# PWR Owners Group

*NRC Public Meeting – December 16, 2009*

# *Jet Impingement Issue Resolution*

# ISSUE #1

*1A Shock waves behave spherically (not like a jet).*

- *Significance: Equivalent ZOIs calculated by jet volumes during insulation testing is non-conservative for shock damage and may underestimate spherical ZOI diameter by more than a factor of 2.*

Proposed Resolution To Issue #1:

Shock waves (overpressure) from a chemical detonation decay as a function of the distance from the explosion divided by the radius of the initial explosive mass (Sach's Scaling Law; see memo by Mike Epstein). Hence, the L/D representation is consistent with the expected maximum overpressure (loading) from any significant compression wave.

Therefore, the Wyle tests are representative of the reactor conditions based on the dimensionless distance L/D. Also, the comparisons between chemical explosives, air pressurized glass spheres and pressurized liquid in glass spheres show that compression waves generated by flashing liquids are much weaker that the equivalent energy tests with explosives or pressurized air.

# ISSUE #1 (cont.)

*1B Testing was performed at Cold leg temps while Hot leg and PZR temperatures are above the superheat limit of 577F for water.*

- *Significance: Vapor Explosions are possible above 577F which could yield a large shock wave.*

Proposed Resolution to Issue 1B:

Homogeneous (spontaneous) nucleation is a function of both temperature and pressure as presented by Skripov (1974). Superheat explosion analyses require that the highly superheated liquid exists at atmospheric pressure. The manner in which this is conservatively used by van den Berg (2008) is to assume that high temperature liquids can be depressurized to atmospheric pressure. Edwards and O'Brien (1970) experimentally demonstrated that the available nucleation processes are sufficient to prevent significant depressurization even at initial water temperatures of 467ºF and 544ºF. Further increasing the water temperature makes the nucleation rate even faster (easier) (because of homogeneous nucleation) and this prevents the pressure from decreasing significantly below the saturation pressure corresponding to the initial water temperature.

Hence, the flashing mixture is close to the equilibrium behavior that is modeled in NUREG/CR-2913.

# ISSUE #1 (cont.)

*1C The water temperature at the nozzle at test initiation was significantly lower than the water in the tank and resulted in a lower corresponding initial saturation pressure at the nozzle.*

- *Significance: Lower initial temperature minimized shock wave formation potential which likely resulted in less insulation damage.*

Proposed Resolution to Issue 1C:

The lower initial water temperature results in a central jet core that remains intact for an extended distance as modeled in NUREG/CR-2913. This is due to the subcooled nature of the axial jet that is discharged from the nozzle compared to the radial erosion rate of the jet as it flashes to the surrounding ambient pressure. Consequently, with the higher mixture density and discharge velocity for the subcooled jet, the dynamic head (and the damage potential) is maximized (along the centerline) due to these jet properties. Conversely, as discussed for other flashing experiments, the compression waves generated by a flashing liquid (Epstein, 2009) are very small compared to the dynamic head of the jet.

# ISSUE #1 (cont.)

*1D Rupture disks, like those used during testing, have a finite opening time which impacts shock wave formation.*

- *Significance: Acceptance that the test results included shock wave damage requires inherent acceptance by the staff of a finite break opening time for LBLOCAs, which are normally considered instantaneous.*

Proposed Resolution to Issue 1D:

By their very nature, blowdown experiments will have an inherent break opening time characteristic. Consequently, the opening time will have a direct influence on the perceived issue (strength of the compression wave) that is to be addressed by the experiment. As a result, the issue of whether a significant compression wave would be formed in the analyzed condition for a LBLOCA is best addressed using analyses and experiments with ruptured glass spheres such as those performed by Boyer et al. (1958), Esparza and Baker (1977a) and Esparza and Baker (1977b).

## ISSUE #1 (cont.)

*1E No method for scaling the shock wave from a test nozzle to a plant LBLOCA pipe size has been provided.*

- *Significance: Small nozzles used during testing underestimate the shock wave potential during a LBLOCA.*

Proposed Resolution to Issue 1E:

As discussed by Epstein (2009), the compression wave (shock wave) potential decays as a function of the pipe diameter to the radius travelled as presented by Sachs Scaling Law (Sachs, 1944). This is the same scaling as the Wyle blowdown jet experiments that have been performed; i.e. the ratio of the distance to the target divided by the pipe diameter. Hence, the experiments are representative of the reactor accident condition.

# ISSUE #1 (cont.)

References for Issue #1

Boyer, D. W., Brode, H. L., Glass, I. I., and Hall, J. G., 1958, "Blast from a Pressurizer Sphere," UTIA Report No. 48, Institute of Aerophysics, University of Toronto.

Edwards, A. R. and O'Brien, T. P., 1970, "Studies of Phenomena Connected with the Depressurization of Water Reactors," The Journal of the British Nuclear Energy Society, 9, pp. 125-135.

Epstein, M., 2009, "Blowdown Compression Wave Overpressure," Memo to H. K. Fauske and R. E. Henry.

Esparza, E. D. and Baker, W. E., 1977a, "Measurement of Blast Waves from Bursting Pressurized Frangible Spheres," NASA CR-2843, Southwest Research Institute, San Antonio, TX (May).

Esparza, E. D. and Baker, W. E., 1977b, "Measurements of Blast Waves from Bursting Frangible Spheres Pressurized with Flash-Evaporating Vapor or Liquid," NASA Contractor Report 2811, Contract NSG-3008, National Aeronautics and Space Administration (November).

Sachs, R. G., 1944, "The Dependence of Blast on Ambient Pressure and Temperature," BRL Report 466, Aberdeen Proving Ground, Maryland.

Skripov, V. P., 1974, Metastable Liquids, A Halsted Press Book, John Wiley & Sons, New York.

van den Berg, A. C., 2008, "Blast Charts for Explosive Evaporation of Superheated Liquids," Process Safety Progress, 27, pp. 219-224.

