Mission-intensive Inspection 2.0

By far your most effective machinery condition monitoring strategy

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Machines Fail Because of What People Do… and What They Don't Do

Tribology is a Behavioral Science

Main Points

- Fishing for Faults
- Time Domains of Machine Failure
- Virtues of Early Fault Detection
- Agony of Undetected Fault Bubbles
- Creating Inspection Windows
- Deploying Advanced Inspection Aids and Tools
- The Role of the Operator

Noria was founded on the premise that …

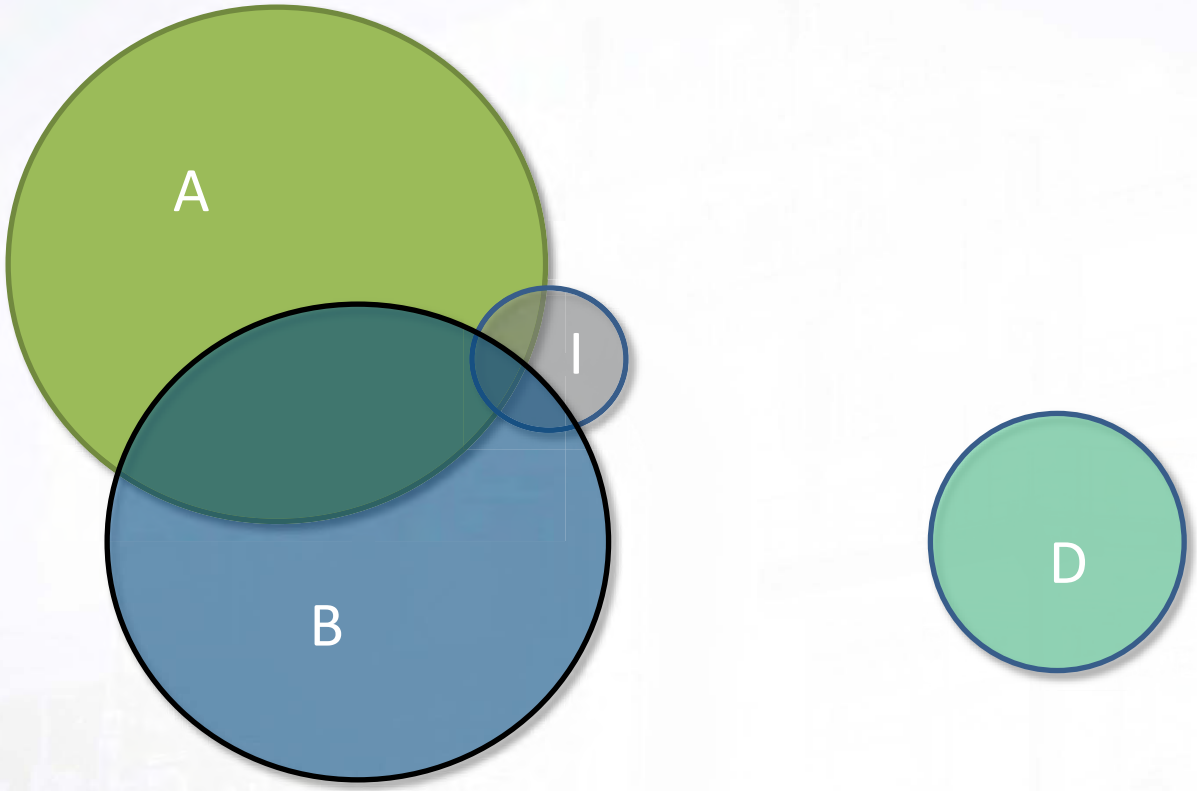
- Maintenance is the No. 1 most controllable expenditure in a plant
- Every plant has a hidden plant that must be found
- Lubrication is the No. 1 cause of machine wear and failure
- There is no greater influence on the state of lubrication than human behavior
- All progress depends on change, and change must be enabled

The Condition Monitoring Universe

Example Methods:

- Vibration
- Thermography
- Acoustics
- Motor Current Analysis

The Condition Monitoring Universe



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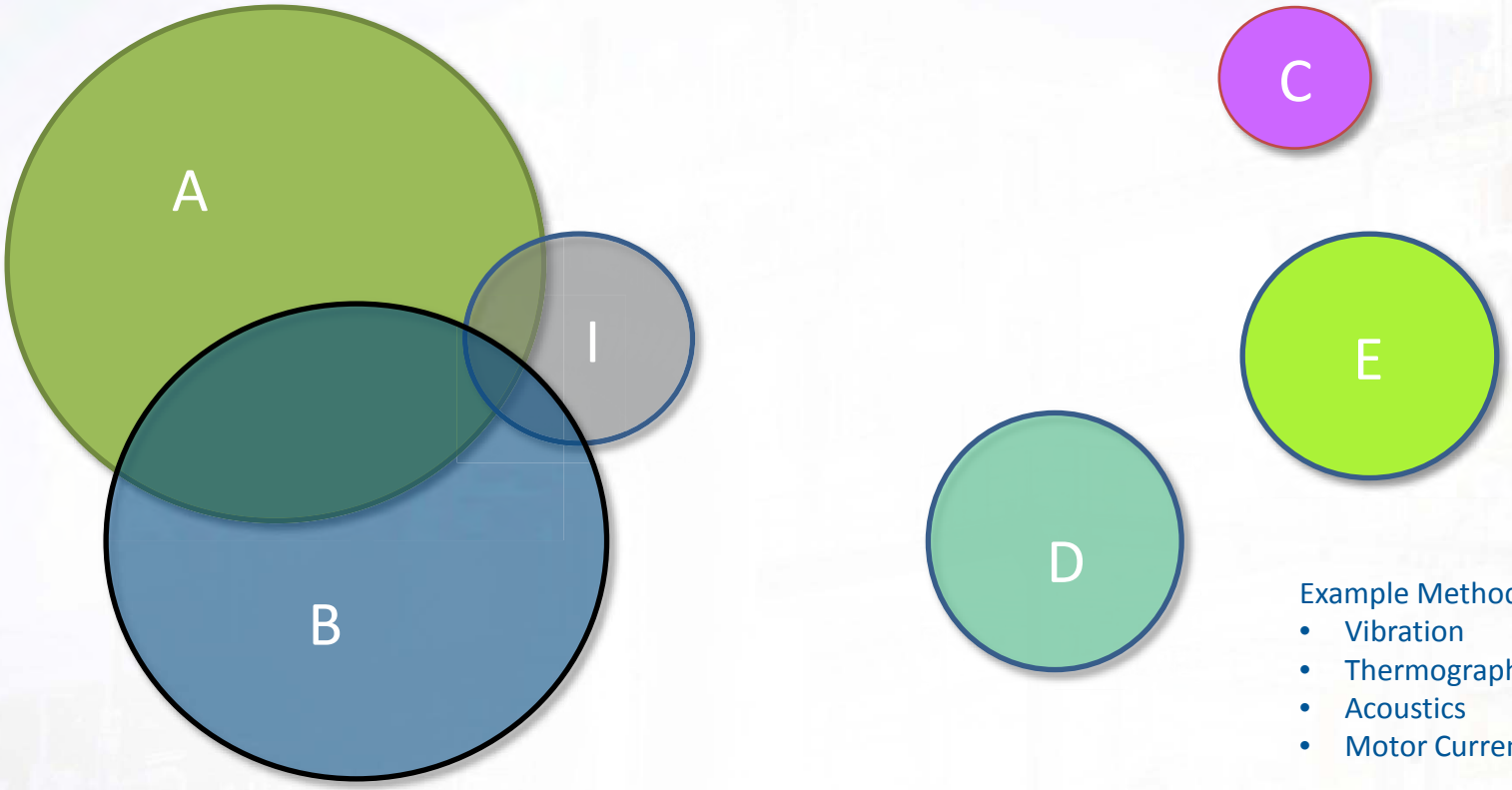

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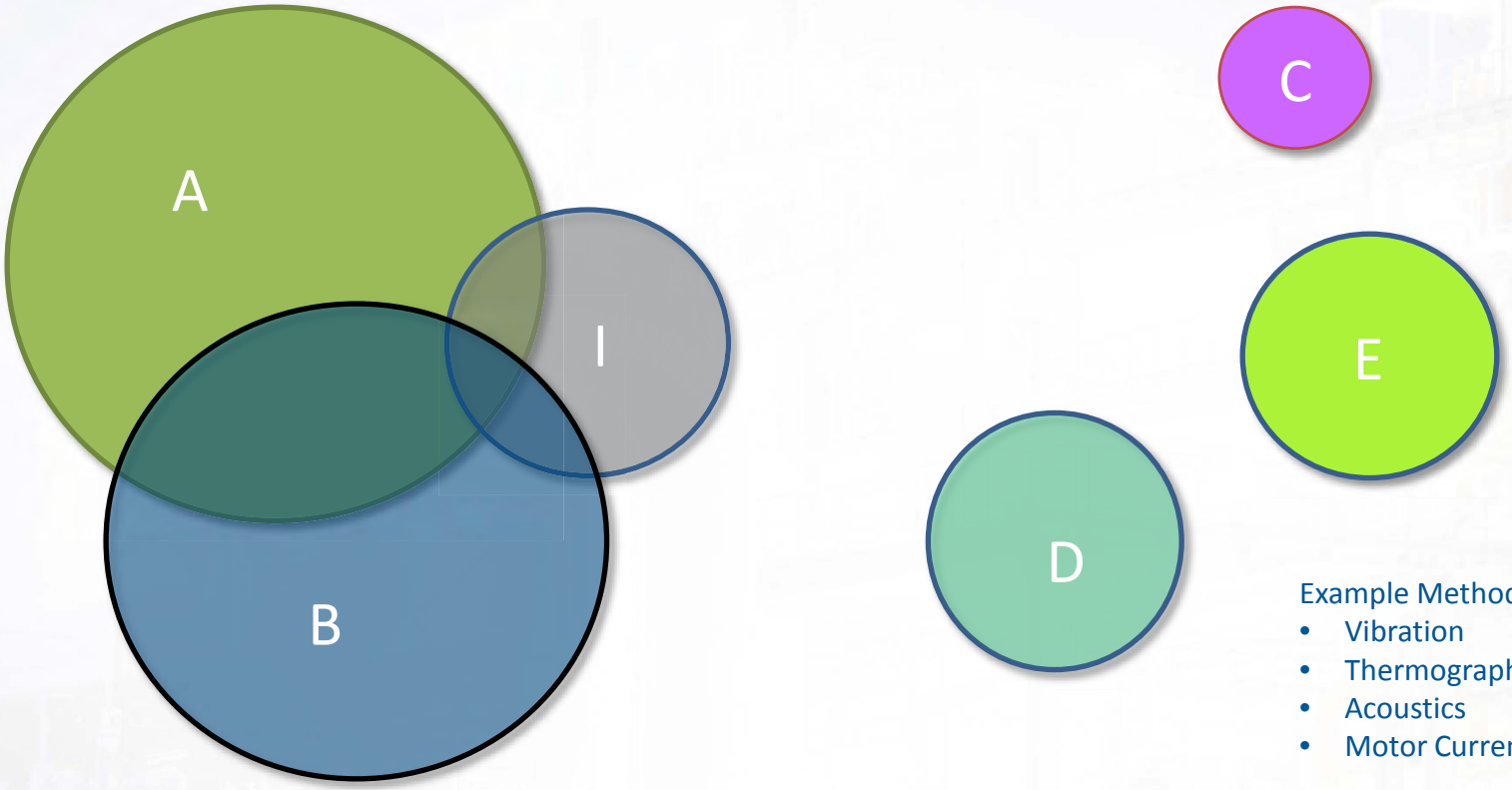

