# ***PASCAL Code Series: JAEA's PFM Codes***

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*Improvement of Nuclear Safety*
*Using Probabilistic Fracture Mechanics*

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✓ This presentation includes results obtained under the contract between the Nuclear Regulation Authority of Japan and JAEA.

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**PASCAL: PFM Analysis for Structural Components in Aging LWR*

# Introduction

- After the severe accidents in Fukushima-daiichi NPPs, the safe long-term operation of nuclear power plants has become more and more important.
- Accordingly the measures for aging degradation to maintain or improve the function and performance of systems, structures and components in the plant, are necessary.
- On the other hand, risk information including failure probability of components are to be utilized to maintain and improve the safety level of the NPPs.
- We have been performing researches on the evaluation methods based on probabilistic fracture mechanics (PFM) to predict the effect of material degradation for long-time operation on the plant risk.

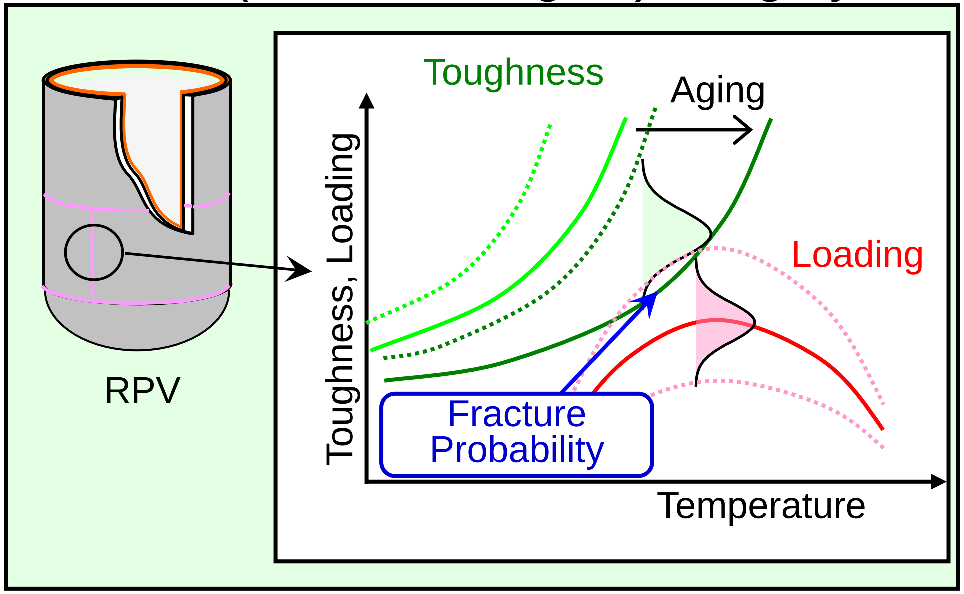
  ✓ Technical basis for safety improvement and probabilistic risk assessment

  ✓ Quantification of safety margin, relative difference in different standards

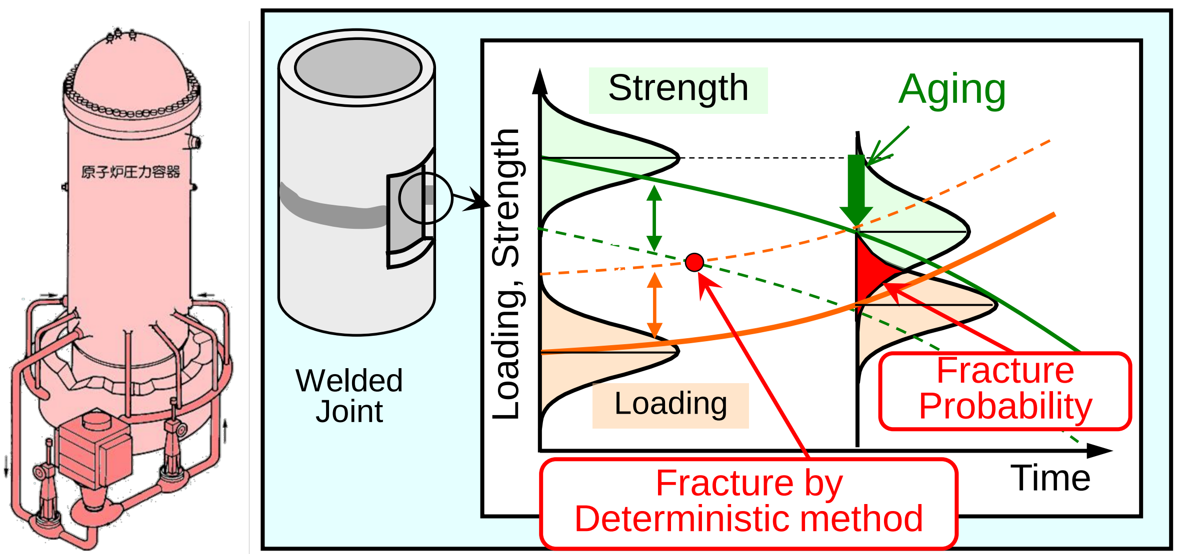
  ✓ Application to the optimization of inspection interval and degree, prioritization of inspection, etc.

# Concepts of PFM

## RPV (Corebelt Region) Integrity




## Piping Integrity



# Main Features of PASCAL Codes

- Failure Probability Evaluation Based on Domestic Regulatory Framework and the Latest Information using PFM for Major Components in NPPs

  - ➢ Based on Domestic Codes and Standards
    - ✓ JSME Rules on Fitness-for-Service
    - ✓ JEA Codes on Fracture Toughness

  - ➢ Latest Information on Fracture Mechanics Analysis
    - ✓ Stress Intensity Factor Calculation
    - ✓ Master Curve Method
    - ✓ Multiple Cracks Treatment

  - ➢ Probabilistic Models based on Domestic Data
    - ✓ Fracture Toughness $K_{Ic}$ and $K_{Ia}$ curves
    - ✓ Crack Growth Rate (Fatigue and SCC)

# Development of PASCAL Codes



| Components | Aging / Loading | 1990 | 2000 | 2010 |
|---|---|---|---|---|
| RPV | Irradiation Embrittlement / PTS | PASCAL | PASCAL2 PASCAL3 | |
| Piping | IGSCC / Residual Stress, Earthquake | PRAISE PASCAL-EQ | PASCAL-SC PASCAL-SP | |
| RPV and Piping | PWSCC NiSCC / Residual Stress | | PASCAL-NP | |
| Piping | Flow Accelerated Corrosion / Operation, Earthquake | PASCAL-EC | | |

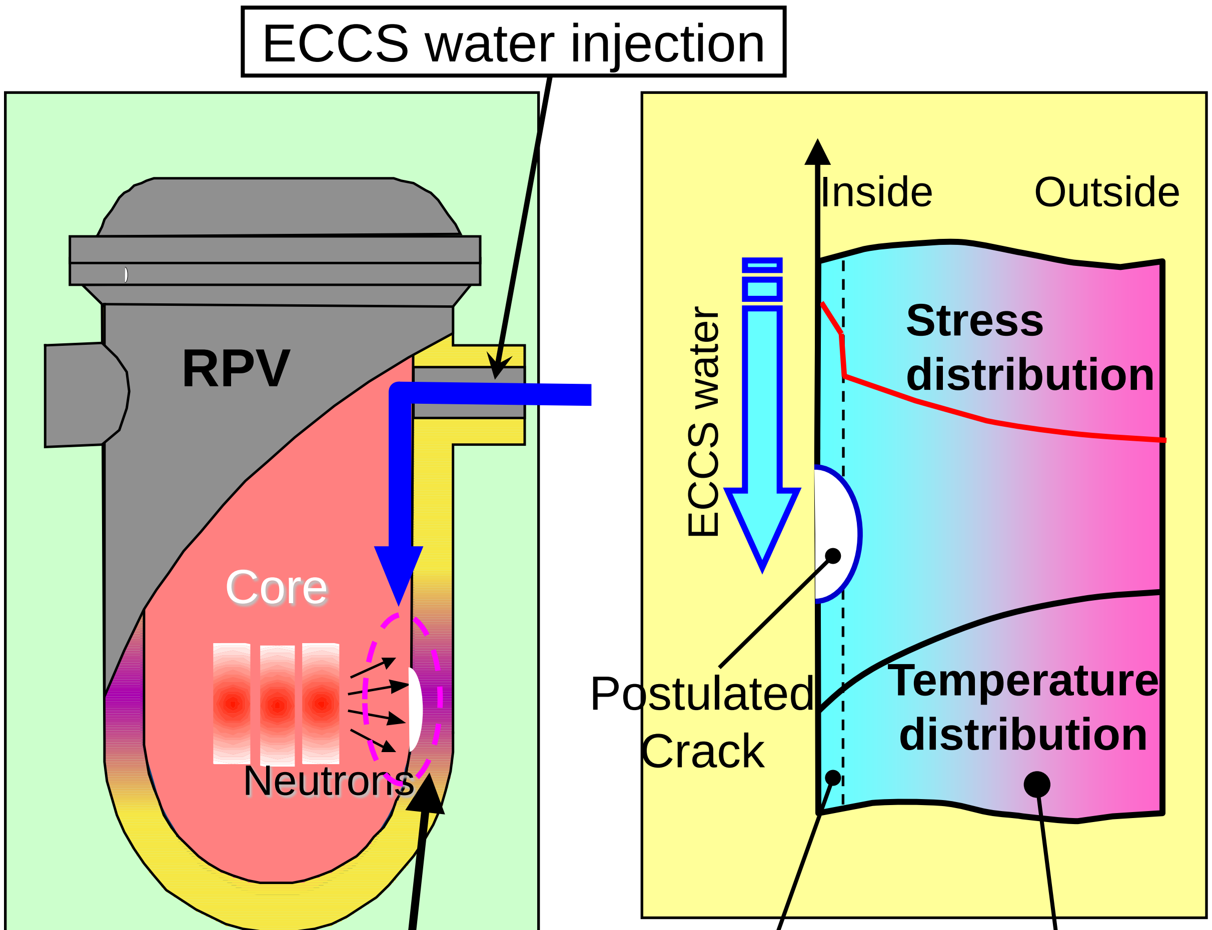
# PASCAL Codes

- PASCAL ver. 3 for RPV Integrity
  - ✓Brittle Fracture during PTS events
  - ☞International Round Robin analyses
  - ☞Studying the standardizing, verification, utilization
- PASCAL-NP for Ni-based Alloys and Welds
  - ✓PWSCC and NiSCC in Ni-based Alloys and Welds
  - ☞Studying the applicability to various cracks, Improvement of Initiation model, case studies
- PASCAL-SP for Piping Integrity
  - ✓Crack Growth due to SCC and Fatigue in Primary Piping
  - ☞Benchmark analyses with the other domestic codes.
  - ☞Studying the applicability to the seismic safety analyses
- PASCAL-EC for Wall Thinning of Piping
  - ✓Wall Thinning due to FAC in Carbon Steel Piping
  - ☞Applied to the analysis on the Mihama-3 accident
  - ☞Improvement on the analysis functions

# ***Probabilistic Fracture Assessment for Reactor Pressure Vessels during Various Transient Loadings***
# ***PASCAL version 3***

- Probabilistic Fracture Mechanics (PFM) analysis is quite useful for the structural integrity/reliability assessment of aged components containing a crack/cracks.
- A PFM analysis code for the structural integrity assessment of RPV during PTS has been developed in JAEA, named **PASCAL**: **P**FM **A**nalysis of **S**tructural **C**omponents in **A**ging **L**WR.
- PASCAL ver. 3 evaluates the conditional probability of failure of a reactor pressure vessel (RPV) under transient loading conditions such as pressurized thermal shock (PTS).
- Using the latest version of PASCAL, some sensitivity analyses were performed for model RPVs during typical PTS events.

# PTS (Pressurized Thermal Shock)




✓High tensile stress due to internal pressure and thermal stress
✓Irradiation embrittlement

- ECCS water injection under pressure cools inner surface and then produces high tensile stress. → PTS
- The difference in thermal expansion coeff. between cladding and base metal makes stress discontinuity.
- Cladding may yield due to tensile pressure and thermal stresses under severe transient.

# Structural Integrity Assessment for RPV during PTS

## Material Data

Chemical Composition of Material

Fracture Toughness

## PTS Transient Data

Change in Coolant Temperature

Change in System Pressure

Thermal Analysis

Stress Analysis

## Operation Data

Neutron Fluence at Evaluation

Attenu-ation in RPV Wall

Postulated Crack

Embrittlement Prediction

Fracture Mechanicas Analysis

Fracture Toughness $K_{Ic}$ Curve at Evaluation

Fracture Toughness $K_{Ic}$ at Crack Tip

$K_I$ value at Crack Tip

Structural Integrity Assessment

$K_{Ic} > K_I$ ?

