

# CGA Energy Nexus & Annual Technical Conference 2025

## Are vintage polyethylene pipelines really ageing out of the natural gas system?

Jacob Speelman  
Jennifer Pethick



# Outline

- About ATCO
- Systems Overview & History
- Sample Collection & Testing
- Risk Profile Development
- Operationalizing Risk Profile
- Slow Crack Growth Characteristics
- Risk Model Implementation Process
- Monte Carlo Simulation
- Asset Attribution
- DIMP Incorporation



# About ATCO



19,000

Employees Throughout ATCO  
and all Subsidiary and Affiliate  
Companies



100+

Countries Throughout our  
History



105,000

Kilometers of Electrical  
Powerlines



64,000+

Kilometers of Natural Gas  
Pipelines

# About ATCO

Own and operate approximately

**9,100 km**

of natural gas transmission pipelines in Alberta



Deliver a peak of

**3.7 billion cubic feet**

of natural gas per day



We are Alberta's largest natural gas distribution company



Transport clean and efficient energy from producers and other pipelines to utilities, power generators and major industries.



**55,000 km**

of gas distribution lines that serve more than 1.3 million customers across Alberta





For more than 100 years, ATCO Gas has delivered clean, safe and reliable natural gas to homes and businesses in Alberta.

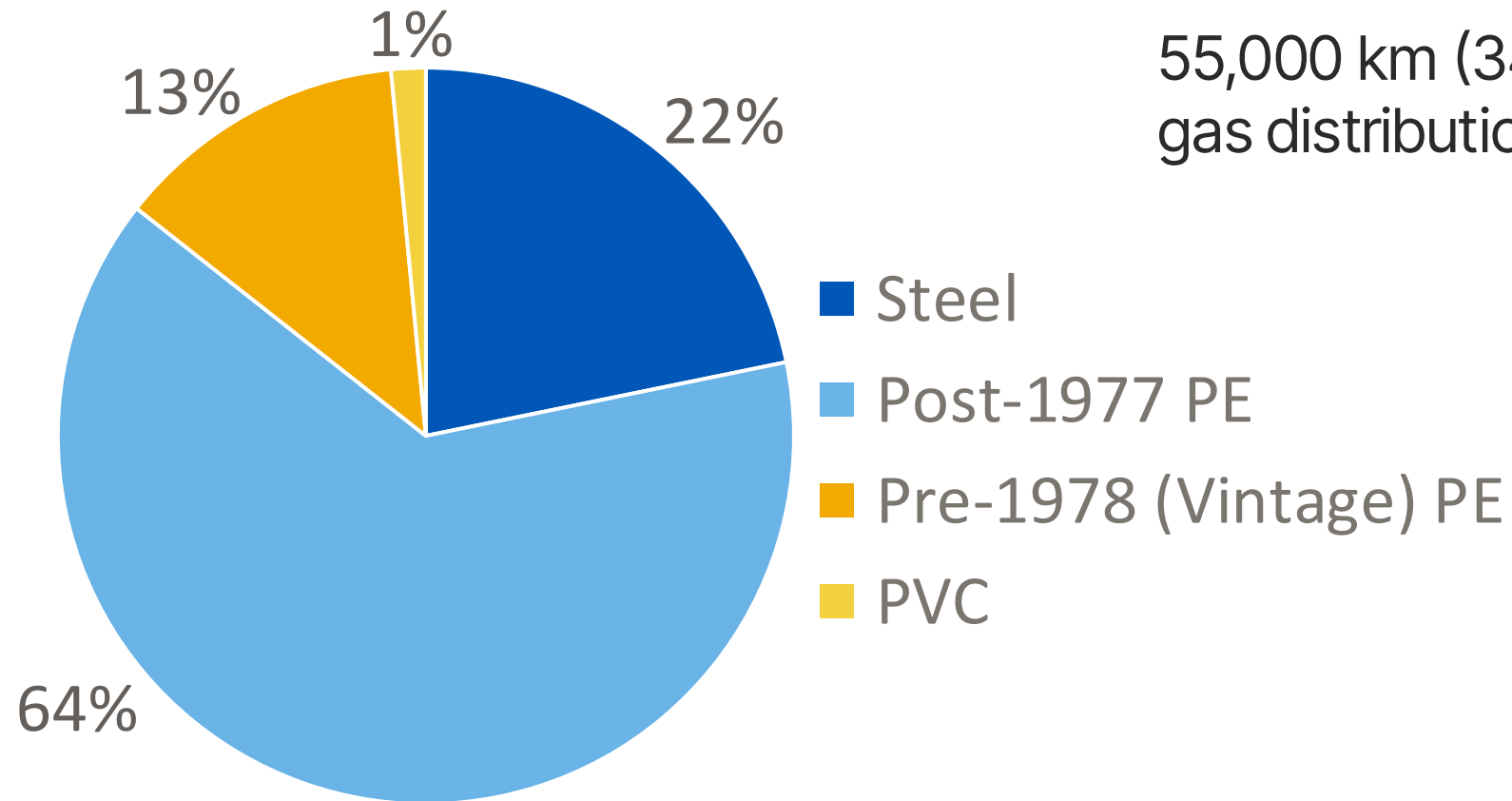


Delivers safe, reliable and cost-effective natural gas to over

**1.3 million customers**

in homes and businesses across 300 Alberta communities

## Systems Overview & History



55,000 km (34,000 mi) of  
gas distribution lines in Alberta



# Systems Overview & History



- First PVC and PE pipe installations in 1960
- In 2011, Plastic Mains Replacement (PMR) Program formally started
  - Targets pre-1978 installations
  - Over-pressure, PE vs. PVC, leak history
  - Service density, urban vs. rural
- In 2020, hired GTI Energy and started PE pipe sample collection and testing
- In 2024, implemented quantitative probabilistic model for pre-1978 PE pipelines

