IGRC Seoul 2011
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Various Methods to Evaluate the Long-term Reliability of PE Pipes and Joints in use at Osaka Gas

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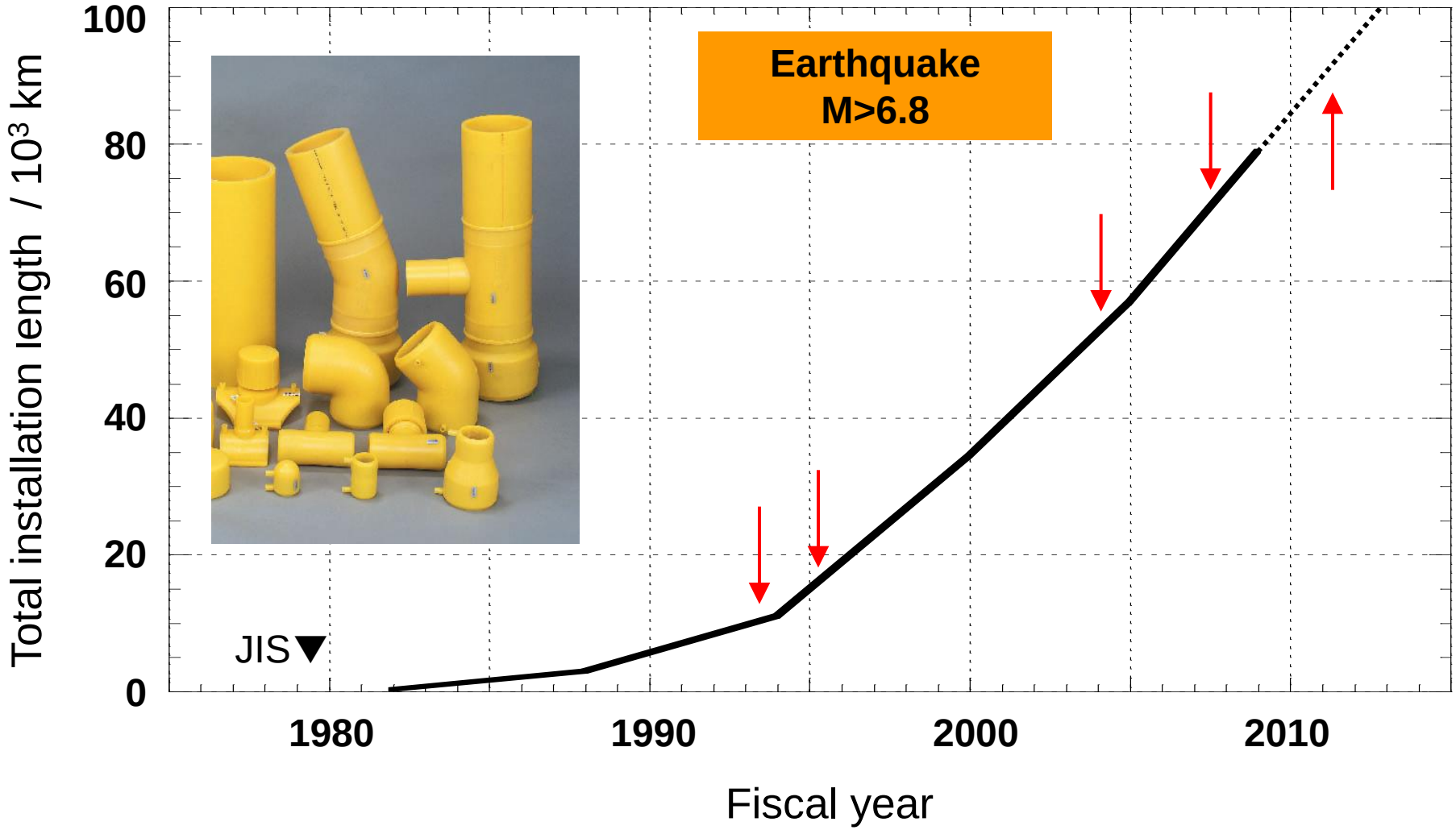
Items for Presentation

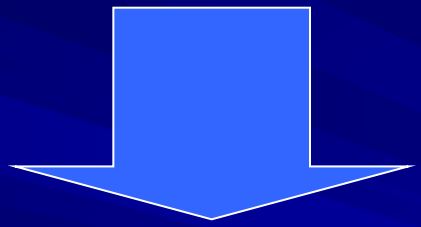
- Introduction
- Objectives
- Evaluation Methods for Pipes
- Evaluation Methods for Joints
- Conclusion

Total Installation Length of PE Pipes in Japan



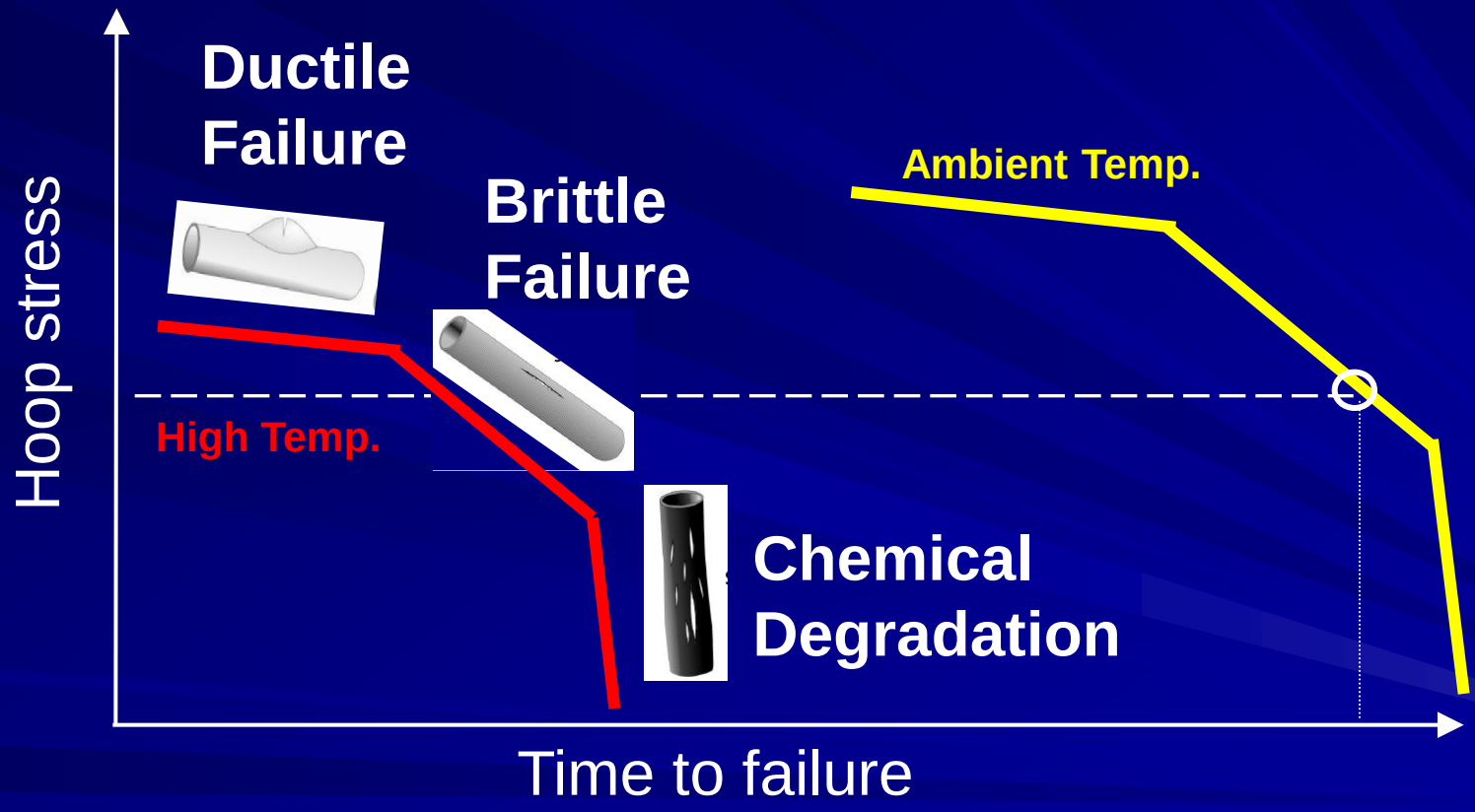
How Do We Estimate the Lifetime of PE Pipes and Joints ?

