An Overview of the Risk-Informed Pressurized Thermal Shock Re-evaluation Project

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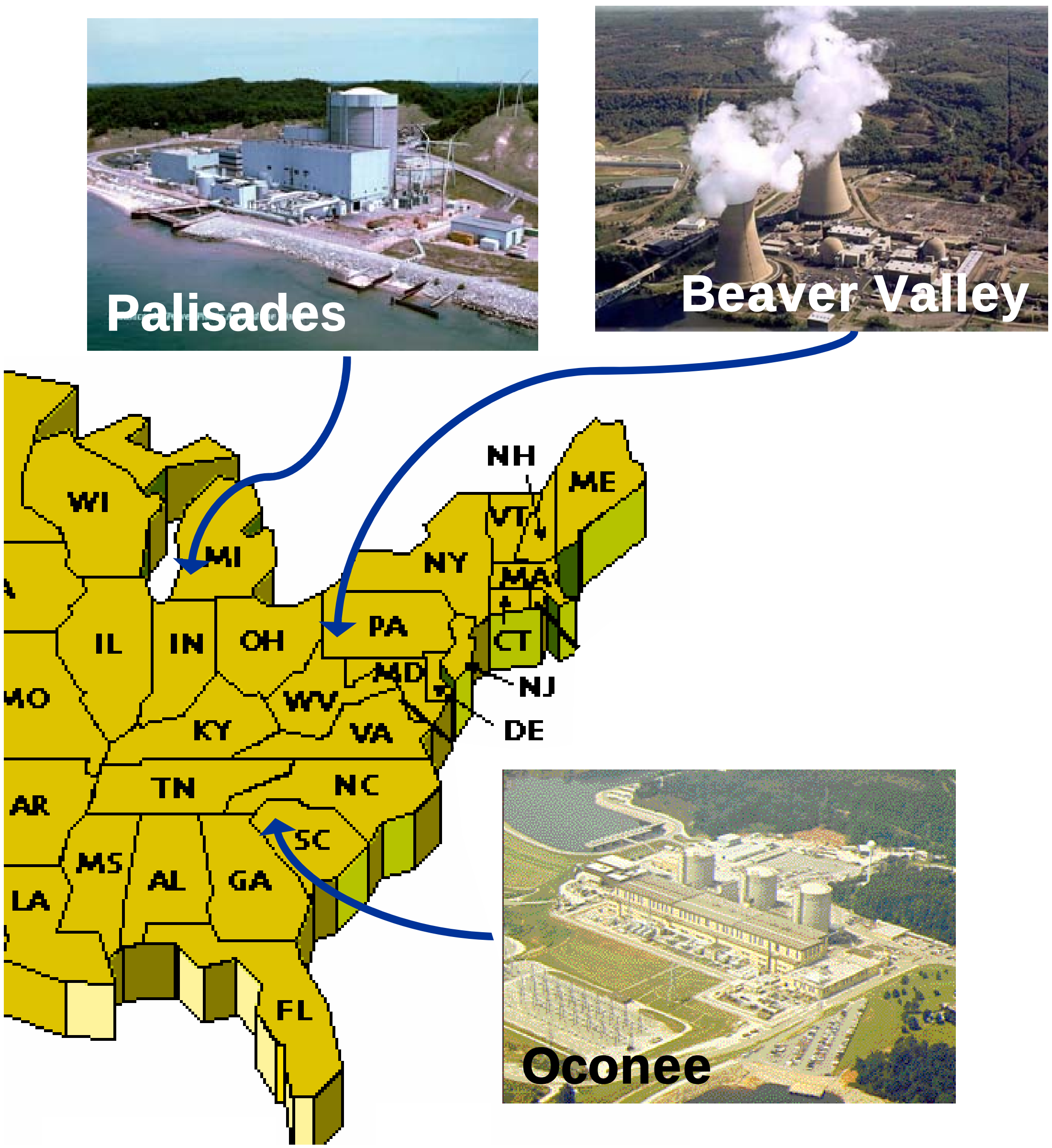
Workshop

Lyon, France

September 25 –27, 2006

Scope of Analysis Performed in PTS Re-evaluation Analysis



All PWR manufacturers

1 Westinghouse

1 CE

1 B & W

2 plants very close to the current PTS screening criteria

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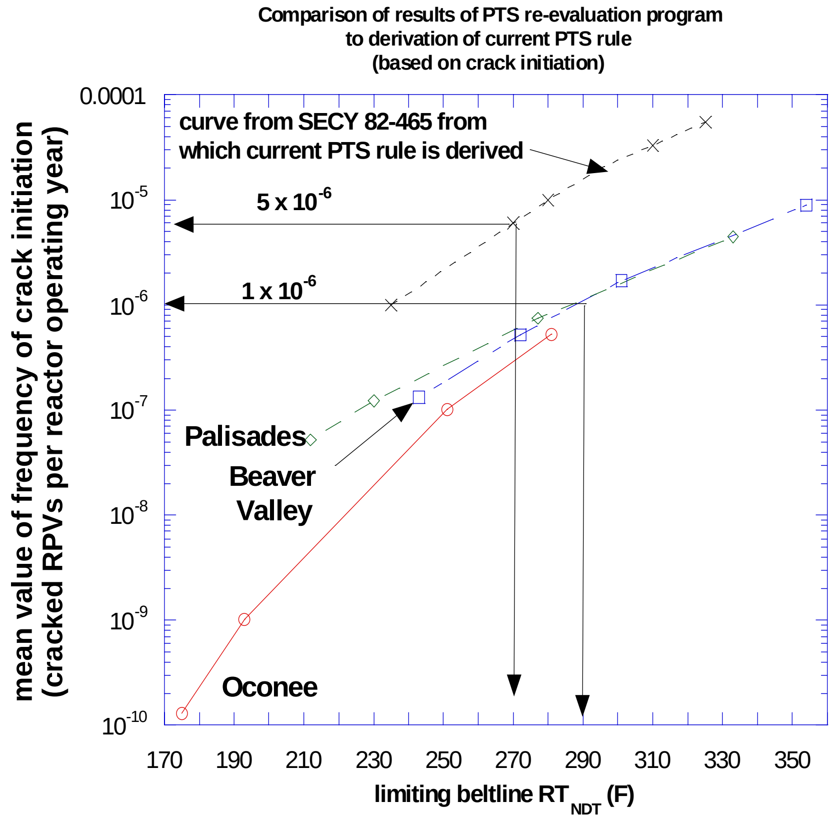
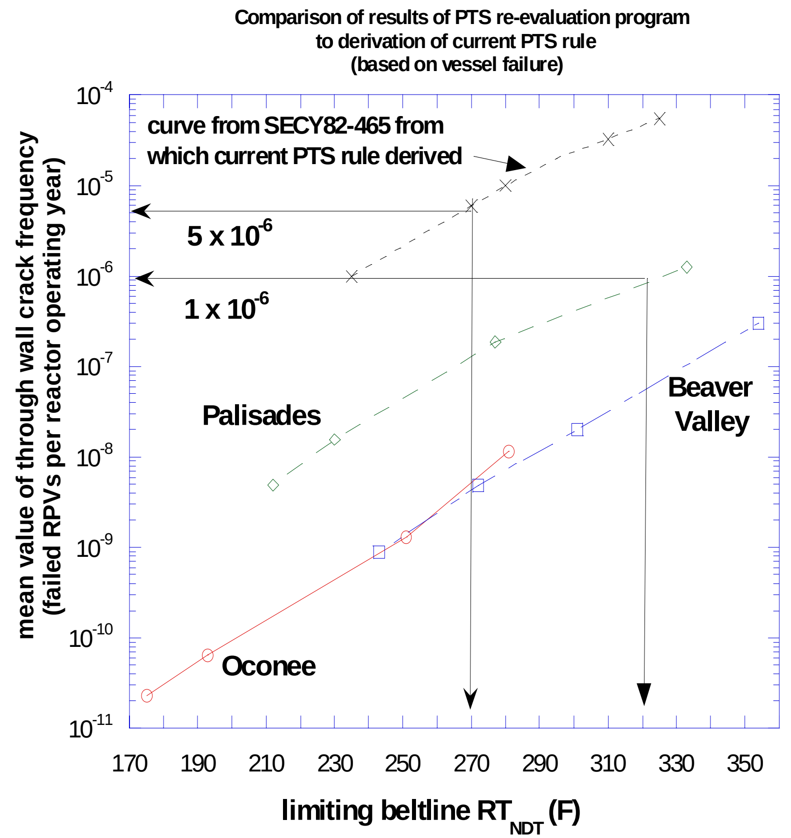
At 60 Operational Years, Maximum Estimated Mean Through-Wall Crack Frequency (TWCF) for the Three Plants is ~1.6e-08 (for Palisades)

