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MEMORANDUM TO: Carl H. Berlinger, Chief
Containment Systems and Severe Accident Branch
Division of Systems Safety and Analysis

FROM: Jack A. Kudrick, Deputy Chief
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Division of Systems Safety and Analysis

SUBJECT: TRIP TO WÜRENLINGEN, SWITZERLAND (PANDA) AND PIACENZA, ITALY (PANTHERS), DECEMBER 9-21, 1995

The main purpose of the trip was to observe some PANDA thermal hydraulic tests scheduled to be run in December, 1995 at the Paul Scherrer Institute (PSI) in Würenlingen, Switzerland. In addition, the trip was extended to include a visit to S.I.E.T. at Piacenza, Italy with regard to PANTHERS PCC test data. The PANDA visit was attended by A. Drozd, K. Campe and myself. Subsequent to witnessing Test M6/8 and discussing the preliminary results and observations with PSI test staff and GE technical staff (tele-conference), Dr. Campe and I drove to S.I.E.T. There, we met with the PANTHERS technical staff and GE representatives for a discussion of previously conducted PCC tests at PANTHERS. The trip was extended so that we could return to PSI in order to witness Test M9 which was run on December 19, 1995.

The PANDA facility management and staff were extremely responsive to our questions and provided a wealth of useful information and insights regarding the detailed understanding of the test data. They displayed a high degree of professionalism and a dedication in providing clear and accurate information regarding the PANDA tests even though they were on a busy schedule of preparing and running the test facility during our visit. The information, always clear and accurate, was provided to us both orally and in terms of written documentation. In regard to the latter, however, we were surprised and dismayed when at the end of the visit we were informed that we would not be allowed to take with us any of the written information that was handed out to us during our visit. Part of our difficulty in this regard was that we had been operating with the understanding that we would be able to take the material with us. Hence, we spent only a minimal amount of time in taking notes or otherwise keeping a running record of our findings during the visit. Only after we protested to GE management was the situation corrected and we were allowed to bring back written materials.

The first test we witnessed (Test M6/8, run on December 12/13, 1995) was designed to accommodate two separate tests, back to back. We were surprised at the relative shortness of the first part of the test. Although PSI had assured us that the test time was adequate, the preliminary results indicated that some of the measured variables continued to show transient behavior right up to the termination of the test. We believe that continuation of the test would have produced additional useful information about the thermal hydraulic

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response of the system. The dominant factor in limiting the test duration was the availability of low cost heater power. The PANDA facility is constrained by PSI procedure to make the runs during the night shift (starting around 6 PM), when the available electric power is at a low cost. Hence, this limits the overall test duration to something less than about 12 hours. In view of this, we are concerned that the test was incomplete and that the two runs should be made as separate tests in order to provide adequate time coverage.

The second test we witnessed (Test M9, December 19, 1995) [*** I do not have any notes on this. Do you Jack?***].

During our visit to S.I.E.T. (December 18, 1995) in Piacenza, Italy, we met with the management and staff of the PANTHERS facility. We had ample opportunity for an in formal exchange of information regarding data evaluation for the previously completed PANTHERS PCC tests, as well as some discussion regarding the IC test data which we anticipate getting in the near future. The PANTHERS staff was very cooperative and provided us with copies of some preliminary IC test data as well as a brief tour of the test facility.

The attached writeup is a more detailed summary of our test observations and test result discussions that we made at the PANDA and PANTHERS facilities.

Attachment: As stated

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TRIP REPORT ON DECEMBER 11-19,1995 VISIT TO THE PANDA AND PANTHERS FACILITIES

A. VISIT TO THE PAUL SCHERRER INSTITUTE, DECEMBER 11-13, 1995

1. Objectives

Dr. Campe and myself began our visit by meeting Dr. Healzer, a representative for GE at PSI. During the initial meeting we discussed our objectives for the next four days. Specifically, we indicated the following items we wanted to cover:

- Review the procedures for test M6/8
- Witness several hours of pretest preparations
- Witness several hours of tests
- Witness the add-on test
- Review past test matrix results
- Review the unofficial tests for test configuration and type of data taken to allow an understanding of the degree of deviation form the matrix tests

A discussion of the objectives did not lead to any objections and we proceeded directly to the initial task of reviewing the test procedures for M6/8.After agreeing on the objectives, we began to review the test procedures.

2. Test Procedures

The test procedures for M6/8 had been finalized on December 8, prior to the December 12 (Tuesday) test day. We reviewed test procedures and were satisfied that they were reasonable and appropriate for the scheduled test. Our review did raise the following points for discussion:

- GE had previously indicated (Torbeck memo to Don McPherson, 11/17/95) a test duration of 20 hours. The procedures we reviewed, however, limited the test to 10 hours.
- Venting of the IC is considered to hold pressure. Is this a credible sequence?

