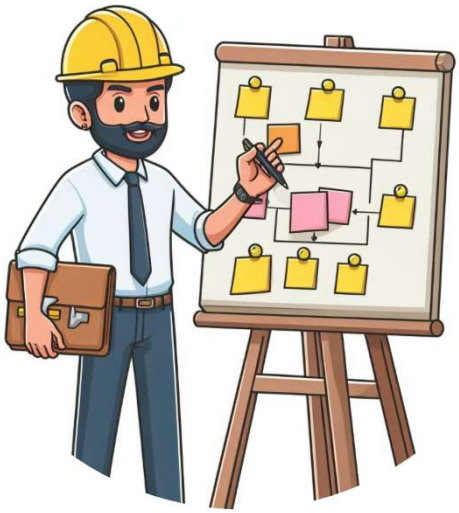
Analysis Tools

- Logic Tree
- 5 Whys
- Fishbone



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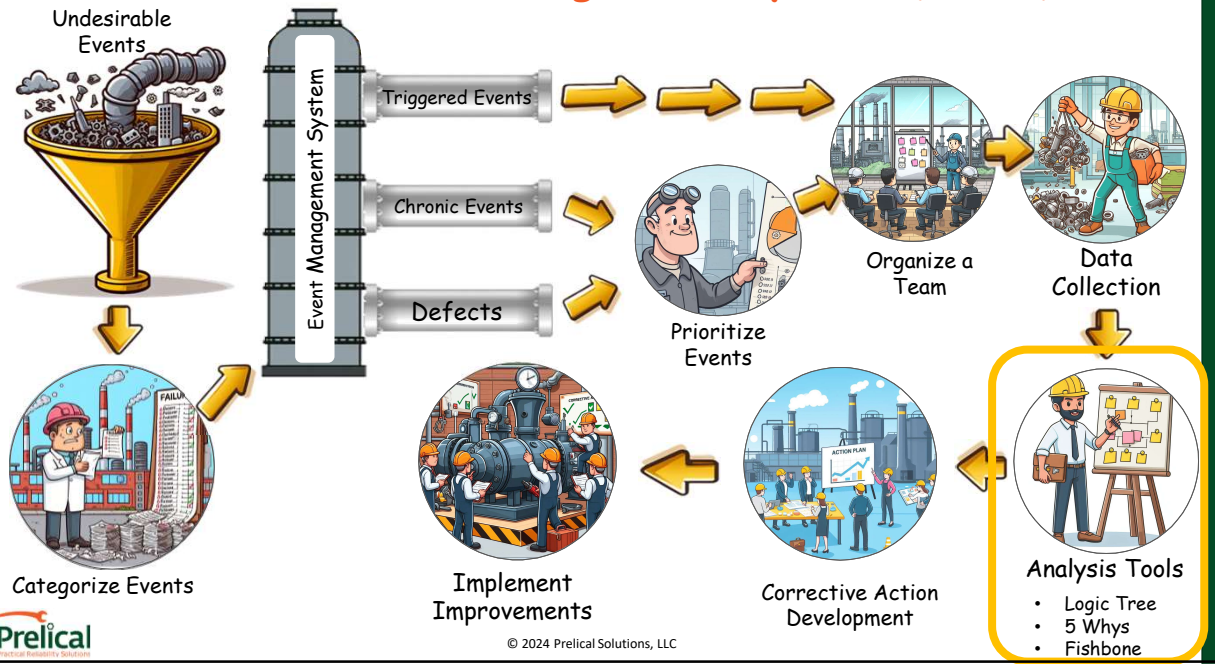
Prelical Event Management System (PEMS)



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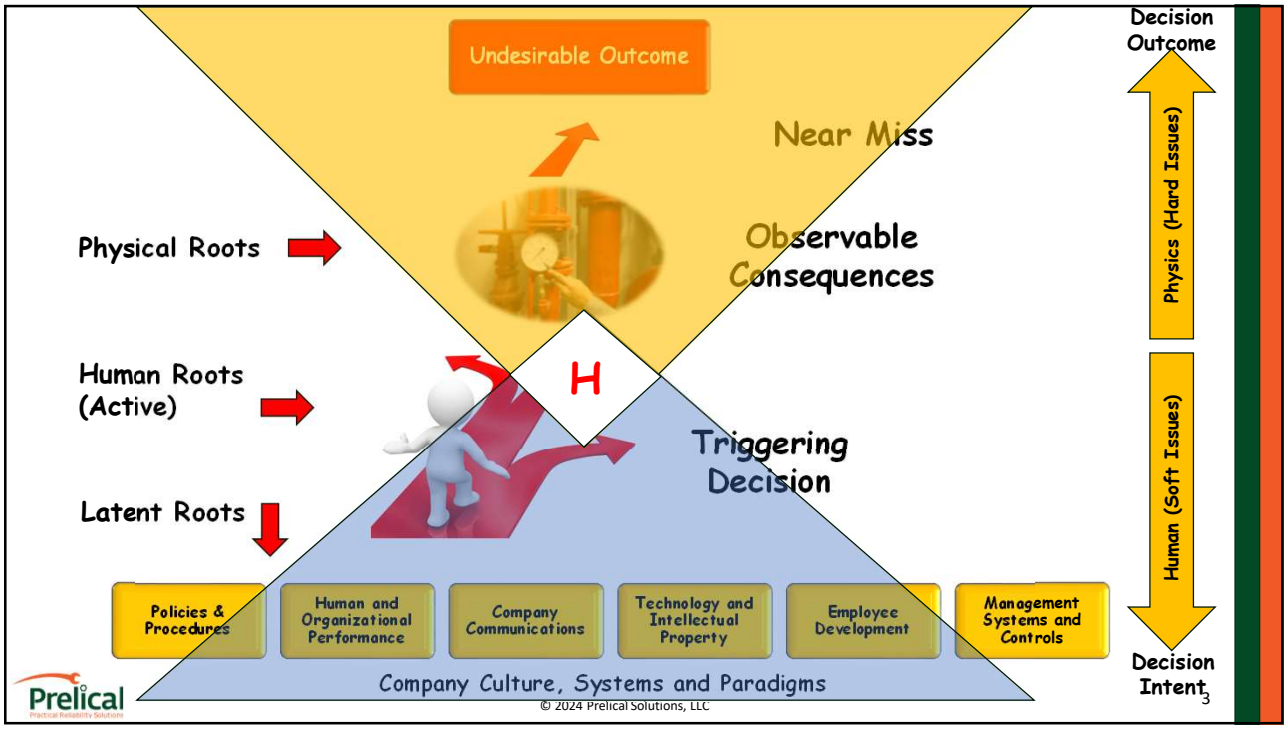
Undesirable Outcome
Near Miss
Observable Consequences
Physical Roots
Human Roots (Active)
Latent Roots
H
Triggering Decision
Policies & Procedures
Human and Organizational Performance
Company Communications
Technology and Intellectual Property
Employee Development
Management Systems and Controls
Company Culture, Systems and Paradigms
Decision Outcome
Physics (Hard Issues)
Human (Soft Issues)
Decision Intent
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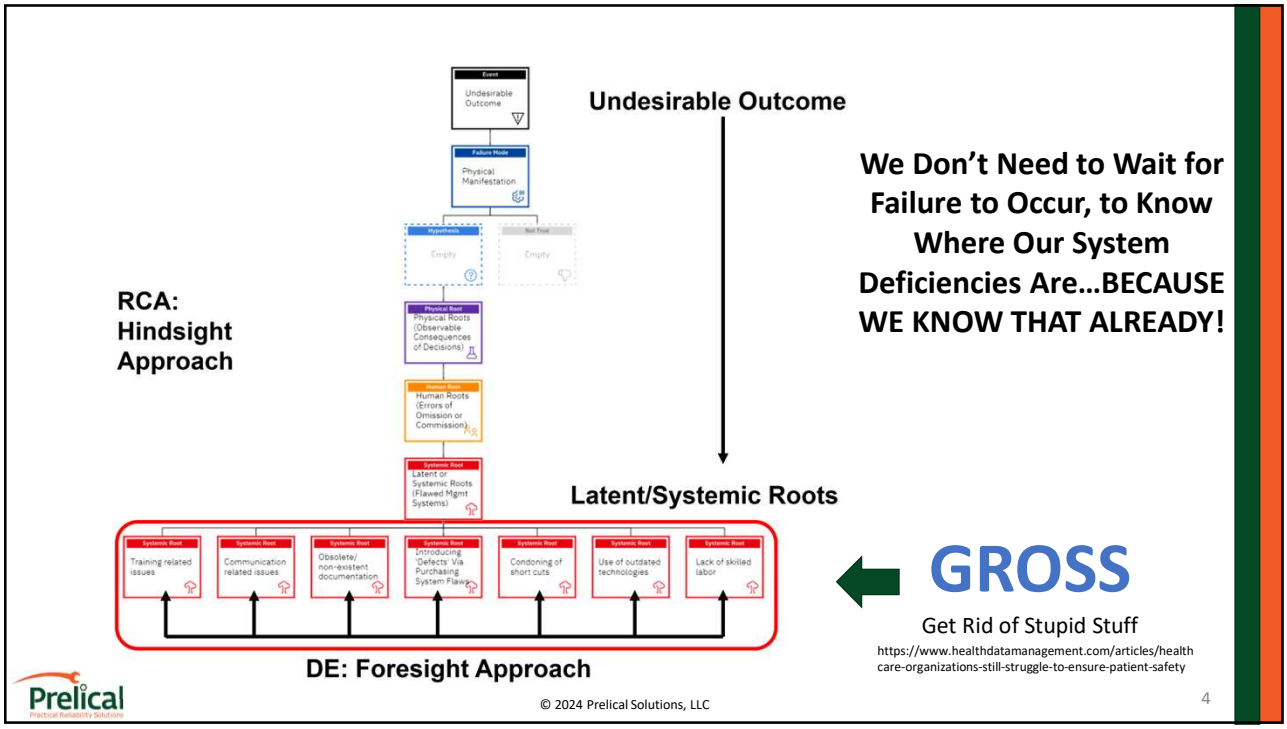
Undesirable Outcome
Physical Manifestation
Physical Roots (Observable Consequences of Decisions)
Human Roots (Errors of Omission or Commission)
Latent or Systemic Roots (Flawed Mgmt Systems)
Training related issues
Communication related issues
Obsolete/ non-existent documentation
Introducing 'Defects' Via Purchasing System Flaws
Condoning of short cuts
Use of outdated technologies
Lack of skilled labor
RCA: Hindsight Approach
Undesirable Outcome
Latent/Systemic Roots
DE: Foresight Approach
We Don't Need to Wait for Failure to Occur, to Know Where Our System Deficiencies Are…BECAUSE WE KNOW THAT ALREADY!
GROSS
Get Rid of Stupid Stuff
https://www.healthdatamanagement.com/articles/healthcare-organizations-still-struggle-to-ensure-patient-safety
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What is HOP?

#	HOP* Core Principles
1	People make mistakes
2	Blame fixes nothing
3	Context drives behavior
4	Learning is vital
5	Response matters

HOP = Human and Organizational Performance

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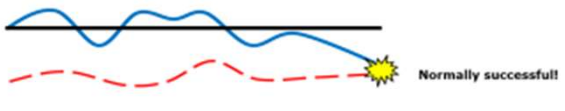
HOP* and the 'Blue Line'

Work as Imagined (WAI)
vs.
Work as Done (WAD)



"Workers are masters of the blue line."

- Conklin/Edwards

* **HOP** = Human & Organizational Performance

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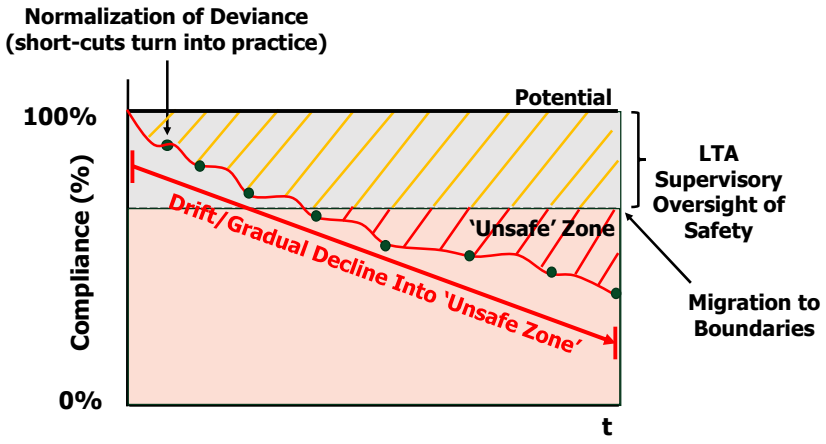
Drifting Into Complacency...
"Forgetting to be Afraid"



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Quick Exercise:
Thought for the Day…

"The single greatest impediment to error prevention in the medical community is that we ***punish people for making mistakes****."*

- Dr. Lucian Leape, Professor, Harvard School of Public Health, in testimony before Congress on health care quality improvement.

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RCA Methodologies vs Tools

Source: Pixabay.com

RCA Methods vs Tools

	Description	Example Approaches/ Tools
RCA Methods	Process flows that outline the steps to successfully apply a specific RCA Method.	1. Sologic 2. ThinkReliability 3. Apollo 4. Taproot 5. PROACT
RCA Tools	These are common tools that aid in effectively executing the above-mentioned RCA methods. They are typically graphical expressions of logic using specific rules associated with an RCA methodology.	1. 5-Whys 2. Fishbone Diagram 3. Causal Factor Trees 4. Logic Trees 5. Fault Trees 6. Bow Ties

Are All RCA Tools Created Equal?

Source: Pixabay.com

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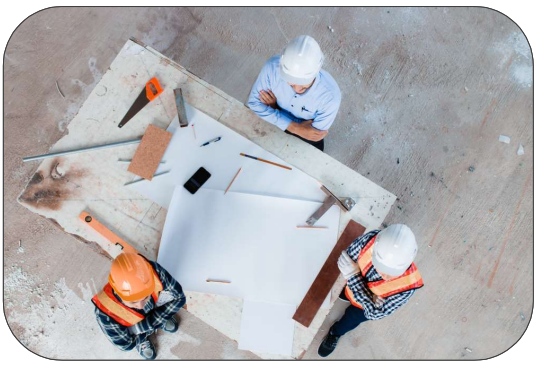
Using the Right Tool for the Analysis at Hand

- 5 - Whys
- Logic Tree
- Fishbone Diagram



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RCA Preference Poll

What is your preferred RCA Approach?

- ○ 5 Whys
- ○ Fishbone Diagram
- ○ Logic Tree/Causal Factor Type Tree
- ○ Other

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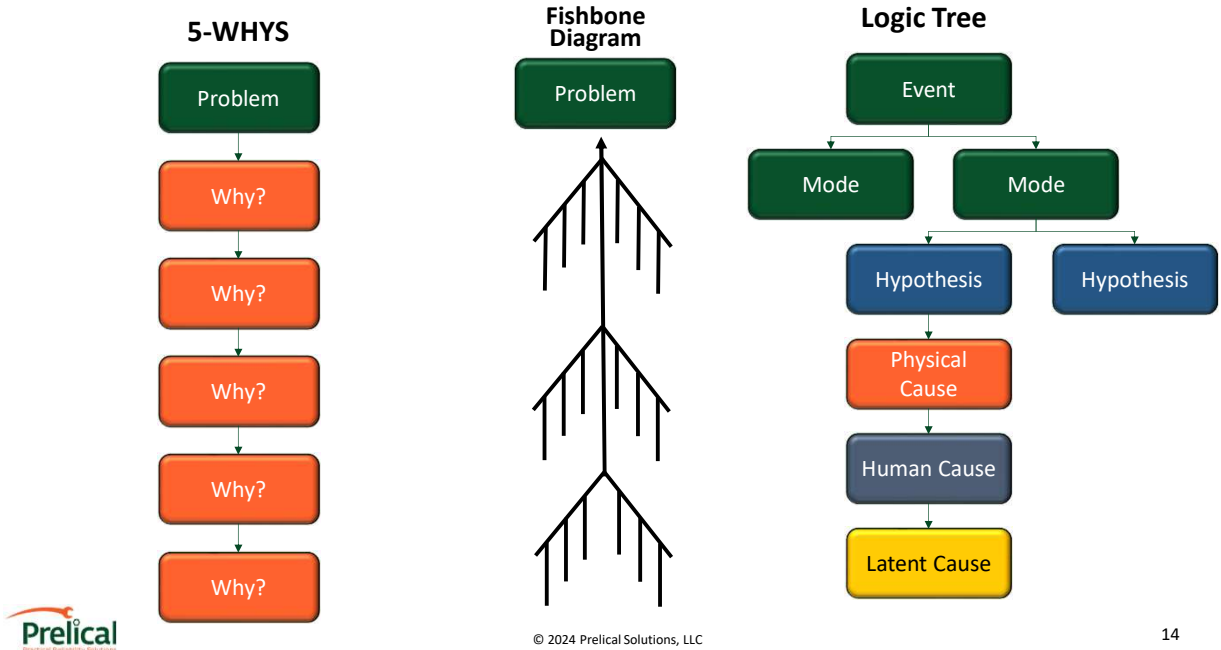
Exploring the 3 Most Common RCA Tools



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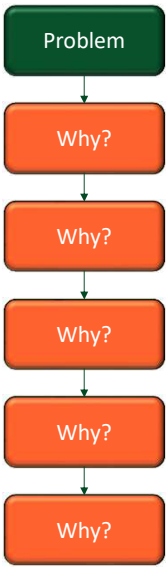
5 Whys



The "5 Whys" technique is a problem-solving and root cause analysis method aimed at uncovering the underlying reasons for an issue by repeatedly asking "why" questions.