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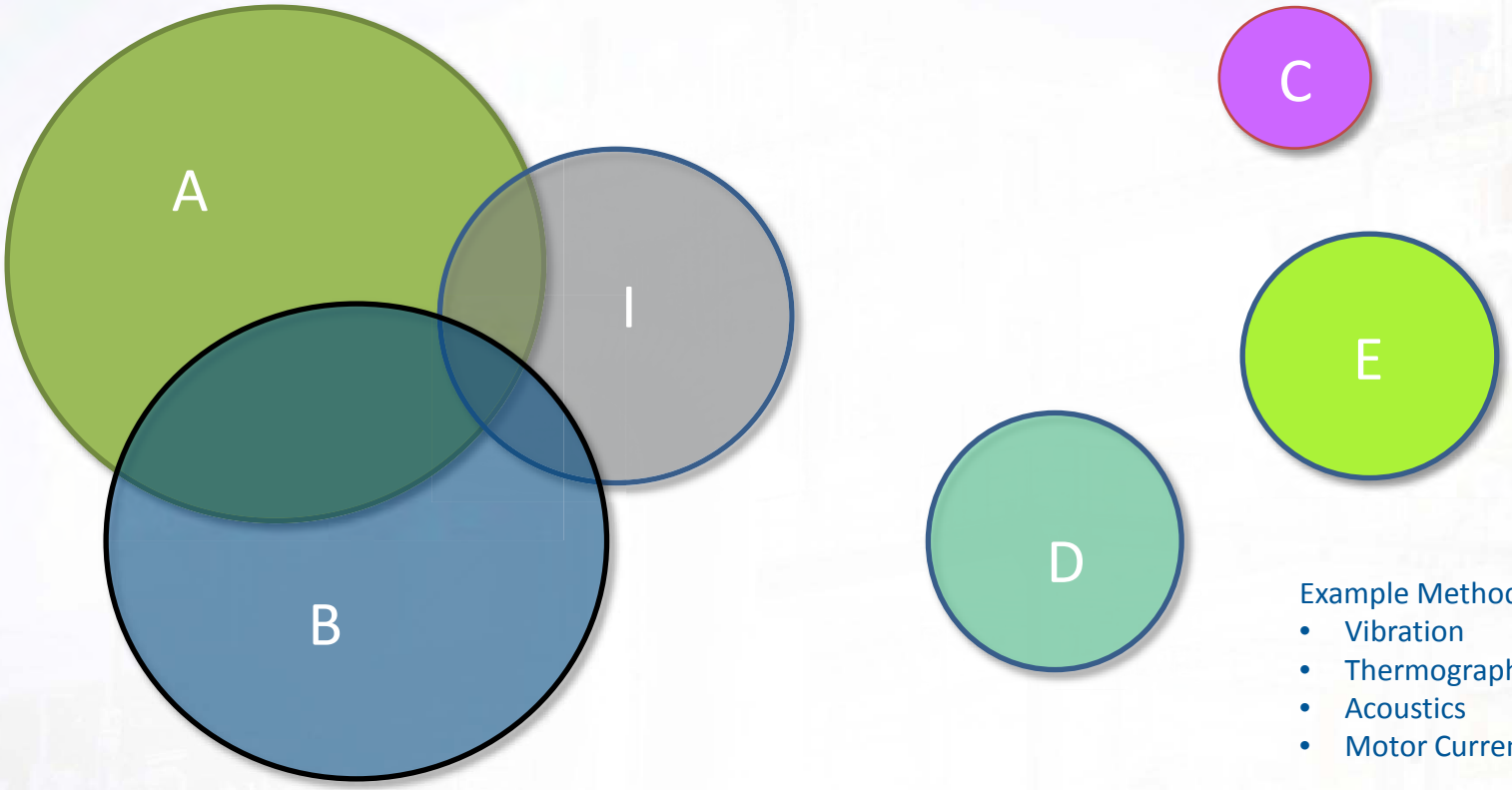

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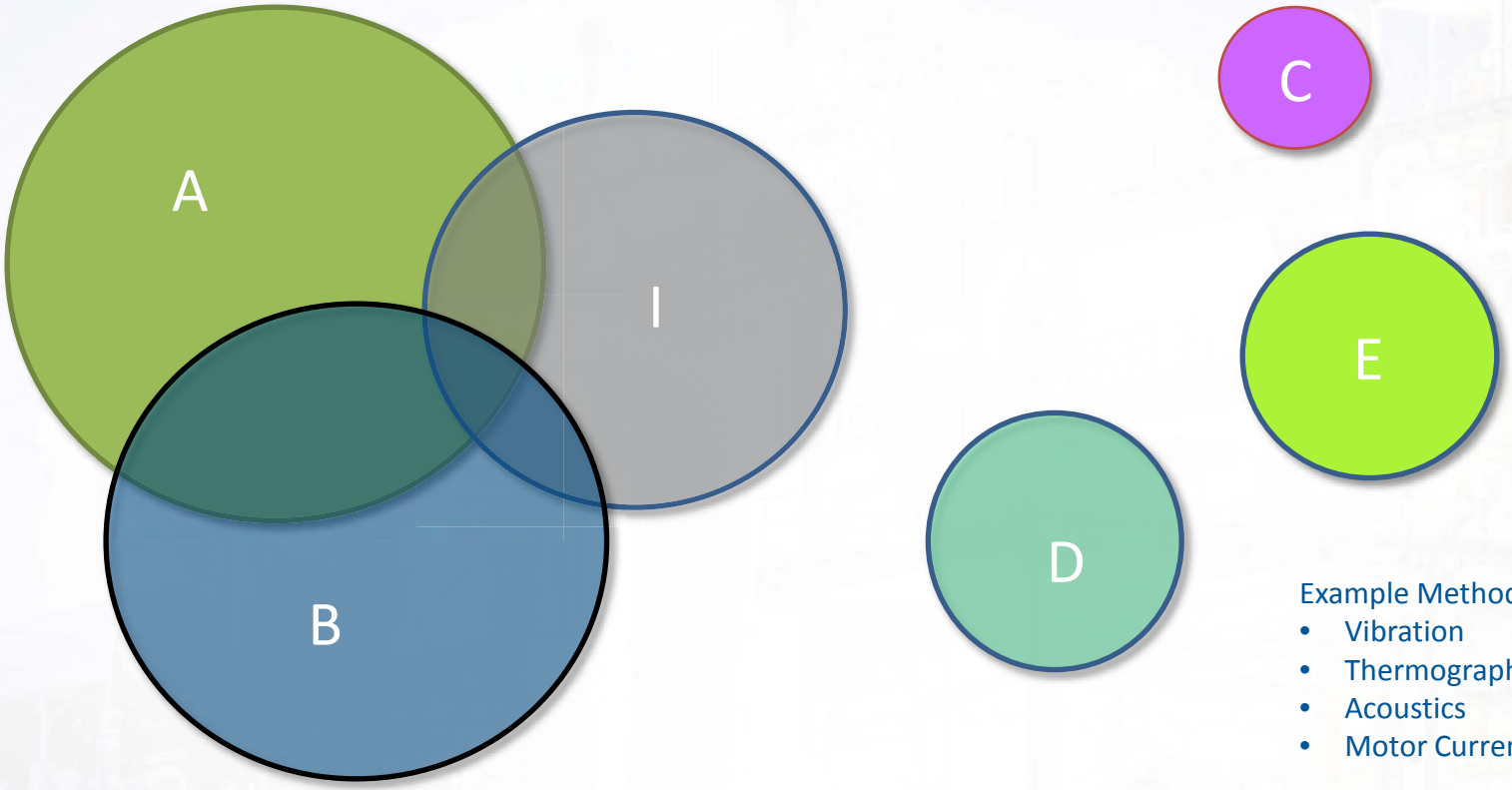

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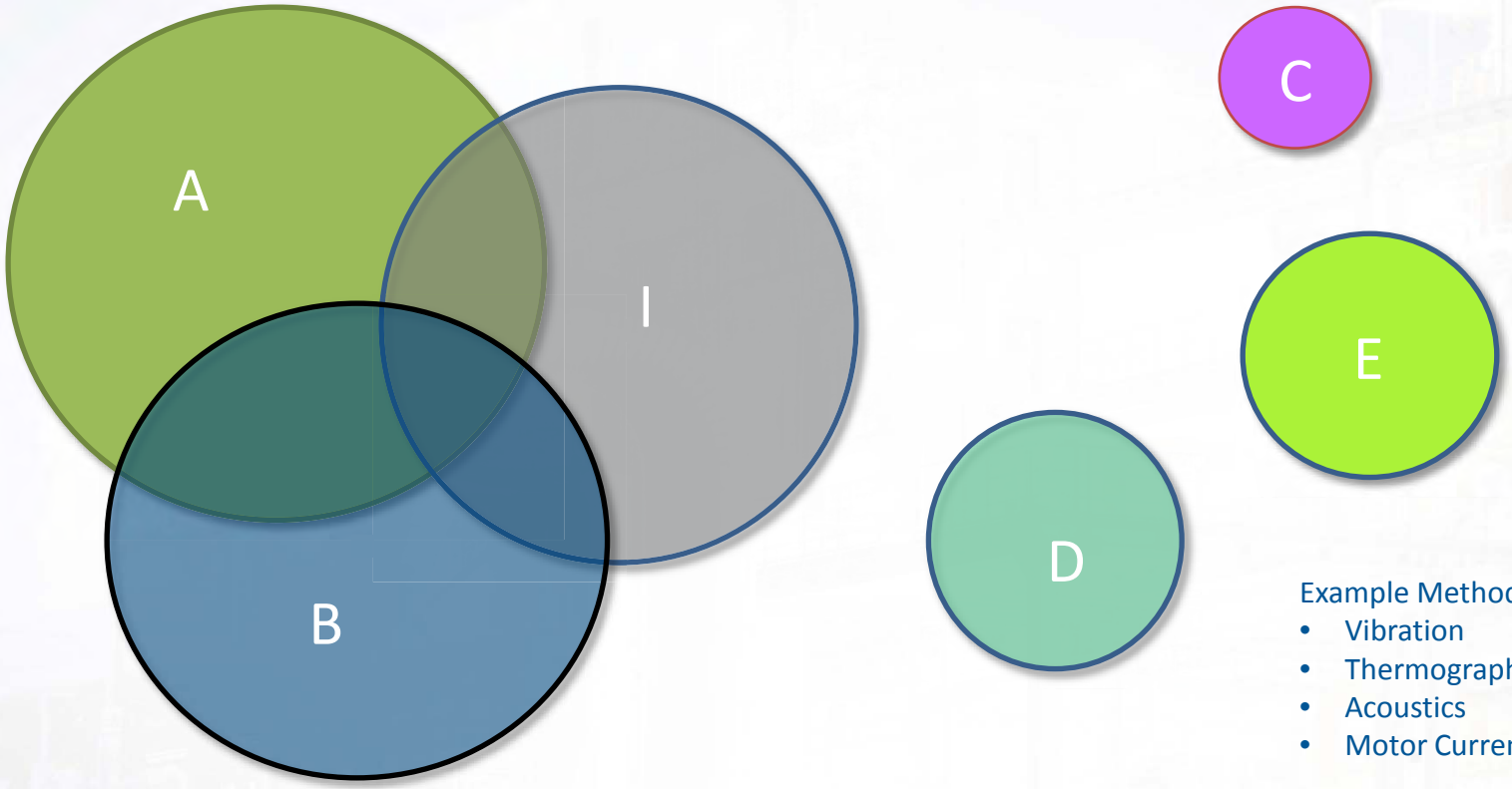