# Systems Overview & History

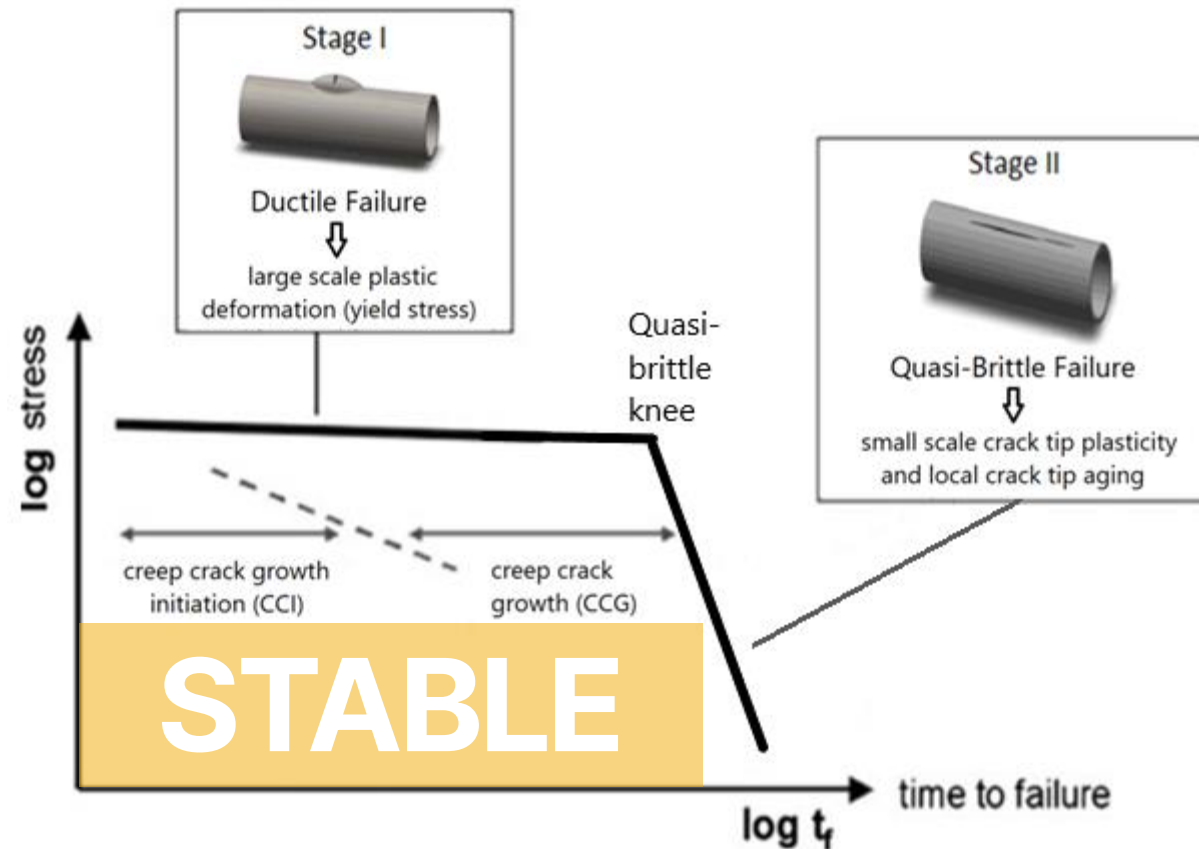


Figure modified from sources: [1] Frank, Andreas & Pinter, Gerald & Lang, R.W.. (2009). *Prediction of the remaining lifetime of polyethylene pipes after up to 30 years in use*. Polymer Testing. 28. 737-745. 10.1016/j.polymertesting.2009.06.004. [2] Wee, Jung-Wook & Choi, Byoung-Ho. (2016). *Modeling of axisymmetric slow crack growth of high-density polyethylene with circularly notched bar specimen using crack layer theory*. International Journal of Solids and Structures. 97-98. 189-199.

# Sample Collection & Testing





ARE VINTAGE PE PIPELINE ASSETS REALLY AGEING OUT?

# Sample Collection & Testing



CANADIAN WESTERN NATURAL GAS COMPANY LTD.  
"DISTRIBUTION DEPARTMENT"

PLAN FOR WORK ORDER NUMBER **76-W744**

DESCRIPTION Cosidele R.E. - Scheme #1 (2076)

LOCATION Portions of Twp. 10, Rge's 18 & 19, V. 4th M. and Twp. 9, Rge's 18 & 19, V. 4th M.

COUNTY OF MIDDLESEX #25 SECTION 1 PLAN SHEET NO. 1

M.S. OF TAPES #15

REVISIONS

SPECIAL INSTRUCTIONS TO FOREMAN

APPROVED *[Signature]*  
MANAGER OF DISTRIBUTION  
FOR GENERAL MANAGER

SCALE: as in. shown ft.

LEGEND

INSTALL \_\_\_\_\_  
EXISTING \_\_\_\_\_  
ABANDON OR RECOVER \_\_\_\_\_

UTILITIES:  
Water \_\_\_\_\_ Telephone conduits \_\_\_\_\_  
Sanitary Sewer \_\_\_\_\_ Electric conduits \_\_\_\_\_  
Storm Sewer \_\_\_\_\_

SPECIFICATIONS  
Pipe fabricated in accordance with API-5L  
Pipe coating Yellow Jacket  
Joint coating Fluoroc  
Maximum working pressure 80 psi  
Normal working pressure 80 psi

Designed by D. Fitzpatrick Date Aug. 16/76  
Drawn by J. Macdonald Date Sept. 15/76  
Staked by N. Boreas & W. W. W. W. Date Nov. 21/76  
Welded by \_\_\_\_\_ Date \_\_\_\_\_  
Excavated by \_\_\_\_\_ Date \_\_\_\_\_  
Work commenced \_\_\_\_\_ Date Nov. 22/76  
Work completed \_\_\_\_\_ Date Dec. 18/76  
Details checked by R. G. G. G. Date Dec. 21/76  
Plotted by \_\_\_\_\_ Date \_\_\_\_\_  
Excavation permit number 11621

Tested under air test of 16.0 lbs. per sq. inch for 24 hours.  
DEC. 18/76 R. E. RICHARDS  
DATE DATE CFW CHIEF  
DEC. 21/76 K. H. BLAIR  
DATE DATE FOREMAN

BILL OF MATERIAL

ESTIMATE	USED	ESTIMATE	USED
2" Pip. PE 2304 Ser. 125	60.618	15" Pip. PE 2304 Ser. 125	96.1
2" Pip. PE 2304 Ser. 125	706	15" Pip. PE 2304 Ser. 125	29.615
15" Pip. PE 2304 Ser. 125	55.636	15" ST. PIPE	78.1
15" Pip. PE 2304 Ser. 125	86.7	TRENCH MARK	20.876
15" Pip. PE 2304 Ser. 125	18.712	7M ARROWS	2
15" Pip. PE 2304 Ser. 125	58.7		
15" ST. PIPE	118		
TRENCH MARK	18.712		

# Sample Collection & Testing



Creep Rig



Hydrostatic Pressure Test



Dynamic Thermomechanical Analysis (DTMA)

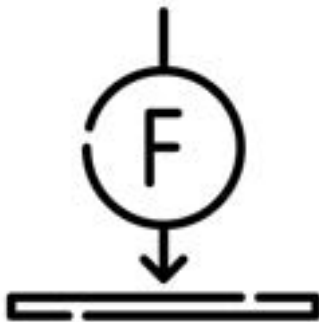
- Oxidation inductive time (OIT) testing
- Carbonyl index testing (by FTIR-ATR)
- Tensile testing