3. Review of results for past tests led to the following discussion questions:

a. Questions on Test M-2 results

- Why is there a spike in input power?
- When PCC unit 2 "sleeps", does the steam flow go to zero?
- What causes the temperature rise in the external pools?
- Is it possible to display an expanded time scale for the last hour or two of the test? This would allow a better view of what is happening in the PCCs.

b. Questions on Test M-3 preliminary results

- Two apparently independent curves are shown in a plot of RPV power versus time. Why are there two curves?
- In a plot of MSL pressure difference versus time, what is the reason for the slight pressure jump about 40000 seconds into the test?
- What is the reason for the jump at about 30000 seconds in one of the wet well air partial pressures? Which curve corresponds to which wet well?
- In the plot of PCC pool level versus time, is it possible to identify the pool level curves?

c. Questions on Test M-7 results

- What causes the pressure oscillation in RPV and DW1 at 21 hours (as indicated in a November 15, 1995 trending plot of RPV, DW, and GDC pressure versus time)?

4. Test M6/8 Observations (December 12/13, 1995)

On December 11, the staff members were provided a copy of the test procedure. As a result we were familiar with the process of achieving the test objectives. The procedure described the test in terms of two four-hour parts. The first part of the test was intended to provide information on the potential for system interactions between the IC and the PCCS. In order to determine the degree of interaction, one needs to first determine the effective heat rejection rate of the IC. Then to compare the heat rejection rate of the PCCs without the help of the IC and with the IC. In this way, one can begin to understand the operation of the system.

We were surprised at the shortness of the first part of the test. We had expected the test duration to be sufficiently long, so as to capture most of the system interaction transients. However, PSI assured us that the test time identified in the procedure was a minimum time and that the test would continue until the test variables stabilized.

For the second part, the test objective was to determine the system response with a 0.4 square centimeter flow path between the drywell and wetwell (simulation of a suppression pool bypass). Similar to the previous test, four hours was estimated for this phase. The test was to be terminated if either the system achieved steady state or a peak drywell pressure of 4.2 bars was reached.

We began gathering at the control room about 4 hours prior to the initiation of the test. The preparation of the facility proceeded without incident. All of the required conditions were established by a few minutes past 6 PM.

At the beginning of the test (6:19 PM), the IC was vented to establish pure steam conditions. About 30 minutes into the test, we went to observe the external pools and noticed that the IC pool was boiling violently, causing the pool surface to form waves of several inches. The PCCs were showing only mild boiling, with relatively little surface perturbations. DAS data confirmed that the IC was rejecting about 50 percent of the total heat, while the three PCCS were rejecting the remaining 50 percent, the load being distributed about equally among the three units.

The initial power level was 1123 kW and was reduced to 966 kW in about 45 minutes in accordance with the power decay curve.

Once the IC was vented to establish pure steam condensation, it dominated the heat removal role in this test. It's energy removal rate remained more or less constant for the test duration. There was no indication of non-condensibles collecting within the IC. The PCC energy removal rate followed the input energy decay. At 9:45 PM, the IC pool level was much lower than the PCC pool level.

After about 4 hours of IC testing (about 10:20 PM), the next testing phase was entered. The bypass path was opened in accordance with the procedures. The system reacted very slowly. The most obvious indication was a gradual heat up of the wetwell liner heat. The observed pressure curves reflected this. Specifically, absolute pressures rose about 6 kPa (0.88 psi)during the first 45 minutes of the bypass test. This proved to be more or less a constant pressure rise rate for the two hour period that the IC was operable and the bypass path in an open position. During this time, the IC rejected at a nearly constant rate and the PCCs rejected the remaining load much like the earlier test.

After two hours (12:30 AM, next day), the IC was isolated and the test continued for approximately another 4 hours. With the IC isolated, the PCC started working immediately. Again, the pressures rose at about a constant rate. However, this time the pressure jumped ~6 kPa, followed by continuation of pressurization at the rate of ~10 kPa/hr. It should be noted that discussions regarding the design specifications for the IC led to the following observation: the IC tube inside diameter is 51.0 mm, rather than 50.8.

5. Test M6/8 Review of the Results

Chart one shows the pool levels. Part one of the test shows that the IC level started at 4.75 m and dropped to slightly below 3 m (2.9 m, which is about the lower bottom of top drum. The bottom of drum is at 3.05 m and the top of the drum is at 3.8 m). For the PCC, the top of the drum is at 3.55 m and bottom is at 2.8 m. The initial IC level was at 4.75 m and had dropped to 4.5 m when the IC was isolated. It had dropped to 4.2 m at the end of the test.

It took about 30 min to saturate the PCC pools after the IC was isolated. This is because the PCC pools were not totally saturated due to the small amounts of energy being dumped into the pools during IC operation.

