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Optimization of Preventive Maintenance and Operator Essential Care

Results Oriented

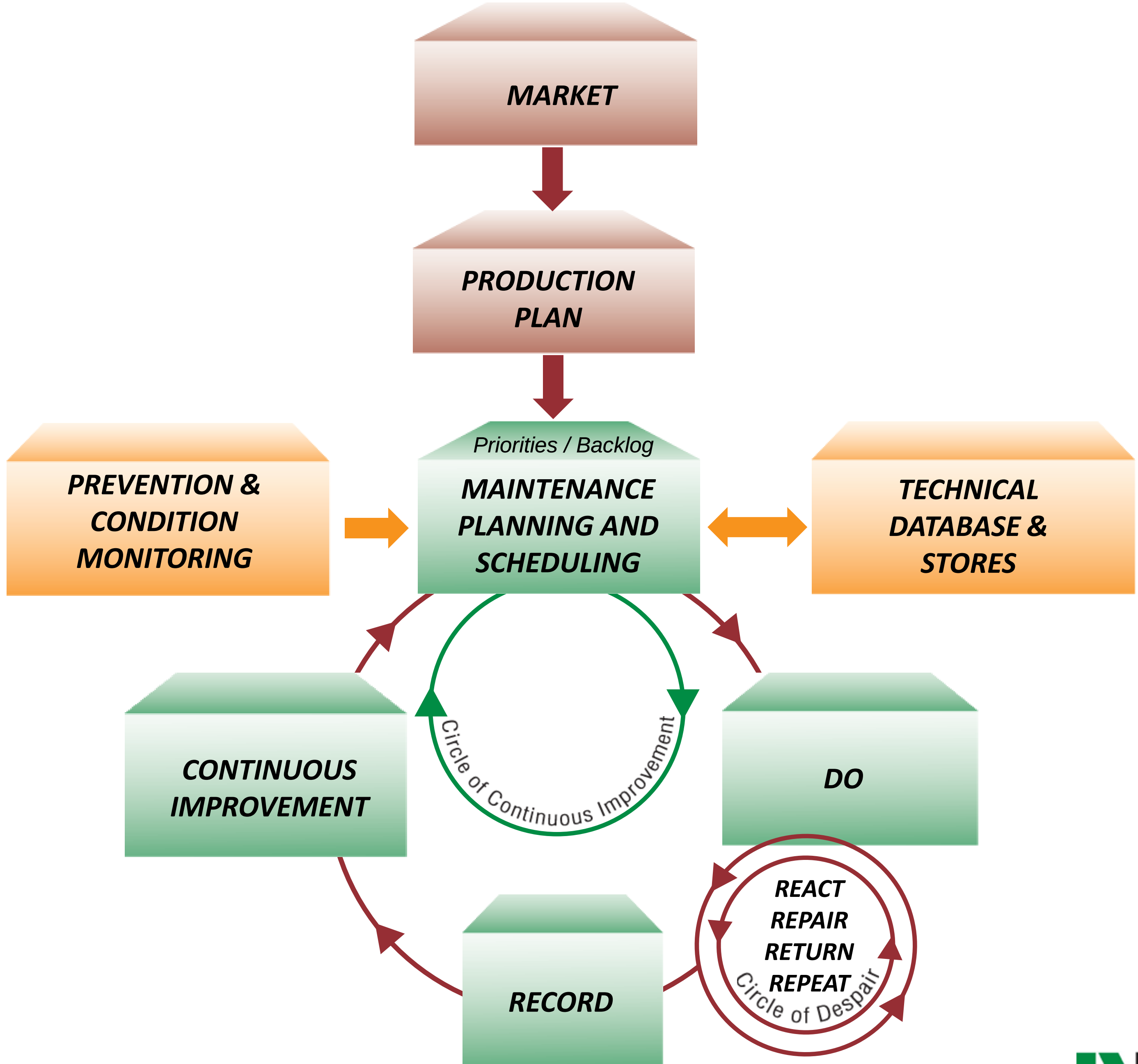
Reliability and Maintenance

Consulting and Training

Rate your Current Operator Essential Care & Preventive Maintenance System

- On a loose sheet of paper please write a number between 1 and 10.
- Using your personal definition of what Operator Essential Care & preventive maintenance (PM) is in your plant. Please rate how well you currently do OBR & PM at the plant.