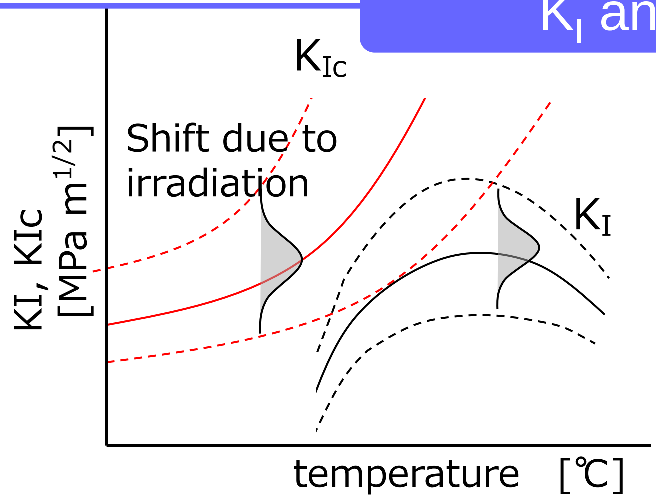
*Current Approach: **Deterministic!***

Ref.: JEAC 4201 and 4206

# Probabilistic Structural Integrity Assessment



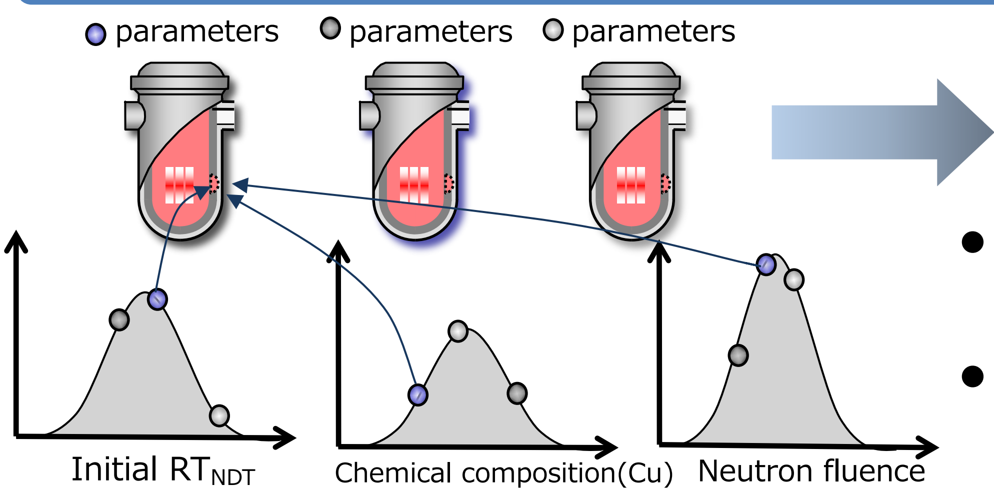
## $K_I$ and $K_{Ic}$ curves during PTS

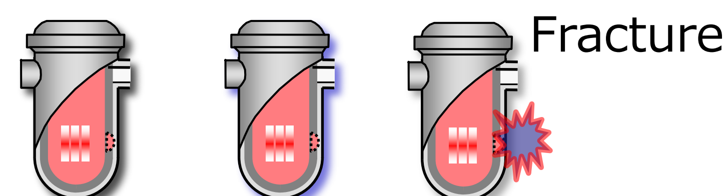



✓Structural integrity is maintained if $K_I$ is smaller than $K_{Ic}$ in deterministic approach.

✓However there are large uncertainties in $K_I$ and $K_{Ic}$.

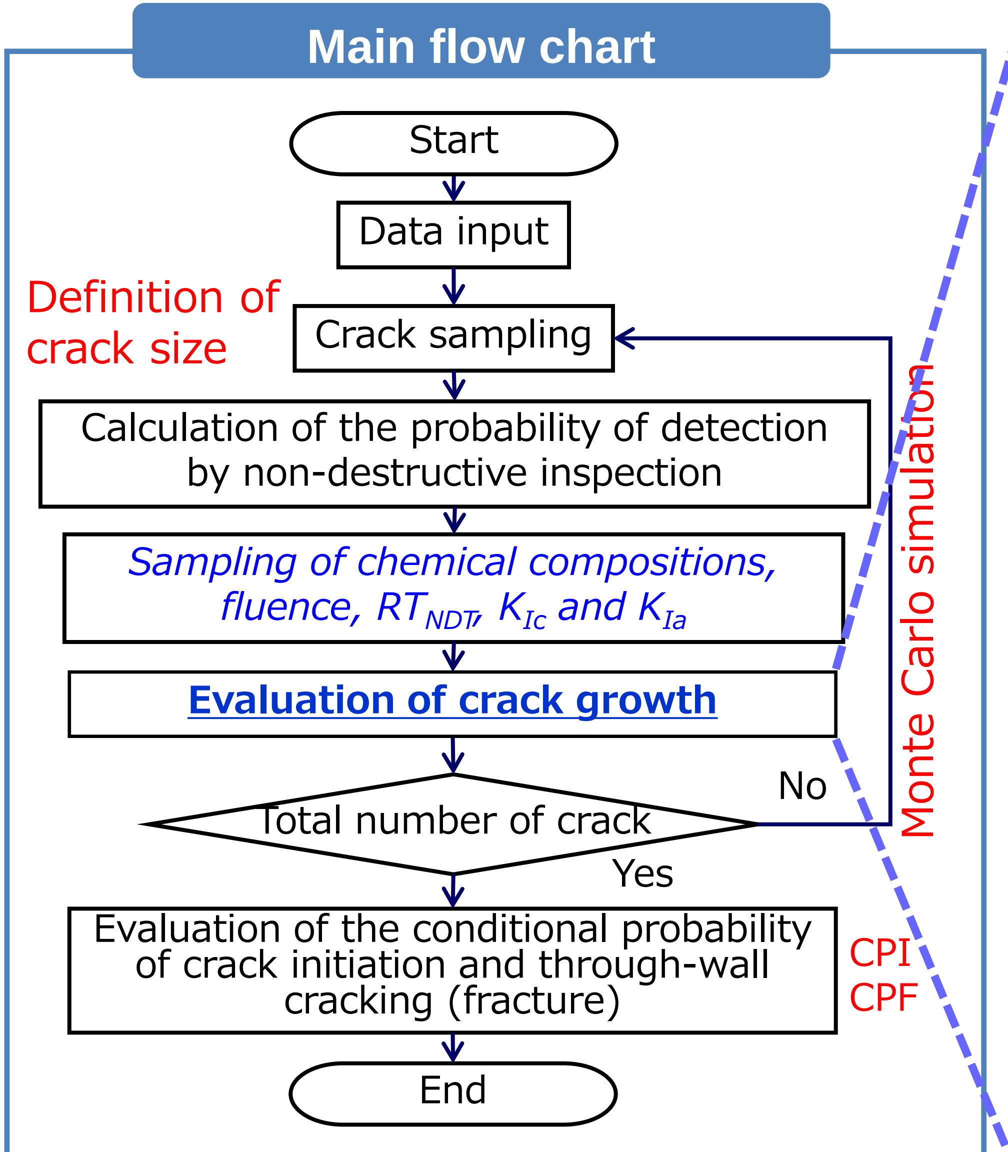
## Schematic of PFM analysis by Monte Carlo simulation

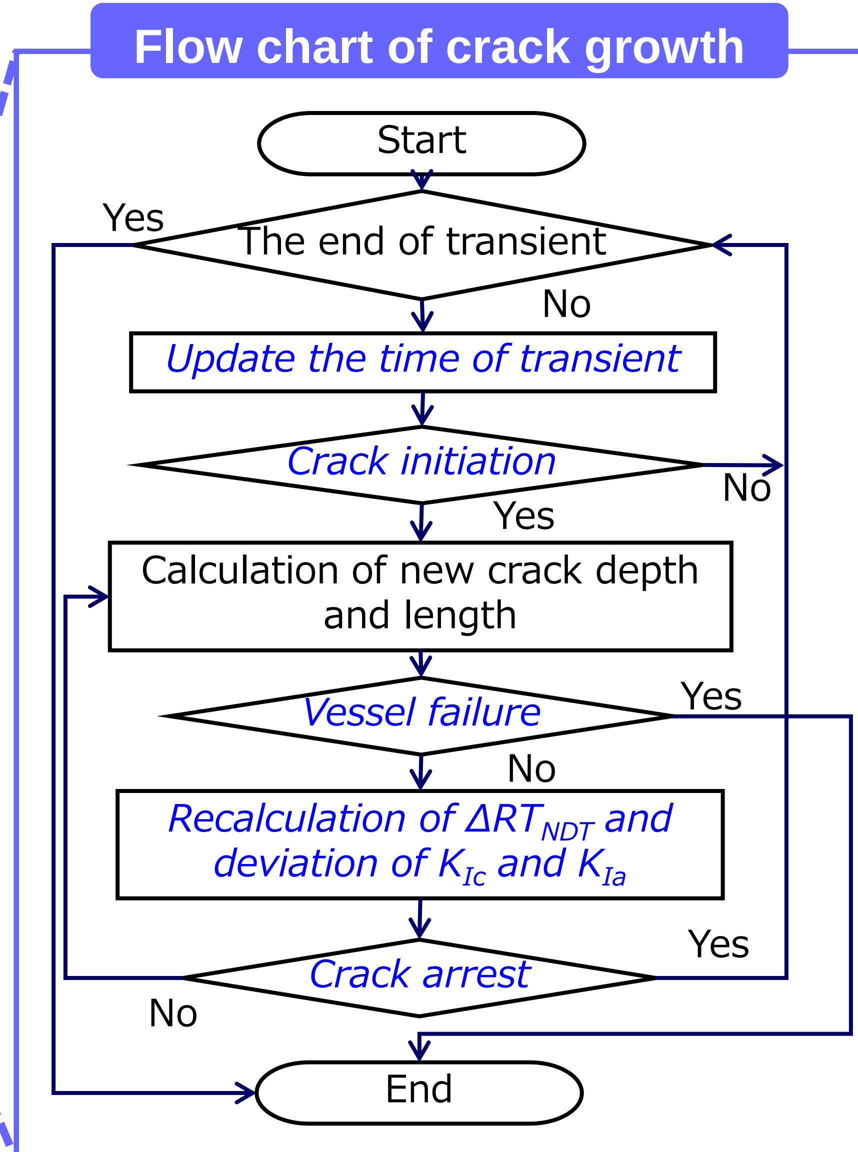



- Each calculation of the integrity evaluation is performed in deterministic fracture mechanics approach.
- The fracture probability is calculated from the number of fractured vessels and number of samples of all.

# Outline of PASCAL3 for PTS Assessment



# Main Features of PASCAL3



- Prediction of Irradiation Embrittlement
  - JEAC4201-2007 (2013 addenda)
- Stress Intensity Factor Calculation
  - Overlay cladding is considered.
  - Influence Function Method developed by CEA for through-cladding surface crack and JSME FFS for embedded crack
- Fracture Toughness
  - Statistical Model based on $K_{Ic}$ and $K_{Ia}$ Data from Japanese RPV Steels
- Probability of Detection by NDE
  - POD Model developed statistically based on Domestic NDE Project Results
- Consideration of Inhomogeneous Properties in Heat Affected Zone adjacent to Welds
  - Crack Initiation/Growth Model in Inhomogeneous HAZ

# PFM Analysis Conditions

- Conditional probabilities of crack initiation and through-wall cracking can be calculated by *PASCAL3* code using basically the default conditions listed below.

| Item | Condition |
|---|---|
| $K_I$ for thru-clad surface crack | Influence function method by CEA |
| $K_I$ for embedded crack | JSME FFS Code |
| $K_{Ic}$ and $K_{Ia}$* equation | Statistical distribution model |
| $RT_{NDT}$ shift equation | JEAC 4201 equation |
| Chemical composition | Cu, Ni |
| Failure criterion | $K_{Ic}/K_{Ia}$ and plastic collapse |
| Warm pre-stress | No crack initiation after and below the maximum SIF during PTS |
| Decrease in upper shelf toughness | JEAC 4201 equation |

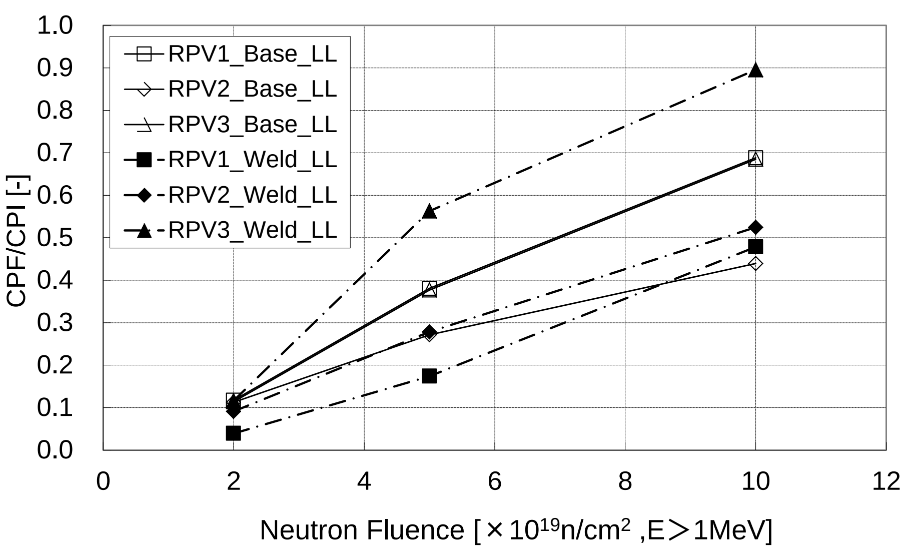
*$K_{Ia}$ model is under development

# PFM Analysis Results for Model RPVs

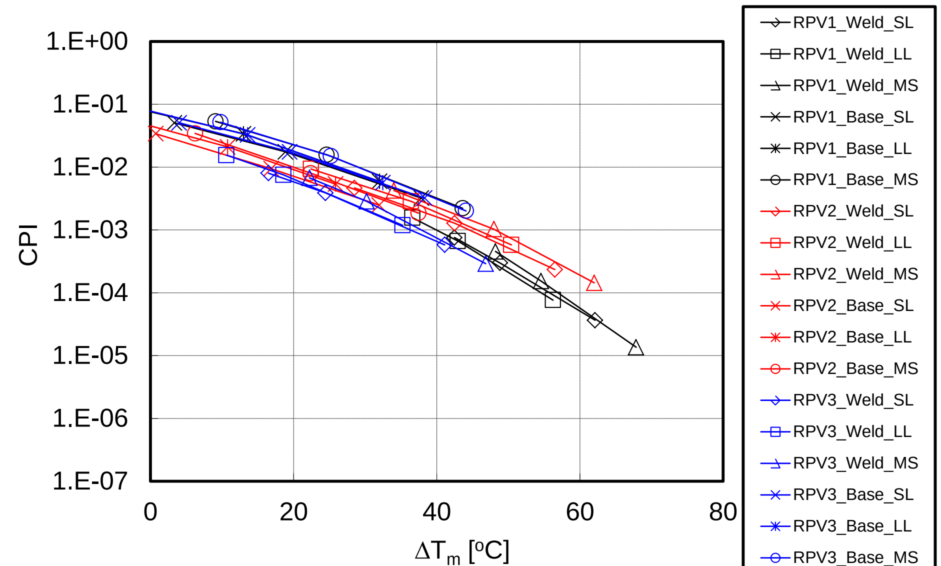
## Analysis conditions for model RPV Nos. 1 to 3