Pros	Cons
Simple execution	Uses linear logic
Quick results	Concludes with 1 root cause
Individual and/or Team Based	'Why' questioning is limited
Limited data/evidence collection required	Seeks opinions
Reactive and proactive application	Lacks technical capability to explore multiple paths of failure
Big contributor to Defect Elimination (DE) Efforts	Often concludes with replacing parts and/or blaming decision-makers

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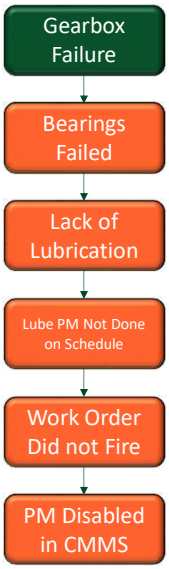
5 Whys Example



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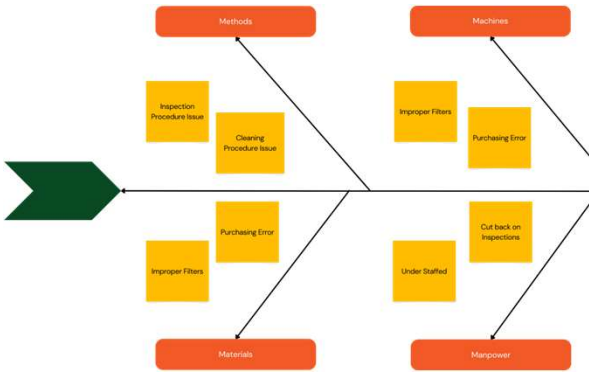
Fishbone Diagram



A Fishbone Diagram, also known as an Ishikawa Diagram or Cause-and-Effect Diagram, is a visual tool used for problem-solving and root cause analysis. It is named "Fishbone" because of its shape, which resembles a fish's skeleton. The Fishbone Diagram helps teams and individuals identify and categorize the potential causes contributing to a specific problem or effect. It is a structured way to visualize the relationship between various factors and their impact on a particular issue.

Pros	Cons
Simple execution	Categorical RCA tool
Quick results	Brainstorms within cause categories
Doesn't always require evidence to support opinion	Doesn't always require evidence to support opinion
Typically, team-based	Non-uniform cause categories (fishbones)
Reactive and proactive application	Tool is as good as the analyst

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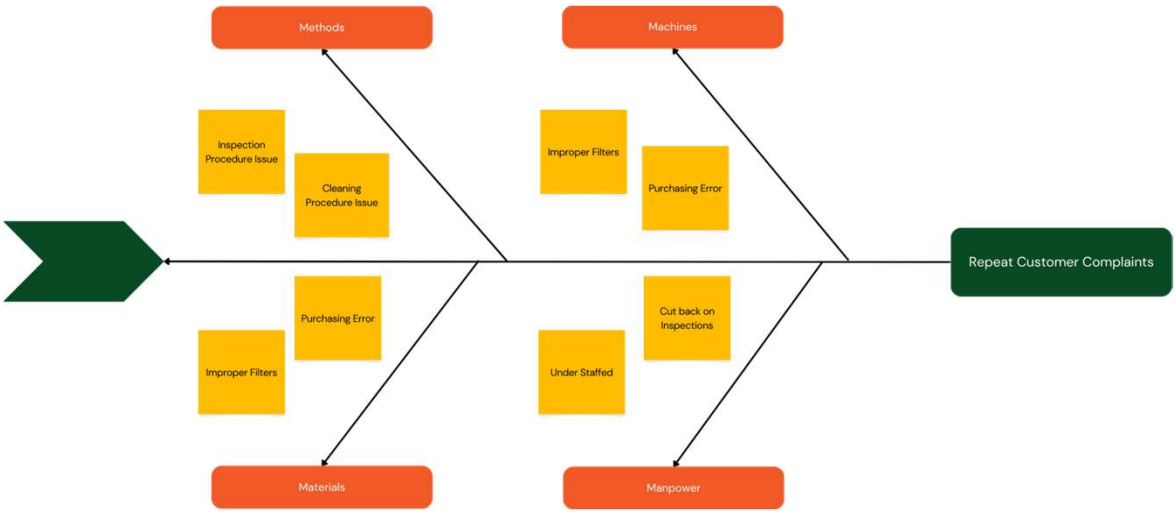
Fishbone Diagram Example



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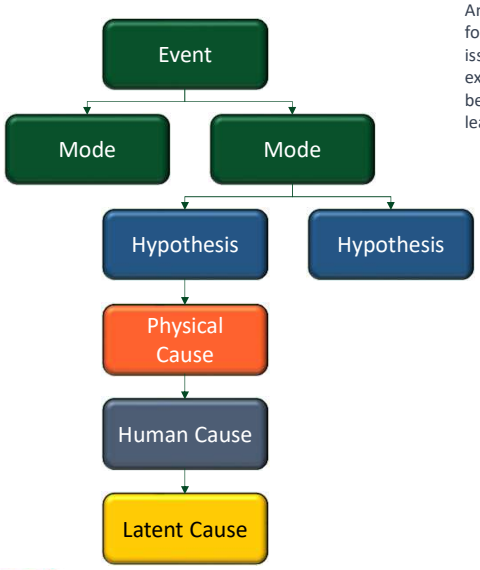
Logic Tree (aka Causal Factor Tree)



An RCA Logic Tree, or Root Cause Analysis Logic Tree, is a structured and hierarchical method for organizing and visually representing the causes and effects related to a specific problem or issue. It is a visual tool used in the context of Root Cause Analysis (RCA) to systematically explore and analyze the various causes (physical, human and latent) and contributing factors behind a problem. This tool helps in understanding the cause-and-effect relationships and will lead to the identification of root causes.

Pros	Cons
Very disciplined	Time consuming
Requires extensive data collection	Requires extensive data collection
Requires diversity of team members	Requires SMEs as needed
Requires unbiased facilitator	Requires accountable team
Reactive and proactive application	Requires management support
Explores multiple, simultaneous paths to failure	
Explores how mgmt systems influence decision making	
Can explore Human and Organizational Performance (HOP) Issues	

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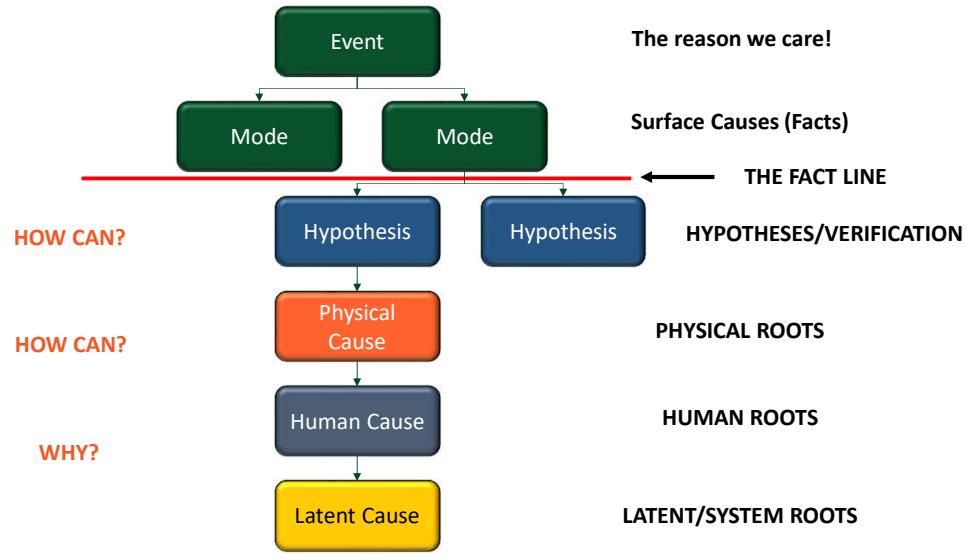
Basic Logic Tree Elements Used for Event Reconstruction



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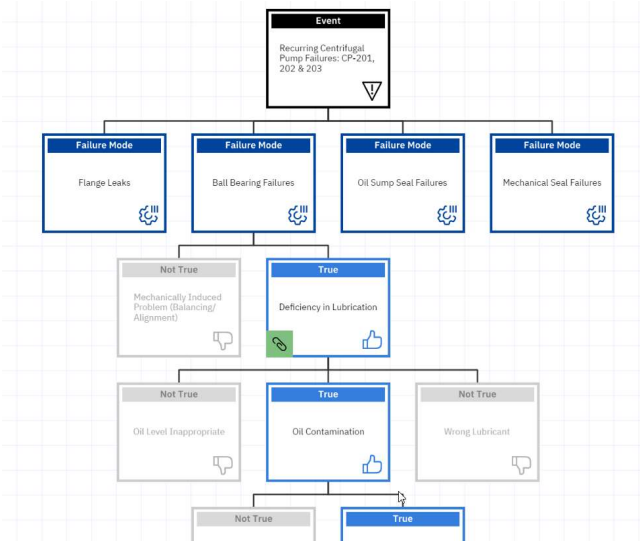
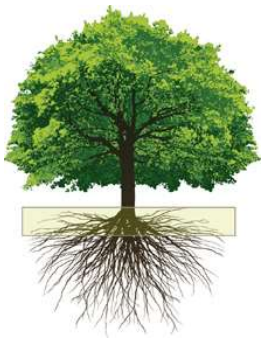
Group Exercise – Building a Logic Tree



The Root Cause Analysis (RCA) Approach

Dissecting the Logic Tree/Causal Factor Tree (Synonyms ☺)



1. Stating the Event

On 11.1.2X at 2a ET we experienced an unexpected outage lasting 4 hours, and resulting in $525k of total aggregate losses

Example

Considerations When Stating the Event
The most important node on the logic tree. It is a direct link to leadership about the business impact of the Event, and why they should be interested in the RCA.
Should reflect the key elements of the team's Problem Statement.
At its core, the Event is the 'reason you care' enough to do an RCA.
Least acceptable consequence
The Event description MUST ONLY CONTAIN FACTS!!!!

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2. Stating the Mode(s)

Critical Pump (P-100) Bearing Failure

Example

Considerations When Stating the Mode(s)
Often the Mode is mistakenly identified as the Event.
The Mode(s) are the observable failure mechanisms.
The Mode(s) are anomalies that need to be explained.
There can be more than 1 Mode on any given RCA.
All Modes **MUST ONLY CONTAIN FACTS**.

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3. Exploring the Hypotheses

Hypothesis

Considerations When Exploring Hypotheses
Hypotheses are “educated guesses”.
When coming off facts (from the parent nodes), these are the potential answers to the question ‘How Could?’ and ‘Why?’. We will explore when it is appropriate to ask which questions in a few minutes.
The statement should reflect some type of deficiency (i.e. – lubrication vs. lubricant contamination, or frequency was less than adequate)

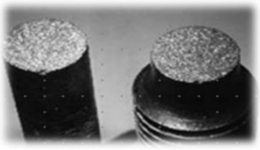
3. Exploring the Hypotheses

Erosion

Corrosion

Fatigue

Overload



How Material Failure Occurs

Material Loss	Material is Overpowered
➢Erosion (Wear) ➢Corrosion	➢Fatigue ➢Overload

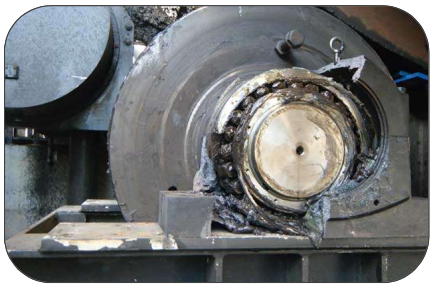
And many combinations of these four mechanisms!

“How Could P-100 Bearing Have Failed?”

4. Identifying Physical Roots

Excessive Vibration

Considerations When Labeling a Physical Root (PR)
Physical roots are often the primary, observable consequences of decisions.
A decision often triggered this condition to become observable (i.e. – I chose to put in more lubricant than was specified, in the hopes I would not have to come back as often to do my rounds – Physical Root: Too Much Lubricant).
There can be multiple Physical roots in any given RCA.



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5. Identifying Human Roots

"Today we are going to decide who to blame.'

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5. Identifying Human Roots

P-101 Bearing Not Aligned Properly

Considerations When Labeling a Human Root (HR)
Human roots are the choices/decisions people make, that trigger observable consequences.
Human roots are acts of decision-making that are typically based on good intent, and often common business practices.
Human roots are NOT the end of an analysis, they are often the beginning of the analysis.
Unless there is malice with intent (sabotage), **BLAMING SOMEONE WILL RESULT IN A SHALLOW CAUSE ANALYSIS, NOT A ROOT CAUSE ANALYSIS!!**

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6. Identifying Latent/Organizational System Roots

Less Than Adequate (LTA) Oversight of Field Qualifications

Field Tech Not Properly Trained in Latest Alignment Best Practices

Considerations When Labeling a Latent Root
Latent roots represent the human reasoning for a decision error.
These are the answers to 'WHY?' people made the decisions they did, that day.
Latent roots are often the flawed organizational systems that decision-makers relied on, to make their decision.
Such organizational systems could be inadequate, insufficient, or non-existent.
Latent roots can encompass varying levels of depth, that may or may not include socio-technical factors (i.e. – external factors like regulatory and insurance influences) as well as cultural norms (i.e. – we've always done it that way).

Image provided by Ludeca

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7. Identifying Contributing Factors

On 1.28.86, at Launch of Mission 51-L it was 36F at Cape Canaveral FL

Considerations When Labeling a Contributing Factor
Conditions that existed the day of the Event, but may not be in the control of the organization to change (i.e. – it was freezing that day, which was uncharacteristic for the region)
May more may not be actionable, must be explored (i.e. – a lightening strike triggered an automated shutdown, but was the facility properly grounded [mitigation exploration])

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Human Error Defined

"Error will be taken as a generic term to encompass all those occasions in which a planned sequence of mental and physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to some chance agency."