# ISSUE #2

*2A Larger pipe sizes in the plant as compared to test configuration may result in different failure mechanisms.*

*2D Jacket tears due to lip lifting by the jet may not be the failure mode on large pipes. In addition, most plants use stainless steel jacketing which is stronger than tested aluminum, therefore lift forces may damage the banding and latches resulting in greater loss of jacketing.*

Potential failure mechanism other than jacket tearing would be breakage of the bands or clasps holding insulation in place.

Load mechanism: Pressurization of entire interior of jacket, with external load due to jet impingement pressure on the front side of the jacket.

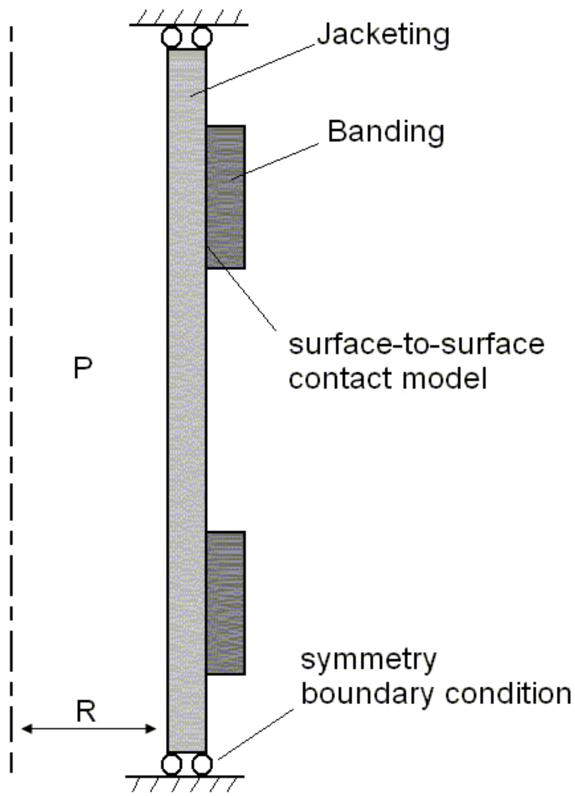
<u>Analytical Approach</u>

Finite element models will be developed.

- Three-dimensional models using tetrahedral plate/shell elements
- FEA package: Solid Work Simulation (non-linear capability)
- Model 1: Jacket with bands (for CalSil systems)
- Model 2: Jacket with linear elements to represent clasps (Nukon systems)

# ISSUE #2A/2D (cont.)

- Boundary conditions:  Guided on ends of model.  (Banded case shown; same for clasped case.)



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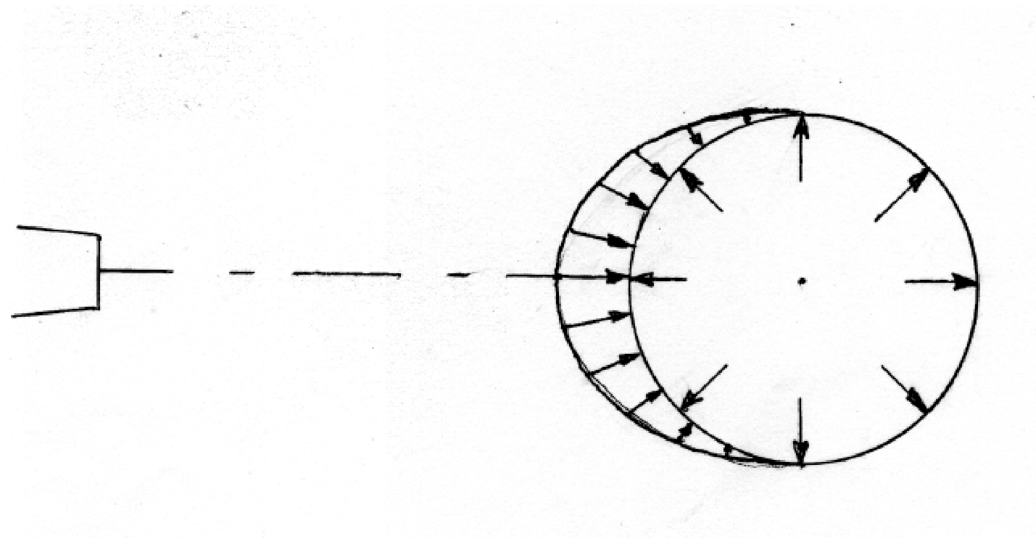
*NRC Public Meeting – December 16, 2009*

**ISSUE #2A/2D (cont.)**

- Loading
  - Each model will be loaded to represent external and internal pressure due to jet impingement.
  - Stagnation pressure from NUREG/CR-2913 corresponding to ZOI of 8.0 internally. Same pressure externally at jet centerline, decreasing linearly to zero at +/- 90° positions



**ISSUE #2A/2D (cont.)**

Benchmarking

- Further FE models will be constructed to reflect as-tested conditions. Purpose is to establish conservative nature of model behavior as compared to known test observations.

Analysis of FEA Results

- For jacketed / banded model, comparison of stress in bands to ultimate strength of band material
- For jacketed / clasped model, load determined from the model will be compared to known allowable load for clasps.

