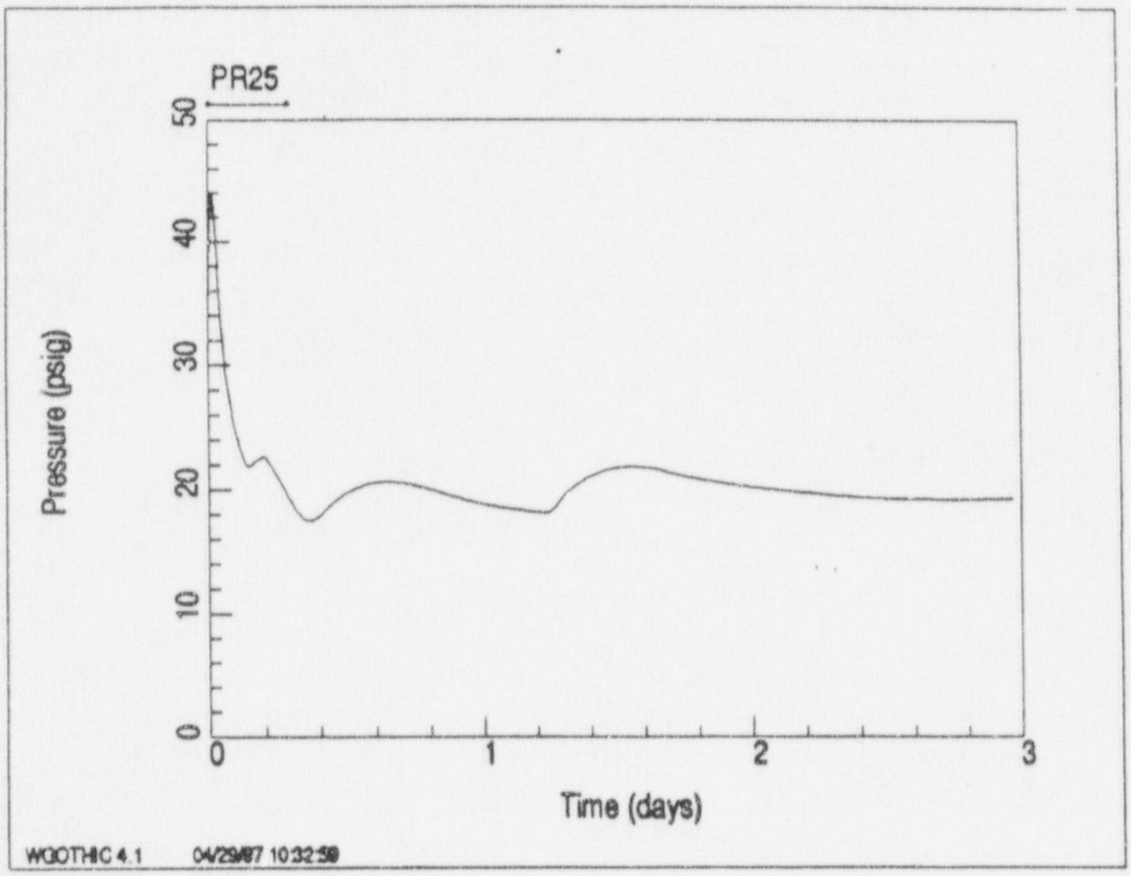


Figure 6.2.1.1-7

DECLG LOCA Case for 3 Days

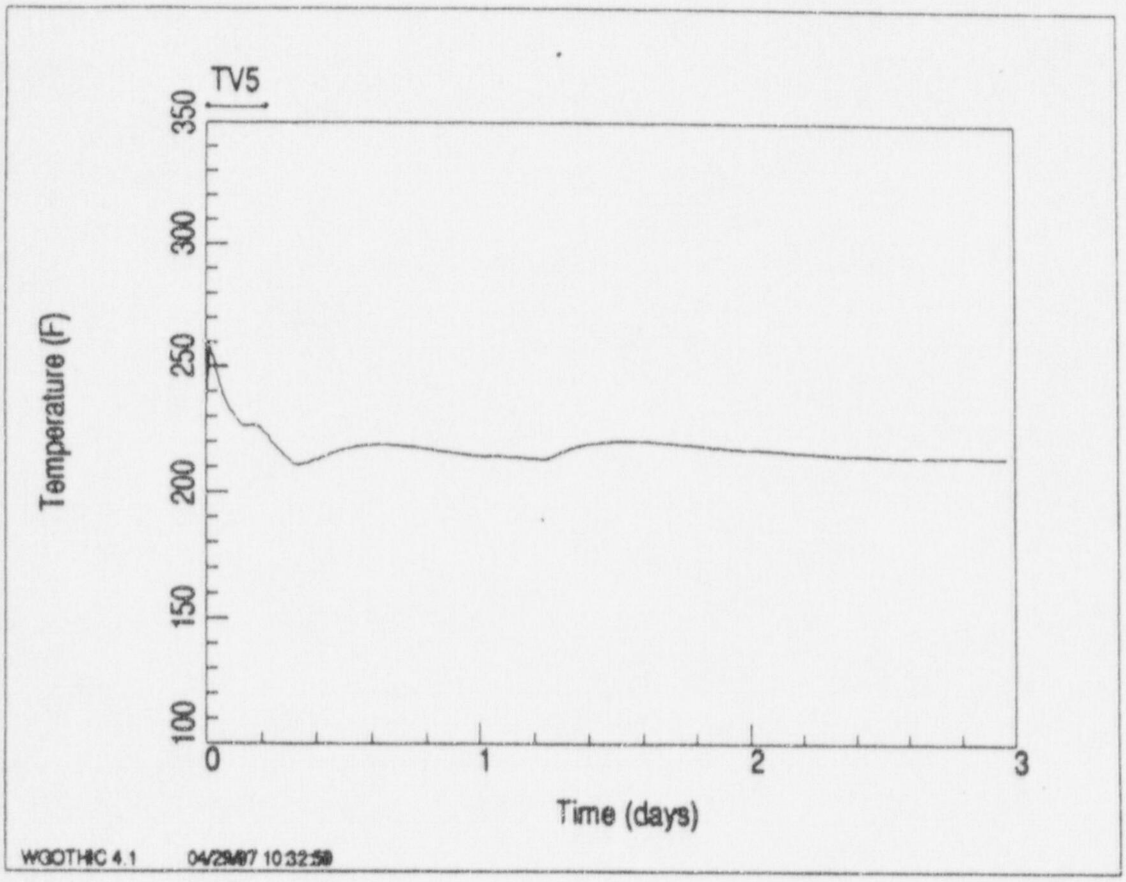


Figure 6.2.1.1-8

DECLG LOCA Case for 3 Days