- 1 – Non existent
- 2
- 3
- 4
- 5 – Average in industry
- 6
- 7
- 8
- 9
- 10 – Not cost effective to improve


MARKET
PRODUCTION PLAN
Priorities / Backlog
MAINTENANCE PLANNING AND SCHEDULING
PREVENTION & CONDITION MONITORING
TECHNICAL DATABASE & STORES
Circle of Continuous Improvement
CONTINUOUS IMPROVEMENT
DO
RECORD
REACT
REPAIR
RETURN
REPEAT
Circle of Despair

Exercise!

How is Preventive Maintenance Defined?

How is Operator Essential Care Defined?

Preventive Maintenance & Operator Essential Care Definition?

"All actions to prevent a failure

or

detect a failure early"

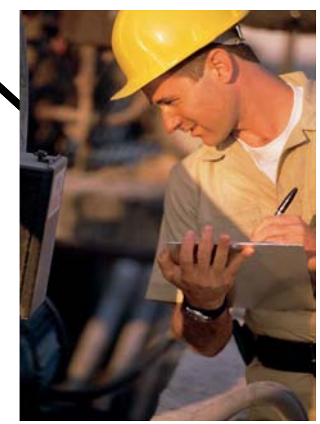
Failure & Break Down

When the failure has developed
to the point that the equipment is unable
to operate
BREAK DOWN

FAILURE
When the equipment condition
reaches an unacceptable level

SOURCE
Event that initiate
Failure developing

The failure is detected
and reported



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IDCON Definition - Preventive Maintenance / Essential Care and Condition Monitoring (PM/ECCM)

Essential Care
Prevents Failures

- Lubrication
- Alignment
- Balancing
- Detailed Cleaning
- Operating Practices
- Installation Practices
- Filtration
- Adjustments
- Fixed Time Maintenance

Condition Monitoring
Detects Failures

Objective
Provides a comparable reading

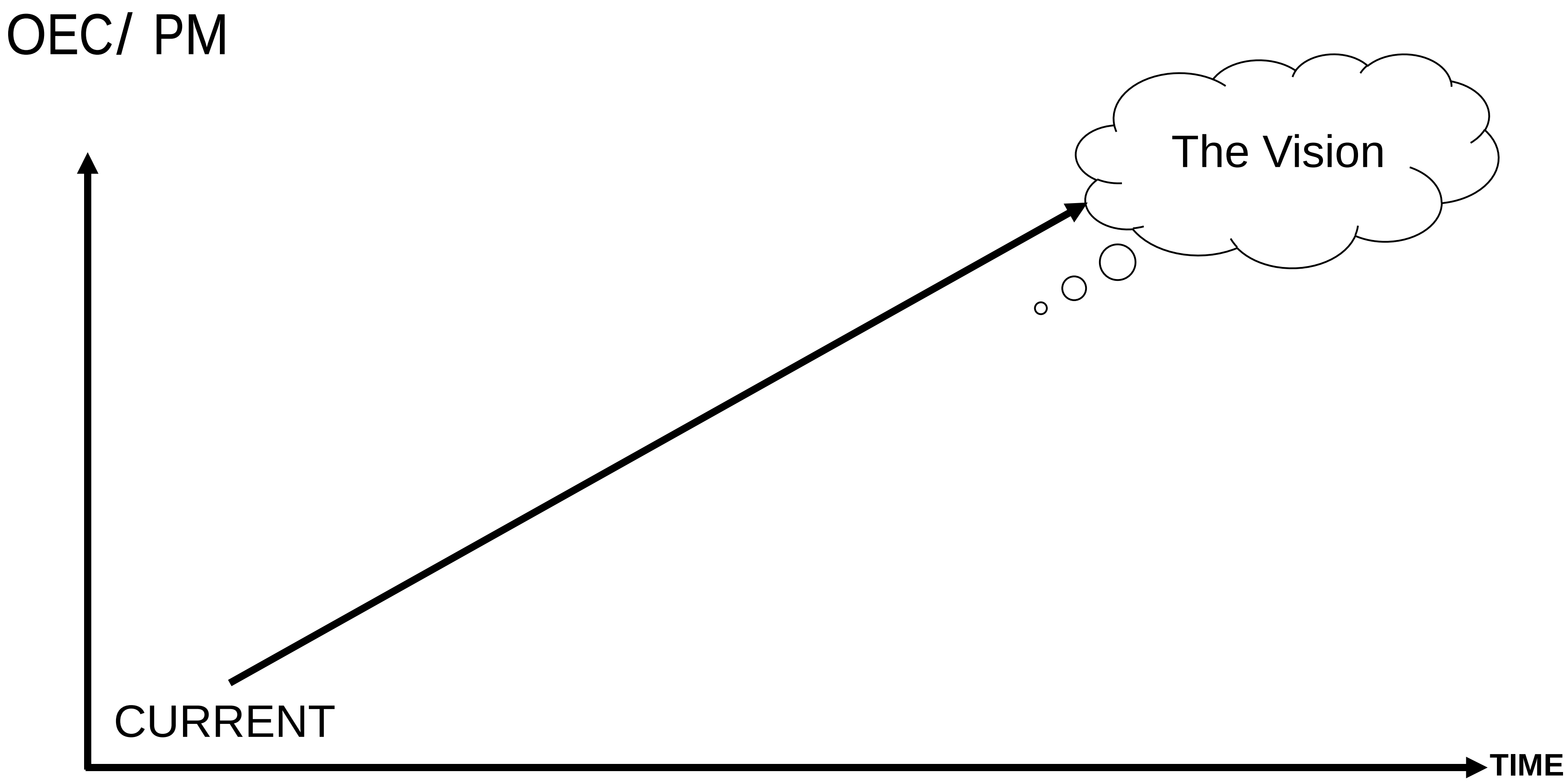
Measuring
- Pressure
- Flow
- Current, Voltage
- Distance
- Vibration
- Temperature
- Decibels