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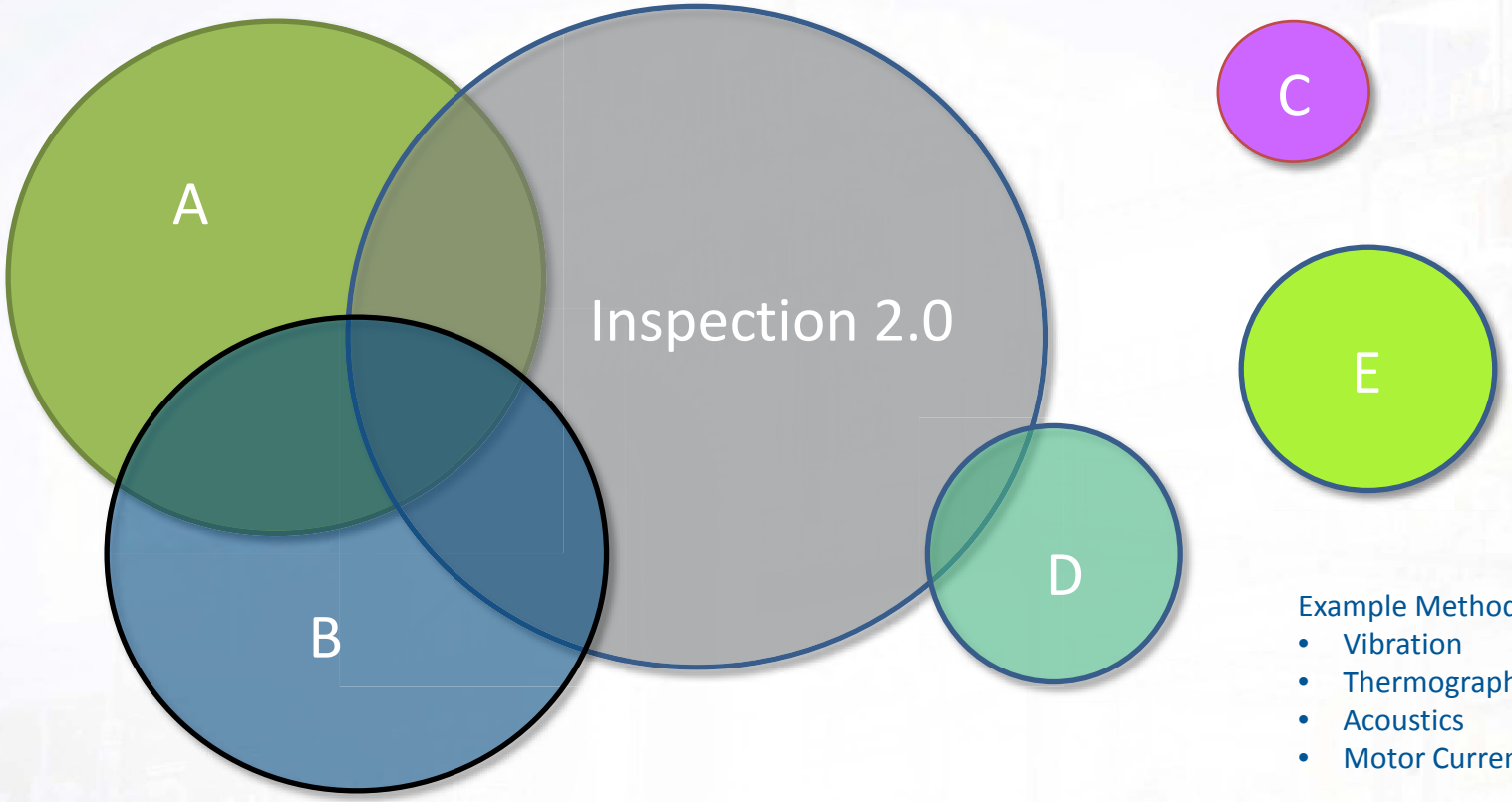

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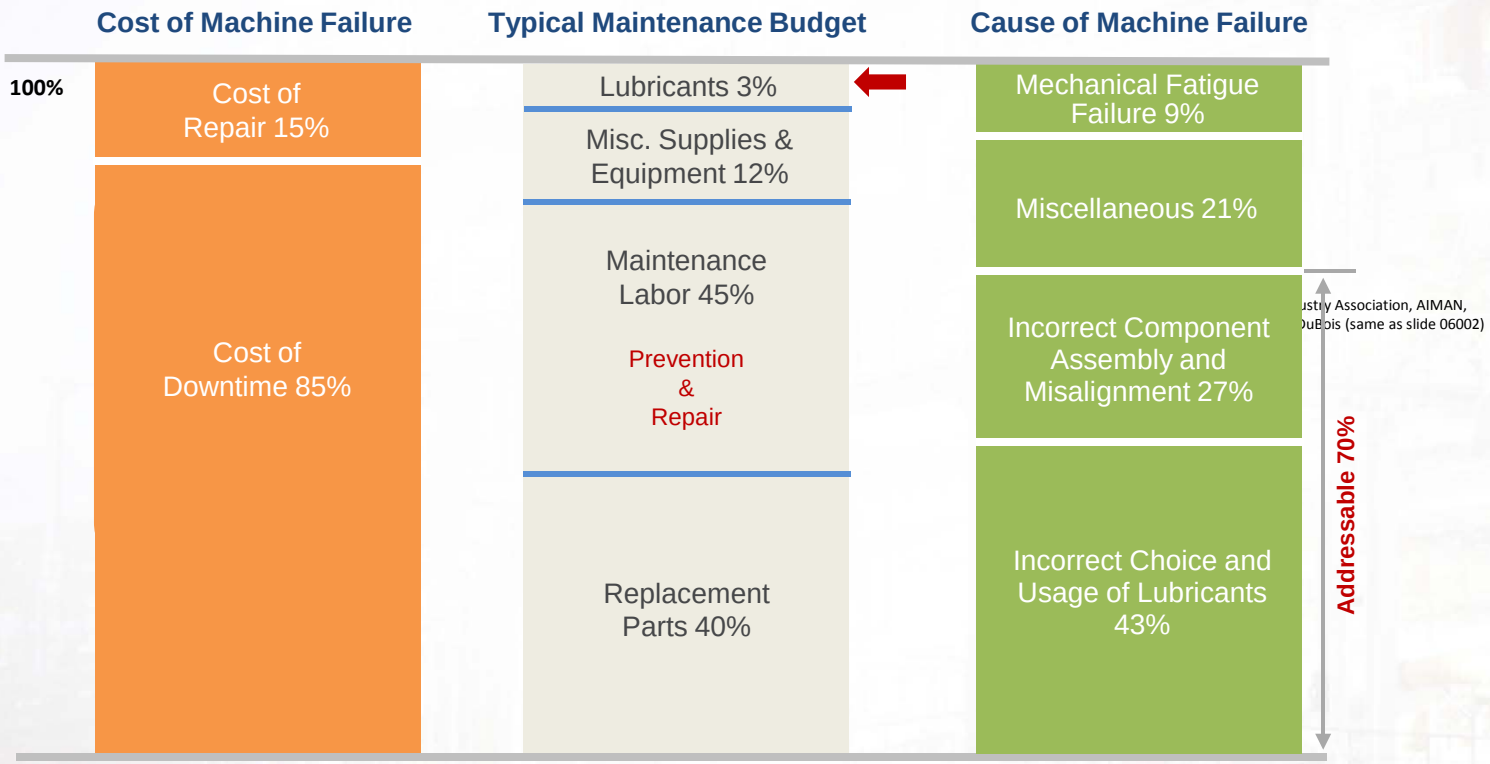
Addressable Opportunities in Lubricants and Lubrication



Philosophies that Frame Today's Reliability Culture

- Condition-based Maintenance
- Reliability-centered Maintenance
- Total Productive Maintenance
- Inspection 2.0
- Asset Management (ISO 55000)

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Philosophies That Frame Today's Reliability Culture

- Condition-based Maintenance
- Reliability-centered Maintenance
  - Failure modes and effects analysis (FMEA)
  - Criticality analysis (failure effects and consequences)
  - P-F interval and predicting life expectancy
  - Maintenance strategy planning
- Total Productive Maintenance
- Inspection 2.0
- Asset Management (ISO 55000)

Philosophies That Frame Today's Reliability Culture

- Condition-based Maintenance
- Reliability-centered Maintenance
- Total Productive Maintenance
  - Autonomous maintenance (with inspection)
  - Continuous improvement (kaizen)
  - Operator-centric maintenance
  - Cleanliness and orderly work environment
  - Culture and motivated employee involvement
- Inspection 2.0
- Asset Management (ISO 55000)

Philosophies That Frame Today's Reliability Culture

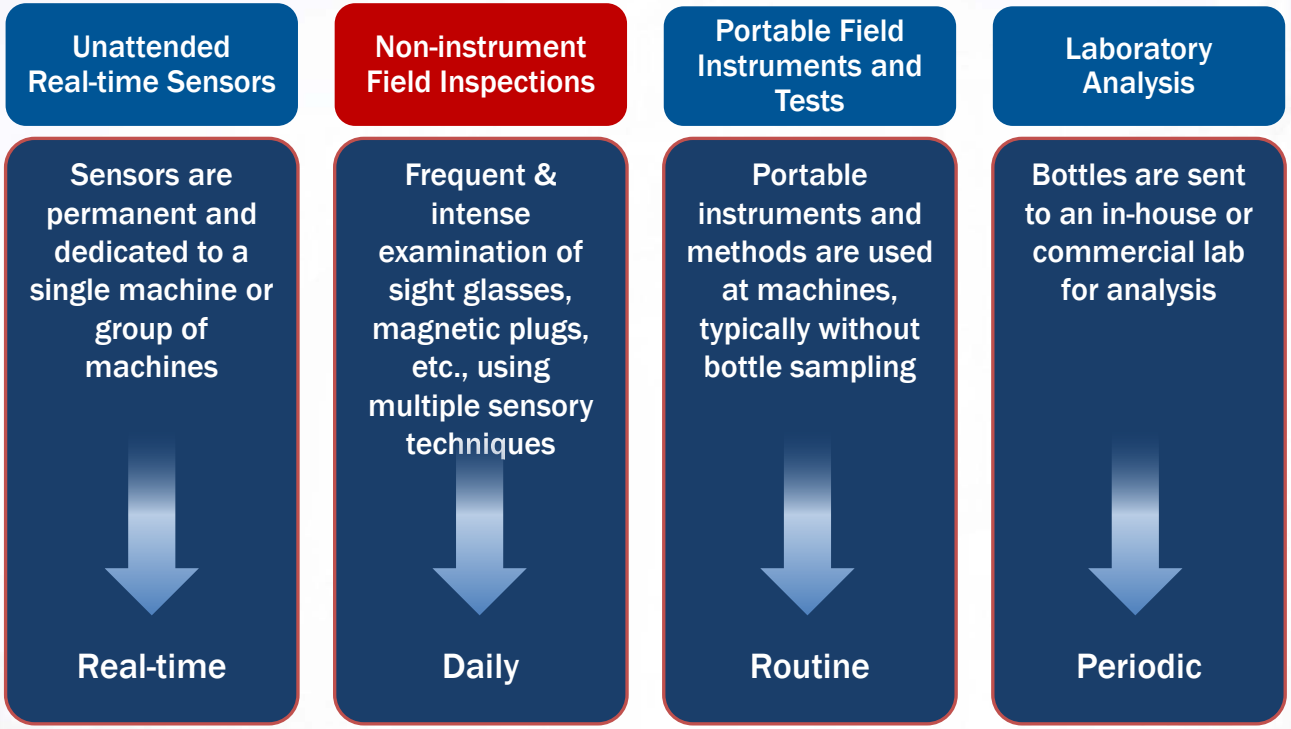
- Condition-based Maintenance
- Reliability-centered Maintenance
- Total Productive Maintenance
- Inspection 2.0
  - Advanced inspector skills
  - Machine inspection readiness with inspection windows
  - Advanced inspection tools and aids
  - Inspection protocol aligned to failure modes
  - Early fault and root cause emphasis
  - Origin of >90% of unscheduled work orders
- Asset Management (ISO 55000)

Philosophies That Frame Today's Reliability Culture

- Condition-based Maintenance
- Reliability-centered Maintenance
- Total Productive Maintenance
- Inspection 2.0
- Asset Management (ISO 55000)
  - Provides an overall structured approach to asset management
  - Modeled after 9001 (quality)
  - Not maintenance prescriptive; instead it codifies
  - Alignment to broader organizational objectives
  - Transformation planning to reach optimum state
  - Regular performance/compliance assessment
  - Continuous improvement

Reliability is everyone's responsibility

Lubricant Condition Monitoring Options



REF: JCF

Why Inspection 2.0 Condition Monitoring?