# Risk Profile Development



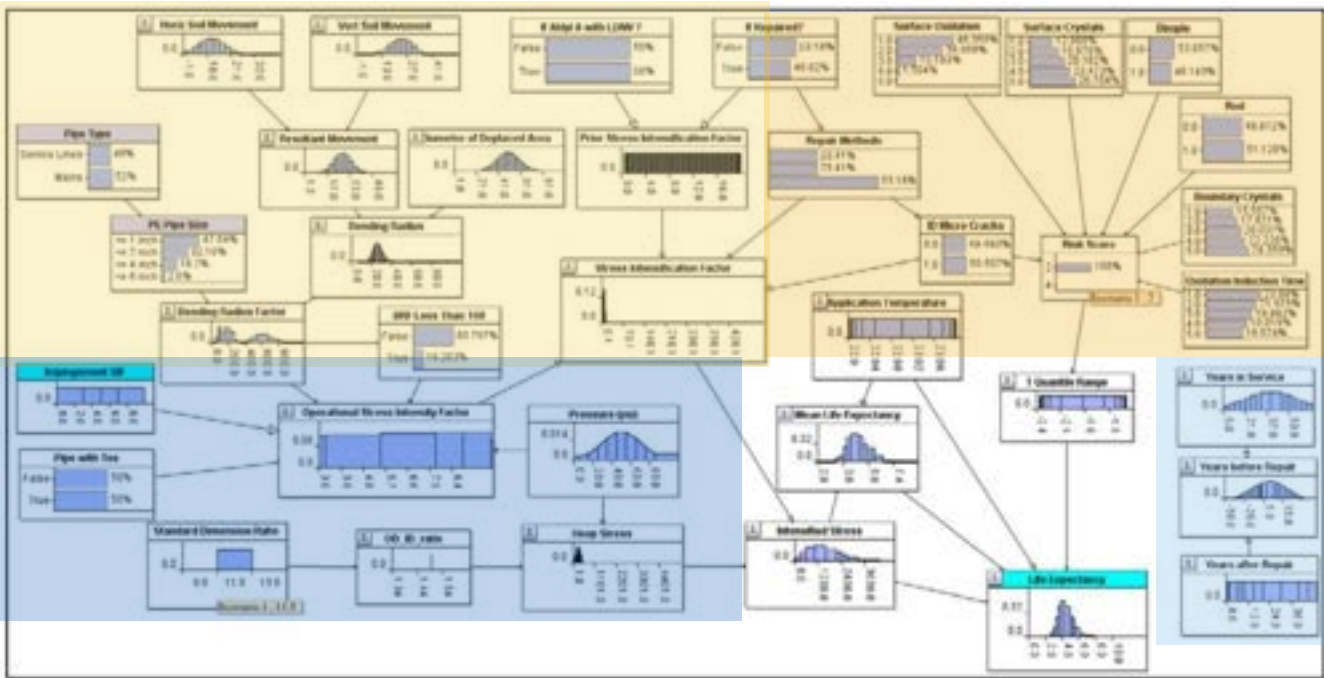
Material Properties



Stress Distribution

Soil

Pipe &  
Pressure



Inner Surface  
Features

Years in  
Service

Bayesian Network

# Risk Profile Development

The GTI Energy Lifetime Prediction Model Equation:

$$S = C \cdot \exp \left[ \frac{V \cdot \exp(k(T - T_{ref})) + \frac{H}{n}}{R} \left( \frac{1}{T} - \frac{1}{T_{ref}} \right) \right] t^{-\frac{1}{n}}$$

Where,

**S** = Test stress at test temperature, [psi]

**t** = Test time at test temperature, [h]

**T<sub>ref</sub>** = Reference temperature, [K]

**T** = Test temperature, [K]

**C** = Stress that will result in a failure in one (1) hour @ T<sub>ref</sub>, [psi]

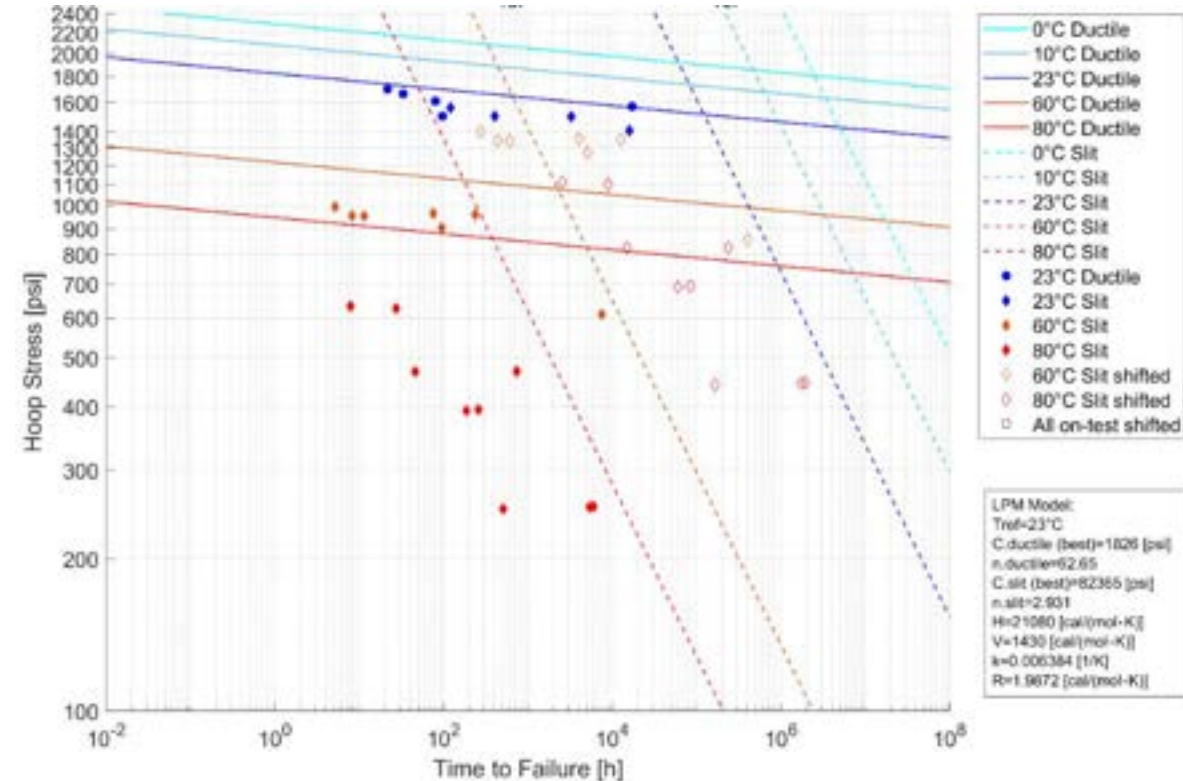
**n** = Characteristic creep rate exponent, [unitless]

**H** = Horizontal activation energy, [cal/(mol\*K)]

**V** = Vertical activation energy @ T<sub>ref</sub>, [cal/(mol\*K)]

**k** = Temperature dependence factor of the vertical activation energy, [K<sup>-1</sup>]

**R** = Ideal gas constant, 1.9872042586 [cal/(mol\*K)]





## Risk Profile Development

Resins with predicted remaining lifetimes of hundreds – or even thousands – of years do not account for the inevitable bulk depletion of stabilizers.