Using
- Infrared Cameras
- Vibration Sensors
- Shock Pulse Measurement
- Ultrasonic Thickness Test
- Ultrasonic Listening (leaks)
- Oil Analysis
- Gauges, etc

Subjective
Provides no reading

- Look
- Listen
- Feel
- Smell

Do We Know Exactly where We are Going?



Communicate a Vision to the Plant

- If want people to buy into the concept of OEC or PM, you must “paint a picture” of the future. *What will this system look like when we are done.*

- *An Example*

What Exactly is it We Want Operations To Do?

- You need to decide for your plant

Typically

1. Inspections of running equipment, mostly mechanical inspections
2. Detailed cleaning of equipment & housekeeping
3. Operate equipment with reliability in mind
4. Minor maintenance tasks
5. *Coordinate Production Schedule & Maintenance Schedule*
6. *Joint Root Cause Elimination*

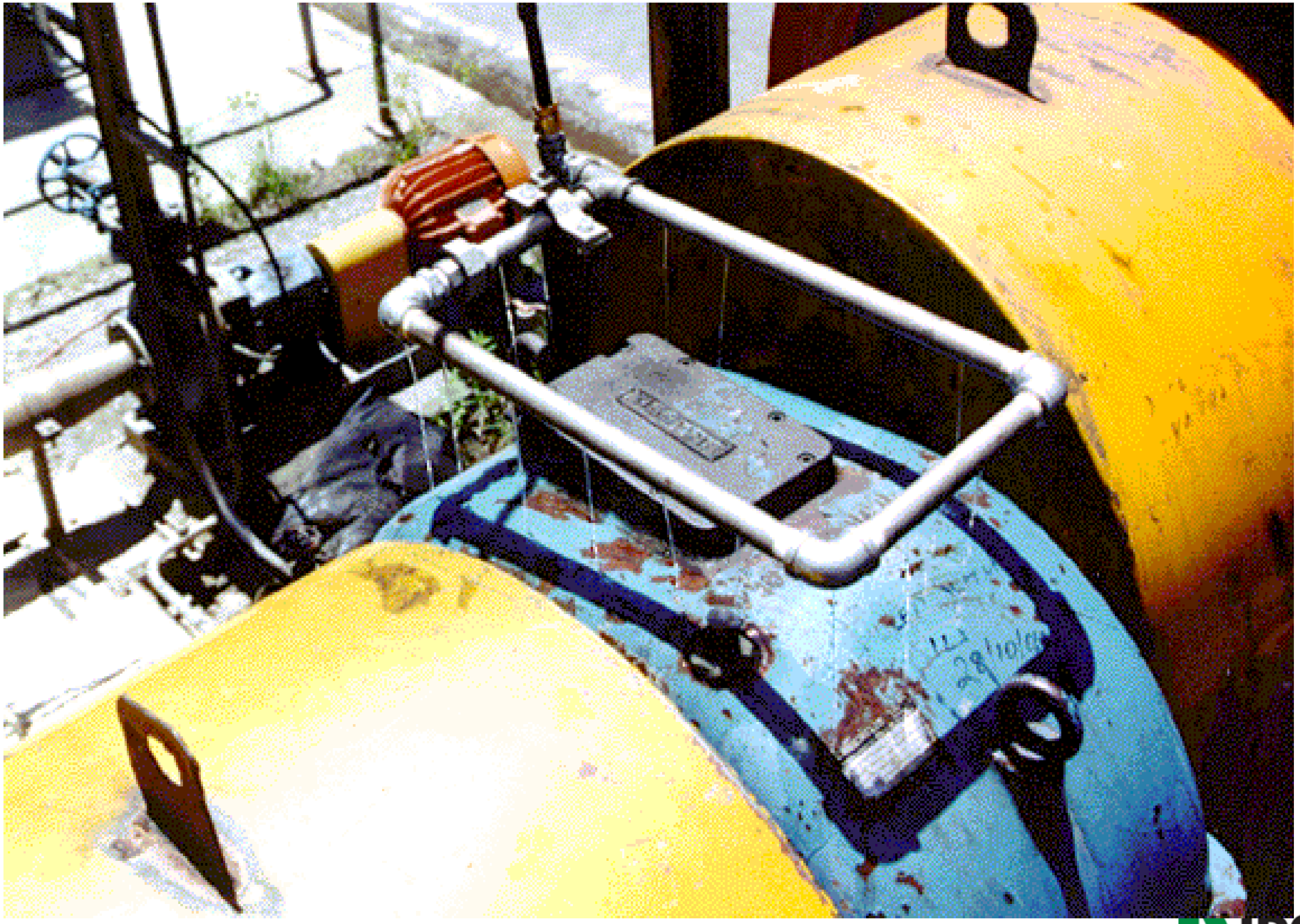
What's more important?