- J.T. Reasons

University of Manchester

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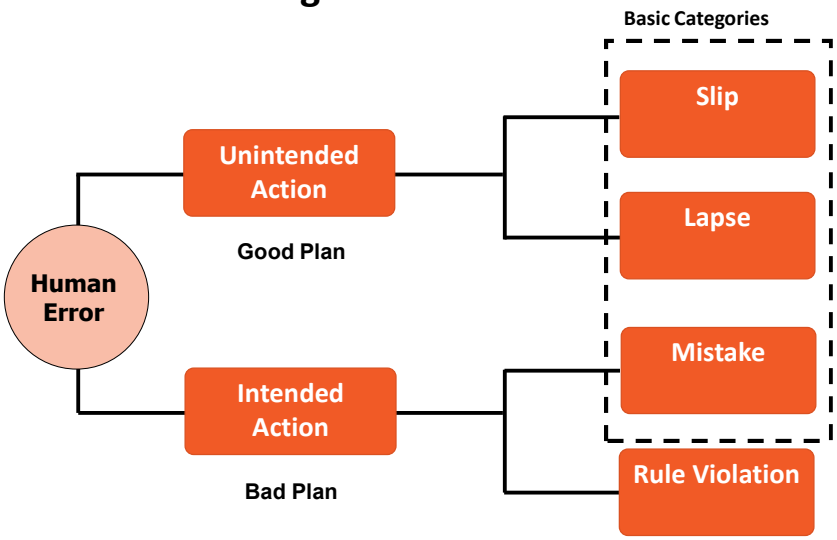
Human Error
The Logic Tree "Branch"



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Term	Definition
Unintended Actions	Actions that deviate from intended action fall into two classes; those that nevertheless achieve the goal, and those that do not.
Slips	Are potentially observable as externalized actions-not-as-planned (i.e. – slips of the tongue).
Lapses	Are generally more covert errors and involve failures of memory.
Intended Actions	Even when the intended actions proceed as planned, they can still be judged as erroneous if they fail to achieve their intended outcome. In this case, the problem resides in the adequacy of the plan rather than conformity of its actions to some prior intention. If the intention is not appropriate, it is a mistake.
Mistakes	Are defined as deficiencies or failures in the judgmental and/or inferential processes involved in the selection of an objective or in the specification of the means to achieve it, irrespective of whether or not the actions directed by this decision-scheme run according to the plan.

Source: Managing the Risks of Organizational Accidents (Reason)

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Why Do Mix-Ups Occur?

Human Factors in Design – Medication Labeling and Procedure Writing

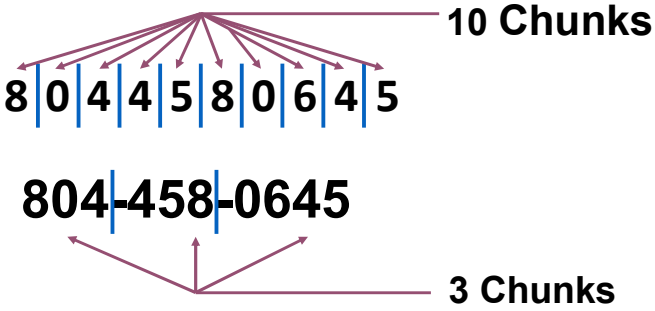
Procedure Writing – Mixed Case:
The attending surgeon shall record in the medical record the correct side for and name of the surgical procedure

Procedure Writing – All Upper Case:
THE ATTENDING SURGEON SHALL RECORD IN THE MEDICAL RECORD THE CORRECT SIDE FOR AND NAME OF THE SURGICAL PROCEDURE

Medication Unique Pattern

MEDICATION Generic Pattern

Human Factors in Design – Brain Processing Capability



Of all the signals that reach our sensory register, we focus on a few that seem important (normal capacity is about seven “chunks” of information).

Source: Making Connections: Teaching and the Human Brain (Caine and Caine 1991)

What Do You See?
The Mind is a Mysterious Thing (#1)

**A bird in the
the hand is
worth two in
the bush**

Perceptions are mental models developed in the brain to interpret incoming information the way it SHOULD BE versus the way that it IS.

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What Do You See?
The Mind is a Mysterious Thing (#2)

I cdnuolt blveiee taht I cluod aulaclty uesdnatnrd waht I was rdanieg. The phaonmneal pweor of the hmuan mnid Aoccdrnig to a rscheearch at Cmabrigde Uinervtisy, it deson't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoatnt tihng is taht the frist and lsat ltteer be in the rghit pclae. The rset can be a taotl mses and you can sitll raed it wouthit a porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe. Amzanig huh?

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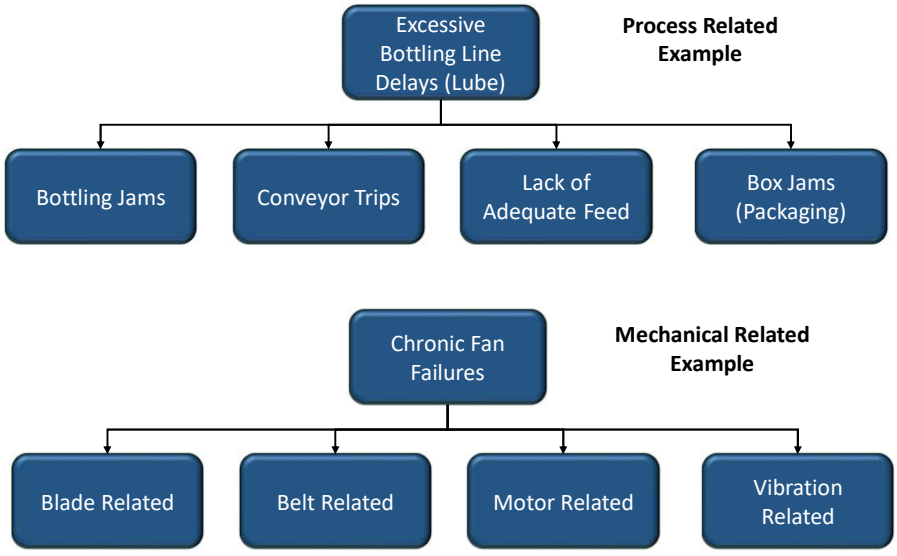
Sample of Common Logic Tree Branches



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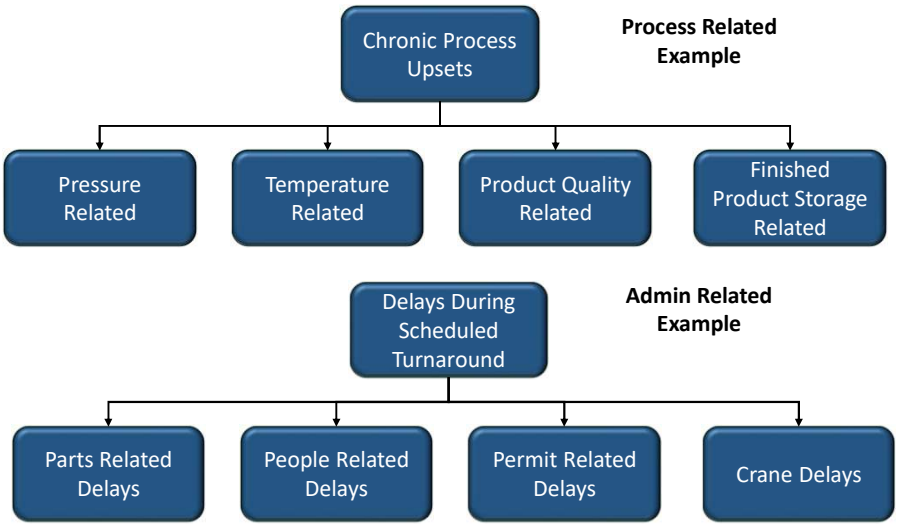
Sample of Common Logic Tree Branches



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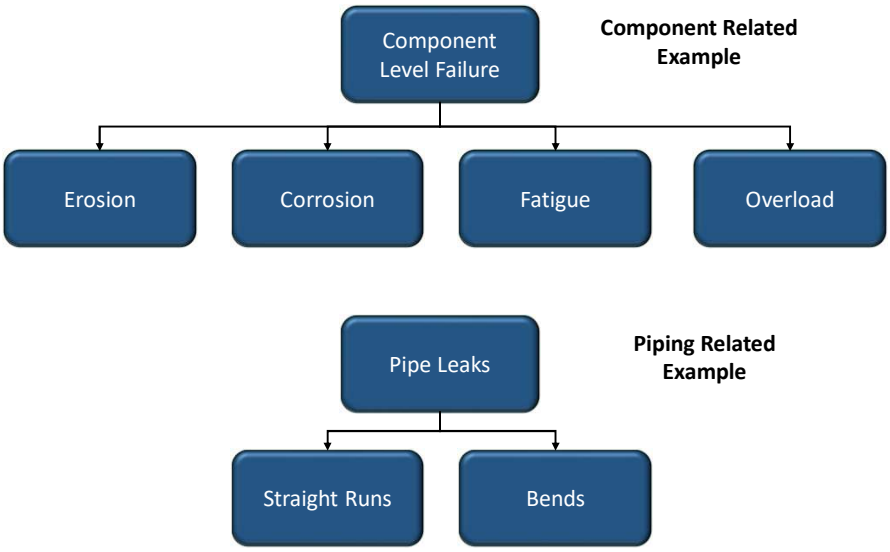
Sample of Common Logic Tree Branches



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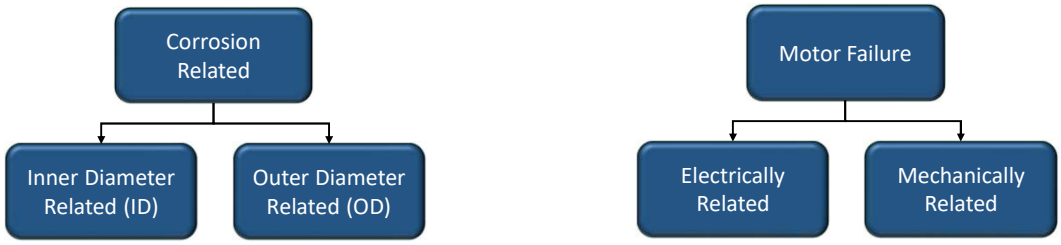
Sample of Common Logic Tree Branches



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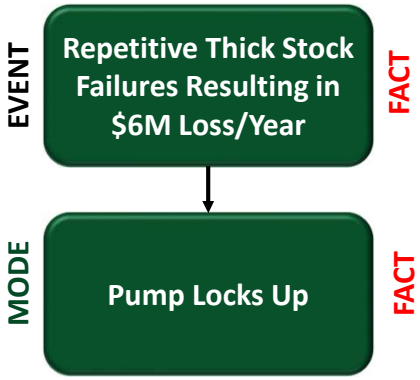
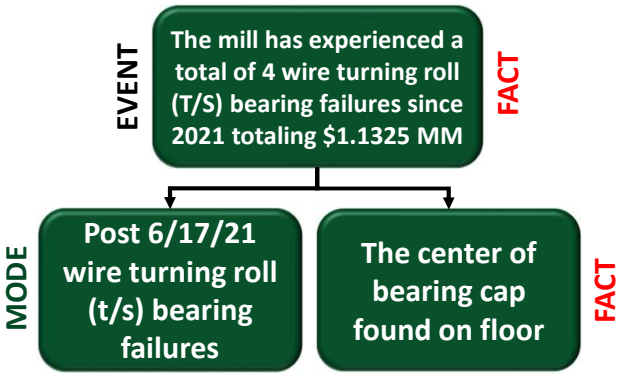
Top Box – Definition





Thick Stock Pump – Top Box

Logic Tree Facilitation

Tips & Tricks

Logic Tree Facilitation – Tips and Tricks

Considerations When Labeling a Latent Root
The 'Broad and All-Inclusive' Test
Managing the FACT Line
Maintaining the Verification Log (VL)
Node Confidence Factors (0 – 5 Scale, 5=True and 0 = Not True)
Beware Conventional Wisdom
Draw a Sketch of the Event Being Analyzed
Construct a Timeline of the Event

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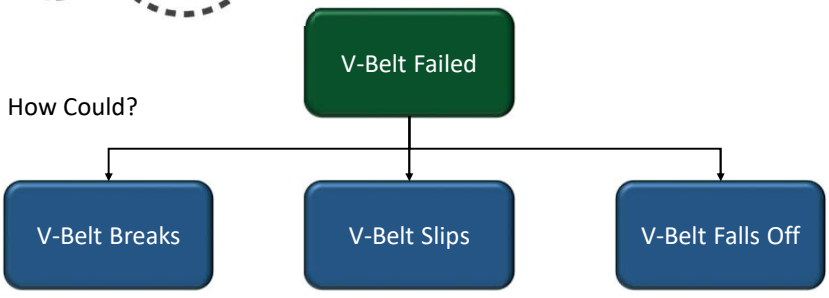
Logic Tree Facilitation – Tips and Tricks



The Test: Is the only the V-belt could have failed, from: breaking, slipping and/or falling off?

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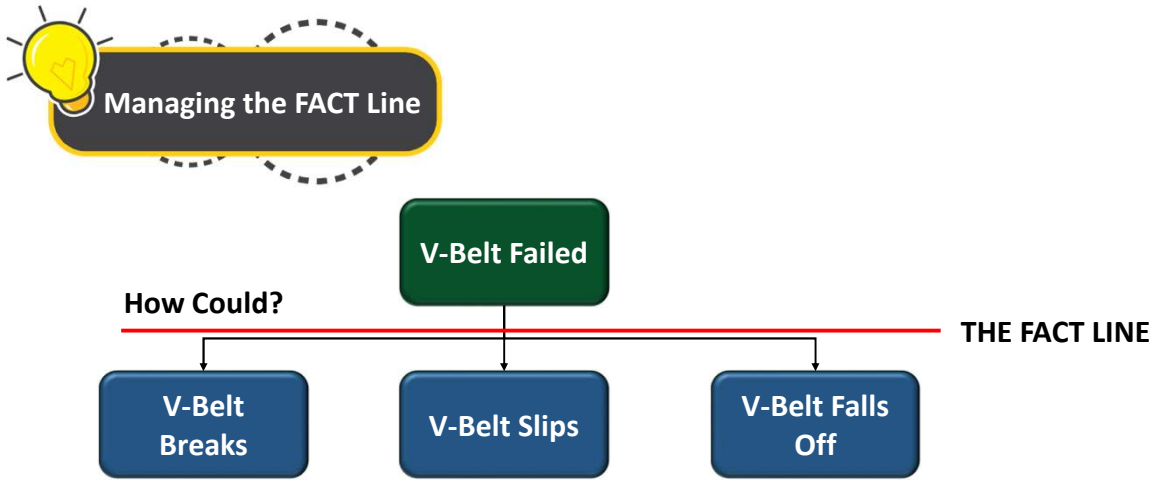
Logic Tree Facilitation – Tips and Tricks



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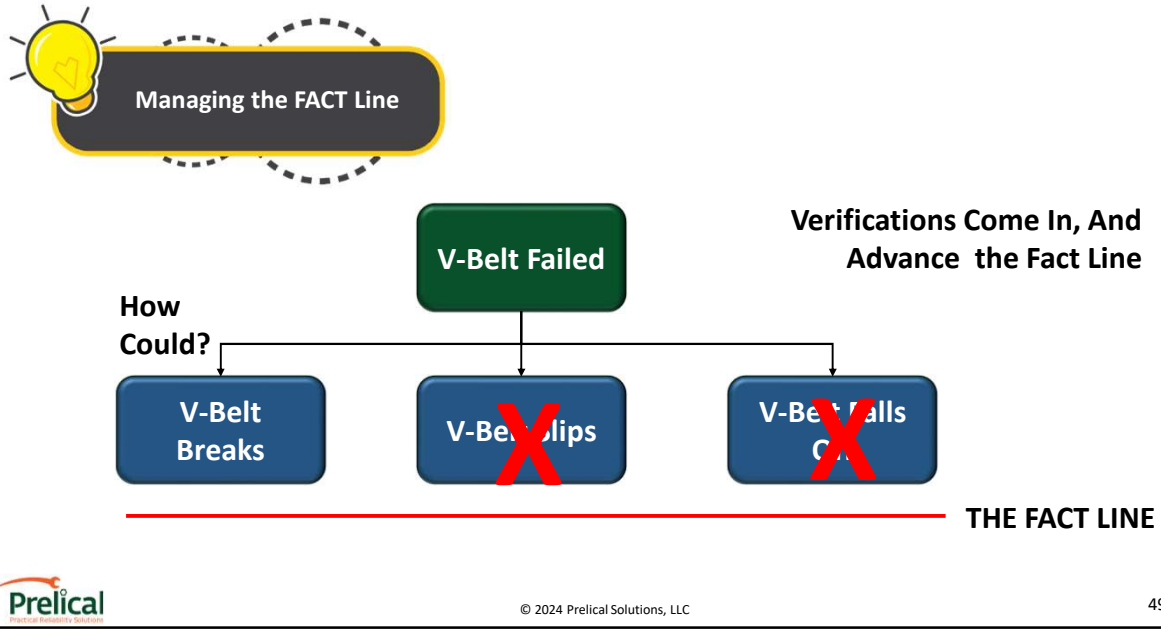
Logic Tree Facilitation – Tips and Tricks



