Managing WTG Unreliability Costs through Failure Prediction and Proactive Maintenance

enXco Service Corp.

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About the Presenter

Mike Smith holds a BS in mechanical engineering from Iowa State University and quality engineer and quality auditor certifications from American Society for Quality. Mike manages over 1000 MW of wind generating capacity in Iowa, as well as performing various other engineering and management functions at enXco. Mike has 12 years experience in heavy manufacturing operations, engineering, and quality, and 6 years experience in wind.

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Presentation Preview

1. It's a 3-Step Program: Where are You?
2. O&M Costs Related to Reliability
3. You Must be Proactive
4. Design, Manufacturing, Quality, & Reliability
5. Practical, Proactive Methods
6. Attacking Reliability Issues and Placing Your Organization in Control

It's a 3-Step Program. Where are You?

Every organization has to go through the 3 phases of asset reliability:

- Denial: Failure to recognize there is a reliability problem.
- Recovery: Understanding where assets are in their life cycle.
- Freedom: Managing assets by minimizing life cycle costs.

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O&M Costs Related to Reliability

Preview

- *Life cycle costs—the bathtub curve.*
- *Reliability related costs.*
- *Remaining useful life reduction vs. cost of unplanned maintenance.*

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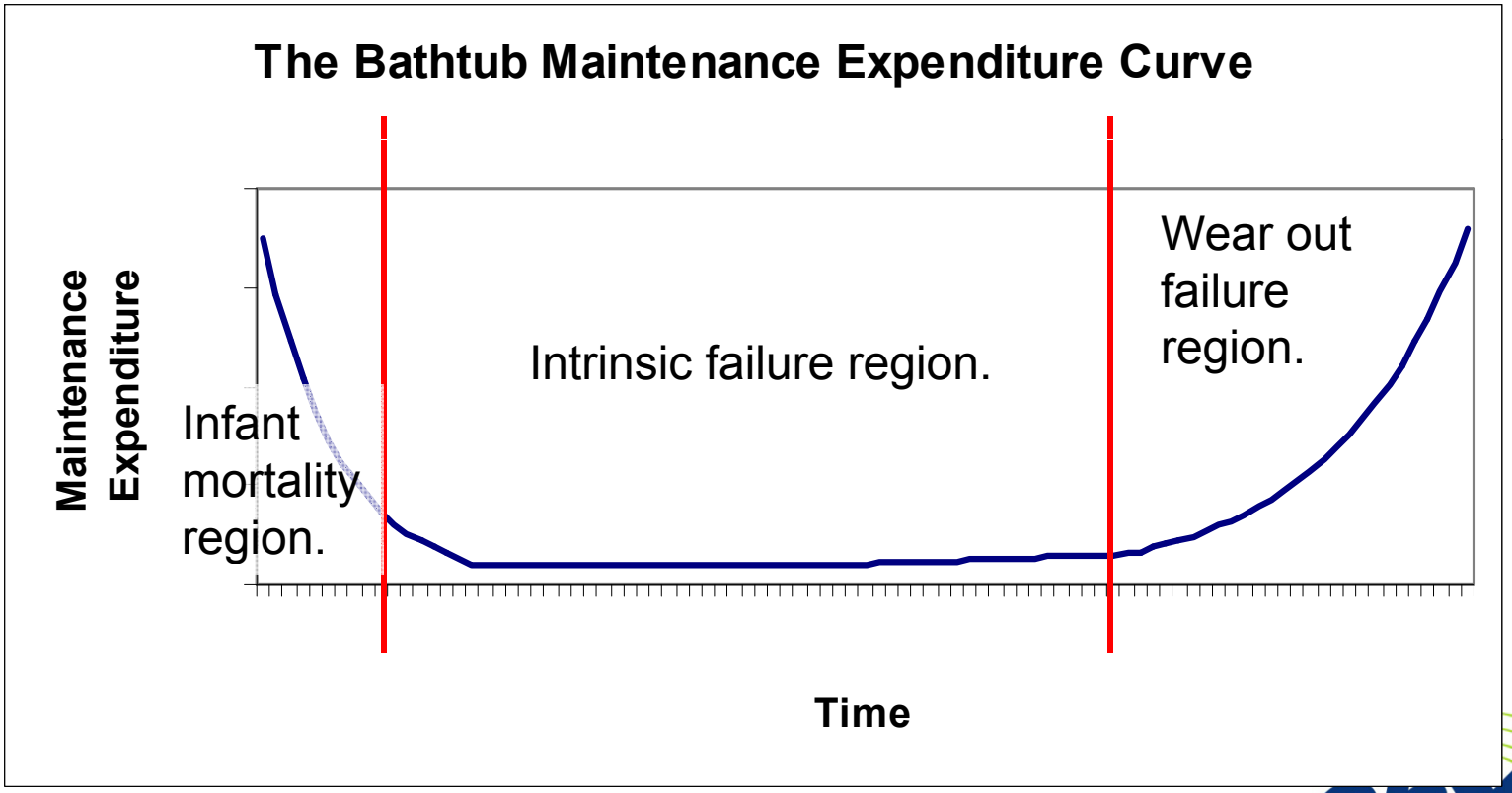
O&M Costs Related to Reliability