Reactor	EFPY(1)	RT_{NDT}(2) (°F)	Mean FCI (cracked RPVs per reactor operating year)	Mean TWCF (failed RPVS per reactor operating year)
Oconee(3)	32	175	1.29e-10	2.30e-11
	60	193	1.02e-09	6.47e-11
	Ext-Oa	251	1.01e-07	1.30e-09
	Ext-Ob	281	5.42e-07	1.16e-08
Beaver Valley(4)	32	243	1.32e-07	8.89e-10
	60	272	5.19e-07	4.84e-09
	Ext-Ba	301	1.71e-06	2.02e-08
	Ext-Bb	354	8.87e-6	3.00e-07
Palisades(5)	32	212	5.22e-08	4.90e-09
	60	230	1.23e-07	1.55e-08
	Ext-Pa	277	7.46e-07	1.99e-07
	Ext-Pb	333	4.47e-06	1.26e-06

RT_{NDT} = 290 F corresponds to 1e-6 CRACK INITIATIONS per reactor operating year
RT_{NDT} = 320 F corresponds to 1e-6 FAILED vessels per reactor operating year (Consistent with PTS Rulemaking Plan {NRC ADAMS# ML060530653})

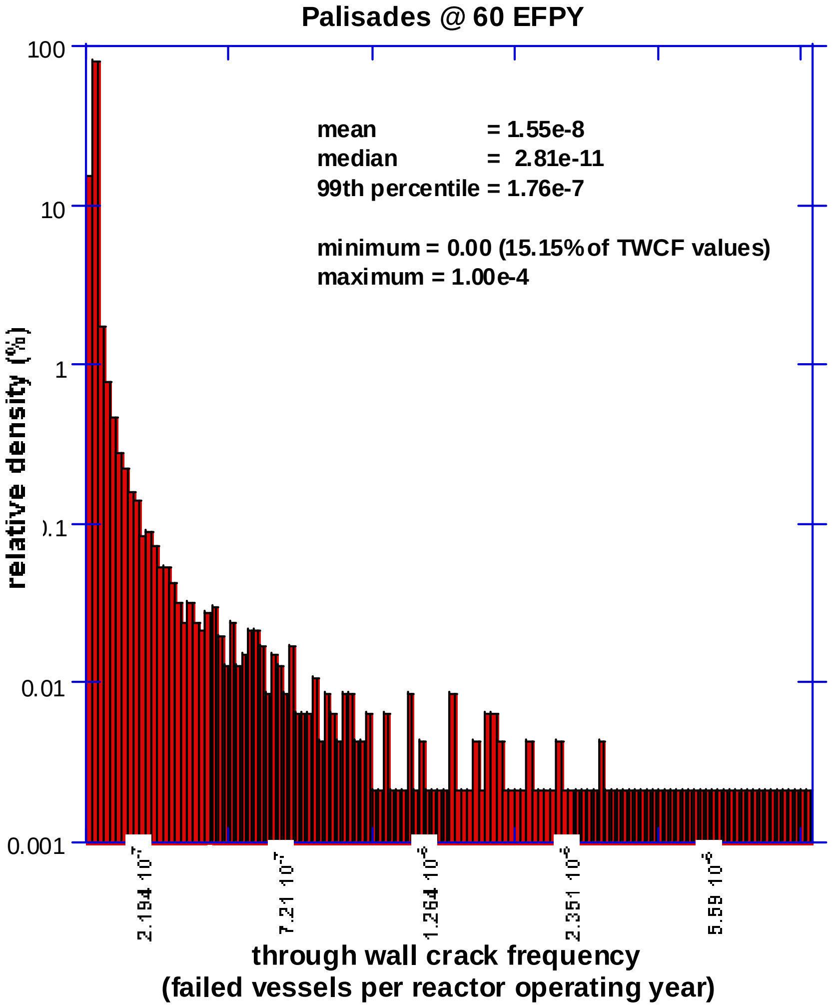


Note: Includes 60 F margin term for curve from SECY 82-465 does not include margin term for Palisades, Beaver valley, and Oconee



Note: includes 60 F margin term for curve from SECY 82-465 does not include margin term for curves for Palisades, Beaver Valley, and Oconee

The “bottom line” of an analysis performed by FAVOR is a statistical distribution of the through-wall crack frequency



