ATTACHMENT

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AP600 RESPONSE TO NRC STAFF CONCERNS RELATED TO HIGH PRESSURE, FULL HEIGHT INTEGRAL TESTING

1.0 INTRODUCTION

AP600 has been designed with passive safety systems which provide fundamental improvements to plant response for accident scenarios, resulting in increased safety margins for design basis events and lower risk of severe accidents as compared to current plants. To verify the performance of the AP600 passive safety systems, Westinghouse has established and is implementing a test and analysis program which provides detailed information on important phenomena, provides data to verify analysis models and demonstrate system and component performance.

As part of NRC staff preliminary review of AP600 passive safety systems and the Westinghouse testing program, the NRC staff has identified a set of specific concerns which the staff felt would require high pressure, full height integral testing for resolution. These NRC staff specific concerns were identified in a January 30, 1992, letter from D. M. Crutchfield to B. A. McIntyre. The following sections provide discussion of AP600 system performance, the AP600 test and analysis program, and responses to each of the NRC staff concerns. This documents the rationale that leads to the conclusion that the current Westinghouse test and analysis program is sufficient to establish the confidence in system performance necessary to certify AP600 safety.

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2.0 DISCUSSION OF AP600 SYSTEM PERFORMANCE

Westinghouse has been developing the AP600 passive safety systems since 1985 and have developed system behavior and performance knowledge based on interactions involving design, analysis (deterministic and probabilistic), and testing. This discussion addresses those aspects of this process which pertain to the specific NRC staff concerns relevant to high pressure, full height integral testing.

<u>Small Break LOCA Events</u>

The AP600 design addresses small break loss-of-coolant accidents (SBLOCA) with features for improved prevention and mitigation as compared to current plants. Features incorporated in the AP600 design which reduce the probability of SBLOCA include:

- canned motor reactor coolant pumps which preclude pump seal LOCA,
- reduced number of welds in primary loop piping and conservative leak-before-break piping design,
- large pressurizer to accommodate plant transients without power operated relief valves which have potential to not reseat,
- no reactor vessel penetrations below the top of the core.

For SBLOCA mitigation the AP600 provides improved safety margins via design features which include:

- core makeup tanks for increased high pressure safety injection capacity,
- increased accumulator capacity for intermediate pressure safety injection,
- automatic primary system depressurization and sustained low pressure injection without active switchover from injection to recirculation mode,
- automatic safety grade reactor coolant pump trip precludes accelerated coolant inventory loss due to pump head,
- loop seal in primary piping eliminated to preclude temporary reduction of coolant inventory in core,
- safety injection directly to reactor vessel which reduces potential injection flow losses to a break,
- increased reactor vessel downcomer height to drive flow through core,
- reduced primary loop flow resistance which enhances circulation flow for core cooling,
- increased inventory in steam generator secondary side to absorb primary system heat,
- increased initial coolant inventory in primary system and pressurizer,
- reliable non-safety reactor coolant makeup and heat removal systems available to operator to supplement safety systems,
- reliable digital technology protection system with two out of four logic for safeguards actuation backed up by non-safety diverse actuation system,

- safety systems not affected by AC power failures or other active support systems,
- man-machine interface designed to provide increased operator understanding of plant conditions which reduces potential for inappropriate action.

The AP600 safety systems (Figure 2-1) are designed to mitigate SBLOCA scenarios in a functionally similar manner as current Westinghouse plants; i.e., with high pressure safety injection, intermediate pressure accumulators and long term low pressure safety injection. The major difference at high pressure is that AP600 uses the gravity head of the CMTs to drive safety injection flow rather than using high head pumps. Core cooling during a SBLOCA is a gravity driven process both for current plants and for AP600, both at high pressure and at low pressure. During the initial, high pressure phase of a SBLOCA flow through the core and the primary loop is driven by the gravity head difference between the column of subcooled liquid in the vessel downcomer and the two phase mixture in the core and upper internals; initially the downcomer water is from the RCS inventory and later is from safety injection. For AP600, the safety injection makeup to the downcomer is driven by the elevation head of the water column in the CMT and its injection path, relative to the head of the fluid from the downcomer injection point up the CMT vent path from the cold leg to the top of the CMT. Initially during a SBLOCA the CMT cold leg vent path will be filled with hot, but subcooled, liquid from the initial RCS inventory; the density difference between the cold liquid in the CMT injection path and the hotter liquid in the CMT cold leg vent path is sufficient to drive a net 12 lb/sec of safety injection flow into the downcomer. [Note: CMT flow during this time will also be supported by venting from the CMT - pressurizer balance line for most break locations but would be disabled by a break in this line, and is not required for CMT performance.] As the primary system continues to depressurize and the steam generator secondary side heats to the secondary side safety valve setpoint, the primary side fluid in the cold legs will become two phase and this two phase mixture will flow into the CMT cold leg vent lines, increasing the driving head for CMT injection by the increased density difference between the injection and vent paths. Thus the CMT response to reduced RCS inventory is increased injection flow.

As the SBLOCA proceeds, steam from the core and from flashing separates from the liquid phase creating a two phase mixture interface above the core and a saturated liquid/saturated steam interface in the cold leg. As this interface forms, liquid in the CMT cold leg vent path drains to the cold leg/downcomer and is replaced by steam. This further increases the CMT driving head and the injection flow to the downcomer which maintains the driving head for core cooling. When the CMT level falls to the 75 percent level, the first stage of ADS is actuated which further depresssurizes the primary system by venting steam from the top of the pressurizer. Injection from the CMTs continues to makeup for inventory loss from the ADS venting and break flow and actuates the remaining ADS stages as CMT level falls. During this time, the primary system pressure falls below the accumulator pressure (700 psi) and injection from the accumulators occurs. The accumulator flow in the injection line is sufficient to temporarily decrease injection from the CMT, but during this time the accumulator injection provides more injection than the CMT alone would. As the accumulator flow decreases, CMT injection proceeds, leading to full ADS venting and long term low pressure injection from the head of water in the In-containment Refueling Water Storage Tank (IRWST).

Non-LOCA Events

The AP600 passive safety systems are designed to mitigate the postulated design basis non-LOCA events such as steam generator tube rupture, steam line breaks and other secondary side events which effect the normal heat removal path through the steam generators. The PRHR system and the CMTs provide high pressure decay heat removal and primary system boration for these events.

The AP600 is designed to preclude operation of the ADS in design basis non-LOCA events. For non-LOCA events there are at least two completely separate levels of defense that protect the core without the use of ADS. One of those uses the non-safety systems, the other uses the passive systems (without ADS).

For example, in a design basis steam generator tube rupture event, the high pressure makeup pumps, startup feedwater pumps and operator action similar to current PWRs will allow the tube leak to be terminated without the need for any passive system operation. If the non-safety systems are unavailable, the passive systems will automatically terminate the tube leak without use of ADS and without any operator action.

For low probability, non-LOCA scenarios which involve multiple failures (beyond design basis events), such as multiple tube rupture or multiple failures in the passive safety systems, ADS actuation can occur and will serve to maintain core cooling. AP600 capability to cope with a multiple tube rupture scenario is improved relative to current PWR plants by virtue of the additional steam venting capability provided by ADS and reduced potential for overfilling the steam generator secondary side.

