ECCS Suction Strainers ZOI Adjustment for Air Jet Testing Issue No. 7

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NRC / BWROG Resolution Plans
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Topics

Issue Overview & History

BWR/PWR Considerations for Air Jet Testing

Resolution Strategy

Next Steps and Milestones

Conclusions

ZOI Adjustment for Air Jet Testing Issue Overview

Debris generation Zones of Influence (ZOI) are based on debris generation tests conducted with air as a test fluid

There is concern that steam may be more destructive than air, requiring an increase in the size of the ZOIs

ZOI Adjustment for Air Jet Testing
Air Jet Testing Issue History

1996: BWROG submitted Utility Resolution Guidance (URG)
- air jet testing results,
- NPARC CFD model of air and steam jet pressures,
- comparison to Marviken test results, and
- justification that air jet testing is conservative for BWRs

August 1998: NRC SER on BWROG URG accepts the use of air jet testing, for BWR conditions, to simulate steam

December 2004: NRC SER on NEI 04-07 questions use of air jet test results for PWR subcooled liquid breaks and requests 40% reduction in destruction pressures

November 2007: NRC Staff met with BWROG and indicated applicability of air jet testing needs to be reviewed

ZOI Adjustment for Air Jet Testing PWR vs BWR Differences

PWR vs BWR differences related to jet damage:

- BWR main steam lines contain essentially dry steam, which constitute the most limiting breaks
- PWR hot leg and BWR recirc line contain liquids with small amount of subcooling
- PWR cold leg contains liquid with significant subcooling, which accounts for 40% reduction in destruction pressure

ZOI Adjustment for Air Jet Testing Debris Generation Methodology

Insulation is assumed to fail when the jet stagnation pressure is equal to the debris–specific damage pressure value

For BWR's, air test results defined the damage pressure for specific debris

- Calculated stagnation pressure at the jet centerline to characterize the point of failure
- The use of stagnation pressure as the damage pressure accounts for differences among media
- NPARC jet model (using air) provides stagnation pressure in tests

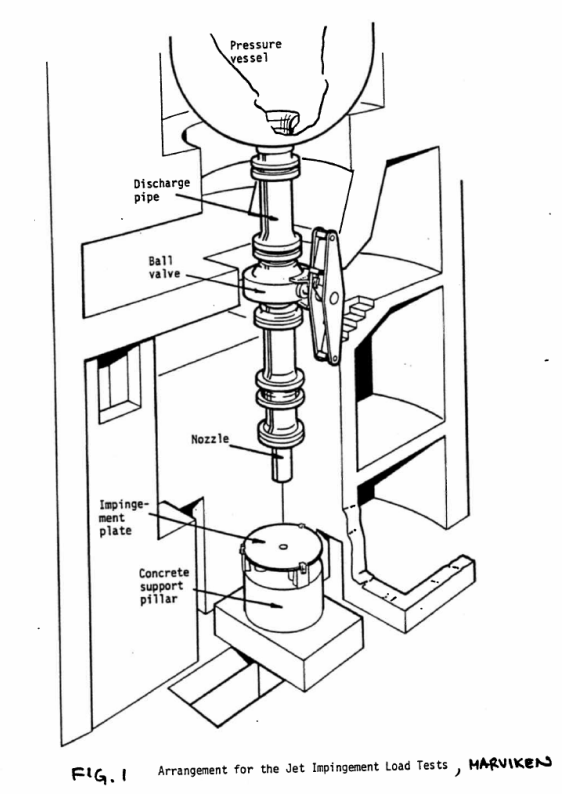
NPARC model used to calculate break jet characteristics (using steam) to define the ZOIs

- Determines jet physical properties (diameter, velocity, and pressure) at locations removed from break
- Demonstrated that air jets produce higher stagnation pressures at same distances than steam jets

ZOI Adjustment for Air Jet Testing Debris Generation Methodology (cont.)

