

# Heat Exchanger Bundle Module Update

API RBI User Group Meeting  
Houston Marriott Greenspoint



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October 5, 2006

PROPRIETARY INFORMATION  
For Authorized Company Use Only



# API RBI Bundle Module

- Currently being revamped to address many of the deficiencies and negative votes brought out in the balloting process
  - Major focus was on CW bundles
  - MTTF for process bundles
    - Determine MTTF for non-CW bundle population
    - Apply factors (F1, F2, F3)
      - Tube Metallurgy/Corrosion Factor
      - Differential Pressure (>300 psig)
      - TEMA Type
    - Lack of matching or filtering criteria for process exchangers
  - Inspection planning was not very rigorous
    - Inspection modifiers were used to reduce risk (Highly Effective = 2.0, Usually effective = 1.5, etc.)
    - Did not consider damage mechanism
    - Completely different than other components in RBI
  - How do you address actual bundle condition, or remaining life?
    - 75% bundle life assumption when using MTTF of specific bundle
    - Modification of installation date based on number of successive inspections with no corrosion

# API RBI Bundle Module

- Consequence of Failure (COF)

$$COF = Cost_{prod} \times \frac{Rate_{red}}{100} \times Sddays + Cost_{env} + Cost_{sd}$$

- Probability of Failure (POF) is determined either of four methods
  - User Input Weibull Parameters
  - User Input MTTF
  - Filtering on Local and Seed Failure Libraries
  - Specific Bundle Inspection History
- User Supplied Weibull parameters or MTTF
  - If supplied, will be used
  - Required, if no failure data or insufficient amount of data is available either locally or from seed

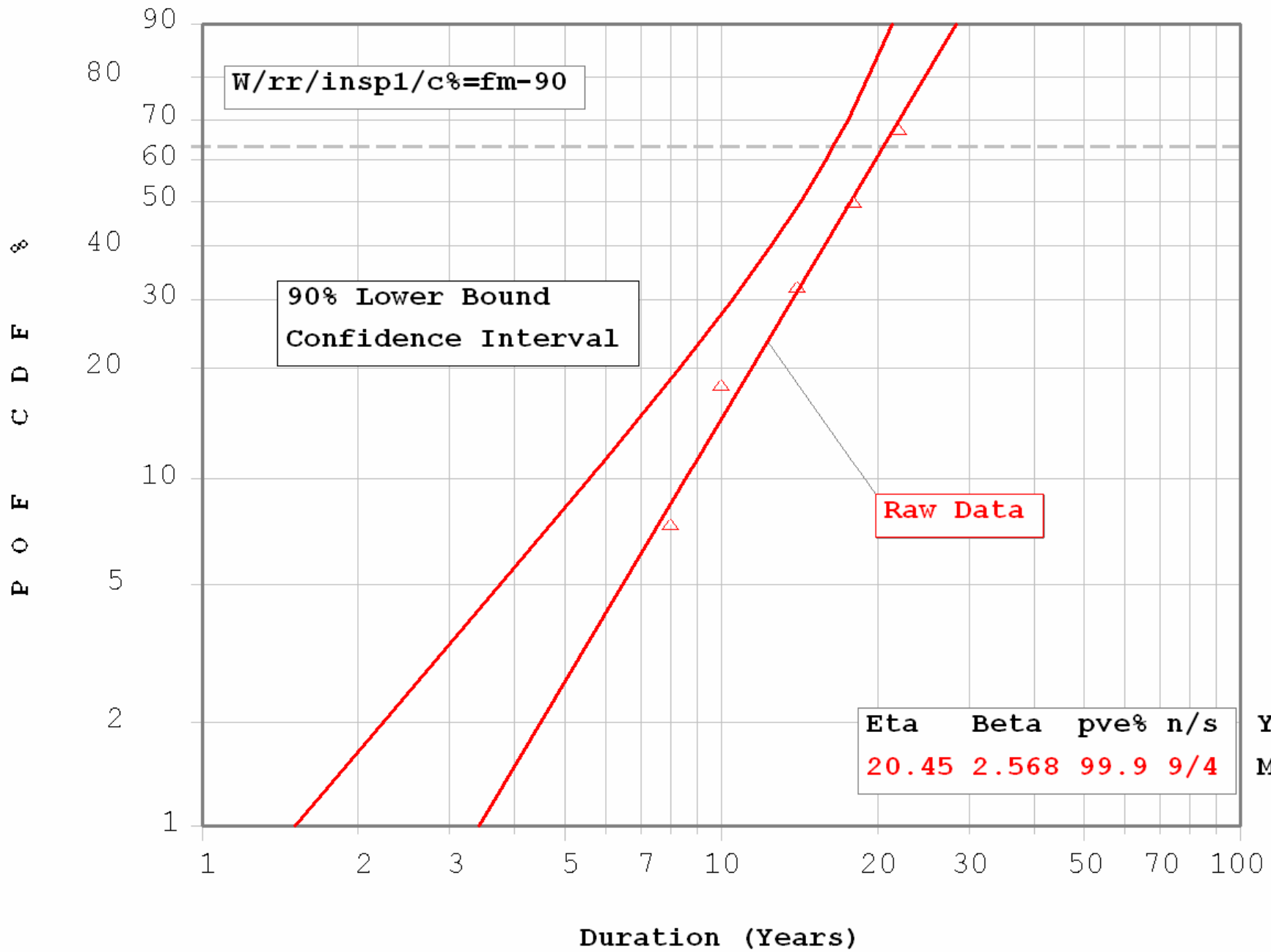
# API RBI Bundle Module

- Filtering on Local and Seed Failure Libraries
  - Local database includes active and inactive bundles from J-tree
  - Seed database is accessible and includes corporate library or other similar failure database.
- Filter on failure Libraries
  - Exchanger Type
  - Tube metallurgy
  - TS and Shellside Fluid Categories
  - Operating conditions, Temps, Pressures, Velocities, etc.
  - Process Unit
  - Controlling Damage Mechanism
  - Fluid Damage Modifiers (H<sub>2</sub>S, Sulfur, Caustic, etc.)
  - Many, many others