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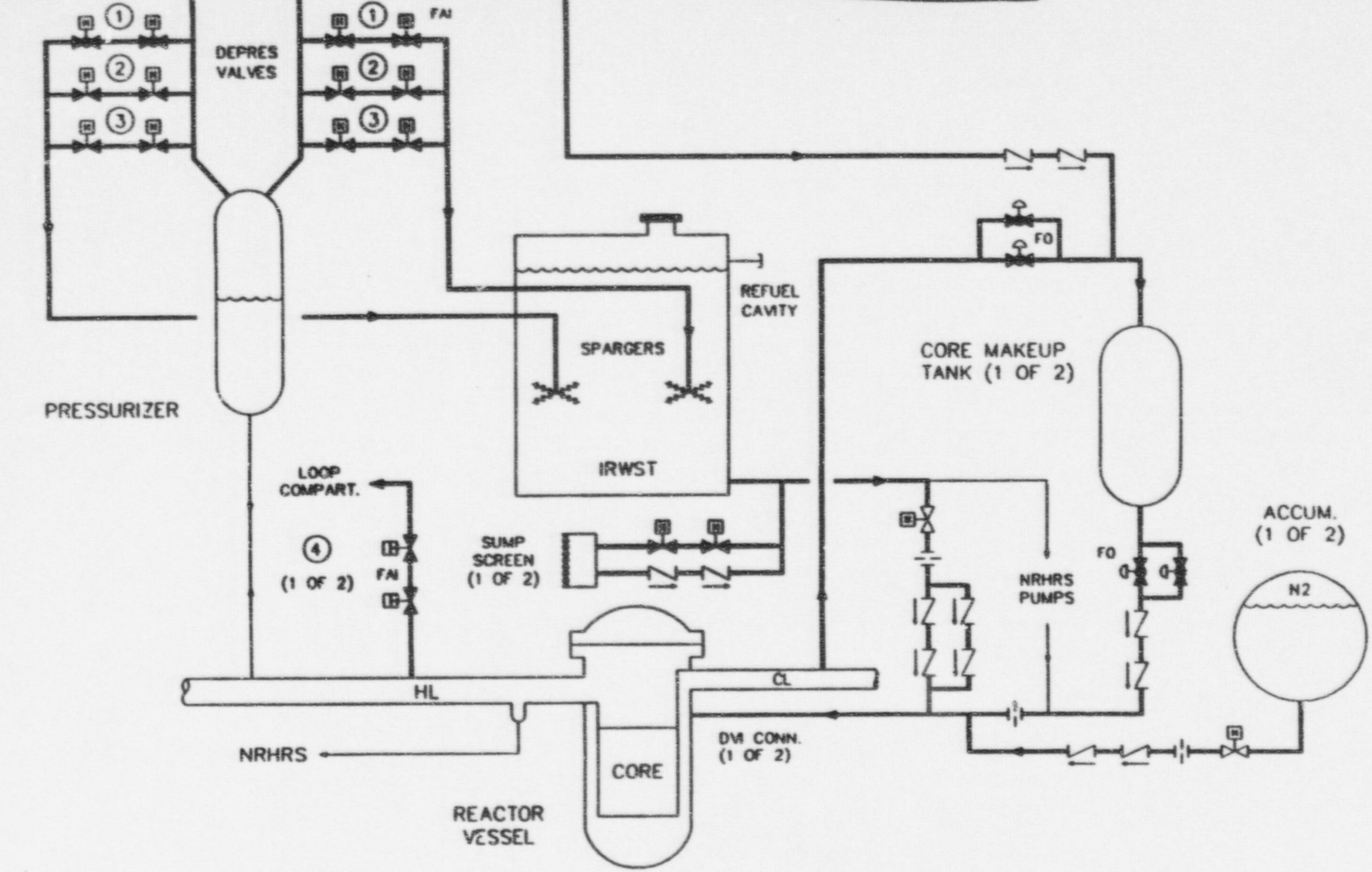


Figure 2-1: AP600 PASSIVE SAFETY INJECTION

3.0 AP600 TEST AND ANALYSIS PROGRAM

Westinghouse has developed an integrated test and analysis program to generate the test data needed to validate Westinghouse and NRC computer codes which will be used to assess the passive safety system performance for the AP600. The process which was used to establish this program was to examine each particular transient; large break LOCA, small break LOCA, containment behavior, non-LOCA transients, and long-term cooling, to determine the key phenomena for each transient, the code models which are used to calculate that phenomena, how that phenomena is affected by the features of the AP600 design, and what code validation exists for this phenomena for the AP600 geometry. Where sufficient data exists from the literature or from the NRC light water reactor research programs as compiled in NUREG-1230, then AP600 testing was not needed. However, where phenomena were identified for which no data existed, test programs were designed to fulfill this need. For passive core cooling and passive residual heat removal safety system performance, specific experiments were identified. These tests are relevant to the staff concerns regarding high pressure behavior and are discussed in the following paragraphs.

<u>Core Makeup Tank Systems Test</u>

Westinghouse will perform a CMT Systems Test. This test consists of an ~1/6th width and ~1/3 height CMT tank, a steam/water reservoir which simulates the plant reactor coolant system, both steam balance lines, and CMT water drain line. The piping simulates the actual plant piping layout so that plant piping ΔPs can be simulated and the CMT is elevated above the steam/water reservoir so that the elevation heads that exist in the plant are duplicated. (See Figures 3-1 through 3-3).

This test has been designed to fulfill the following specific test objectives:

- Demonstrate all the operating modes of the AP600 CMTs over a complete range of reactor operating pressures and temperatures (2250 psia/650°F to 20 psia/228°F). These operating modes include drain down with steam supplied via the pressure balance line(s), natural circulation operation to simulate operation when the cold leg is full, and intermittent operation to simulate cold leg voiding and refilling.

- Demonstrate the gravity drain of the CMT during depressurization transients and over a range of scaled flowrates that bound the prototypic design.

- Measure the rate of steam condensation on the CMT walls and water surface vs. steam pressure, and vs. water drain rate.

- Obtain detailed measurements of CMT through-wall temperature profiles and CMT liquid inventory temperatures, vs. steam pressure.

- Demonstrate behavior of the CMT steam/water interface as the cold water drains and is replaced by steam over a wide range of drain rates.

- Evaluate and demonstrate the operation of CMT level instrumentation which is used to actuate the automatic depressurization system during all CMT operating modes.

- Simulate the arrangement and operating conditions of the CMT steam supply piping.

Automatic Depressurization System Test

The operation of the Automatic Depressurization System (ADS) for the AP600 will be demonstrated by the currently specified ADS Test. These experiments consist of full scale steam/water sparger experiments to determine sparger performance, loads on structures, and condensation behavior within the In-containment Refueling Water Storage Tank (IRWST); as well as single and two-phase flow tests to characterize the critical and subsonic flow behavior of the ADS valves and piping over a wide range of prototypical pressures and qualities. The valves which will be tested will be prototypical full scale valves that would be used in the AP600 plant. In addition, data will be obtained on two-phase pressure drop for prototypical ADS piping configurations. The resulting data from these experiments will be used to validate the computer code models for the ADS system.

Passive Residual Heat Exchanger Test

The heat transfer behavior of the Passive Residual Heat Removal heat exchanger, which is used to remove the reactor decay heat if steam generator heat removal is unavailable has been quantified by test. The experiments consisted of three full length PRHR tubes, arranged with prototypical spacing placed in a large tank of water. The full range of primary system conditions were tested and design correlations were developed from the data. Tests included transient performance starting with a full IRWST tank at cold conditions progressing to elevated IRWST tank temperatures, and boil-off of the IRWST.

Integral Systems Test

Westinghouse is performing an Integral Systems Test at Oregon State University which will include a full representation of the AP600. This test will include: a simulated reactor vessel with a heated core, downcomer, upper plenum, upper head; both RCS loops will be modeled along with two active steam generators, each loop will contain two cold legs and one hot leg; two core make-up tanks, two accumulators, the ADS valves/system, the PRHR HX, as well as the non-safety pumped systems. The containment sump and the IRWST will also be modeled.