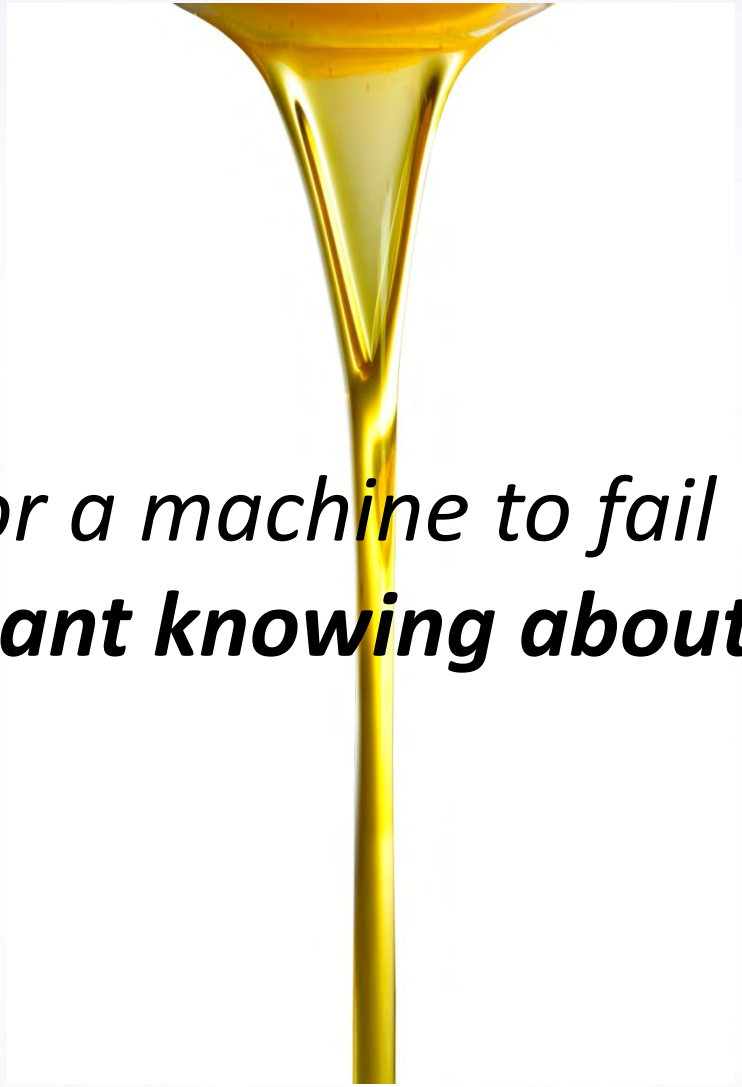
Ease of Use

- Inexpensive, simple, lasting deployment
- Operator-driven, autonomous maintenance (TPM)
- Emphasis on examination skills, less on technology

Early Detection

- The power of the one-minute daily inspection
- Proactive, root-cause oriented
- Early fault detection, less “just-in-time” saves
- Economics of “lead time” and scheduled remediation

REF: JCF



It's hard for a machine to fail without ***the lubricant knowing about it first***

Remember these Hidden Objects Puzzles from Highlights Magazine?

Can you find the objects on the list?

What if you didn't have the list?

Could a super-computer find them?

- Kite
- Flashlight
- Cowboy boot
- Whale
- Balloon
- Slice of pie
- Bird
- Tea cup
- Compass
- Ice cream cone
- Magnifying glass
- Rhino head
- Banana

Let’s do an inspection now …

Can you find the 10 reportable conditions from this tank?

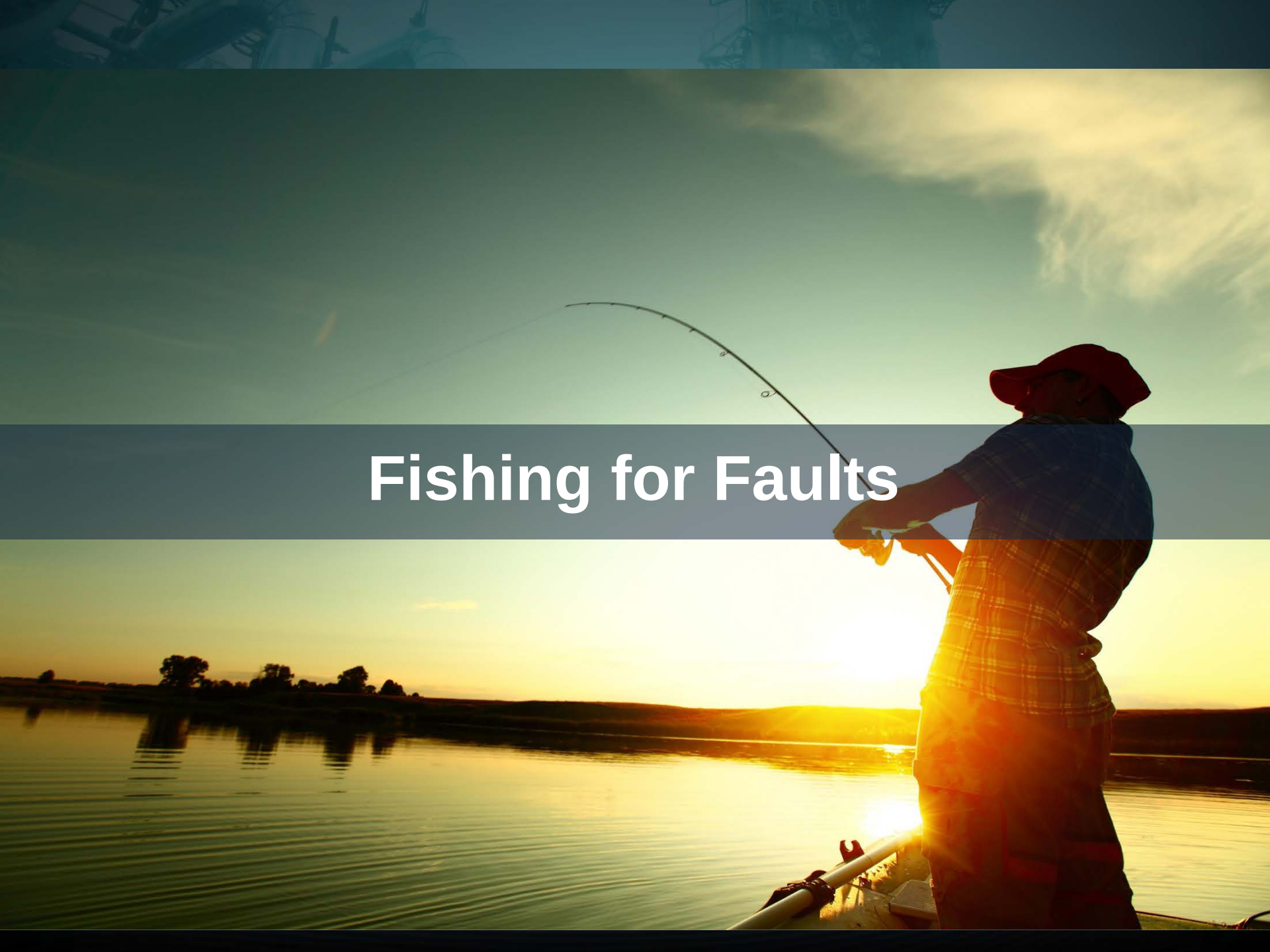
REF: JCF

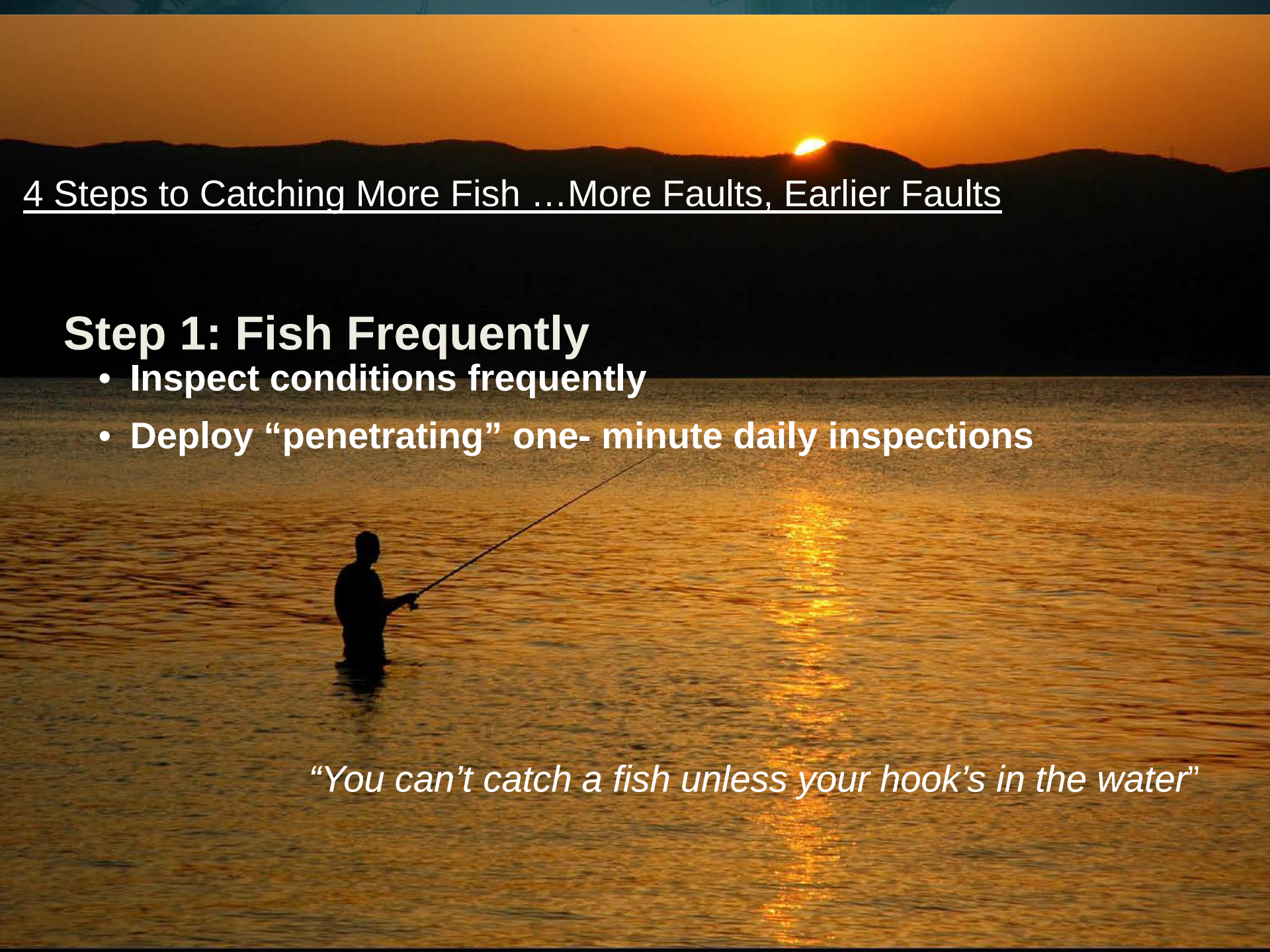
Ten Reportable Conditions:

How many would have been reported by your inspection program?

Your laboratory from a sample of oil?

Your vibe program?