# ISSUE #2 (cont.)

*2B Target size was too large / too close to test jet which resulted in less force on target edges than in the center as evidenced by center focused damage in test photos.*

Response to Issue 2B:

- Photos referred to are from FPL test data; these tests were run at L/D = 5.08 (ZOI = 3)
- Only FPL test "D" showed significant center-focused damage (tearing of jacket); this test used aluminum jacketing.
- FPL Test "B" – same pipe/jacket geometry and L/D (5.08) but used SS jacketing – no noticeable center-focused damaged.
- Centered damage is predicted using NUREG/CR-2913 model. The effect is amplified as L/D values decrease.
  - For example, OPG test #10 with SS overclad, L/D = 3.0 (closer to nozzle than the FPL tests) showed noticeable centered jacket deformation, but jacket did not tear.
- Examination of photos for other tests (e.g., WCAP-16710-P Nukon tests at ZOI = 5) do not show discernible center-focused damaged. This is consistent with NUREG/CR-2913 predictions (flattening of pressure profile radially outward from center of jet as L/D increases).
- For tests in which the target was close to the nozzle and damage was center-focused, analysis will be used (same approach as issue 2A) to determine tensile stress in bands as nozzle diameter and target size is increased.

# ISSUE #2B (cont.)

FPL – Test B (3/4 pipe, SS jacket)

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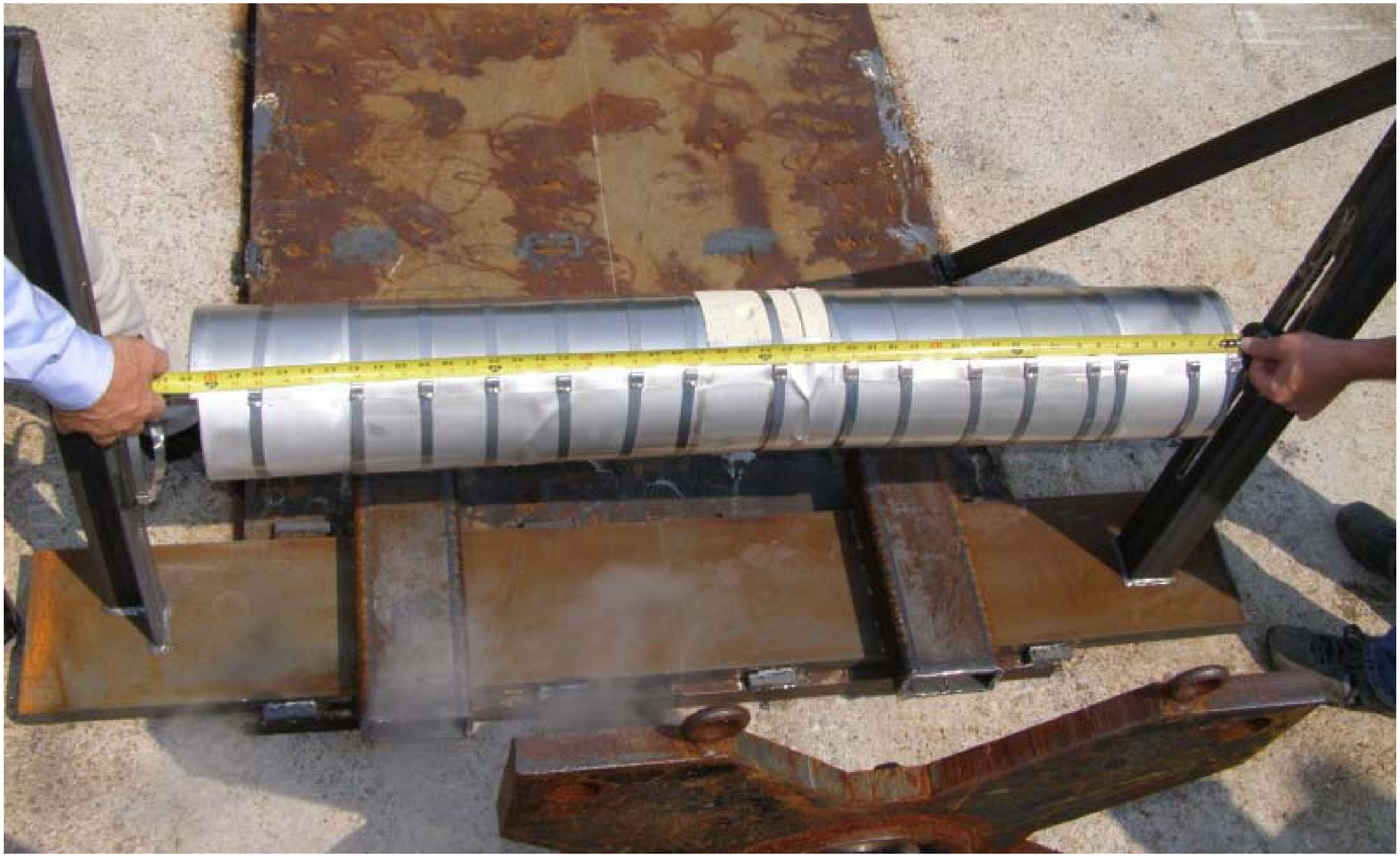
*NRC Public Meeting – December 16, 2009*

## ISSUE #2B (cont.)



FPL – Test D (3/4 pipe, Aluminum jacket)

# ISSUE #2 (cont.)

*2C Pipe jacketing failures are not the same as large component jacketing failures. Specifically, distance between band latches, number of latches, installation differences, band length, panel area under jet force, damage propagation under large S/G panels.*

*2F Potential for damage propagation outside tested ZOI on large components (i.e., getting under large S/G panels)*

## Solution path for Issue 2C/2F:

- Due to presence of support skirt, pressurizers insulation systems are not challenged by jet loadings.
- For steam generators and RCPs, further jet impingement testing will be performed.

**ISSUE #2C/2F (cont.)**

Test conditions

•2200 psi, 530°F for all tests

•Same test rig as on previous tests

Test configurations

1. Nukon insulation on SGs and RCPs
   - Hemispherical backing plate (24" radius).
   - Nukon insulation blankets held in place with wire mesh (as in plant installations).
   - Single test; nozzle distance corresponding to 5D ZOI. Jet impingement perpendicular to target.