The vacuum breaker location in the wetwell is at 9.5 m and the temperature thermocouple locations are at 10.5, 9.8, and 8.6 m. The top two measured hot, while the bottom one measured close to the pool. The air temperatures in the second wetwell started at about 79°C and ended at 83°C. The air temperature in the first wetwell rose to 130°C. The partial pressure of air in the second wetwell started at 2.4 bar and reached 3.0 bar at the end of the test. PSI calculated the pressures assuming saturated conditions throughout the tests. The calculated values agreed quite well with the measured results and therefore they concluded that saturated conditions existed at all times during the tests.

During the test, another oxygen sensor was lost, leaving three out of the eight installed sensors operable.

The results show a pressure rise of 25 kPa (0.25 bar) over the last 4 hours of the test. Using this rate of pressure rise, and assuming IC isolation as the starting point, a linear projection indicates that the test would have to be continued to about 16.7 hours in order to reach 425 kPa (4.2 bar).

A review of the data showed that after IC isolation the pressure difference across the vacuum breaker quickly shot up to 10 kPa and then after 2 hours gradually began to decay, reaching about to 6.5 kPa at the end of the test. This indicates that the PCCs were extracting more energy than was being produced. The initial power of 650 kW had decayed down to 600 kW at the end of the four hours of the test.

6. Test M9 Observations

[*** I do not have any notes on this.***]

7. Discussion of Unofficial Tests

a. RPV/DW cool down behavior test (AT-COOL)

The following aspects were investigated in this test:

- The effect of shutting off each of the three PCCs, one at a time.
- Refilling PCC pools from the top to see the effect of pool subcooling.
- Observe RPV/DW cool down after shutting off RPV heaters.

With respect to PCC shutoff, it was found that air had to be injected into the drywell in order to get all of the units reject heat at the same rate. The results for this run are limited to trending plots. It appears that good procedures were used in making the run. The power was maintained at a constant value of 800 kW during this phase of the test.

Good mixing was observed during the refilling of the PCCs with cold water. Although a small centerline temperature decrease was observed in the lower portion of the PCC tubes, the overall system behavior did not show any significant changes.

With the RPV heater power shut off, the RPV, drywell, and PCC pressures dropped at a rate of about 0.2 bar in 14 minutes. This was attributed to the excess heat removal capacity of the PCCs.

b. PCC response to power increase under pure steam conditions (AT-M3B1, AT-M3B2)

At the end of Test M3B, the run was continued along the power curve in order to see long-term PCC performance under pure steam conditions. Pure steam conditions were established in all of the PCCs. Data were recorded and the procedures can be reproduced. The normal recording of valve status was not done for these unofficial tests. However, the specific valves which were either opened or closed are noted in the procedures and the operators noted the temperature and or pressure readings around the valve to assure that the change in valve position was achieved. The vacuum breaker was disabled.

When the heater power was increased to 1000 kW, all three PCCs returned to equal power, even though PCC2 had "shut down" (loss of heat rejection capability due to presence of non-condensibles) at the end of M3B.

Then heater power was increased to 1433 kW, resulting in MSL flow and pressure oscillations. PCC and main vents opened periodically during this phase of the test.

Finally, the RPV power was reduced to 0.8 MW. Some PCC tube centerline temperatures dropped to pool temperature values, indicating a decrease in the PCC heat transfer area.

c. IC operation tests after Test M10B (AT-M10B)

This test was intended to provide additional observations of IC operation after test M10B. It was run on Dec 6, 1995. The data were recorded and the procedures can be reproduced. To some extent, this test represents a shortened version of M6. However, in this case air was not injected into the RPV.

This resulted in air entering the IC and shutting it down. The system response was for the PCCs to pick up the heat load. Then the IC was vented. Immediately, the IC returned to its previous rate of rejecting energy.

Then air was injected to DW2. However, this time there was no air accumulation in the IC unit. The PCCs did vent as a result of the air addition to DW2.

8. Test data obtained at PSI

The following is a list of test data (trending plots) obtained at PSI for NRC use:

a. S-1 through S-6 Panda steady state test results, ALPHA-509, June 6, 1995

b. Panda Instrumentation (temperature only), ALPHA-514-B

c. Panda Instrumentation System line as-built drawings, ALPHA-515-A

d. Table 5.3 of Panda Instrumentation list, ALPHA 410-2

e. Trending Charts for tests M2,M3,M3A,M3B,M6/8,M7,M9, M10A, and M10B.

f. M6/8 test procedure. ALPHA-529

g. Material composition inspection certificate for PCC tube material

h. List of items on PCC tubes, with dimensions, 4-290-131/132

i. A list of four unofficial tests, AT-COOL, AT-M3B1, AT-M3B2, AT-M10B

j. TRACG model and nodalization

B. VISIT TO S.I.E.T., DECEMBER 18, 1995

On December 18, 1995, Dr. Campe and I met with some of the PANTHERS technical staff at S.I.E.T. in Piacenza, Italy. The purpose of the visit was to share informally PANTHERS test information. On our side, there were a number of items regarding test data evaluation that needed clarification and better understanding. Conversely, we provided the PANTHERS staff with some preliminary insights we had gained in our review and evaluation of the PCC test data available to date.

