Jet Impingement Evaluation Methodology for APR1400

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Introduction

Objectives of the Meeting

- Explain the plan of the KHNP analysis methodology to satisfy the NRC key issues from DSRS Appendix A.

- Discuss the schedule for NRC meeting and report submission.

Background

- SRP 3.6.2 Rev. 2 issued March 2007 identified concerns with the modeling of jet impingement forces in ANSI 58.2-1998 which had been accepted by NRC.
  - The ANSI/ANS 58.2 standard has been accepted by the NRC. However, based on recent comments from the Advisory Committee on Reactor Safeguards (ACRS) (V. Ransom and G. Wallis), it appears that some assumptions related to jet expansion modeling in the ANSI/ANS 58.2 standard may lead to nonconservative assessments of the jet impingement loads of postulated pipe breaks on neighboring SSCs. The NRC staff is currently assessing the technical adequacy of the information pertaining to dynamic analyses models for jet thrust force and jet impingement load that are included in this SRP Section and ANSI/ANS 58.2. Pending completion of this effort, the NRC staff will review analyses of the jet impingement forces on a case by case basis. These analyses should show that jet impingement loadings on nearby safety related SSCs will not impair or preclude their essential functions.

Background

- NRC Interaction
  - Acceptance Review Comment Clarification Meeting (2014. 02)
    - As noted in SRP 3.6.2 Section III.3, following interactions with the ACRS on the jet models described in that Standard, the staff determined that there were potential non-conservatisms in these models. Pending completion of general guidance on this topic, the staff is reviewing analyses of the jet impingement forces on a case-by-case basis. Therefore, the DCD should address the potential non-conservatism of the Standard's model with respect to blast wave effect, jet plume expansion and zone of influence, pressure distribution within the jet plume and jet dynamic loading including potential feedback amplification and resonance effects.
  - Conference Call (2015. 03)
    - NRC developed design-specific review standard, Appendix A during the mPower review and that draft guidance is available and should be used for APR1400 as a starting point for the information needed. If a bounding analysis is presented for APR1400, KHNP must demonstrate and justify that the applicable issues in Appendix A are addressed. If an issue is thought not to be applicable to the APR1400 design, the basis must be described.

Background

- NRC developed Design-Specific Review Standard(DSRS) during the mPower review. Key Issues from DSRS Appendix A are as follows:

  - Jet Plume Expansion and Zone of Influence
  - Distribution of Pressure within the Jet Plume
  - Blast Wave Effect
  - Feedback Amplification/Resonance Effect

Overall Evaluation Plan

- Overall Methodology to solve key issues
  - Use the CFD and analytical model based on open literatures.
  - 2D, axi-symmetric CFD model for unconfined domain
    - Jet Plume Expansion and Zone of Influence
    - Distribution of Pressure within the Jet Plume
    - **Blast wave effect without reflection**
  - **Semi-analytical approach for unconfined domain**
    - **Blast wave effect without reflection**
  - 2D, planar CFD model for the confined domain
    - Blast Wave Effect including reflection
  - **Empirical** model using multiplication factor based on related literature reported to represent maximum effects
    - Feedback Amplification/Resonance Effect

* Detailed analysis methodology will be presented in Methodology Section.

Methodology

mPower DSRS Appendix A Requirements

– 1. Blast Wave - *In the event of a high pressure pipe rupture, the first significant fluid load on surrounding SSCs would be induced by a blast wave. A spherically expanding blast wave is reasonably approximated to be a short duration transient and analyzed independently of any subsequent jet formation. However, the expansion of blast waves in an enclosed space is not purely spherical, and reflections and amplifications may need to also be accounted for. Blast waves are not considered in the ANSI/ANS 58.2 Standard for evaluating the dynamic effects associated with the postulated pipe rupture.*

– KHNP Evaluation Methodology for Blast Wave

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mPower DSRS Appendix A Requirements

– KHNP Evaluation Methodology for Blast Wave (Cont’d)

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mPower DSRS Appendix A Requirements

– KHNP Evaluation Methodology for Blast Wave (Cont'd)

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mPower DSRS Appendix A Requirements