- Mechanical Methods
- Chemical Methods



	Pipe	Joint
New	1	3
Failed	2	4

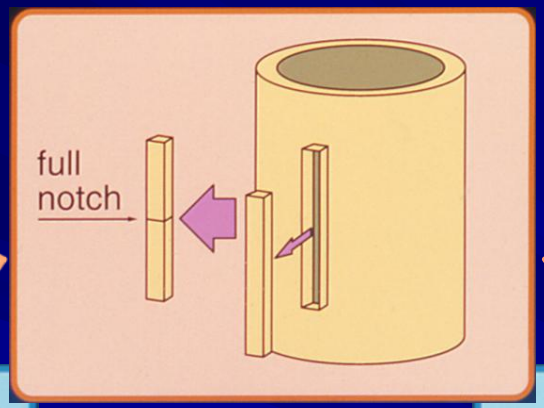
Mechanical Methods
- Hydrostatic Stress Rupture Test -



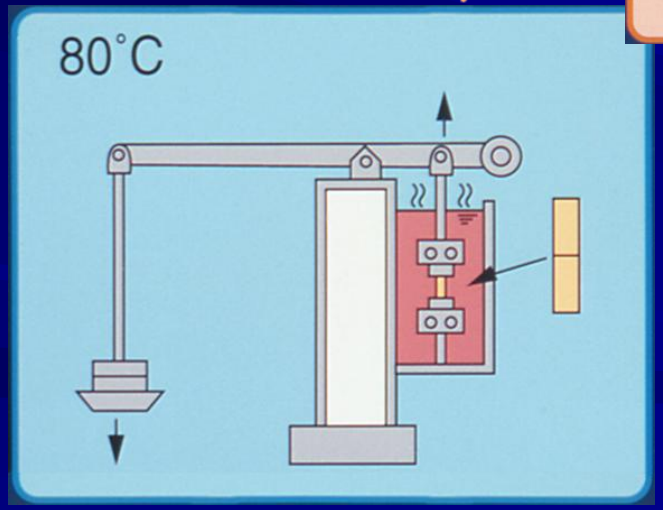
Failure = Crack Initiation + Crack Propagation

Mechanical Methods

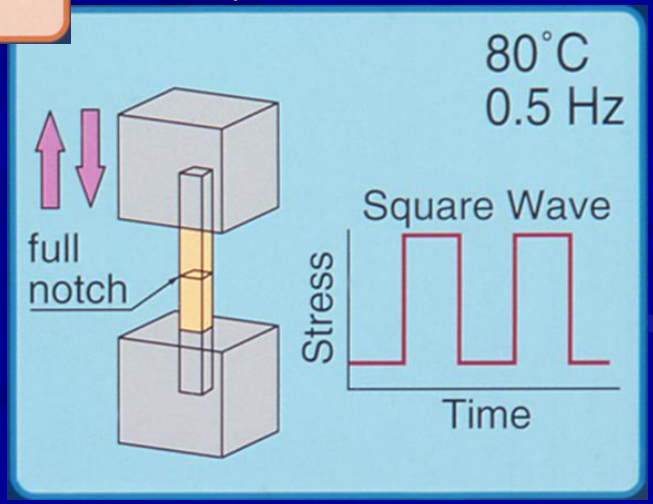
- Full-Notched Tensile Creep Test (FNCT) -
- Full-notched Tensile Fatigue Test (FNFT) -



FNCT



FNFT

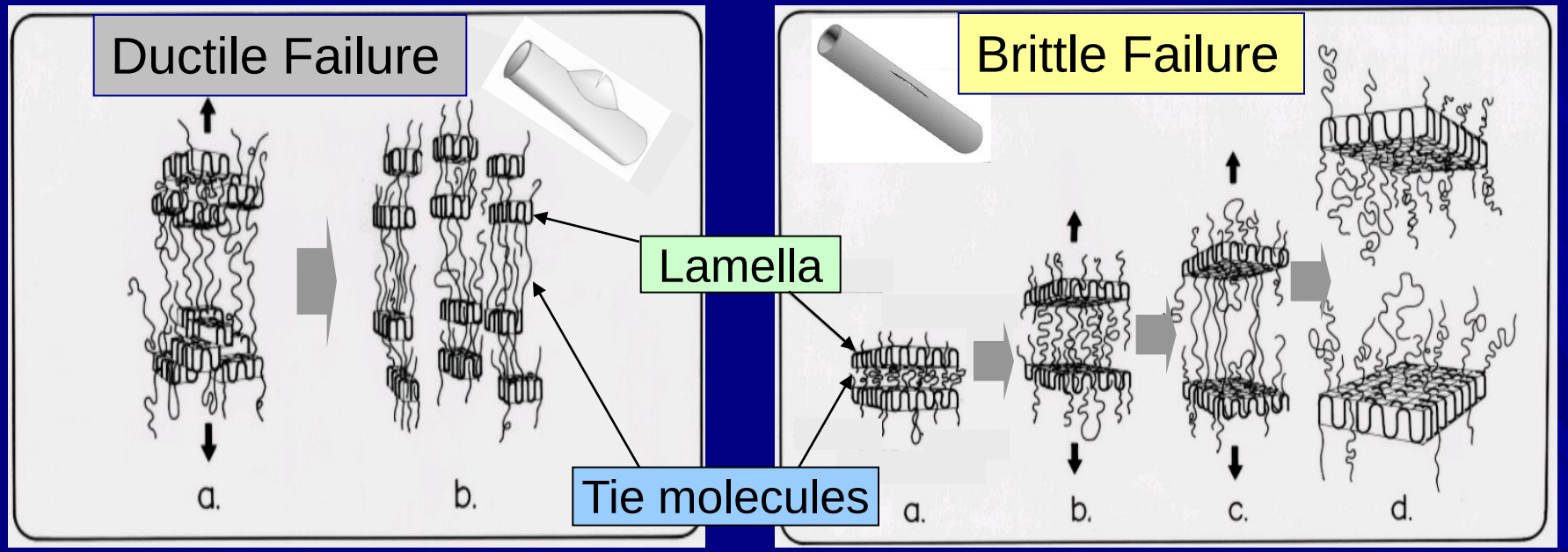


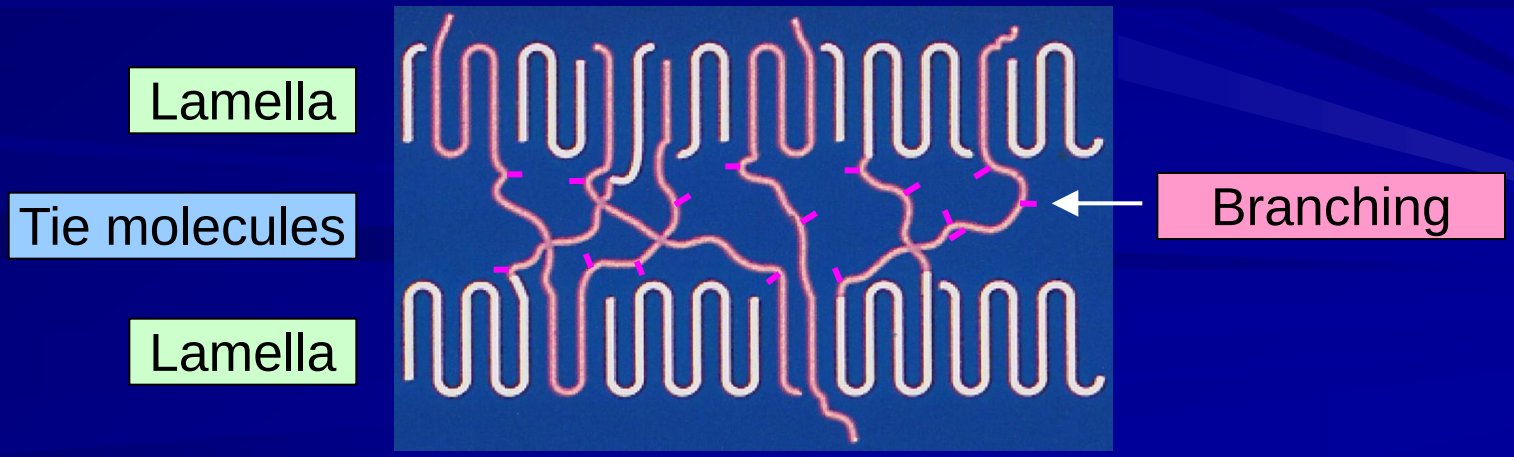
Failure = Crack Initiation + Crack Propagation

