Use of QRA as part of Hydrogen in Piping and Ancillary Vessels (HPAV) Design Assessment

CRESP Workshop

Rockville, MD

September 21-22, 2010

Robert A. Bari

BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

Office of Science
U.S. DEPARTMENT OF ENERGY

WTP QRA Review Team

- R. Bari, Brookhaven National Laboratory
- J. Lehner, Brookhaven National Laboratory
- T. Ginsberg, Brookhaven National Laboratory
- R. Nelson, Department of Energy (EM)

- J. O'Brien, Department of Energy – Sponsor/Direction

  - Short term review
  - Limited scope and depth
  - Report available: http://www.hss.doe.gov/deprep/2010/AttachedFile/TB10U18A_Att.pdf

Objective of Study

- To perform a Peer Review of the **Hanford Waste Treatment Plant** (WTP) December 2009 Draft **Quantitative Risk Assessment** (QRA) of the impact of potential hydrogen combustion events on WTP pipes and vessels.

- The WTP project intends to utilize the results of the QRA to support the design of the piping in the WTP.

Overview of Issue and Potential Consequences

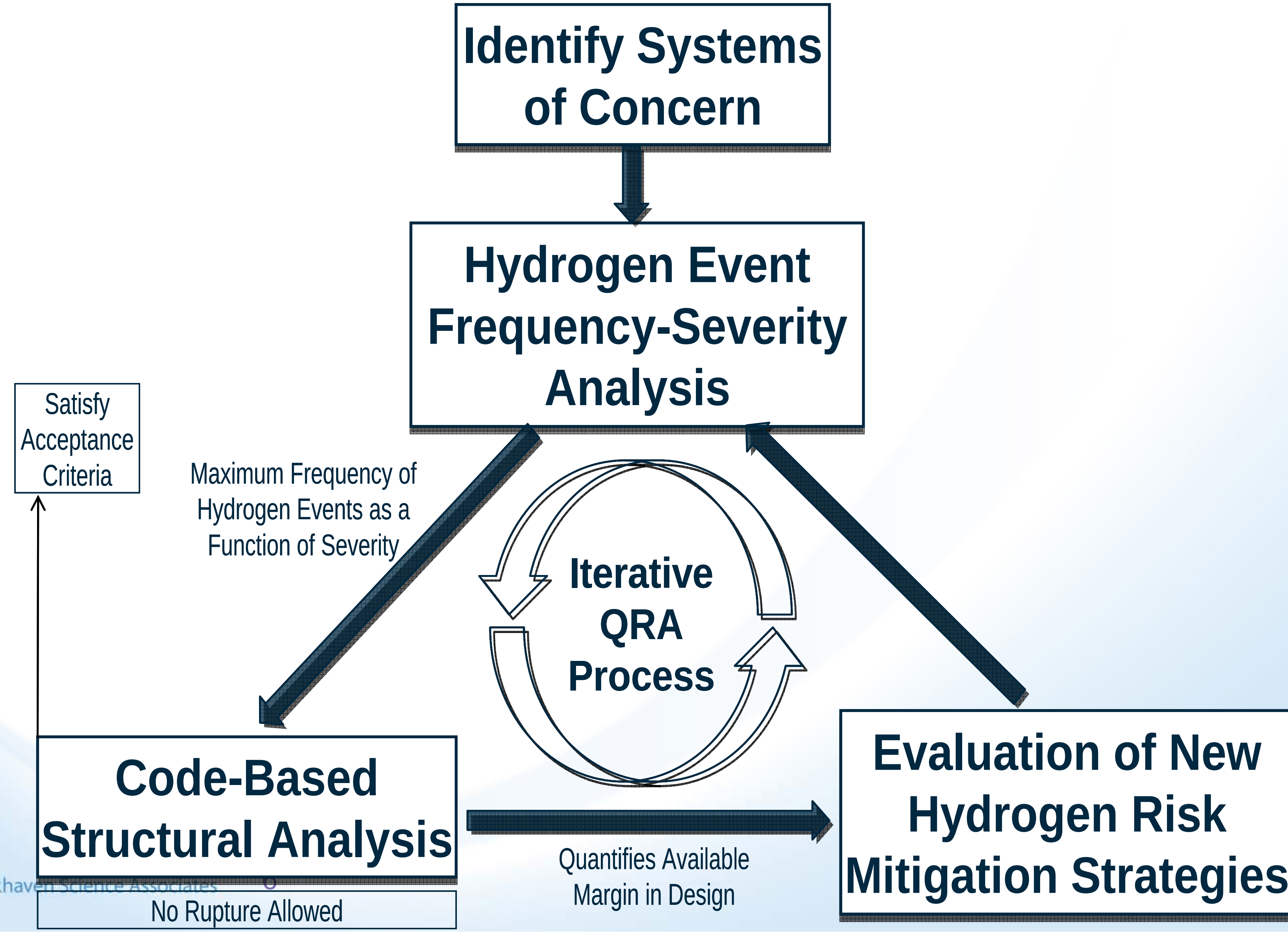
- Potential for hydrogen combustion within WTP piping
- Conventional design code approach would lead to prohibitively expensive design considerations
- Alternative approach to design, based on probabilistic analysis, has been developed.
- Failure to mitigate hydrogen threats would lead to damage of facility.