– *2. Jet Plume Expansion and Zone of Influence*

In the characterization of supersonic jets given by the ANSI/ANS 58.2 Standard, some physically incorrect assumptions underlie the approximating methodology. The model of the supersonic jet itself is given in Figures C-1 and C-2 of the ANSI/ANS 58.2 Standard. The standard assumes that a jet issuing from a high pressure pipe break will always spread with a fixed 45 degree angle up to an asymptotic plane and subsequently spread at a constant 10 degree angle. The characteristics of the jet, however, are not universal. Initial jet spreading rates are highly dependent on the ratio of the total conditions of the source flow to the ambient conditions. Subsequent spreading rates depend, at a given axial position, on the ratio of the static pressure in the outermost jet flow region to the ambient static pressure.

mPower DSRS Appendix A Requirements

– *2. Jet Plume Expansion and Zone of Influence (continued):*

In the ANSI/ANS 58.2 Standard, the asymptotic plane is described as the point at which the jet begins to interact with the surrounding environment. This has been interpreted to mean that the jet is subsonic downstream of the asymptotic plane. Experts have Proposed - For Interim Use and Comment 3.6.2-15 Revision 0 - May 2013 demonstrated (References 7 and 8) that, supersonic or not, the jet is highly dependent on the conditions in the surrounding medium and, at a given distance from the issuing break, will spread or contract at a rate depending on the local jet conditions relative to the surrounding fluid pressure.

mPower DSRS Appendix A Requirements

– KHNP Evaluation methodology for Jet Plume Expansion and Zone of Influence

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mPower DSRS Appendix A Requirements

– KHNP Evaluation methodology for Jet Plume Expansion and Zone of Influence (Cont'd)

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mPower DSRS Appendix A Requirements

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mPower DSRS Appendix A Requirements

– *3. Distribution of Pressure within the Jet Plume - The ANSI/ANS 58.2 Standard's formulas for the spatial distribution of pressure through a jet cross-section are incorrect for certain locations. The ANSI/ANS 58.2 Standard's assumes that the pressure within a jet cross section is maximum at the jet centerline; far from the break, however, the pressure variation is quite different, often peaking near the outer edges of the jet. Applying the ANSI/ANS 58.2 Standard's formulas could lead to non-conservative pressures away from the jet centerline.*

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mPower DSRS Appendix A Requirements

– *4. Jet Dynamic Loading including Potential Feedback Amplification and Resonance Effects - Furthermore, unsteadiness in free jets, especially supersonic jets, tends to propagate in the shear layer and induce time-varying oscillatory loads on obstacles in the flow path. Pressures and densities vary non-monotonically with distance along the axis of a typical supersonic jet, feeding and interacting with shear layer unsteadiness. In addition, for a typical supersonic jet, interaction with obstructions will lead to backward-propagating transient shock and expansion waves that will cause further unsteadiness in downstream shear layers. In some cases, synchronization of the transient waves with the shear layer vortices emanating from the jet break can lead to significant amplification of the jet pressures and forces (a form of resonance) that is not considered in the ANSI/ANS 58.2 standard. Should the dynamic response of the neighboring structure also synchronize with the jet loading time scales, further amplification of the loading can occur, including that at the source of the jet.*

mPower DSRS Appendix A Requirements

– *4. Jet Dynamic Loading including Potential Feedback Amplification and Resonance Effects (Continued): Some general observations by past investigators are that strong discrete frequency loads are observed when the impingement surface is within 10 diameters of the jet opening, and that when resonance within the jet occurs, significant amplification of impingement loads can result.*

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mPower DSRS Appendix A Requirements

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Verification and Validation Approach

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Preliminary CFD Analysis Details

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Schedule

Proposed Schedule

	4	5	6	7	8	9	10
NRC Public Meeting	▼						
Fluid Mechanics Analysis with support of CFD calculation			▼				
Interaction with NRC			▼				
Documentation (Calc. & Report)					▼		
Final Report Submission						▼	

- Analysis including dynamic effects of jet impingement will be completed about the middle of June.
- To demonstrate results after analysis completion, technical meeting with NRC is proposed around the end of June.
- Final report will be submitted by September 30.