Fishing for Faults

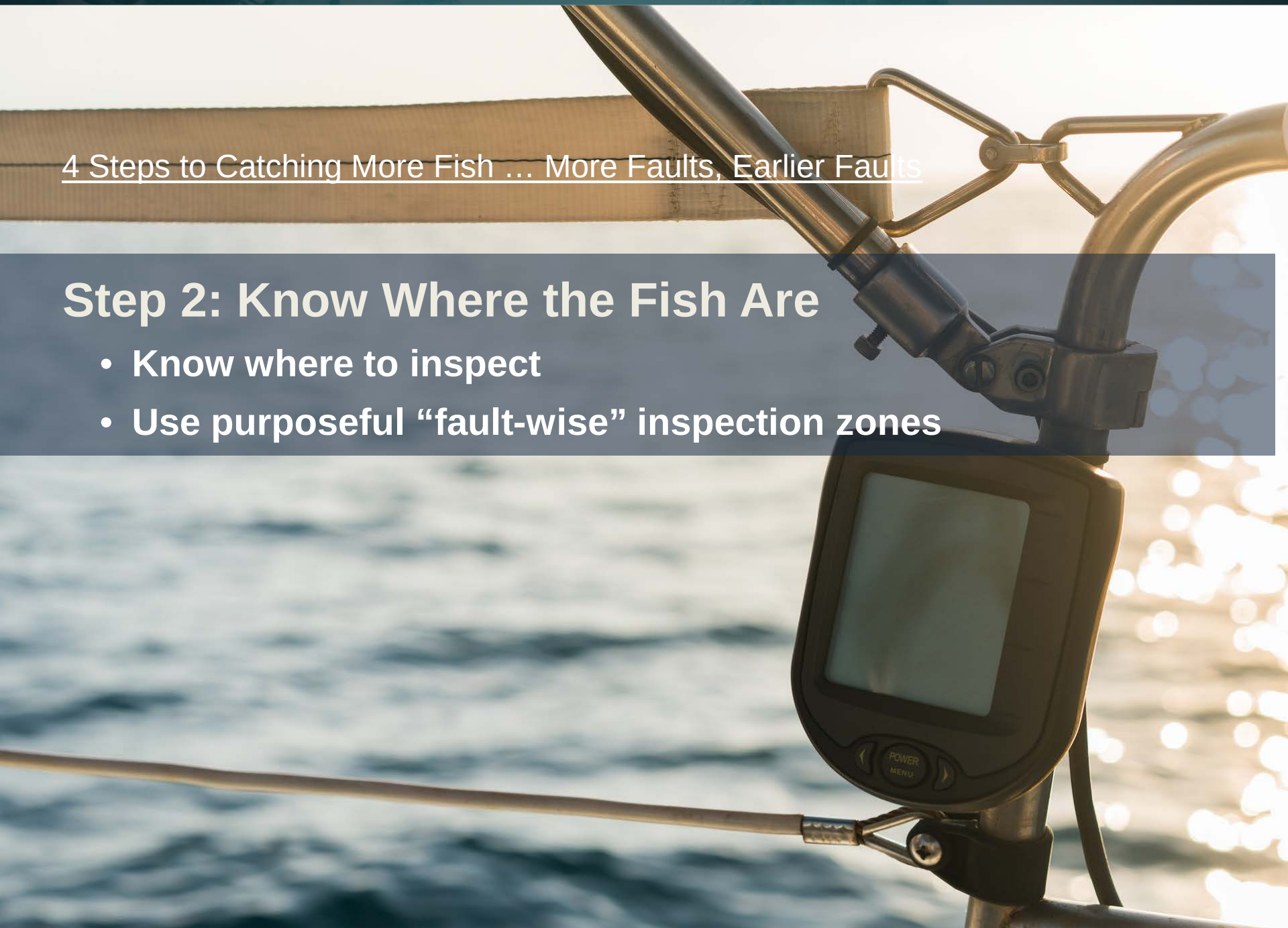


4 Steps to Catching More Fish …More Faults, Earlier Faults

Step 1: Fish Frequently

- **Inspect conditions frequently**
- **Deploy “penetrating” one- minute daily inspections**

“You can’t catch a fish unless your hook’s in the water”



Step 2: Know Where the Fish Are

- **Know where to inspect**
- **Use purposeful “fault-wise” inspection zones**

Step 3: Use Proper Tackle

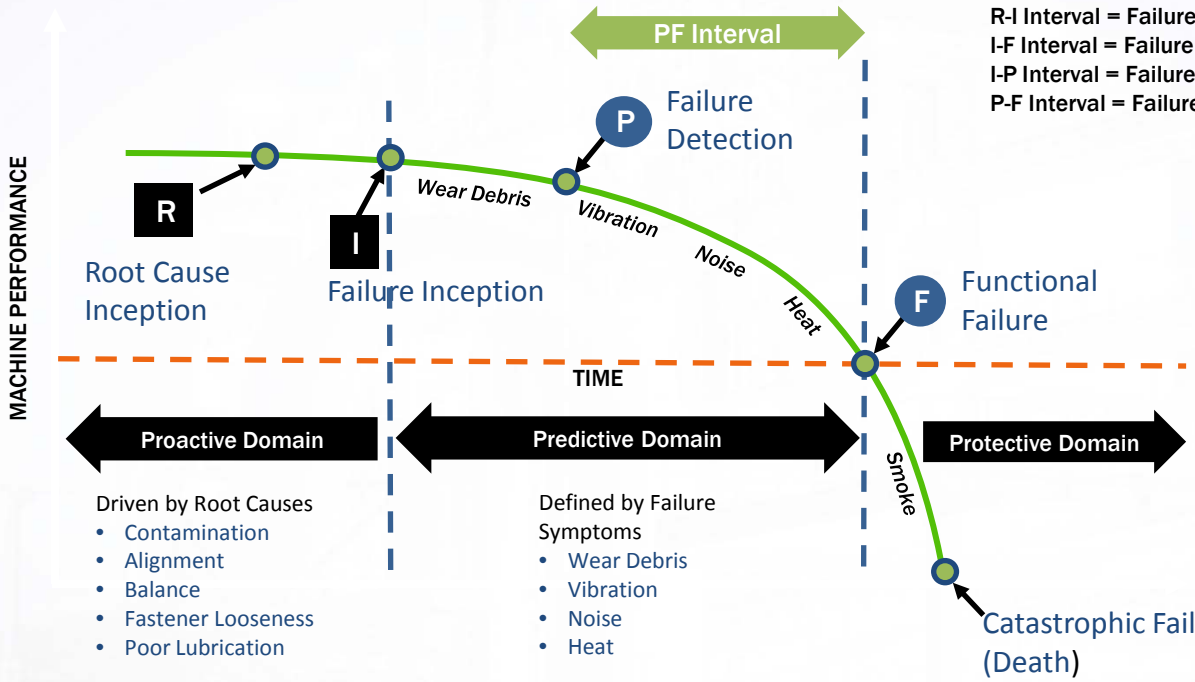
- **Use proper inspection aids, tools and methods**
- **Install inspection windows, visual oil analysis, inspection aids**

4 Steps to Catching More Fish … More Faults, Earlier Faults

Step 4: Fish Skillfully

- **Inspect skillfully**
- **Learn from a master, perfect skills, practice relentlessly**

Condition Monitoring and the Time Domains of Machine Failure



The Intervals of Failure-in-Progress

R-I Interval = Failure Gestation Time
I-F Interval = Failure Development Period
I-P Interval = Failure Elapsed Time
P-F Interval = Failure Lead Time (to correction)

Driven by Root Causes
- Contamination
- Alignment
- Balance
- Fastener Looseness
- Poor Lubrication

Defined by Failure Symptoms
- Wear Debris
- Vibration
- Noise
- Heat

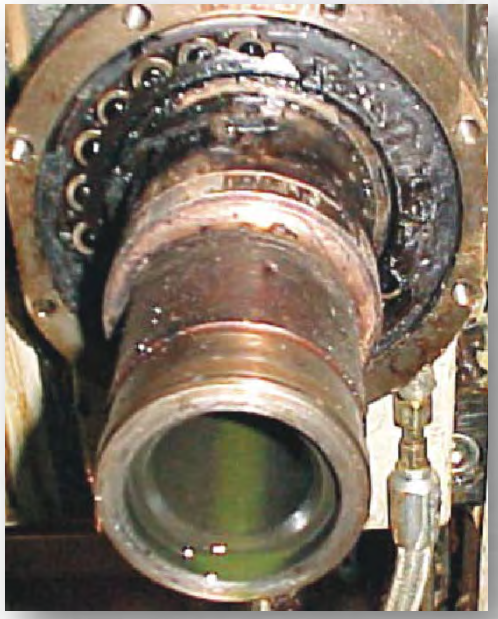
Controlling Consequences
- Safety
- Collateral Damage
- Business Interruption

Ref. Moubray, Troyer, JCF

Fallacy of Linking Inspection Intervals to P-F Intervals

Out: Linking the Inspection Interval to the P-F Interval (e.g., ½ the P-F Interval)
Why? Who can predict what the next P-F interval will be?
It varies for all of these reasons:

- One machine, multiple components
- Multiple failure modes
- Running conditions change (loads, speeds, exposures)
- Remaining Useful Life (RUL) varies with age
- Failure detection methodology and effectiveness vary (ability to detect weak signals)



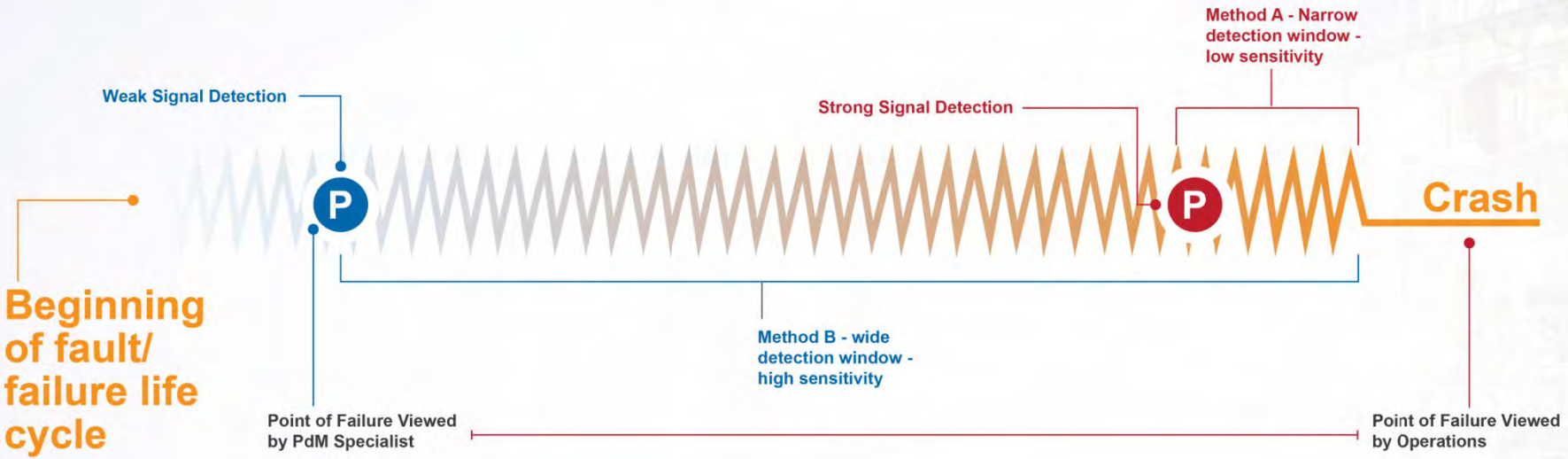
A visible oil drip proceeded this bearing lock-up.