Do the right thing

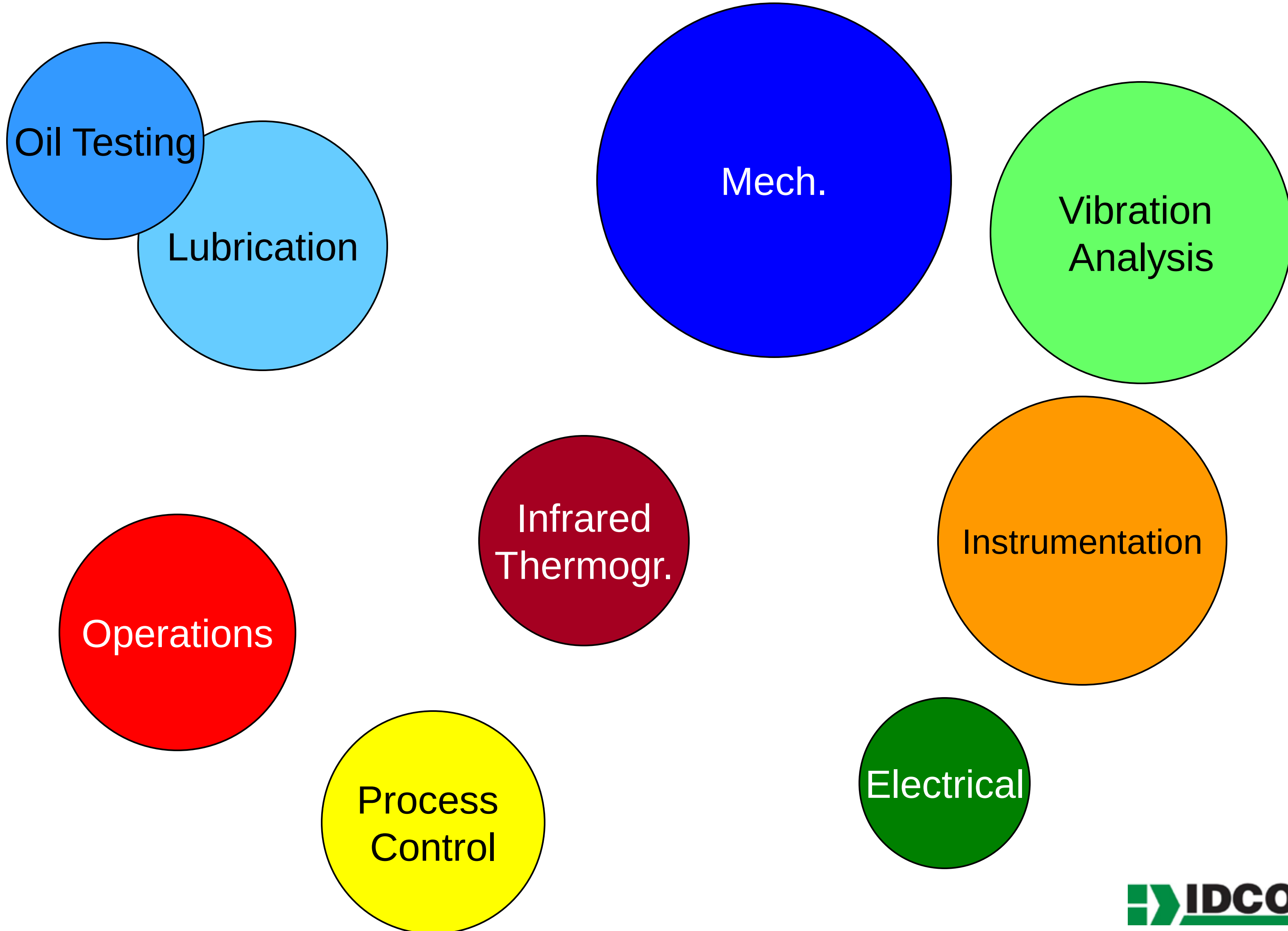
OR

Do things right