## ISSUE #2C/2F (cont.)

<u>Test configurations (cont.)</u>

2. Nukon insulation on SG barrels
   - Curved backing plate; cylindrical radius = 48”
   - Blankets secured to plate such that they will remain attached to the plate and be exposed to jet for duration of the test.
   - No jacketing will be installed.
   - Two tests:

     (1) Impingement on end of blanket (longitudinal) – on seam of blanket.
       - Nozzle distance corresponding to 5D ZOI.

     (2) Impingement on face of blanket
       - Directed 40° along axis of SG barrel (worst case)
       - Nozzle distance: Greater of (a)calculated distance for 5D ZOI or (b) actual dimension of 71.32”

**ISSUE #2 (cont.)**

Test configurations (cont.)

3. Nukon insulation on unjacketed piping
   - Prototypical installation on 8” OD Schedule 80 pipe.
   - Blankets secured to pipe such that they will remain attached to the pipe and be exposed to jet for duration of the test.
   - Single test; nozzle distance corresponding to 5D ZOI.

Acceptance Criterion

For all tests, 100% visual inspection will be performed post-test. Considered successful if no breach of blanket covering is found during inspection.

# ISSUE #2 (cont.)

*2E Staff currently considers an open latch to be the same as a disengaged latch due to the random uncertainty in achieving this configuration. PWROG has not provided a basis for predicting repeatability for when a latch will open and disengage when a latch will open and remain engaged.*

Proposed Response to Issue 2E:

The WCAP-16710-P jacketed Nukon tests at 8D, 10D, and 13D are consistent in that the jacketing was not removed from the insulation, irrespective of which latches remained engaged or disengaged. Considered as a whole, this is considered a repeatable result.

# ISSUE #2 (cont.)

*2G Axial jet impingement on insulation may be worse than perpendicular, especially for damage propagation along the pipe.*

Solution path for Issue 2G:

- Discussion: When exposing an open end of an insulated pipe to jet loading, the entire annular volume between the pipe OD and jacket cannot be subjected to jet pressure because the pipe itself will shadow a portion of the annular opening from the jet. Hence, there is an escape path for pressure in the annular volume, and internal pressurization of the jacketing cannot occur.

- Analytical approach: It is conservative to assume that the entire inside of the jacket is exposed to pressure from the jet. The same finite element analysis models discussed in response plan to issues 2A and 2D will be employed, without considering external pressure loading.

# ISSUE #3

3. *Staff does not accept statement that unjacketed Nukon was not damaged at 5D because this insulation was jacketed at the beginning of the test.*

Proposed revision to statement:

The Nukon series of tests was conducted with stainless steel jacketing; no unjacketed Nukon was tested. During two of those tests, the stainless steel jacket was removed from the blanket by the jet forces, and the blanket was exposed directly to the jet pressure. The time at which the jacket was removed and the magnitude of the subsequent direct jet loading (force) that the blanket was exposed to was not recorded. Thus, while it can be stated that the tests were consistent in the fact that no debris was generated, the tests should not be used solely as a basis to justify that original unjacketed Nukon will not experience damage under a plant DBA conditions.

# ISSUE #4

***<u>NRC overall concern</u>:*** ***Large uncertainties exist using ANSI/ANS-58.2-1988 subcooled jet expansion model to calculate insulation loads***

## Response

The ANSI model was not used to calculate insulation loads

## ANSI Model Usage

- The ANSI/ANS-58.2-1988 standard was used to set nozzle-to-target distances for jet impingement tests
  - As the tests progressed the test article was moved closer to the nozzle for each subsequent test until a limiting distance with successful results was obtained.
  - Again, the nozzle-to-target distances were set based on ANSI model predictions for the applicable ZOI
- The final, limiting distance for each set of tests was converted back into a ZOI using the ANSI model
  - The compression wave existed in the test data
  - Using the ANSI model to calculate the ZOI included the effects of the compression wave implicitly

## ANSI Model Inputs

- In each case, conservatively low supply temperatures were assumed using the ANSI standard
  - Lower supply temperatures (more subcooling) result in larger jet forces at a given distance from the jet
  - Thus, the use of low supply temperatures results in the calculation of a larger ZOI than with warmer temperatures

# ISSUE #4 (cont.)

Dynamic Effects

- While the ANSI/ANS-58.2-1988 standard is an equilibrium model, NUREG/CR-2913 includes dynamic jet effects
  - For a given target-to-nozzle distance, the ANSI model predicts a lower pressure than the NUREG model does
  - Thus, the target at the predicted ZOI is actually subjected to higher pressures/loads during any given test than was predicted by the ANSI model

Conclusion

- <u>Use of the ANSI/ANS-58.2-1988 subcooled jet expansion model is therefore a convenient way to communicate test results in a conservative manner</u>

# ISSUE #4 (cont.)

*4A Describe the procedure used to calculate isobar volumes used in determining equivalent spherical ZOI radii using the ANSI/ANS-58.2-1988 standard.*

Proposed Response to Issue 4A:

- Guidance is provided in Appendices B, C, and D of ANSI/ANS Standard 58.2-1988
  - Mass flux determined using the Henry-Fauske model, as recommended in Appendix B, for subcooled water blowdown through nozzles, based on homogeneous non-equilibrium flow
  - The initial and steady-state thrust forces were calculated based on the guidance in Appendix B and the postulated reservoir conditions
  - Jet outer boundary and regions mapped using the guidance in Appendix C, Section 1.1 for a circumferential break with full separation.
- Inputs to equations of Appendix C for the thermodynamic conditions at the asymptotic plane were calculated using ASME Steam Tables routines at supply tank conditions
  - Saturated liquid and vapor specific volumes (densities) at break plane (jet nozzle)
  - Stagnation enthalpy, saturated liquid enthalpy and heat of vaporization at the break plane
  - Stagnation pressure at the break plane
  - Supply tank pressure and temperatures, represented by 2000 psia and 530°F