Why QRA was Used

- To risk-inform the piping design
- To have an alternative to the conventional design process involving conservative criteria which would have lead to an expensive and cumbersome design
- Much uncertainty in combustion phenomena and associated likelihoods
- QRA approach allows for management of these uncertainties and improved decision making

<u>*Note*</u>*: the QRA as presented by WTP is a design tool for use in an assessment. The assessment itself was not reviewed*

Iterative QRA Process



Pros and Cons of Approach

Pro

- Based on realistic estimate of risks
- Gives integrated picture of risks
- More cost-effective than conventional approach
- Providing input to design to prevent failure, unlike the typical use of QRA/PRA to predict the risk of failure.

Con

- Must deal with many uncertainties
- Requires absolute (not relative) risk numbers
- Limited lessons-learned because of lack of information base from previous studies (unlike nuclear power plant studies)

How Result will be Used

- To set design requirements for piping
- Review and concurrence by oversight organizations

Peer Review Process
(all dates are 2010)

- Direction from HS via draft Project Plan for Peer Review and formation of review team: ***January***
- Kick-off meeting with WTP: ***February***
- Conference calls with WTP: ***February - May***
- Preliminary draft of Review Report to DOE: ***March***
- Update of Review Report: ***April***
- Comments of Review Report by WTP: ***April***
- Teleconference with WTP on their comments: ***April/May***
- Final report submitted to DOE: ***May***

Review Criteria

- QRA and available standards
- Appropriateness of the QRA model including the modeling assumptions
- Adequacy of data utilized in the QRA and treatment of uncertainties
- Adequacy of QRA development process to ensure quality

Peer Review Observations

- QRA logic model used conventional risk practices to estimate hydrogen event frequencies: WTP recognized appropriate guidance from existing standards and guides
- QRA model is reasonable and well thought out
- Some assumptions lacked sufficient justification (H distribution and pocketing)
- Uncertainty was not systematically treated
- Limited documentation of QA process

Lessons Learned

- More overview information in kick-off meeting
- Conference calls were effective
- Feedback from DOE (HS, EM) during course of review was helpful
- Time scale for review
- Much information backs up the WTP risk report: should be subject to more detailed review

Backup Slides: Details of the Review

- QRA and available standards
- QRA development process
- QRA data and uncertainties
- Phenomenological models and model assumptions
- Suggestions

QRA and available standards

- For the specific WTP application no DOE standards or guidance currently exist.