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Logic Tree Facilitation – Tips and Tricks

Hypotheses	Verification Method	Resp.	Due Date	Completion Date	Verification Outcome
High Vibration on CP-235 Outboard Bearing	Review Vibration Alarm Limits and Histories	KCL	10.31.23	11.1.23	Review of Alarm Limits and Histories Reveals a Trending of Increased Vibration Starting on 9.23.23

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RCA Verification Techniques

Visual Techniques

- Metallurgical Analysis
- High Speed Photography
- Video Cameras
- Borescopes
- Human Observation
- Strobe Lights

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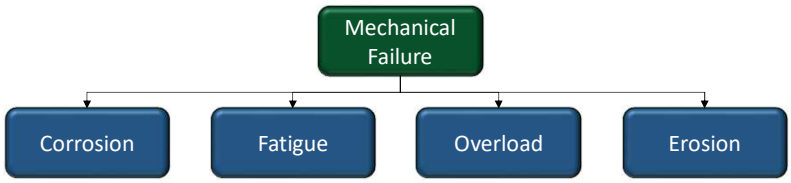

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Overload Failures

- Ductile
- Brittle

Example of a Ductile Overload

A Brittle Overload would not be deformed and would be fractured

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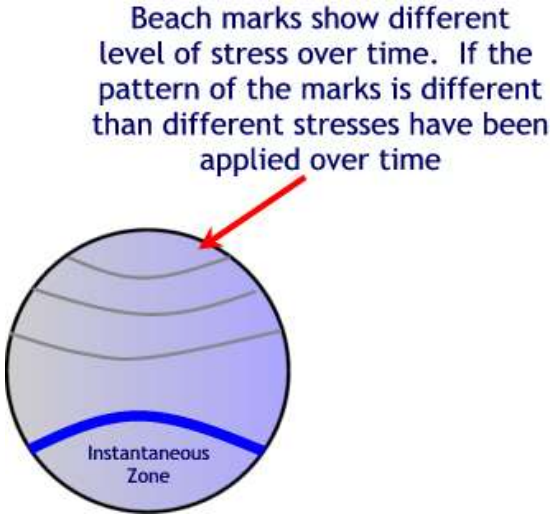
Fatigue Failures

- Bending
- Torsion
- Tension



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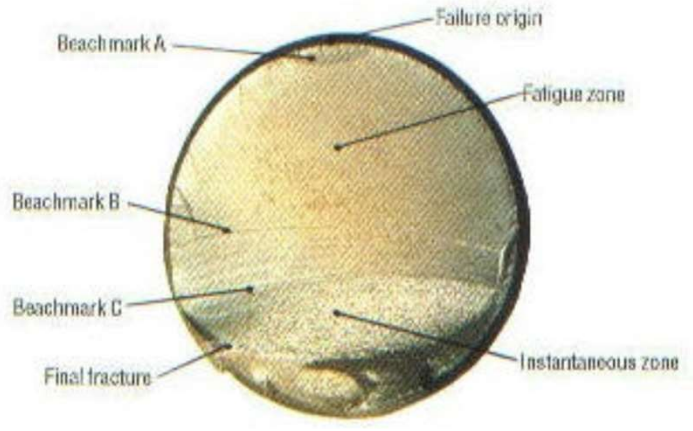
Fatigue Failures



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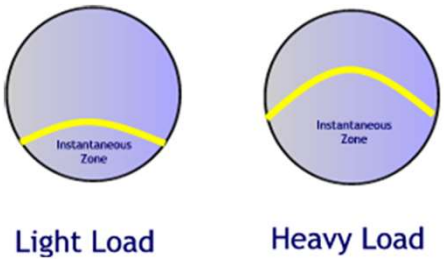
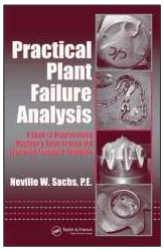
Fatigue Failures



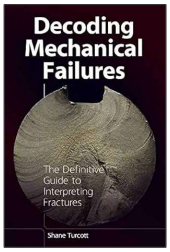
56

Reference Books



Practical Plant Failure Analysis

ISBN: 0849333768

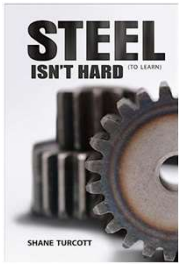


Decoding Mechanical Failures

ISBN: 1777157609

How Components Fail

ISBN: 0871701898



Steel Isn't Hard (to Learn)

ISBN: 978-1777157616

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RCA Verification Techniques

NDT (Non-Destructive Testing)

- Laser Alignment
- Vibration Monitoring & Analysis
- Ultrasonics
- Infrared Thermography
- Lubrication Sampling/Analysis
- Scanning Electron Microscopy
- Experimental Stress Analysis
- Motion Amplification

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Analyze
RCA Verification Techniques

Data Analysis

- Trend Analysis
- **Weibull Analysis**
- Modeling (Reliability Block Diagram)

59

Reliability Data Analysis

Statistical analysis

- Distribution analysis
  - Normal
  - LogNormal
  - **Weibull** (used **95%** of the time for reliability analysis)
- Trend Tests
  - Army Material Systems Analysis Activity (AMSAA)

Prelical

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Reliability Data Analysis

Why use statistical analysis?

- To identify a failure pattern
- Provides capability to assess failure risk
- Provides accurate estimation of MTBF
- Helps make general assumptions about seemingly unrelated data

Prelical

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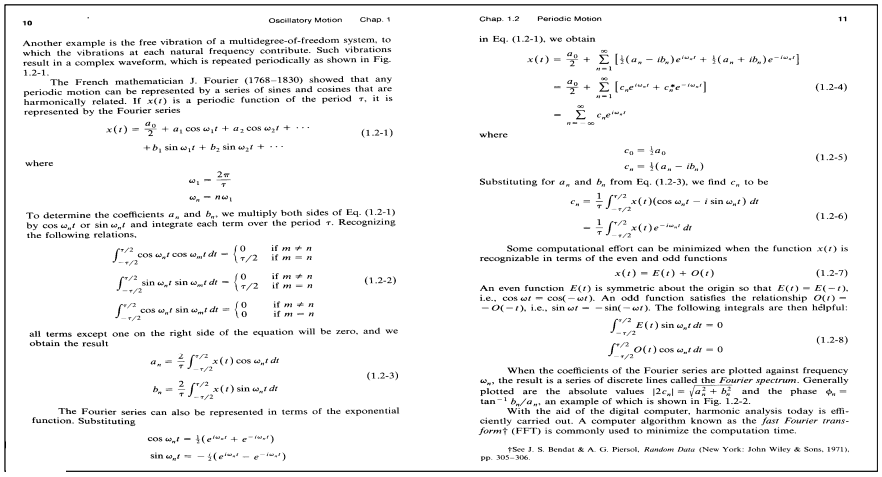
Can you explain these calculations?



10 Oscillatory Motion Chap. 1

Another example is the free vibration of a multidegree-of-freedom system, to which the vibrations at each natural frequency contribute. Such vibrations result in a complex waveform, which is repeated periodically as shown in Fig. 1.2-1.

The French mathematician J. Fourier (1768–1830) showed that any periodic motion can be represented by a series of sines and cosines that are harmonically related. If $x(t)$ is a periodic function of the period τ, it is represented by the Fourier series

$$x(t) = \frac{a_0}{2} + a_1 \cos \omega_1 t + a_2 \cos \omega_2 t + \cdots + b_1 \sin \omega_1 t + b_2 \sin \omega_2 t + \cdots \quad (1.2\text{-}1)$$

where

$$\omega_1 = \frac{2\pi}{\tau}$$
$$\omega_n = n\omega_1$$

To determine the coefficients a_n and b_n, we multiply both sides of Eq. (1.2-1) by $\cos \omega_n t$ or $\sin \omega_n t$ and integrate each term over the period τ. Recognizing the following relations,

$$\int_{-\tau/2}^{\tau/2} \cos \omega_n t \cos \omega_m t \, dt = \begin{cases} 0 & \text{if } m \neq n \\ \tau/2 & \text{if } m = n \end{cases}$$
$$\int_{-\tau/2}^{\tau/2} \sin \omega_n t \sin \omega_m t \, dt = \begin{cases} 0 & \text{if } m \neq n \\ \tau/2 & \text{if } m = n \end{cases} \quad (1.2\text{-}2)$$
$$\int_{-\tau/2}^{\tau/2} \cos \omega_n t \sin \omega_m t \, dt = \begin{cases} 0 & \text{if } m \neq n \\ 0 & \text{if } m = n \end{cases}$$

all terms except one on the right side of the equation will be zero, and we obtain the result

$$a_n = \frac{2}{\tau} \int_{-\tau/2}^{\tau/2} x(t) \cos \omega_n t \, dt$$
$$b_n = \frac{2}{\tau} \int_{-\tau/2}^{\tau/2} x(t) \sin \omega_n t \, dt \quad (1.2\text{-}3)$$

The Fourier series can also be represented in terms of the exponential function. Substituting

$$\cos \omega_n t = \tfrac{1}{2}(e^{i\omega_n t} + e^{-i\omega_n t})$$
$$\sin \omega_n t = -\tfrac{1}{2}(e^{i\omega_n t} - e^{-i\omega_n t})$$

Chap. 1.2 Periodic Motion 11

in Eq. (1.2-1), we obtain

$$x(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} \left[\tfrac{1}{2}(a_n - ib_n)e^{i\omega_n t} + \tfrac{1}{2}(a_n + ib_n)e^{-i\omega_n t}\right]$$
$$= \frac{a_0}{2} + \sum_{n=1}^{\infty} \left[c_n e^{i\omega_n t} + c_n^* e^{-i\omega_n t}\right] \quad (1.2\text{-}4)$$
$$= \sum_{n=-\infty}^{\infty} c_n e^{i\omega_n t}$$

where

$$c_0 = \tfrac{1}{2}a_0$$
$$c_n = \tfrac{1}{2}(a_n - ib_n) \quad (1.2\text{-}5)$$

Substituting for a_n and b_n from Eq. (1.2-3), we find c_n to be

$$c_n = \frac{1}{\tau} \int_{-\tau/2}^{\tau/2} x(t)(\cos \omega_n t - i \sin \omega_n t) \, dt$$
$$= \frac{1}{\tau} \int_{-\tau/2}^{\tau/2} x(t) e^{-i\omega_n t} \, dt \quad (1.2\text{-}6)$$

Some computational effort can be minimized when the function $x(t)$ is recognizable in terms of the even and odd functions

$$x(t) = E(t) + O(t) \quad (1.2\text{-}7)$$

An even function $E(t)$ is symmetric about the origin so that $E(t) = E(-t)$, i.e., $\cos \omega t = \cos(-\omega t)$. An odd function satisfies the relationship $O(t) = -O(-t)$, i.e., $\sin \omega t = -\sin(-\omega t)$. The following integrals are then helpful:

$$\int_{-\tau/2}^{\tau/2} E(t) \sin \omega_n t \, dt = 0$$
$$\int_{-\tau/2}^{\tau/2} O(t) \cos \omega_n t \, dt = 0 \quad (1.2\text{-}8)$$

When the coefficients of the Fourier series are plotted against frequency ω_n, the result is a series of discrete lines called the *Fourier spectrum*. Generally plotted are the absolute values $|2c_n| = \sqrt{a_n^2 + b_n^2}$ and the phase $\phi_n = \tan^{-1} b_n/a_n$, an example of which is shown in Fig. 1.2-2.

With the aid of the digital computer, harmonic analysis today is efficiently carried out. A computer algorithm known as the *fast Fourier transform*† (FFT) is commonly used to minimize the computation time.

†See J. S. Bendat & A. G. Piersol, *Random Data* (New York: John Wiley & Sons, 1971), pp. 305–306.

Can you interpret this graph?

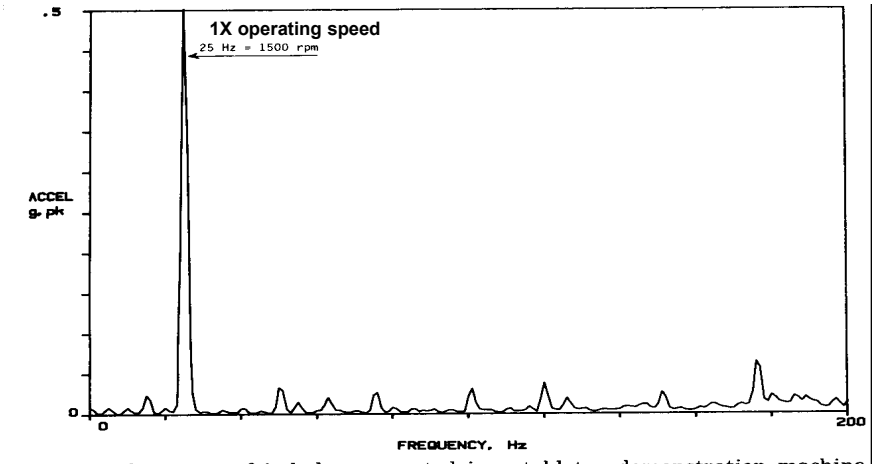


Figure 5.5 Spectrum of imbalance created in a tabletop demonstration machine turning at 1500 rpm (25 Hz).

What's the point?

- You don't have to know the FFT theory to benefit from Vibration Analysis.
- Likewise, you don't have to know statistical methods theory to benefit from statistical analysis of failure data.
- You just need know how to apply the methods and interpret the results!

Prelical

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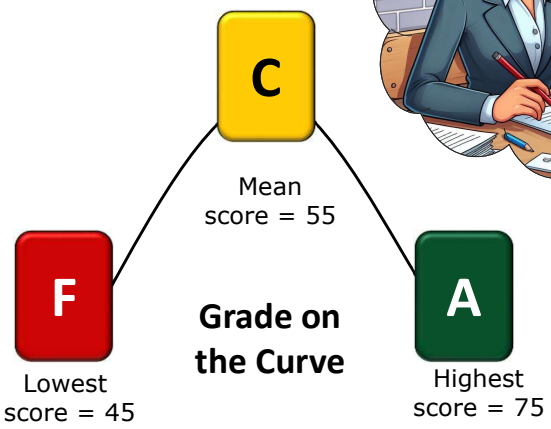
Our First Introduction to Statistics!