(B: Base metal, W: Weld metal)

| RPV No. | Embrittlement prediction | Fracture toughness $K_{Ic}$ | Chemical comp. (average wt.%) |
|---|---|---|---|
| 1 | JEAC4201-2007 | Japanese Weibull (PFM)<br>JEAC4206-2007 (DFM) | B: Cu 0.16, Ni 0.61<br>W: Cu 0.14, Ni 0.80 |
| 2 | 10CFR50.61a | ORNL Weibull (PFM)<br>ASME Sec.XI (DFM) | B: Cu 0.16, Ni 0.61<br>W: Cu 0.14, Ni 0.80 |
| 3 | JEAC4201-2007 | Japanese Weibull (PFM)<br>JEAC4206-2007 (DFM) | B: Cu 0.16, Ni 0.59<br>W: Cu 0.19, Ni 1.08 |



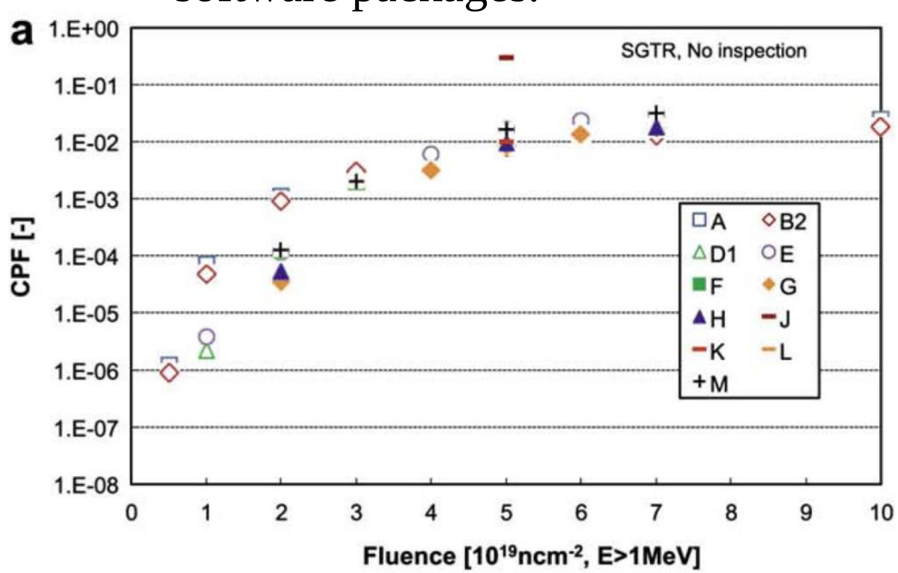

Ratio of conditional probability of fracture to the crack initiation (LBLOCA)

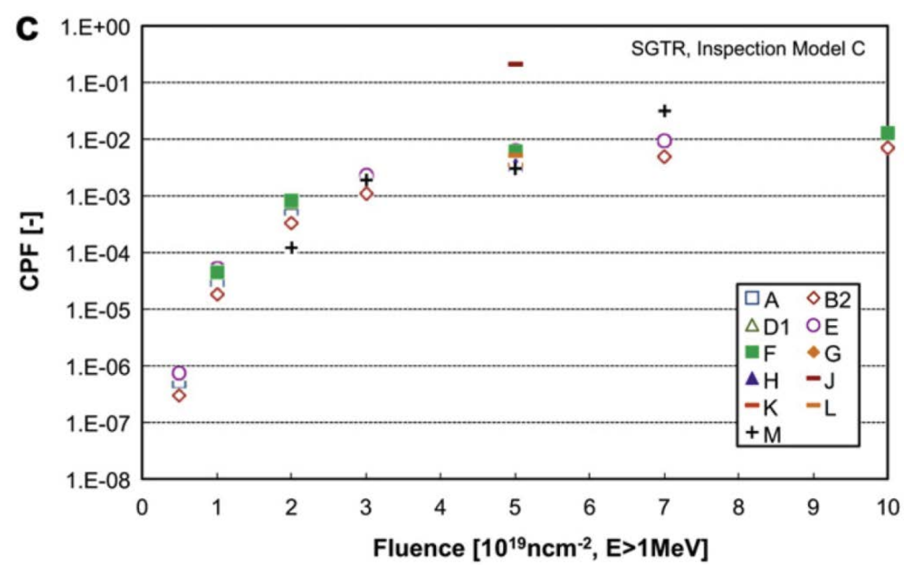



Relationship between deterministic temperature margin and CPI

# International PFM Round Robin Analyses 

- DFM and PFM Analyses for PTS events
- 12 Participants from China, Japan, Korea and Taiwan
- Proposed in 2008, Analysis Started in 2009, and finished 2010. Details were published in IJPVP90-91 (2012) 46-55.
- PFM Code: PASCAL2, WinPraise, Own codes
- Major Conclusion drawn from RR;
  - Although the calculated probabilities of vessel failure have a good agreement in general, there are some variation between participants, which is apparently caused by the difference of stress and stress intensity factors among participants due to the selection of different input parameters for analysis, and use of different probabilistic software packages.



# Ongoing Work for PASCAL3

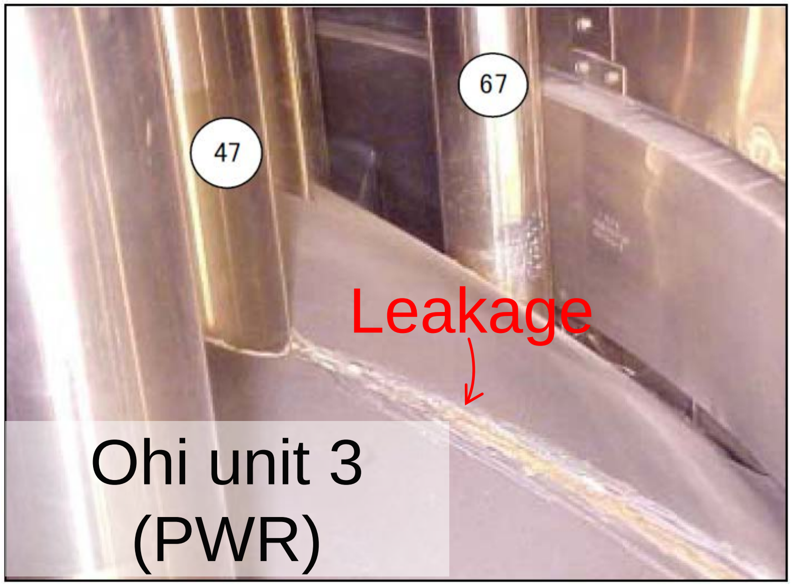
- Study on Applicability to Regulation, Codes and Standards
  - Sensitivity Analyses on Inspection Performance, Safety Margin Quantification, etc.
- Improvement of Analysis Functions and Models
  - SIF Calculation, $K_{Ia}$ model, etc.
- Research on Utilization of PASCAL3
  - Guideline for standardized procedures of PFM analysis
  - Selection of typical input data and analysis functions of PASCAL3
  - Verification of PASCAL3
- International PFM Round Robin Analysis
  - Proposed Phase 2 Problems to Asian Countries as an Activity within the PFM Sub-committee

# ***Probabilistic Fracture Mechanics Analysis Code for Ni-based Alloy welds PASCAL-NP***

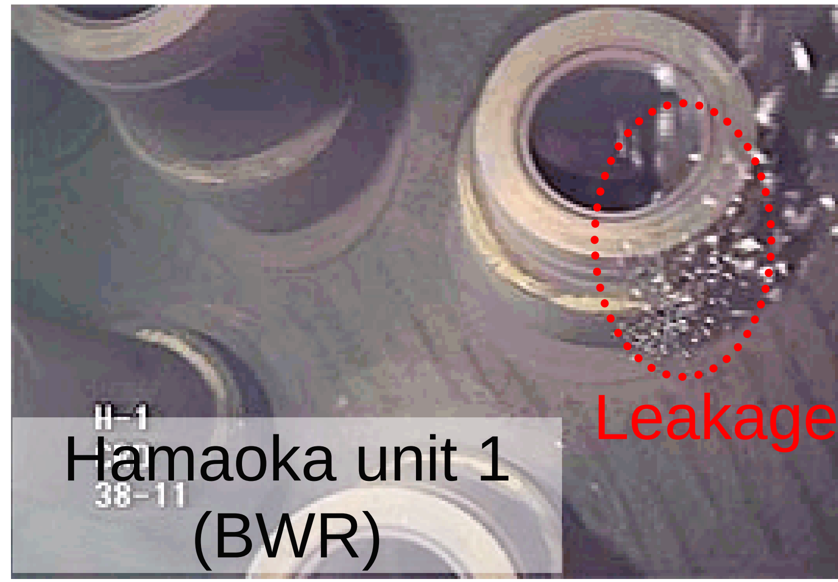
(NP: NiSCC and PWSCC)

# PWSCC and NiSCC

- PWSCC (PWR)
  - VHPs
    (Vessel Head Penetrations)




- NiSCC (BWR)
  - CRD housings
    (Control Rod Drive)




➡ To properly assess the structural integrity with considering the scatters of parameters related to PWSCC and NiSCC, we developed a probabilistic fracture mechanics analysis code for Ni-based alloy welds, named PASCAL-NP.

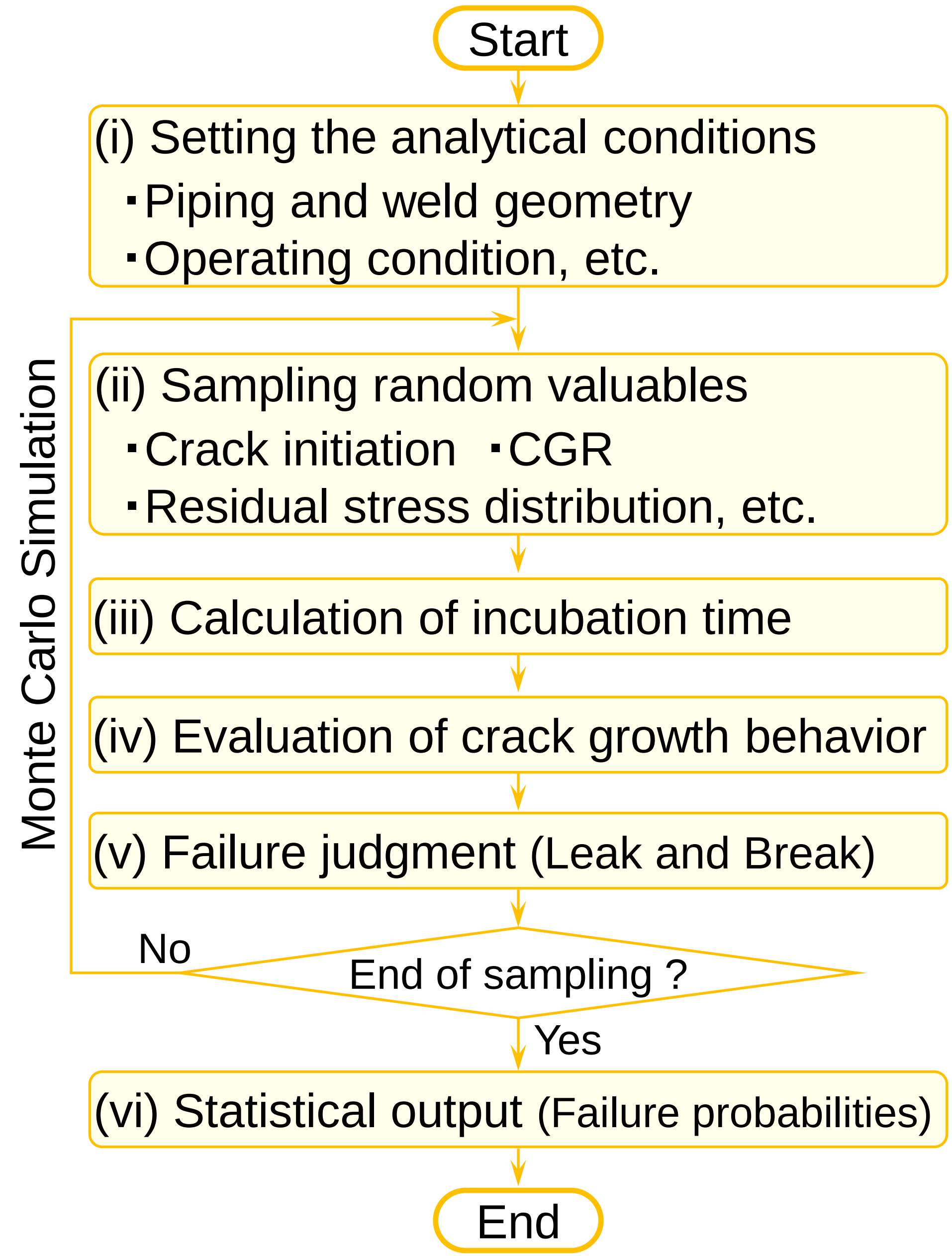
# *Outline of PASCAL-NP*

- Main causes for PWSCC and NiSCC

| | PWSCC | NiSCC |
|---|---|---|
| Environment | PWR | BWR |
| Material | Ni-based alloy base / weld metal | |
| Stress | Welding<br>Surface machining<br>Operating loads | |

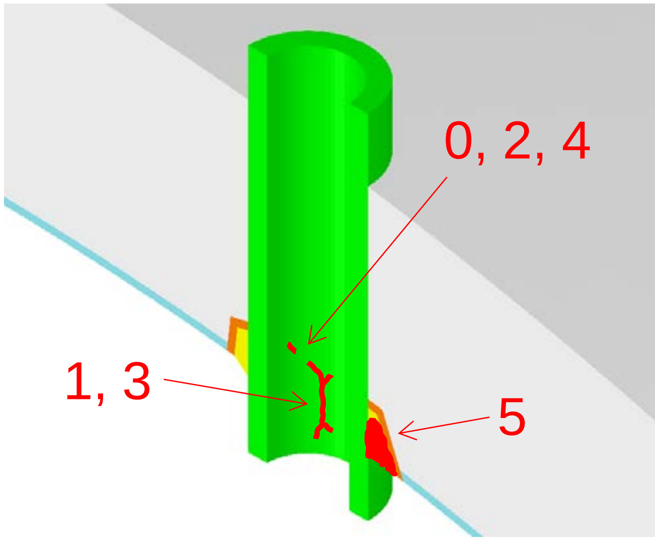
✓ It is difficult to detect PWSCC and NiSCC in weld metal by using UT.