PTS Re-evaluation Project Conclusions

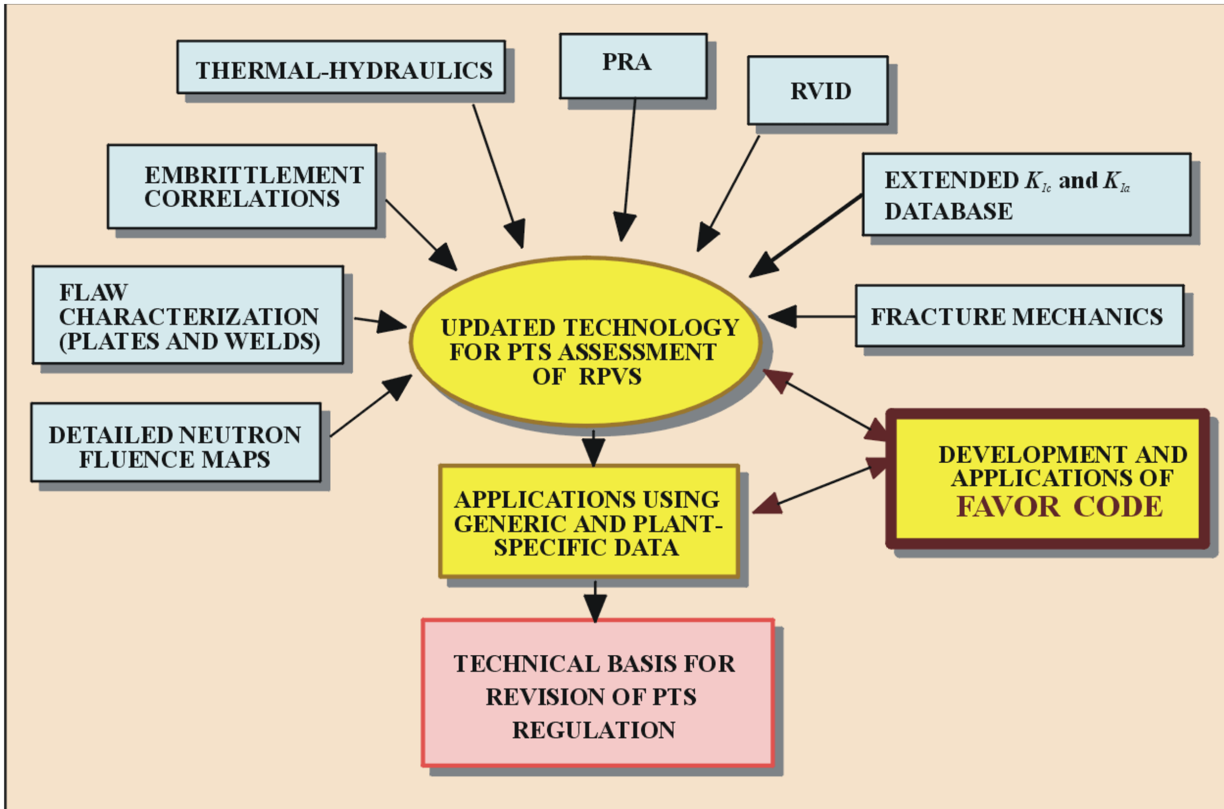
The analyses performed during the *PTS Re-evaluation Project* indicate that the degree of PTS challenge for currently anticipated lifetimes and operating conditions is low.

The US domestic commercial operating fleet of 68 PWRs is in little danger of exceeding either the limit on TWCF of 5e-6/yr expressed by current PTS regulations or the proposed new value of 1e-6/yr. (Consistent with the PTS Rulemaking Plan {NRC ADAMS# ML060530653})

The results provide a technical basis to support a relaxation of the current PTS regulations while continuing to provide reasonable assurance of adequate protection to public health and safety.

The PTS Re-evaluation Project Integrated Advancements Across a Range of Technical Disciplines Relevant to PTS Assessement Methodologies

Updated Technologies were Implemented into the FAVOR Code to Perform Integrated Re-Evaluation of Current PTS Rule

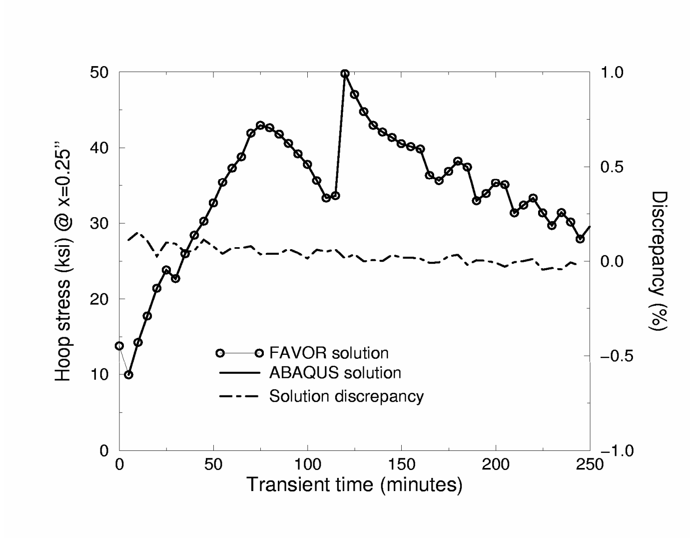


There has been an ongoing collaborative effort to validate FAVOR solutions

- Generated ORNL letter report, i.e.,

Verification and Validation of the FAVOR Code – Deterministic Load Variables,

that compared FAVOR and ABAQUS finite element solutions for temperature, stress, and K_I (embedded and surface-breaking flaws) for complex transients