This test facility is shown in Figure 3-4. This test will be a 1/4-scaled simulation of the AP600 with a design pressure of 300 psia. A detailed scaling study has been performed to determine the facility sizing using the scaling analysis techniques given in NUREG-CR5809. The 300 psia maximum pressure was chosen to provide a sufficiently high pressure such that the higher pressure portion of the transients could be modeled where the steam generators are a heat sink as well as lower pressure transients in which the steam generators become a heat source. With a starting pressure of 300 psia, the test system can be used to initiate transients from a water solid natural circulation situation which would be representative of the high pressure portion of the small break LOCA transient described earlier. Piping breaks can be created in the test facility which will result in a transition from single phase natural circulation to two-phase natural circulation. As the test continues, the simulated CMT tanks will inject water into the RCS to maintain core inventory as the system blows down. The simulated ADS valves will open and create a hot leg vent which will cause a more rapid depressurization as in the plant.

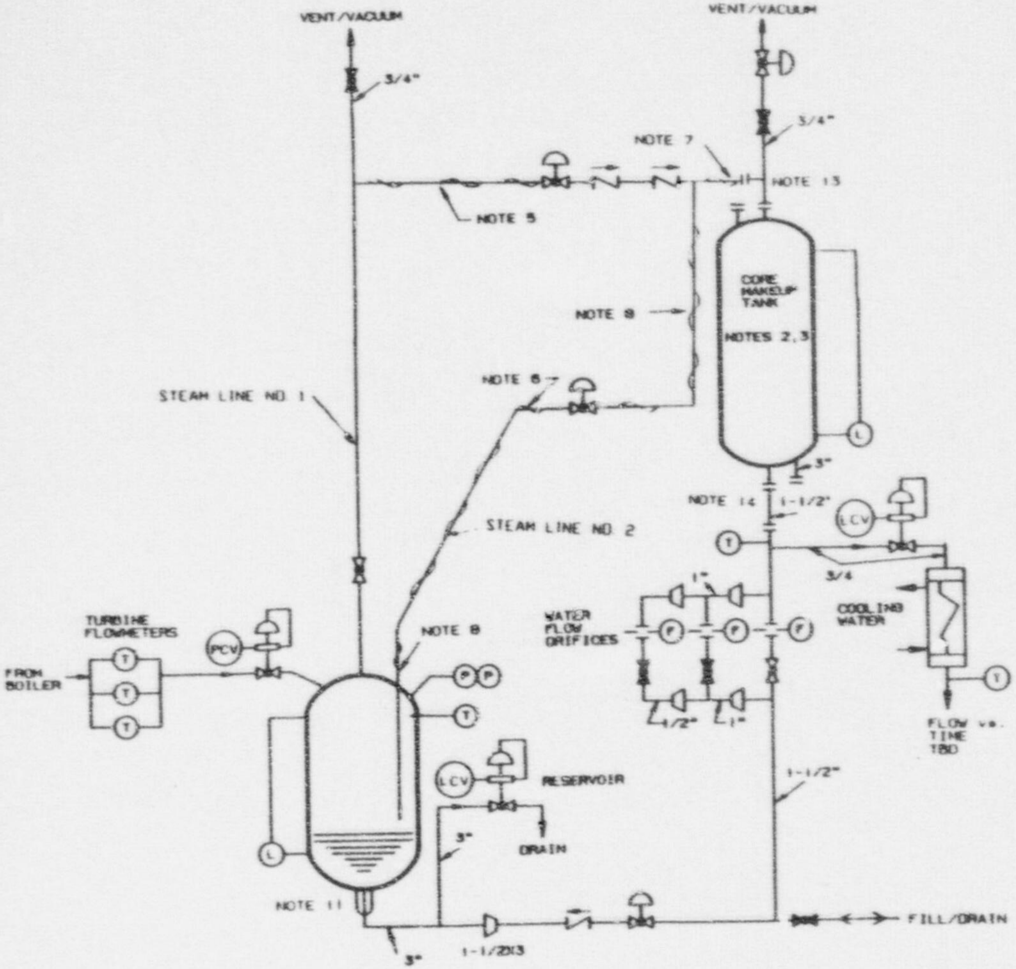
Scaling studies are currently being performed to determine break sizes, pressure scaling as well as system scaling using the scaling methodology given in NUREG-CR5809. These studies will provide a range of initial and systems conditions that can be tested in the facility to study the high to moderate pressure transition. In addition, full pressure representation will be simulated from 300 psia down to atmospheric conditions.

At high pressures, for small breaks, the CMT has the largest driving head as it starts to empty. At intermediate pressures, the gas filled accumulators provide ample safety injection when the RCS pressure is below 700 psia. Once the accumulators are finished injecting the system pressure is well below the 300 psia test facility pressure. This facility is fully capable of directly simulating this portion of the transients where steam specific volume is greatest and increases the demands on the ADS vent capability.

The Integral Systems Test facility will provide the necessary data to validate systems computer codes for the depressurization and long-term cooling portions of the transient and will be a faithful reproduction of the full AP600 system with all flow paths modeled. The facility will be highly instrumented to provide the flow, pressure, pressure drop, and mass inventory data needed to verify system computer codes for the AP600. By being able to start tests with liquid solid natural circulation, the mass inventory system states at high pressure can be simulated as well as the lower pressure states where the reactor coolant system is voided.

Analysis Models

The experiments which have been described above together with data from previous experiments will be used to validate the models and system response for the Westinghouse Best Estimate thermal hydraulic code; WCOBRA/TRAC. The WCOBRA/TRAC code has been specifically developed to use best estimate thermal hydraulic models such that an accurate representation of the AP600 passive system performance can be assessed. The NRC staff has reviewed and approved the WCOBRA/TRAC code for Westinghouse two-loop PWR's and is currently reviewing the documentation for the code which will comply with the 1988 Appendix K rule change.



NOTES:

1) The CMT is to be designed to operate at 2300 psig, 650°F.
2) All piping is 1-1/2" unless otherwise noted.
3) Bottom of core makeup tank to be ~24 ft. above reservoir water level.
4) See Figures 6.1 - 6.3 for instrumentation and tank pipe fitting details.
5) 20-40 ft. of horizontal pipe to be provided.
6) 12 ft. of horizontal pipe to be provided.
7) 2 ft. of horizontal pipe to be provided.
8) Vertical pipe sections to be ~10 ft. long.
9) Piping with symbol is to be heat treated and insulated. Thermocouples measuring water temperature are to be placed every 10 ft.
10) Required over pressure protection devices not shown.
11) Thermal sleeve or other thermal shock protection required.
12) Piping to be sloped at ~60° from horizontal.
13) CMT inlet and outlet flange connection to be as close to CMT as possible. Use 1.5D bend elbow.
14) Flanged section provided in order to install vortex breaker, if required.

Figure 3-1: AP600 CORE MAKEUP TANK TEST SCHEMATIC

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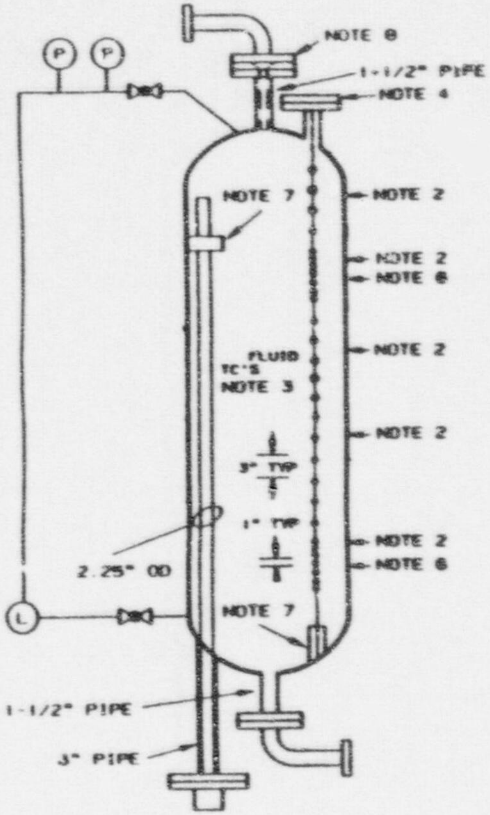

NOTES:

1) CMT TANK MAY BE CONSTRUCTED FROM 24-INCH, SCH 160, CARBON STEEL PIPE. SUITABILITY OF STANDARD PIPE CAPS TO BE DETERMINED.