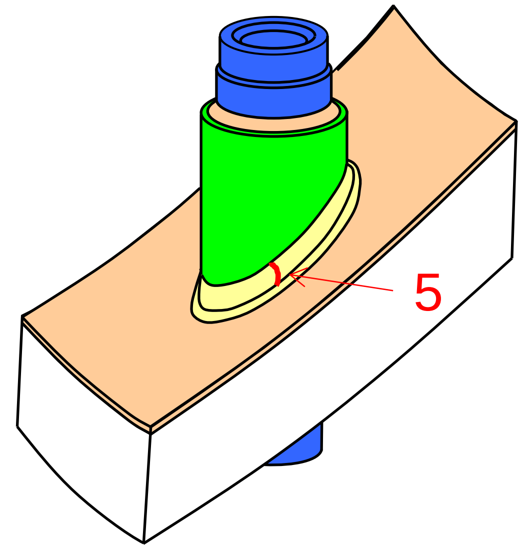
✓ Therefore, it is important to develop analytical models of not only crack growth but also crack initiation for PWSCC and NiSCC.



# Crack types treated in PASCAL-NP

- PWSCC in VHPs
- NiSCC in CRD housings




■ : SCCs

| Crack types no | Orientation | Position |
|---|---|---|
| 0 | Hoop | Inner surface |
| 1 | Axial | |
| 2 | Hoop | Outer surface |
| 3 | Axial | |
| 4 | Hoop | Through wall |
| 5 | Radial, Axial | In weld metal |

➡ PASCAL-NP has functions to evaluate crack growth behaviors for these types of cracks and to calculate failure probabilities considering features of PWSCC and NiSCC.

# Incubation Time to Crack Initiation

- Calculation model

$$t_i = \frac{t_{i0}}{i_\theta \times i_\sigma \times i_m} \times \alpha_i$$

**Temperature and ECP**

$i_\theta = A_\theta(ECP) \times \exp(-Q_i / RT)$

**Stress**

(PWSCC) $i_\sigma = A_\sigma \times \sigma_{eff}^{\,n}$

(NiSCC) $i_\sigma = A_\sigma \times (\sigma_{eff}-\sigma_y)^n$

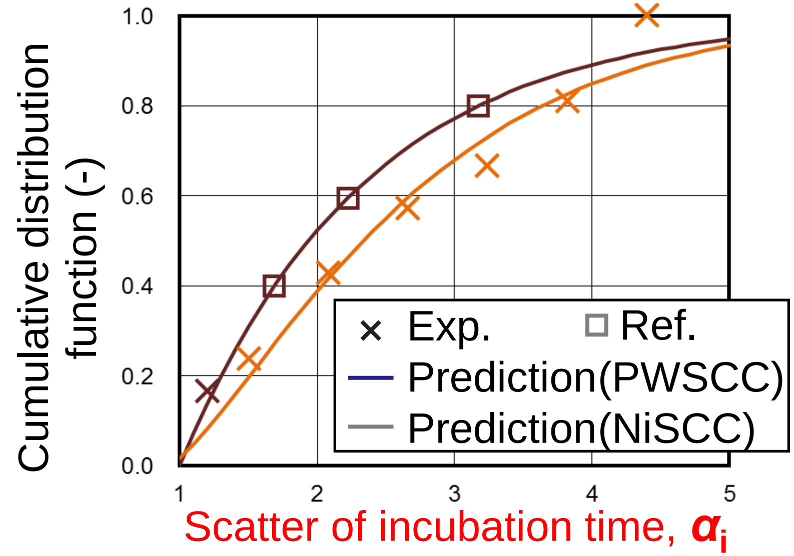
**Material**

Manufacturing process (hot or cold work)

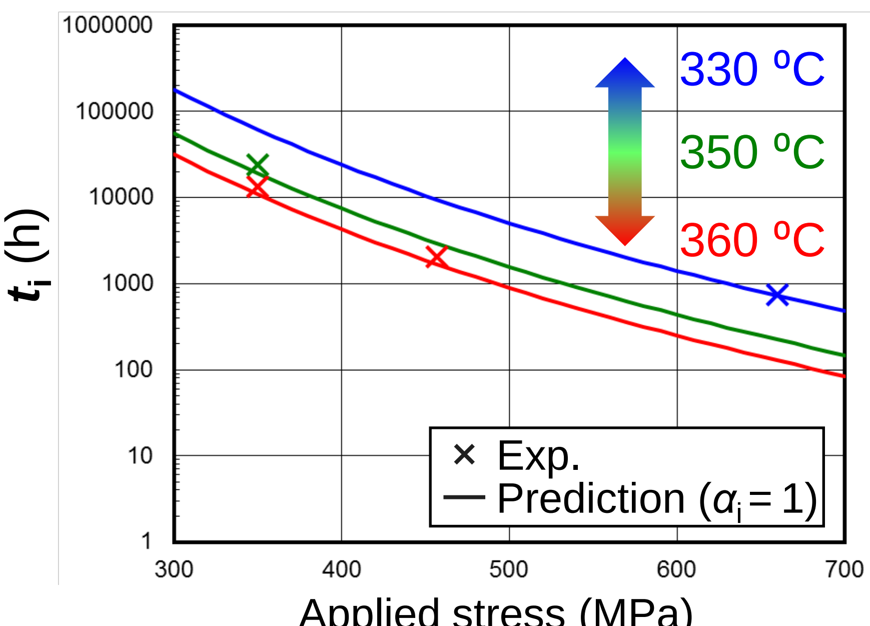
Chemical composition (Cr contents)

Thermal treatment

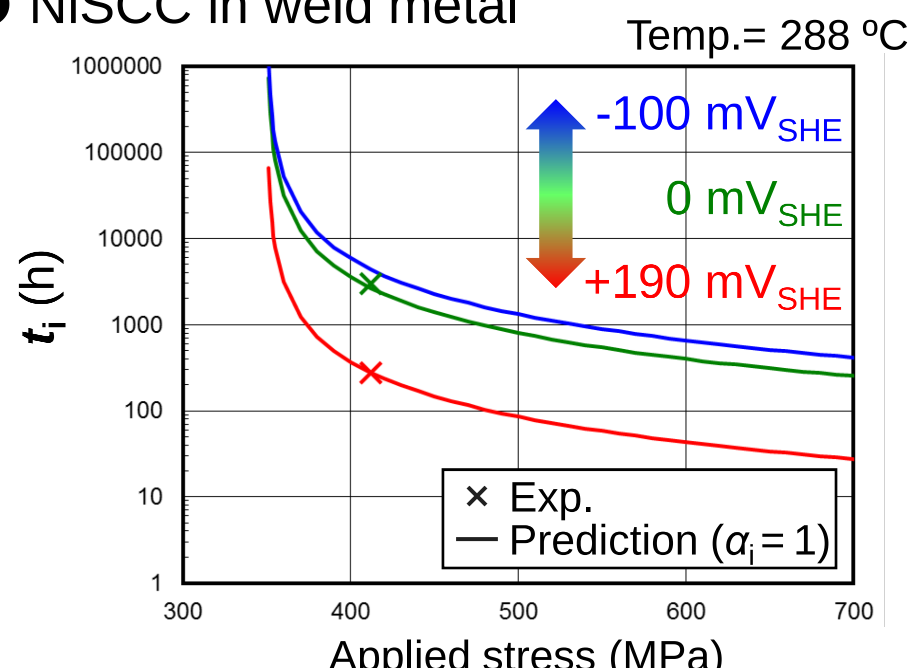
C. Amzallag, *et al*. (2000), T. Couvant, *et al*. (2011), N. Saito, *et al*. (1999)