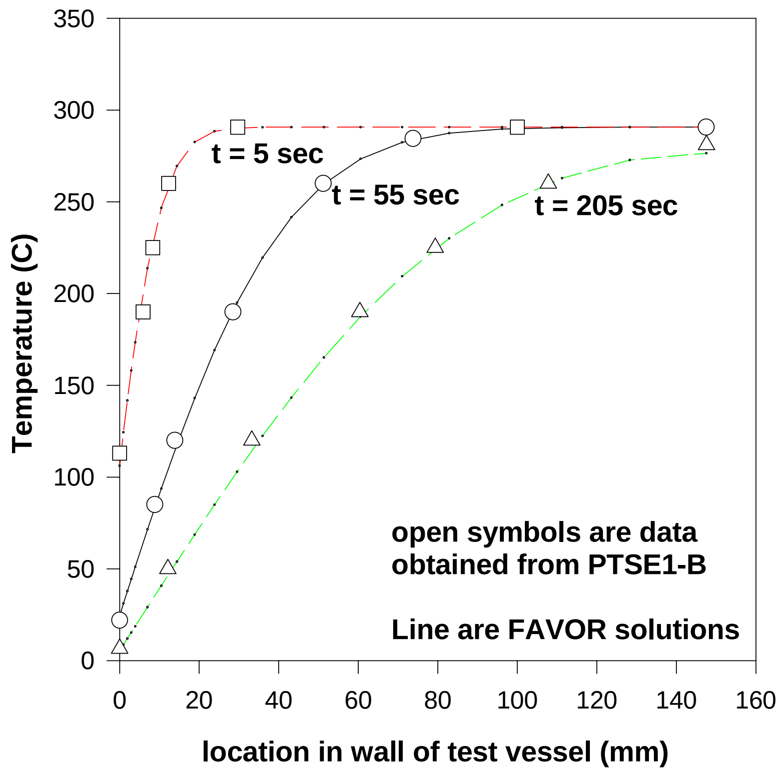


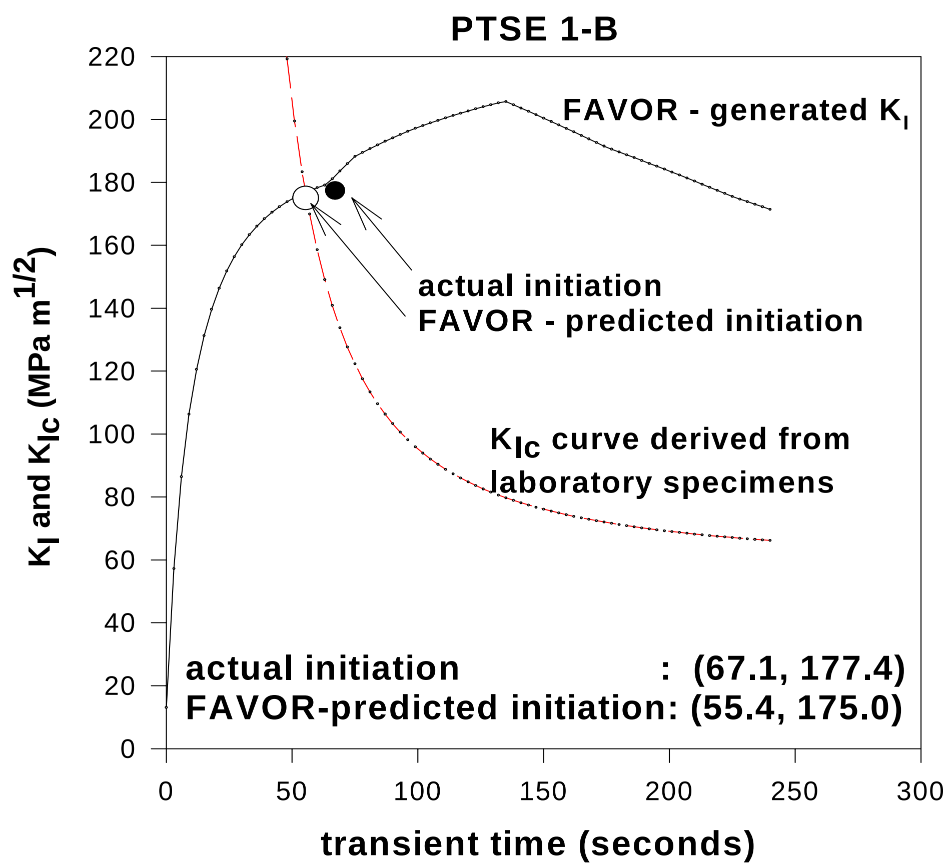
- ORNL Coordinated efforts with other laboratories / industry:

➢ INEEL - V & V of probabilistic (sampling) protocols used by FAVOR
➢ PNNL - V & V of FAVOR processing of flaw-characterization data
➢ Westinghouse - V & V for processing of embrittlement – related correlations
➢ EPRI - V & V of overall FAVOR PFM methodology

A more fundamental aspect of the ongoing validation of FAVOR is demonstration that it can be used to successfully predict the results of large-scale fracture experiments

(2004 ASME PVP Paper – Dickson, EricksonKirk)





The current FAVOR (version 05.1) documentation consists of a Theory Manual and a User's Manual

NUREG/CR-6855
ORNL/TM-2004/245

Fracture Analysis of Vessels – Oak Ridge FAVOR, v04.1, Computer Code: User's Guide

Prepared by
T. L. Dickson, P. T. Williams, and S. Yin

Oak Ridge National Laboratory

Prepared for
U.S. Nuclear Regulatory Commission

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Fracture Analysis of Vessels – Oak Ridge FAVOR, v04.1, Computer Code: Theory and Implementation of Algorithms, Methods, and Correlations

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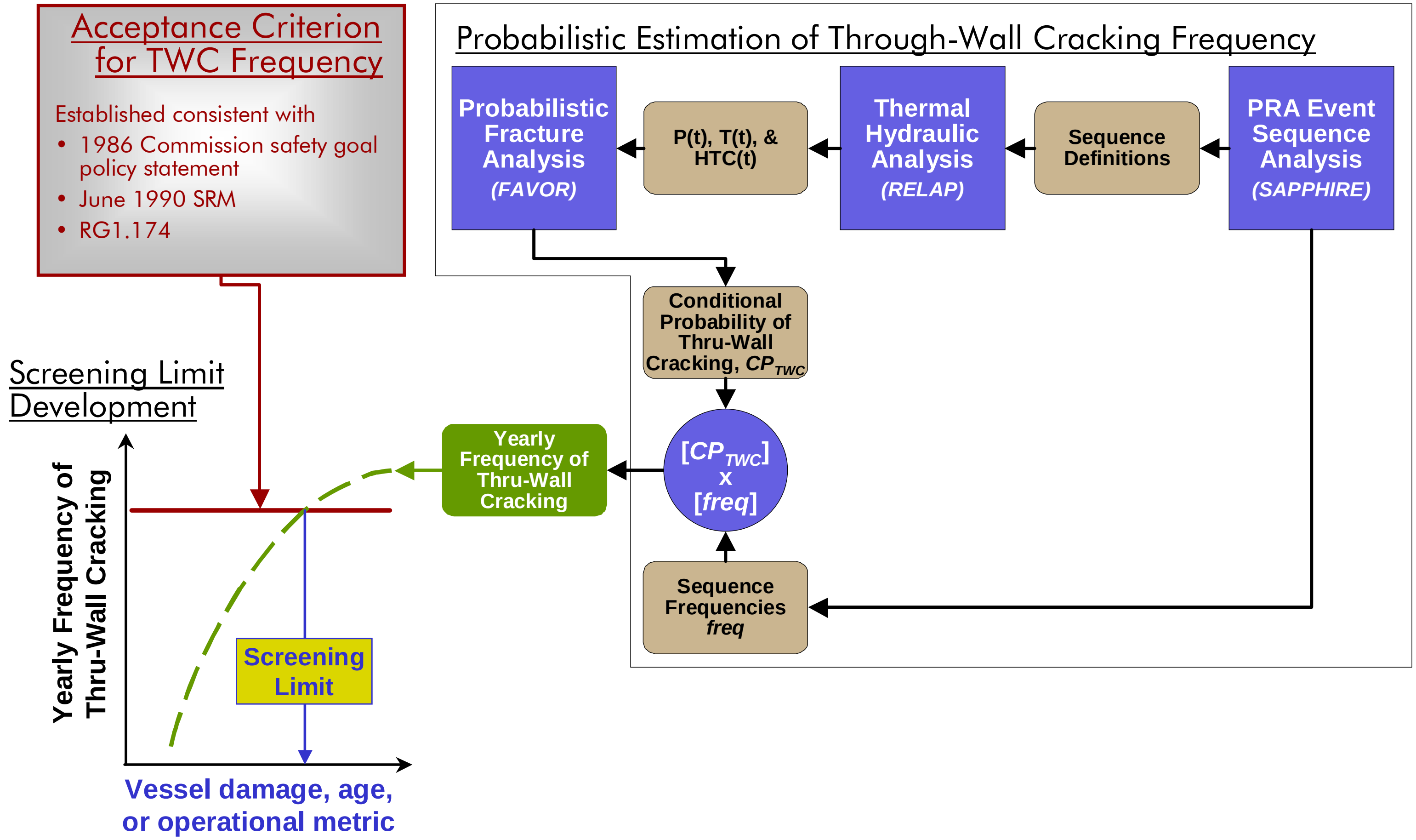
Three Models (Shown in Blue Squares) Provide Essential Elements of the Integrated PTS Assessment



