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

ATTENTION: T. R. QUAY

SUBJECT: WESTINGHOUSE RESPONSES TO OPEN ITEMS ON THE AP600

Dear Mr. Quay:

Enclosed are three copies of the Westinghouse responses to open items on the AP600. This transmittal addresses the areas of SPES-2 and OSU testing. Responses to OITS items 2310 through 2319 and OITS items 2321 through OITS 2330 are included.

The NRC technical staff should review these responses as a part of their review of the AP600 design. These responses close the 20 open items.

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

for

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

/nja

Enclosures

cc: T. Kenyon, NRC (w/o enclosures)
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2807A

Add: T. R. Quay

E004
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OITS 2310

Re: SPES-2 Test S00401

The upper plenum appears to drain much more quickly than the upper head. Explain this behavior.

Response:

The upper plenum level reflects the fluid steam fraction that is exiting the heated rod bundle and is entering the hot legs, since it is part of the flow path through the reactor vessel. The upper head is not part of this flowpath, and only communicates with the upper plenum via four holes in a plate simulating the AP600 upper support plate. The top of the upper head is connected to the downcomer portion of the vessel by a small bypass line, which allows a small amount of water from the cold legs to flow to the upper head when the reactor coolant pumps are running. In SPES-2, this bypass flow keeps the upper head at, or near, the cold leg water temperature.

Because of the above physical arrangement, the upper head typically drains only when the primary system pressure decreases and is less than the saturation corresponding to the upper head water temperature. When this occurs, steam can form/exist at the top of the upper head; and water can drain through the upper support plate into the upper plenum. This behavior is expected and is similar to the behavior in the AP600. This is clearly illustrated in Plots 4 and 31 for each of the SPES-2 matrix tests in the SPES-2 TESTS Final Data Report, WCAP-14309, Rev. 1.

SSAR Revision: NONE

OITS 2311

Re: SPES-2 Test S00401

The acceptance criteria specified in the Test Objectives section are so general that it is difficult to assess, from the data presented, whether or not they were actually achieved. The absence in the QLR of a list of critical measurements or instruments adds to this uncertainty. Explain and demonstrate whether or not the acceptance criteria was achieved, and provide a list of critical measurements or instruments for this test.

Response:

Section 3 of the SPES-2 TESTS Final Data Report, WCAP 14309, Rev. 1 provides a discussion of how the test data were reviewed and validated. Table 3-2 provides a list of the instruments identified as critical for the analysis of the tests.

SSAR Revision: NONE

OITS 2312

Re: SPES-2 Test S01613

The same upper plenum/upper head draining behavior as noted in Comment 1 for Test S00401 is seen in this test. Explain this behavior.

Response:

The upper plenum level reflects the fluid steam fraction that is exiting the heated rod bundle and is entering the hot legs, since it is part of the flow path through the reactor vessel. The upper head is not part of this flowpath, and only communicates with the upper plenum via four holes in a plate simulating the AP600 upper support plate. The top of the upper head is connected to the downcomer portion of the vessel by a small bypass line, which allows a small amount of water from the cold legs to flow to the upper head when the reactor coolant pumps are running. In SPES-2, this bypass flow keeps the upper head at, or near, the cold leg water temperature.

Because of the above physical arrangement, the upper head typically drains only when the primary system pressure decreases and is less than the saturation corresponding to the upper head water temperature. When this occurs, steam can form/exist at the top of the upper head; and water can drain through the upper support plate into the upper plenum. This behavior is expected and is similar to the behavior in the AP600. This is clearly illustrated in Plots 4 and 31 for each of the SPES-2 matrix tests in the SPES-2 TESTS Final Data Report, WCAP-14309, Rev. 1.

SSAR Revision: NONE

OITS 2313

Re: SPES-2 Test S01613

On page 6-3, in the discussion of Plot 28 (L_000P), the core makeup tank (CMT) recirculation-to-drain transition time is given as 2800 s. In the very next paragraph (Plot 32), the time is given as 2625 s. Explain the difference.

Response:

The correspondence of the heated rod bundle water level (L_000P), shown in Plot 28, to the CMT's transition from recirculation to draindown was intended to mean that; L_000P stabilized at approximately 2800 seconds into the event, as a result of the increased CMT delivery that occurred when the CMTs transitioned from recirculation to draindown injection.