- PWSCC in weld metal

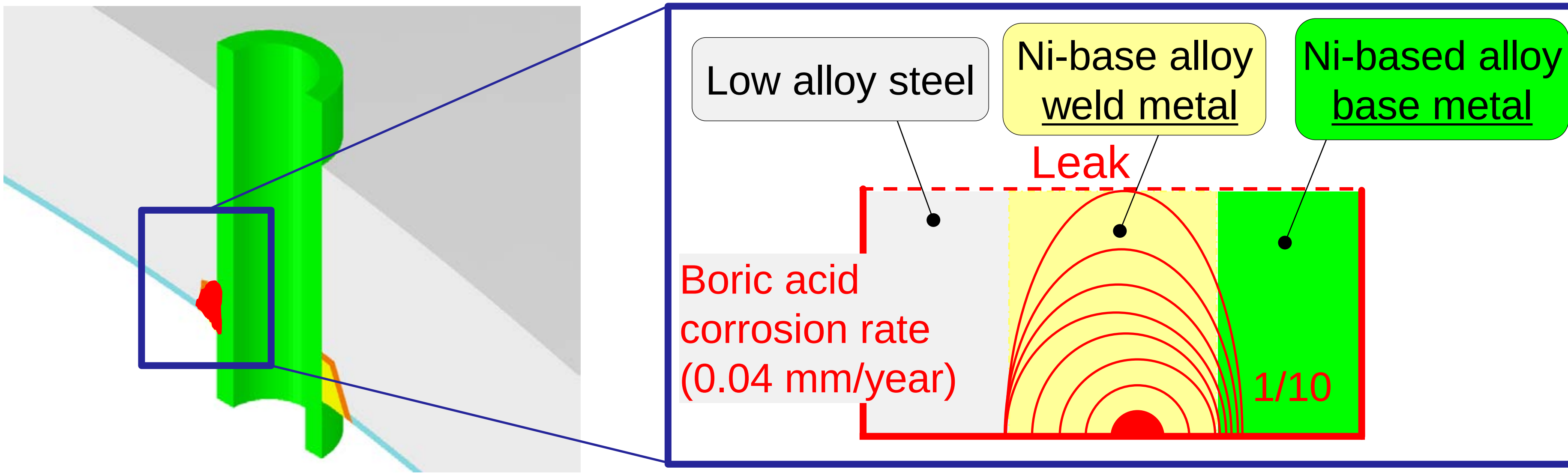



- NiSCC in weld metal

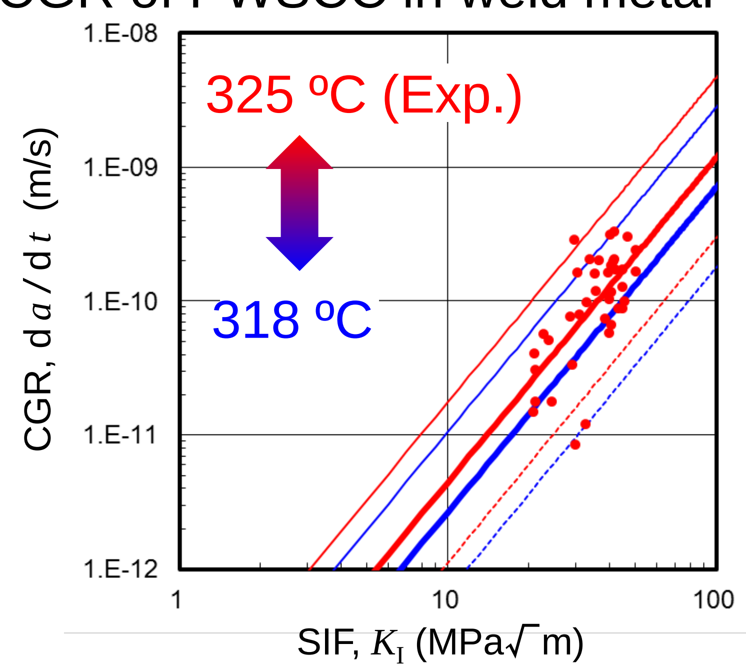


# SCC Growth Behavior in Ni-base Alloy/Welds

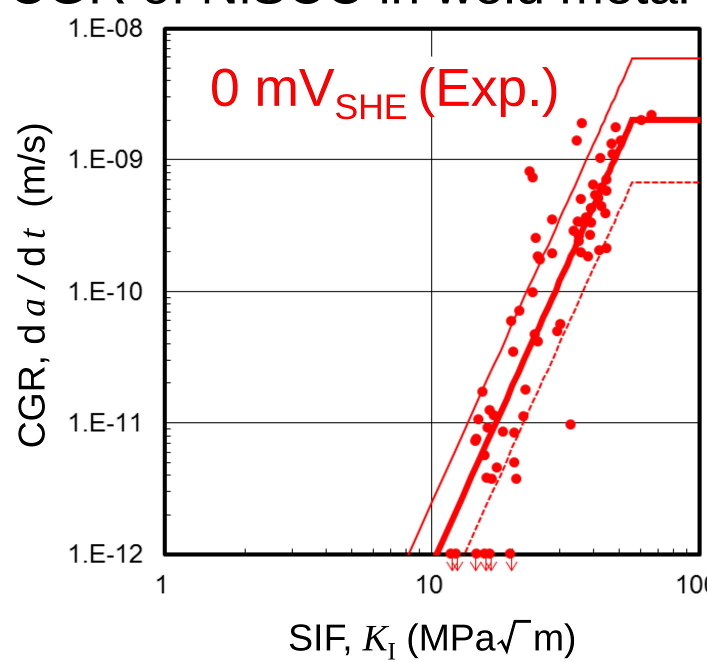
- PWSCC CGR in dissimilar welds




- CGR of PWSCC in weld metal

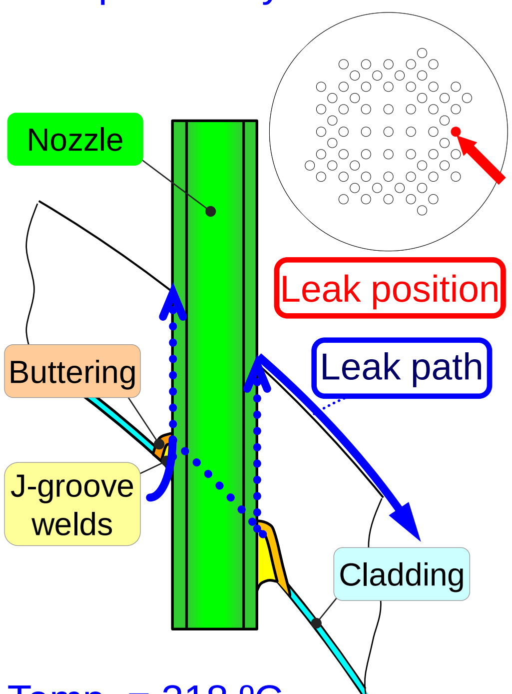



- CGR of NiSCC in weld metal



# Case study for Ohi unit 3 (PWR)

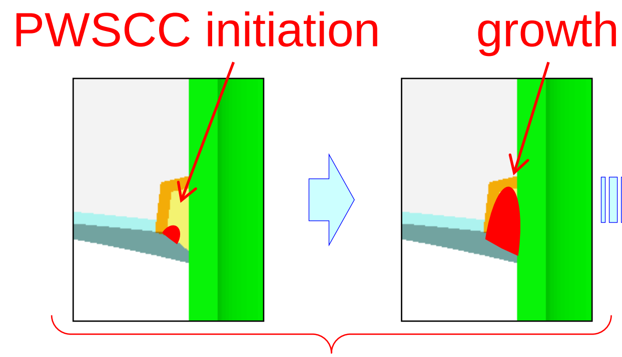

Total number of nozzles = 69
Leak probability ≒ 1.4 %




Temp. = 318 ºC

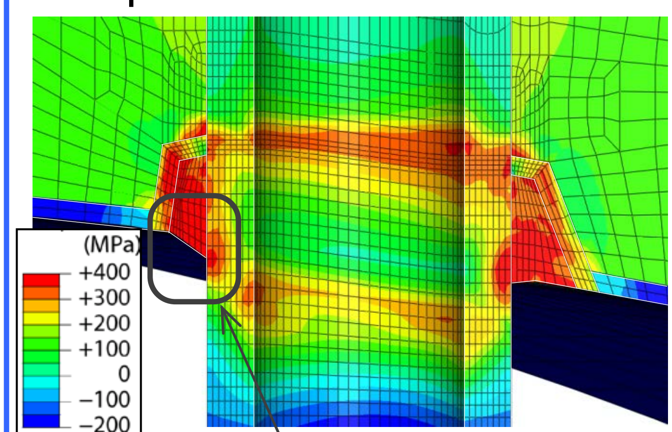
NISA, (2004)
T. Fukumura, *et al.*, (2008)
N. Totsuka, *et al.*, (2010)

## Step 1: Leak probability evaluation
Radial crack initiation and growth in weld metal (welds)



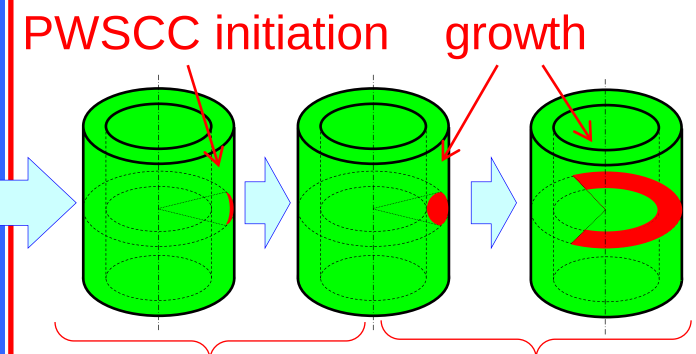

Crack type: 5
(Radial, in weld metal)

Hoop stress distribution



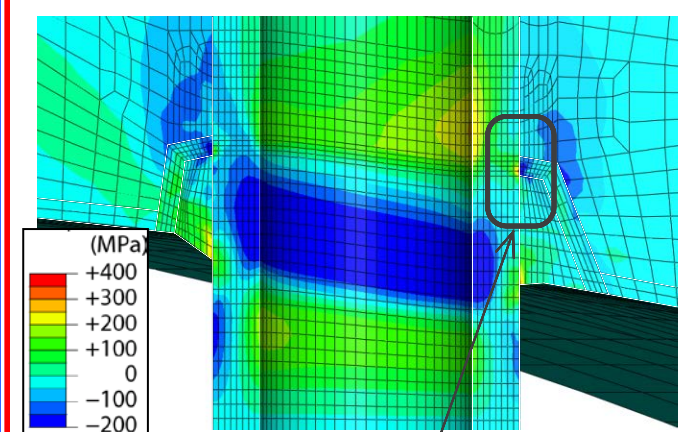

$\sigma_H$ = 379 MPa > $\sigma_{th}$ (250 MPa)
Hardened depth due to grinding = 100 μm

## Step 2: Break probability evaluation
Hoop crack initiation and growth in base metal (nozzles)



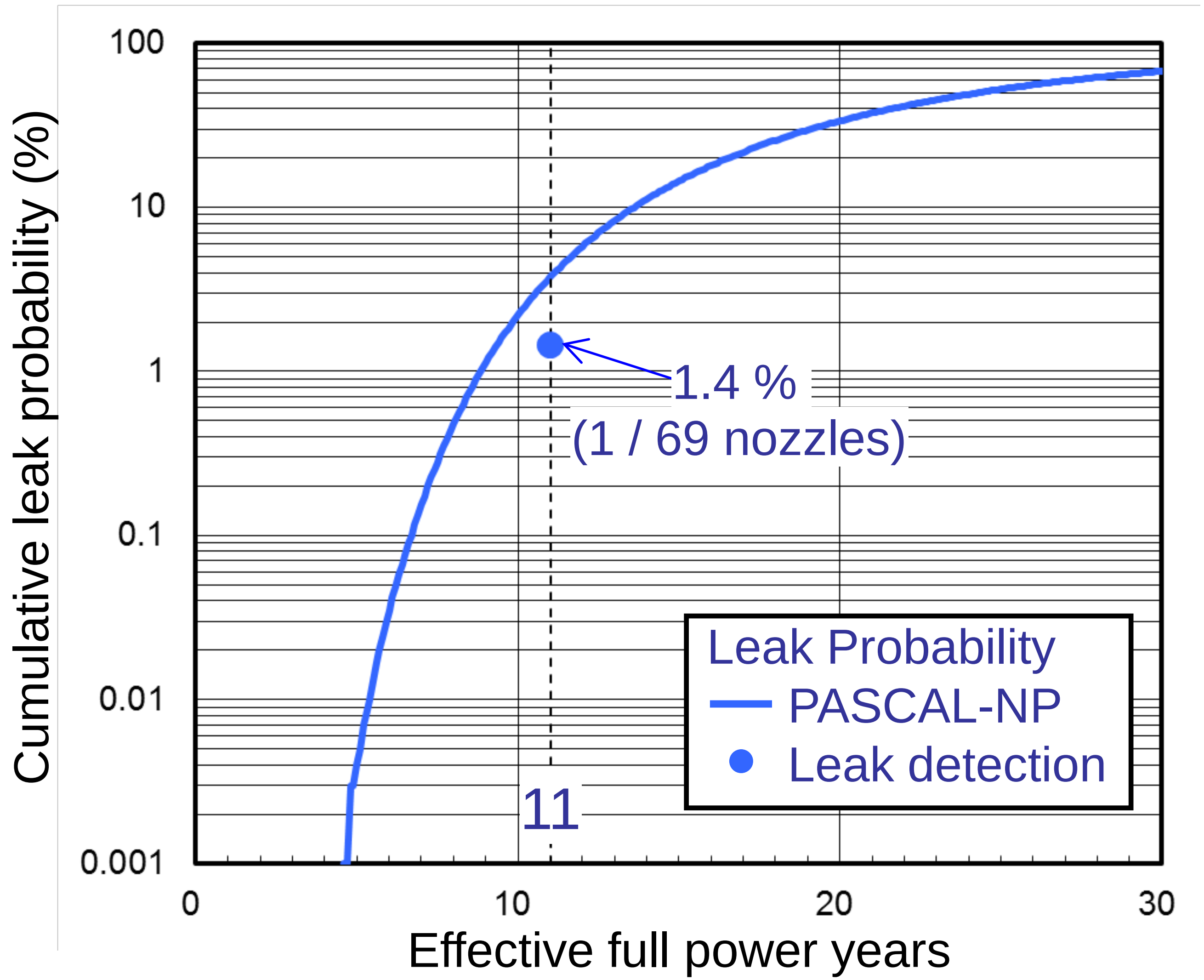

2 (Hoop,Outer)
4 (Hoop,Throgh-wall)

Axial stress distribution




$\sigma_A$ = 389 MPa > $\sigma_{th}$ (250 MPa)
Hardened depth due to machining = 100 μm

# PFM analysis results for Ohi unit 3




At 11 EFPY, PFM analysis results agreed with leak detection data.

# Ongoing Work for PASCAL-NP

- Improvement of Analysis Functions and Models
  - SIF Calculation Method for High Aspect-ratio Crack
  - SCC Initiation Model
  - SCC Growth Rate Hybrid Model
  - Fatigue CGR model, etc.

- Research on Utilization of PASCAL-NP (Future work)
  - Selection of typical input data and analysis functions of PASCAL-NP
  - Verification of PASCAL-NP

# ***Probabilistic Failure Assessment for Welded Joints in Piping***
# ***PASCAL-SP***

(SP: SCC at Welded Joints of Piping)

# Introduction

Many Stress Corrosion Cracks (SCC) Have Been Observed at Some Piping Joints Made by Austenitic Stainless Steel in BWR Plants