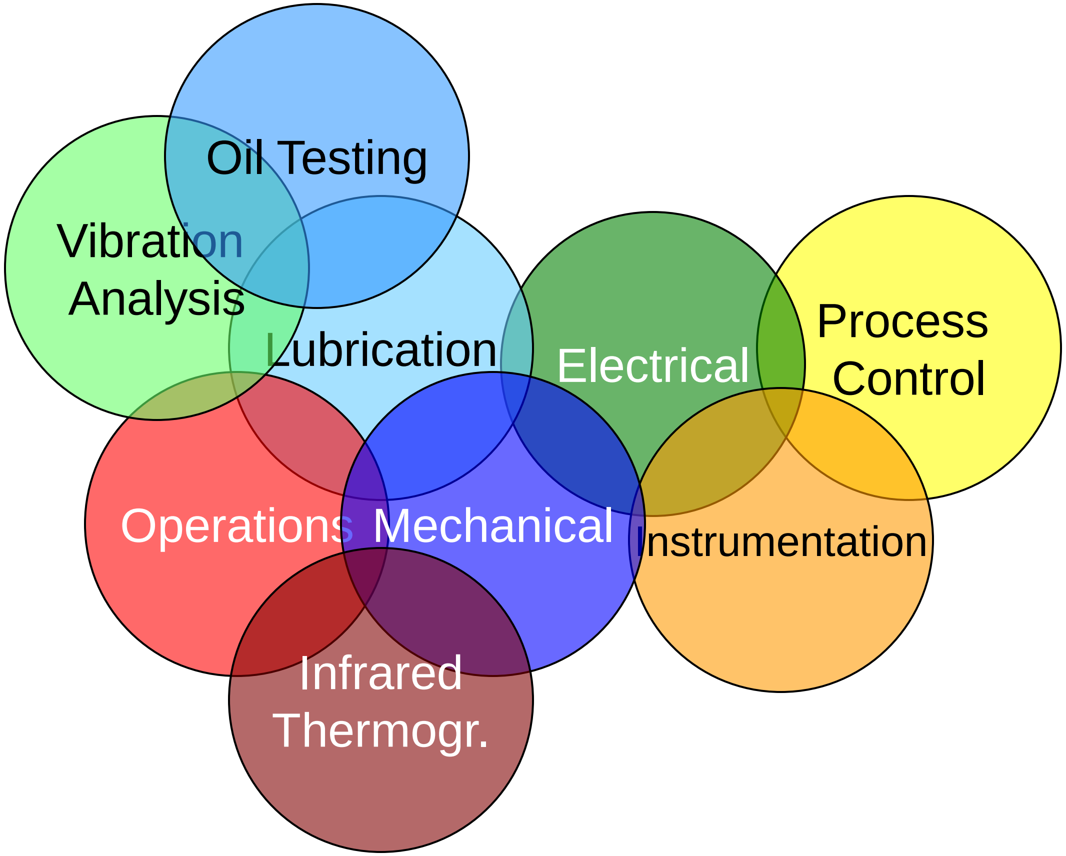
Do you see a problem?