# API RBI Bundle Module

- Specific cooling water circuits can be filtered by selecting filters as follows:
  - Local failure database
  - Fluid Category – Cooling Water
  - Process Units – List those supplied by Cooling Tower System
- Weibull plot based on filtered set of similar bundles
  - Goodness of fit test
  - If poor fit, redo filter/cut set
  - Ability to review matching bundle set
  - Eliminate outlier bundles as necessary to make the fit more appropriate
- Lower confidence bound set at 90%

# Weibayes Analysis of Heat Exchanger Bundle



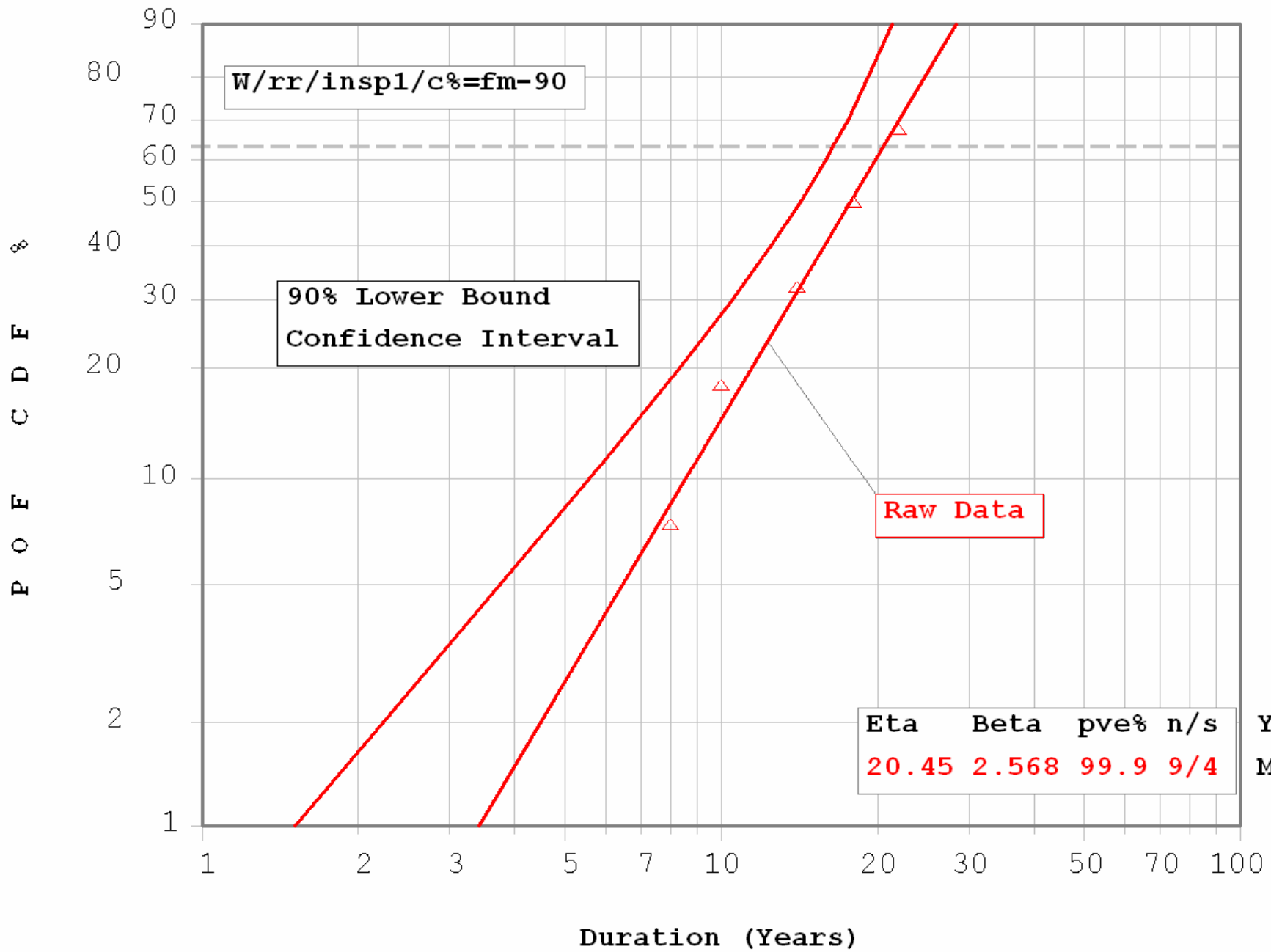
# API RBI Bundle Module

- Inspection effectiveness
  - Use uncertainty of weibull plot based on level of inspection
  - Better inspections reduce uncertainty, shifting weibull curve to the right