Acceleration to evaluate long-term reliability by using Mechanical Methods

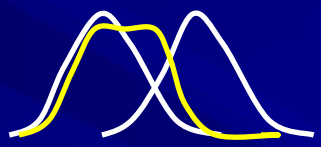
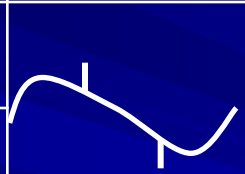
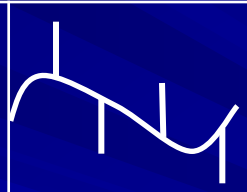
Year	1979		1990		1993
Test method	Mechanical methods				
	Hydrostatic stress rupture		Tensile creep -FNCT-		Tensile fatigue -FNFT-
Evaluation period	One year		Six months		Three months
Feature	・Pipe ・Creep		・Specimen ・Creep		・Specimen ・Creep ・Fatigue

Failure Mode and Structure

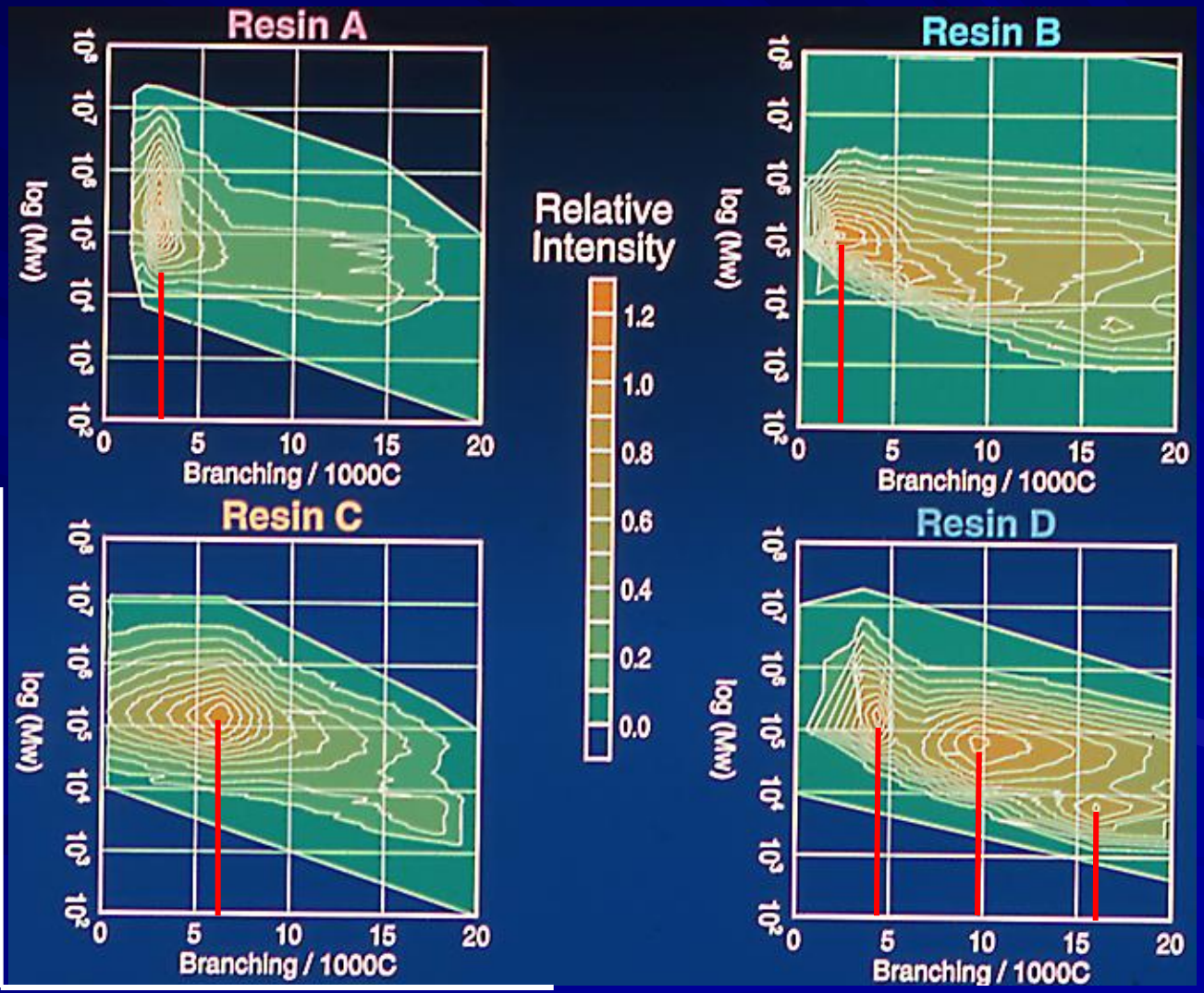




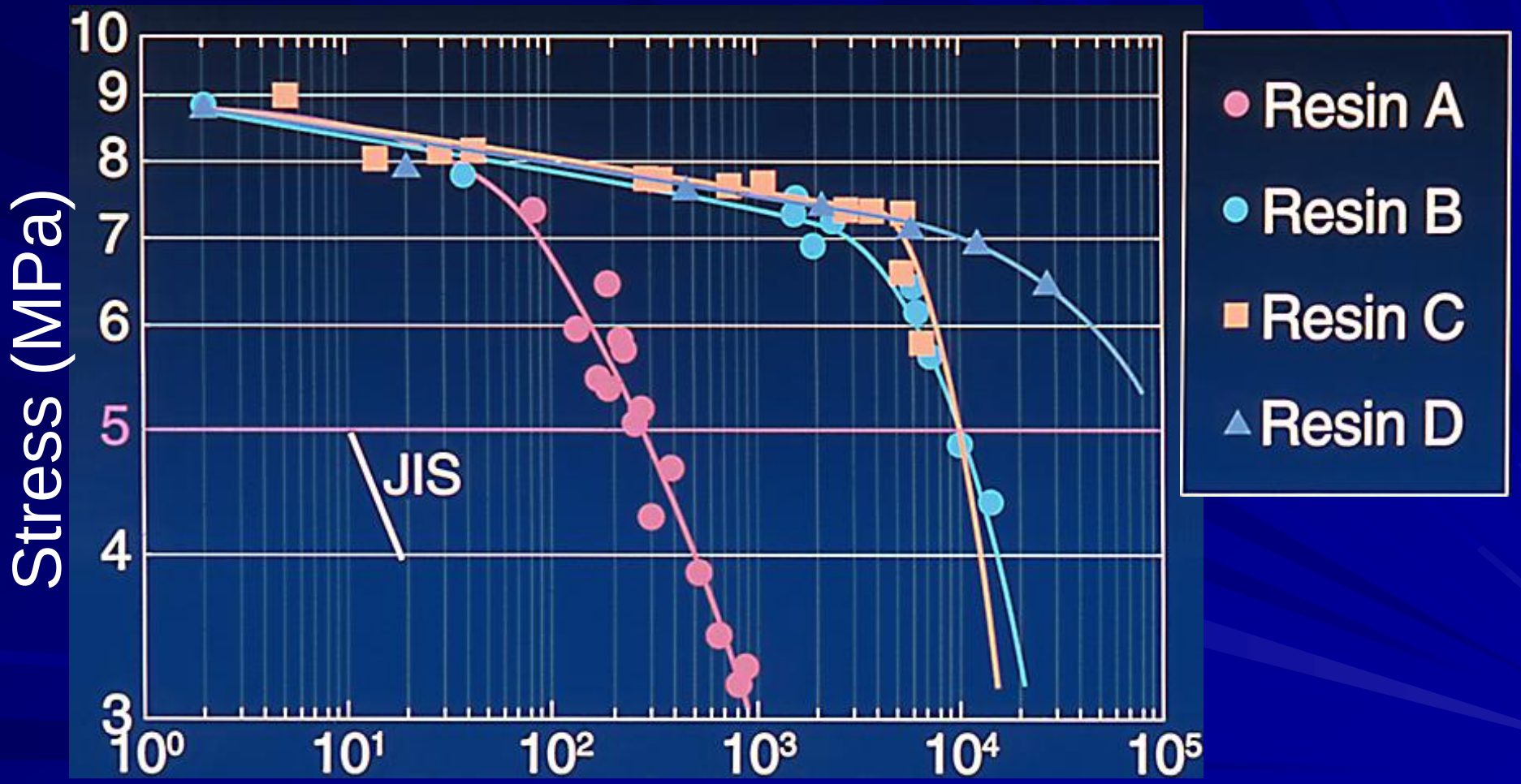
Chemical Methods - Analysis of PE Resin Structure -

Parameters	Factors	Concept	Equipment
Molecular weight	Number		GPC
	Distribution		
Branching	Length	 	^{13}C-NMR
	Amount		IR
	Distribution		TREF-GPC
Antioxidant	Composition	Phenol, sulfur phosphorus,HALS	TLC,MASS
	Contents		HPLC,DSC