SSAR Revision: NONE

OITS 2314

Re: SPES-2 Test S01613

Comment 2 for Test S00401 regarding acceptance criteria is relevant for this test, as well (and in general). Explain and demonstrate whether or not the acceptance criteria was achieved, and provide a list of critical measurements or instruments for this test.

Response:

Section 3 of the SPES-2 TESTS Final Data Report, WCAP 14309, Rev. 1 provides a discussion of how the test data were reviewed and validated. Table 3-2 provides a list of the instruments identified as critical for the analysis of the tests.

SSAR Revision: NONE

OITS 2315

Re: SPES-2 Test S01309

In Section 3 of the QLR, it is stated that the ADS 1 and 3 orifices were modified each to represent an ADS 1 valve open at 50 percent flow area. The reasons for doing this are never explained in the report, nor is any mention made in the test objectives. The reasons for this modification should be made clear, especially in light of the fact that ADS actuation was not expected (and did not occur) in the test. (Note: There is some additional explanation of this modification in the "Test Procedure" section (5.0), but it is still not clear whether this was done to simulate some aspect of the AP600 plant behavior, or simply to provide better control of the test facility either during or after the test.)

Response:

Test S01309 was the simulation of a single SGTR in which manual operator actions were performed and non-safety active systems were used in the recovery from the event. The main objective of this test was to show that the same operator actions typically used in current Westinghouse PWRs can be used in the AP600 with the passive safety systems operating. As part of the manual operator actions the ADS 1 flowpaths are used to reduce the RCS pressure in a controlled manner. They are utilized in the AP600 in a manner similar to how the pressurizer PORVs would be used in current plants, if the reactor coolant pumps were not operating and no pressurizer spray was available.

The ADS 1 valves are designed for, and are intended to be used by the operator to manually reduce reactor pressure to equal the faulted SG pressure, and thereby terminate flow from the RCS to the faulted SG following a SGTR event. This depressurization would be performed when the RCS was sufficiently cooled to maintain subcooling in the hot legs during the depressurization. In order to simulate this manual depressurization in the SPES-2 facility, the ADS 1 and 3 orifices were reduced in size to each have the flow area of one ADS 1 globe valve open at 50%. (Note that these orifices were previosly sized to simulate two fully open ADS 1 and ADS 3 globe valves, respectively.)

Because the SPES-2 ADS flowpath isolation valves were not positionable; i.e. they could only be open or closed: the SPES-2 ADS 1 flowpath isolation valve was initially opened for 10 seconds out of every 30 seconds. In this manner, the SPES-2 ADS 1 would vent the scaled amount of steam from the pressurizer that an AP600 ADS 1 at ~17% open would. A larger ADS 1 valve opening could be simulated by increasing the fraction of time the SPES-2 isolation valve was open, and an ADS 1 valve completly open could be simulated by leaving both the SPES-2 ADS 1 and 3 flowpaths open.

SSAR Revision: NONE

OITS 2316

Re: SPES-2 Test S01309

The means of simulation of the break in this test, while using an orifice scaled to a double-ended break, still did not represent the situation that would occur in the plant, where, instead of a single flow path (as in the test), two paths would exist (one from each side of the broken tube). [Note: This was also a subject of discussion at an ACRS Thermal Hydraulic Phenomena Subcommittee meeting.] The potential differences in system response arising from this method of break simulation compared to the situation in the plant should be more fully explained.

Response:

The potential differences between the AP600 plant SGTR response versus the SPES-2 SGTR simulation, due to the break device, are small and have been minimized by design.The SPES-2 steam generator tube rupture (SGTR) simulation consisted of one flowpath from the primary system at the exit (cold leg side) of the SG, to the secondary side of the SG. The break flowpath contained a break orifice with a flow area that was 1.2 times the scaled area of a single AP600 SG tube end. The break line also contained two venturis, one on each side of the break orifice, which provided the capability to measure the break flow in either flow direction. This break arrangement design was choosen both to accurately simulate a single, double-ended SGTR near the SG cold-leg-side tube sheet, as discussed below; but also so the actual break flow could be directly measured in order to verify the safety analyses computer code modelling.