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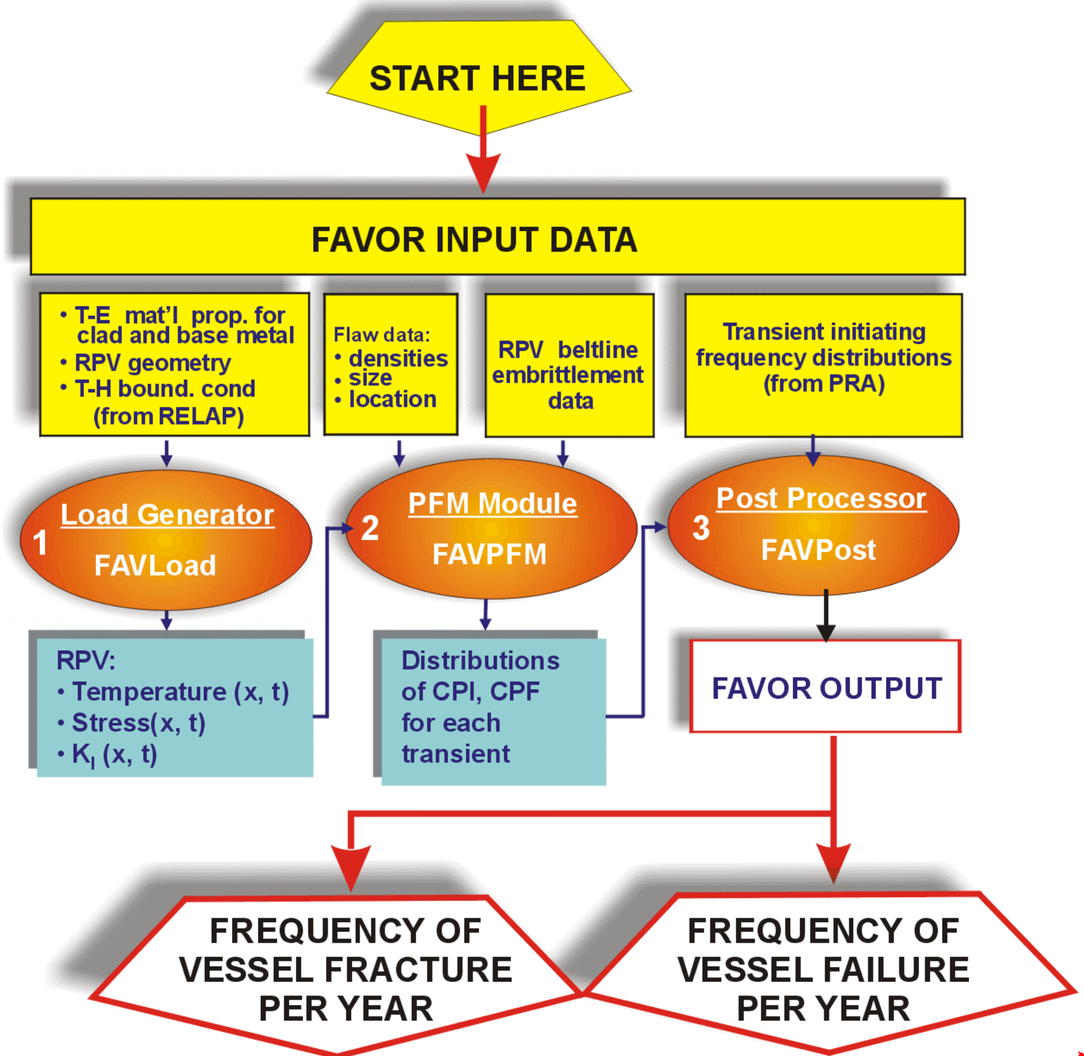
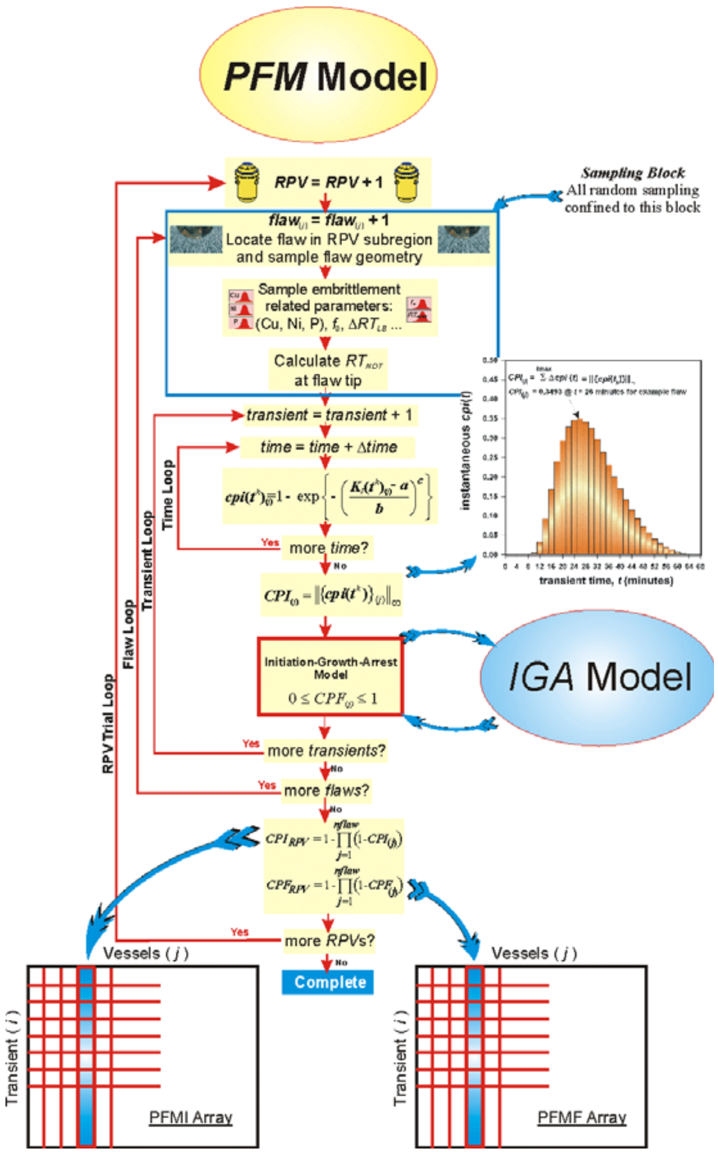
FAVOR Fracture Mechanics Code has a Modular Structure



