P-376

# Analysis of Possible Aging Trends in the Estimation of Piping System Failure Rates for Internal Flooding PRA

*PSAM 14*
*Los Angeles, USA*
*September 19, 2018*

PSAM 14
Probabilistic Safety Assessment and Manager


*Authors:*

*B.O.Y. Lydell*
*Sigma-Phase, Inc.*
*Vail, AZ*

*K.N. Fleming*
*KNFC LLC*
*Spokane, WA*

*J.-F. Roy*
*Electric Power Research Institute*
*Palo Alto, CA*

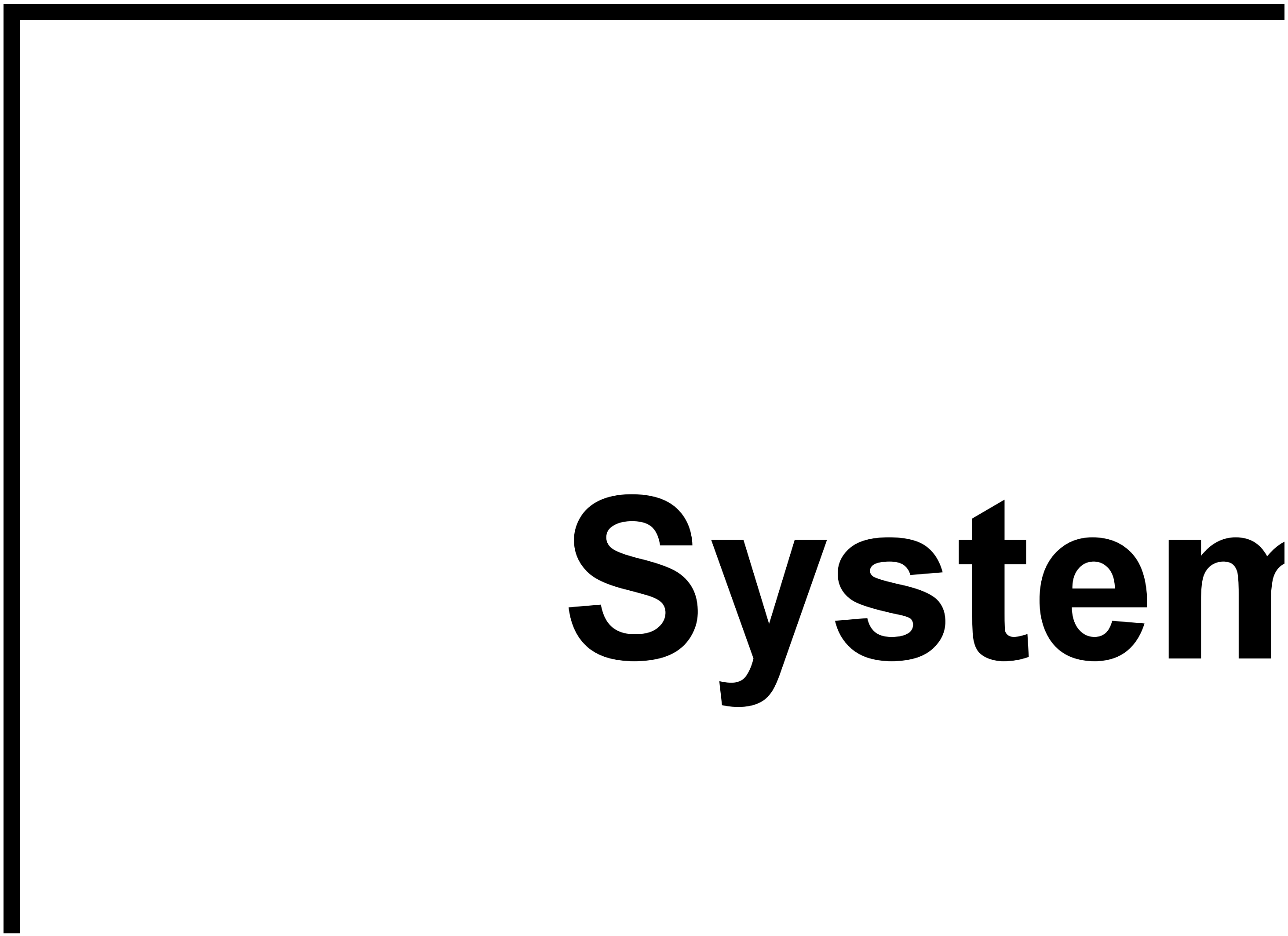
# Overview

- EPRI Internal Flooding PRA (IFPRA) Technical Support
  - Project Status
- Estimating Pipe Failure Rates for IFPRA
- Temporal Trends vs. Age Dependent Pipe Failure Rates
- Technical Approach
- Some Results
- Aging Factor Application Guidelines
- Concluding Remarks