SCC Degrades Structural Integrity of Piping

## Assessment of the Structural Integrity at Aged Piping

Deterministic Approaches Have Been Used

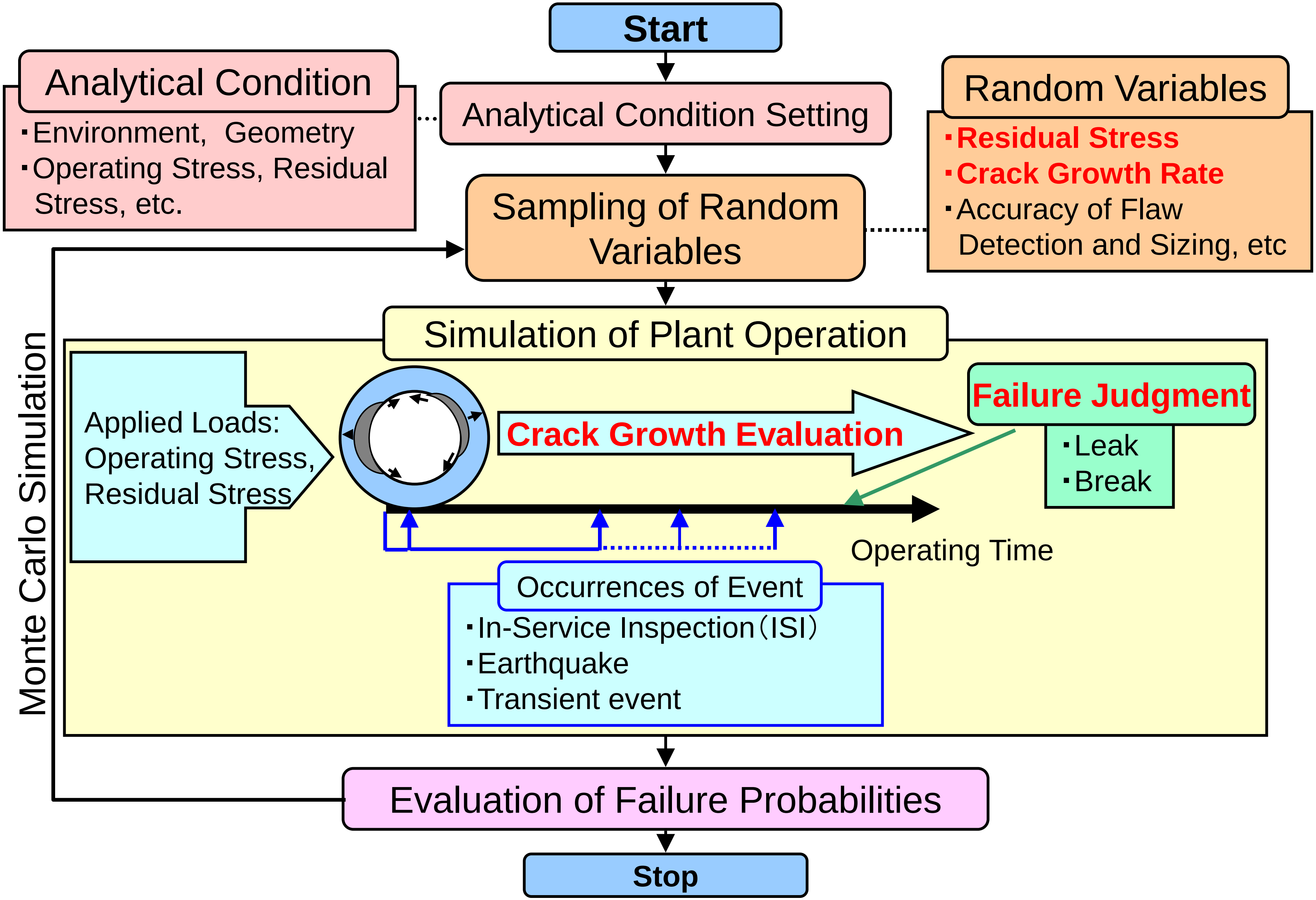
Qualitative Approaches Whether Failure or Not Based on Empirical Values

Possible Uncertainties and Scatters

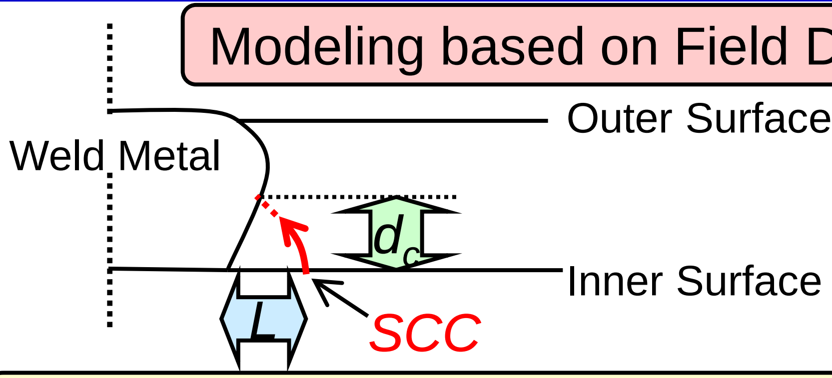
- ✓ Material Properties
- ✓ Crack Initiation and Growth
- ✓ Residual Stress Distribution
- ✓ Accuracy of Flaw Detection and Sizing
- ✓ Occurrence and Magnitude of Earthquake, etc

Probabilistic Fracture Mechanics (PFM) Approach is More Suitable to Evaluate the Structural Integrity of Piping

# Analysis Flow of PASCAL-SP Code

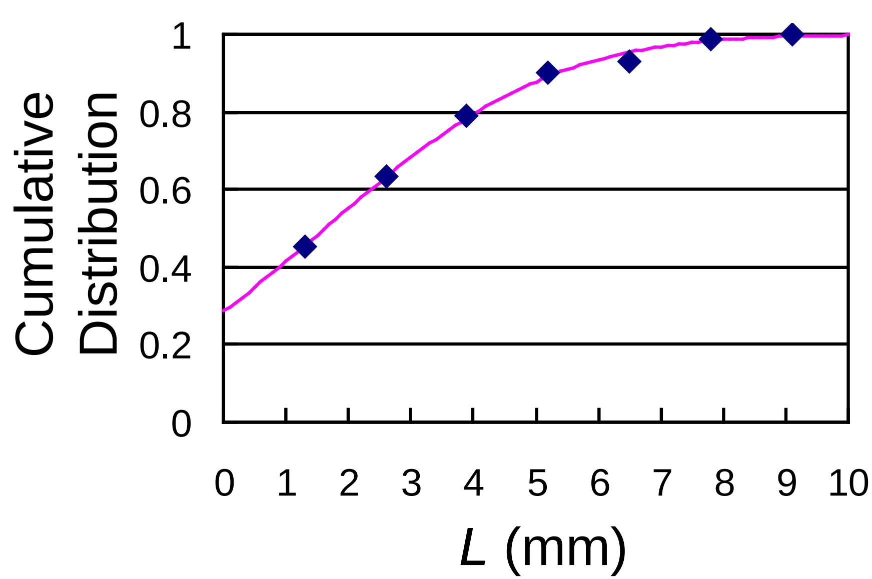


Modeling based on Field Data and the Approach of NISA

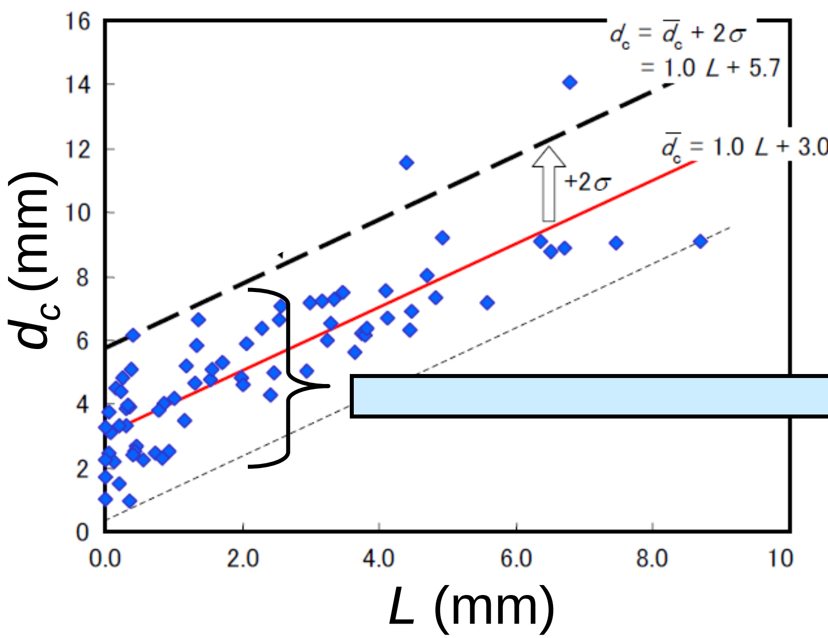



Statistical Modeling for *L*

Observed Data for *L* are Regressed to Normal Distribution




Relationship between Position of Crack Initiation *L* and Crack Depth Reaching Boundary between Base and Weld Metal $d_c$




Probabilistic Modeling of Relation between *L* and $d_c$

Fitted to Normal Distribution

# Crack Growth Model on SCC in Type 316L

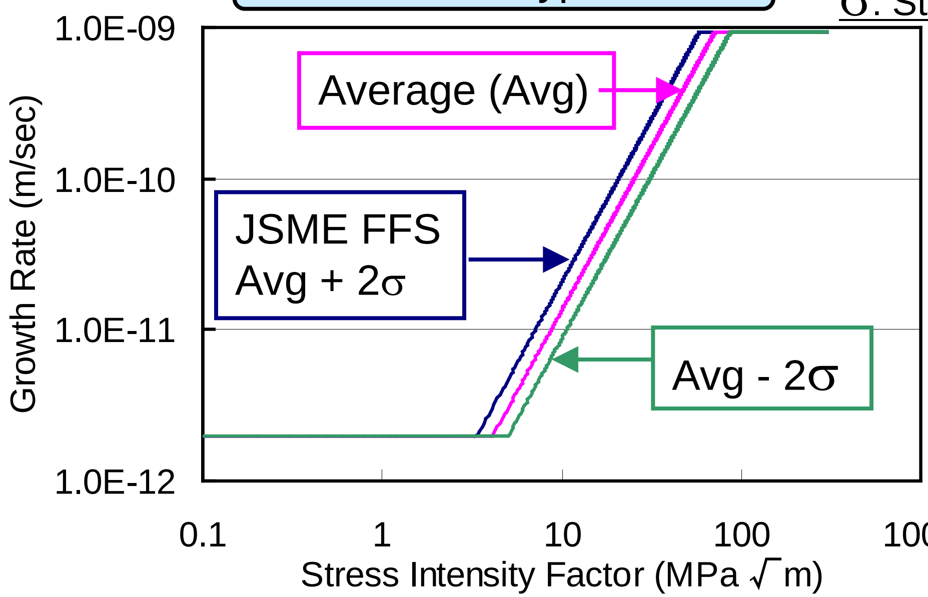
## Crack Growth Model based on the NISA Approach

- ✓ Crack Growth is evaluated by 2 steps, from (1) Heat Affected Zone (HAZ) to (2) Weld Metal Zone.
- ✓ Crack Growth Rate
  - (1) HAZ → CGR Diagram of Sensitized Type 304
  - (2) Weld Metal Zone → CGR Diagram of Type 316L (Low Carbon)
- ✓ Crack Growth Rate Switches from (1) to (2) at Crack Depth $d_c$.

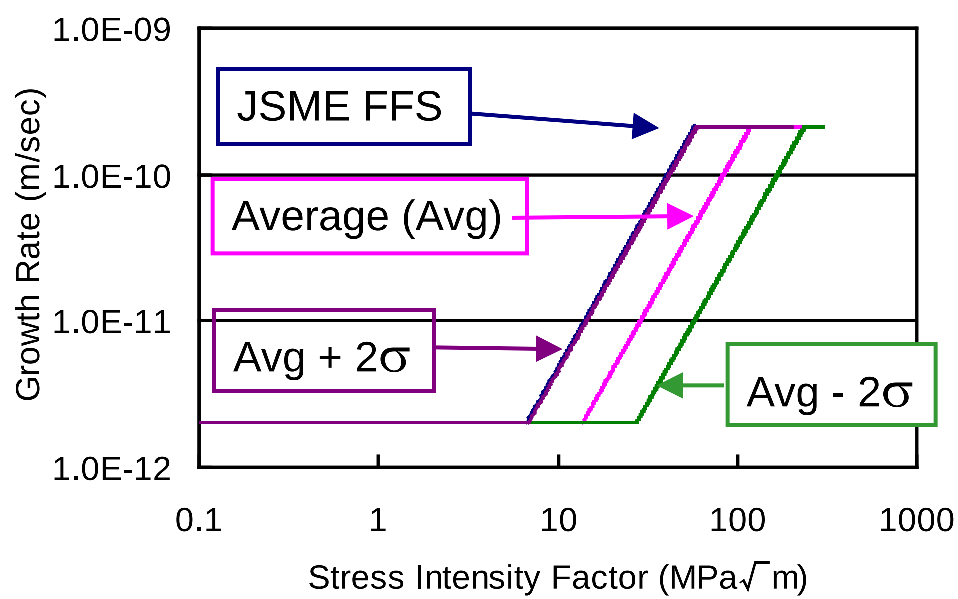
**Probabilistic Model for Crack Growth Rate to Follow Log-Normal Distribution Referring to JSME FFS Code Diagram and its Original Data**

σ: Standard Deviation

Sensitized Type 304

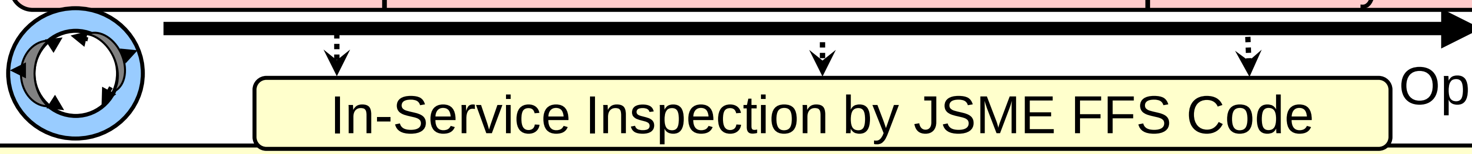



Type 316L



# Models for Accuracy of Flaw Detection and Flaw Sizing

Accuracies of flaw detection and sizing at in-service inspection is an important factor to evaluate failure probability.



Operating Time

In-Service Inspection by JSME FFS Code

**Flaw Detection**

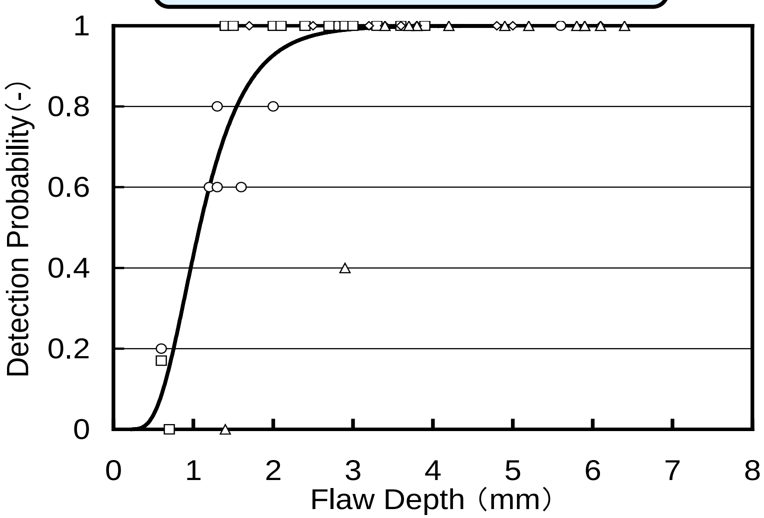
Some models exist, but they are based on old experimental data.