2) ARROWS SHOW LOCATION OF SETS OF FIVE THERMOCOUPLES INSTALLED IN CMT WALL. ALL FIVE THERMOCOUPLES IN EACH SET ARE TO BE AT THE SAME ELEVATION. SEE FIGURE 6.2.

3) FLUID TEMPERATURE THERMOCOUPLES ARE TO BE LOCATED 3 INCHES FROM TANK WALL, ADJACENT TO CMT WALL THERMOCOUPLES.

4) 1-1/2" FLANGED CONNECTION SHOWN FOR STRING OF IN-TANK THERMOCOUPLES. DETAILED DESIGN OF ELECTRICAL PENETRATION AND ACTUAL REQUIRED FLANGE SIZE TO BE DETERMINED.

5) ALL INSTRUMENTATION TO BE REMOVEABLE SO THAT ANY FAILED COMPONENTS CAN BE REPLACED.

6) ARROWS INDICATE ELEVATION OF FIXED CMT WATER LEVELS.

7) BRACKET OR SOCKET TO SUPPORT LEVEL/TEMPERATURE INSTRUMENTATION IN TANK.

8) 1-1/2" CMT INLET PIPING/FLANGE TO ACCOMODATE 1" SCH. 160 PIPE INSERT.

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Figure 3-2: AP600 Core Makeup Tank Test - CMT Instrumentation Schematic

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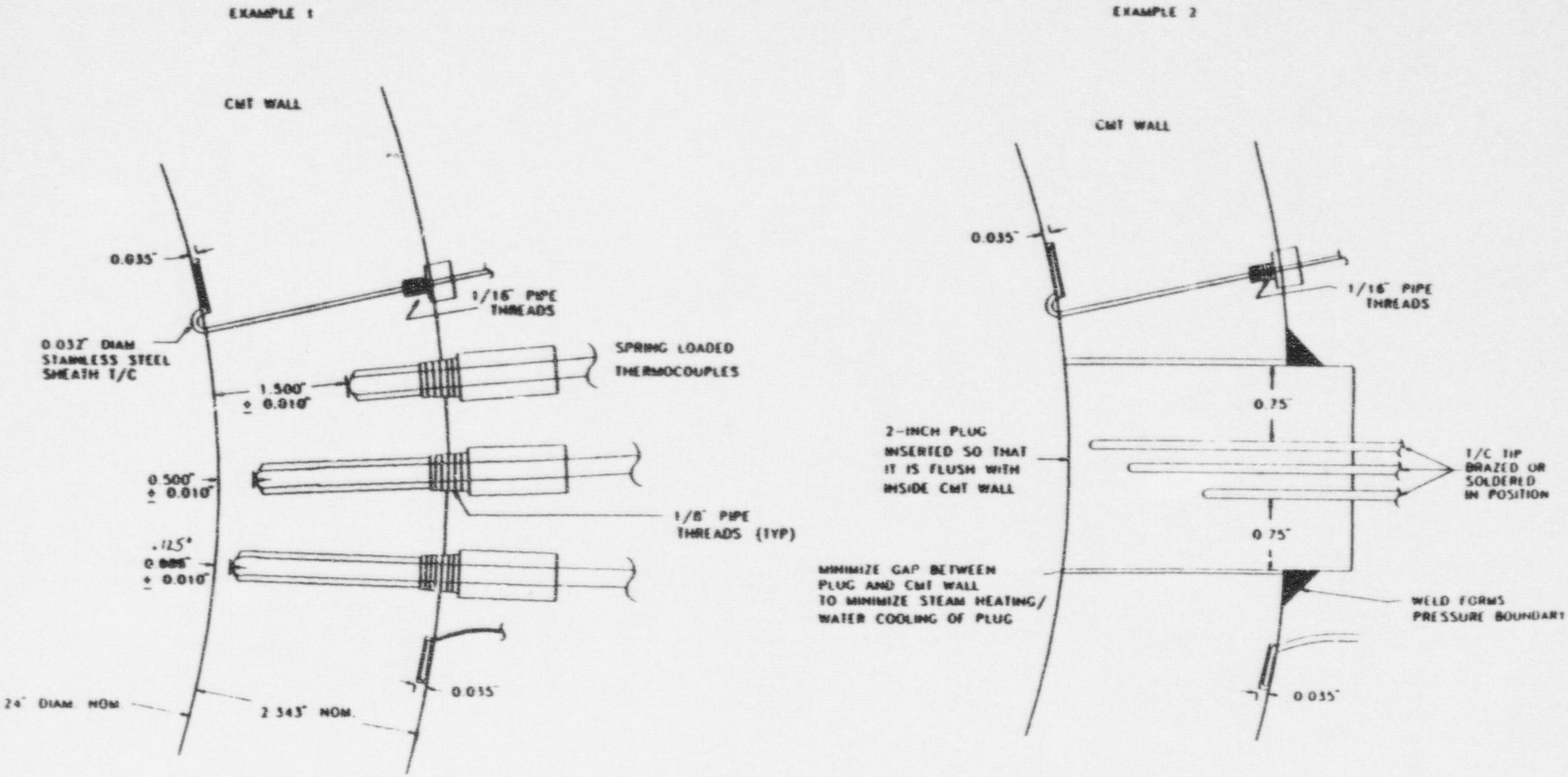

Figure 3-3: AP600 Core Makeup Tank Test - CMT Wall Thermocouple Installations (Examples Only)

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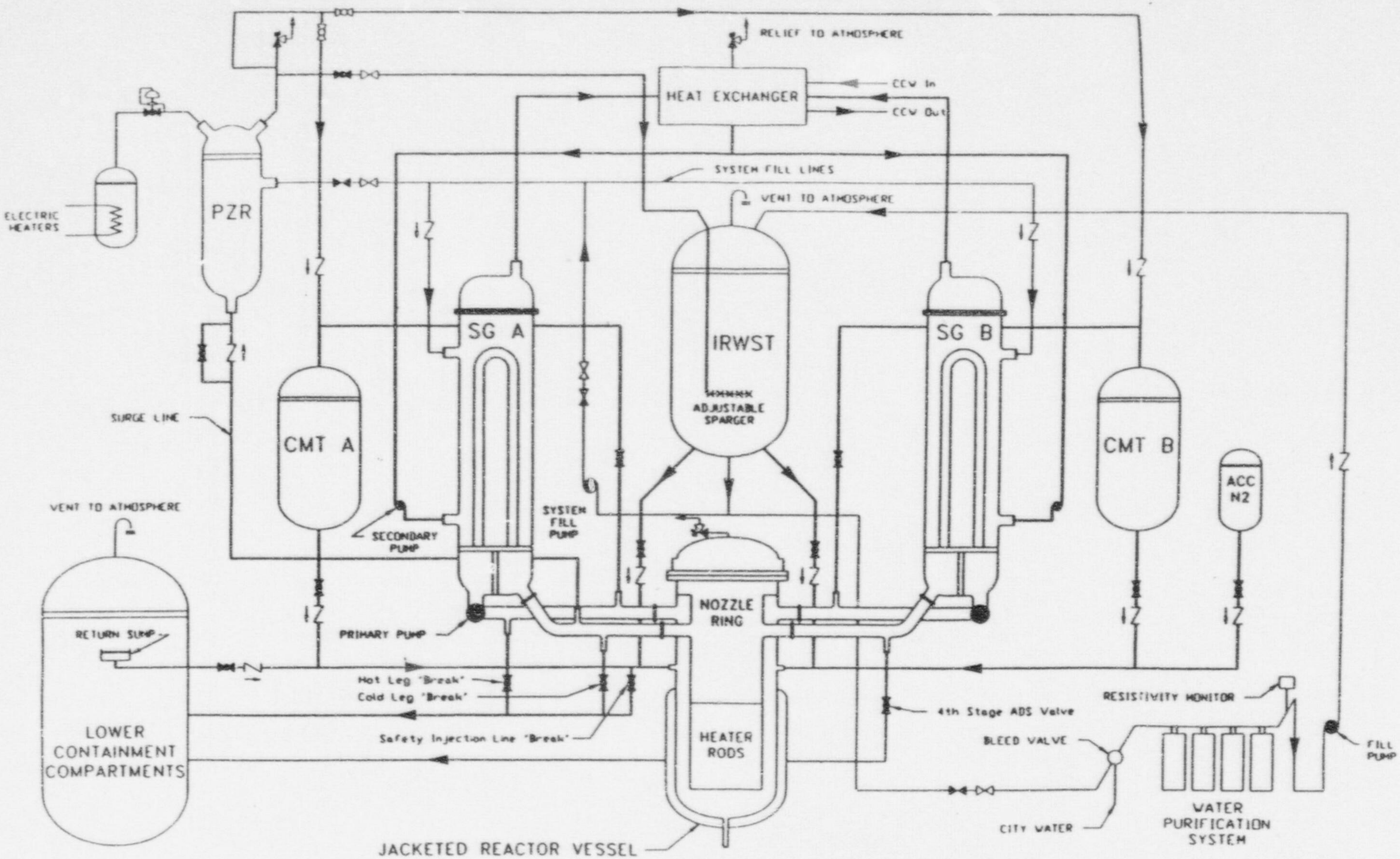