- Damage pressures from air jet testing are based on stagnation pressure at debris location
- NPARC steam jet model is validated for single phase steam jets
  - Pressures predicted correctly
  - Model used to predict pressures in the jets for determination of where the stagnation pressures are equal to the damage pressure (i.e. defines the ZOI)
- Stagnation pressure in a single phase steam jet is always less than the stagnation pressure in a two-phase (steam/water mixture) jet

Marviken Jet Impact Test Arrangement[1]



- Large Scale Blowdown Experiment conducted at Swedish power palnt
- Considered representative of nuclear plant conditions
- Measured stagnation pressures on a flat plate
- Setup was such that first subcooled water, then saturated steam/water mixture, and finally dry steam impacted the target plate

[1] Marviken Full-Scale Jet Impingement Tests, Marviken Power Station, 1980/1981

Marviken Jet Impact Data – Tests 7, 8 & 10

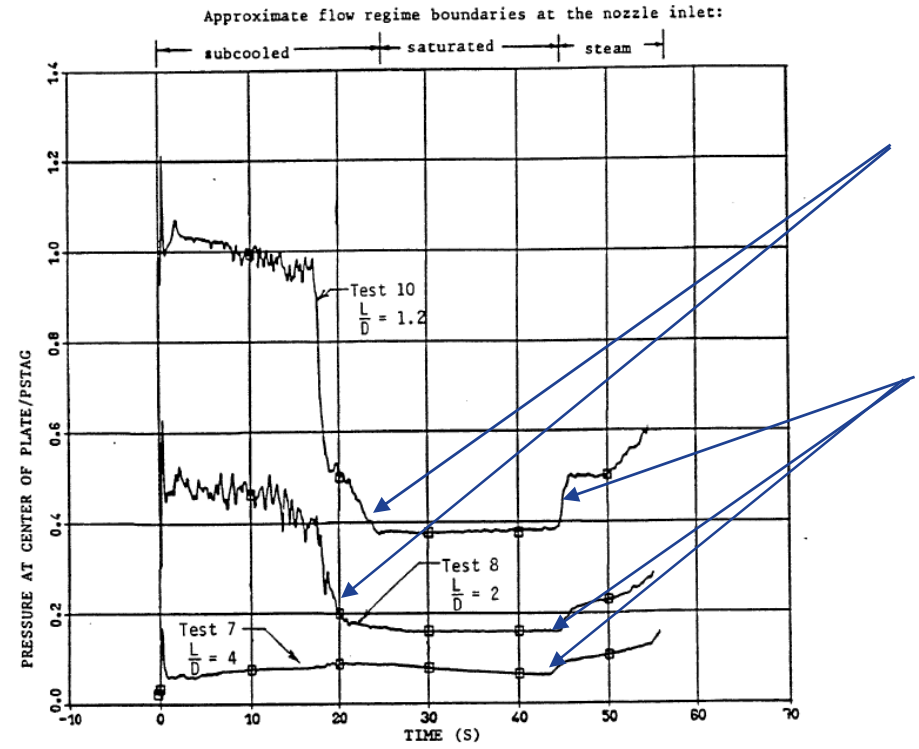


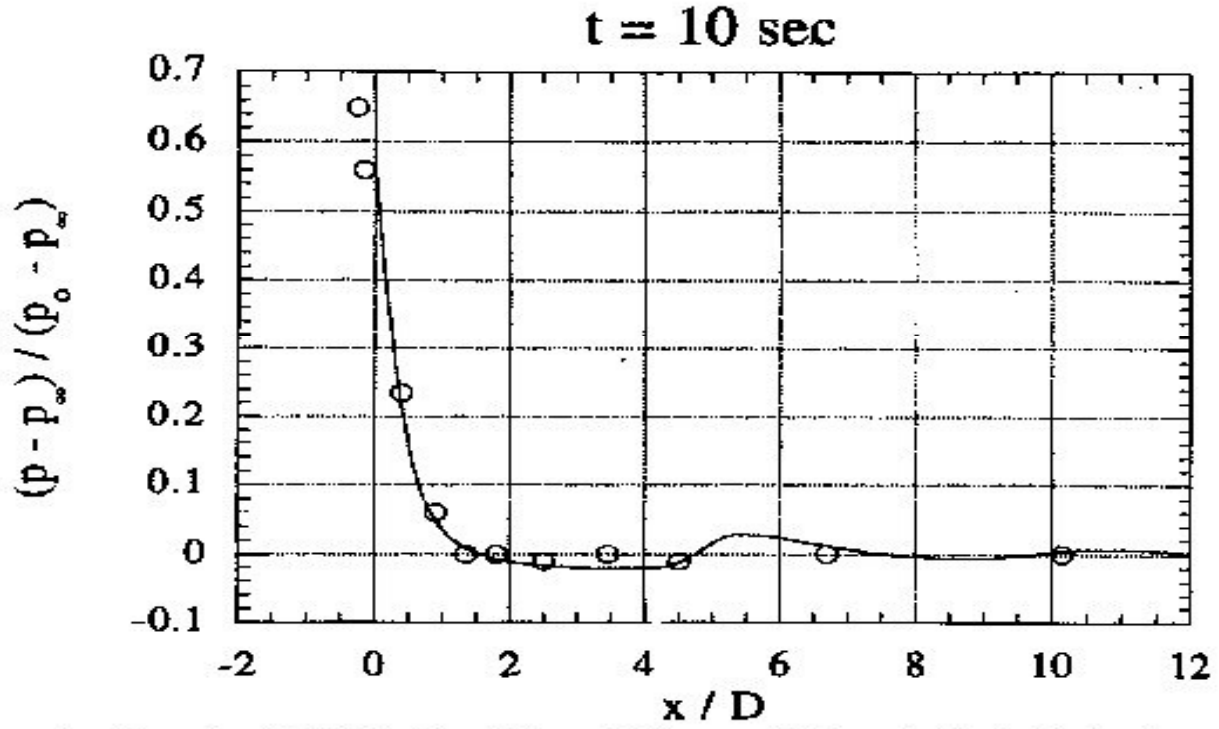
FIG. 2 Stagnation Pressure at Impingement Plate Center for Tests 7, 8 and 10

Transition from subcooled water to steam/water mixture

Transition from steam/water Mixture to steam only

Test 7 has sufficient distance from the nozzle to the impact target that local pressure is reduced to the point where the water jet has flashed to 2-phase (Typical of a BWR)

NPARC Prediction of Marviken Jet Blow-down Pressures Agree with Test Results



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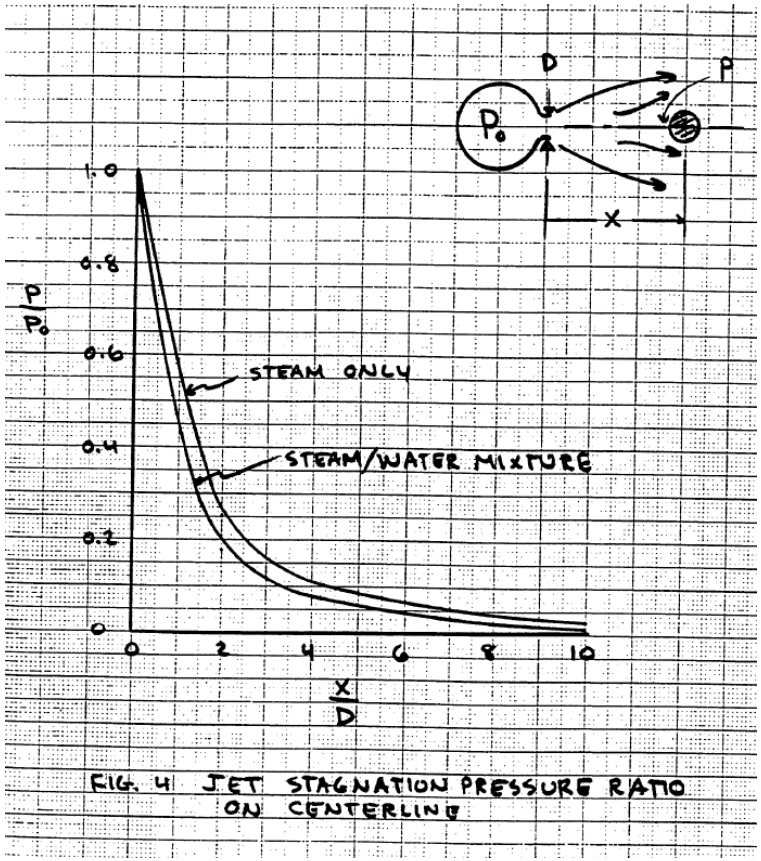
Revision 3

Figure 6. Comparison of NPARC code predictions of static pressure (solid curve) with the Marviken data (circles) from Ref. 19. The coordinate x is along the centerline of the expanding jet. The blowdown time is 10 seconds.