Life Cycle Costs—the Bathtub Curve



O&M Costs Related to Reliability

Reliability Related Costs

- Safety costs.
  - Fire/catastrophic failure.
  - Training.
  - Temporary staffing.
- Crane costs.
  - Mobilization.
  - Hourly.
  - Stand by.
- Labor costs.
  - Temporary staffing.
  - O/T.
  - Specialized skills.
- Destroyed component costs.
  - Higher cost to repair destroyed components.
  - You touch it; you break it.
- Lost revenue costs.
  - Energy value.
  - Federal/State PTC value.
- Loss of remaining useful life (RUL).

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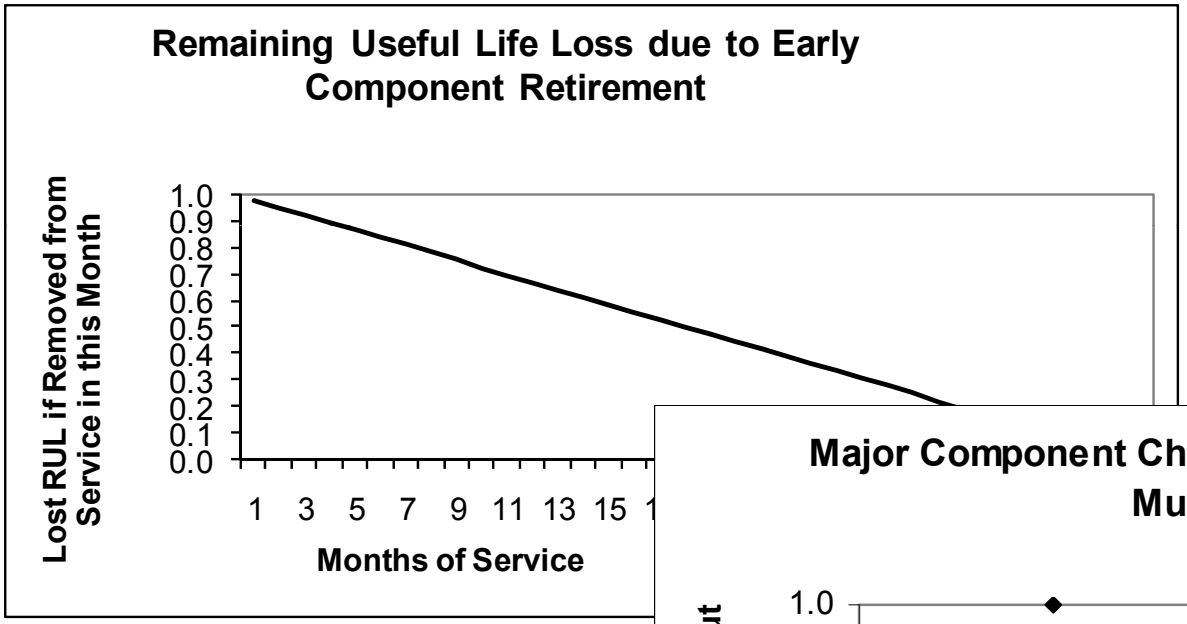
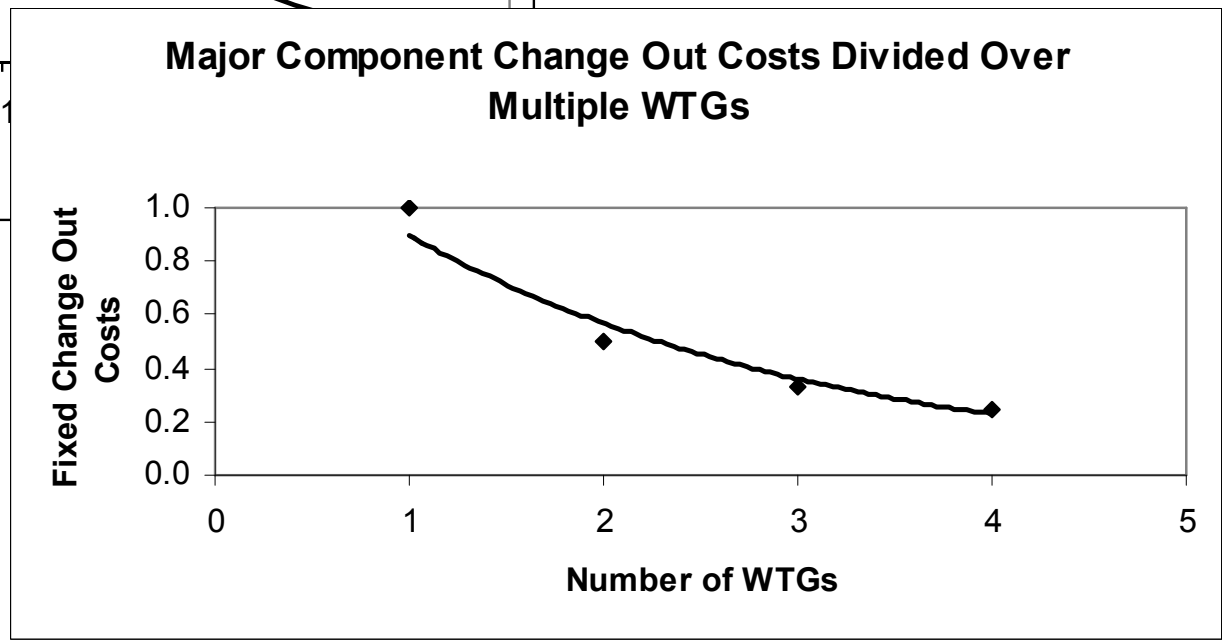
O&M Costs Related to Reliability