Figure 3-4: AP600 Integral Systems Test at Oregon State University

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4.0 RESPONSES TO NRC STAFF SPECIFIC CONCERNS

Staff Concern:

1. **Condensation in the core makeup tanks, which may cause pressure oscillations that could affect the gravity driven injection from those tanks.**

Response:

There are two pressure balance lines to the CMT, one line is from the top of the Pressurizer and the other is from the top of a cold leg. Each of these lines performs different functions.

The Pressurizer line provides pressurization of the CMT during normal plant operation to allow smooth initiation of the CMT. This line is 3" pipe and is about 120' long. It is designed to support small CMT injection flows typical of non-LOCA events (10 lb/sec. per CMT). During LOCAs, its operation is not required and in some break locations/failure situations, it will not function. The line contains two series check valves to isolate the CMT from the pressurizer when Pressurizer pressure is less than the CMT pressure.

The cold leg pressure balance line supports the greater injection flows required during LOCA events. Each CMT has a separate line that connects to a different cold leg to prevent interactions between the CMTs. It is 8" pipe that is about 60' long which results in very low pressure drops. At the maximum CMT flows (about 110 lb/sec each) the volumetric steam flow into each CMT has been calculated to be about three times the water flow, accounting for steam condensation on the CMT walls and at the steam/liquid interface in the CMT. Even with these high flows the pressure drop in the cold leg balance line is only .06 psi compared to a total driving head of about 11 psi. The basic approach has been to conservatively size the cold leg balance line to permit CMT injection with low steam velocity and pressure drop in the cold leg balance line even when condensation effects are considered.

To verify this conservative design, the CMT System Test currently planned by Westinghouse will directly measure the rate of steam condensation in the CMT vs. time, vs. water level, vs. pressure, and vs. water drain flow rate. The test will be extensively instrumented to measure not only overall steam and water flow rates but also includes:

- Sets of five thermocouples installed at various depths through the CMT wall to measure the local wall heat flux (steam condensation rate). Five such local heat flux measurements are provided at different tank wall heights.

- Twenty-nine thermocouples located in the CMT fluid along the length of the tank. These thermocouples are strategically placed to monitor the CMT water heatup due to steam condensation on the water surface and accumulation of condensate from the tank walls.

This test apparatus is designed to provide a greater range of steam velocities at the CMT steam inlet nozzle and a greater range of drain rates than in the plant, so that both initial and long term steam condensation conditions can be tested over a wide range. The test matrix includes tests with no water in the tank, and tests with fixed water levels so that the steam condensation on the tank walls, and on the water surface, can be separately and accurately measured.

Thus, the CMT System Test will provide an accurate simulation of the steam condensation conditions which can occur in the actual CMT. Also, this test is heavily instrumented in order to measure the steam condensation rates and observe the CMT water behavior and drain rate. Separate tests are specified in the test matrix to provide information about these phenomena and to simulate the full range of CMT operating conditions. These tests provide sufficient data to understand condensation affects on CMT performance and to verify treatment of these condensation effects in safety analysis models.

The 1/4 scale Integral Systems Tests will also simulate the two core make-up tanks. If oscillations would occur, they will be evident and measured in the planned Integral Systems Test facility. If there is an impact of condensation on the CMT water delivery, this will be evident from the experiments. Various experiments will be performed to characterize the core make-up tank behavior. The Integral Systems Tests along with the CMT tests will be used to validate Westinghouse safety analysis models.

<u>**Staff Concern:**</u>

2. The effect of thermal stratification in the CMT's on hydrodynamic behavior.

<u>Response:</u>

Thermal stratification is expected in the CMTs as a result of steam condensation. Some of the hot steam entering the top of the CMT is expected to condense on the colder tank walls and the water surface. The condensation rate decreases as the tank walls heat up and a layer of hot condensate accumulates on top of the colder CMT water. As the CMT injections continues, the hot condensate layer is expected to increase.

The hot condensate layer benefits CMT operation. The hot layer reduces the steam condensation rate which increases CMT injection rates somewhat. The accumulation of hot condensate actually produces additional safety injection water that will then be available for later injection into the RCS. The overall CMT injection rate will slowly drop as the level decreases and as the layer of hot condensate increases. However, the CMT injection rate remains sufficient to maintain the vessel downcomer inventory which keeps the core covered.

To verify this aspect of CMT behavior, the current CMT system test will provide detailed information about the rate of thermal stratification that occurs during CMT operation. As discussed in the response to Staff Concern Number 1 above; the test tank will contain 29 thermocouples inside the tank to measure water temperature vs. tank height. Furthermore, these thermocouples include close-spaced groupings so that thermal stratification can be observed. In addition to a range of drain down flow rates where thermal stratification effects will be very small, the test matrix includes test runs where the water level is fixed so that the buildup of a thermal layer vs. time can be readily observed.

Thus, this test will provide sufficient data to understand thermal stratification and its effects on CMT operation and provide the data to verify treatment of thermal stratification effects in safety analysis models.

The effects of stratification will also be observed in the core make-up tanks for the Integral Systems Tests. Therefore, there will be two sets of data, at two scales to examine these effects which can be used to validate Westinghouse and NRC computer codes.

Staff Concern:

3. **The effect of system depressurization on CMT behavior, such as flashing or level swell, which is important since ADS actuation is dependent upon CMT level, and the pressurizer is the source of steam for both the ADS and the CMTs.**

Response:

As described in the response to Staff Concern Number 2, as CMT injection proceeds, it is anticipated that there will be a layer of saturated water in the CMT. As the RCS pressure drops some of this saturated water will flash into steam. Such flashing is not expected to be a problem for the following reasons:

- the layer of saturated water is expected to be several inches thick compared to a total tank height of 20 ft,

- the RCS pressure drop during ADS will be relatively slow because of the use of four stages of ADS valves and because of the slow opening of the valves. Stage one valves are 4" globe valves that open in about 25 sec, stage two and three valves are 8" gate valves that open in about 105 seconds,

- with a slow RCS depressurization the steam generation rate will be slow and combined with the 12.5 ft diameter CMT (123 ft^2 area) the level swell in the CMT is expected to be small. In addition it should not last long,

- the ADS logic is such that if the low level signal is removed (by swell) after a stage of ADS is actuated the ADS valves will not reclose,

- the flashing steam will reduce the need for displacement steam from the cold leg which will result in a minor increase in CMT injection flows.