# EPRI IFPRA Technical Support

- **Since 2004, EPRI has sponsored projects to provide guidance and data to support IFPRA**
  - "Pipe Rupture Frequencies for IFPRA" Revision 1, 2006
  - "Guidelines for Performance of IFPRA", 2009
  - "Pipe Rupture Frequencies for IFPRA" Revision 2, 2010
  - "Pipe Rupture Frequencies for IFPRA" Revision 3, 2013
  - "Piping System Failure Rates for Corrosion Resistant Service Water Piping, 2014
  - "Pipe Rupture Frequencies for IFPRA" Revision 4, 2018
- **Objectives of IFPRA Technical Support**
  - To assist plant owners in meeting the requirements of the ASME/ANS PRA Standard in the performance of IFPRAs
  - Provide updates to the pipe failure rates database to cover an increasing scope of piping systems & progressively greater amount of piping operating experience

# Scope of Pipe System Cases and Service Experience Revision 4



# Current Status & Objectives of EPRI IFPRA Technical Support

- The 4th Revision to the IFPRA Pipe Failure Rate Database has been completed & will be published in the 4th quarter 2018
- Primary objectives in preparing the 4th Revision were to
  - Address the temporal trends in piping system performance
  - Where feasible, assess the effects of plant aging on piping system performance
  - Provide technical guidance for how to address potential aging effects for plants that have entered onto long-term operation (LTO)
  - Consolidate separate studies including corrosion resistant SW pipe and high energy line breaks into a single report
  - Provide information in a more useful format addressing input from PWR Owners Group

# Estimating Pipe Failure Rates and Flood Frequencies for IFPRA

- **The Key Elements of the EPRI Approach**
  - Simple data-driven model (DDM) in which the frequency of pipe rupture is expressed as the product of a pipe failure rate and a conditional pipe rupture probability (CRP) which varies with the size of a rupture
  - Failure defined as any event involving repair or replacement and each failure considered as precursor to a rupture
  - A Bayes methods is used to characterize uncertainties in the DDM
  - The underlying piping operating experience comes from a continuously maintained, updated comprehensive database (PIPExp)
  - Homogeneous piping component populations are defined to analyze the failure and exposure term data
    - Isolate the key factors that influence the pipe failure potential
  - Rupture frequencies may be adjusted to account for different reliability & integrity management (RIM) programs using a Markov model of piping reliability
  - The approach produces a library of pipe failure rates and rupture frequencies for each piping system and pipe size within the scope of an IFPRA

# Class 3 PWR Sea NPS 2" Pipe Cumulative Flood Mode Frequencies (1970 – 2015 data)

**Flow rate[3]**

# Temporal Trends vs. Age Dependent Pipe Failure Rates

- The existing body of piping failure operating experience is very extensive and some general conclusions can be drawn from it:
  - For many combinations of piping systems, materials and operating environments very clear temporal trends are evident
  - The temporal trends should be adequately accounted for in the pipe failure rate estimation process
    - The presence of negative and positive aging trends may be determined through a screening process by calculating a "temporal change factor" (TCF)
      - TCF = $\lambda_{(P1+n)} / \lambda_{P1}$ where "P" is time period
      - The TCF accounts for potential aging, data completeness, and changes the pipe failure reporting process
        - Period 1 (P1): 1/1/1970 through 12/31/2004 (Revision 1)
        - Period 2a (P2a): 1/1/2005 through 3/31/2009 (For certain system)
        - Period 2b (P2b): 1/1/2005 through 3/31/2010 (For certain systems)
        - Period 3a (P3a): 4/1/2009 through 12/31/2015 (R4, for certain systems)
        - Period 3b (P3b): 4/1/2010 through 12/31/2015 (R4, for certain systems)
        - Period 4 (P4): 1/1/1970 through 12/31/2015 (Revision 4)