Remaining Useful Life Reduction vs. Cost of Unplanned Maintenance.





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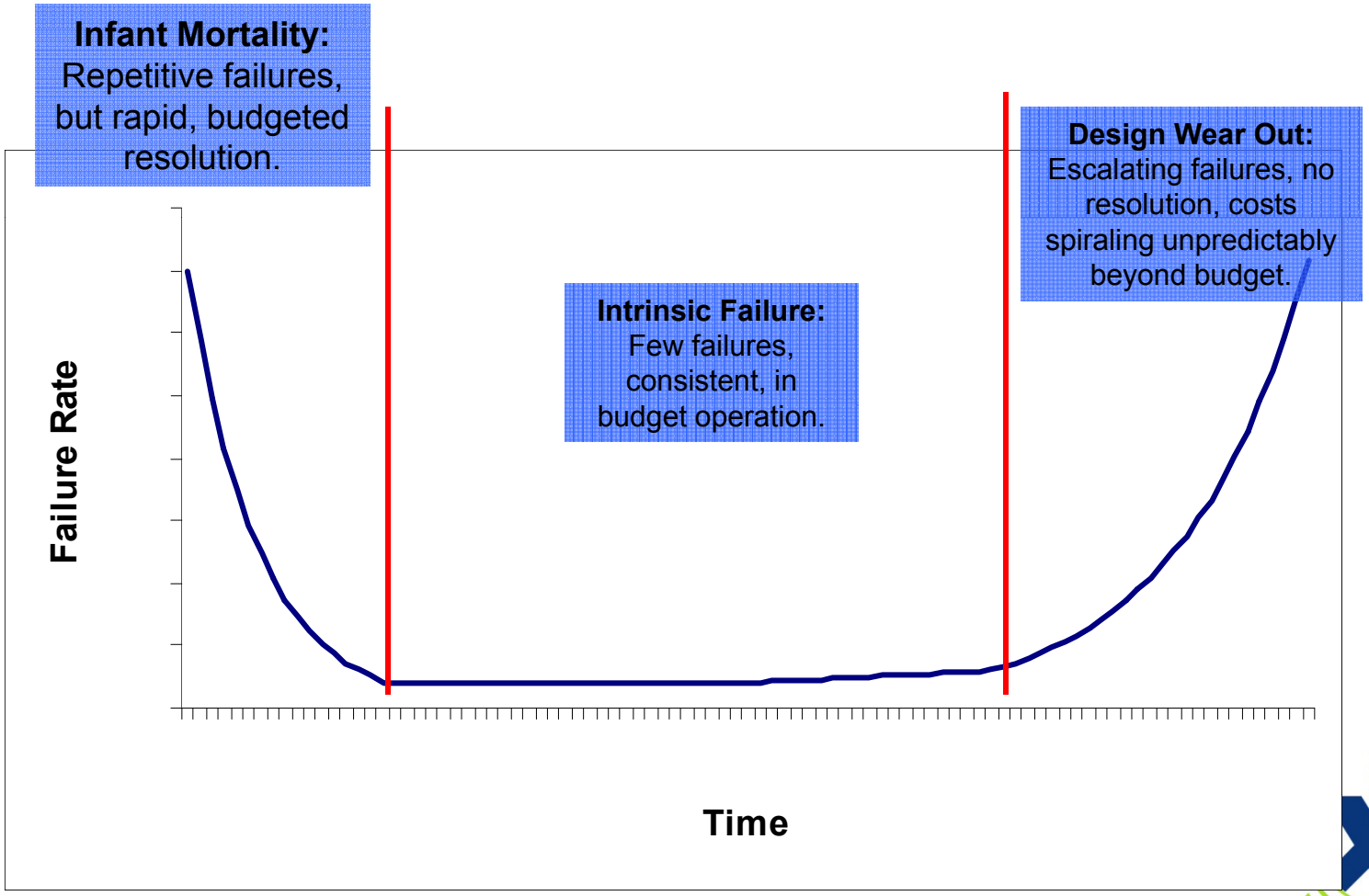
You Must be Proactive