The structure of FAVOR PFM Module is based on Monte Carlo Technique

The FAVPFM model has four primary nested loops
RPV trial loop (2) Flaw loop (3) Transient loop (4) time loop



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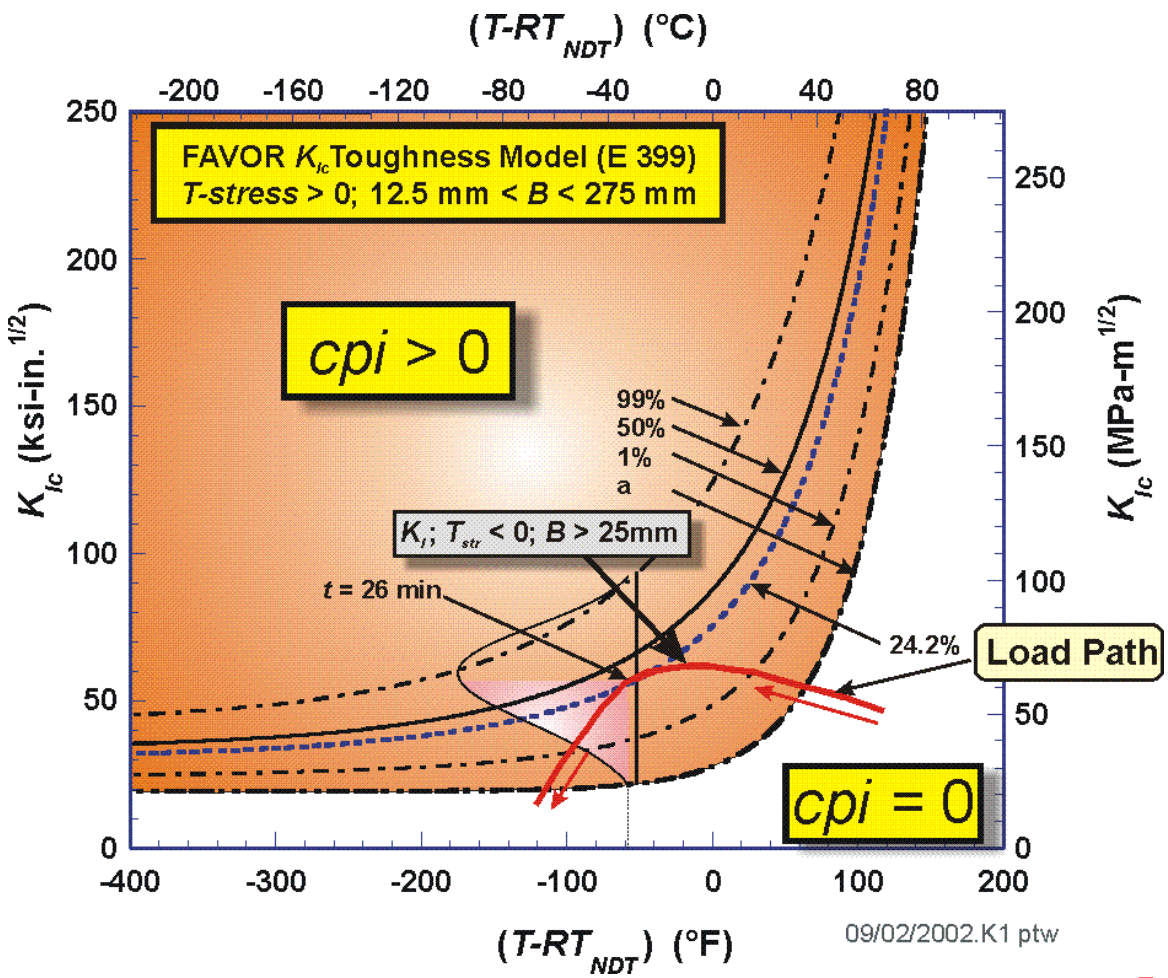
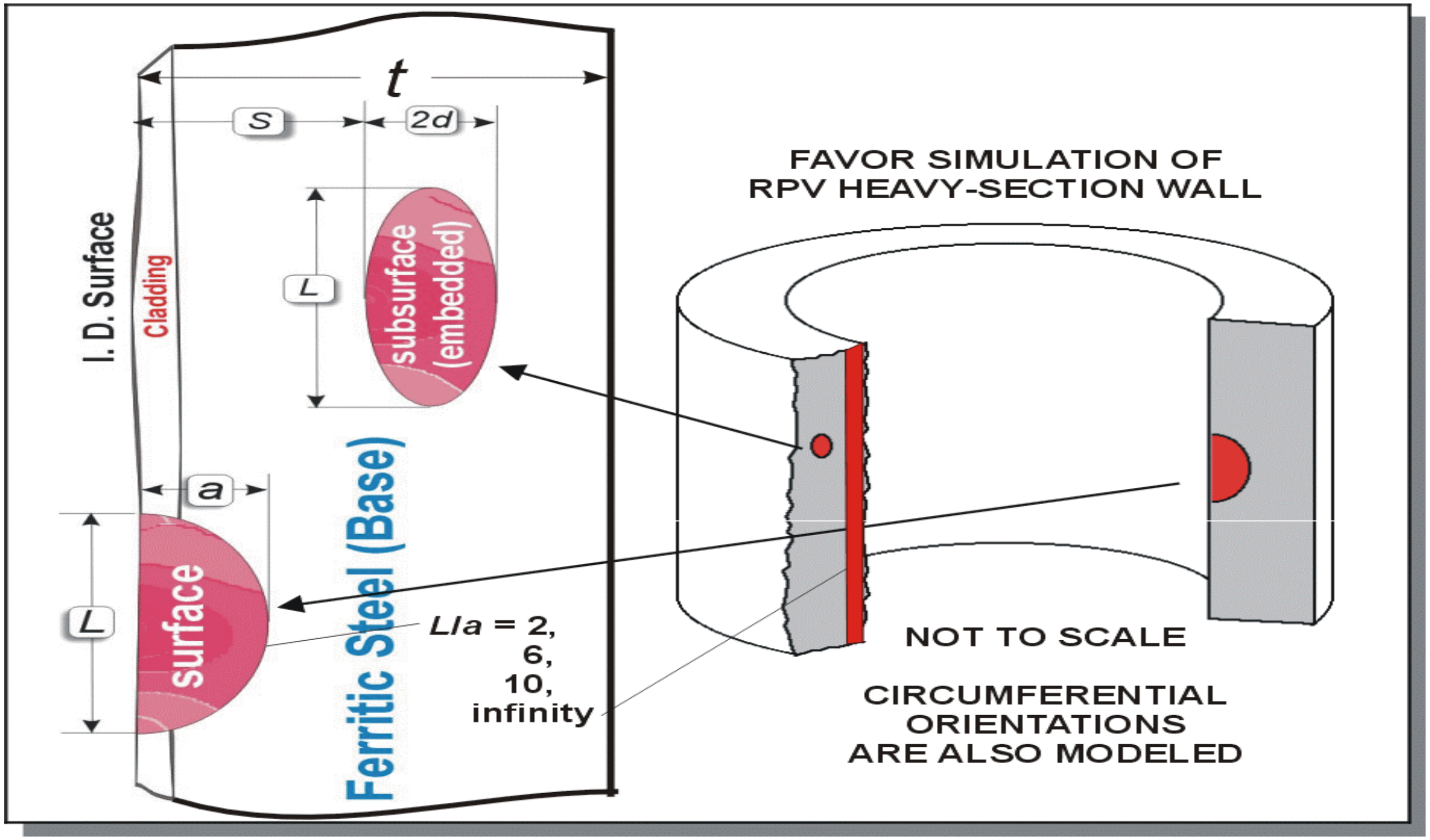
The basic element of the PFM analysis is the interaction of the driving force (applied K_I) with the finite-probability space defined by a 3-parameter Weibull K_{Ic} statistical distribution