# ISSUE #4 (cont.)

Proposed Response to Issue 4A (cont.):

- A spectrum of isobars was mapped using the guidance in Appendix D
  - The volume encompassed by an isobar was calculated using a trapezoidal approximation to the integral
  - A sufficiently fine resolution of the trapezoidal approximation was used to ensure that the results obtained were not sensitive to the resolution of the trapezoidal approximation used
    - This was confirmed via sensitivities that assured no change in results
- Since the volume result only represents the volume encompassed by the isobars in a single free jet, the encompassed volume was doubled to represent the double-ended guillotine break (DEGB)
- The radius of an equivalent sphere was calculated to encompass the same volume as twice the volume of a feely expanding jet calculated from the previous step
- The radius calculated in the step above is the spherically equivalent ZOI at a given stagnation pressure

## ISSUE #4 (cont.)

*4B Explain why the WCAP-16710 analysis was based on 530°F rather than the initial test temperature of 550°F. Include an explanation of how the initial temperature differences between rupture disk water and tank water were incorporated into the jet sub cooling analysis.*

<u>Proposed Response to Issue 4B:</u>

- For a given supply tank pressure, the larger the subcooling, the larger the distance from the jet nozzle, L, that the a given isobar intersects the jet centerline
  - For example, for a given nozzle, a stagnation pressure of 24 psi and a supply pressure of 2250 psi
    - Fluid temperature at jet exit = 610°F, L = 49.9 inches
    - Fluid temperature at jet exit = 540°F, L = 52.0 inches
  - Basing the WCAP-16710-P jet expansion calculations on 530°F rather than the initial test temperature of 550°F maximized the ZOI at a given stagnation pressure

# ISSUE #4 (cont.)

- However, for a given supply tank pressure, the observed variation in initial temperature differences between the rupture disk water and the supply tank water have negligible effect on the ZOI
  - For example, for a given nozzle size and a 2000 psi tank pressure, the distance, L, of the target from the jet nozzle is calculated using the ANSI/ANS-58-2-1988 Standard as:

**Table 1 Distance of Targets from Jet Nozzle as a Function of Temperature for Various Spherical Equivalent Zones of Influence (ZOI); Pressure = 2000 psia**

| Fluid Temperature at Nozzle | ZOI | | | | |
|---|---|---|---|---|---|
| | 5D | 6D | 8D | 10D | 13D |
| 506°F | 44.76” | 62.16” | 91.68” | 125.16” | 175.22” |
| 530°F | 44.40” | 61.32” | 90.84” | 124.80” | 174.00” |
| 550°F | 44.04" | 60.48” | 90.00” | 124.44” | 172.78” |

## ISSUE #4 (cont.)

*4C Explain assumptions on how mass flow rate was determined considering potential for two-phase flow and temperature dependent water and vapor densities.*

Proposed Response to Issue 4C:

- The mass flux from the postulated break was determined using the Henry-Fauske model, as recommended in Appendix B of ANSI/ANS Standard 58.2-1988, for subcooled water blowdown through nozzles, based on a homogeneous non-equilibrium flow process.
- No irreversible losses were considered
- A circular break geometry was used for the calculations
  - This break geometry is representative of both a postulated DEGB of primary piping as well as the DEGB of piping attached to the RCS
  - The complete breaking of a pipe, either primary piping or piping attached to the RCS, provides for a maximum debris generation volume as there are two ends of the break to release fluid

## ISSUE #4 (cont.)

Proposed Response to Issue 4C (continued):

- Fluid reservoir conditions of 2000 psia and 530°F were used for the calculations
- These conditions are intended to represent a bounding minimum PWR cold leg at full power.
  - As shown in the response to 4B, provide for a conservatively large ZOI that bounds hot-leg conditions at power operations.
  - Also as shown in the response to 4B, variations in the test temperatures about the 530°F have negligible effect on the distance of the target from the jet and, consequently, on the ZOI.

## ISSUE #4 (cont.)

Proposed Response to Issue 4C (continued):

- Ambient pressure of 14.7 psia was used for the mass flux calculation
  - This is conservative - maximizes flow as no credit taken for containment backpressure
- Two-phase flow in test loop prior to jet nozzle not possible
  - The subcooling of the working fluid is large (>100°F)
  - There was only a small pressure drop (< 50 psid) as fluid flowed from tank to nozzle
  - A pressure drop of >1000 psi is needed for flashing to occur in the loop
  - Therefore, water remained in a single-phase liquid state until reaching the jet nozzle
  - This allowed standard single-phase flow rate calculations to be used

## ISSUE #4 (cont.)

Proposed Response to Issue 4C (continued):

- Temperature and pressure influence on water density is accounted for in the mass flow rate calculation
  - The liquid density may vary by as much as 7.0% over the range of test conditions
    - 49.32 $lb_M/ft^3$ at 506°F and 2000 psia
    - 46.09 $lb_M/ft^3$ at 550°F and 1200 psia
  - The calculation of mass flow rate used thermodynamic properties at conditions local to the flow venturi

**ISSUE #4 (cont.)**

*Question #1: How are distances used in the tests related to the plant and plant conditions.*

Proposed Response to Question #1

- The method used to relate the distance of the target tested to the plant is described in Section 11.2 in WCAP-16710-P
- This description starts on page 11-1 and extends to page 11-3

# ISSUE #4 (cont.)

*Question #2: The distance of the test article from the jet nozzle as calculated using a fluid pressure of 2000 psia. The initial test fluid pressure may have been below 2000 psia. What is the influence of pressure on the distance of the target for a given Zone of Influence (ZOI)?*

Proposed Response to Question #2:

- The effect of lower pressure on distance of the target from the nozzle for a given ZOI is shown in the following table
  - For all cases that the initial test fluid pressure is less than 2000 psia, the lower pressure will result in a smaller mass flux, resulting in a slightly lower stagnation pressure that the 2000 psia case
  - For the 5D and 6D equivalent spherical ZOI cases, the variation in fluid pressure has negligible impact on the distance of the target from the jet nozzle; 0.24” and 0.72”, respectively
  - For the 8D, 10D and 13D cases, the variation in distance from the jet nozzle ranged from 1.56” (or a change of about 1.6%) at an 8D equivalent spherical ZOI to 3.72” (or a change of about 2.1%) at a 13D equivalent spherical ZOI.
- The last row demonstrates that the distances calculated at 2000 psia and 530°F provide for the target to be located closer to the nozzle than if a cooler initial temperature and slightly lower pressure were considered

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*NRC Public Meeting – December 16, 2009*

## ISSUE #4 (cont.)

**Table 2 Distance of Targets from Jet Nozzle as a Function of Pressure for Various Spherical Equivalent Zones of Influence (ZOI); Temperature = 505˚F**

| **Nozzle Pressure (psia)** | **ZOI** | | | | |
|---|---|---|---|---|---|
| | **5D** | **6D** | **8D** | **10D** | **13D** |
| 2000 | 44.76” | 62.28” | 97.20” | 127.92” | 180.36” |
| 1990 | 44.76” | 62.16” | 96.96” | 127.44” | 179.64” |
| 1980 | 44.64” | 62.04” | 96.60” | 126.96” | 178.92” |
| 1970 | 44.64” | 61.08 | 96.36” | 126.48” | 178.20” |
| 1960 | 44.52” | 61.68 | 96.00” | 126.00” | 177.48” |
| 1950 | 44.52” | 61.56 | 95.64” | 125.52” | 176.64” |
| Distance at 2000 psia and 530˚F | 44.40” | 61.32 | 90.84” | 124.80” | 174.00 |

## ISSUE #4 (cont.)

*Question #3: The pressure of the tank decays as the test progresses. What is the influence of this pressure decay on the jet impingement test results?*

Proposed Response to Question #3:

- Two pressure histories are give on the following slide
  - A postulated LOCA for Westinghouse 4-Loop PWR in a large dry (not an ice condenser) containment
  - A representative pressure history in the test tank during a test (ZOI = 5D test)
- Comparing the two pressure histories, the supply tank pressure of the test did not decay as was predicted for the RCS
- The elevated pressure in the supply tank provides for the test article to be subjected to a larger mass flux than would be the case for the postulated LOCA
- It follows that the test provides for bounding jet loading conditions compared to the plant

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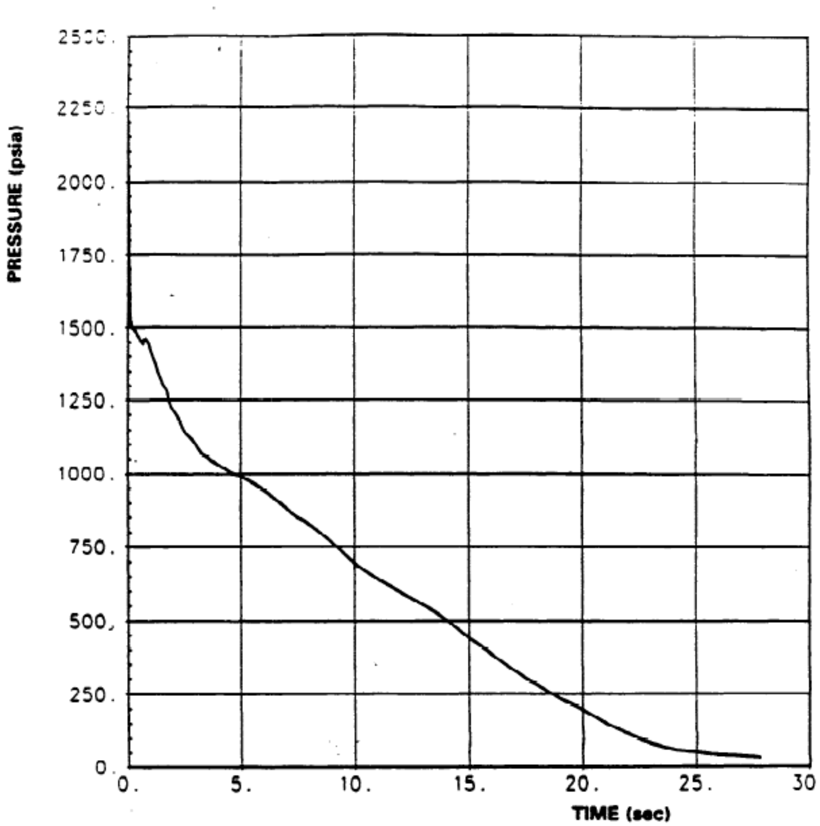
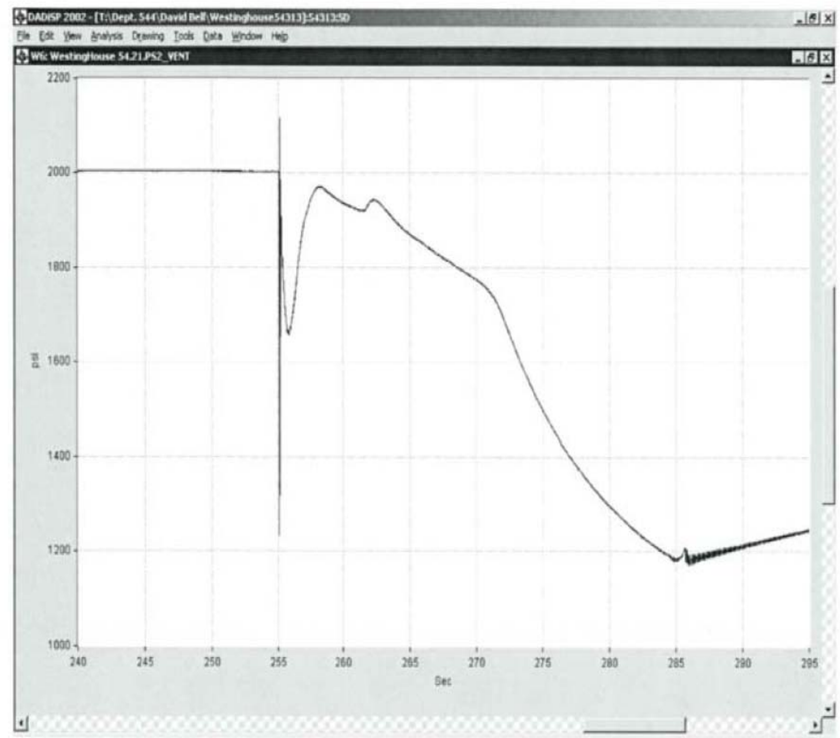
## ISSUE #4 (cont.)