**Flaw Sizing**

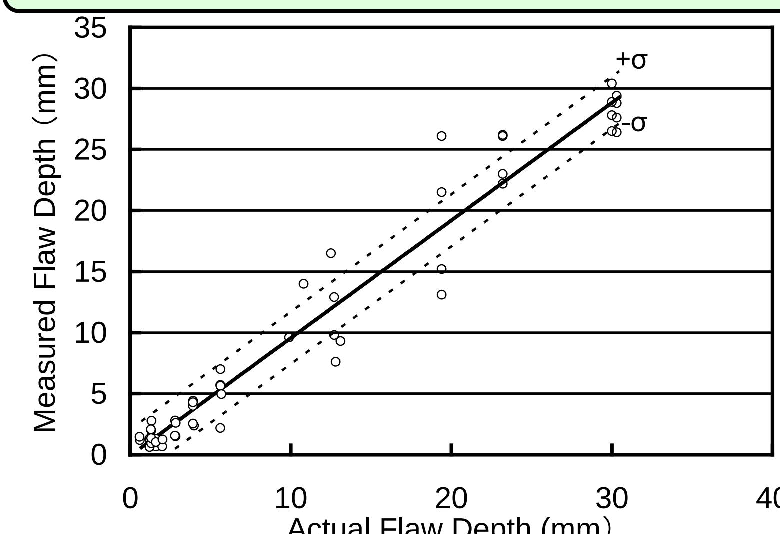
No flaw sizing models exist.

New models were established by regression analyses of data from the Ultrasonic Test & Evaluation for Maintenance Standards (UTS) project in Japan.

**Flaw Detection (SCC)**




**Sizing of Flaw Depth (TOFD Method)**



# Modeling of Uncertainties and Scatters in Residual Stress

Uncertainties and scatters of residual stress distribution may affect SCC behavior.

**Possible Uncertainties and Scatters in Welding Condition**

- ✓ Heat Input
- ✓ Welding Velocity, etc

**Uncertainties and Scatters of Residual Stress Distribution**

- ✓ We Assumed Uncertainties and Scatters Follows Normal Distribution.

## Outline of Modeling

**Experiments of Welded Pipe Joint**

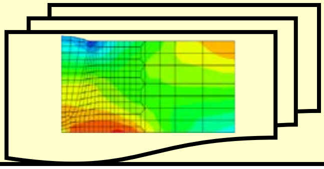
- ✓ Record of Welding Conditions
- ✓ Evaluation of Uncertainties and Scatters of Residual Stress

**Parametric FEM Analyses verified by the Experiments**

- ✓ Establishing Database Including Uncertainties and Scatters

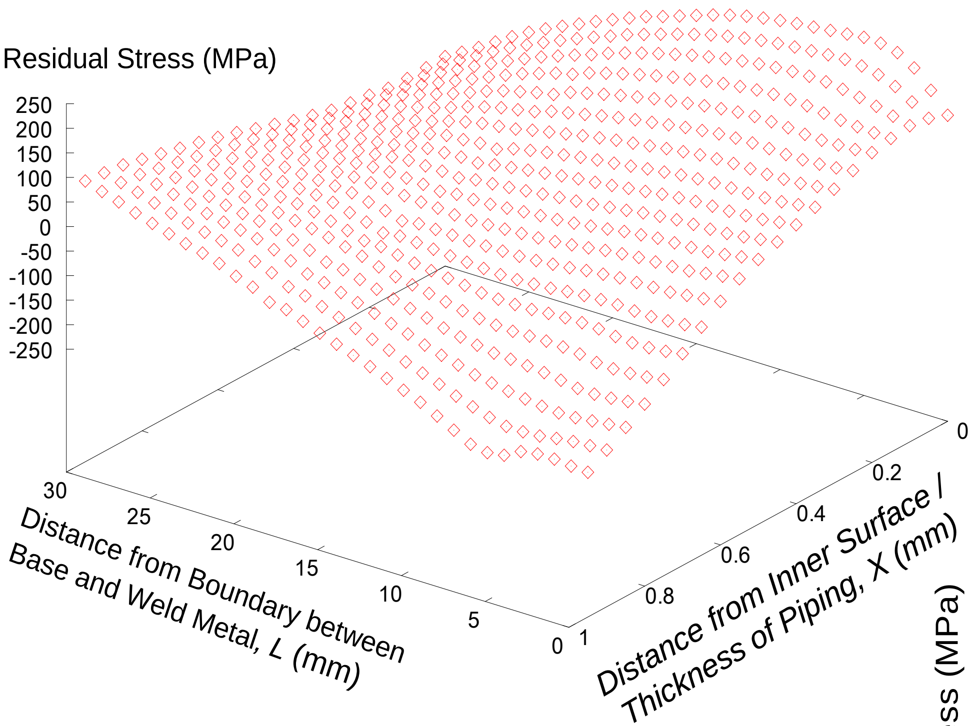
**Modeling Uncertainties and Scatters of Residual Stress Distribution**

**Database**



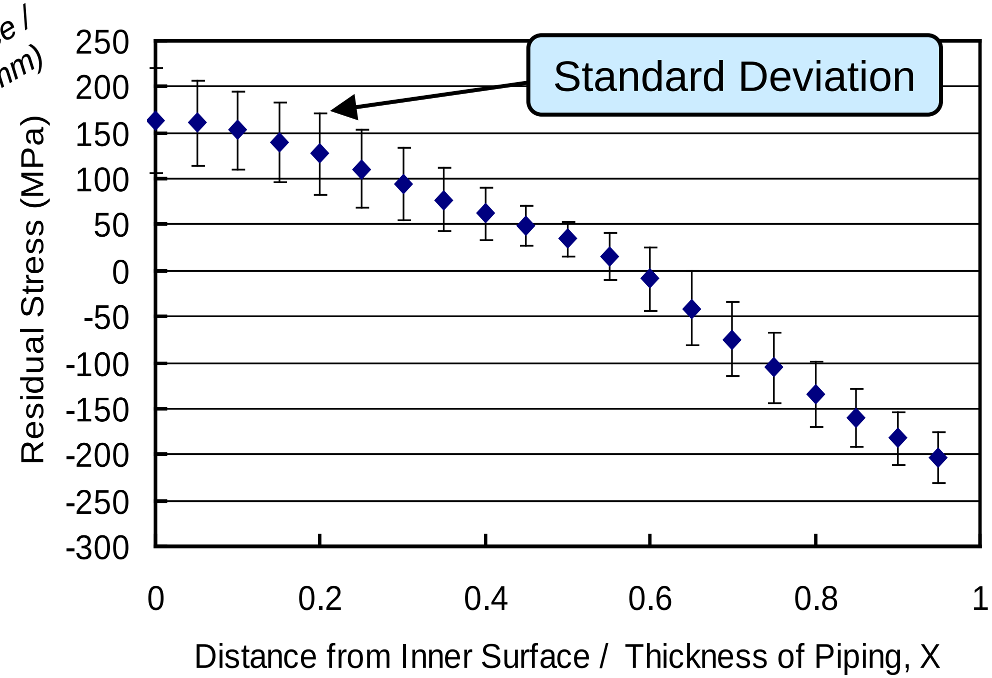
# Example of Residual Stress Distribution

Residual Stress Database by Parametric FEM Analyses Concerning Heat Input and Welding Velocity

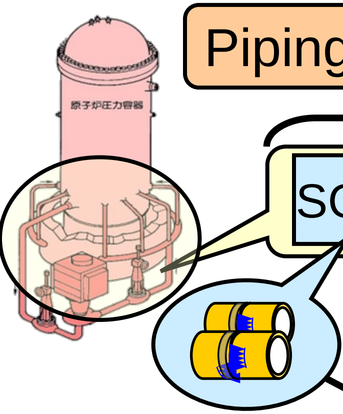



- 250A Sch. 80 pipe butt weld by submerge arc welding
- Heat input: ~20.7 (kJ/cm)
- Welding velocity: ~0.00113 (m/s)

Through-thickness residual stress distribution @ *L* = 1 mm



# Failure Judgment



Piping system including welding lines

SG1 | SG2 | SG3 | …

Segment (SG) consisting of several welding lines is defined.

Intact

Failure Judgment of Single Welding Line

**Leak**
When cracks grow through the wall and the leak from the crack is detectable

**Break**
When applied stress exceeds the failure stress

**Maintenance and Replacement (MR)**
When the crack detected at ISI is judged to be significant by the evaluation method of JSME FFS Codes

**Evaluation of Entire System Failure Probability**

1. Probability of Single Welding Line
2. Probability of Segment

# Application of PFM analysis Results

## ① Benchmark Analysis

Confirmation of the reliability of the PFM analysis codes through the benchmark analyses on SCC and fatigue
→presented by Dr. Li

## ② Quantification of safety margin

Deterministic assessment ←Comparison→ Probabilistic assessment by PFM

| Deterministic assessment | Probabilistic assessment by PFM |
|---|---|
| ✓Safety factor is used based on the knowledge.<br>✓Assessment if the piping will break or not. | ✓Best estimate method considering the uncertainties and scatter of material properties, stress distribution, CGR, NDE accuracy<br>✓Failure probability considering the aging degradation is evaluated. |

## ③ Seismic Safety Analysis

Failure probabilities and fragility curves of aged pipes
✓Presented by Dr. Li

# Ongoing Work for PASCAL-SP

- Improvement of Analysis Functions and Models
  - SIF Calculation Method for High Aspect-ratio Crack and Through-wall Crack
  - SCC Initiation Model
  - Low Probability - High Confidence Calculation, etc.

- Modification to include Thermal Aging Degradation
  - Two Parameter Method, etc.

- Research on Utilization of PASCAL-SP (Future work)
  - Selection of typical input data and analysis functions of PASCAL-SP
  - Verification of PASCAL-SP

# *Structural Reliability Assessment of Wall-thinned Piping* *PASCAL-EC*

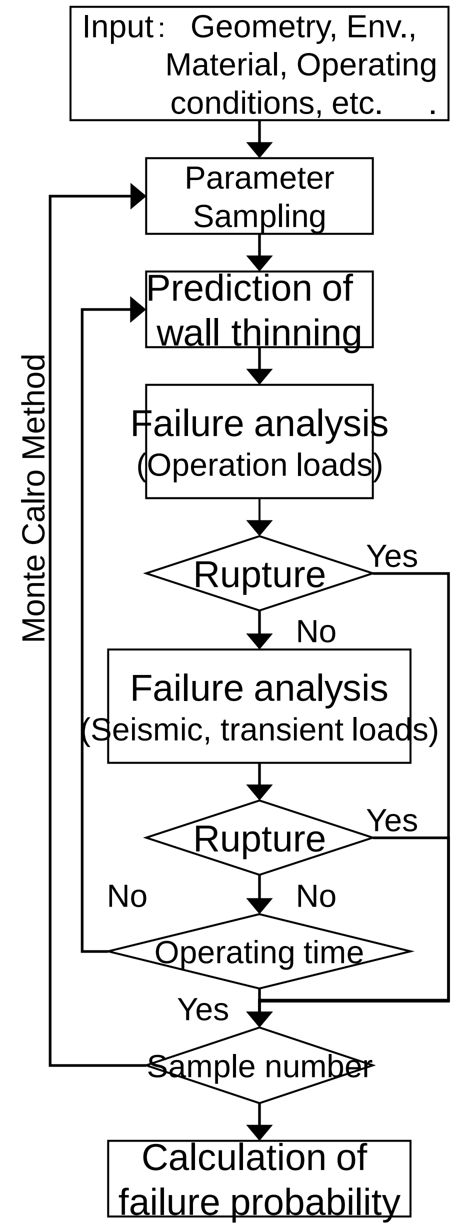
(EC: Erosion and Corrosion)

# Failures due to Wall Thinning

- Examples in USA･･･>30 events (PWR／BWR)
  - PWR Feedwater Piping･Elbow･Shell (Rupture)：
    - ✓Oconee-2, Surry-1&2, ANO-1, Loviisa-1, Millstone-2&3, Fort Calhoun, Point Beach-1
  - PWR Feedwater System (Leak)：
    - ✓Oconee-3, Zion-1, San Onofre-2, Callaway
  - PWR Feedwater Piping Wall Thinning：
    - ✓Trojan, Surry-2, Diablo Canyon
  - BWR Feedwater Heater Shell Failure：
    - ✓Dresden, Pilgrim, Susquehanna
  - BWR Drain Piping･45$^{o}$ Elbow Leak：
    - ✓Vermont Yankee, LaSalle
- PWR Secondary Piping Rupture: Mihama Unit 3

# Structural Reliability Assessment of Thinned Pipe

- Failure Probability Analysis Code for Carbon Steel Pipe Thinned due to Erosion/Corrosion developed at JAEA: ***PASCAL-EC****
- Wall thinning rate: Kastner's equation
  - ✓ Parameters with uncertainties (Chemical comp., Water chemistry, Temperature, etc.) are treated as probabilistic ones. Failure probability is calculated by Monte Carlo simulation
  - ➢ Probabilities to reach the minimum required thickness and rupture as a function of operation time
- Failure analysis is performed using applied loads (pressure, design bending moment). Leakage and/or rupture are calculated as a function of operation time, i.e. progression of wall thinning.
  - ➢ Failure diagram developed at JAERI based on the experiments
  - ➢ Applicable to seismic loading considering fatigue and ratcheting