NPARC model successfully predicts pressure in a single phase steam jet

Comparison of Steam Only and Steam / Water Mixture Stagnation Pressures



Graph developed from Marviken data by Fred Moody and submitted to NRC in 1996 report[2] confirms that BWR steam/water mixtures always have lower stagnation pressures than steam-only jets

[2] "Total Pressure Topography and Zone of Destruction for Steam and Mixture Discharge from Ruptured Pipes," F.J. Moody, 1996

What Do Real BWR Condition Jets Do?

- BWR main steam line breaks (saturated vapor) result in saturated or superheated jets
  - Conditions dependent on expansion pressure

- BWR recirculation line breaks (slightly subcooled) result in 2-phase jets
  - No such thing as a “liquid jet” in BWRs

What Do Real BWR Condition Jets Do? Isenthalpic expansion results

- Expanding saturated steam jet from 1000 psia to:
  - 200 psia ⇒ jet remains saturated (>99% quality)
  - 50 psia ⇒ jet superheats (~330 F)

Steam line break jets remain single phase jets

- Expanding saturated liquid jet from1000 psia to:
  - 200 psia ⇒ jet flashes to 2-phase (~20% quality)
  - 50 psia ⇒ jet flashes to 2-phase (~30% quality)

Saturated liquid break jets become 2-phase jets
Change to 20 F subcooled liquid reduces jet quality by ~3% (absolute)

ZOI Adjustment for Air Jet Testing Single/Two-Phase Results

- Grobe April 2008 letter: "European testing has clearly demonstrated that saturated water jets are less destructive than steam jets"
  - "Saturated water jets" and slightly subcooled jets (typical of BWR) expand to 2-phase saturated water/steam jets
- Local stagnation pressure of a steam/water mixture is always less than the stagnation pressure of a steam-only discharge
- URG NPARC evaluation that air jet tests are conservative relative to steam jets is unaffected.

Resolution Strategy - Summary

1. Steam breaks – already conservative by URG
2. Liquid breaks – URG already includes a measure of conservatism, which is even more conservative than steam breaks
3. Subcooled liquid breaks – large amounts of subcooling are not relevant for BWRs

ZOI Adjustment for Air Jet Testing Recommended Resolution Approach

BWROG position is that the 40% reduction in air jet test destructive pressures applied to PWR subcooled liquid jets is not appropriate for BWR conditions

Action Plan:

- Document basis for acceptability of using air jet test results (without 40% reduction factor) for BWRs
- Submit basis for acceptability to NRC for review
- If necessary, the BWROG will obtain independent 3rd party review of the applicability of air jet test results to BWRs

ZOI Adjustment for Air Jet Testing
Key Relationships to Other Issues

None Identified

ZOI Adjustment for Air Jet Testing Proposed Milestones

Milestone	Date
Confirm resolution path with NRC	4Q 2010
Issue report to NRC	2Q 2011

ZOI Adjustment for Air Jet Testing Conclusions

Technical basis for conservatism of air jet testing to determine BWR damage pressures provided in URG and confirmed adequate by NRC in 1998

- Air jets have higher stagnation pressures than BWR steam jets
- Characterization of damage pressure by stagnation pressure makes the results fluid medium independent
- BWR steam jets have higher stagnation pressures than BWR saturated water/steam jet mixtures
- BWR (slightly subcooled water) jets have nearly identical properties as saturated water/steam jet mixtures

Nothing in the GSI-191 PWR evaluations challenges this position

40% reduction in assumed damage pressures for PWR subcooled liquid jets are not applicable to BWRs