The SGTR break location and size was selected to provide as accurate a simulation of a cold leg side tube rupture as possible, since this is the break location analyzed in the safety analysis. This break location results in the highest primary to secondary break flow, thus providing the greatest challange for maintaining primary side inventory and preventing overfill of the faulted SG. The break orifice size was selected to obtain the proper break flow, based on previous SGTR analyses, and accounts for the flow losses that occur through the tube to the broken ends. Also, because the break flow from the hot leg SG plenum would be cooled as it traversed the length of the broken tube in the AP600 plant, the SPES-2 break fluid temperature entering the secondary side of the SG is properly simulated.

In test S01309, where the primary side fluid remains subcooled, there should be no discernable difference in system response due to the SPES-2 SGTR break arrangement; since the overall mass and energy balance between the primary and secondary systems is not affected by the break device, and the hot and cold legs are in direct communication.

SSAR Revision: NONE

OITS 2317

Re: SPES-2 Test S01309

The same upper plenum/upper head draining behavior as noted in Comment 1 for Test S00401 is seen in this test. Explain this behavior.

Response:

The upper plenum level reflects the fluid steam fraction that is exiting the heated rod bundle and is entering the hot legs, since it is part of the flow path through the reactor vessel. The upper head is not part of this flowpath, and only communicates with the upper plenum via four holes in a plate simulating the AP600 upper support plate. The top of the upper head is connected to the downcomer portion of the vessel by a small bypass line, which allows a small amount of water from the cold legs to flow to the upper head when the reactor coolant pumps are running. In SPES-2, this bypass flow keeps the upper head at, or near, the cold leg water temperature.

Because of the above physical arrangement, the upper head typically drains only when the primary system pressure decreases and is less than the saturation corresponding to the upper head water temperature. When this occurs, steam can form/exist at the top of the upper head; and water can drain through the upper support plate into the upper plenum. This behavior is expected and is similar to the behavior in the AP600. This is clearly illustrated in Plots 4 and 31 for each of the SPES-2 matrix tests in the SPES-2 TESTS Final Data Report, WCAP-14309, Rev. 1.

SSAR Revision: NONE

OITS 2318

Re: SPES-2 Test S01309

The post-test inventory (Table 6-9) shows more water mass in the upper plenum than there was at the beginning of the test. Comparing the before and after numbers, it appears that the volume dropped about 10 percent, while the density increased by about 30 percent, which would account for the increase in mass. However, the post-test volume seems to disagree with the water level as indicated in Figure 28 of the instrument plots, where the upper plenum does not appear to refill to anything near 90 percent of its original height. This discrepancy should be examined and more fully explained.

Response:

The post-test inventory listed in Table 6-9 is correct. It must be noted when observing the water levels depicted by L_A15P and L_A16P in Plot 28, that the water levels shown while the reactor pumps are running are not correct; since they are a combination of both the water head sensed by the instruments and the dP due to flow through the upper head. Once the reactor coolant pumps have been tripped and the dP due to flow losses is essentially zero, water level can be accurately measured. Therefore, after ~500 seconds the sum of L_A15P and L_A16P indicate the total water level in the upper plenum. These instruments readings have a combined range of ~5.5 feet, and as Plot 28 shows, the upper plenum stays full through most of the transient. At ~5500 seconds, the water level in the portion of the upper plenum above the hot legs (L_A16P) begins to decrease slightly. When the transient was terminated at ~6300 seconds, L_A16P had decresed by ~0.5 feet making the sum of L_A15P and L_A16P equal to 4.5 feet; which is 90% of the original level.

SSAR Revision: NONE

OITS 2319

Re: SPES-2 Test S01309

Although the test numbering system gives an indication of the order of performing the tests, a chronology of test performance (e.g., adding dates to Table 4-1 should be provided).

Response:

Table 1-2 in Section 1 of the SPES-2 TESTS Final Data Report (Ref. WCAP-14309, Revision 1) provides a complete listing of all the SPES-2 test runs and the date on which they were performed.