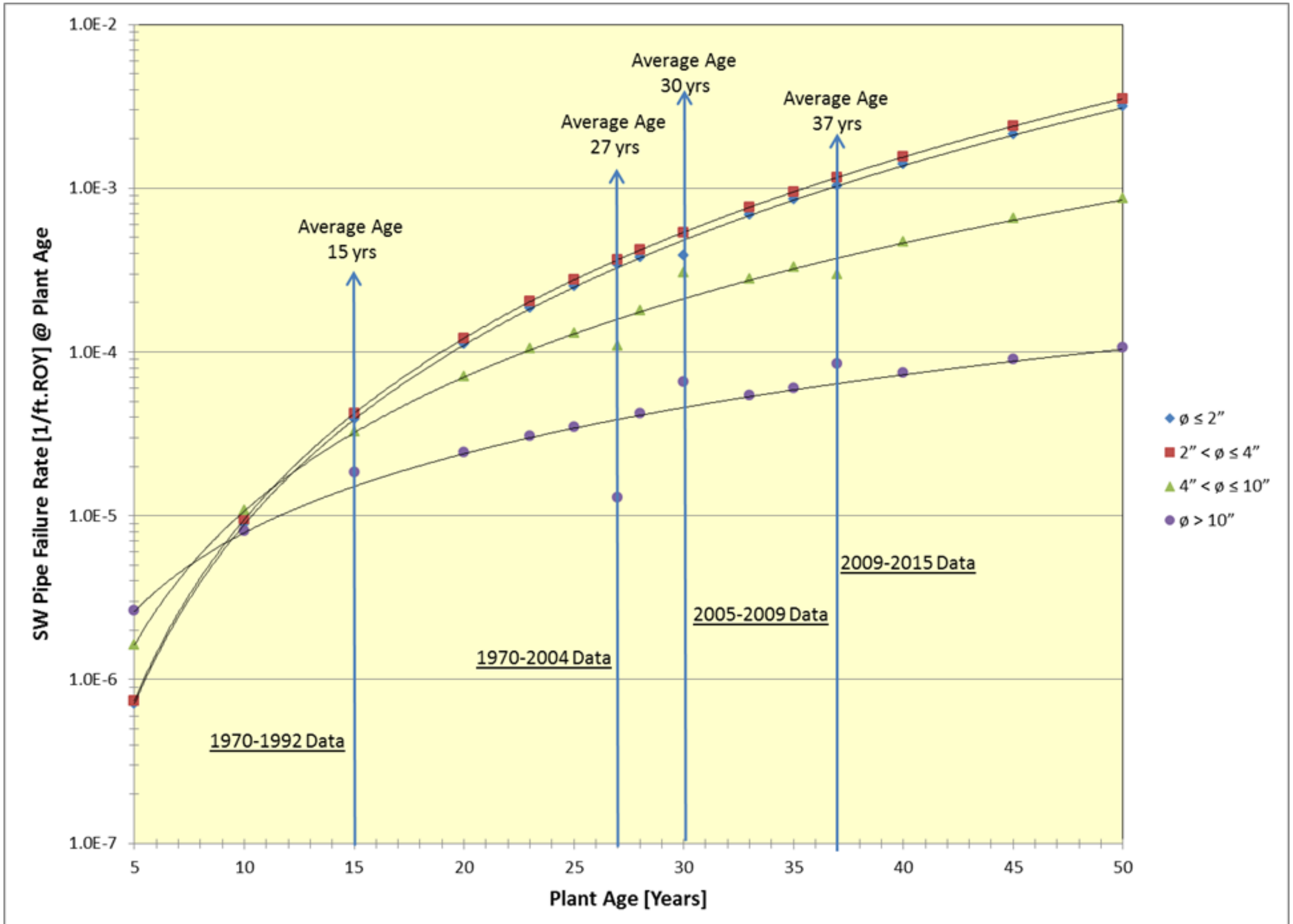
# Temporal Change Factor Screening Guideline

| TCF | Period(s) | Interpretation | Impact on Pipe Failure Rates & Rupture Frequency Calculations |
|---|---|---|---|
| **< 1** | P2, P3, P4 | Effective flow-accelerated corrosion (FAC) aging management. No significant trend change anticipated beyond 2015. FAC-free piping performance is achievable. | Applies to FAC-susceptible steam cycle piping systems. Extensive operating experience data available. Most FAC-susceptible piping systems have been replaced with material that is resistant to flow-assisted wall thinning. Simple update; average across chosen time period. |
| **> 1 but < 2** | All | No adverse trend in operating experience. | Insufficient data to support aging factor assessments. Alternatively, existing aging management programs sufficiently effective to prevent adverse trends. Simple update; average across chosen time period |
| **> 2** | P2 & P3 or All | Indicative of aging of raw water piping systems; CW, FP and SW systems | Results of formal aging factor assessment could be factored into failure rate calculations. |