Preview

- *Recognizing where you are in the process—the bathtub curve.*
- *Cost comparison: proactive component replacement vs. reactive component replacement.*

You Must be Proactive

Recognizing Where You Are in the Process—the Bathtub Curve



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You Must be Proactive

Cost comparison: Proactive Component Replacement vs. Reactive Component Replacement.

1.5 MW Gearbox R&R		
Activity	**Unscheduled R&R**	**Scheduled R&R with 2 additional crane activities.**
Crane Mobilization	60,000	$20,000
Crane Time	22,000	7,333
Gearbox Rebuild	175,000	125,000
Labor	12,500	7,500
Travel	2,500	0
Total Cost	$272,000	$159,833

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Design, Manufacturing, Quality, & Reliability

Preview

- *Reliability vs. quality—the bathtub curve.*
- *Design for reliability.*
- *Manufacturing quality & process control.*
- *Manufacturing cannot improve reliability.*
- *Latent Defects*

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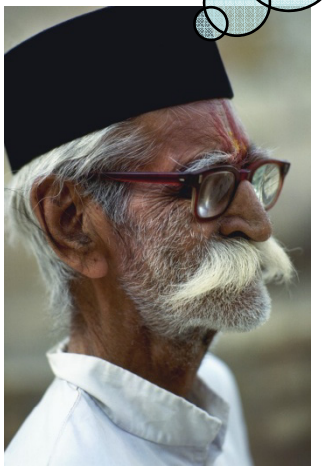
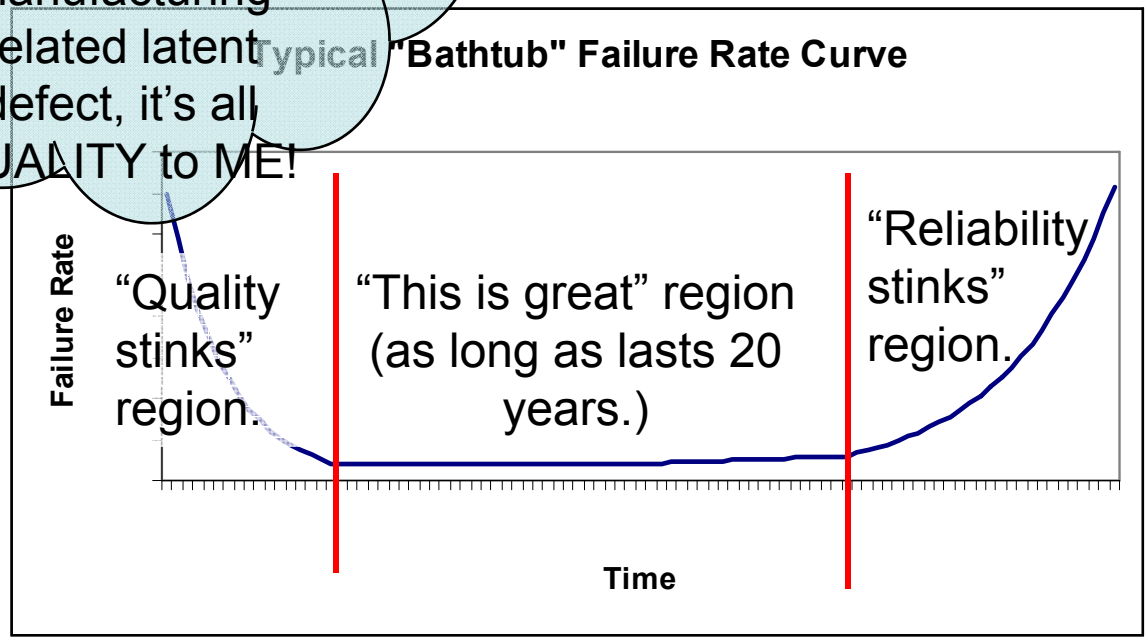
Design, Manufacturing, Quality, & Reliability