Chemical Methods
Molecular Weight and Branching

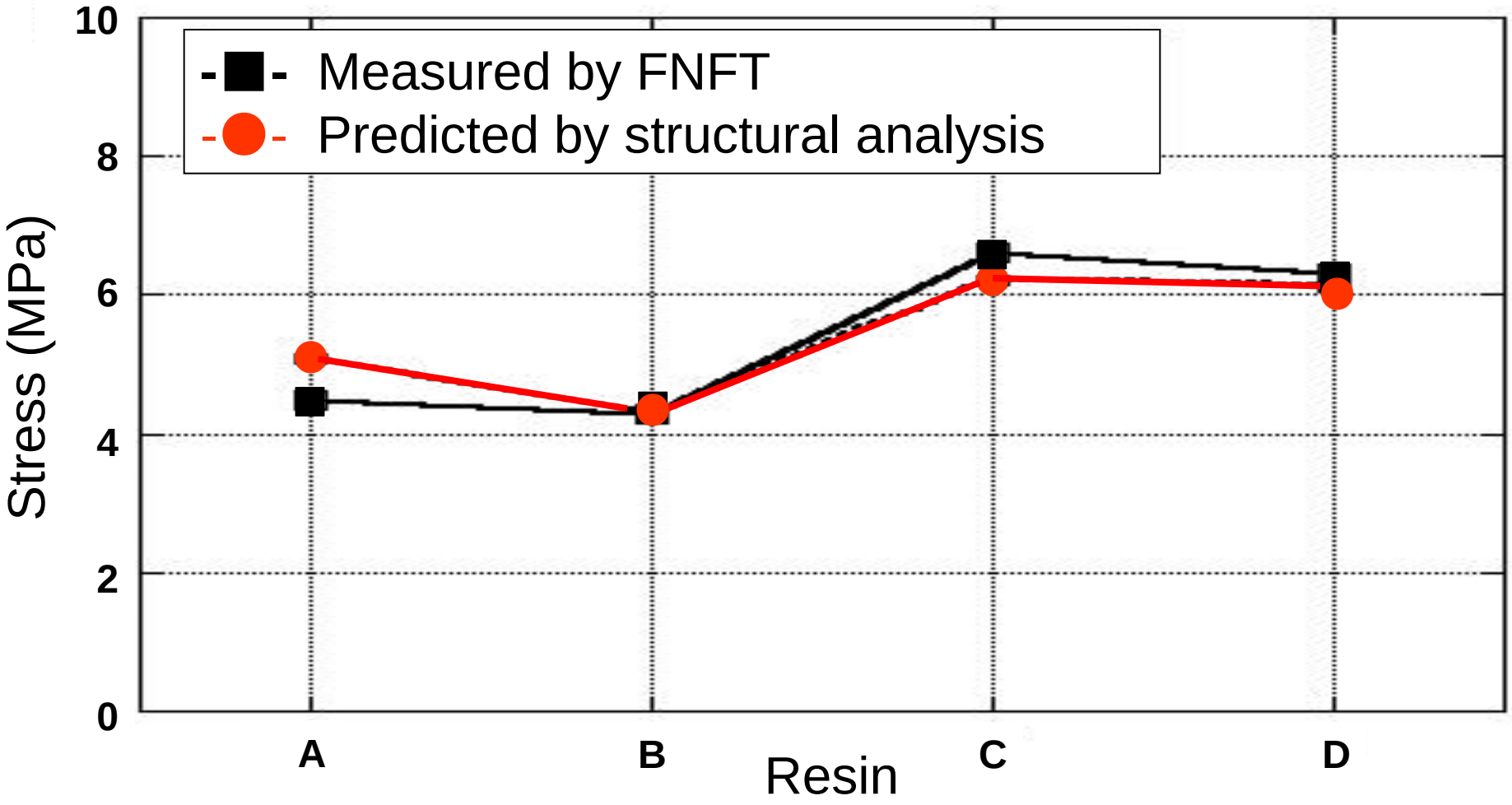


Tensile Creep Result - FNCT -



Long-term reliability : A < B ≒ C < D

Estimation of Long-term Reliability from Resin Structure



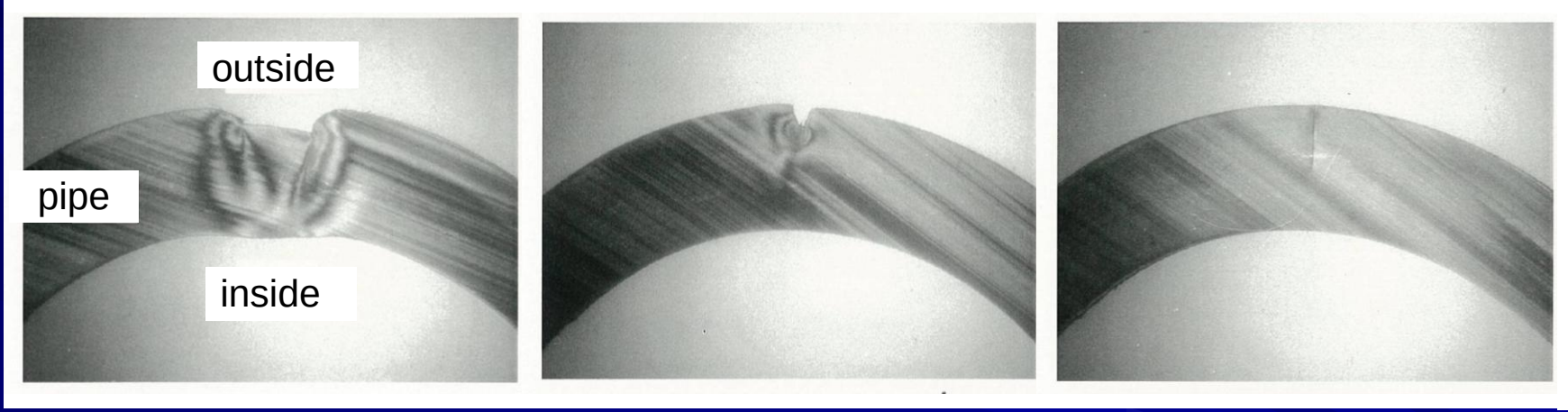
Long-term reliability was estimated by structural analysis.

Acceleration to Evaluate the Long-term Reliability of PE Pipes

Year	1979		1990		1993		1997
Test method	Mechanical -Macro-					Chemical -Micro-	
	Hydros-tatic stress rupture	→	Tensile creep -FNCT-	→	Tensile fatigue -FNFT-	→	Analysis
Evaluation period	One year		Six months		Three months		Three Weeks
Feature	Pipe Creep		Specimen Creep		Specimen Creep Fatigue		Resin