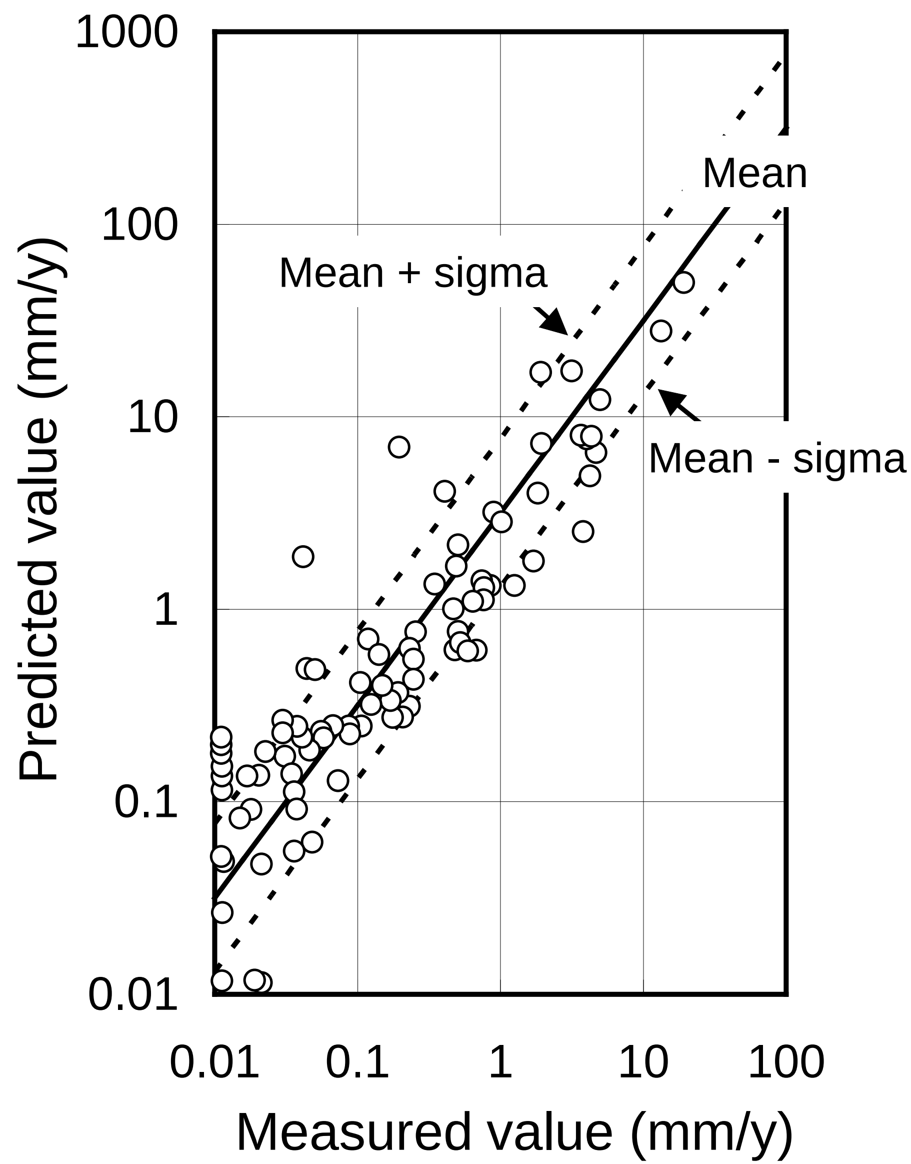


Analysis flow of PASCAL-EC

* PFM Analysis of Structural Components in Aging LWR – Erosion / Corrosion

# Scatter of Wall Thinning Behavior

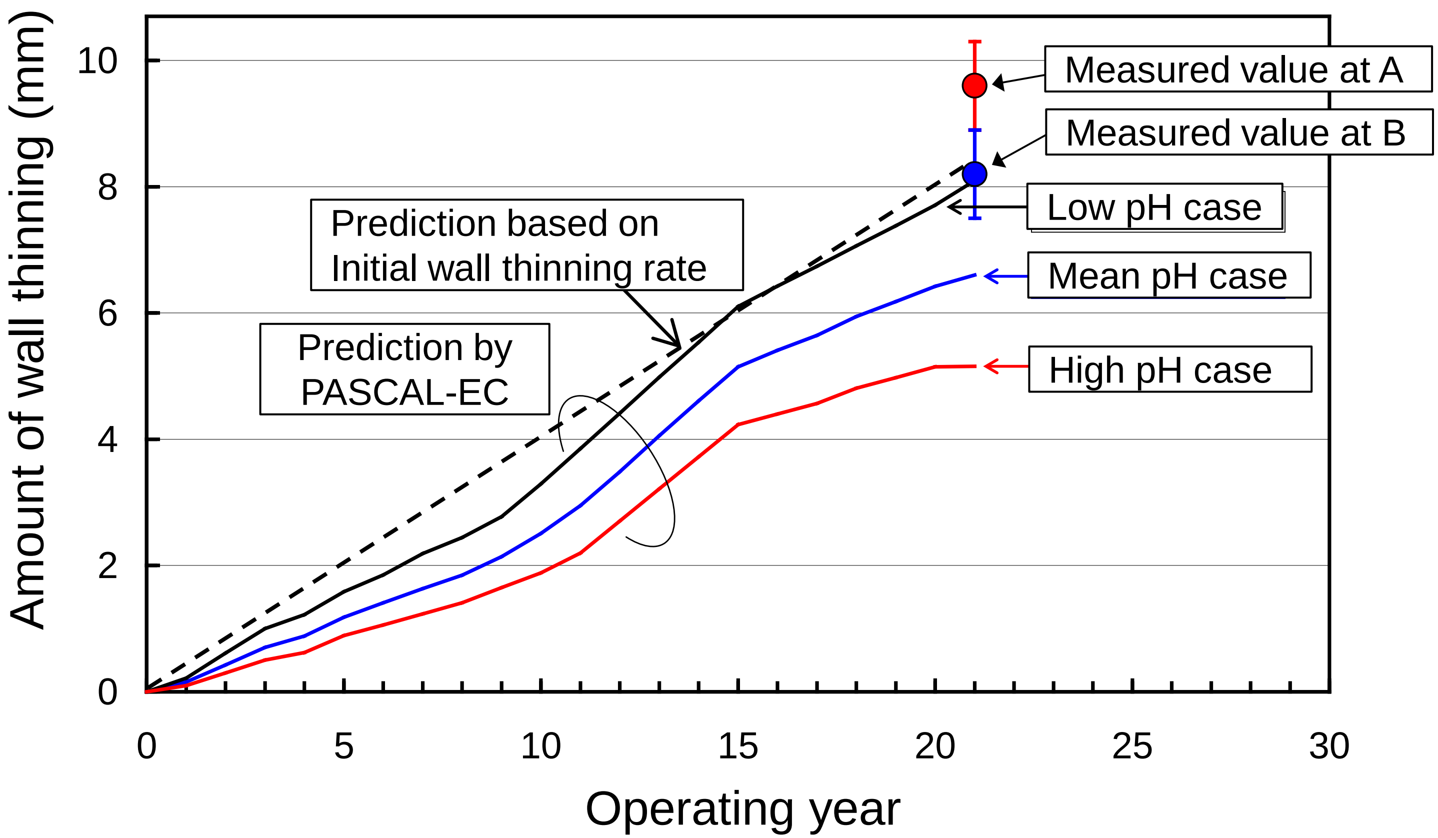
- Statistical Analysis of Wall Thinning due to E/C based on Experiments and Prediction by Kastner
- Average Difference and Standard Deviation for Log-normal Distribution of Kastner's eq. (single phase flow): 3.2 and ~2.4
- These value are used for probabilistic analysis for wall thinning rate calculation.




Comparison of measured data and prediction

# Analysis Results of Wall Thinning

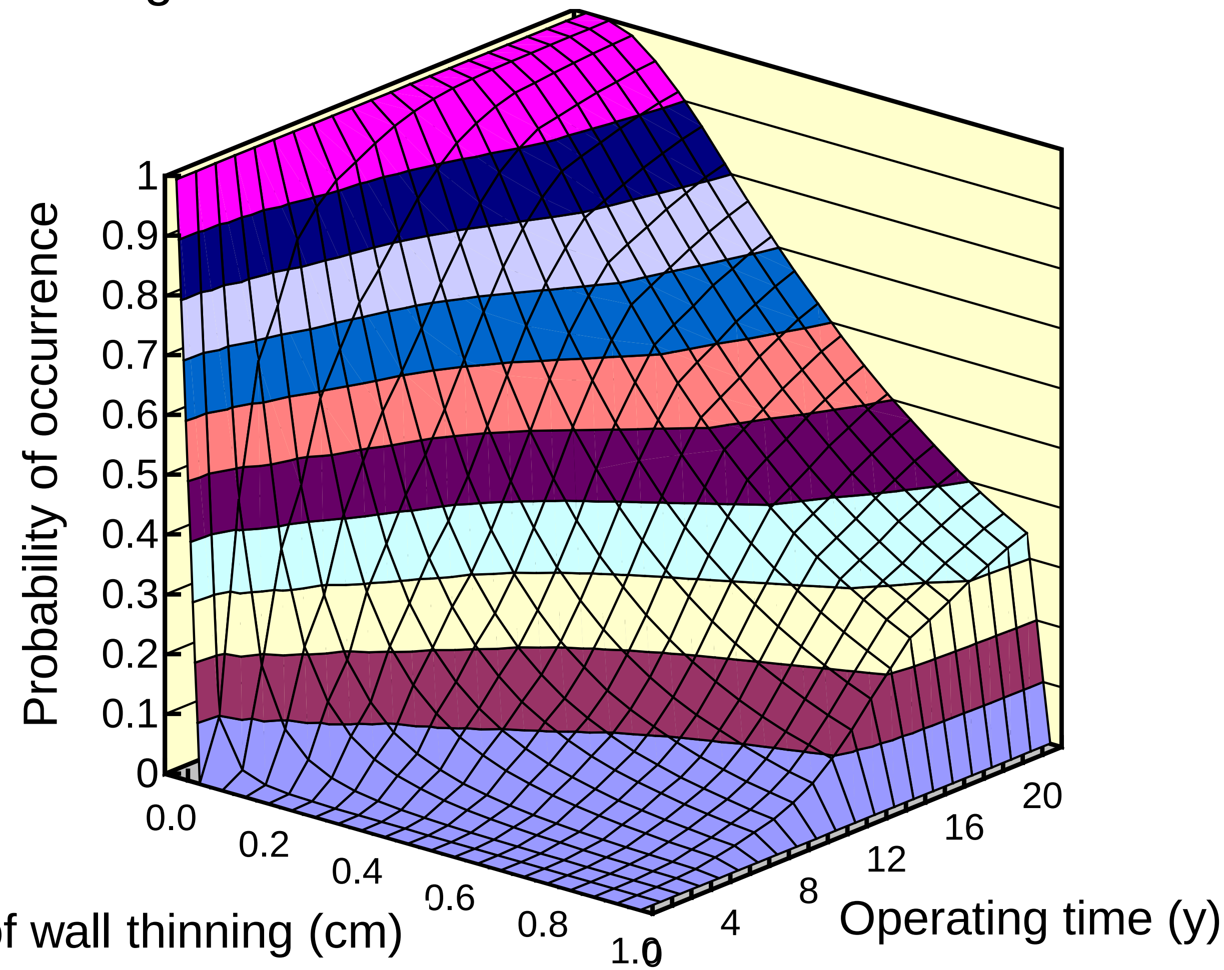
- Wall Thinning Behavior of Secondary Piping at Mihama Unit 3
  - Calculated Wall Thinning with varying pH values and measured thickness at the piping lines A and B



# Probabilistic Analysis Results of Wall Thinning

Probabilistic analysis results by PASCAL-EC

- Case Study of wall thinning at Mihama unit 3
- Results obtained from data scatter in previous figure
  - Log-normal distribution with std. dev. of 2.4



# Ongoing Work for PASCAL-EC



- Improvement of Analysis Functions
  - Wall Thinning Prediction based on Measured Data
  - Probabilistic Model, etc.

- Research on Utilization of PASCAL-EC (Future work)
  - Selection of typical input data and analysis functions of PASCAL-EC
  - Verification of PASCAL-EC

# Summary

- PFM analysis codes PASCAL series have been developed for the application to the regulation, codes and standards.
- The PASCAL series have various target components with aging degradation such as neutron irradiation embrittlement, SCC fatigue and wall thinning as follows;
  - Reactor Pressure Vessel Corebelt Region
  - Nickel Alloys and the Welds
  - Primary Piping Welded Joints
  - Carbon Steel Piping
- These codes have been published and are being updated and verified for standardizing the PFM analysis methods.
- Based on the analysis results for various portions of components and piping, PFM analysis technique is highly expected for the risk quantification for safety improvement, optimization of inspection, review and quantification of safety margin, etc.

# How to get PASCAL Codes

- Access PRODAS Website
  - http://prodas.jaea.go.jp/
  - JAEA Program and Database Retriaval System
- Users' Manual
  - PASCAL Ver.3
    - ✓http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAEA-Data-Code-2010-033.pdf
  - PASCAL-NP
    - ✓ http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAEA-Data-Code-2013-013.pdf
  - PASCAL-SP
    - ✓ http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAEA-Data-Code-2009-025.pdf
  - PASCAL-EC
    - ✓ http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAEA-Data-Code-2006-001.pdf