Reliability vs. Quality—the Bathtub Curve

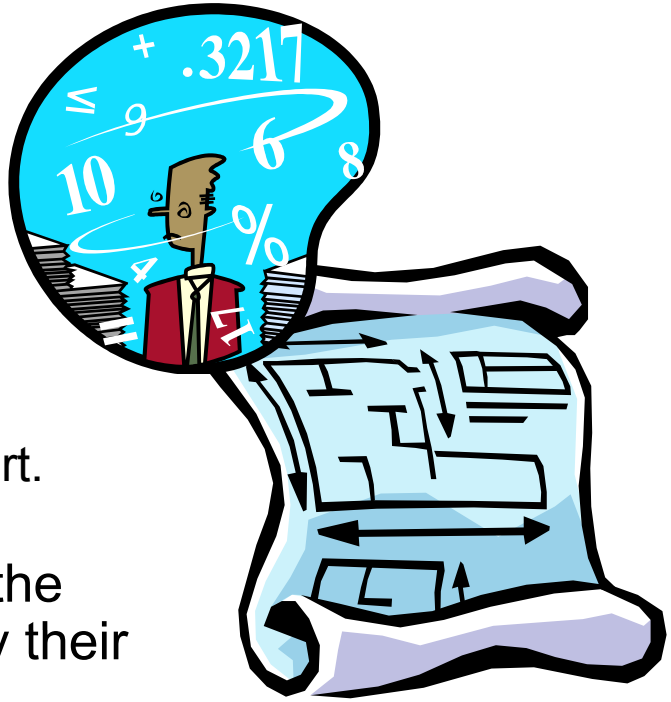
Design wear out, manufacturing related infant defect, or manufacturing related latent defect, it's all QUALITY to ME!





Design, Manufacturing, Quality, & Reliability

Design for Reliability

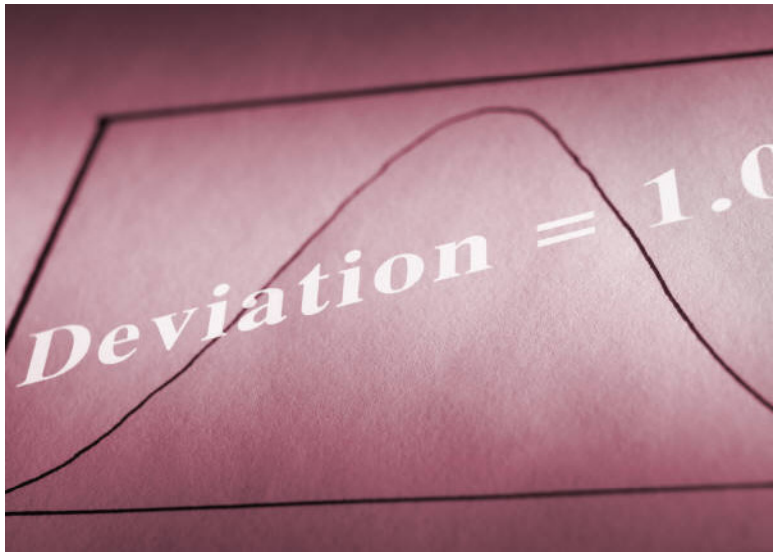


- The design of the product dictates long term reliability.
  - Materials.
  - Geometry.
  - Mass.
  - Manufacturability.
  - In manufacturing, state of the art is state of the art. Don't try to design above and beyond.
- *Design Wear Out* occurs when components of the product reach the end of their life as dictated by their design (not manufacturing errors).
- *Design Life* is the intended life span of the component. Hopefully design wear out coincides with design life!

