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Predicting Pipe Rupture Frequencies Using xLPR

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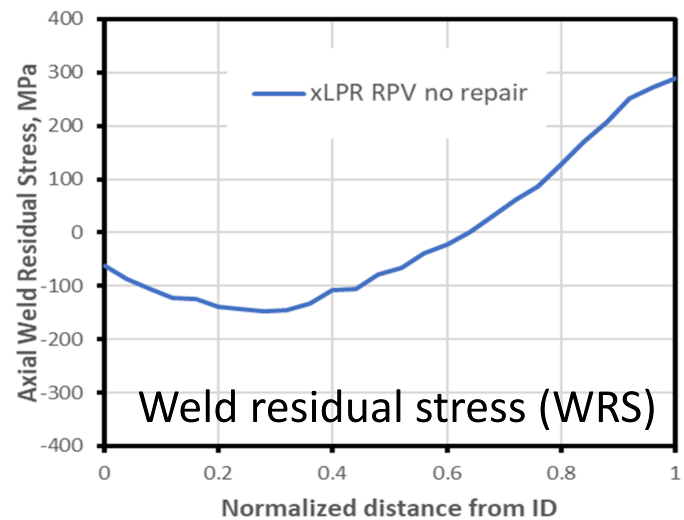
Purpose

- This presentation discusses an initial study conducted in 2019 focused on whether xLPR can be used to estimate pipe rupture frequencies
- The focus of xLPR Version 2.1 has been investigating leak-before-break behavior of reactor coolant piping
- Can xLPR be used to confirm pipe rupture frequencies?
  - NUREG-1829, “Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process”
- This presentation will not address or discuss any regulatory issues or requirements

Base Input – Per xLPR Inputs Group

- OD=34 inch (864mm), t=2.6 inch (66mm)
- Alloy 82/182, Dissimilar metal weld
- 605F (318C), 2,250 psi (15.5MPa)
- Operating load – 20ksi (138MPa) bending, membrane 0.5ksi (3.4MPa)
- Earthquake loading considered – 0.0002/yr
- Typical transients considered – impact to fatigue trivial
- 10-yr inservice inspection (ISI) with no mitigation
- 1 GPM leak detection (LD)



- Primary water stress-corrosion cracking (PWSCC) initiation – Direct Model 1
- 1.5mm deep, 4.8mm long
- Circumferential cracks