Long-term Reliability of Damaged PE Pipes

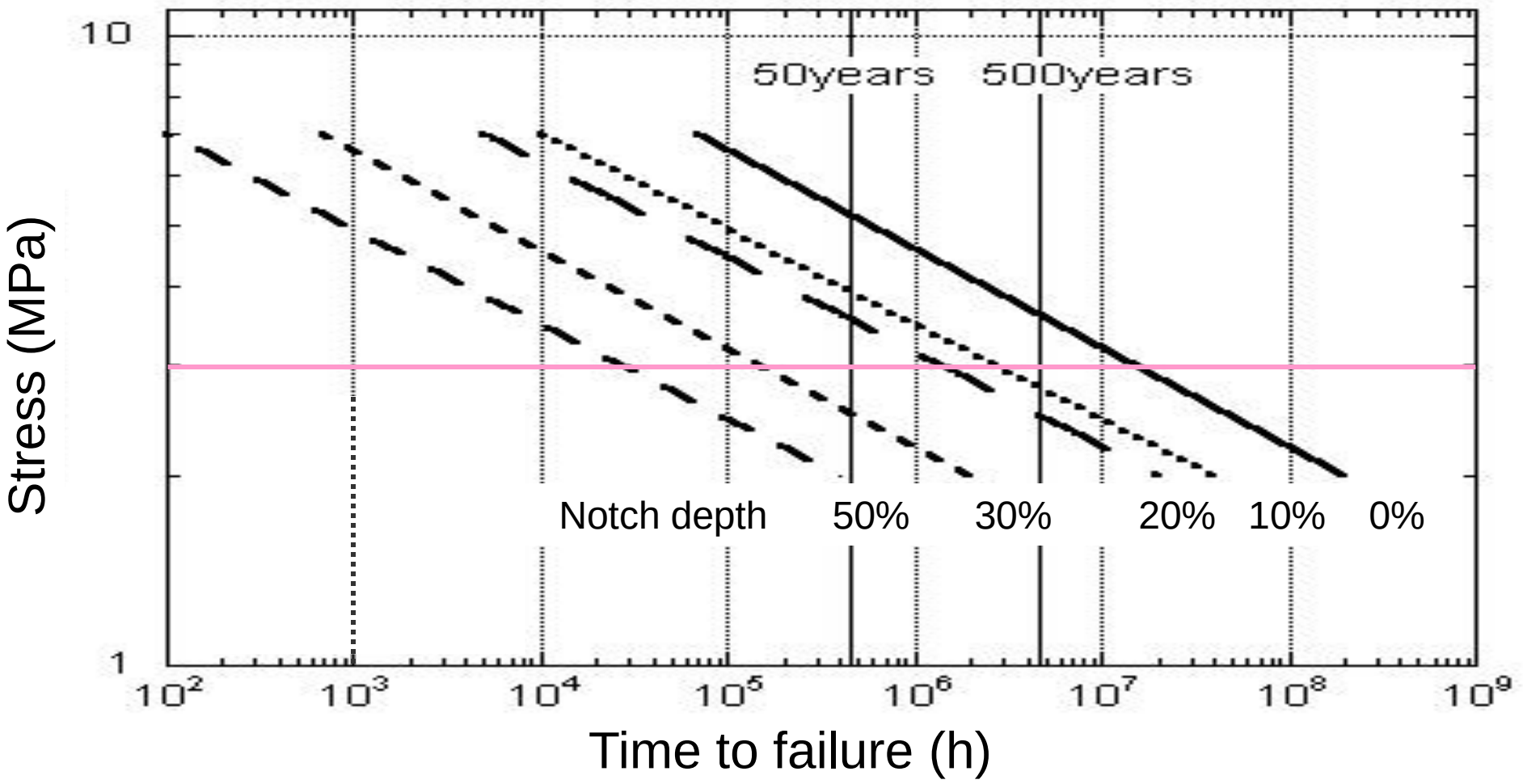
- Polarized Microscope -



Pickax	Shovel	Razor notch
much	Residual strain	little
dull	Tip of damaged part	sharp
small	Stress intensity factor	large

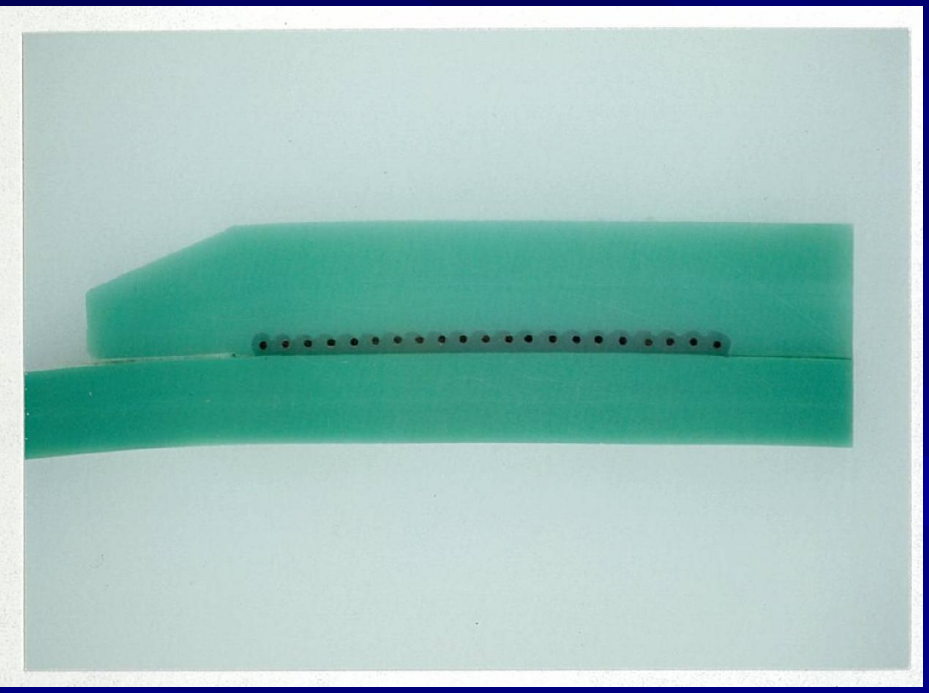
Long-term Reliability of Damaged PE Pipes

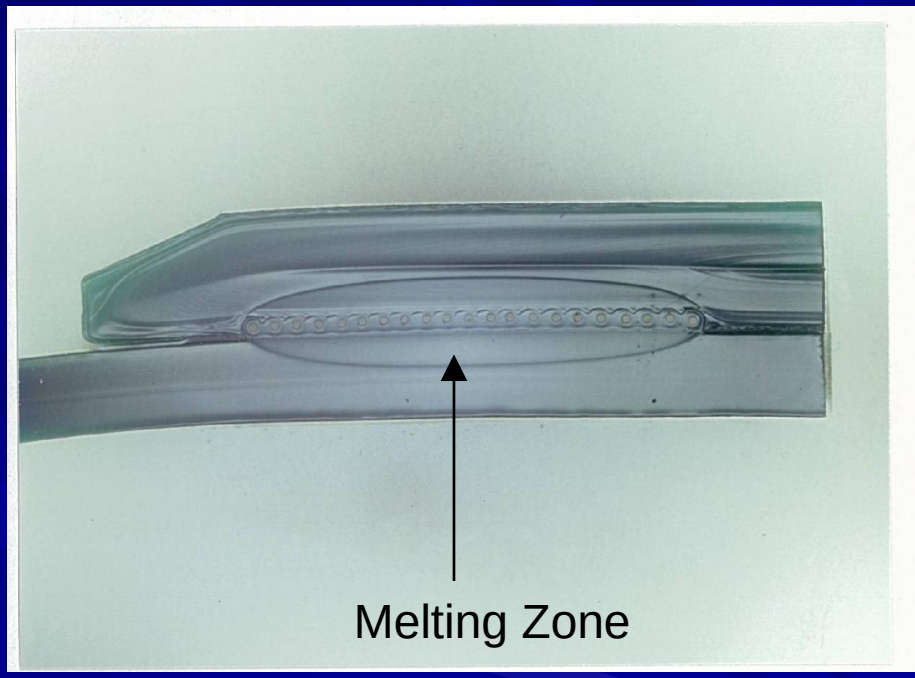
- FNCT -



Pipes with more than 30% notch depth have significantly decreased long-term reliability.

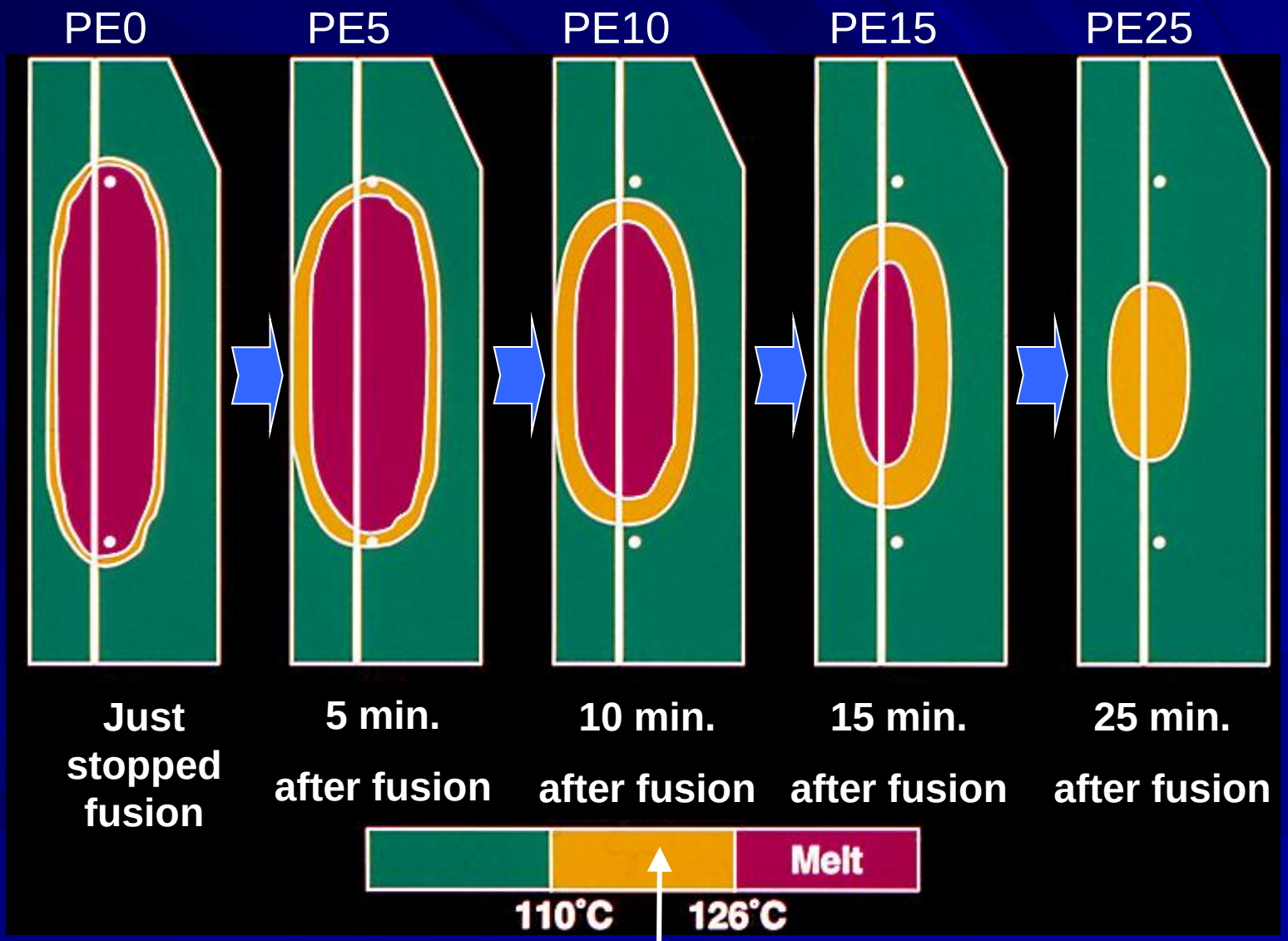
Polarized Microscope - Electrofusion Joint -