Further, as discussed in the response to Staff Concern Number 1, the CMT pressure balance line from the pressurizer can aid initial CMT injection but is not required for LOCA. The LOCA vent path for the CMT is the cold leg line.

To verify the expected CMT behavior, the current CMT system test matrix includes depressurizations of the CMT after thermal stratification of the water has occurred. The water level behavior in the test tank can be observed by the in-tank thermocouples and any effects on both ΔP type level and the prototypic (identical to the plant CMT level instruments) heated thermocouple level instruments will be observed. In addition, the test tank wall and fluid thermocouples will provide for the direct measurement of reverse heating into the CMT fluids during the depressurization. The above information will enable a detailed energy balance (water and tank wall sensible heats) to be observed. Thus, this test will provide sufficient data to understand system depressurization effects on CMT performance and to verify treatment of these effects in safety analysis models.

The planned Integral Systems Test facility will also include depressurization transients in which any saturated water in the core make-up tank will be able to flash. The systems effects of the flashing will be simulated in the Integral Systems Test facility, providing further data to verify the Westinghouse and NRC systems codes.

Staff Concern:

4. Possible refilling of CMT's through recirculation from cold leg or from accumulator. This could inhibit ADS, since the CMT level may rise or stay constant.

Response:

The CMT injection rate will inherently vary based on the needs of the reactor; if the cold legs are filled with water then the reactor does not need much water and the CMTs will inject slowly (10 lb/sec each). If the cold legs are voided, then the core needs more water and the CMTs will inject rapidly (110 lb/sec).

Recirculation of liquid from the cold leg is only possible when the cold legs are filled or mostly filled, i.e., when high CMT injection is not required. When the cold legs are filled, the CMTs will naturally circulate with the cold leg; hot water will flow through the cold leg line to the CMTs while cold water is injected into the RCS. This mode of operation would initially result in a total injection of about 50 lb/sec and about 12 lb/sec net injection. If the break is small enough to sustain a full cold leg for an extended time, recirculation will eventually heat the CMT fluid to cold leg conditions. This would take longer than 30 minutes. Since the cold leg has been water filled during this time, core cooling is sustained and the cold leg fluid in the CMT is still available for injection when the cold leg voids. Furthermore the reduced decay heat beyond 30 minutes more than compensates for the reduction in CMT injection rates due to the lower density water.

It is also possible for the CMTs to partially drain and then to refill. This is not expected to occur in a LOCA but may occur during non-LOCAs. Again the cold leg would have to be filled or nearly filled indicating that core cooling is not an issue. Refilling of the CMTs is viewed as a beneficial effect in that it helps maintain level in the CMTs and provide margin to ADS actuation for these non-LOCA events where ADS is not needed.

Diversion of accumulator flow from the reactor into the CMTs is precluded by the design. The CMTs have redundant series check valves in their discharge lines that are included for the express purpose of preventing the diversion of accumulator flow into the CMTs.

To verify this mode of CMT behavior, the CMT system test matrix includes both natural circulation and "intermittent" drain down tests that simulate the refilling of the CMT from the cold leg, that can occur if the cold leg is filled (or re-filled) and pressurizer steam is not available. These test runs with benefit of the extensive test article instrumentation will demonstrate that this is an acceptable mode of operation. These tests will include depressurization of the CMT after heatup so that the effects of flashing fluid in the tank on CMT delivery and level instruments are demonstrated. Thus, the CMT test provides sufficient data to understand the recirculation mode of CMT behavior and to verify treatment of this CMT mode in safety analysis models.

The planned Integral Systems Test will also permit operation where the core make-up tanks operate in the recirculation mode or with venting by steam coming from the pressurizer. This test has the flexibility to isolate pressure balance lines, either the pressurizer or cold leg, so experiments can be performed to examine the system behavior for different modes of core make-up tank operation, providing additional data to verify system codes.

Staff Concern:

5. **Interactions between the reactor coolant system (including the pressurizer) and the CMTs during accidents, particularly small-break LOCAS that involve the Pressurizer/CMT or cold leg/CMT pressure balance lines. Since maintaining CMT injection depends upon maintaining the communication between the RCS and the CMTs, disrupting the communication path could have a serious impact on the ability of the CMTs to provide high-pressure safety injection. In addition, since the ADS depends upon CMT level, degraded CMT performance may inhibit system depressurization, perhaps resulting in core uncovery.**

Response:

The CMTs are designed to be redundant and independent; they are separated from each other such that a pipe break that degrades one CMT will not affect the other CMT. Only one CMT is required to protect the core in a LOCA.

As discussed in the response to Staff Concern Number 1, the Pressurizer balance line is isolated from each CMT by redundant check valves. For a pipe break on the pressurizer side, these valves will prevent the loss of either CMT since the cold leg balance lines are unaffected. For a pipe break on the CMT side, that one CMT would be affected however the other CMT would be protected by the check valves in its pressurizer line. These check valves also protect the CMTs from the effect of the ADS valves on the pressurizer pressure.

A pipe break in one CMT cold leg balance line will affect at most one CMT; the other CMT has a completely separate balance line to another cold leg which will prevent interactions between the CMTs.

These pressurizer balance line check valves along with the cold leg balance lines allow the CMT to operate independent of the pressurizer as required during pressurizer breaks and during ADS.

As discussed in the responses to Staff Concern Numbers 1 through 4, interactions between the CMTs and RCS via the pressure balance lines such as condensation, thermal stratification, recirculation and depressurization effects are not expected to adversely effect CMT behavior and will be well understood and verified by the planned CMT System testing.

To provide additional verification of expected behavior, interactions between the CMT and the reactor coolant system will be studied in the Integral System Test Facility. While the facility will have an upper pressure limit of 300 psia, the transients can be initiated from a liquid solid or two-phase natural circulation condition, which would be the starting point for a small break LOCA transient. The system depressurization can be initiated and controlled by creating a "break" in the RCS. As the system depressurizes, the RCS/pressurizer/CMT interactions can be studied, as well as, the activation of the simulated ADS on the pressurizer. If system interactions are to occur, the lower pressure of the planned Integral Systems Test facility would tend to overemphasize these interactions, not reduce them, due to the lower system pressure which makes the steam specific volume changes with pressure, more sensitive. This planned Integral Systems Test data will provide further verification for the integrated use of analysis models verified by the high pressure CMT tests and by high pressure SBLOCA tests previously performed.

Staff Concern:

6. The effect of non-symmetric safety injection, as might occur in the event of a break in a direct vessel injection line.

Response:

As discussed in the response to Staff Concern Number 5, the CMTs are redundant and independent. A DVI line break potentially causes one CMT, accumulator and IRWST line to completely spill. However, the other CMT, accumulator and IRWST line are designed to protect the core. Such a situation will clearly lead to an early actuation of ADS when the affected CMT blows down to the ADS level setpoint. Also, the two DVI injection connections to the reactor vessel are located 180 degrees apart from each other and include flow diverters to direct injection flow downward into the downcomer. This ensures injection from the intact CMT will maintain downcomer level needed for core cooling.

Furthermore, AP600 is not unusual in this respect since current plants have non-symmetric safety injection if a cold leg break is postulated. For example, the current two-loop plants would spill the accumulator flow and pumped high pressure safety injection flow in the failed loop, while the intact loop, ~180° around the vessel would maintain the accumulator flow and the pumped high pressure flow into the intact cold leg. Performance of this type of injection has been verified in tests for current plants.

Further verification of this type of injection will be provided by the planned Integral Systems Test. The planned Integral Systems Test will simulate the two cold legs, one hot leg configuration for each loop as well as the two direct vessel injection locations into the reactor vessel downcomer. The direct vessel injection locations will also have the turning devices included similar to the AP600 design.