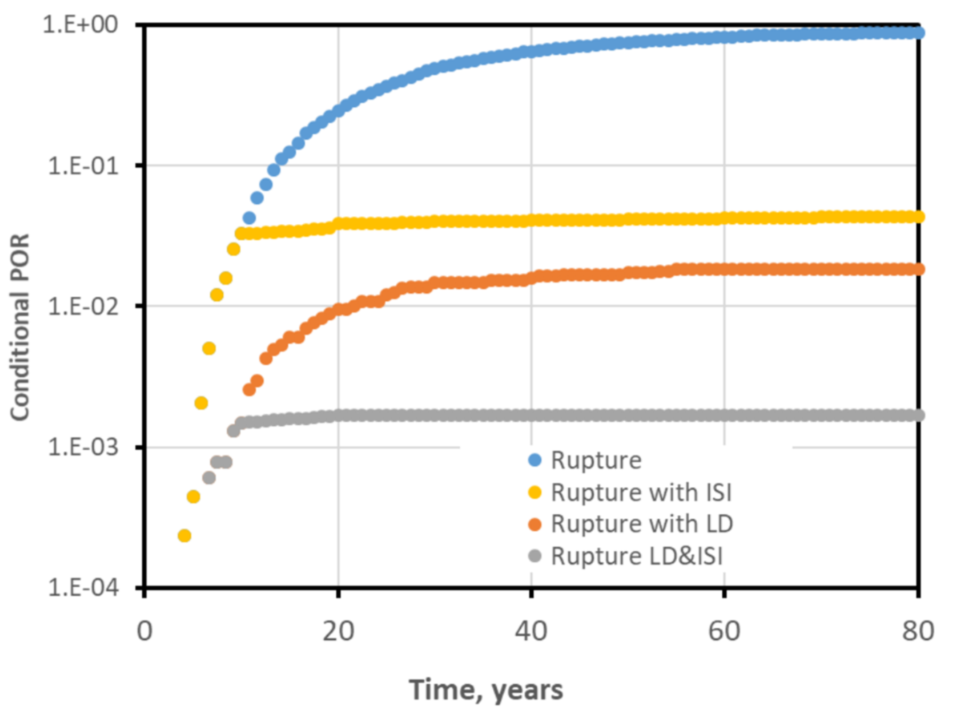
All other inputs per xLPR documentation

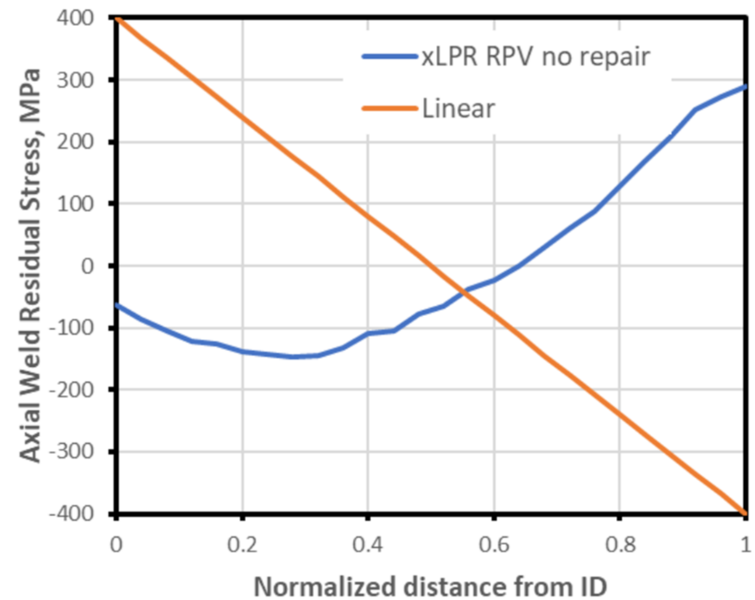
Initial Runs

- Focused on probability of pipe rupture with 1 GPM LD and 10-year ISI
- Even with many realizations and importance sampling on WRS and PWSCC growth parameters, no ruptures predicted with LD and ISI
- To aid in calculation, initiation model was turned off and five initial flaws were used, each with a depth of 1.5 mm and a length of 171 mm, which covers 37% of the inner circumference

Initial Runs

- WRS was also modified





- Failures caused by surface crack rupture (5%) or transition crack ruptures (95%)

- Only very long surface cracks can cause rupture with LD and ISI.

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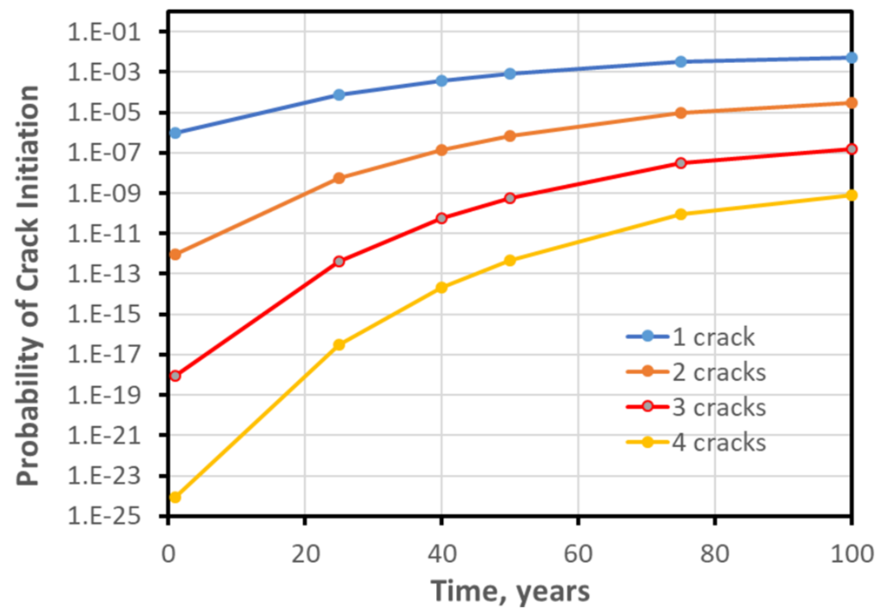
Crack Initiation