Preventive Maintenance
Common PM (including OEC) Before Improvement



Preventive Maintenance Painting the Picture of Finished Product



- Many PM's moved from off-line to on-the-run
- Coordinated PM process between skills reduces PM process size
- Essential Care reduces amount corrective work , not necessarily Preventive

Operator Essential Care, Preventive Maintenance, Root Cause, Planning and Scheduling, Spare Parts Management

- Making any of the above an isolated effort is a mistake.
- Focus on one temporarily can work
- They have to be integrated

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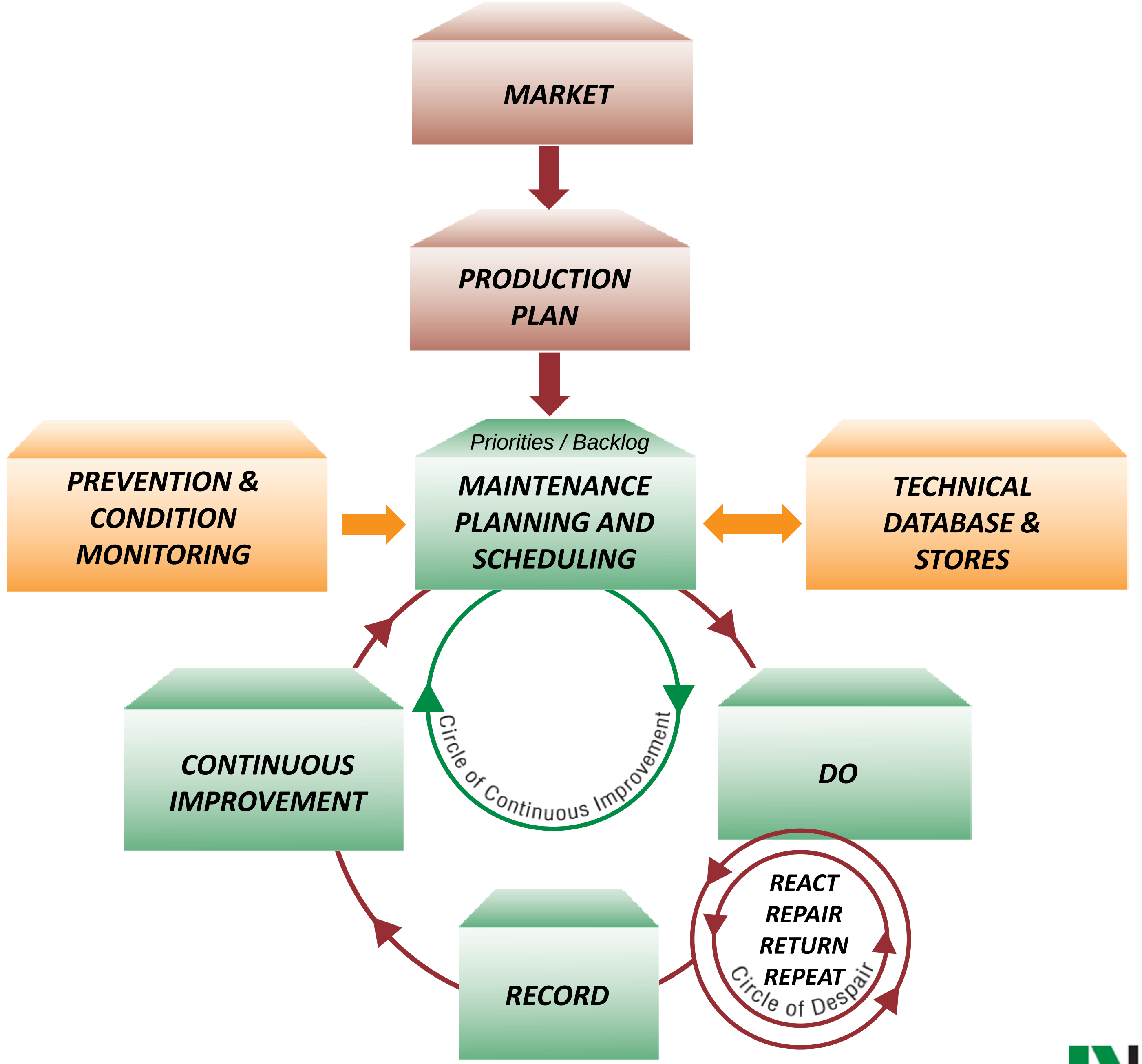
Essential Care - Prevent