Design, Manufacturing, Quality, & Reliability

Manufacturing Quality & Process Control

- Manufacturing quality relates to how well the manufacturing process duplicates the design.
- Process control, or lack thereof, is linked to infant mortality and intrinsic failure.



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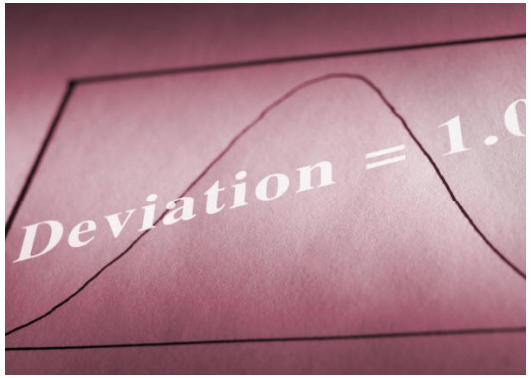
Design, Manufacturing, Quality, & Reliability:

Manufacturing Cannot Improve Reliability

- At best, the manufacturing process can produce a product with the designed reliability, but nothing better!
- In practice, manufacturing errors cause some failures.
  - Infant mortalities occur early in the life cycle and are caused by “special cause variation.”
  - Intrinsic failures occur later in the life cycle and are caused by “common cause variation.”



Design, Manufacturing, Quality, & Reliability:

Latent Defects

- All failures follow a pattern of progression.
- If the initiation of this progression occurs before the warranty expires, and the fruition occurs after the warranty expires, this failure may be described as a “latent defect.”
- A latent defect is a failure at any point in its progression.
- “Once metal moves, the component has failed.”

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Practical, Proactive Methods

Preview

- *Failure modes and effects analysis.*
- *Tracking, tracking, and more tracking.*
- *Modeling & prediction: Weibull, regression, & others.*
- *Tracking, tracking, and more tracking.*

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Practical, Proactive Methods

Failure Modes and Effects Analysis

Use the FMEA to:

- Predict failure causes.
- Prioritize activities.
- Document corrective actions and their effectiveness.
- Visit www.asq.org for more information on the FMEA.

Failure Modes and Effects Analysis												
Process	FMEA											
Latest Revision	5/25/2006											
Failures									**Countermeasures**			
Task	**Potential Failure Mode**	**Effect of Failure**	**Severity**	**Cause of Failure**	**Occurrence**	**Current Controls**	**Detection**	**Risk Priority Number (RPN)**	**Action**	**Responsible**	**Severity**	**Occurrence**
You can break any process down to a series of tasks. After identifying a potential failure mode, enter the task in question here. You need not identify every task in the process--only those for which potential failure modes have been identified.									Describe the action you will take to mitigate this failur			
	Describe the how the task can fail here. There may be more than one way for a task to fail. In that case, make a complete new entry on a new line.									Assign a responsible party to ensure the		
		What happens when the failure occurs? Describe here.									Re-do the rankings WITH IN PLACE to see what yo	

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Practical, Proactive Methods

Tracking, Tracking, and More Tracking

- Track items in a database format.
  - Use database principles.
  - One record for each critical component.
  - Vitally important!
- Track critical components and their identifiers (model numbers and serial numbers).
- Differentiate failure modes when completing R&R of major components. Pictures are a plus!
- **Document aging parameters when completing R&R of major components** (operating hours, MWh, hard stops, etc.)

