Estimating Conditional Failure Probabilities of Observed Piping Degradations

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Presentation Overview

- Pipe Reliability Needs to Support Event and Condition Assessments
  - NRC Significance Determination Process
  - Desired features
- Approach
  - Review of past work / literature
  - Use of OECD/NEA OPDE data project
- Challenges / Limitations
- Next Steps
  - Alternative Approach Options

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NRC Pipe Reliability Needs

- NRC assesses operational events and conditions identified through inspection findings
  - PRA models used to determine significance of event/condition (i.e., calculate the ΔCDF)
  - Piping systems are typically not modeled in PRA
- NRC needs tools/methods to address degraded piping conditions

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Desired Features for Pipe Reliability Method

- Develop a method for estimating conditional failure probabilities of observed degraded piping
  - Support Significance Determination Process (SDP) analyses of observed degradations
  - Provide tool for use by NRC risk analysts
  - Provide results with short turnaround time
  - Employ established, referenced methods to extent possible

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Review of Past Work and Literature

- SKI / SSM – long history of work on passive component failure database
  - Leading to OECD/NEA OPDE Project
- Other areas of related pipe research
  - Use of expert elicitation
    - e.g. NUREG-1829, *Estimating LOCA Frequencies*
  - Probabilistic Fracture Mechanics calculations

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Selected Approach

- Method based on pipe failure data
  - Build upon extensive experience in estimating pipe reliability parameters
  - Make use of data from OPDE project
  - Other recent applications with similar approaches
    - EPRI internal flood frequency estimation method
    - U.S. DOE Risk-Informed Safety Margin (focused on plant aging)

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Method Description

- Characterize the observed pipe degradation
  - Identify System-Material-Environment-Stress combination applicable to pipe condition
- Collect relevant operating experience data
  - Select OPDE data records with similar attributes to the observed condition
- Estimate conditional failure probability
  - Count the number of failure events and number of events that were precursors to failure

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Estimate Conditional Probability

- Prob(F|C)
  - F = piping failure occurs (e.g., large leak, rupture or severance)
  - C = presence of an observed degraded condition

    i.e., system-material-environment-stress condition that may lead to pipe failure (e.g., Carbon Steel SWS piping carrying raw freshwater with corrosion)

Number of Failures	Number of Records Meeting Condition	Prob (F|C)
5	182	3.0E-2

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Challenges / Limitations of Method

- How to define pipe failure?
  - Consider severity of event type
    - Large leaks, rupture, and severance
  - Consider state of system or train
    - System or train disabled
  - Consider impact on plant operation
    - Initiating event occurs, forced plant shutdown
- Failure definitions may not align well with the PRA model failure criteria

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Challenges / Limitations of Method

- Model limitations
  - Simple conditional failure model assumes all pipe degradations are precursors to failures
  - Features that are *not* explicitly modeled: duration of condition, detection, repair
  - A more detailed model may be needed
- Data limitations
  - OPDE provides comprehensive database
  - However, focus on a specific System-Material-Environment-Stress combination limits the number of applicable data records
  - Possible under-reporting of some degradations

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Next Steps

- Can existing challenges / limitations be overcome?
  - To support SDP analyses method requires a high level of scrutiny
- Considering alternative approaches to make use of OPDE data
  - Consider qualitative features of observed conditions
  - Bin conditions into significance levels

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Qualitative Approach

- Focus on qualitative features
- Assign a conditional system/train failure probability based on condition characteristics
- Features to consider:
  - Presence of “bad” material-environment-stress combinations
  - Duration of condition
  - Repeated occurrences
  - Pipe size (diameter)
  - Potential to impact single train, multiple train, header, entire system?
  - Consider other unique features: buried pipe, lined pipe

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Consider a Binning Approach

Significance Level	Assign Multiplier	OR	Degraded IE Frequency (per year)	Degraded System Failure Prob.
High	Base case x 10		1E-02	1E-03
Medium	Base case x 5		5E-03	1E-04
Low	Base case x 2		1E-03	1E-05

- Assign multiplier or generic degraded prob./freq. based on qualitative significance level
- Need to establish the technical basis for bin assignments (use OPDE data, expert judgment)

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Summary

- Attempting to develop a method for assessing degraded pipe conditions
  - Build upon others' past efforts in using data to estimate pipe reliability parameters
- Demonstrated method for estimating conditional failure probabilities
- Identified challenges in incorporating method into PRA analyses
- Considering alternate approaches
  - Binning based on qualitative features