- The previous results were conditional on the existence of 5 initial cracks
- Can use the initiation model to estimate the probability of multiple cracks

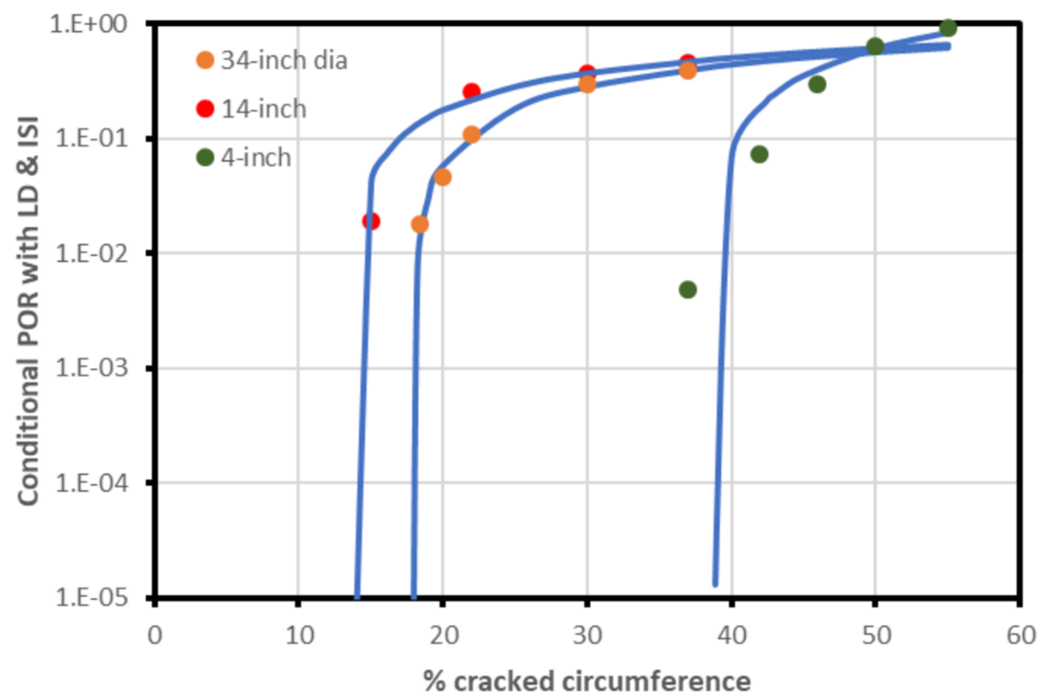


$$\frac{1}{t_{INI,nom}} = Ae^{\frac{-Q}{RT}}\sigma^n \quad \sigma \geq \sigma_{th}$$

Assumed 400MPa (58ksi) stress and a temperature of 318C (605F)