Grades	
Student	Score
Jack	45
Beth	55
Joe	60
Mike	60
Lisa	55
Fred	50
Lynn	50
Jason	75
Sara	55
Tina	55
Chris	65



Prelical

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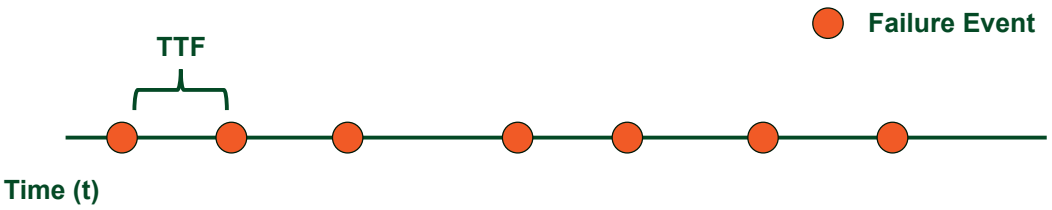
Distribution Analysis

Mean Time Between Failure (MTBF)

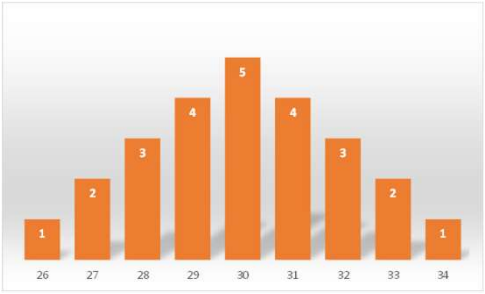


$$MTBF = \frac{TTF1 + TTF2 + TTF3 + TTF4 + TTF5 + TTF6}{6}$$

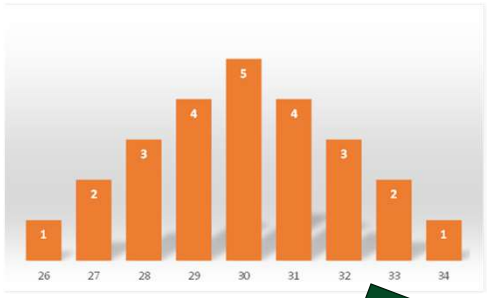
Normal Distribution

Asset ID	TTF
Asset101	26
Asset101	28
Asset101	33
Asset101	33
Asset101	27
Asset101	30
Asset101	32
Asset101	34
Asset101	28
Asset101	29
Asset101	30
Asset101	32
Asset101	27
Asset101	28
Asset101	30
Asset101	31
Asset101	29
Asset101	31
Asset101	31
Asset101	29
Asset101	30
Asset101	32
Asset101	30
Asset101	29
Asset101	31

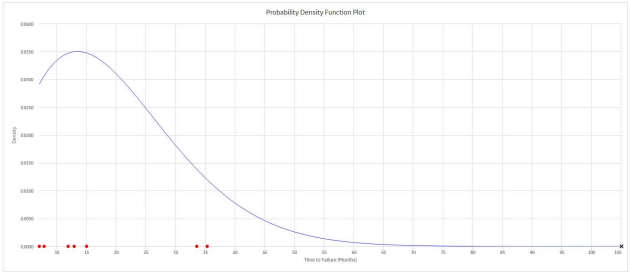
TTF	n
26	1
27	2
28	3
29	4
30	5
31	4
32	3
33	2
34	1



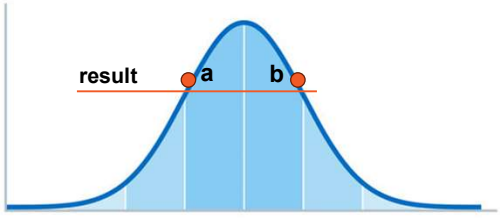
Normal Distribution



PDF = f(t)
Probability Density Function



Interpreting MTBF Results

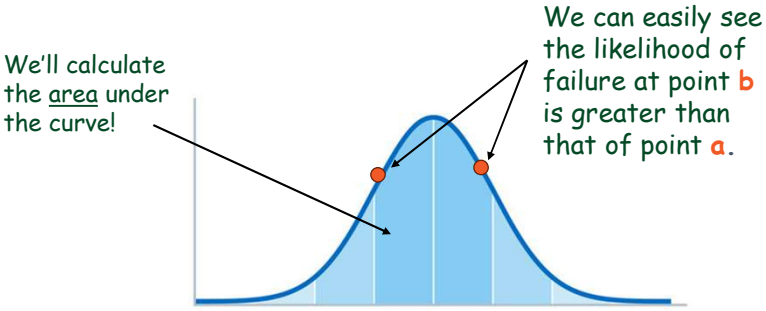


PDF = f(t)

If you solve the **PDF** at points **a** and **b**, and you get the same results … showing the probability of failing at points **a** or **b** …

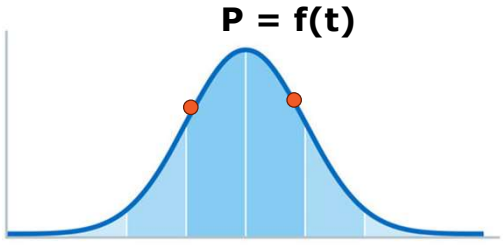
…But nothing about how many failures have occurred before points a or b!

How does this distribution indicate reliability?



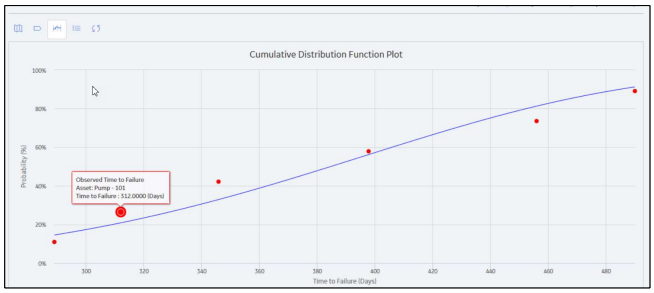
Weibull Distribution

Probability of failure = Area under the curve



PDF = f(t)

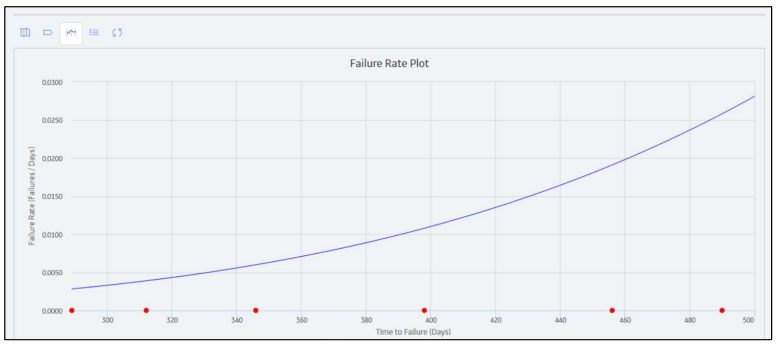
Weibull Distribution



P=F(t) is commonly known as the Cumulative Distribution Function or **CDF**

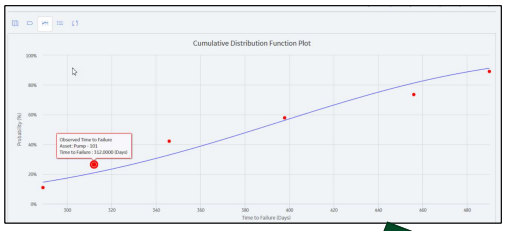
CDF = F(t)

Weibull Distribution

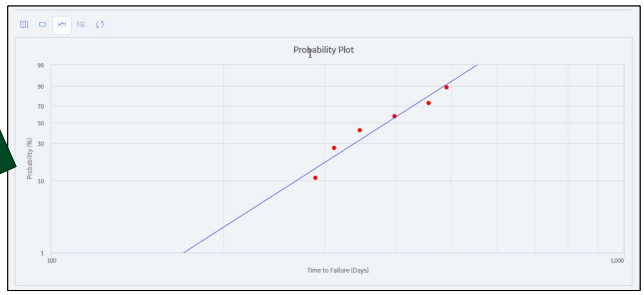


Failure Rate Plot

Weibull Distribution



A straight-line results when the CDF is plotted on log paper.



Prelical

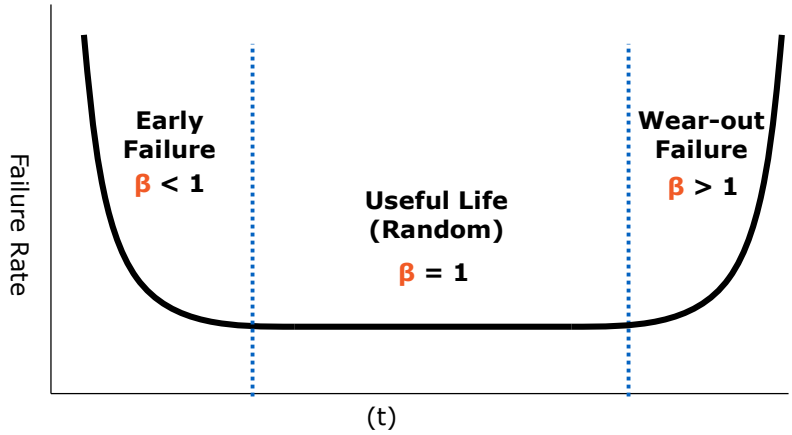
Weibull Distribution

Two Parameters:

- **β (Beta)** = Shape Factor
  - Indicates failure pattern
  - Slope of probability plot
- **η (Eta)** = Characteristic Life
  - Indicates expected life
  - Point where 63.2% of population has failed

Prelical

Beta and the Bathtub Curve



Weibull Distribution

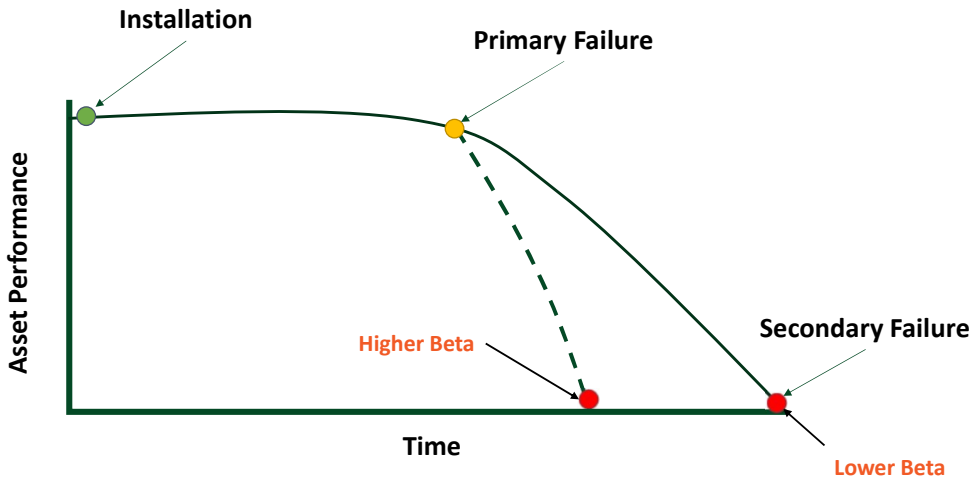
General Rules for Beta:

$\beta < 1$ Indicates infant mortality

$\beta = 1$ Indicates random failure

$1 < \beta < 4$ Indicates early wear-out failure

$\beta > 4$ Indicates rapid wear-out failure



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Weibull Distribution

- Extremely applicable to most every failure mode
- Will produce good results even with a small amount of data
- Best starting point for reliability analysis
- **95%** of the time, Weibull is the best tool
- Requires quality data for meaningful results

Weibull Distributions can only be used on one failure mode at a time

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Risk Manager

- Allows you to estimate probability of failure
- Good for short-term planning
- Helps predict which machines will make it to the next scheduled maintenance

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Risk Manager

Q201 Failures

Last modified by Kenneth.Latino@contractor.p66.com on Wednesday, December 13, 2023 12:36 PM

Report | Site: RB01

Future Age | Future Probability

ASSET ID	INSTALLATION DATE	LAST REPLACEMENT	PRESENT AGE	FUTURE AGE	PRESENT FAILURE PROBABILITY	FUTURE FAILURE PROBABILITY
RB01-COK0050-67-Q201		2023-06-22T17:04:47.000	68.0948	268.0948	12.3582	21.1840

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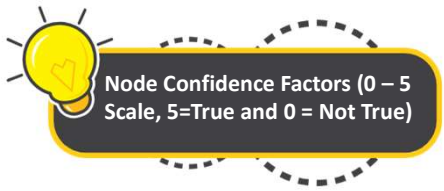
Logic Tree Facilitation – Tips and Tricks



V-Belt Breaks
[5]

Confidence Factor: Confidence that we have, that with the verification data available, the Node is either True, Not True or shades of gray in between. Shades of gray result when the evidence available cannot be totally conclusive.

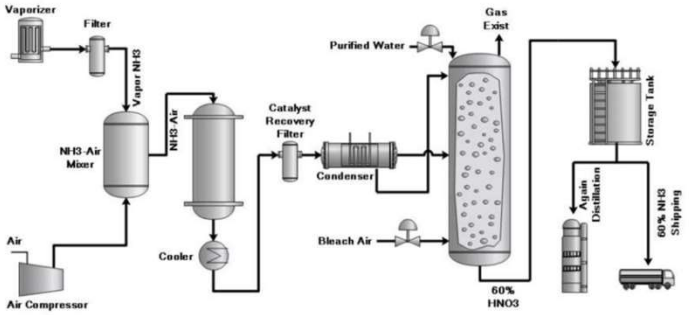
Logic Tree Facilitation – Tips and Tricks

- We don't need this team; I know what the problem is because I've been here 22 years!!
- We've tried that before
- It's old equipment
- We don't have time to do an RCA on this failure

Conventional Wisdom: Beware of the above as they are most often 'Assumptions' and not facts. A successful RCA will NOT allow hearsay to fly as FACT!!

Logic Tree Facilitation – Tips and Tricks

Draw a Sketch of the Event Being Analyzed



Source: https://chemicalengineeringworld.com/process-flow-diagram-pfd/

Logic Tree Facilitation – Tips and Tricks

Construct a Timeline of the Event

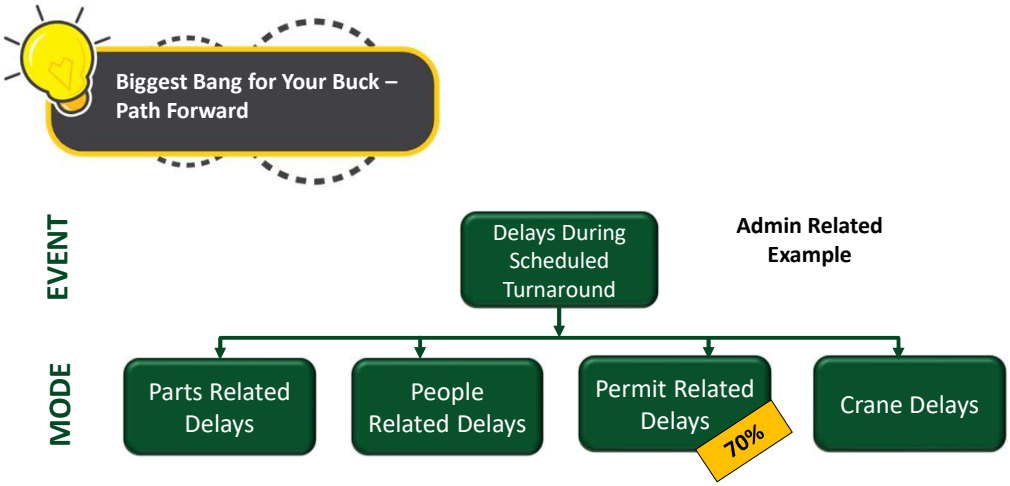
NASA
Johnson Space Center

STS 51-L Incident Investigation
Integrated Events Timeline

CAMERA	PHOTOGRAPHIC EVENT	MET SEC	MET SEC	INSTRUMENTATION EVENT	DATA SOURCE
			66.764	START ET LH2 ULLAGE PRESSURE DEVIATIONS	T41P1700C
			65.524	LHOB ELEVON ACTUATOR DELTA P CHANGE	V58P0866C
			65.404	END VEHICLE PITCH RATE CHANGE	V90R2525C L
E204	BRIGHT SUSTAINED GLOW ON +Z AND -Z SIDES OF ET	64.705	64.937	START ME LARGE PITCH VARIATIONS	V58H1100A
E204	ABRUPT CHANGE IN ANOMALOUS PLUME SHAPE, FIRST INDICATION OF LH2 LEAK NEAR ET 2058 RING FRAME	64.660	64.604	START VEHICLE PITCH RATE CHANGE	V90R2525C L
			63.924	RHOB ELEVON ACTUATOR DELTA P CHANGE	V58P0966C
E207	FIRST EVIDENCE OF PLUME DEFLECTION CONTINUOUS	60.988			
E203	FIRST EVIDENCE OF ANOMALOUS SRB PLUME ATTACHING TO THE ET 2058 RING FRAME	60.248	62.484	RHOB ELEV ACT HINGE MOMENT SPIKE	V58P0966C
E207	FIRST EVIDENCE OF PLUME DEFLECTION - INTERMITTANT	60.238	62.094	START L SRB TVC ROCK ACT SPIKE	B58H1150C
E204	VISUAL EVIDENCE OF FLAME FROM R SRB IN +Z DIRECTION, NEAR ET ATTACH RING (SEEN FROM SOUTH SIDE).	59.763			
E207	CONTINUOUS WELL-DEFINED PLUME ON R SRB IN +Z, -Y COORDINATES	59.262	60.004	SRB CHAMBER PRESS DIVERGENCE RH VS LH	B47P2302C R B47P1302C L
E207	FLICKERING DYNAMIC PLUME ON R SRB	TBD			
E207	FIRST EVIDENCE OF FLAME ON R SRB	58.788	59.000	*RECONSTRUCTED MAX Q 720 PSF	JSC DATA

[Ref. 3/21-29]

Logic Tree Facilitation – Tips and Tricks



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Additional Cases

- Cooling Tower Fan #2 Motor Failure
- Lubrication Degradation Mechanisms RCA
- Industry Example
- RCA on RCA

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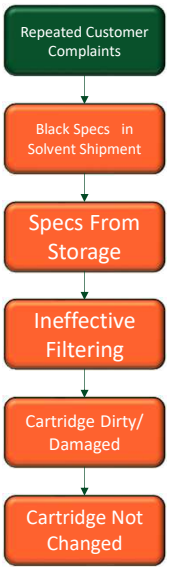
Let's Try an Equivalency Test…

Case Study Background: XYZ Company was receiving numerous complaints from a particular customer about contamination of their delivered product (solvent), which had visible black 'specks'. This was unacceptable and the delivery was refused and returned by the client.