The S.I.E.T. participants were led by Dr. Paolo Masoni of ENEA, who has the responsible engineer for the PANTHERS facility. In addition to PANTHERS technical staff, the meeting was also attended by an ANSALDO Systems Engineer (E. Lumini) and a GE Liaison Engineer (S.Kanobelj).

During the meeting we had the opportunity to discuss the following items:

- Questions relating to the time signatures of the recorded data points.

  It had been our observation that a set of time-dependent data files for a given test run did not appear to be exactly synchronized (a few seconds or minutes of mismatch between two "simultaneous" data points). This was confirmed to be the case but the view was that for a multi hour steady state test this was not a significant problem. That is two "mismatched" points could be treated as if they were simultaneous.

- We had noticed that some of the instrumentation used for PCC structural/ mechanical measurements (i.e., strain gauges) included thermocouples installed within the sensor. We asked if these thermocouple readings could be used as supplemental temperature data for use in our PCC thermal/hydraulic analyses. We were told that these thermocouples were used to measure the pool side wall temperatures. Their intended use was for temperature compensation with respect to the strain gauges. They are not useful for absolute temperatures. However, on a relative basis, they may be usable for comparisons from test to test.

- We discussed the results of some of our preliminary heat transfer analyses and provided the participants with copies of the plotted results. One particular calculation (using the PANTHERS code), involving the PCC tube averaged heat transfer coefficients, appeared to be anomalous for one of the tests (Test T-51). We plan to reexamine this to see if it is an error or a true indication.

- We discussed and provided preliminary plots of PCC tube pressure and temperature profiles. In particular, we indicated the pressure profiles appeared to be counter-intuitive. Although we did not get any definitive explanations on this, it was pointed out that we may be trying to read too much into the data. That is, the pressure and temperature differences could be well within the uncertainties inherent in the instrumentation (e.g., the pressure error is noted as plus or minus 6 kPa in accordance with Standard No. SIET00393RP95). Also, with respect to the pressure profiles, their may be a need to double-check the true location of the pressure taps corresponding to the pressure readings being used in the evaluation.

- We asked for specifics on the status and current schedules regarding the availability of IC test data. The thermal hydraulic IC testing has been completed. At the time, the cause of some leakage observed at the upper header if the IC was not completed. A preliminary suspicion was that it was caused by a thermal transient induced by the surge of relatively cold water into the header when isolating the IC drain valve. An appropriate consideration is to see if this could carry over as a problem in the SBWR design. IC restart is not expected before March of 1996.

Additional discussions led to the following observations provided by the S.I.E.T. staff:

- Preliminary data evaluation indicates tube to tube heat transfer variation (e.g., T-76) that appears to be similar to the "sleeper" PCCs in the PANDA tests. Some tubes appear to "go to sleep" 5 to 10 minutes before recovering. The observation was that this was stochastic in nature and that it was attributable to unit over-capacity.

- It was observed that IC pressure recovery (T-12) was ~ 1 hour once the upper header was vented (nitrogen injection).

- Pressure recovery in the vent tank due to gravity head (15 meters)

- The mixing device was eliminated due to mixing in the inlet pipe. Test was rerun without the mixer.

- A delta-P reading is obtained through a single measurement (condensate tank air space pressure minus vent tank air space pressure).

- With respect to temperature measurements, thermocouple T-4001 was rated as non-essential (it may have been wet). T-4002 was rated essential and is the reference point for determining degree of superheat.

- In all tests (with the exception of the high steam flow case), the PCC inlet piping (submerged) was enough to desuperheat the steam. In the case of high steam flow, about a 30°C superheat was observed.

- A high condensate flow rate is sufficient to "flush out" the non-condensibles continuously.

- The low pressure IC tests were characterized by the following two sets of conditions:

  - A pressure of 300 kPa and a steam flow rate of ~ 1 kg/sec (~ 2.2 MW)

  - A pressure of ~ 800 kPa and a steam flow rate of 2.98 kg/sec (~ 6.1 MW)

A plot of IC heat rejection rate versus IC inlet pressure indicated an outlier data point at ~ 4500 kPa. The presence of some non-condensibles was suspected and the test was repeated. The new results indicated that the same point was now "within" the curve.

- We obtained copies of the following preliminary IC test results:

  - IC inlet pressure versus time for Tests T12 and T13
  - IC heat rejection rate versus IC inlet pressure for Tests T02 through T11