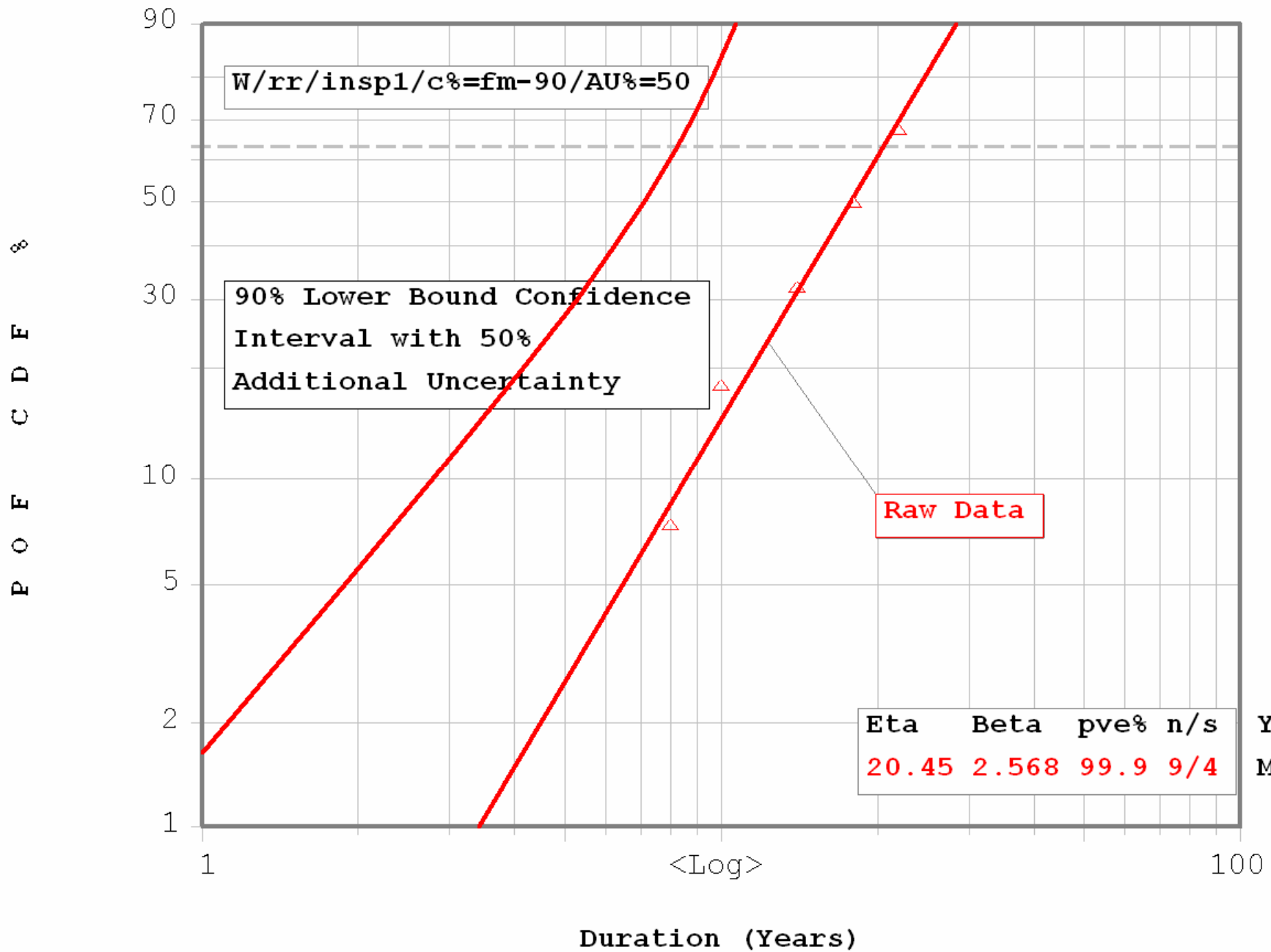
### Inspection Effectiveness and Uncertainty

Inspection Effectiveness	General Corrosion		Other Damage Mechanisms	
	Description	Uncertainty (%)	Description	Uncertainty (%)
E - Ineffective	Visual or thickness sampling without documentation of wall thickness	50		
D - Usually Not Effective	0-10 % Elliot Gage/Caliper Readings with Hydrotest	30		
C - Moderately Effective	10-20% Elliot Gage/Caliper Readings with Hydrotest	20		
B - Usually Effective	10-20% Eddy Current	10		
A - Highly Effective	100% Eddy Current	5		