Staff Concern:

7. **Influence of high-pressure system response on thermal-hydraulic conditions that exist when the system reaches low pressure, and subsequent effects on low-pressure safety systems behavior. This is akin to setting realistic starting points for low-pressure integral systems tests.**

Response:

Core cooling will be sufficient regardless of the course of events at high pressure. As discussed in the response to previous items, the CMTs will respond to the inventory needs of the core at high pressure and continue to deliver injection together with accumulators at intermediate and low pressure. The resultant conditions in the transition from high to low pressure will be a water column in the vessel downcomer feeding the core and making up inventory losses to the break and ADS vents.

Also, as discussed in previous responses relative to CMT behavior at high pressure, the CMT response will vary depending on the inventory need of the primary system. These CMT response modes will be tested in depth in the planned high pressure CMT System tests.

The computer analysis of the AP600 system will generate a range of conditions for different transients. Parameters such as the reactor vessel mass and the mass inventory distribution in the reactor coolant system including the core make-up tanks, loops, as well as the break flows from the break and ADS can be calculated for different SBLOCA, LBLOCA assumptions. The Integral Systems Test facility has the flexibility of initiating tests from liquid solid natural circulation or two-phase natural circulation with different CMT water levels, break sizes and locations such that the planned Integral Systems Test conditions can overlap with the ranges of parameters calculated for the AP600 plant transients. If desired, the variation in the high pressure system behavior can be simulated through different computer calculations and used as different initial conditions in the planned Integral Systems Tests.

Also, the planned Integral Systems Test can start tests from a liquid solid natural circulation condition at ~300 psia. For these cases, a break can be initiated and controlled such that a gradual blowdown occurs, which will allow the system interaction to occur at lower pressure and with roughly the same mass inventory as at higher pressure in the AP600. In the

FLECHT-SEASET natural circulation test program, we were able to overlap flow and inventory data with higher pressure semi-scale tests and were able to simulate all three natural circulation cooling modes thought to be important at high pressure, with a facility at very low pressure.

Therefore, the combination of the high pressure CMT testing, plant analysis and planned Integral Systems Testing will provide verification that core cooling is not adversely effected by high pressure system response.

Staff Concern:

8. Influence of operator actions, including actuation of non-safety systems, on high-pressure safety performance.

Response:

The only high pressure non-safety system is the Chemical and Volume Control System (CVS). This system has relatively small makeup capabilities; it can maintain the pressurizer level in a 3/8" break. It connects to the SG cold leg channel head which makes it completely separate from the CMT connections. If this non-safety system is operating together with the CMTs, it will only result in a small additional mass addition from the CVS pumps which helps to support inventory makeup to the vessel downcomer.

The AP600 has automatic controls to ensure proper passive system operation and to ensure that the non-safety systems do not adversely affect the plant conditions. There are automatic safety grade interlocks that ensure that the CVS pumps only inject borated water following any reactor trip or safety injection signal. These pumps are also automatically stopped on a high pressurizer level to prevent pressurizer overfill.

The AP600 will also have clear emergency procedures defining the steps for the operators to follow. For the most part the operators will only have to verify that automatic actions have taken place. The emergency procedures will clearly establish the actions for operators to follow if the plant conditions indicate a need for the operator to intervene. The operators will be given clear instructions defining under what circumstances the passive safety systems may be restored to their standby conditions.

Staff Concern:

9. Behavior of multiple natural circulation paths and possible steam generator holdup effects.

Response:

Natural circulation in the primary loop is a principal phenomena in mitigating accident scenarios for AP600 as it is for all PWR plants. AP600 also uses natural circulation for CMT injection and passive residual heat removal. When the primary system is liquid solid, and at high pressure, there is the normal natural circulation path through the RCS loop, steam generator and back to the vessel. In this time period the steam generators are a heat sink. If an S signal occurs due to a small break, the CMT valves automatically open and establish natural circulation between the core makeup tanks and the RCS either through the pressurizer balance line or through the cold leg balance line. This initiates the CMT behavior discussed in the responses to Staff Concern Numbers 1 through 5 and which will be tested in depth in the planned high pressure CMT System tests.

During a SBLOCA scenario the AP600 protection system will automatically initiate natural circulation from the RCS hot leg through the passive residual heat removal (PRHR) heat exchanger based on signals indicating low level on the steam generator secondary side or ADS actuation. The effect of natural circulation through PRHR is to remove heat from the primary system, aiding depressurization.

Steam generator holdup in a SBLOCA scenario is a phenomena which has been studied extensively for PWRs. These studies are directly applicable to AP600. SBLOCA analysis models account for this phenomena and have been verified by high pressure integral tests. The phenomena involves the accumulation of liquid phase coolant in the upside of the steam generator tubes and the influence of this liquid on the driving head for natural circulation through the primary loop. This phenomena is less of a factor in AP600 than in current PWRs as a result of the increased natural circulation capability of the AP600 primary loop and the additional steam venting capability provided by the AP600 automatic depressurization system.

Steam generator liquid holdup was observed in semiscale test S-UT-08. The holdup caused a core liquid level depression prior to loop seal blowout. The liquid holdup in the semiscale generator was attributed to cold secondary side conditions and a reduction of the upper head bypass flow in the test. This particular phenomena was examined in detail in WCAP-10054 using the NOTRUMP code and it was found that the NOTRUMP calculations agreed with the semiscale data for this test. When the same model is used in PWR calculations, there is no calculated core uncovery due to the steam generator holdup.

The AP600 has features which will further mitigate the potential for liquid holdup in the steam generators. The flow area in the generators is larger for the AP600 such that the vapor velocity in the tubes will be lower and less holdup could occur. The lack of a loop seal on the downhill side of the generators will ensure that mixture condensed on this side will flow directly into the vessel. The core also sits lower in the vessel for the AP600 such that there is additional margin to core uncovery. Further, the ADS provides vent paths which are independent of the steam generators.

AP600 natural circulation behavior will be tested extensively in the planned Integral Systems Test. This facility includes all of the natural circulation paths discussed above. The 300 psi and 400°F capability of this facility is sufficient to test the natural circulation phenomena which would occur during the high pressure phase of SBLOCA. The planned CMT System test will also provide full height, high pressure data for the natural circulation behavior which drives CMT injection. These tests provide sufficient data to verify the plant analysis methods for these phenomena.

Staff Concern:

10. Transient, non-LOCA performance, notably steam generator tube rupture and multiple tube ruptures, and other events that could require actuation of passive safety systems.

Response:

The AP600 passive safety systems are designed to mitigate the postulated design basis non-LOCA events such as steam generator tube rupture, steam line breaks and other secondary side events which effect the normal heat removal path through the steam generators. The PRHR system and the CMTs provide high pressure decay heat removal and primary system boration for these events. The AP600 test program includes full height, high pressure tests to verify PRHR heat transfer performance and to verify CMT performance.

The AP600 is designed to preclude operation of the ADS in design basis non-LOCA events. For non-LOCA events there are at least two completely separate levels of defense that protect the core without the use of ADS. One of those uses the non-safety systems, the other uses the passive systems (without ADS).

For example, in a design basis steam generator tube rupture event, the CVS pumps, startup feedwater pumps and operator action similar to current PWRs will allow the tube leak to be terminated without the need for any passive system operation. If the non-safety systems are unavailable, the passive systems will automatically terminate the tube leak without use of ADS and without any operator action.

For low probability, non-LOCA scenarios which involve multiple failures (beyond design basis events), such as multiple tube rupture or multiple failures in the passive safety systems, ADS actuation can occur and will serve to maintain core cooling. AP600 capability to cope with a multiple tube rupture scenario is improved relative to current PWR plants by virtue of the additional steam venting capability provided by ADS and reduced potential for overfilling the steam generator secondary side.