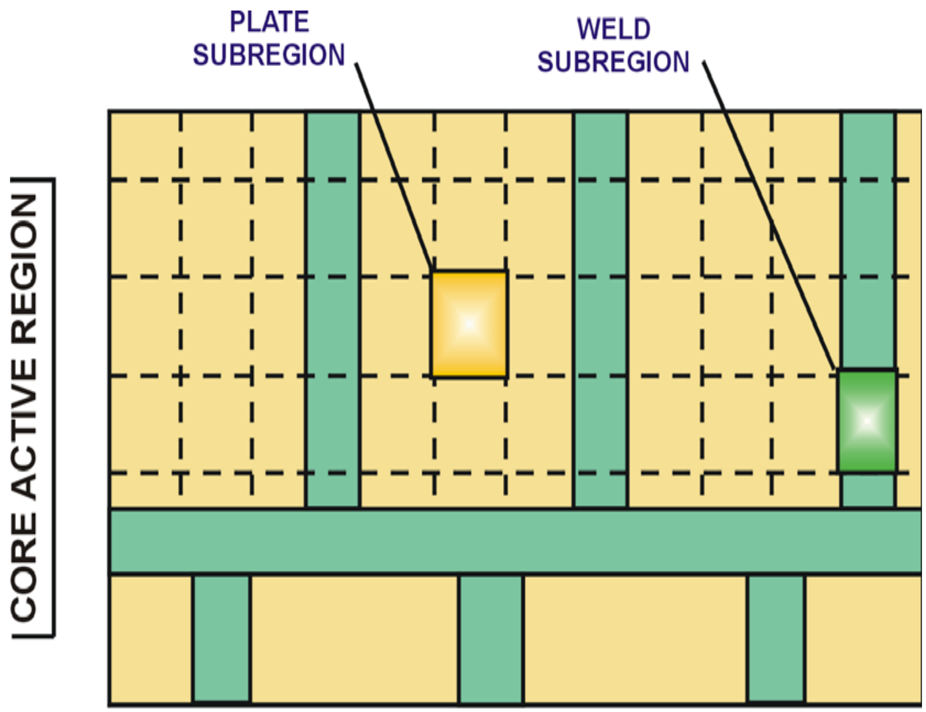


Flaw models in FAVOR include infinite length and finite-length semielliptical surface breaking flaw and fully elliptical embedded flaws

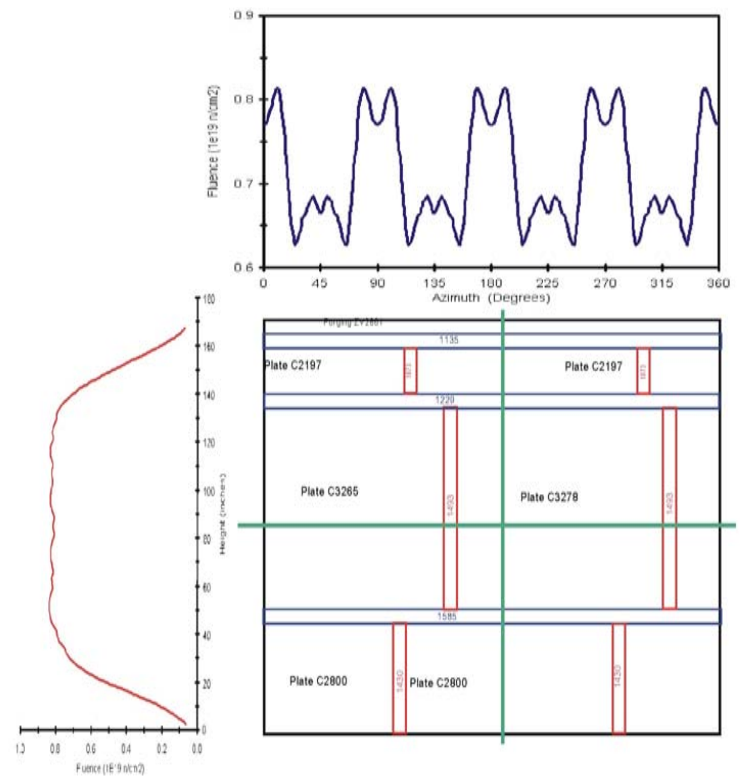


FAVPFM allows the RPV beltline to be discretized into major regions (plates, axial welds, circ. welds) which have unique chemistries

The major regions may be further discretized to accommodate detailed neutron fluence maps