Testing of resins from ATCO's system show that the salient difference between them, in terms of remaining lifetime, lies in their remaining capacity of stabilizers.

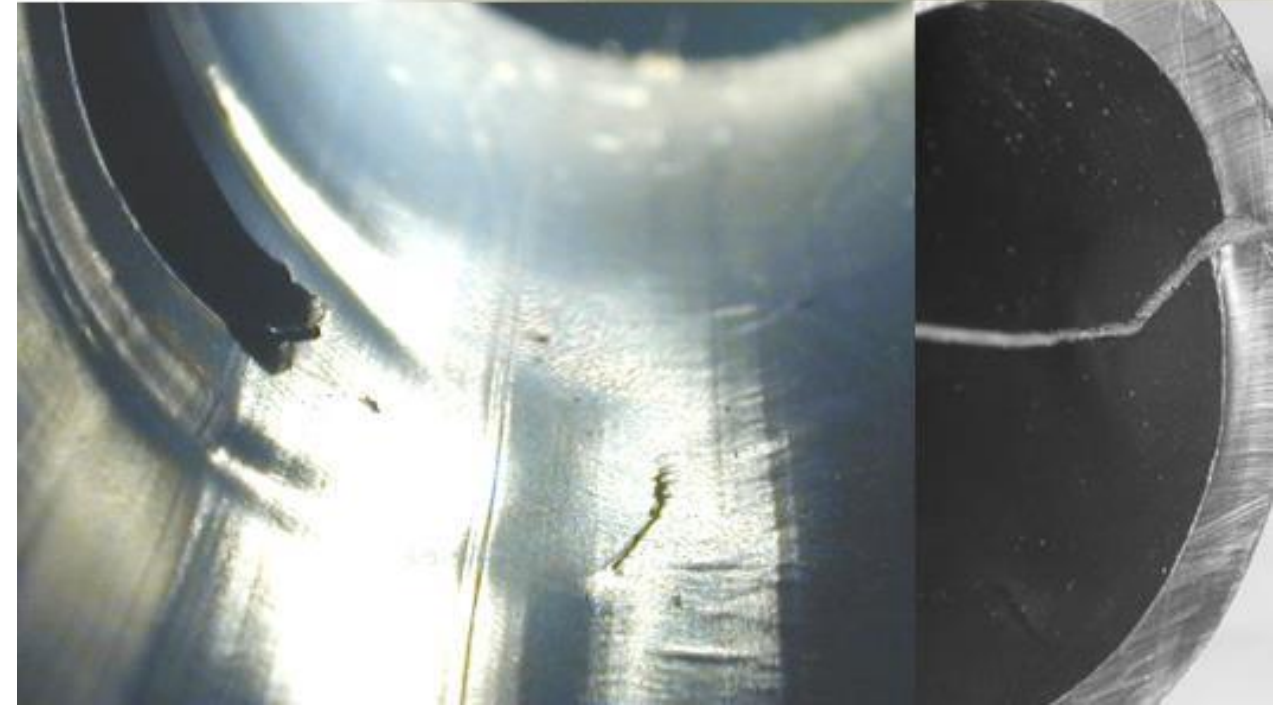
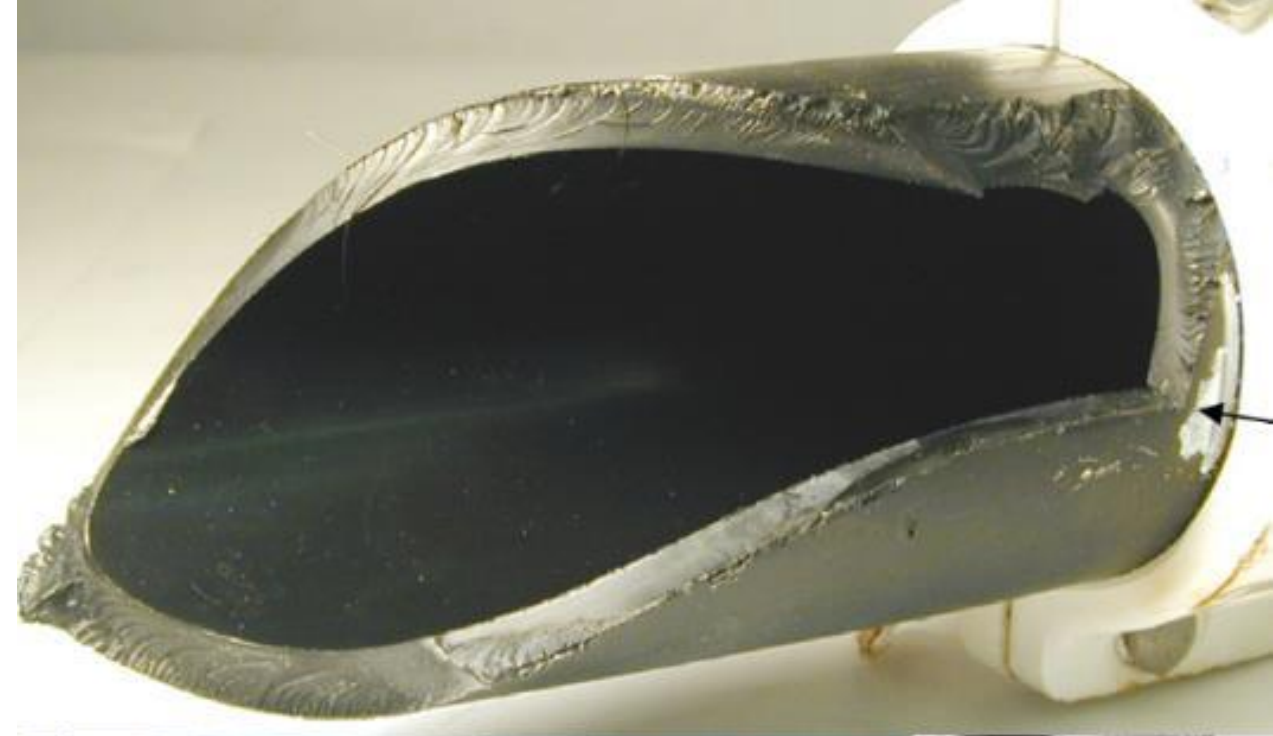


ARE VINTAGE PE PIPELINE ASSETS REALLY AGEING OUT?