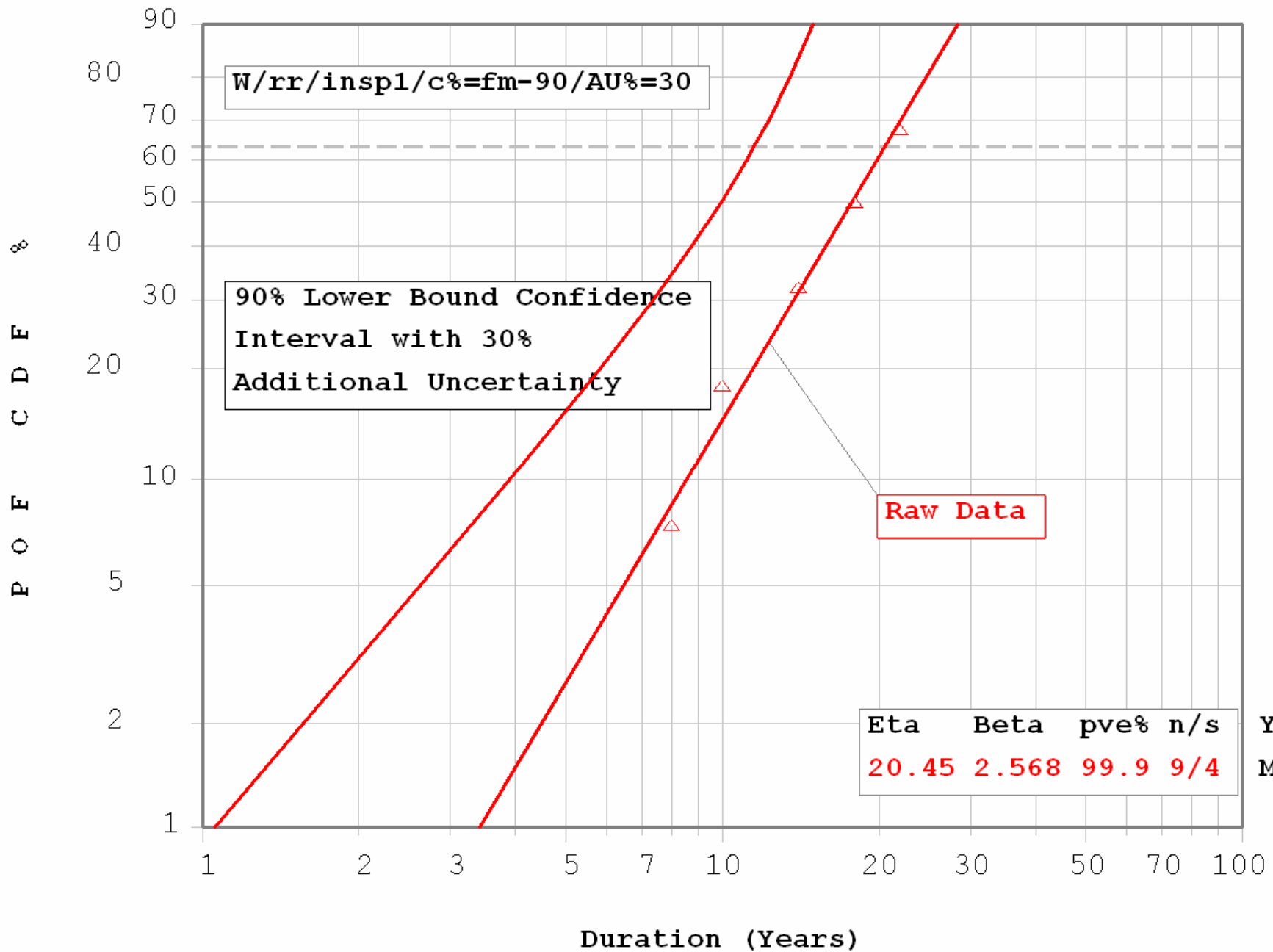
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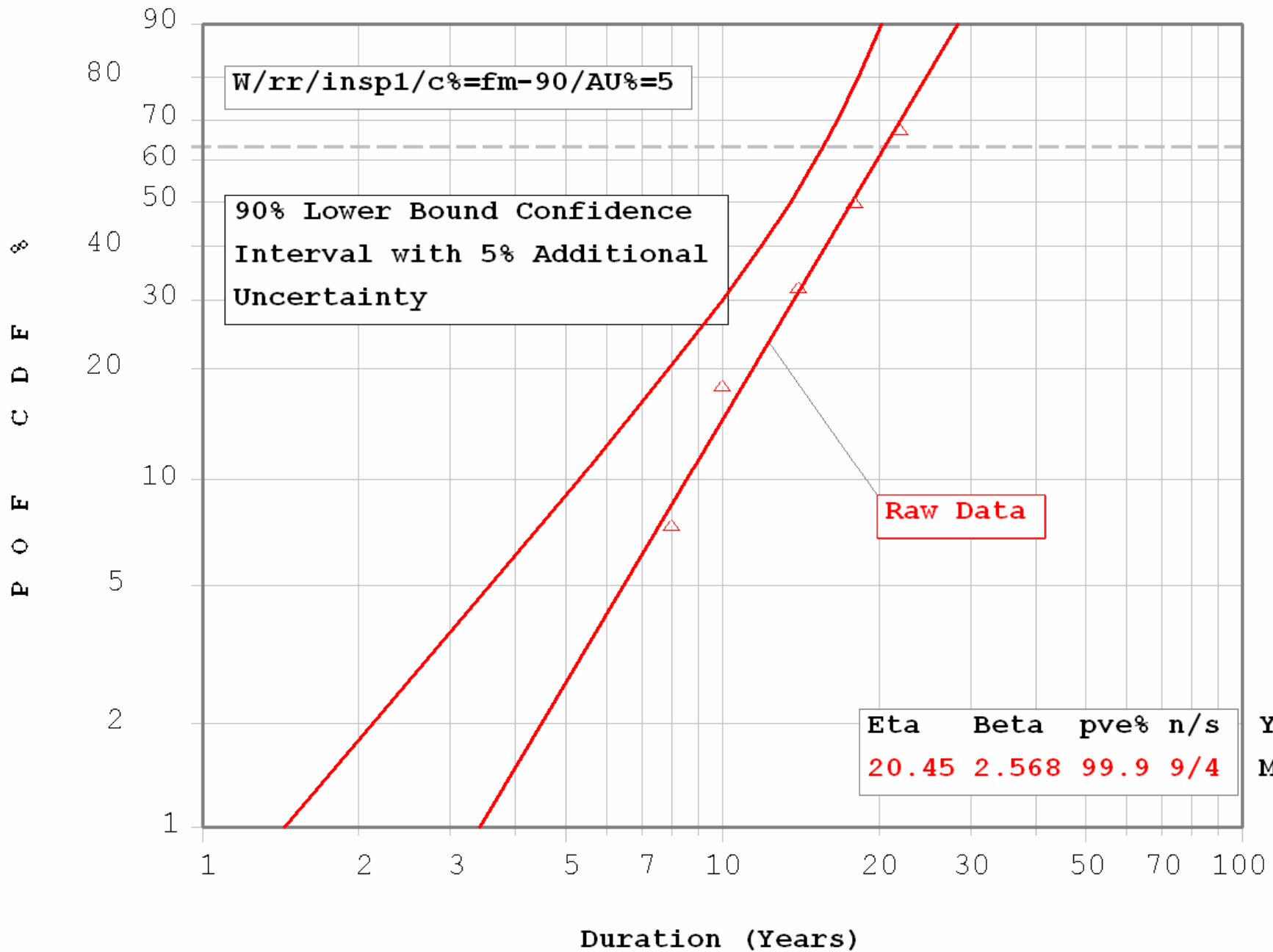
# Weibayes Analysis of Heat Exchanger Bundle