SSAR Revision: NONE

OITS 2322

Re: OSU Test SB4 Question #2

There is insufficient explanation of the events of this test. In addition, the explanation that is provided appears at least partially contradictory. No specific indications are given for the times at which the non-safety-related systems were actuated, and there does not appear to be any direct measurement of their characteristics (flows, temperatures, pressures, etc.). In addition, the text states that "the transient continued through ADS actuation, CMT/Accumulator injection, and CMT refilling" (page iii). However, in Table 6-2, times for ADS 1, 2, and 3 actuation are shown as "N/A." The description of the core water level behavior is too simplistic, does not appear to correspond to the plot (LDP-127), and does not account for many of the features seen in the plot, including the sustained down-spikes late in the test. IRWST injection is referred to, but nowhere does it appear to be indicated that this injection is due to pumping by the RNS system rather than by gravity drain. There is also no explanation of the apparent asymmetry of IRWST flow (unless FMM-702 is indicating approximately zero flow because it failed). Provide a more detailed description of the events of this test (including non-safety system actuations), measurements of the non-safety systems' behavior, and integral system responses (e.g., CMT refill, PRHR flow oscillations) to assist the staff in interpreting the data.

Response:

Section 5.2.1 of WCAP-14252, AP600 Low-Pressure Integral Systems Test at Oregon State University Final Data Report, provides in depth explanations of the events that took place during this test and will answer most of the questions put forth.

The Quick Look Report (QLR) Table 6.2 should not have had N/A for ADS 1, 2 , and 3 actuation times since they did open due to a low level in CMT-1 406 seconds after the break valve received an OPEN signal. The ADS valve opening times appear in Table 5.2.1-3 of WCAP-14252.

It is correct to assume that there was no injection flow directly from the IRWST during this test and that is explained in Section 5.2.1 of WCAP-14252. FMM-702 was not failed and was providing a correct indication of zero flow. The flow indicated by FMM-701 was the flow going to the suction of the RNS pump and then injected into the DVI lines. This can be seen on P&ID G-23 of Appendix G to WCAP-14252.

SSAR Revision: NONE

OITS 2323

Re: OSU Test SB11 Question #1

There were numerous failed or erratic instruments, including many flows related to the safety systems (e.g., both CMT flowmeters are noted as having problems). Several instruments also appear to have substantial offsets. These kinds of problems should be addressed in the final test reports, including what sorts of backup instrumentation was used to compensate for the loss of critical measurements.

Response:

The CMT FMMs noted as having problems are FMM-502 and -503 which are located in the CMT cold leg balance lines and become erratic when the lines are no longer liquid solid. The balance lines can be considered no longer liquid solid when the CMT makes the transition from recirculation to draindown. See WCAP-14252, Section 2.4.3.2, for a discussion of the effects of two-phase or steam flow on FMM response.

Phenomena affecting instrument response, other than when the instrument was considered out-of-service, are discussed in Section 2.4.3 of WCAP-14252.

There was specific criteria in each Matrix test procedure for what instrumentation was required to be operable prior to starting a test. For those Matrix tests analyzed in WCAP-14252 there is a section in each test description devoted to a discussion of inoperable critical instruments including backup instruments that may have been utilized.

SSAR Revision: NONE

OITS 2324

Re: OSU Test SB11 Question #2

The QLR data for levels do not, for the most part, appear to be density-compensated. This should be corrected in the final reports; if the levels are still reported with uncompensated density, the reader should be given guidance as to how to adjust the data to account for this effect.

Response:

The level plots used in the Quick Look Reports were not density compensated. For some of the data plots in WCAP-14252 a program was developed that compensated selected level data for density. The density-compensated level data on those figures have the LDP designator preceded by a C. For example, CLDP-127 is the density-compensated data for level channel LDP-127. None of the raw level data transmitted with WCAP-14252 has been density compensated.

SSAR Revision: NONE

OITS 2325

Re: OSU Test SB11 Question #3

Systems interactions and dynamic phenomena should be explained. Examples include: rapid oscillations in several parameters near the beginning of the test, including ADS 1-3 liquid flow and CMT-1 flow; flow reversal in the IRWST discharge line, and the rapid decreases seen in cold leg temperatures.