# Risk Model – Factors Affecting Slow Crack Growth (SCG)

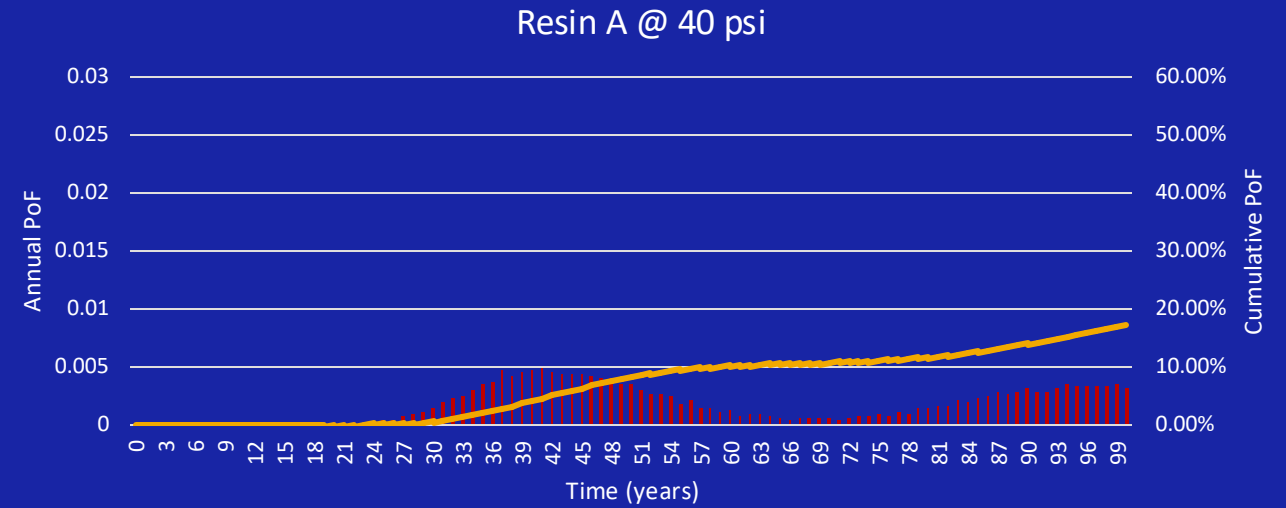
The most relevant factors affecting SCG rates include

- Resin
- Time-in-Service
- Temperature
- Stress

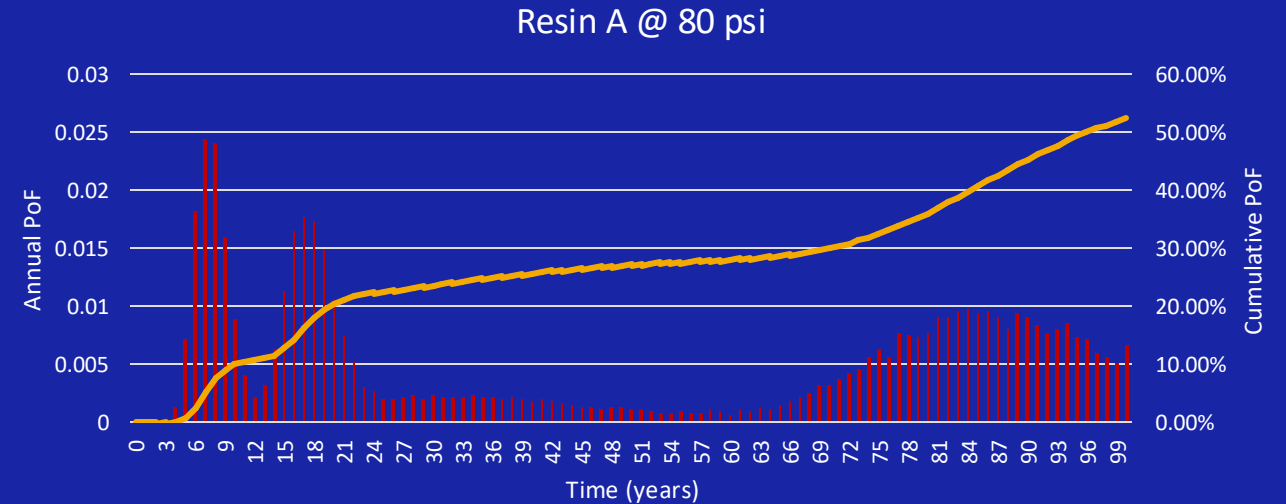


# Impact of Pressure

- Fixed Values:
  - Resin A
  - Temperature = 10.6°C
  - SDR = 11
- Variable Pressure:
  - Pressure 1: 40 psi
  - Pressure 2: 80 psi



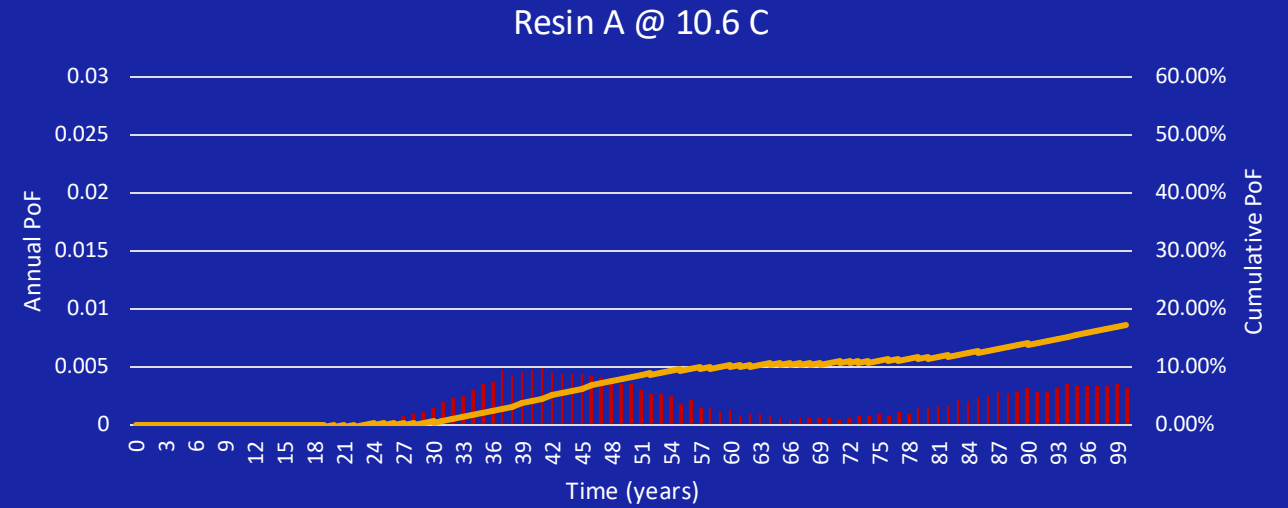
Probability Density Function Cumulative Distribution Function