Some Lubricant-related Failure Modes

- Low lube levels and starvation
- Wrong lube selected or applied
- Lube degradation
- Particle contamination
- Moisture contamination
- Fuel/chemical contamination
- Coolant contamination
- Foam and aeration
- Under-/overgreasing
- Varnish/sludge

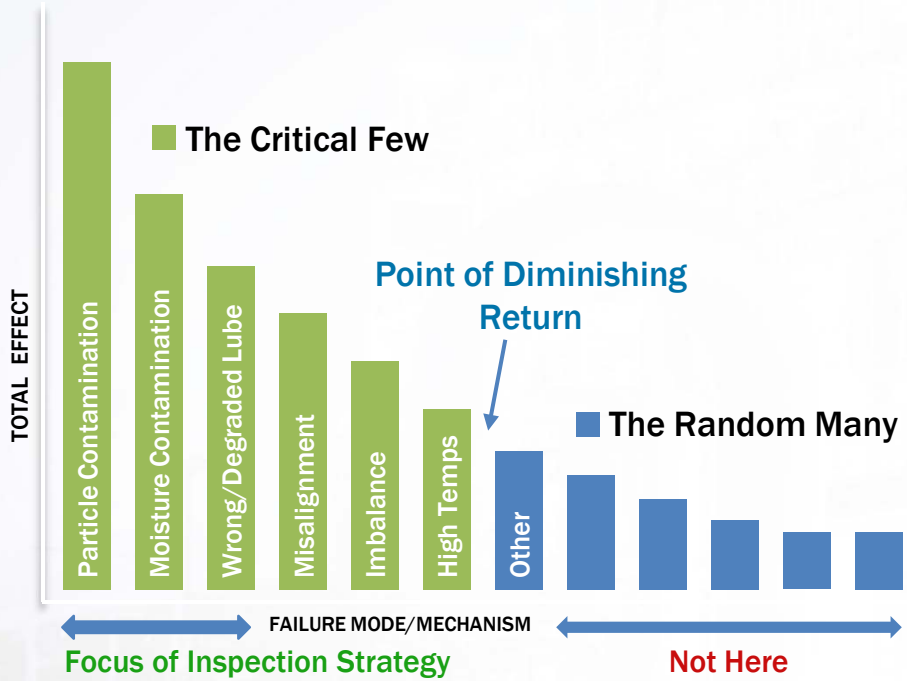
REF: JCF

Early Detection Means Frequent Detection
Frequent Detection Means Frequent Inspection



- *This inspection window finds an active, threatening root cause*
- *See it now!*
- *Act now!*
- *Don't wait for lab to report 20% water*

1. Start by ranking failure modes based on probability and consequence (the definition of risk).
2. Next, define one or more inspection fault detectors for each failure mode.



REF: ECF, JCF

Example Inspection Fault Detectors

- Heat
- Oil Color & Clarity
- Blue Smoke
- Sudden Leakage
- Machine Sing-Song
- Oil Level Change
- Sight-glass Fouling

**Risk is defined as probability of failure X the consequences of failure.*

Pursuit of Long P-F Intervals

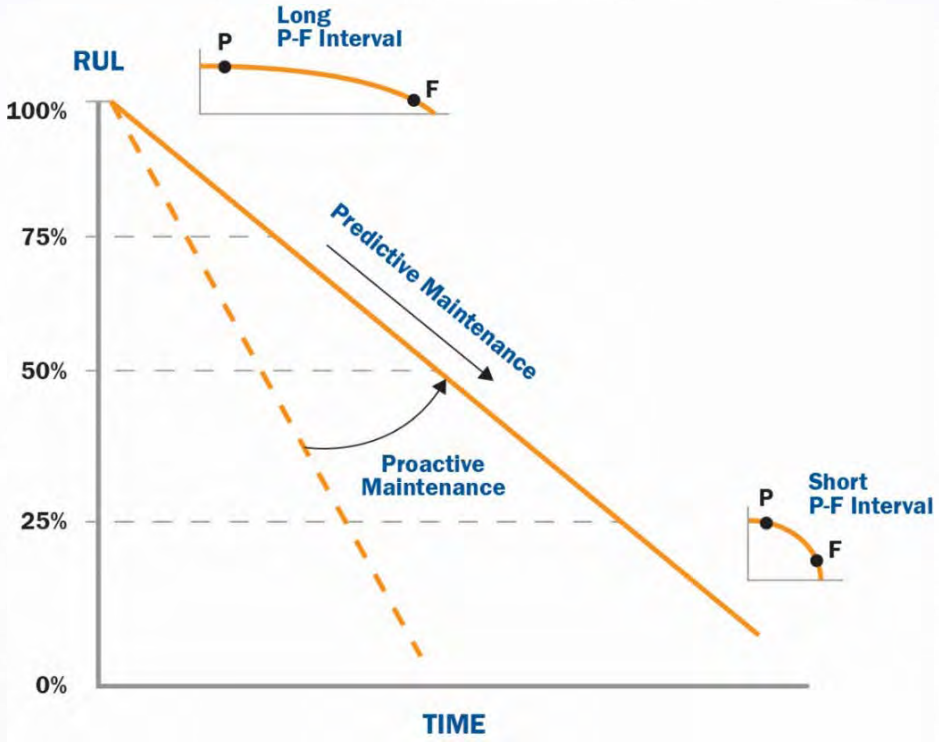
Your Best Strategy:

- **Shorten the inspection interval**
- **Mitigate** the **primary failure agent**
- **Weak signal detection** by better methods and skill
- **Slow down the rate of failure progression**

RUL = Remaining Useful Life

How RUL Affects the P-F Interval

Slow continuous wear reduces a machine's Remaining Useful Life (RUL). The P-F interval for each new failure event can never exceed this diminished state.



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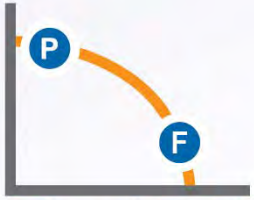


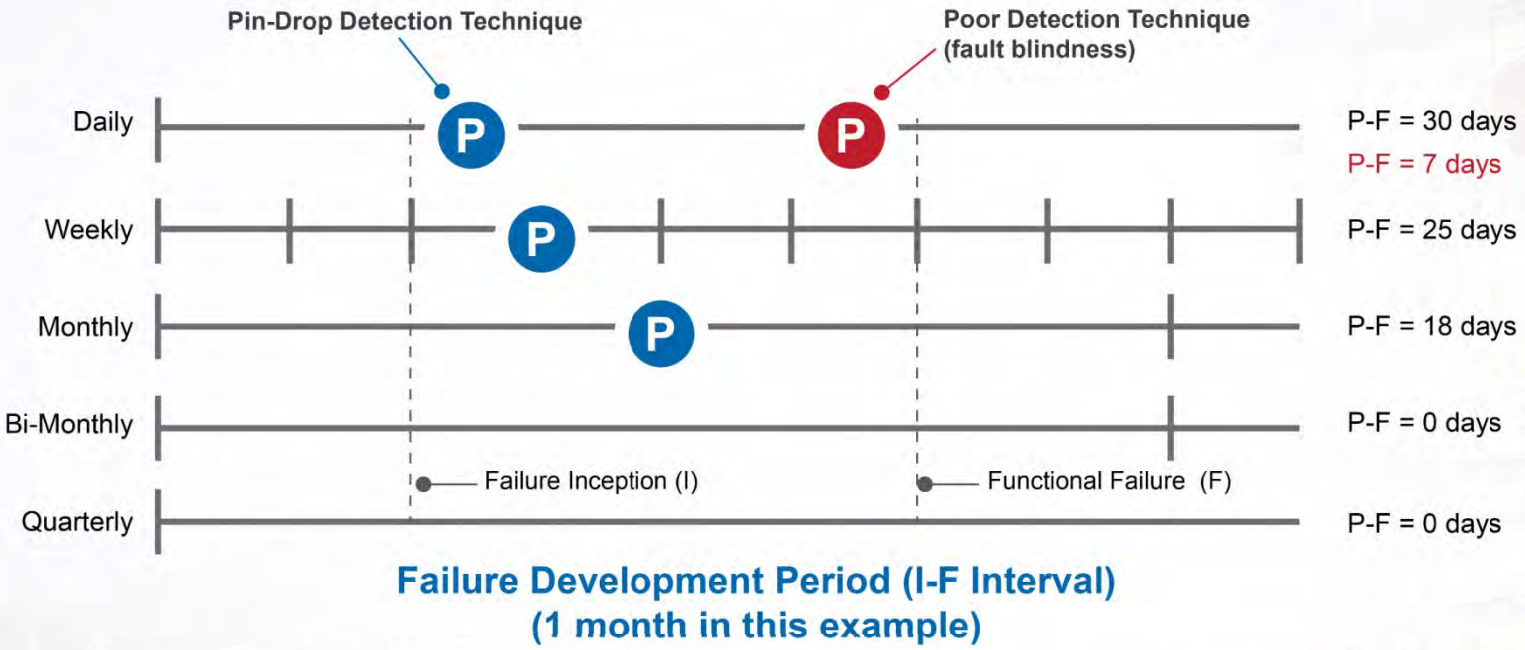
Short P-F Interval

Long P-F Interval

If your car's front wheels became suddenly misaligned, which of the two tires above would be the first to fail?

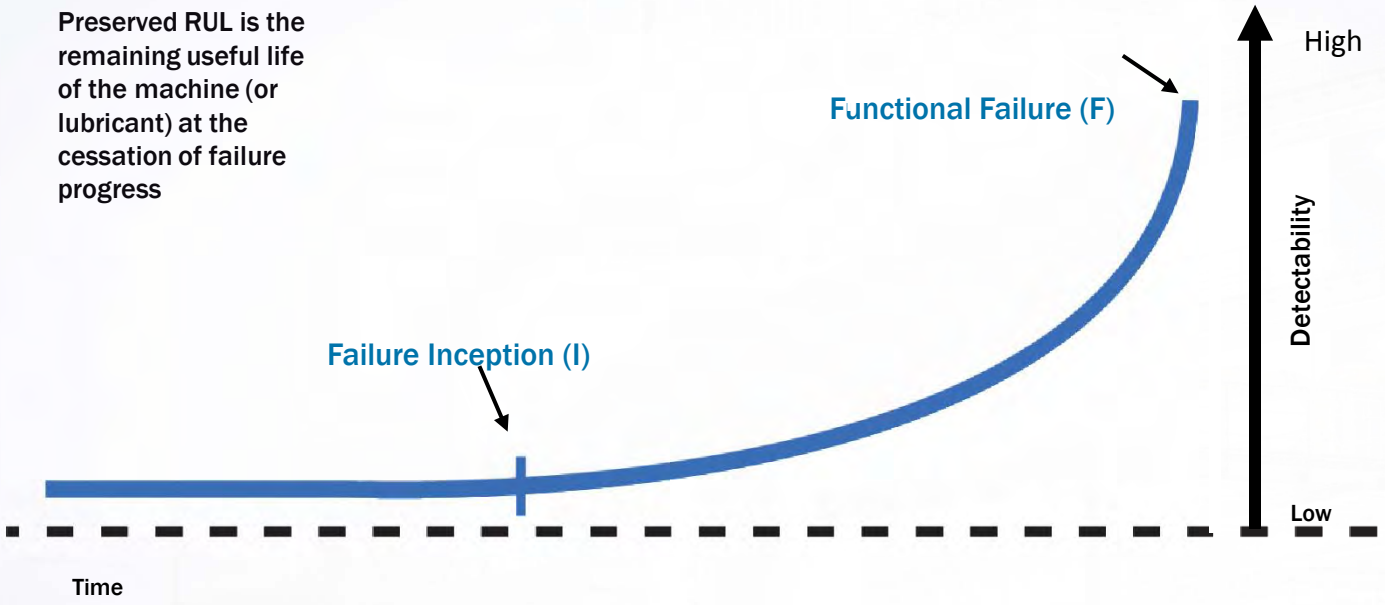
REF: JCF

How Inspection Technique and Frequency Influence the P-F Interval



REF: JCF

Signal Strength Increases as Functional Failure Approaches



… Except for Fault Bubbles

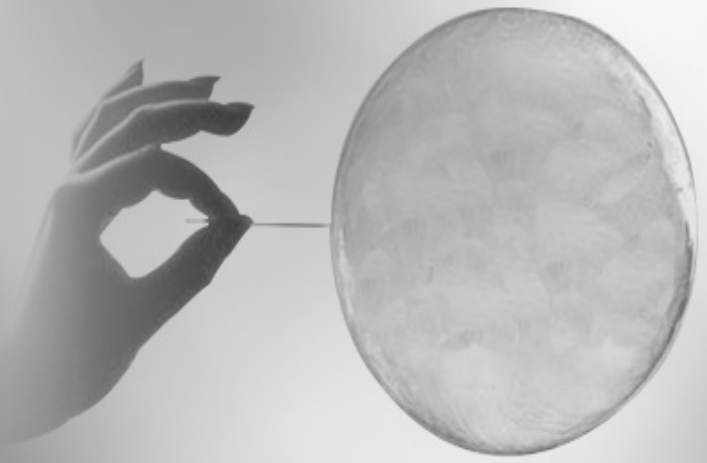
The Agony of Root Cause “Fault Bubbles”

Protection Against Sudden Death or Short P-F Failures

The P-F interval of most complex industrial machines can vary from milliseconds to decades. Sudden-death failures can occur without warning and without a P-F interval for many reasons. **However, they can be stopped with a root cause focus.**

Example Causes of Short P-F and Sudden-Death Failures:

- Ruptured oil filters
- Shock loading
- Stiction/silt lock (motion impediment)
- Wrong oil or severely degraded oil
- Fishbowl conditions (disturbed sediment)
- Sudden and severe misalignment
- Grease “soap lock” (starvation)
- Impaired oil supply (starvation)
- Heavy fuel dilution (thinning)
- Chemical contamination
- Gross seawater contamination



Tires can wear out slowly or than can burst suddenly.
So can machines.