Response:

Matrix test data was collected and reported to the data users in a two step process. The first data report, termed the Quick Look Report (QLR), was generated to provide access to the test data shortly after test completion. The QLR includes a brief summary of the test performed and summarizes the results of the test. Data presented in the QLR is considered preliminary, but has been reviewed against the established test acceptance criteria. The test acceptance criteria involves a check of the initial and boundary conditions, review of critical instrumentation, and performance of a mass balance.
The second data report, termed the Final Data Report (FDR), was written at the conclusion of the test program and assimilated all of the valid tests and key facility information into a single report. System interactions and dynamic phenomena are discussed in the FDR. The test data contained in the FDR has been further reviewed and validated from that performed for the QLRs. Data from selected tests are also plotted against each other to verify the various parametric effects from the tests.

SSAR Revision: NONE

OITS 2326

Re: OSU Test SB15 Question #1

See Comment 1 for test SB11. It is difficult to see how reasonably accurate mass and energy balances can be obtained for this test, since so many flow instruments seem to be out of service or highly erratic. Because this is the only hot leg break test in APEX, it appears that high-quality data is essential for use in code assessment, and it is questionable whether this test can provide such data. Address this concern for Test SB15.

Response:

Phenomena affecting instrument response, other than when the instrument was considered out-of-service, are discussed in Section 2.4.3 of WCAP-14252.

There was specific criteria in each Matrix test procedure for what instrumentation was required to be operable prior to starting a test. For those Matrix tests analyzed in WCAP-14252 there is a section in each test description devoted to a discussion of inoperable critical instruments including backup instruments that may have been utilized.

SSAR Revision: NONE

OITS 2327

Re: OSU Test LTC21 Question #1

See Comments 1 and 2 for test SB11. In addition to accounting for erratic readings, offsets, and so forth, explain the response of certain instruments. For instance, the PRHR inlet flow (FMM-802, plot 42) shows what looks like a negative offset after about 500 s. Is this really an offset, or is there reverse flow in this line that is not capable of being measured by the flowmeter (i.e., the flowmeter is "pegging" at about -2 gpm)? Other odd or erratic instruments of note include: IRWST discharge flow (FMM-701, plot 46) after about 11,000 s; sump injection flow (FMM-901, plot 64), which shows negative flow from t=0 to about 11,000 s, and FMM-902 (plot 65), which appears to give bad data up to about 8,000 s. Address these concerns for these and other instruments that showed erratic behavior.

Response:
Phenomena affecting instrument response, other than when the instrument was considered out-of-service, are discussed in Section 2.4.3 of WCAP-14252.

There was specific criteria in each Matrix test procedure for what instrumentation was required to be operable prior to starting a test. For those Matrix tests analyzed in WCAP-14252 there is a section in each test description devoted to a discussion of inoperable critical instruments including backup instruments that may have been utilized.

The level plots used in the Quick Look Reports were not density compensated. For some of the data plots in WCAP-14252 a program was developed that compensated selected level data for density. The density-compensated level data on those figures have the LDP designator preceded by a C. For example, CLDP-127 is the density-compensated data for level channel LDP-127. None of the raw level data transmitted with WCAP-14252 has been density compensated.

FMM-802 only provided accurate data when it was liquid solid. As soon as FMM-802 started to see a two-phase mixture or steam during the system blowdown following the break the data can no longer be considered reliable.

FMM-701, IRWST 1 injection flow, does indicate a negative flow when the Primary Sump injection valves open during long term cooling. There is an actual flow from the Primary Sump to the IRWST after the sump valves open. The amount of which can be determined by subtracting the indicated flow for FMM-205 from that of FMM-901. An explanation of this phenomenon can be found in the IRWST portion of WCAP-14252, Section 5.1.1.5.

For FMM-901 and FMM-902, the most probable cause for the negative data prior to Primary Sump injection beginning is that there was some air in the FMM. Following each test, the facility was cooled down and drained down to allow for system modifications required for the next test. The facility systems were then filled, vented and prepared for the next test. During this process it is probable that a small amount of air could become entrapped in the Primary Sump injection lines. The FMMs would not provide accurate data unless liquid solid.