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# Results of Weibull Inspection Analysis

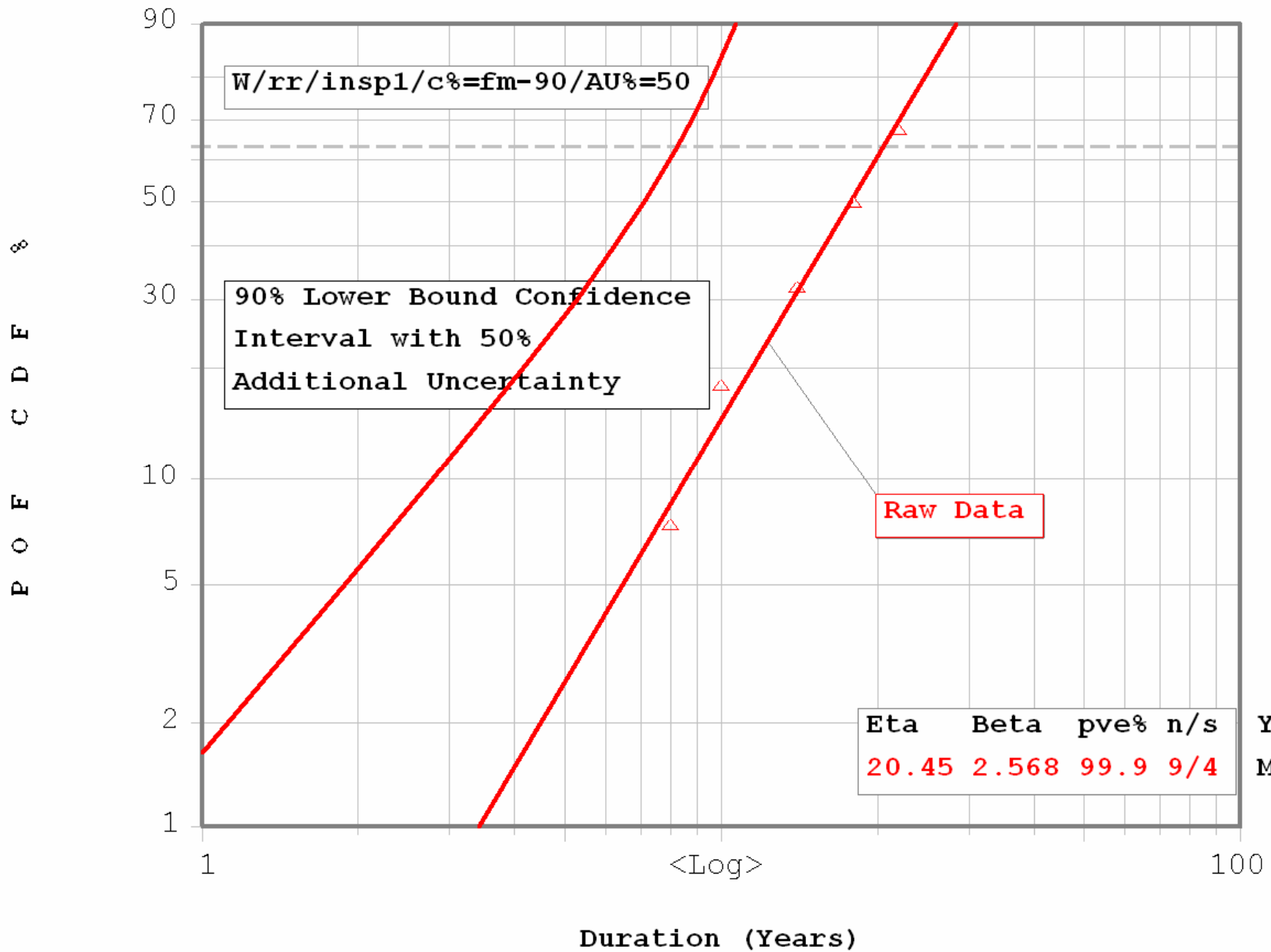
## Time in Service (Duration) as a Function of POF

Method	Time in Service (years)						
	POF= 1%	2%	5%	10%	20%	50%	90%
Weibull (Raw Data)	3.48	4.47	6.43	8.51	11.4	17.7	28.3
90% LBC	1.51	2.24	3.76	5.57	8.31	14.3	21.3
90%LBC with 5% AU	1.44	2.13	3.57	5.29	7.89	13.54	20.2
90%LBC with 10% AU	1.36	2.01	3.38	5.01	7.48	12.8	19.2
90%LBC with 20% AU	1.21	1.79	3.00	4.46	6.65	11.4	17.0
90%LBC with 30% AU	1.06	1.57	2.63	3.9	5.82	9.98	14.9
90%LBC with 50% AU	0.76	1.12	1.88	2.79	4.15	7.13	10.6