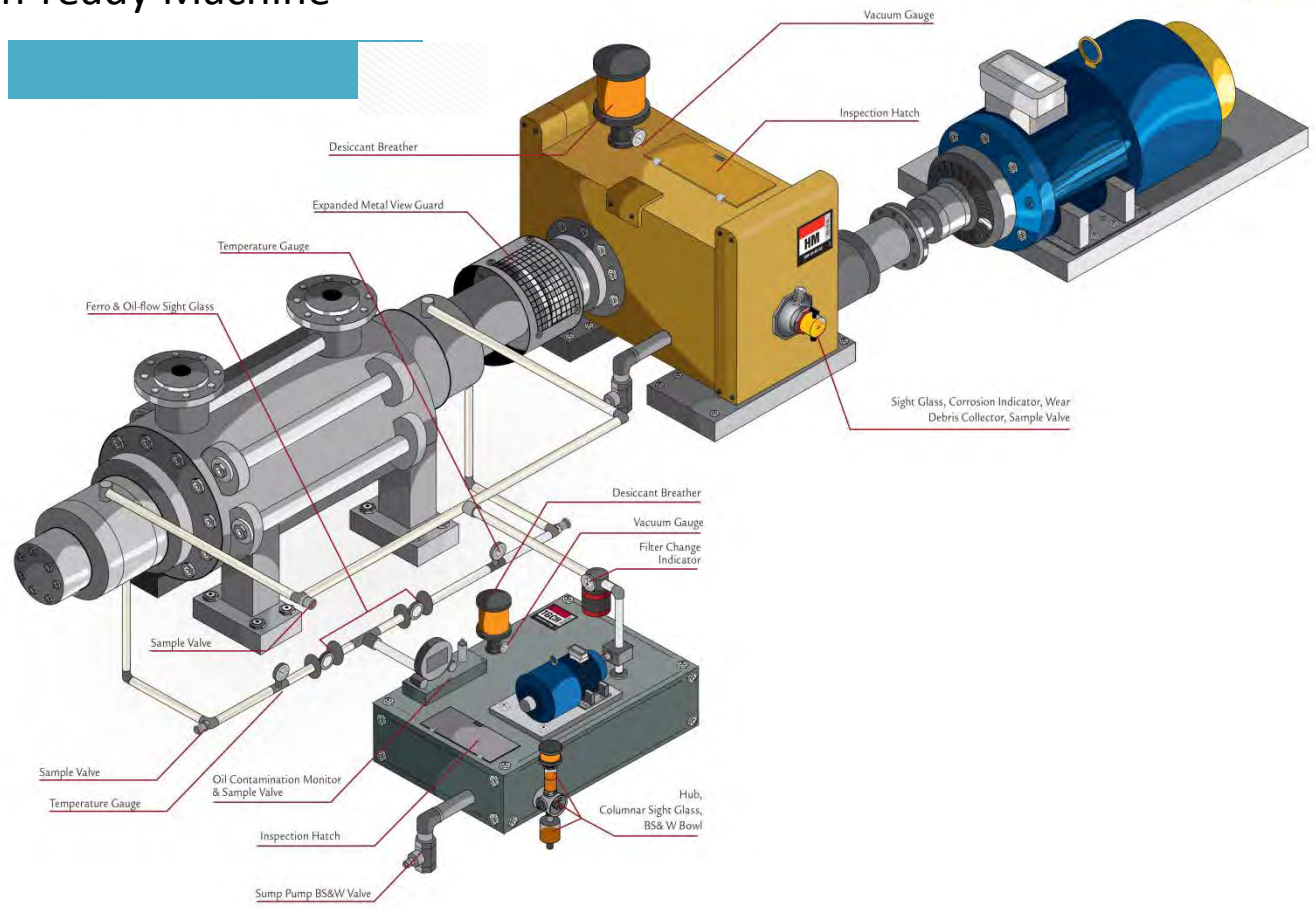
REF: JCF

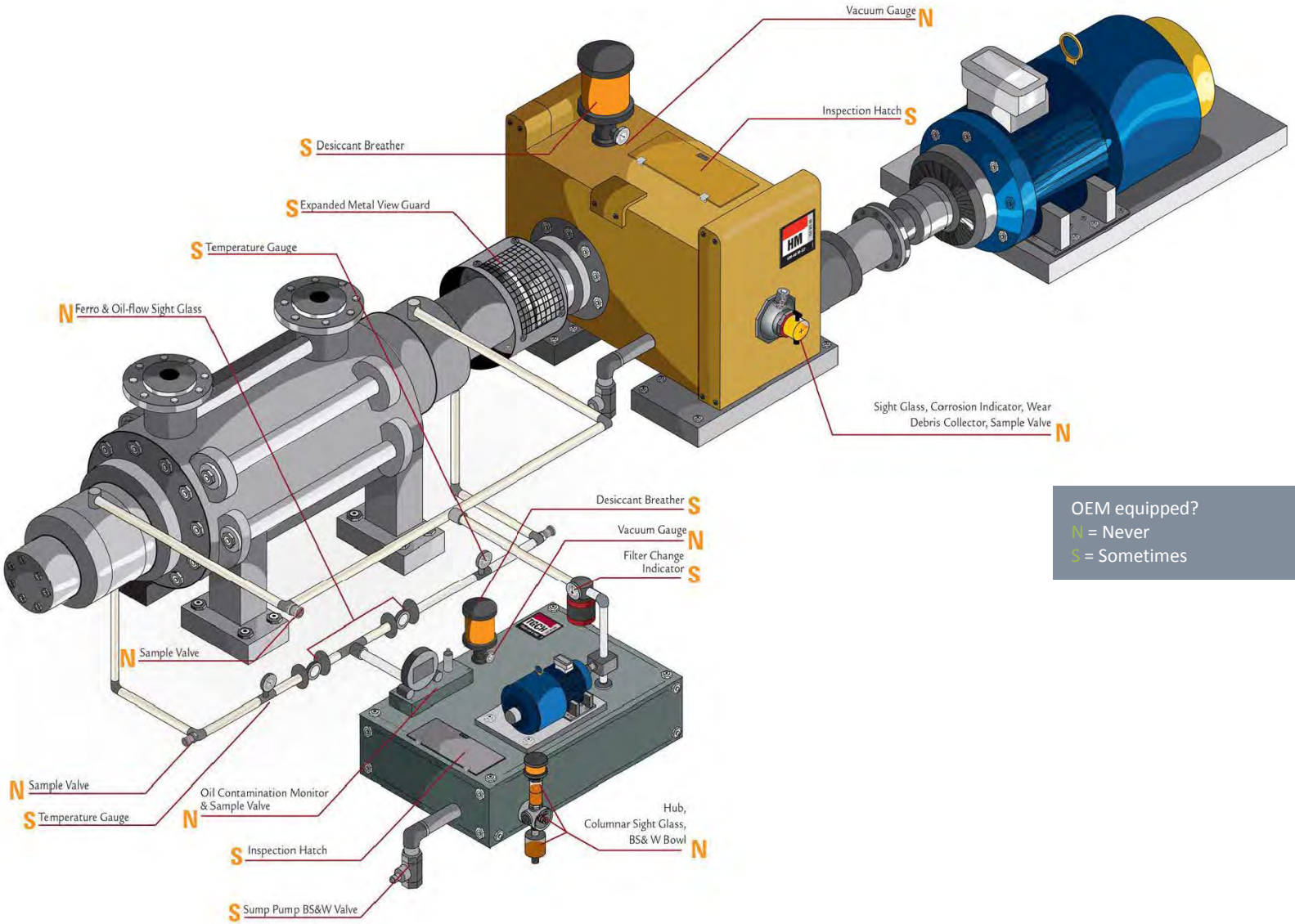

Poor Humpty Dumpty …
*The **failed bearing** that the king's men and horses **could not save***
REF: JCF

1. **Temperature**. Use touch, gauges and/or heat guns to inspect for general or localized hot running conditions.
2. **Oil Volume**. Use level gauges, sight glasses, dipsticks or inspection ports/hatches.
3. **Pressure.** Use gauges or pressure transducers at multiple points as needed.
4. **Filter.** Examine delta-P gauges and bypass indicators to confirm the filter is serviceable.
5. **BS&W.** Take bottom samples or examine bottom sediment and water (BS&W) bowls for abnormal
6. **Ventilation.** Confirm serviceable condition of breathers and inspect for abnormal fumes, vapor and smoke.
7. **Clear and Bright.** Pull samples or inspect sight glasses
8. **Leakage**. Use a powerful flashlight to inspect shaft seals, gaskets, actuators, seals, fittings, unions, ports, hoses, etc.
9. **Fluid Surface and Headspace.** Through inspection hatches and ports, look for foam, varnish, sludge, bathtub rings, etc.
10. **Points of Entry.** Inspect for potential ingression sites such breathers, hatches, clean-out covers, etc.
11. **Dirty Exterior.** Machines that are dirty on the outside are usually dirty on the inside as well.
12. **Spits and Sputters.** Machines emit an assortment of audible signals; some are normal, but others are not.
13. **Grease Condition/Color**. Inspect grease from seals and along shafts for abnormal color, consistency and condition.

REF: ML, JCF 05329

An Inspection-ready Machine

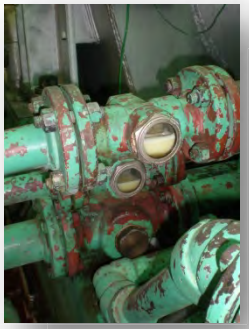




OEM equipped?
N = Never
S = Sometimes

Sight Glass Oil Analysis

- Change in oil level – up or down. Sudden and significant changes are serious.
- Sight glass foaming
- Oil color, darkening, turbidity, etc.
- Bottom sediment and water (BS&W)
- Use blue pen-lights and lasers to check oil level and oil quality.