SSAR Revision: NONE

OITS 2328

Re: OSU Test LTC21 Question #2

There appears to be a contradiction between Table 6.1, which states that TF-532 is about 88 F, and the plot of that instrument (#41), which shows it at less than 80 F. Explain the discrepancy.

Response:

WCAP-14252 Table 5.1.4-1, Matrix Test SB21 Initial Conditions, lists TF-532 average temperature over the time period from when the DAS started recording data until the break valve received an OPEN signal. That average temperature was 101.7°F. The justification for accepting this test with TF-532 temperature out-of-specification can be found in Section 5.1.4.1, System Configuration and Initial Conditions, of WCAP-14252.

SSAR Revision: NONE

OITS 2329

Re: OSU Test LTC21 Question #3

The dynamic behavior (oscillations) in this test, especially those starting near the beginning of the test and extending to around 9,000 s, need to be explained. They appear to be system-wide, since many of the primary and safety system flows, levels, pressures, and temperatures are affected. The character of the oscillations also appears to change as a function of time, and the behavior between about 6,000 and 9,000 s appears somewhat similar to the long-term cooling oscillations noted in several other OSU tests (and previously discussed with Westinghouse). Explain this behavior.

Response:

The oscillations in temperatures, pressures, flow, and levels early in test LTC21 started at about the same time that the ADS-1 valve opened and continued until the CMT-1 balance line began to refill which meant that the cold legs had refilled. A possible cause for the oscillations is fluid at saturation temperature in the hot legs being superheated in the steam generators and then condensing in the cold legs, resulting in multiple condensation/depressurization events in localized areas. Steam generator primary side differential pressure instruments indicated flow through the steam generators during this time period. This phenomenon is discussed further in Sections 5.1.4.4 and 5.1.4.5 of WCAP-14252.

For the oscillations during the long term cooling mode, three mechanisms were investigated in WCAP-14292, AP600 Low-Pressure Integral Systems Test at Oregon State University Test Analysis Report. The candidate mechanisms are:

a) Level fluctuations in the upper plenum opened and closed the steam vent path at the hot leg nozzle. Level fluctuations were driven by pressure changes resulting from alternately covering and uncovering the hot leg nozzle.

b) Slug flow in the ADS-4 lines caused pressure surges when the steam slugs discharged into the separator by changing the two-phase flow regime and pressure drop in these lines.

c) Pressure fluctuations were driven by changes in condensation rates for steam flowing from the upper head and condensing in the downcomer.

The observed oscillations may be a combination of all the postulated mechanisms, but the downcomer condensation model is the most probable explanation for the long term oscillations. These long term cooling oscillations are discussed in detail in Section 6.1.3 of WCAP-14292.

SSAR Revision: NONE

OITS 2330

Re: OSU Test LTC21 Question #4

Additional detail is needed to be able to understand the location of the break with respect to the CMT pressure balance line to allow easier interpretation of the data. For instance, the behavior of temperatures in the two CMTs is significantly different (e.g., see plots 38 and 40). This may be due to the interaction between the break and the CMT, i.e., inhibiting of flow from the CL to the CMT PBL in CL #3. However, it is difficult to determine where the break is, relative to the PBL, to verify this hypothesis, or to assess the significance, if any of the differences in CMT behavior after about 800 s.

Provide this information.

Response:

The relative locations of the break nozzles and the cold leg balance line are shown isometrically in AP600 document number LTCT-T3-300, Westinghouse AP600 Long Term Cooling Test at Oregon State University Facility Drawings, Piping and Instrumentation Diagrams, Sketch #CLL, Sh. 3 of 6. The balance line taps off of cold leg #3 at ≈ 6" from the RCP #3 discharge flange. The break nozzles tap off of cold leg #3 at ≈ 27" from the RCP #3 discharge flange.

TF-501 and TF-504 were considered to be inoperable during the performance of OSU Test LTC21 and are listed as such in Table 5.1.4-2 of WCAP-14252. The were both on the critical instrument list for LTC21 so the reason for them being declared inoperable and the justification for accepting the test is described in Section 5.1.4.2 of WCAP-14252. Overall CMT behavior is also described in Section 5.1.4 of WCAP-14252.

SSAR Revision: NONE