Blowdown Pressure History for a Westinghouse 4-Loop PWR in a Large Dry Containment




Representative Test Tank Pressure History; ZOI = 5D Test

**ISSUE #4 (cont.)**

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  - A postulated LOCA for Westinghouse 4-Loop PWR in a large dry (not an ice condenser) containment
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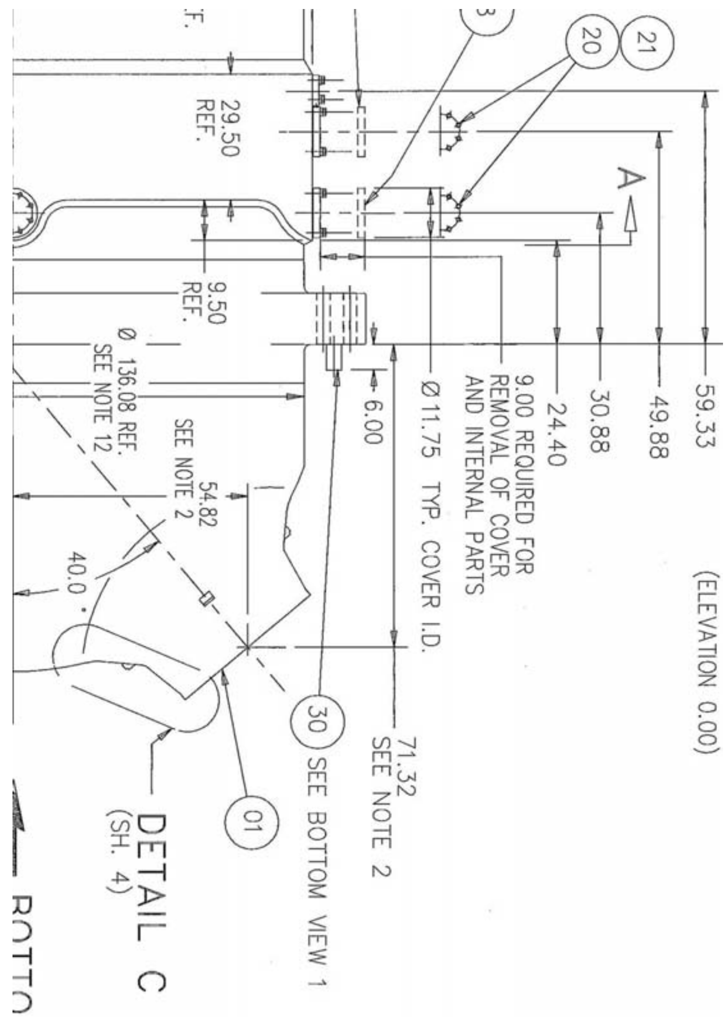
# ISSUE #4 (cont.)

**TESTING OF COMPONENT INSULATION**

Westinghouse steam generator cut-away drawing

- Test article test configuration
  - Impingement angle on bottom head will be 40° off centerline but perpendicular to channel head
  - Angle assumes an off-set of the attached pipe from the steam generator nozzle that remains perpendicular to the channel head
- The distance separating jet nozzle from the target evaluated to be approximately 28 inches
- This configuration also is applicable to the reactor coolant pump
  - In worst case scenario, jet will also be perpendicular to the bowl of the pump
- Angle of impingement on side of the steam generator will also be 40°
- The distance separating the jet nozzle from the target will be scaled based on chocked flow