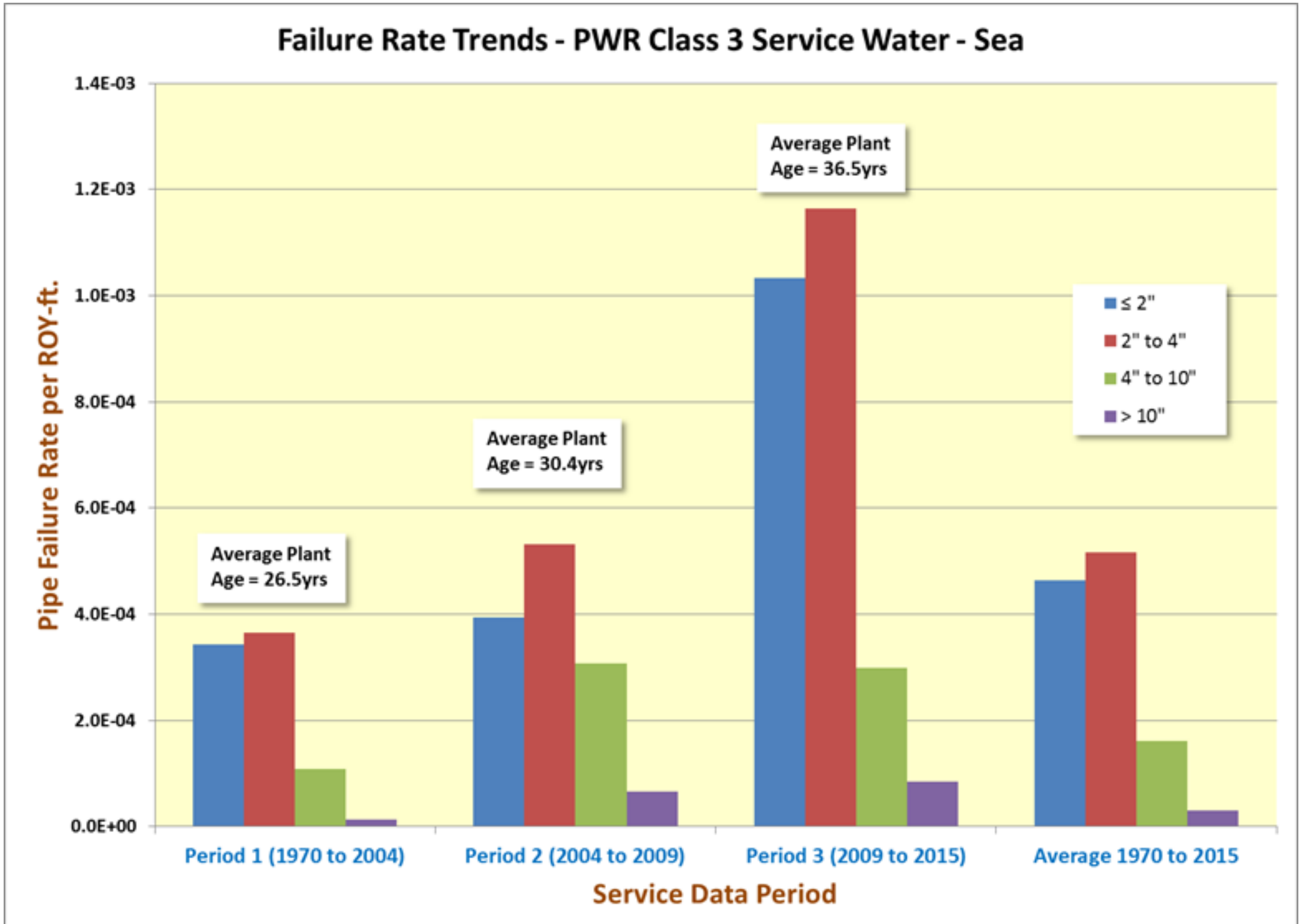
# Age Dependent Pipe Failure Rates – Technical Approach

- **<u>Simplified Approach</u>**
  - Each of the periods P1 though P4 is representative of the accumulated operating experience against an average BWR and PWR fleet age.
  - The estimated pipe failure rates for each calculation case are used as 'anchor values' when plotted against the average plant age for respective period.
  - An additional "calibration value" is calculated for the period 1970 through 1992 corresponding to an average plant age on the order of 15 years. The year 1992 as end point is selected so that the operating experience data incorporates the results of approximately two years of Generic Letter 90-05 relief requests.
  - In Microsoft® Excel a best-fit curve and equation are added to the four calibration points, enabling the calculation of age dependent pipe failure rates. For respective calculation case the aging factor (AF) is determined from:
    - AF = $\lambda_{Age\ 'i'} / \lambda_{Avg.\ (1970\text{-}2015)}$

# Failure Rate Trends for PWR Class 3 Sea Service Water Pipe



# Some Results – Pipe Failure Rates



# Typical Aging Factor Table

# Summary

1. The opportunity to identify & evaluate temporal trends in pipe failure rates has been made possible by a long-term commitment by EPRI to support IFPRA
2. An essential element of the technical approach to assessing temporal trends and aging factors is the availability of a comprehensive pipe failure operating experience database
3. Evidence for aging is not theoretical
4. Recommended that IFPRAs perform preliminary screening using time averaged failure rates and then apply aging factors to risk significant flood-induced accident sequences

# Thank You