Single Crack Analyses

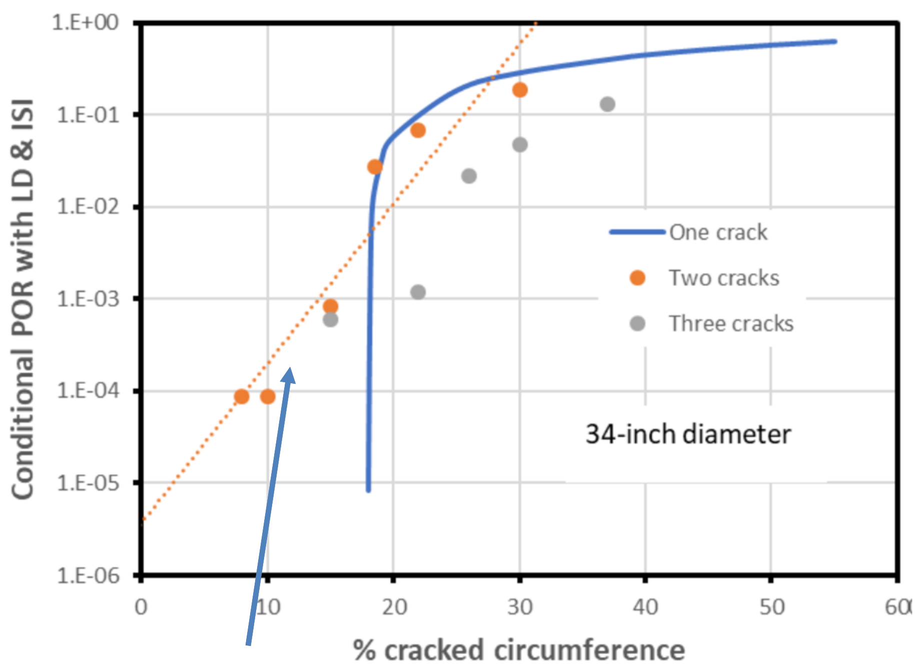
- Same inputs but a single pre-existing crack was assumed
- Varied the initial crack length, kept the initial depth at 1.5mm
- Failures driven by transition crack ruptures



Wall thickness differences cause trends – R/t constant!

Multiple Crack Analyses

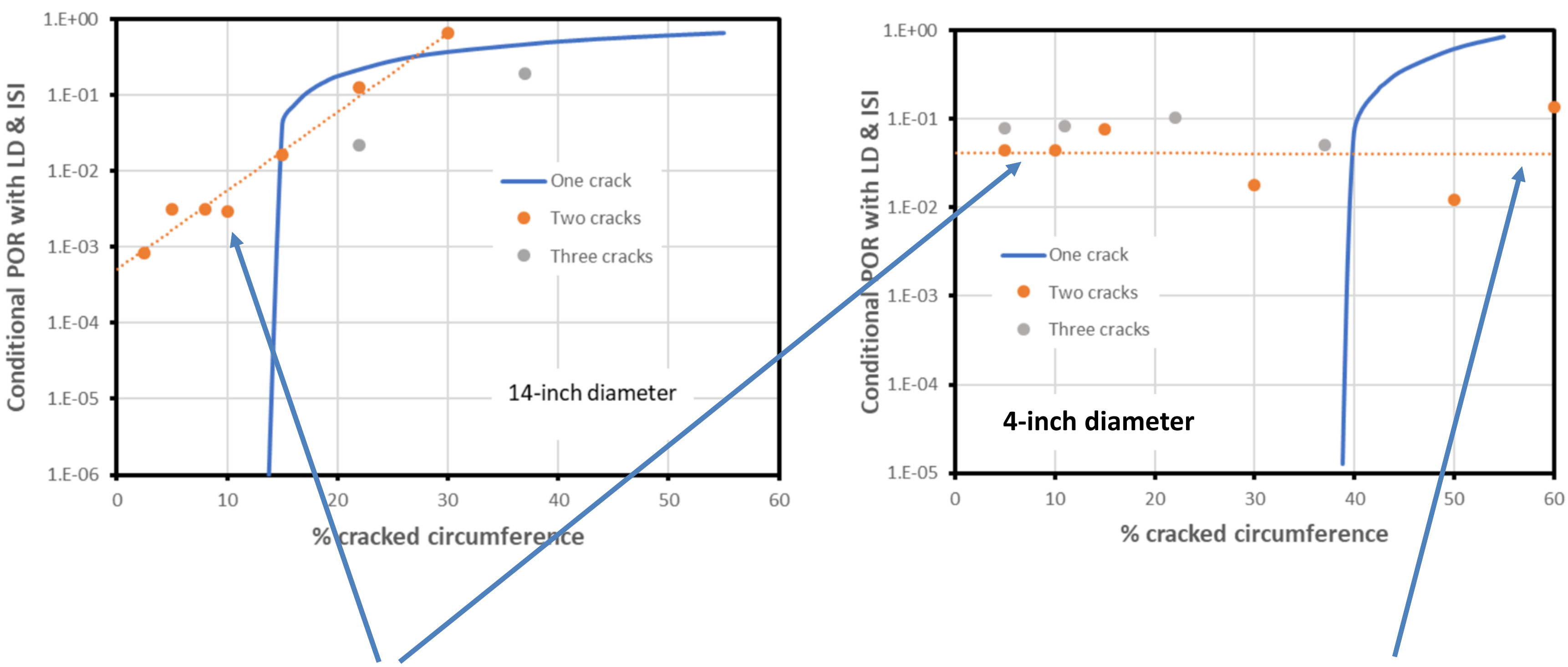
- Same inputs as before, but two and three initial cracks were assumed