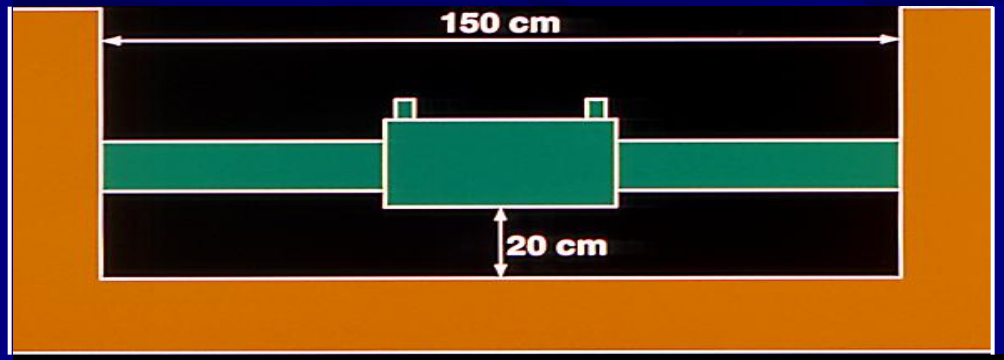


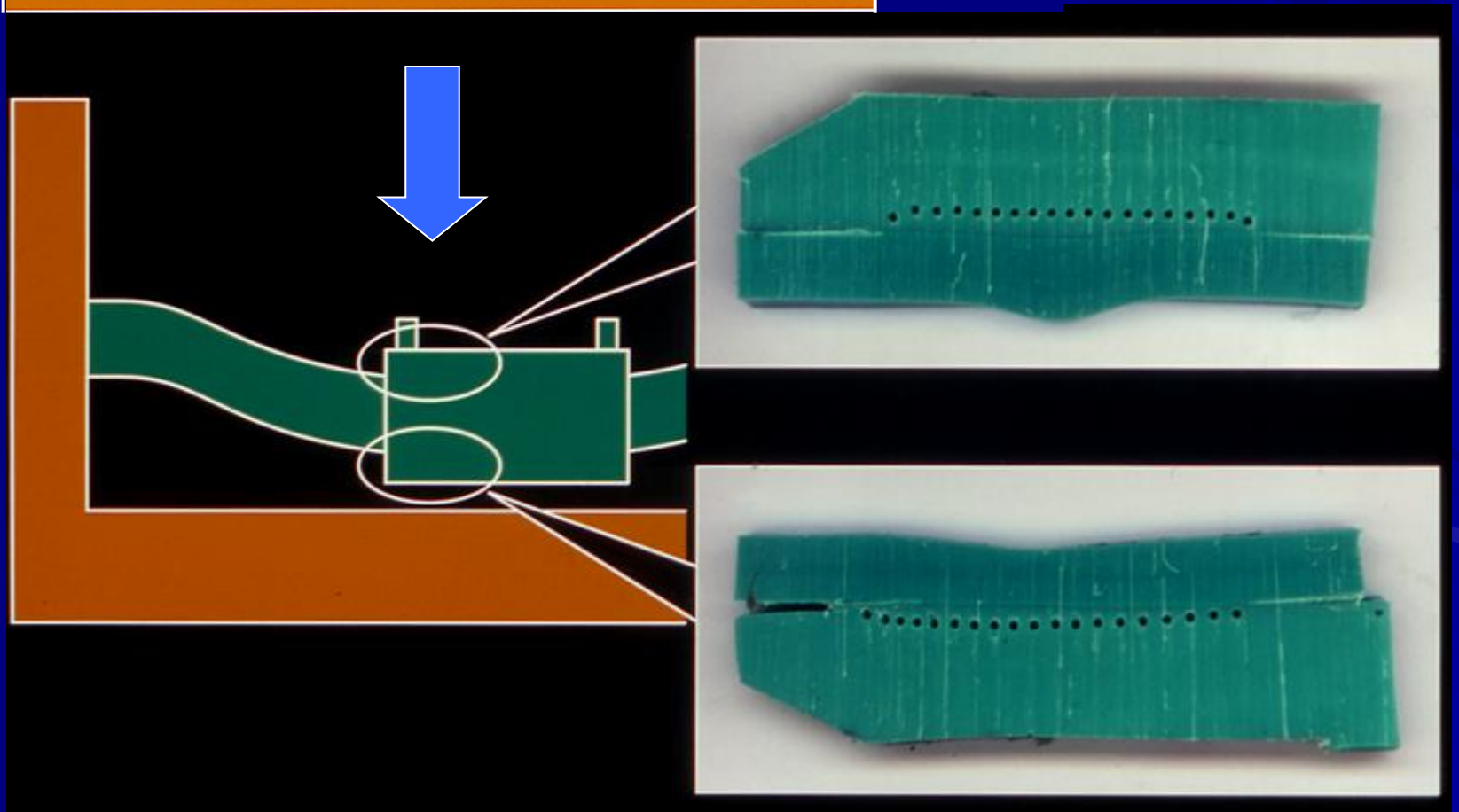
Melting zone can be seen by polarized microscope.
This enables the quality of fusion conditions to be confirmed.