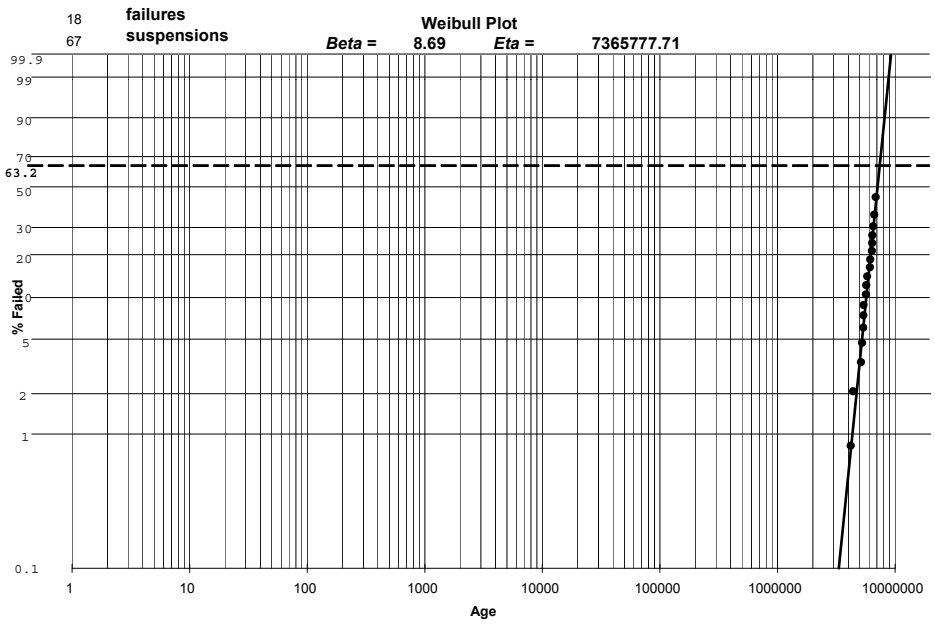
WTG	Component	Make	Model	S/N	Install Date	Retire Date	Install MWh	Retire MWh	Failure Mode	Comment
1	Gearbox	Flender	PEAS 4-000	123456	9/1/2005		0			
2	Gearbox	Flender	PEAS 4-000	654321	9/1/2005		0			
3	Gearbox	Flender	PEAS 4-000	987654	9/1/2005	8/25/2006	0	2543	Intermediate tooth chip	Warranty. First failure of this mode.
3	Gearbox	Flender	PEAS 2-000	100001	8/31/2006		2543			
1	Generator	ABB	A10099	9/A/100	9/1/2005		0			

Practical, Proactive Methods

Modeling & Prediction: Weibull, Regression, & Others

Use Weibull, regression, or other predictive statistics to:

- Better understand how many failure modes are occurring.
- Predict failures based on aging parameters for planning purposes.
- Budget for failures in advance of accounting periods.
- Plan proactive replacements to reduce maintenance costs.
- Remediate common cause and design wear out failures with improved components.



Practical, Proactive Methods

Tracking, Tracking, and More Tracking

- Proper databasing of components and failure modes is critical.
- Statistical analysis is easy.
- Obtaining and logging data is difficult.
- Statistical analysis without data is impossible.

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Attacking and Placing Your Organization in Control

Preview

- *Proactive replacement.*
- *Root cause analysis.*
- *Remediation (tracking, tracking and more tracking).*

Attacking and Placing Your Organization in Control

Proactive Replacement

- With proper prediction and execution, proactive replacement of soon-to-fail components is usually cheaper.
- This is especially true for critical components where individual failures will stop the WTG.
- A proactive replacement program keeps site activities “in control” and able to deal with all issues, not just one failure mode.

Attacking and Placing Your Organization in Control

Root Cause Analysis

- Proactive replacement management techniques facilitate proper root cause analysis.
- Root cause analysis is necessary to move beyond proactive maintenance to remediation of designs with less than adequate design life.

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Attacking and Placing Your Organization in Control: Remediation

- The final step for improved operational performance is the actual solution to the problem.
- Remediation involves re-design of components or processes to increase the design life.
- Remediation includes the re-design as well as the installation of new components and the configuration management involved with the installation effort. (Did we talk about tracking?)

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Review of the Presentation

- Don't be in denial.
- When turbines are not reliable, expect increased costs in everything from labor to crane rental.
- Proactive component replacement costs less than reactive component replacement.
- To the customer, reliability equals quality. Reliability is designed in. Manufacturing errors can detract from reliability, but not improve it.
- Simple methods <u>which must be managed</u> can provide the information necessary to make sound component replacement decisions.
- Taking on reliability issues with a proactive plan puts an organization in control of its budget, its operations, and a better future.

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Thanks for listening!

Mike Smith

enXco Service Corp.

mikes@enxco.com

641-585-1623