Transition crack ruptures

- With crack growth and flaw coalescence a leaking flaw has a long enough crack length such that the transition crack fails before leaking greater than the leak detection limit

Multiple Crack Analyses



Same trends as large diameter case

Surface crack ruptures

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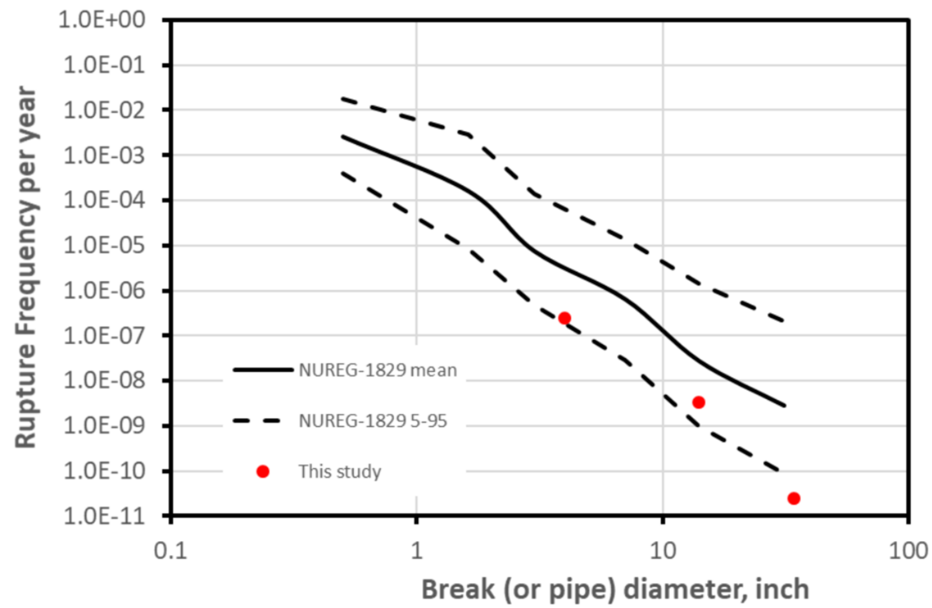
Estimating Rupture Frequency

- Use trends to estimate rupture probability for small flaw
- Combine this with probability of initiating 2 flaws
- Assume 50 welds/pipe system
- Convert to annual frequency



Contribution of non-rupture breaks are NOT included here

Known Conservatisms/Assumptions

- Linear WRS assumption
- No axial defects
- Assumed PWSCC controls all joints in pipe system
- All flaws initiate at time 0 with some probability
- Constant R/t, constant loads

Summary

- These results suggest that the pipe break frequencies in NUREG-1829 were conservative as compared to those calculated in this effort
- However, additional analyses are needed for a more robust comparison with the piping break frequencies developed through the expert elicitation effort of NUREG-1829
- Conducting xLPR analyses with pre-existing defects may be useful for efficiently estimating pipe rupture frequencies with active degradation mechanisms

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ANY
QUESTIONS