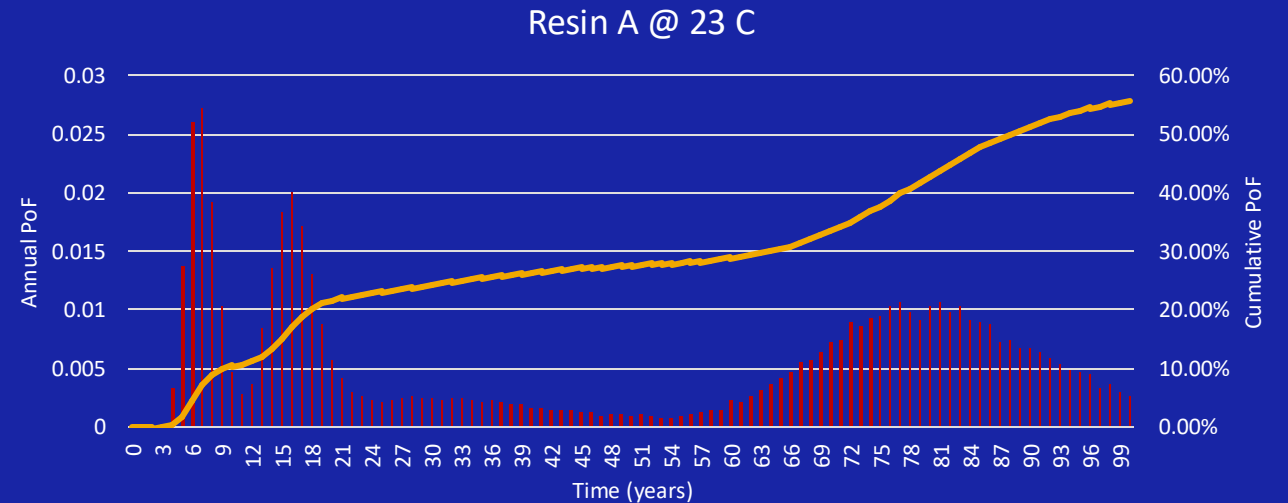
Probability Density Function Cumulative Distribution Function

# Impact of Temperature

- Fixed Values:
  - Resin A
  - SDR = 11
  - Pressure = 40 psi
- Variable Temperature
  - Temp 1: 10.6 °C
  - Temp 2: 23 °C



Probability Density Function Cumulative Distribution Function



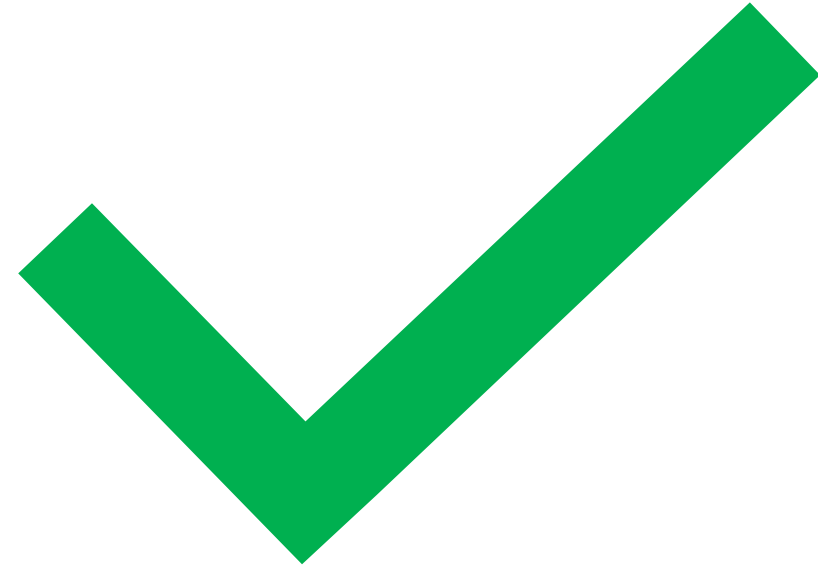
Probability Density Function Cumulative Distribution Function



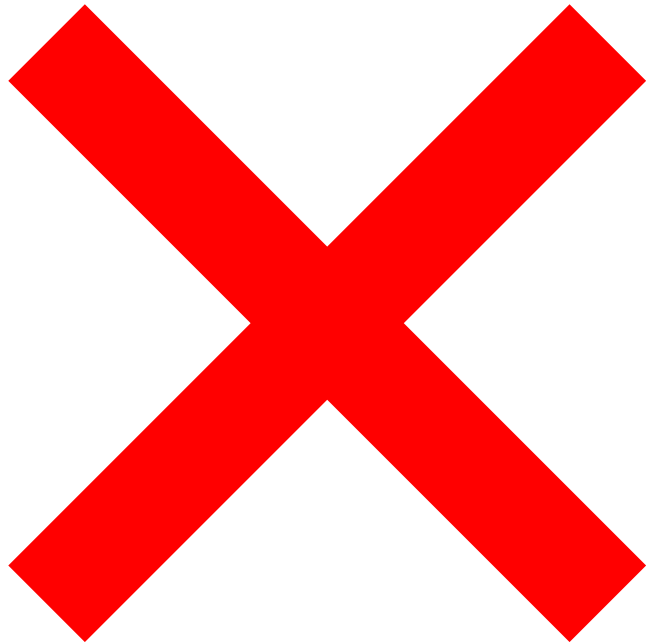
# Risk Model – Operationalization

We Know:

- Current condition
- Temperature and pressure
- Non-material stress intensification factor (SIFs)
- Resin-specific remaining useful life (RUL) curves