# API RBI Bundle Module

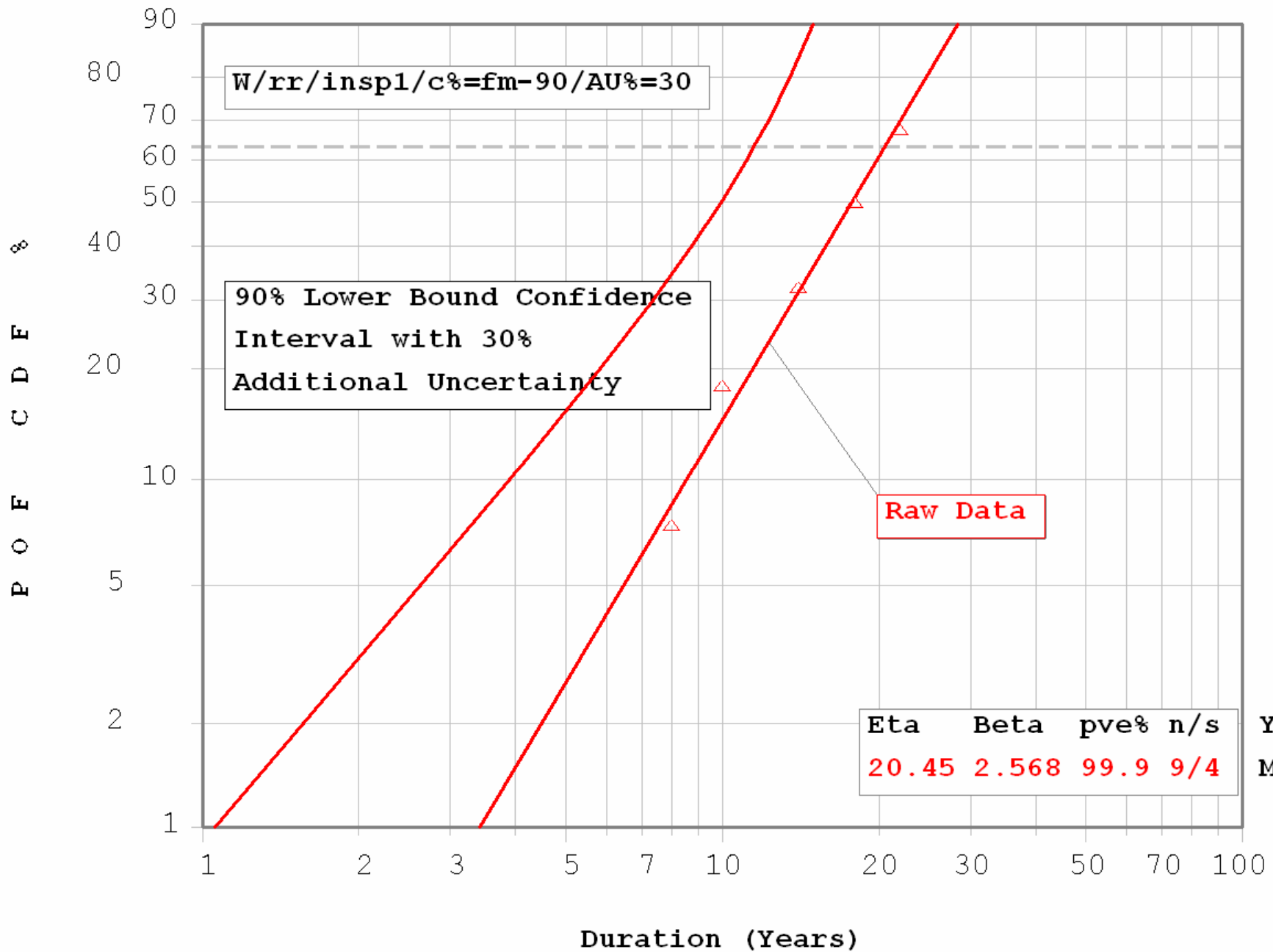
- Inspection Planning
  - An inspection provides us two things:
    - Reduction in uncertainty resulting in the use of a different failure rate curve, e.g. moving from a 50% AU curve (no inspection history) to a curve 20% AU curve (Usually Effective Inspection)
    - Knowledge of the actual condition of the bundle, this may result in a shift of the raw data failure rate curve to the right or to the left. The current condition of the bundle could either be quantified by remaining wall thickness data or by an estimate of the remaining life.