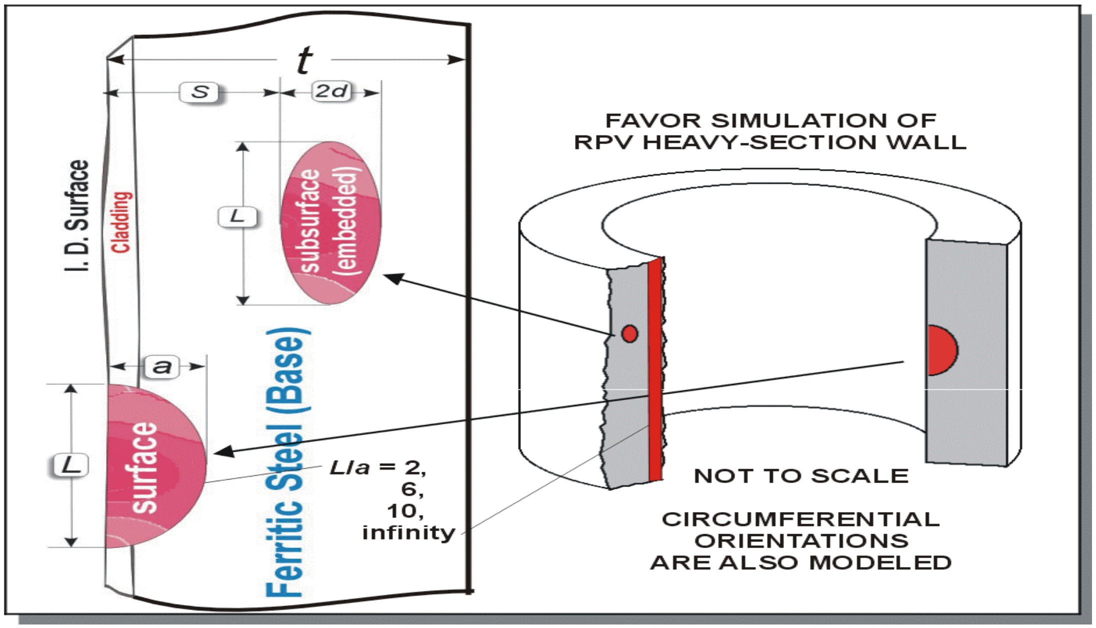
TYPICAL VESSEL BELTLINE ROLLOUT



FAVOR flaw model assumes:

Different flaw depth distributions for plate and weld material

(1) embedded flaws in axial welds are axially oriented
(2) embedded flaws in circ welds are circ oriented
(3) embedded flaws in plates – 50% are axial and 50% are circ



Risk Dominance was Qualitatively Classified in Terms of Transient Classes and Characteristics

Transient severity and likelihood combine to control TWCF contribution of transients. For the range of transients considered: minimum temperature is most important parameter, then cooling rate, then pressure

Transient Class		Transient Severity			Transient Likelihood	TWCF Contribution
		Cooling Rate	Minimum Temperature	Pressure		
Primary Side Pipe Breaks	Large Diameter	Fast	Low	Low	Moderate	Large
	Medium Diameter	Moderate	Low	Low	Moderate	Large
	Small Diameter	Slow	High	Moderate	High	~0
Primary Stuck-Open Valves	Valve Recloses	Slow	Moderate	High	Moderate	Large
	Valve Remains Open	Slow	Moderate	Low	Moderate	~0
Main Steam Line Break		Fast	Moderate	High	Low	Small
Stuck Open Valve(s), Seconday Side		Moderate	High	High	Low	~0
Feed and Bleed		Slow	Low	Low	Low	~0
Steam Generator Tube Rupture		Slow	High	Moderate	Low	~0
Mixed Primary & Secondary Initiators		Slow	Mixed		Very Low	~0

Oconee: most limiting (highest RT_{NDT}) region is circ weld; most initiations predicted to occur in circ welds; all failures occur in axial welds

Palisades: most limiting region is axial weld; most initiations and failures predicted to occur in axial weld

Beaver Valley: most limiting region is plate; most initiations are predicted to occur in circumferential weld; most failures predicted to occur in plates

Reactor	EFPY[1]	RT_{NDT}[2] (°F)	Allocation to originating flaw population					
			FCI			TWCF		
			axial welds	circ welds	plates	axial welds	circ welds	plates
Oconee[3]	32	175	34%	66%	0%	100%	0%	0%
	60	193	19%	81%	0%	100%	0%	0%
	Ext-Oa	251	9%	91%	0%	100%	0%	0%
	Ext-Ob	281	9%	91%	1%	100%	0%	0%
Beaver Valley[4]	32	243	2%	96%	2%	69%	0%	31%
	60	272	3%	94%	3%	39%	1%	60%
	Ext-Ba	301	3%	93%	4%	16%	2%	83%
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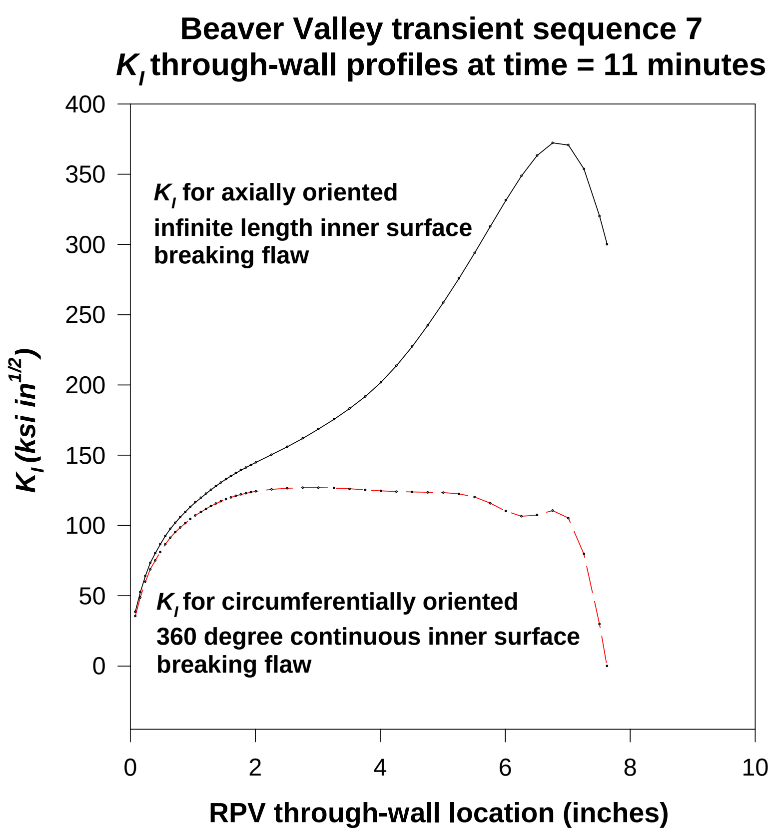
	Ext-Pa	277	84%	15%	0%	100%	0%	0%
	Ext-Pb	333	60%	39%	1%	99%	0%	1%

Axial flaws are much more likely to propagate through-wall to failure than circumferential flaws because the applied driving-force to fracture increases continuously with increasing crack depth for an axial flaw whereas circumferentially oriented flaws experience a driving force peak mid-wall, providing a natural crack arrest mechanism.



Several PFM Sensitivity Studies Were Performed to Provide confidence that the analysis results from the three plants can be generalized to apply to all PWRS

Since many of the input parameters cannot be known precisely, PFM sensitivity analyses have been performed to investigate the impact that credible variations in input parameters could have on the base-line analysis results.

The results of these sensitivity analyses provides a rational basis to assess the impact of credible perturbations of the input parameters on the base-line solutions.

This provides a perspective on the appropriateness of using the base-line analysis results as a technical basis that can be generalized to all domestic PWRs.

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