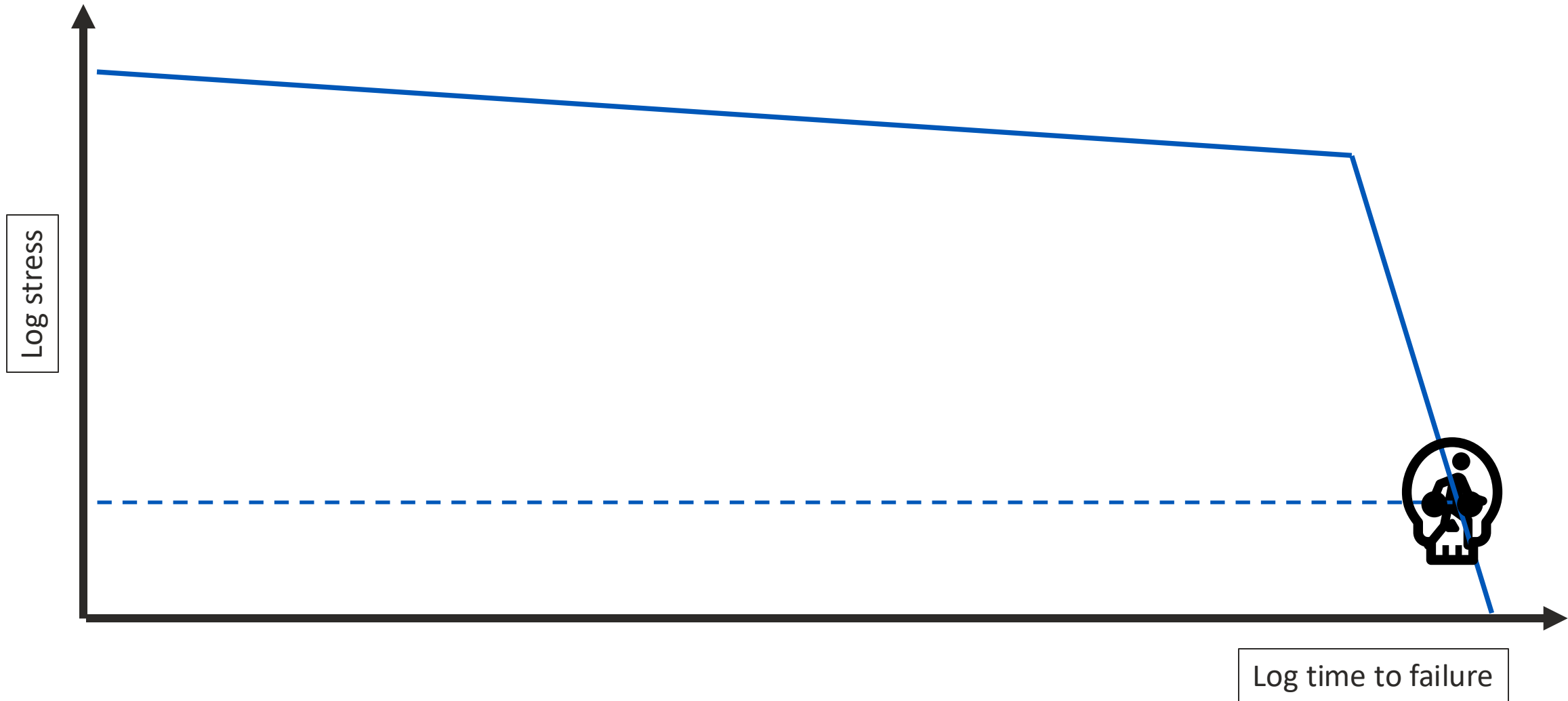
# Risk Model – Operationalization



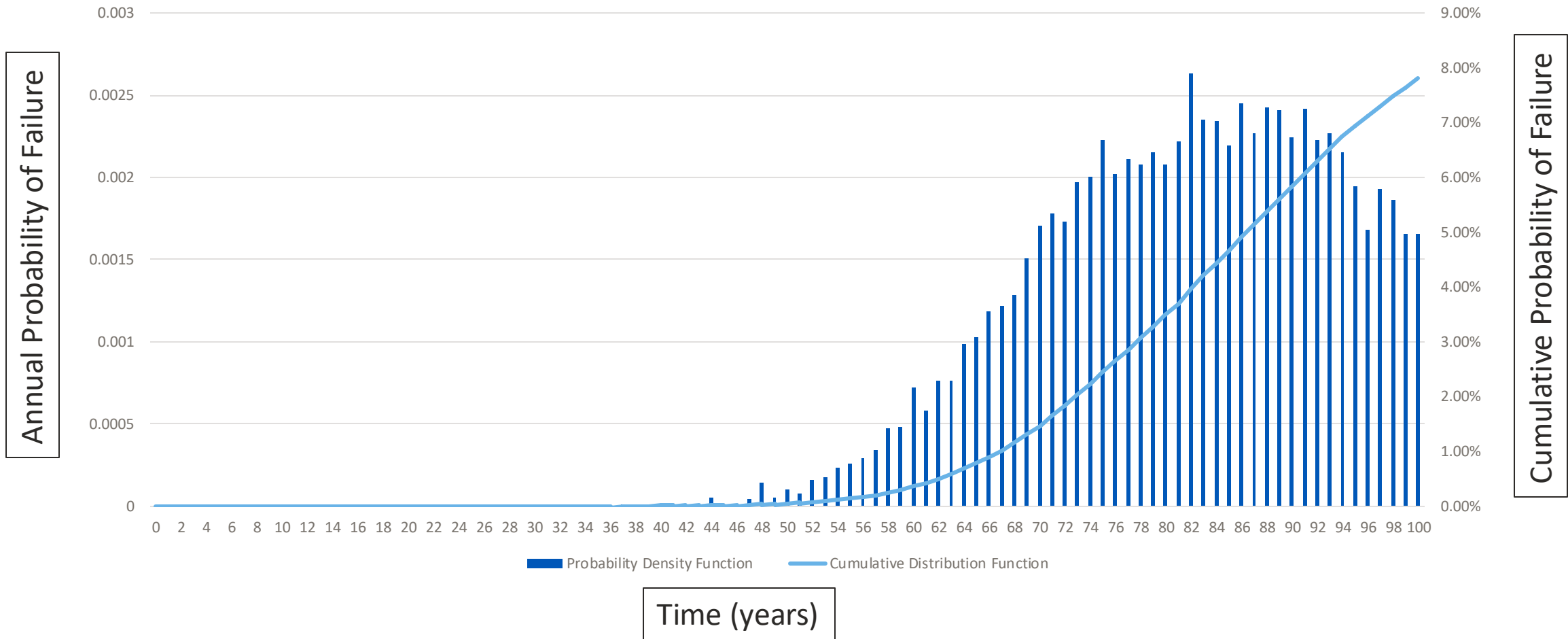
We Still Need:

- Actual operating conditions
- Knowns and unknowns
- Field observations
- Distribution Integrity Management Program (DIMP)