- The WTP project appropriately used best practices and lessons learned from several sources as guidance:
  - U.S. Nuclear Regulatory Commission (NRC)
  - Center for Chemical Process Safety (CCPS)
  - National Fire Protection Association (NFPA)
  - ASME/ANS PRA Standard for light water reactors

QRA development process

- The QRA report had a limited discussion of the approach to quality assurance of the product.

- The discussion of the development process appropriately indicated that conventional quality practices from other industries were used, to the extent applicable, to guide the WTP project.
  - "…the WTP project has used the guidance and best practices of other agencies that have formalized the use of QRA through relevant standards………In addition, personnel with experience in use of probabilistic analysis are supporting the development of the HPAV QRA tool to ensure its quality and completeness."

- The QRA report did not discuss what internal protocols were used to assure quality in the development of the model and its results.

QRA data and uncertainties

- The QRA model is constructed as a probabilistic model to reflect the random nature of some of the constituent basic events such as the initiating events and equipment and/or human failures.
  - some parameter uncertainty is addressed with the Monte Carlo sampling.
  - the source of some of the point estimates used (e.g., human failure rates) were appropriately taken from conventional industry sources.
  - the report provides little discussion as to what process was used to decide which parameters would be treated as distributed, and how the distributions were chosen and justified.
- model uncertainty, or compensation for completeness uncertainty, are not explicitly mentioned.

QRA data and uncertainties (2)

- To make the uncertainty analysis more systematic in accordance with good PRA practice the Peer Review Team understands that:
  - A Phenomena Identification and Ranking Table (PIRT) analysis has been performed and is currently being documented.
  - The PIRT analysis will be used to justify the basis for the representation of inputs as distributions or point values in the QRA model going forward.
  - The PIRT analysis will also guide follow-up sensitivity and uncertainty analyses.

QRA phenomenological models and model assumptions

- Phenomenological models reviewed:
  - Hydrogen generation rate
  - Gas mixture ignition probability
  - Hydrogen distribution and pocket formation
  - Hydrogen combustion
- Focus of qualitative review
  - Are models based on mechanistic principles?
  - Are models supported by adequate data base?
  - Is use of probabilistic parameters adequately complete?

Review Findings: Phenomenological Models and Modeling Assumptions

- Hydrogen generation rate
  - Based on extensive Hanford data base
  - Rate equations fitted to selection of data, providing fitting parameters and uncertainties
  - Basis for triangular probability distribution for hydrogen generation rate not reviewed
  - Basic modeling approach is sound
- Gas mixture ignition probability
  - Not reviewed in detail
  - Conservative assumption of unity is reasonable

Review Findings: Phenomenological Models and Modeling Assumptions

- Hydrogen distribution and pocket formation
  - WTP modeling approach based on simulant experimental program using simulant fluids in simplified pipe network geometries
  - Very detailed pipe network segmenting data base used to formulate model
  - Modeling approach not based on standard mechanistic conservation principles for flowing systems (overall gas mixture mass is conserved)
  - Probabilistic model for pocket size should be modified to include model uncertainty
  - Recommend more realistic experiments: real materials and more complex geometries
  - Based on limited review, BNL could not conclude that model is either realistic or conservative

Review Findings: Phenomenological Models and Modeling Assumptions

- Hydrogen combustion
  - Models to predict dynamic response of piping network to combustion events are based on extensive experimental program
  - State-of-the art combustion models for deflagration and detonation mechanisms and pressure loading are used
  - Large uncertainties exist in flame acceleration phenomena and are reflected in large uncertainties in flame runup distance parameters
    - Sensitivity studies needed to assess impact of these uncertainties
  - Additional probabilistic parameters recommended for QRA model
  - Neglecting inert gas is overly conservative. Presence of inert gas should be incorporated in models
  - Basic modeling approach is sound

Suggestions

- Benchmark against more complex experiments
- Perform more structured sensitivity and uncertainty analyses
- Discuss conservatisms relative to non-conservatisms, incompleteness. Which conservatisms are reduced by QRA methodology