Let's review this case and apply the 5-Whys, Fishbone and Logic Tree Approaches. This was actually done as a test with this particular client using 3 different teams. These were the results.

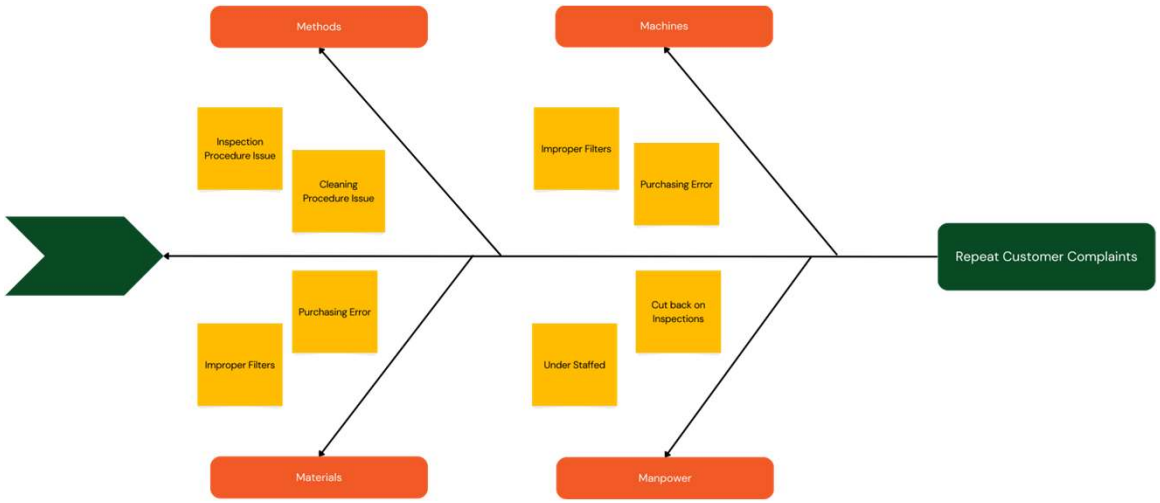
Source: Latino, Latino & Latino.2019.Root Cause Analysis: Improving Performance for Bottom-Line Results.5th Ed.CRC Press. Boca Raton, FL.

The 5-Whys Team

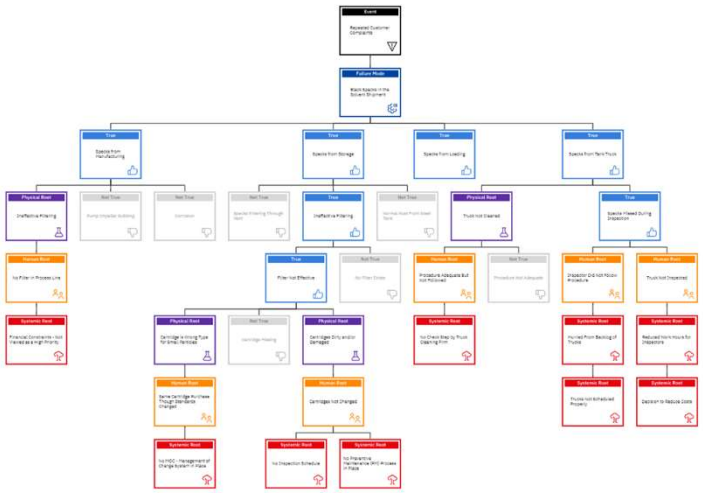


'The ROOT CAUSE'

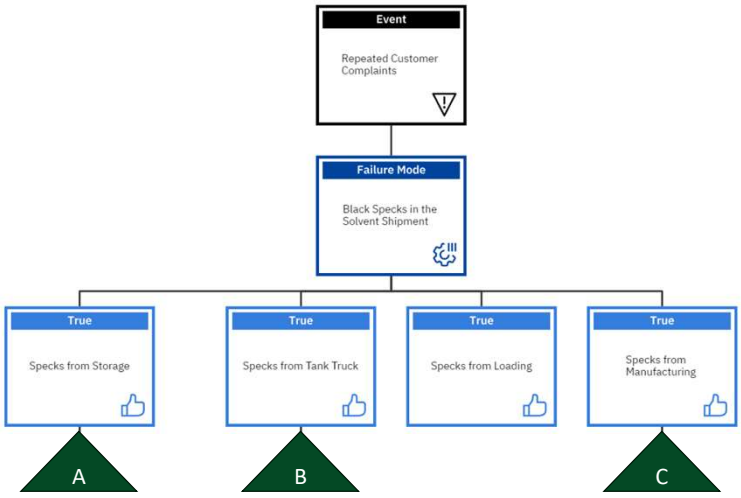
The Fishbone Team (Using the 4 M's)



The Logic Tree Team



Logic Tree Exploration (1)



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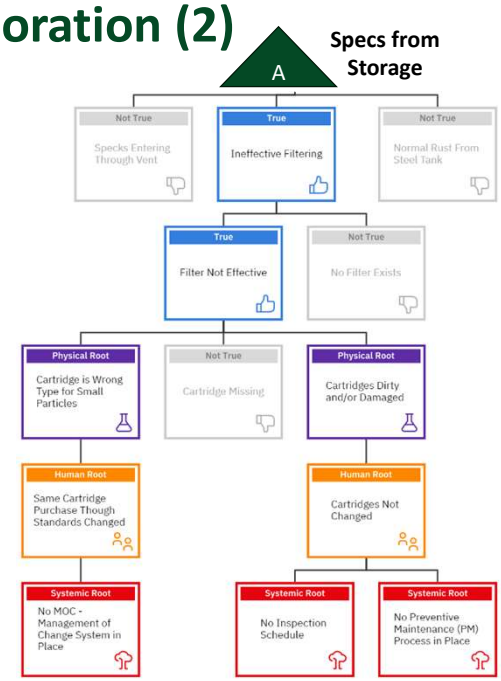
Logic Tree Exploration (2)



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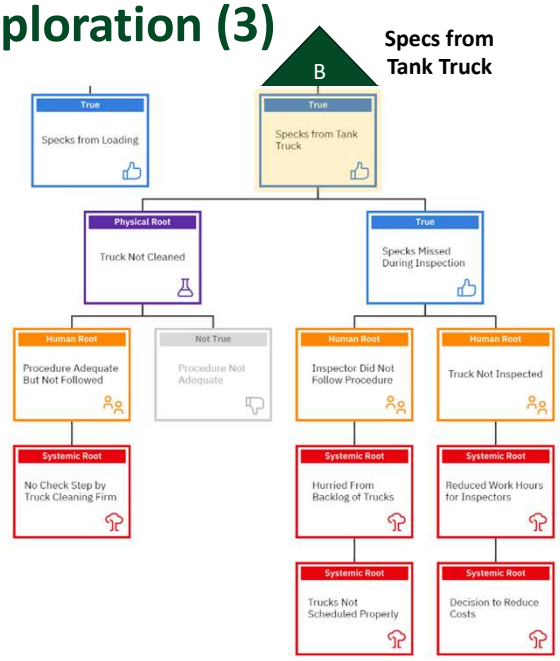
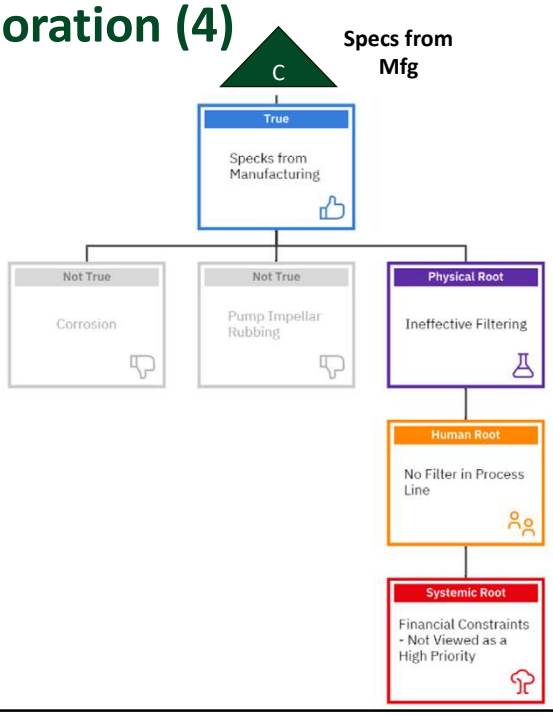
Logic Tree Exploration (3)



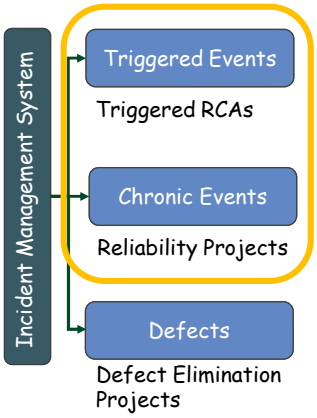
Logic Tree Exploration (4)



Are All RCA Tools Created Equal?

Root Causes Identified	5-Whys	Fishbone	Logic Tree RCA
No Filter in Process Line	X	X	X
Ineffective Filtering		X	X
Purchasing Error		X	Evidence proves this not to be true
Understaffed		X	X
Financial Constraints Made Purchasing Filters Not a High Priority		X	Evidence proves this not to be true
Cartridge was Wrong Type for Small Particles		X	X
Process Changed and Cartridges Not Updates			X
No MOC to Ensure Specs Change When Process Modifications Implemented			X
Cartridges Dirty			X
Cartridges Not Changed			X
No Cartridge Inspection Scheduled			X
Lack of Proper PM Scheduling Program			X
Transfer Truck Not Cleaned			X
Cleaner Did Not Follow Procedure			X
No Check Step By Truck Cleaning Firm			X
Specs Missing During Inspection of Truck			X
Inspector Hurried from the Backlog of Trucks			X
Trucks Not Scheduled Properly			X
Inspectors Work Hours Cut Back			X
Decision to Cut Costs			X

Remember Our RCA Process Flow Diagram…



Root Cause Analysis Exercise

Instructions: Break into teams of 3-5 members. Organize into work teams where each team has at least one member who is **NOT** familiar with the event being analyzed. Follow the steps below and be prepared to report your analysis and findings to the other teams. 60 minutes

Step 1: Identify Event to Analyze

Step 2: Calculate the Annual Losses Associated with Event

Step 3: Sketch Out the Event for Team (Basic)

Step 4: Construct a Basic Timeline

Step 5: Begin Logic Tree Construction

Step 6: Validate Hypotheses Using Data Previously Collected (Virtually)

Step 7: Continue Down Logic Tree Until Latent/System Roots are Identified. Properly Identify Physical, Human, and Latent Root Causes.

Step 8: Propose Corrective Actions for Actionable Root Causes

Step 9: Present Case Study to Leadership (Rest of Class)

Online Case Studies

Thermo-Compressor Cone Failures

(~ 18 minutes)

Turbine Driven Boiler Feed Pump Failure

(~16 minutes)

Case #1

Thick Stock Pump Analysis

100

Line-Item Opportunity Analysis
10/yr x $100k/failure = $1M/year

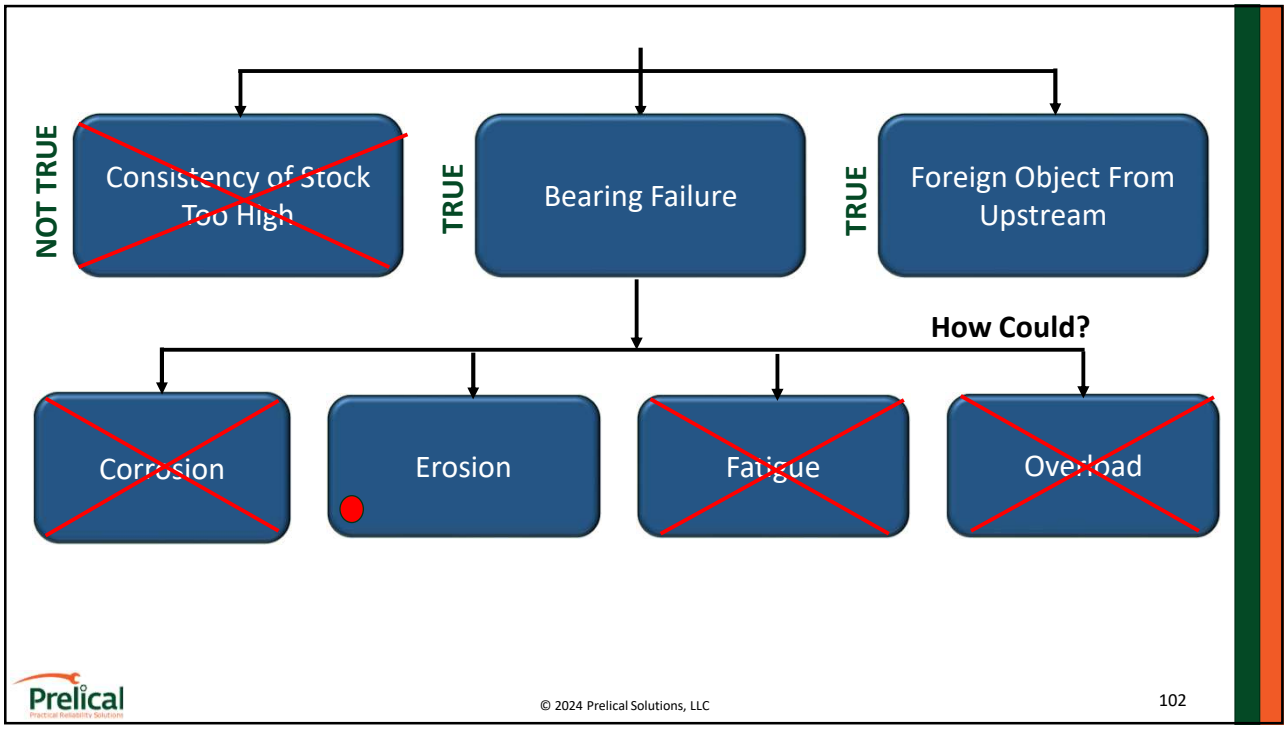
EVENT: **Repetitive Thick Stock Failures Resulting in $6M Loss/Year** — FACT

MODE: **Pump Locks Up** — FACT

How Could?