# Risk Model – Why Monte Carlo?



# Risk Model – Why Monte Carlo?





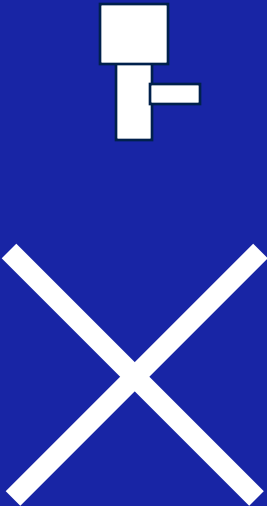
# Risk Model – Monte Carlo Simulation

For each resin

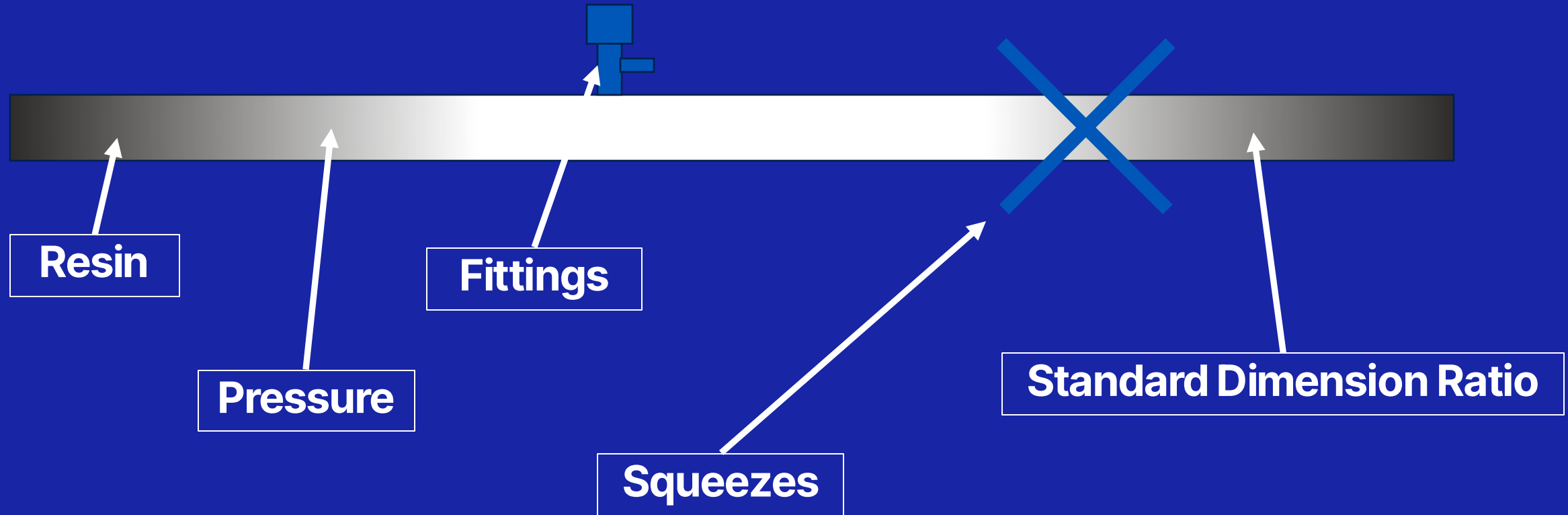
Non-material  
SIFS

Temperature

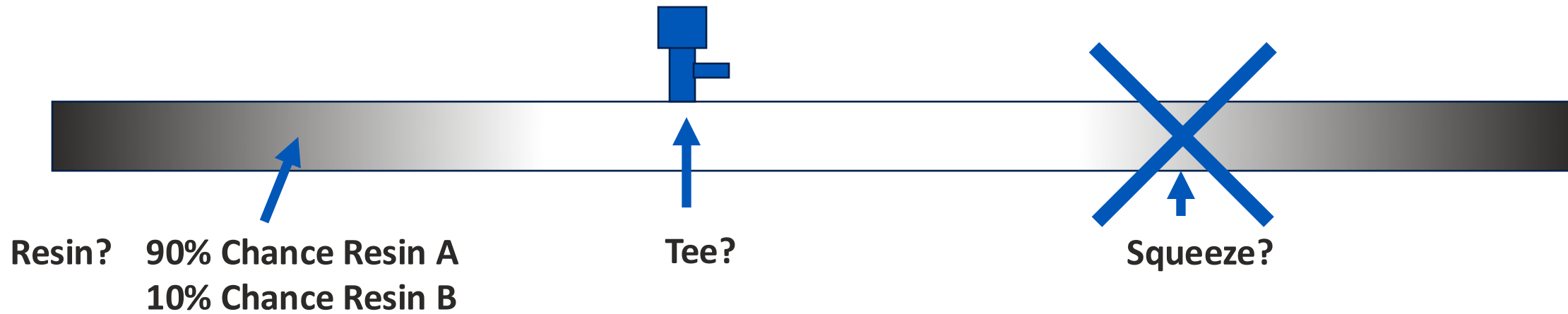
			Performance for Resin A				
			Worst	→			Best
			1	2	3	4	5
Pipe Stress Level	Lowest	1	Curve 1A	Curve 2A	Curve 3A	Curve 4A	Curve 5A
	↓	2	Curve 1B	Curve 2B	Curve 3B	Curve 4B	Curve 5B
		3	Curve 1C	Curve 2C	Curve 3C	Curve 4C	Curve 5C
		4	Curve 1D	Curve 2D	Curve 3D	Curve 4D	Curve 5D
		5	Curve 1E	Curve 2E	Curve 3E	Curve 4E	Curve 5E
		6	Curve 1F	Curve 2F	Curve 3F	Curve 4F	Curve 5F
	Highest	7	Curve 1G	Curve 2G	Curve 3G	Curve 4G	Curve 5G



# Risk Model – Pipe Attributes



## Risk Model – Uncertainty



**1. Uncertainty  
in what/where**

**2. Uncertainty in how  
this affects performance**

# Risk Model – Calibration

Why calibrate?

- Field observations
- Discrete samples vs. continuous pipes

Calibration principles

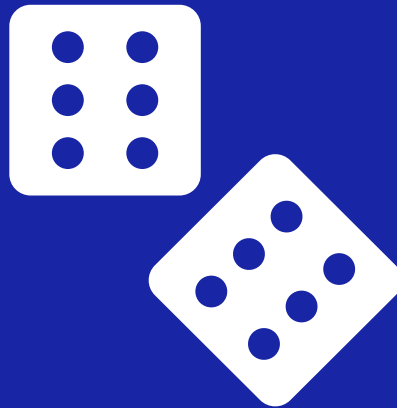
- Sampling data + real-world experience
- Ongoing requirement



# Risk Model – DIMP Incorporation

## Other threats per ASME B31.8S

- Time dependent
  - Internal/external corrosion (can be extended to other degradation mechanisms)
  - SCC (extended to fatigue)
- Stable
  - Manufacturing defects
  - Construction defects
  - Equipment failure
- Time independent
  - External interference
  - Incorrect operations
  - Natural forces



## Consequence of failure

- Not every failure created equal
- Key consequence factors:
  - Leak size
  - Pressure
  - Diameter
  - Leak location
  - Distance to structures
  - Ground cover
  - Services



# Are vintage PE pipeline assets really ageing out?

Poor performing  
resins

Strong performing  
resins

The broader risk  
picture

Data-informed

Remaining  
uncertainty

Path forward



**ATCO** Energy Systems™

**Thank you**

[ATCO.com/EnergySystems](https://atco.com/energysystems)

Tel: 403.292.7500

5302 Forand Street SW  
Calgary, Alberta T3E 8B4  
Canada