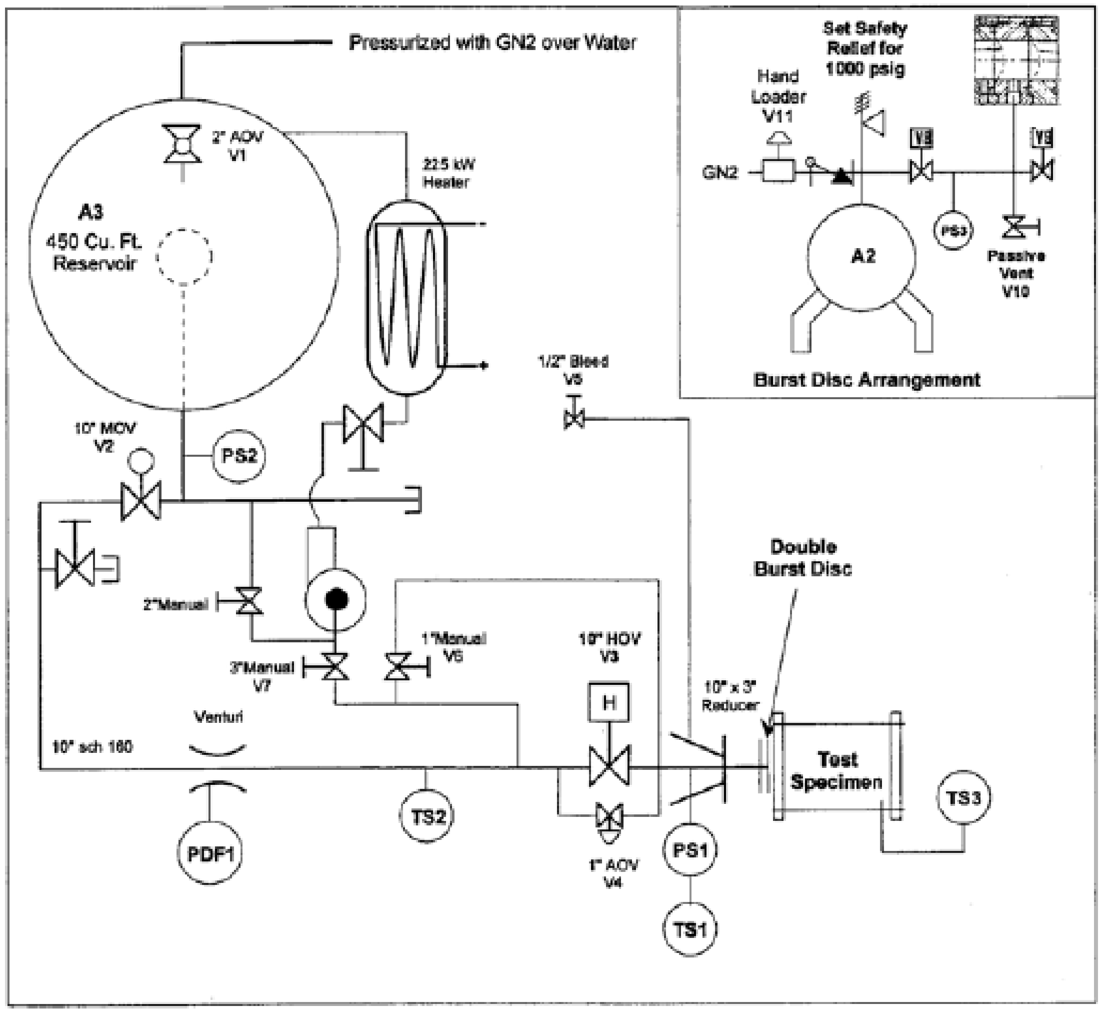
# ISSUE #5

5. *Provide a detailed description of the test apparatus specifically including the piping from the pressurized test tank to the exit nozzle including the rupture disk system.*

Proposed Response:

- The tests were performed at the Hot Water Blowdown Test Facility at Wyle Laboratories (Huntsville, Alabama)
- A schematic and brief description of the test loop is given in Appendix A of WCAP-16710-P and is repeated herein
- In preparing a detailed description of the test facility for NRC
  - It was determined that there was a choke point upstream of the 3.54” nozzle
  - The minimum dimension of the reducer feeding into the burst disk assembly is 2.615”
  - This dimension controls the choked flow rate
- Westinghouse has entered this issue into their Potential Issue (PI) process
- The process is being followed to address this issue

# ISSUE #5 (cont.)


Pressurized with GN2 over Water
2" AOV
V1
A3
450 Cu. Ft.
Reservoir
22.5 kW
Heater
10" MOV
V2
PS2
2"Manual
3"Manual
V7
1"Manual
V6
Venturi
10" sch 160
PDF1
TS2
10" HOV
V3
H
1" AOV
V4
1/2" Bleed
V5
10" x 3"
Reducer
Double
Burst Disc
Test
Specimen
PS1
TS1
TS3
Set Safety
Relief for
1000 psig
Hand
Loader
V11
GN2
V8
V9
PS3
A2
Passive
Vent
V10
Burst Disc Arrangement

## ISSUE #5 (cont.)

- The nozzle inlet pressure is regulated by three remote-controlled dome loaders that inject gaseous nitrogen into the top of the pressure vessel. Any overshoot in the pressure is attenuated by a 2-inch control valve on top of the pressure vessel, which is proportionally-controlled with a programmable logic controller (PLC) that is located in the test facilitiy's control room.

- Test loop instrumentation is described in the table below:

| Channel | Description | Range | Accuracy |
|---|---|---|---|
| PS1 | Status pressure upstream of nozzle exit | 0-5000 psig | +/- 0.3% F.S. |
| PS2 | Tank (pressure vessel) pressure | 0-3000 psig | +/- 0.3% F.S. |
| TS1 | Fluid temperature upstream of nozzle exit | 32-600° F | +/- 4° F |
| TS2 | Fluid temperature near venturi | 32-600° F | +/- 4° F |
| TS3 | Ambient temperature near test specimens | 32-600° F | +/- 4° F |
| PDF1 | Venturi differential pressure for flow measurement | 25 psid | +/- 0.5% F.S. |

# ISSUE #6

6. *Staff does not accept PWROG position that damage observed during testing is not likely in the plant.*

Note: This issue deals with damage noted in the WCAP-16710-P tests of jacketed and clasped NUKON insulation.

<u>Proposed Response:</u>

- For tests where flat end washers were used, this arrangement is not prototypical of the as-installed condition in the plant. When installed, adjacent lengths of jacketing are assembled with a 1" overlap. Hence, damage attributable to the end washers will not occur in the as-installed condition.
- For tests without flat end washers, the test articles were open at the ends. This is not prototypical of the as-installed condition in the plant. Hence, damage attributable to the test fixture will not occur in the as-installed condition.
- The tests for which jet forces removed the jacketing (and for which there was damage attributed to sharp edges of the jackets) were for 5D and 6D ZOIs. WCAP-16710-P subsequently recommended a minimum ZOI of 7D. Hence, for licensees that adopted this recommendation, no consideration of this type of damage need be made.