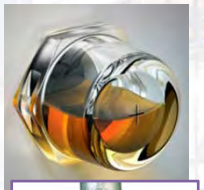













Inline sight glass for non-flooded flow inspection

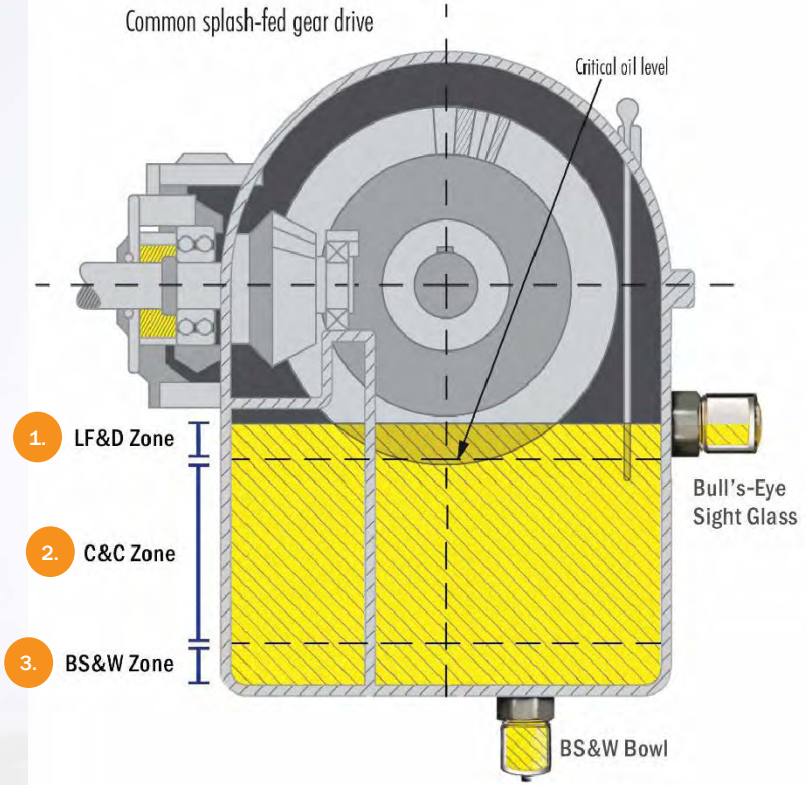
Pod has magnetic plug, corrosion indicator and sample port

Bottom sediment and water inspection

Oil level sight glass

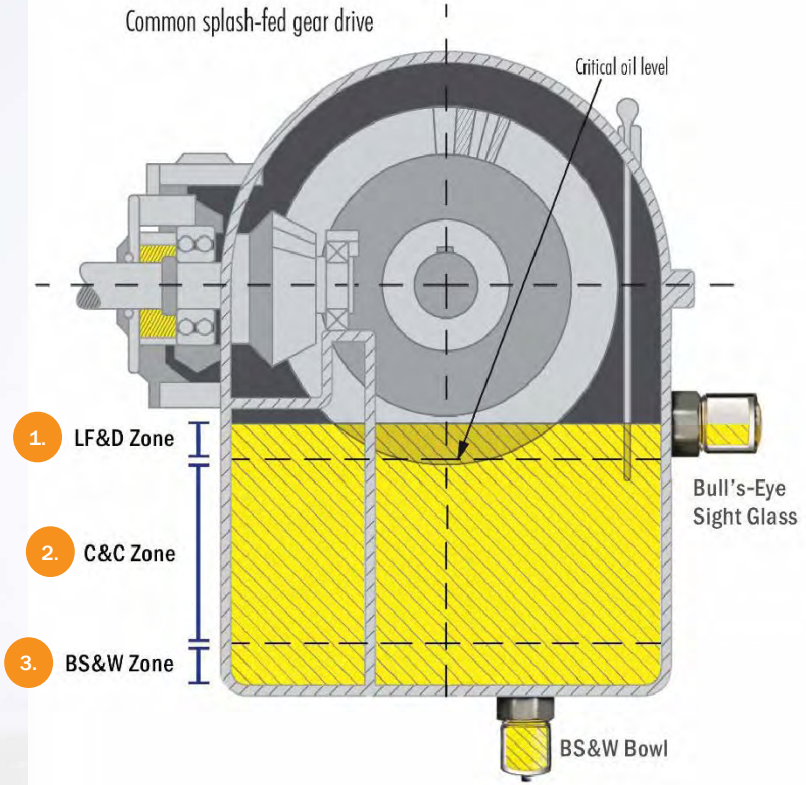
Inline sight glass for full-

Zone Inspections for Early Problem Detection



1. Level, Foam and Deposits (LF+D) Zone
2. Color and Clarity (C+C) Zone
3. Bottom Sediment and Water (BS&W) Zone

Zone Inspections for Early Problem Detection



1. **Level, Foam and Deposits (LF+D) Zone**

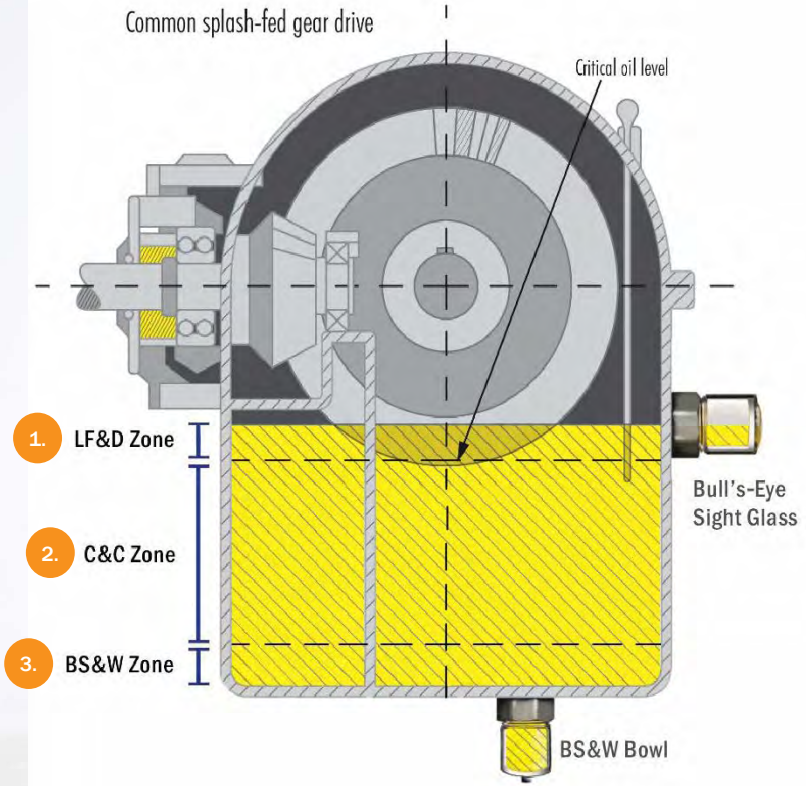
   Level – Inspection confirms critical oil level is maintained

   Foam – Entrained air rises and often forms foam

   Deposits – Oil insolubles (varnish potential) commonly form deposits on splash surfaces above oil level

2. **Color and Clarity (C+C) Zone**
3. **Bottom Sediment and Water (BS&W) Zone**

Zone Inspections for Early Problem Detection



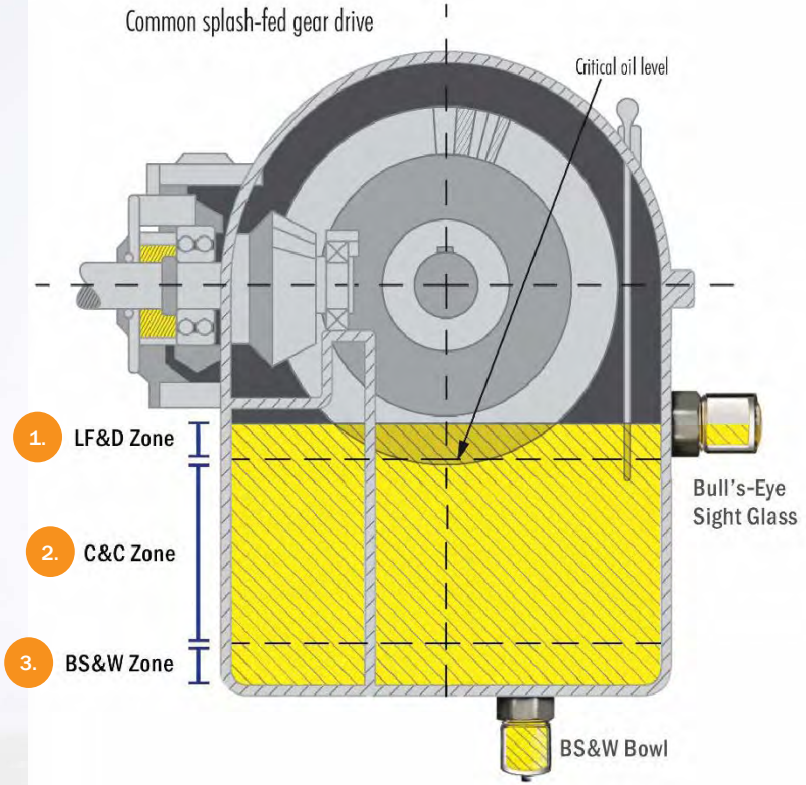
1. **Level, Foam and Deposits (LF+D) Zone**
2. **Color and Clarity (C+C) Zone**

   Contamination (e.g., water) and oil chemistry change often change C+C. These include:

   - Base oil oxidation
   - Thermal degradation
   - Additive stratification (dropout)
   - Microbial contamination
   - Free or emulsified water contamination
   - Air induction conditions
   - Impaired air-release conditions
   - Antifreeze contamination
   - Sludge conditions
   - Varnish potential conditions

3. **Bottom Sediment and Water (BS&W) Zone**

Zone Inspections for Early Problem Detection



1. **Level, Foam and Deposits (LF+D) Zone**
2. **Color and Clarity (C+C) Zone**
3. **Bottom Sediment and Water (BS&W) Zone**
   - Agglomerated sludge (accumulations of resinous solids, gums, oxides and dead additives)
   - Stratified solids (dense zones of soft contaminants, oxides and dead additives)
   - Sediment (settled hard contaminants like dirt and wear debris)
   - Water and other settled liquid contaminants (e.g., antifreeze)

Example Problems Detected by Zone Inspections

Example Problems Detected by Zone Inspections


Ruptured Filter
LF&D - No Change
C&C - No Change
BS&W - Sediment and Wear Debris
Entrained Air and Depleted Foam Inhibitor
Foam
LF&D - Foam Conditions
C&C - Oil is Hazy
BS&W - No Change
Oil Degradation
Sight Glass Fouling
Splash Zone Deposits
LF&D - Early Detection
C&C - Color and Clarity Change
BS&W - Sludge


What’s in your inspector’s toolbox?

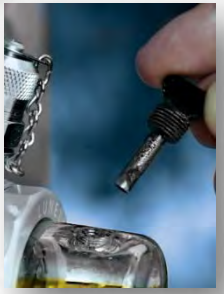
- Heat gun
- Blotter test
- Grease purge traps
- Corrosion gauge
- Varnish gauge
- Oil content gauge for grease
- Stethoscope
- Dipstick
- Viscosity comparator
- Oil color gauge
- Sediment test
- Water separability test
- Magnetic plugs
- Borescope










Even the easiest inspection alert
often gets missed.

Cure for Attention-deficit and Half-measure Inspections

Cure for Attention-deficit Inspections

- Strong reliability culture
- Training and inspection skill competencies
- Stop looking at bearings, seals, couplings, motors, etc. Start "examining" them.
- Celebrate inspection "saves"
- Install penetrating inspection windows
- Use helpful inspection aids
- Respond to inspection-generating alerts and red flags

Review: Comparing Conventional Inspections to Inspection 2.0

DISTINCTION	CONVENTIONAL INSPECTION	INSPECTION 2.0
Emphasis on daily inspections	Sometimes	Always
Emphasis on inspection location	Rarely	Always
Installed inspection windows	Rarely	Always
Inspection alignment to failure mode ranking	Sometimes	Always
Inspection designed to preempt fault bubbles	Rarely	Always
Emphasis on early “weak signal” detection	Rarely	Always
Use of advanced inspection aids and tools	Rarely	Always
Inspectors who are highly skilled and motivated	Sometimes	Always

The 10 Reportable Conditions. Did you see them?

1. Sustained foam, impaired foam inhibitor?
2. Entrained air, source of air ingression?
3. Corrosion on screens, impaired rust inhibitor?
4. Rust on screens, water contamination?
5. Dark oil, oxidized oils?
6. Varnish/deposits on screens. High oil temperature?
7. Liquid/chemical contamination
8. Failed hatch gasket
9. Debris on tank top
10. Low oil level

Thank you.

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