- NOT TRUE: ~~Consistency of Stock Too High~~
- TRUE: Bearing Failure
- TRUE: Foreign Object From Upstream

101


NOT TRUE
Consistency of Stock Too High
TRUE
Bearing Failure
TRUE
Foreign Object From Upstream
How Could?
Corrosion
Erosion
Fatigue
Overload
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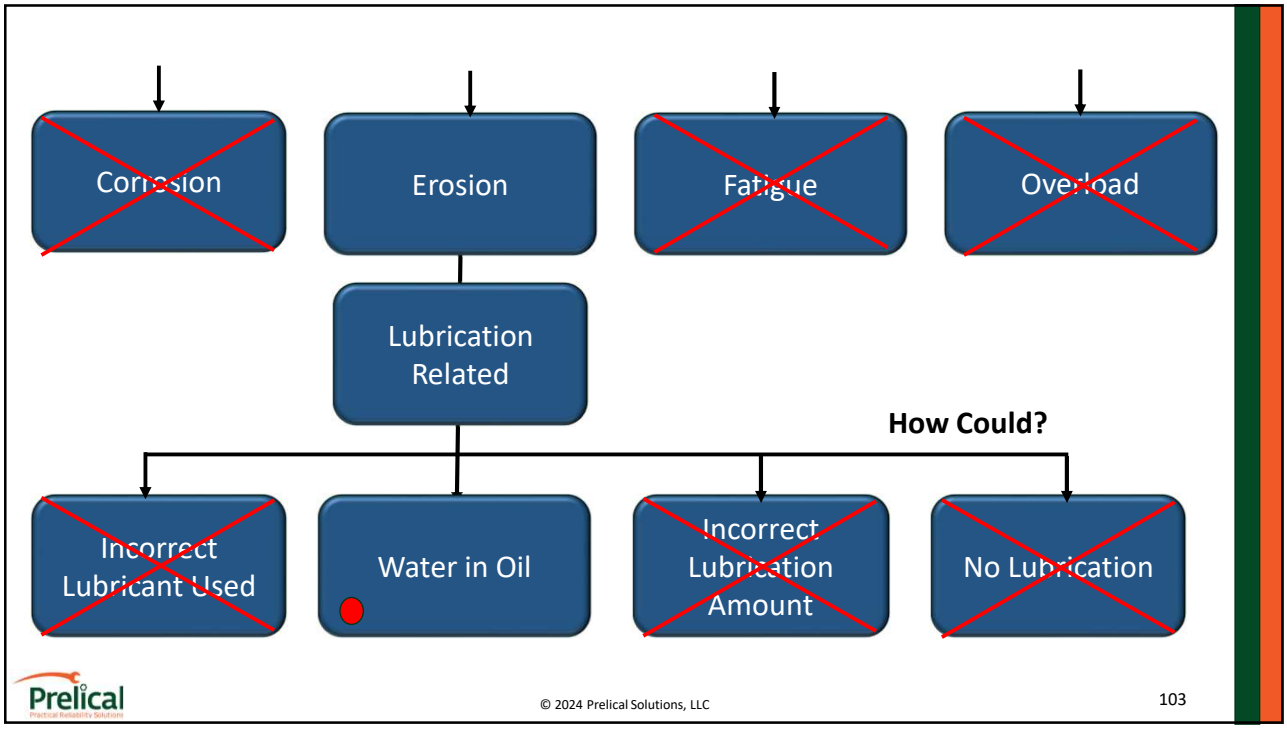
Corrosion
Erosion
Fatigue
Overload
Lubrication Related
How Could?
Incorrect Lubricant Used
Water in Oil
Incorrect Lubrication Amount
No Lubrication
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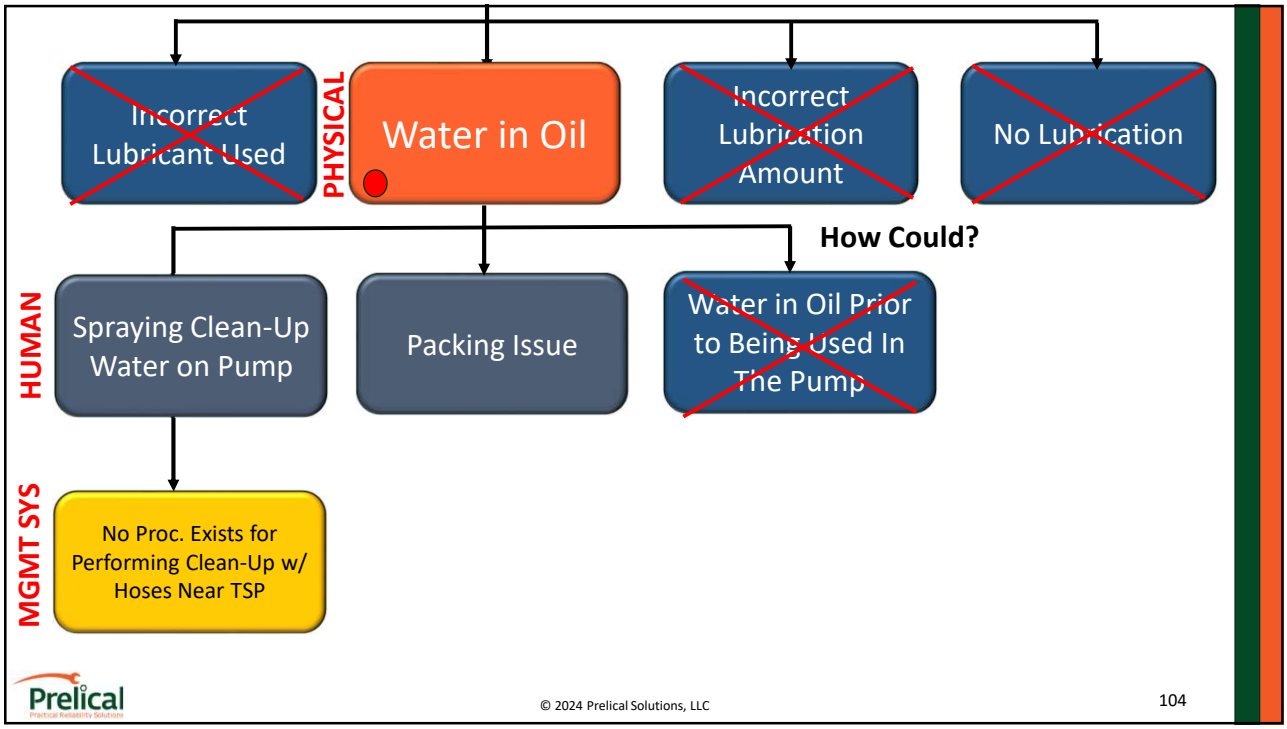
Incorrect Lubricant Used
PHYSICAL
Water in Oil
Incorrect Lubrication Amount
No Lubrication
How Could?
HUMAN
Spraying Clean-Up Water on Pump
Packing Issue
Water in Oil Prior to Being Used In The Pump
MGMT SYS
No Proc. Exists for Performing Clean-Up w/ Hoses Near TSP
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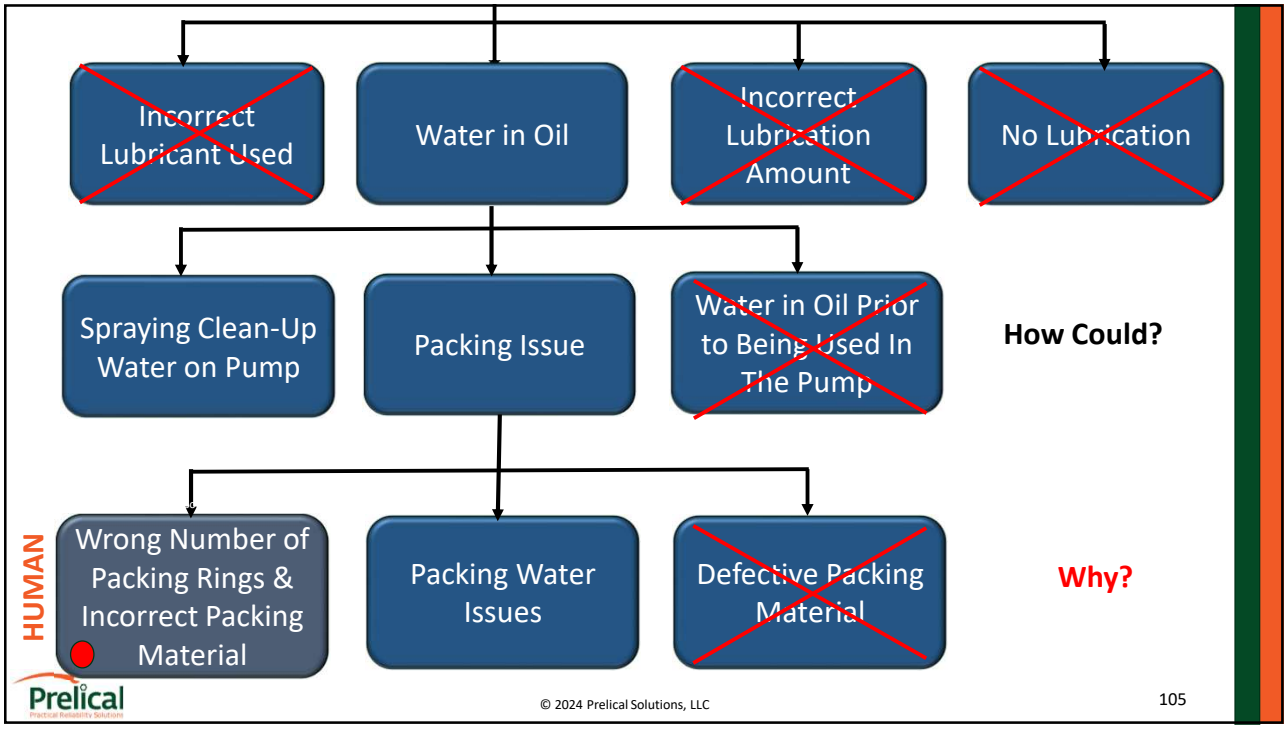
Incorrect Lubricant Used
Water in Oil
Incorrect Lubrication Amount
No Lubrication
Spraying Clean-Up Water on Pump
Packing Issue
Water in Oil Prior to Being Used In The Pump
How Could?
HUMAN
Wrong Number of Packing Rings & Incorrect Packing Material
Packing Water Issues
Defective Packing Material
Why?
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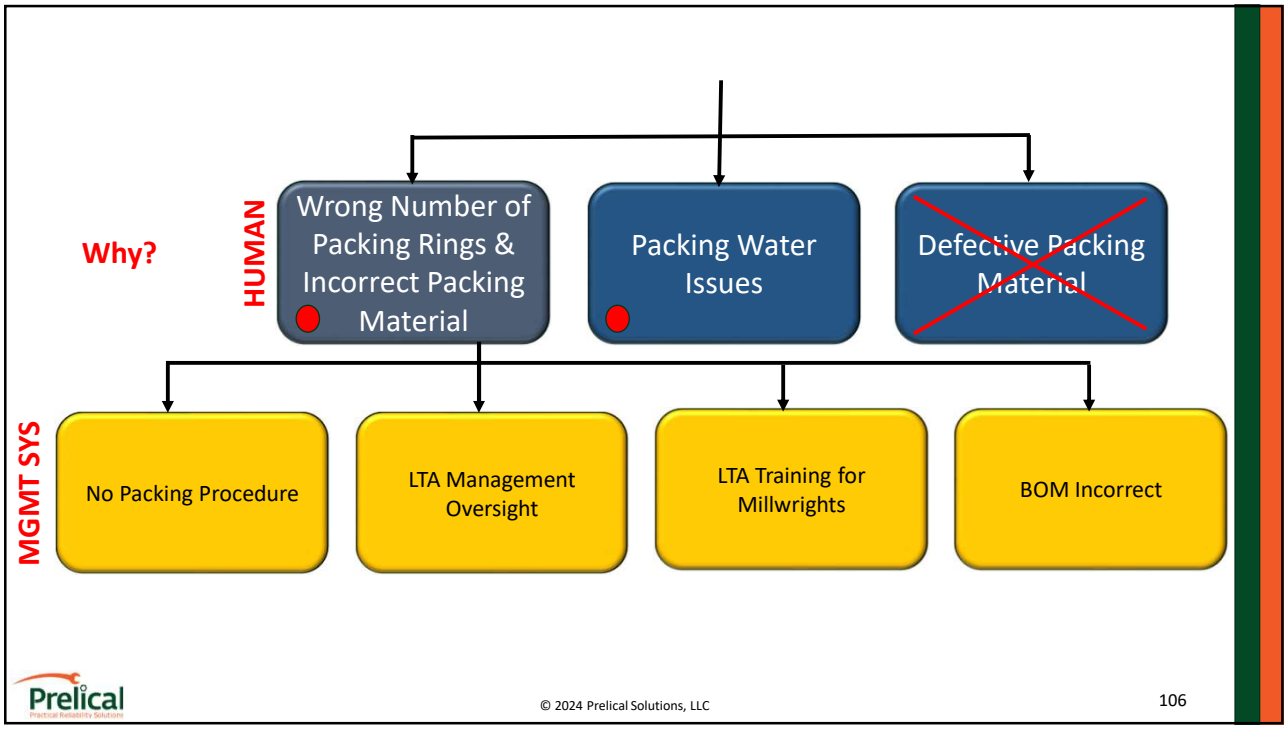
Why?
HUMAN
Wrong Number of Packing Rings & Incorrect Packing Material
Packing Water Issues
Defective Packing Material
MGMT SYS
No Packing Procedure
LTA Management Oversight
LTA Training for Millwrights
BOM Incorrect
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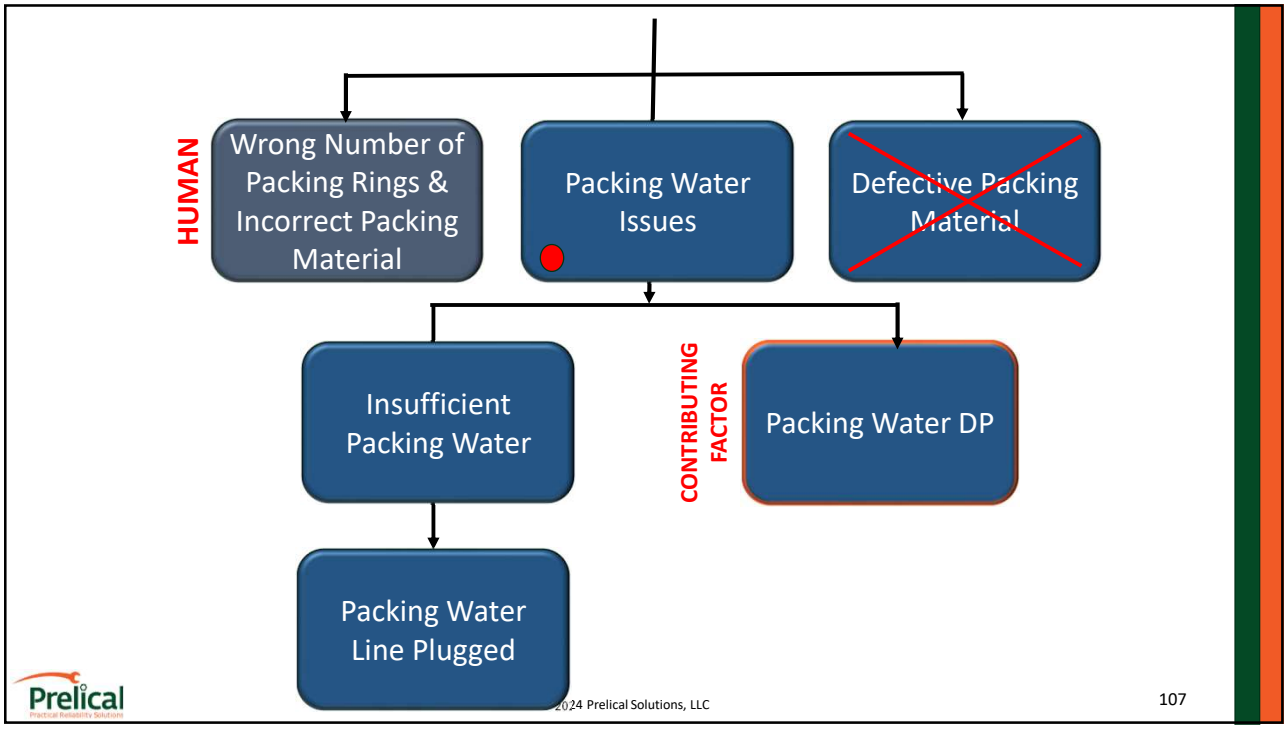
HUMAN
Wrong Number of Packing Rings & Incorrect Packing Material
Packing Water Issues