# Weibayes Analysis of Heat Exchanger Bundle

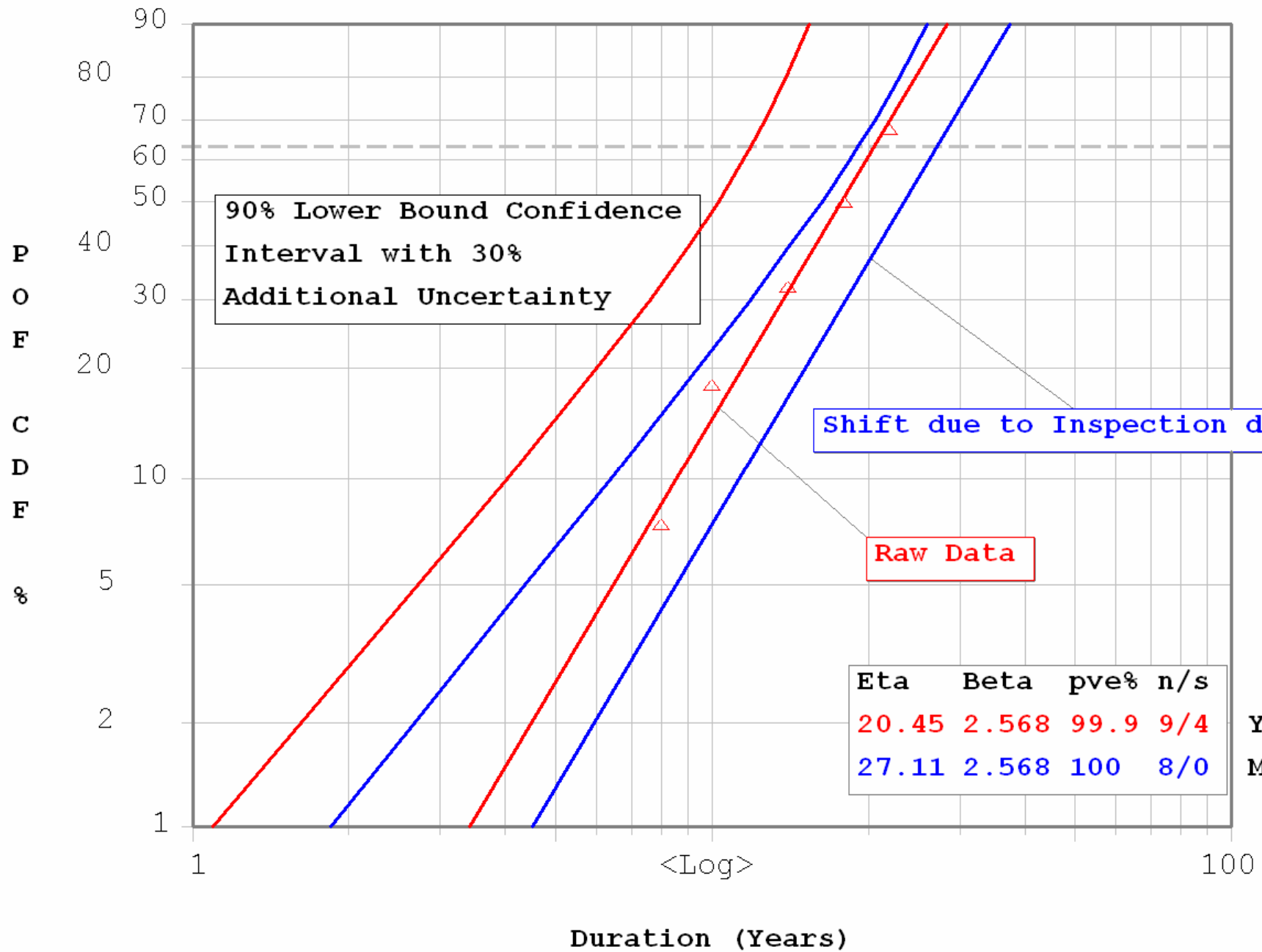


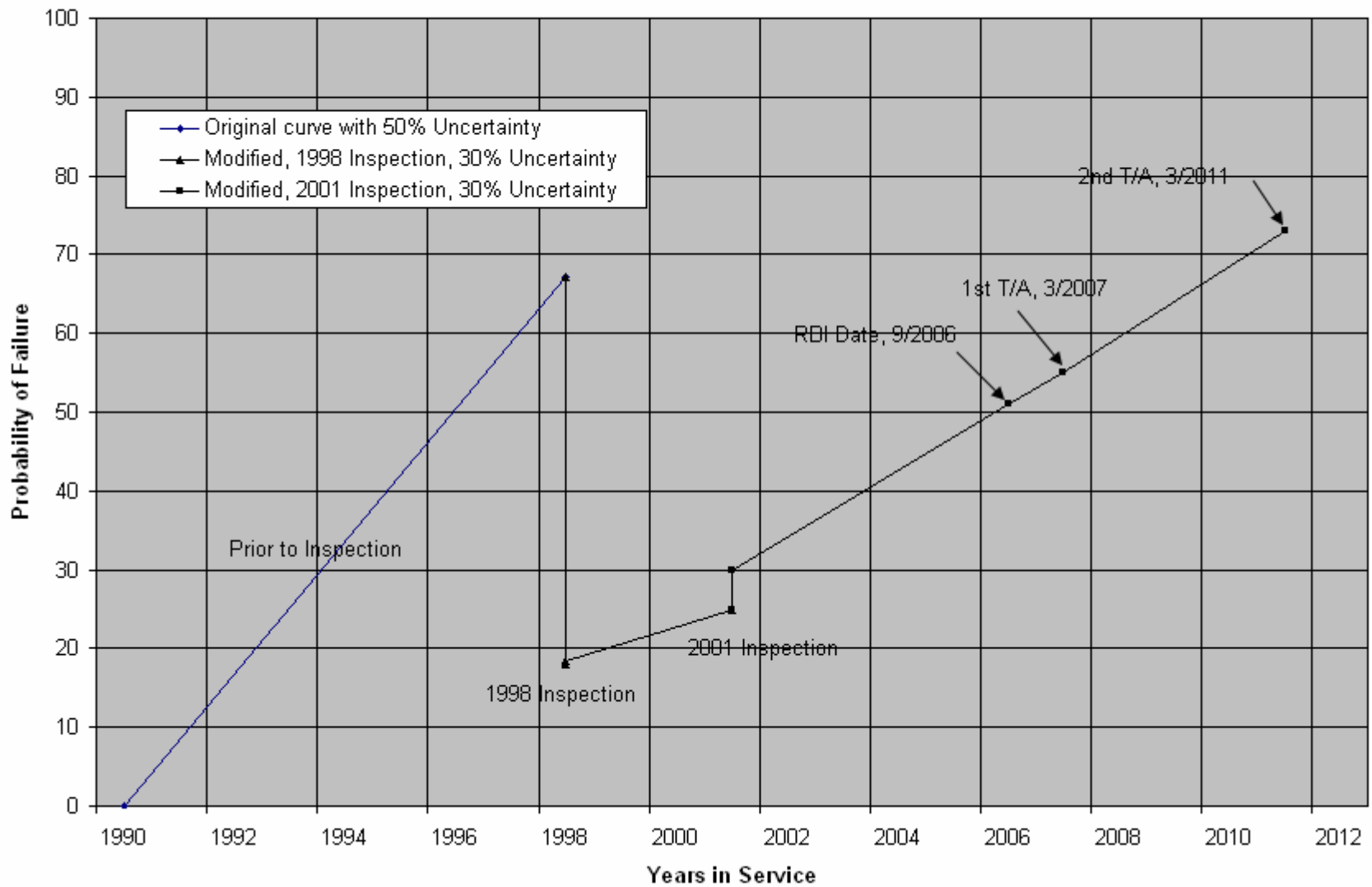
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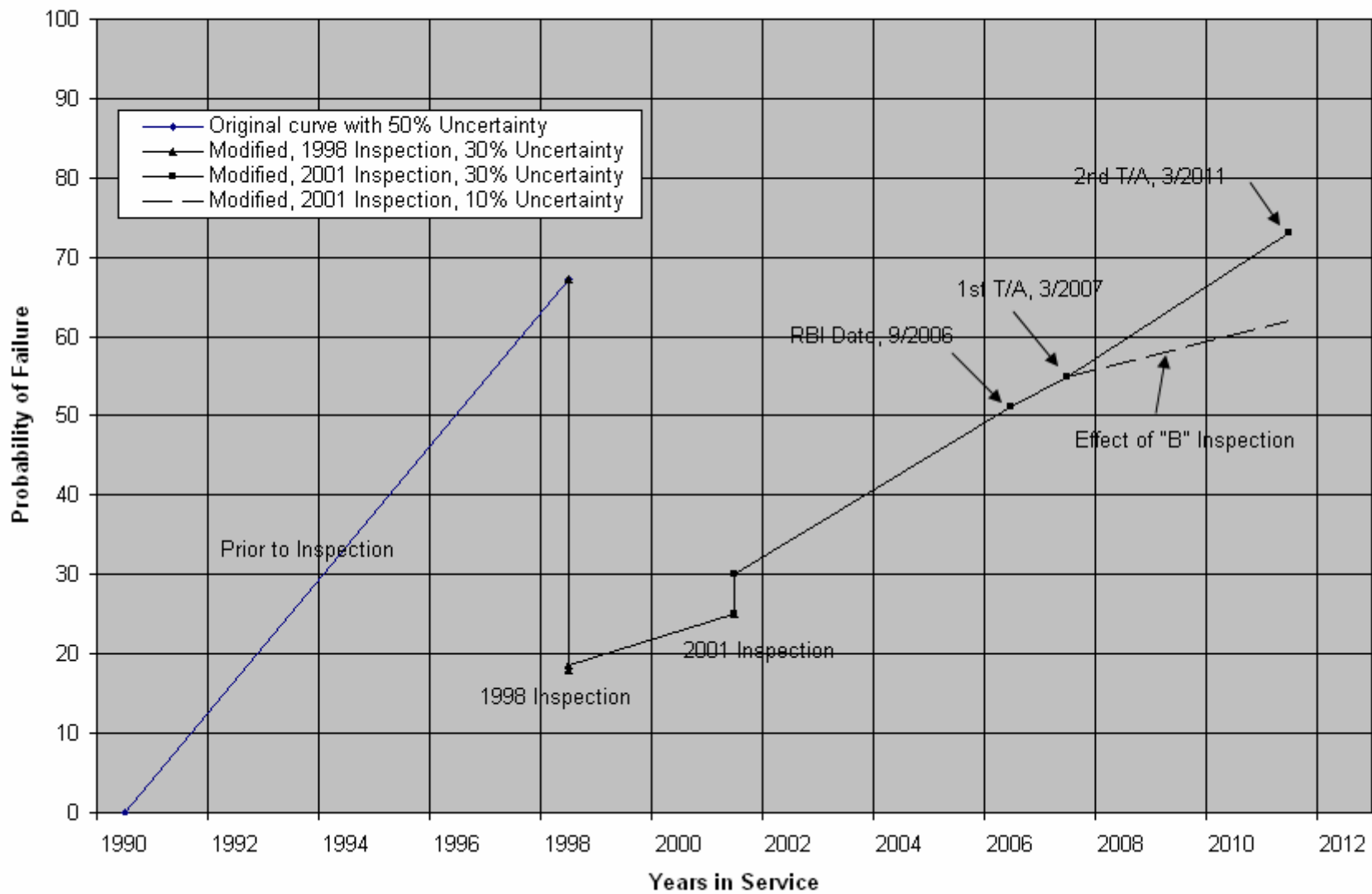
# Weibayes Analysis of Heat Exchanger Bundle



# Weibayes Analysis of Heat Exchanger Bundle







# Technical Questions

- Inspection planning for damage mechanisms other than general corrosion – utilize estimated remaining life field??
  - Cracking
  - Local Corrosion/ Erosion
  - Tube End Thinning
- Inspection Effectiveness table
- What to do when fouling governs inspection cycle?
- Definition of bundle retirement
  - 50% average remaining wall thickness
  - 70%, 80% ??
  - Make it a function of bundle criticality??
  - Make it a User input with default values??
  - Alternate definition is Estimated Remaining Life field

# Technical Questions

- How do you handle life extension efforts after initial tube bundle failure
  - Utilize “Estimated Remaining Life” field
  - Recommend inspection every opportunity?
  - Need to account for bundle rotation, bundle partial re-tube,
  - Remaining wall thickness of unplugged versus plugged tubes
  - Calculate MTBF using history of tube plugging
- Repair versus Replace decisions - Cost Benefit Analysis
- Add Crow-AMSA approach to evaluate bundle population

# Status

- Front-end work progressing well
- Weibull curve plotting capabilities complete
- Inspection planning calculations being programmed
- E2G is collecting data and methodology is being tested in pilot study of 120 bundles
- Any fine tuning of the methodology based on pilot study will be incorporated
- Ballot 2 by end of October, incorporated in 2007 ballot for Part 1 of RP581
- Released as part of version 8.2



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