Simulation of Cooling Process



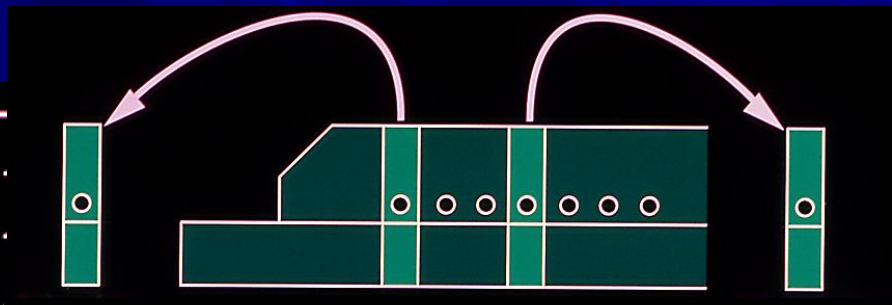
Deformation of EF Joints



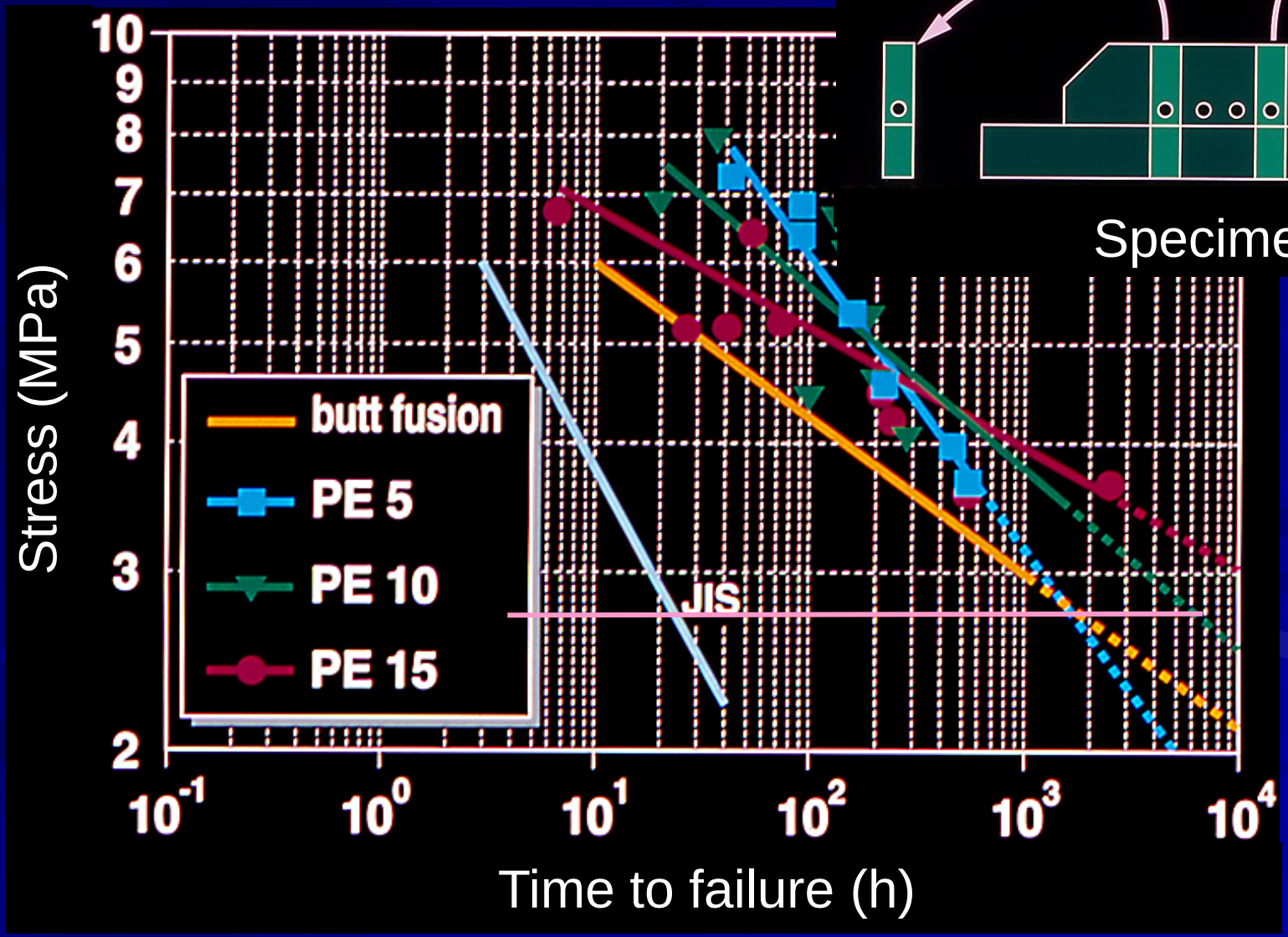


Long-term Reliability of EF Joints

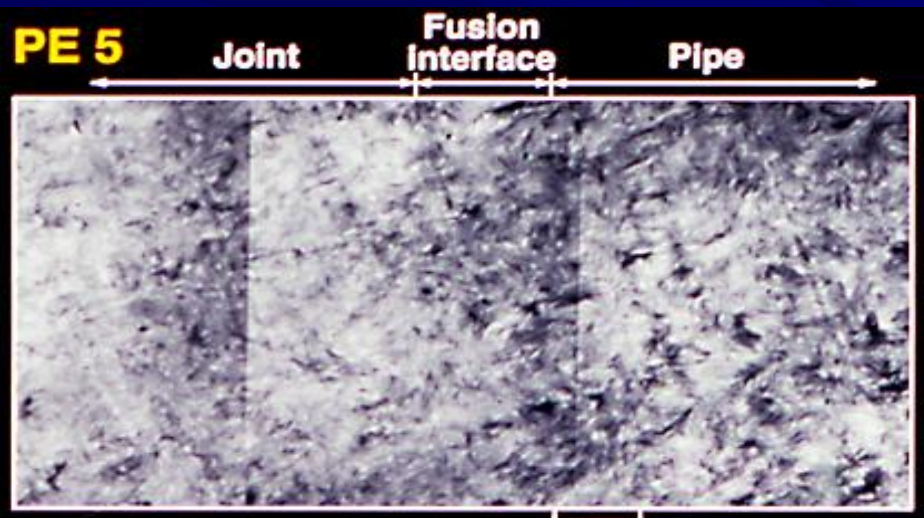
- FNCT -

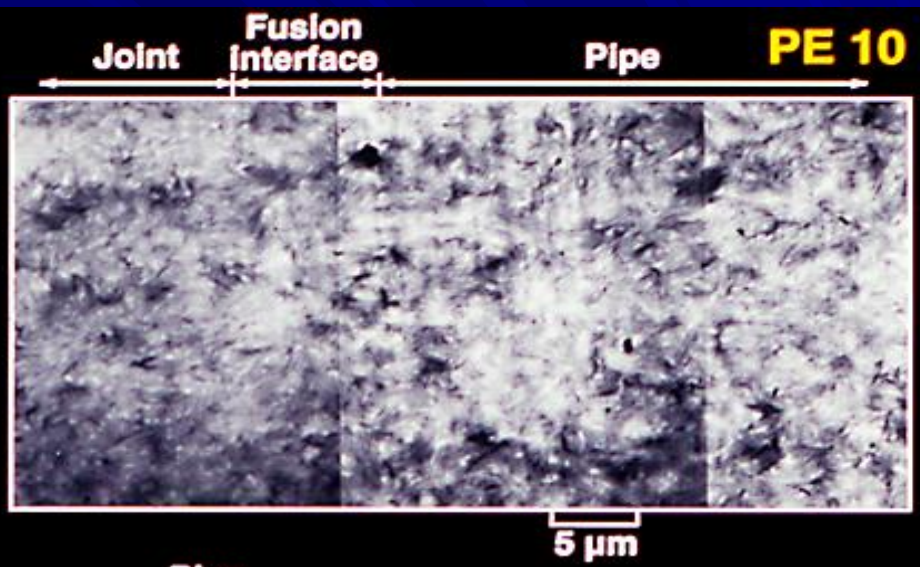


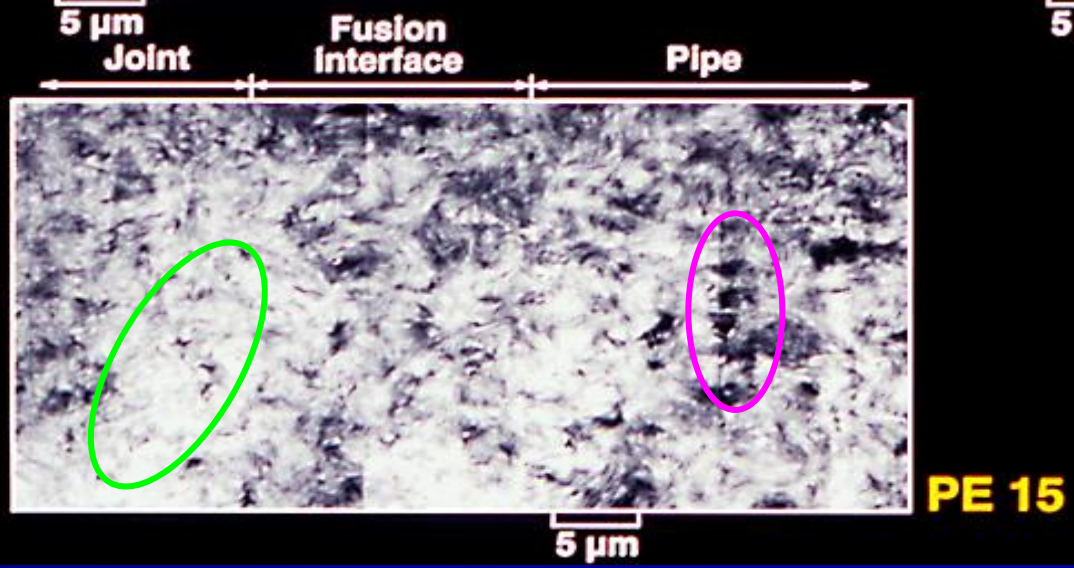
Specimen

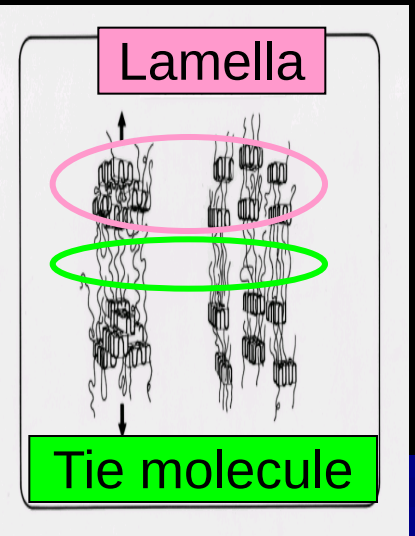


Transmission Electron Microscope -TEM -



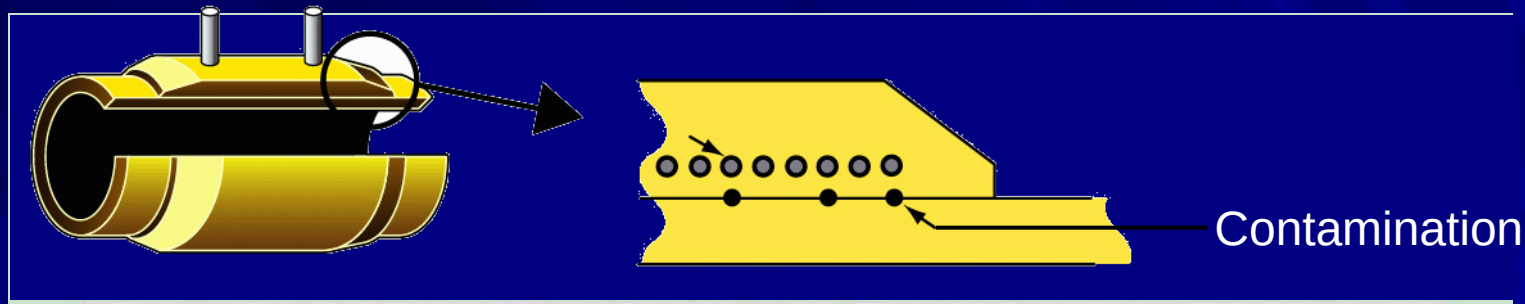


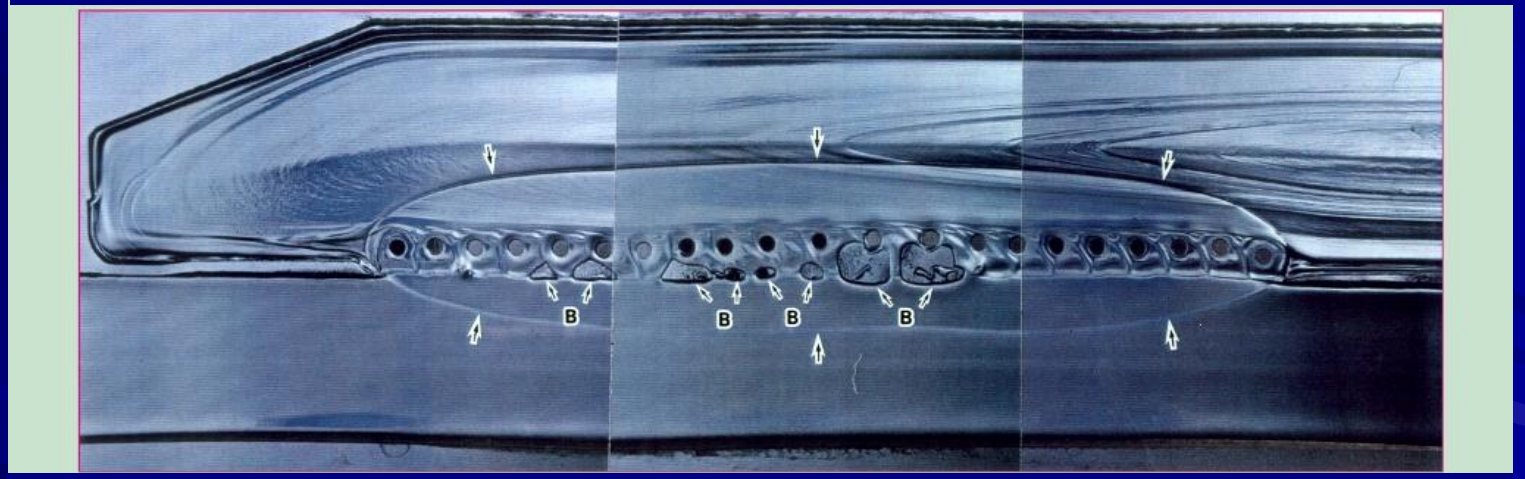




Detecting Contamination
- Polarized Microscope -

Sand or water drops may contaminate the fusion interface





The fusion area decreases due to sand and water contamination on the fusion interface.

Detecting Contamination

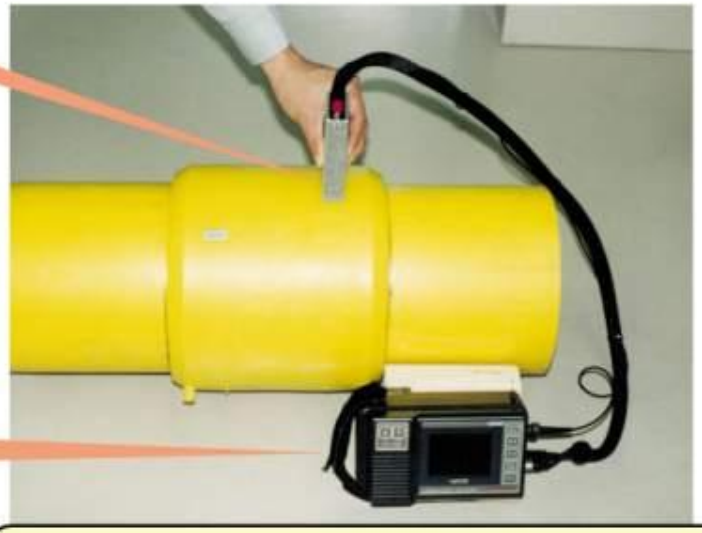
- Ultrasonic Inspection – NDT -