The AP600 CMT testing and PRHR testing provides sufficient data to verify the analysis methods for high pressure performance during design basis non-LOCA events. Non-LOCA safety analyses will be used to quantify the margins available for coping with events beyond design basis.

Staff Concern:

11. Thermal-hydraulic behavior resulting from the reliance on small natural convection driving heads, and the potential for disruption of these driving forces by systems interactions such as those discussed above.

Response:

Natural convection driving head for providing core cooling is used in the AP600 design as it is in current PWR plants. For both small break and large break LOCA, current PWR plants rely on the 16 feet of driving head in the downcomer to force the flow into the core and through the reactor coolant loop to the break. Although current PWRs have pumping systems which inject into the intact cold legs of the plant, they function to maintain the downcomer full, with any extra water spilling out the break in the broken cold leg. The current PWRs maintain natural circulation by using the downcomer driving head.

The AP600 design similarly relies on the downcomer driving head to maintain the natural circulation flow in the reactor coolant system for small and large break LOCAs. The AP600 downcomer driving head is 18.5 feet, 2.5 feet greater than a standard PWR. The loop configuration for the AP600 aids natural circulation with no loop seal, two cold legs per loop. The AP600 safety system design also aids the natural circulation and core cooling with the activation of the ADS system which provides a vent path such that a significant fraction of the loop flow can bypass the steam generators and reactor coolant pumps reducing the total pressure drop. The lower loop pressure drop results in larger flows into the core for the AP600 compared to a standard PWR.

Thus, the verification and analysis methodology for high pressure behavior of natural convection driving head in the primary loop which have been established for current PWR plants are applicable to AP600.

The natural convection behavior related to CMT injection and potential mechanisms for disrupting this path are discussed in the responses to Staff Concern Numbers 1 through 5. The full height, high pressure CMT System tests will provide the data to verify analysis methods for this behavior. The planned Integral Systems Test will provide data to verify that the analysis models properly integrate the overall plant response with natural convection driving heads.

5.0 SUMMARY AND CONCLUSION

AP600 has been designed with passive safety systems which provide fundamental improvements to plant response for accident scenarios, resulting in increased safety margins for design basis events and lower risk of severe accidents as compared to current plants. To verify the performance of the AP600 passive safety systems, Westinghouse has established and is implementing a test and analysis program which provides detailed information on important phenomena, provides data to verify analysis models and demonstrate system and component performance.

The AP600 test and analysis program is based on a thorough review of the phenomena which can occur with the AP600 configuration and which differ from phenomena in current PWR plants that have been extensively studied and verified over many years by the nuclear industry. As described in Section 4.0, the specific concerns raised by the NRC staff relative to high pressure behavior are addressed by a combination of AP600 design features and the ongoing AP600 test and analysis program which includes both high pressure system testing and integral systems testing at lower pressure. Completion of the AP600 test and analysis program will provide sufficient verification of AP600 passive system performance to certify the passive systems contribution to overall AP600 safety.

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NSD-NRC-98-5751
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August 12, 1998

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

ATTENTION: T. R. QUAY

SUBJECT: RESPONSE TO NRC LETTERS CONCERNING REQUESTS FOR WITHHOLDING INFORMATION

Reference: 1. Letter, Sebrosky to McIntyre, "Request for withholding information from public disclosure for Westinghouse AP600 letters of March 9, 1992, April 28, 1993, and July 14, 1998."

2. Letter, Sebrosky to McIntyre, "Request for withholding information from public disclosure for Westinghouse letters dated February 14, 1992, July 29, 1994, and July 14, 1998."

Dear Mr. Quay:

Reference 1 provided the NRC assessment of the Westinghouse claim that proprietary information was provided in a letter dated March 9, 1992, that proposed a cooperative testing program in the Oregon State University, ROSA-IV and Large Scale Test facilities that would have allowed Westinghouse and the NRC to utilize the same testing facilities to perform AP600 related integral systems testing. The NRC assessment was that the information contained was similar to other nonproprietary material or that it did not conform to 10CFR2.790(b)(4). In addition, the material was used by the staff in the development of the draft safety evaluation report for the AP600, and therefore, should remain on the docket. At the time this offer was being proposed, the information was proprietary since it contained information that had commercial value to Westinghouse. At this time, over six years later, this information does not have commercial value and is no longer considered to be proprietary by Westinghouse.

Reference 1 also provided the NRC assessment of the Westinghouse claim that proprietary information was provided in a letter dated April 28, 1993, that provided a copy of WCAP-13383, "AP600 Instrumentation and Control Hardware and Software Design, Verification and Validation Process Report." The NRC assessment was that the information contained was similar to other nonproprietary material or that it did not conform to 10CFR2.790(b)(4). Reference 1 also noted that a subsequent revision of this report was considered nonproprietary. In addition, the material was used by the staff in the development of the draft safety evaluation report for the AP600, and therefore, should remain on the docket. Revision 1 of WCAP-13383 was issued on June 17, 1996, (DCP/NRC0526) to close out DSER open items 7.1.4-1 and 7.1.7-1. At that time, three years after Revision 0 of WCAP-13383

Enclosure 2

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AUG 19 '98 07:54 FR ARC-MONROEVILLE 412 374 4772 TO 81301415002 P.02/03 was issued, the information was no longer considered to be proprietary by Westinghouse and Revision 1 was therefore issued as a nonproprietary report. Since the information in Revision 0 is essentially the same information as in Revision 1, Revision 0 of WCAP-13883 is therefore no longer considered to be proprietary by Westinghouse.

Reference 2 provided the NRC assessment of the Westinghouse claim that proprietary information was provided in a letter dated February 14, 1992, that contained the Westinghouse response to the NRC AP600 issues that would require testing in a high pressure full height test facility. The NRC assessment was that no material in the letter was specifically identified as being proprietary and that a nonproprietary version was not provided. In addition, the material was used by the staff in the development of the safety evaluation for the AP600, and therefore, would need to be provided in another form if Westinghouse decides to withdraw the proprietary information as allowed by 10CFR2.790(c). At the time this subject was being discussed with the NRC technical staff, the information was considered to be proprietary by Westinghouse since it contained information that had commercial value to Westinghouse. At this time, over six years later, this information does not have commercial value and is no longer considered to be proprietary by Westinghouse.

Reference 2 also provided the NRC assessment of the Westinghouse claim that proprietary information was provided in a letter dated July 24, 1994, that provided a copy of WCAP-14132 (Proprietary) and WCAP-14133 (Nonproprietary), "AP600 CMT Program - Facility Description Report." The NRC assessment was that no material in the reports was specifically identified as being proprietary. In addition, the material was used by the staff in the development of the safety evaluation for the AP600, and therefore, would need to be provided in another form if Westinghouse decides to withdraw the proprietary information as allowed by 10CFR2.790(c). In WCAP-14132, it should be noted that the detailed as-built CMT test facility drawings in Appendix A are indicated to be proprietary by the standard proprietary statement used by Westinghouse on drawings. These detailed as-built drawings were deleted from WCAP-14133 to create the nonproprietary version of the CMT facility description report. To indicate what had been deleted, the list of as-built drawings was retained in the nonproprietary version of the report WCAP-14133. Westinghouse still considers the as-built drawings marked as proprietary in WCAP-14132 to be proprietary since the information reveals the distinguishing aspects of a process (structure, method or component) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive advantage over other companies and its use by a competitor would reduce his expenditure of resources in the design, assurance of quality or licensing of a similar product. The text description of the CMT test facility in WCAP-14133 is sufficient to support the staff safety determination for this activity.

This response addresses the proprietary issues delineated in the references.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

jml

cc: J. W. Roe - NRC/NRR/DRPM
J. M. Sebrosky - NRC/NRR/DRPM
H. A. Sepp - Westinghouse

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