Defective Packing Material
Insufficient Packing Water
CONTRIBUTING FACTOR
Packing Water DP
Packing Water Line Plugged
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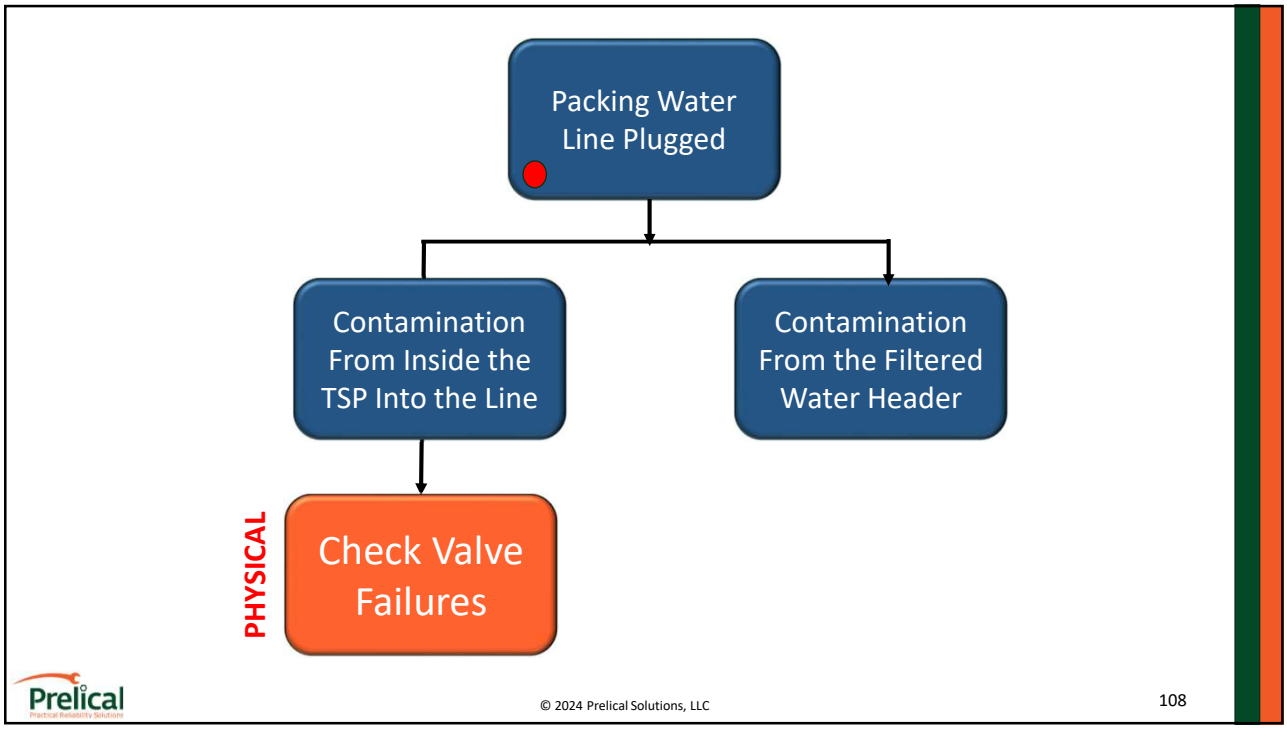
Packing Water Line Plugged
Contamination From Inside the TSP Into the Line
Contamination From the Filtered Water Header
PHYSICAL
Check Valve Failures
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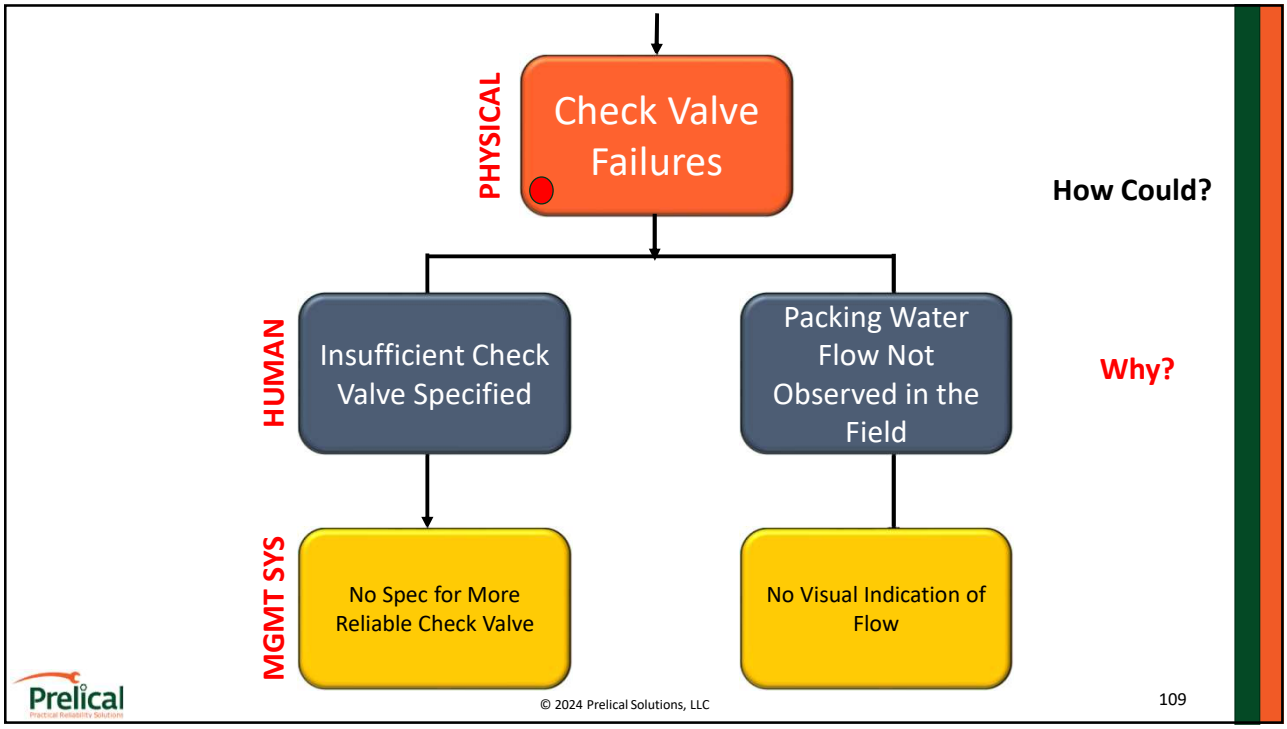
PHYSICAL
Check Valve Failures
How Could?
HUMAN
Insufficient Check Valve Specified
Packing Water Flow Not Observed in the Field
Why?
MGMT SYS
No Spec for More Reliable Check Valve
No Visual Indication of Flow
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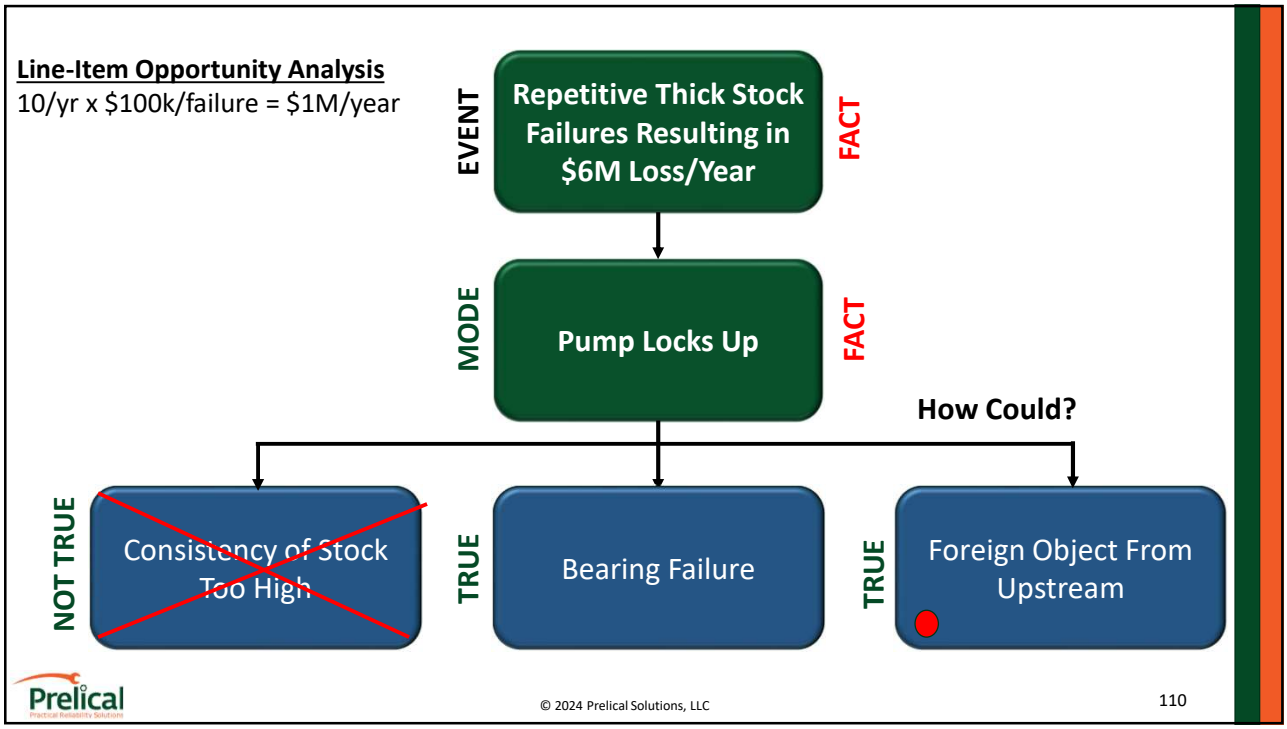
Line-Item Opportunity Analysis
10/yr x $100k/failure = $1M/year
EVENT
Repetitive Thick Stock Failures Resulting in $6M Loss/Year
FACT
MODE
Pump Locks Up
FACT
How Could?
NOT TRUE
Consistency of Stock Too High
TRUE
Bearing Failure
TRUE
Foreign Object From Upstream
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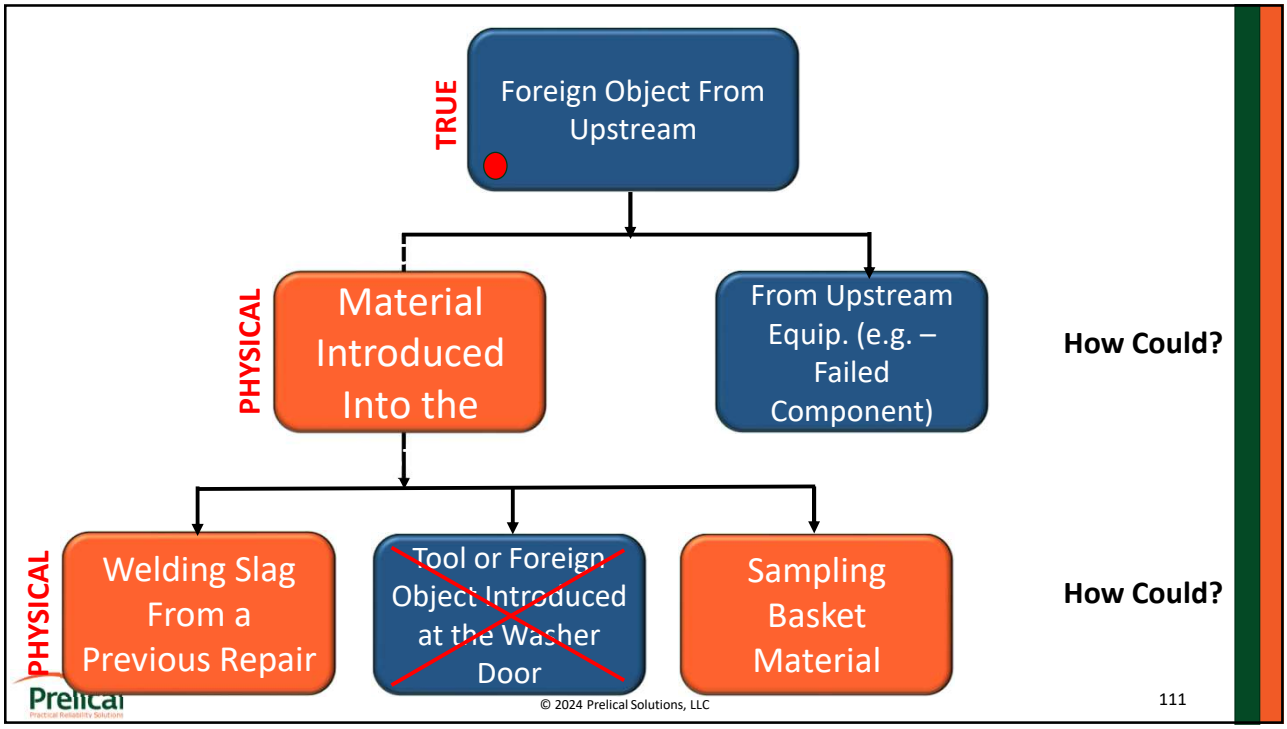
TRUE
Foreign Object From Upstream
PHYSICAL
Material Introduced Into the
From Upstream Equip. (e.g. – Failed Component)
How Could?
PHYSICAL
Welding Slag From a Previous Repair
Tool or Foreign Object Introduced at the Washer Door
Sampling Basket Material
How Could?
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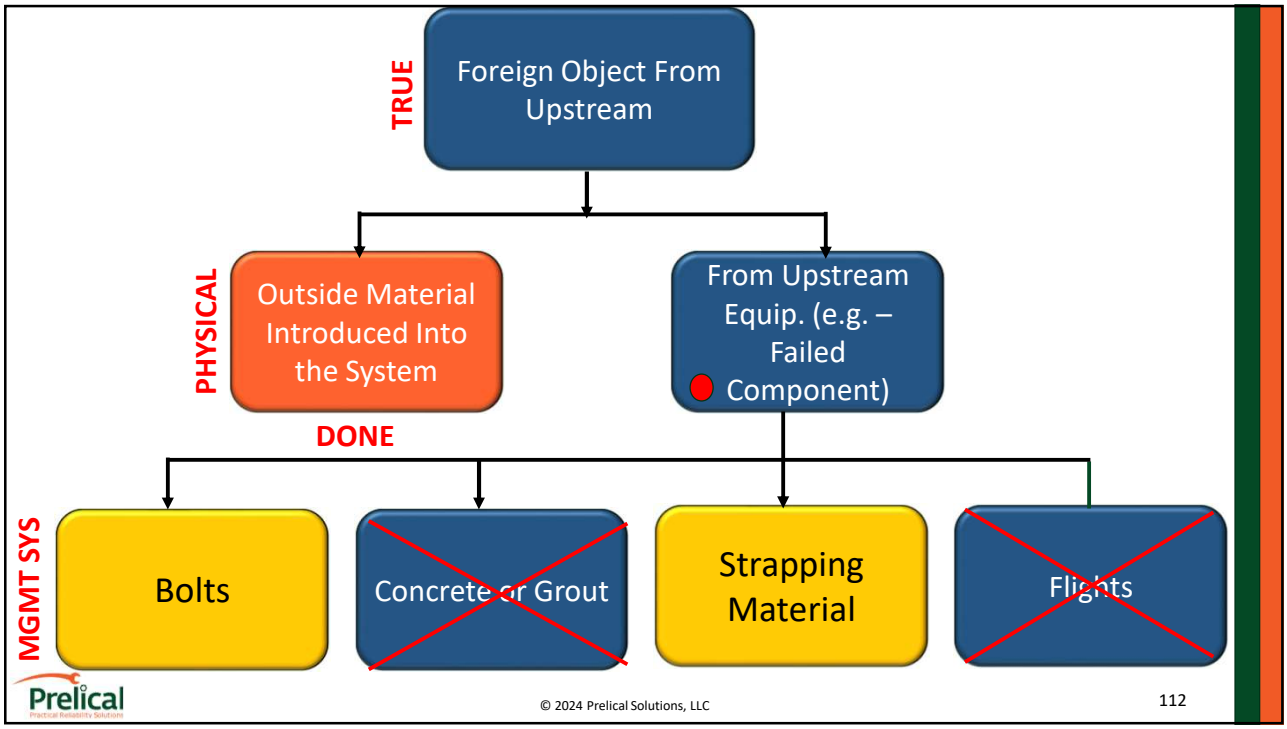
TRUE
Foreign Object From Upstream
PHYSICAL
Outside Material Introduced Into the System
From Upstream Equip. (e.g. – Failed Component)
DONE
MGMT SYS
Bolts
Concrete or Grout
Strapping Material
Flights
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