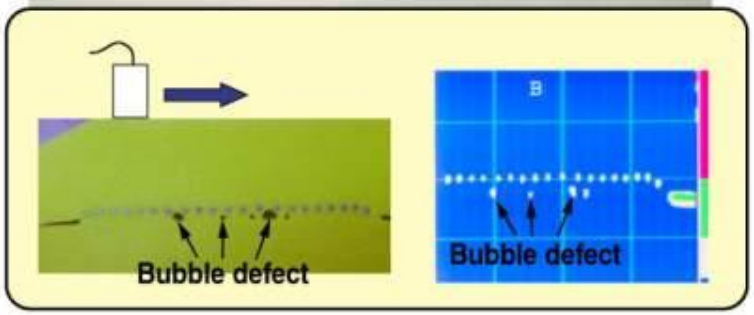
Transducer and jig

- Point-focused type
- Frequency : 5MHz
- Polyethylene shoe
- Polymer transducer

B-scan image ultrasonic machine

- Weight : 0.85kg
- Size : 18×10×8cm



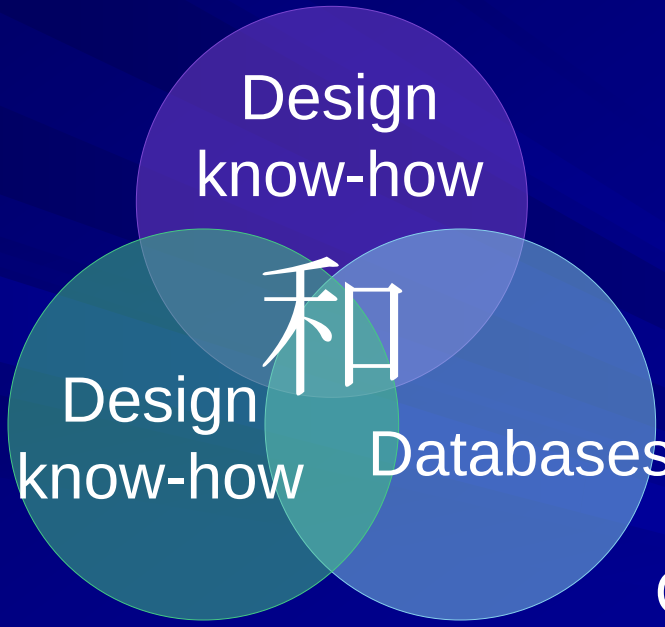


Conclusion

			Long-term reliability methods									
			Mechanical			Chemical					Other	
			Hydrostatic pressure	Tensile creep	Tensile fatigue	Resin structural analysis	Additive analysis	Observation	Polarized microscope	Electron microscope	Simulation	Ultrasonic inspection
Gas	Pipe	Normal	●	O	O	●	O	×	×	×	×	×
		Damage	●	×	×	×	×	O	O	×	×	×
	Joint	Fusion	●	O	O	×	●	×	O	O	●	×
		Contamination	●	O	O	×	×	O	O	O	×	●
Hot Water			●	O	O	O	●	O	O	O	O	O

Mutual collaboration in Japan

Resin Manufacturer



Pipe & Joint
Manufacturer

Gas Company