Results Oriented

Reliability and Maintenance

Consulting and Training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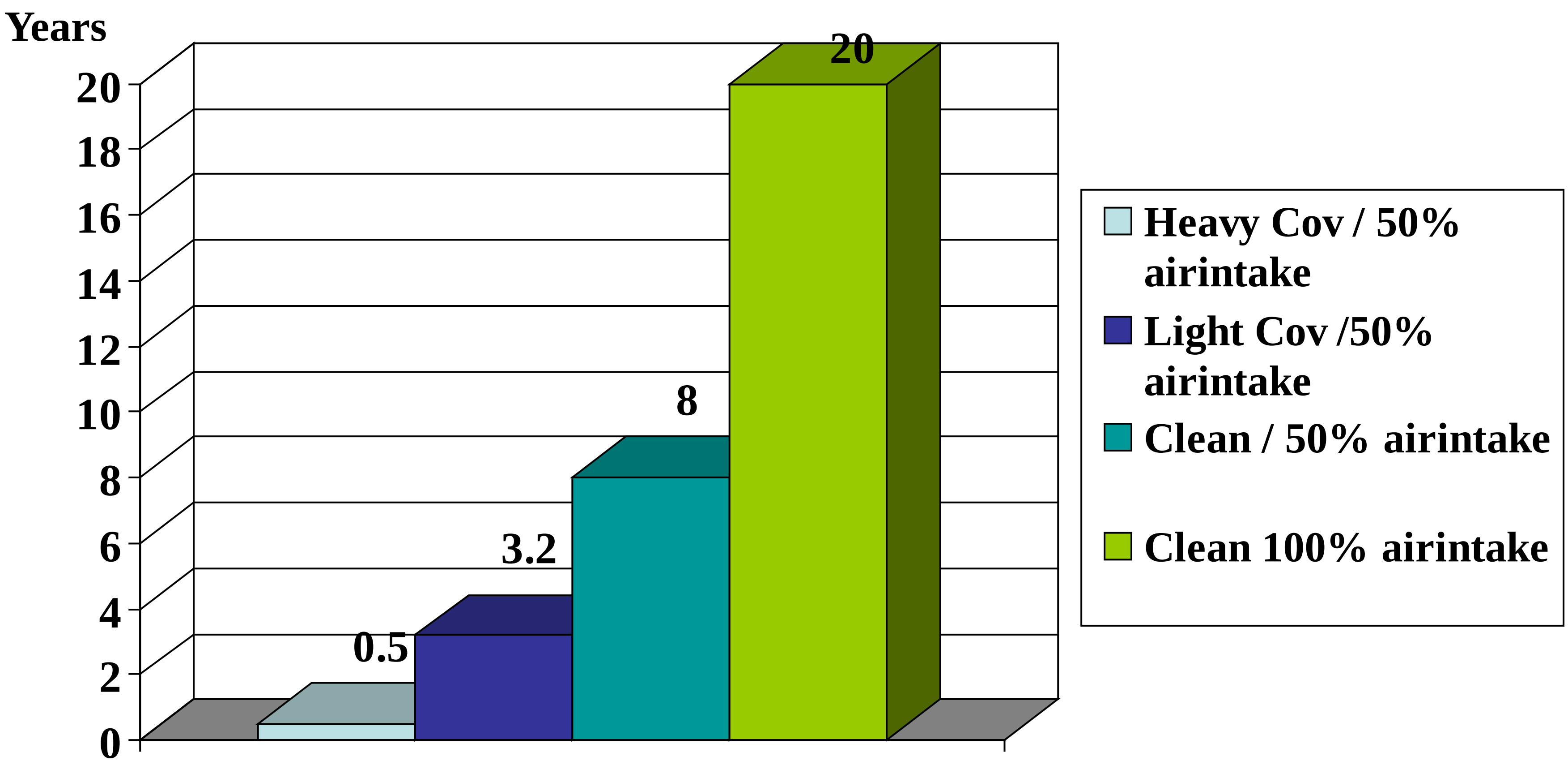
Circle of Despair
RECORD

Motor Life in Relation to Cleanliness



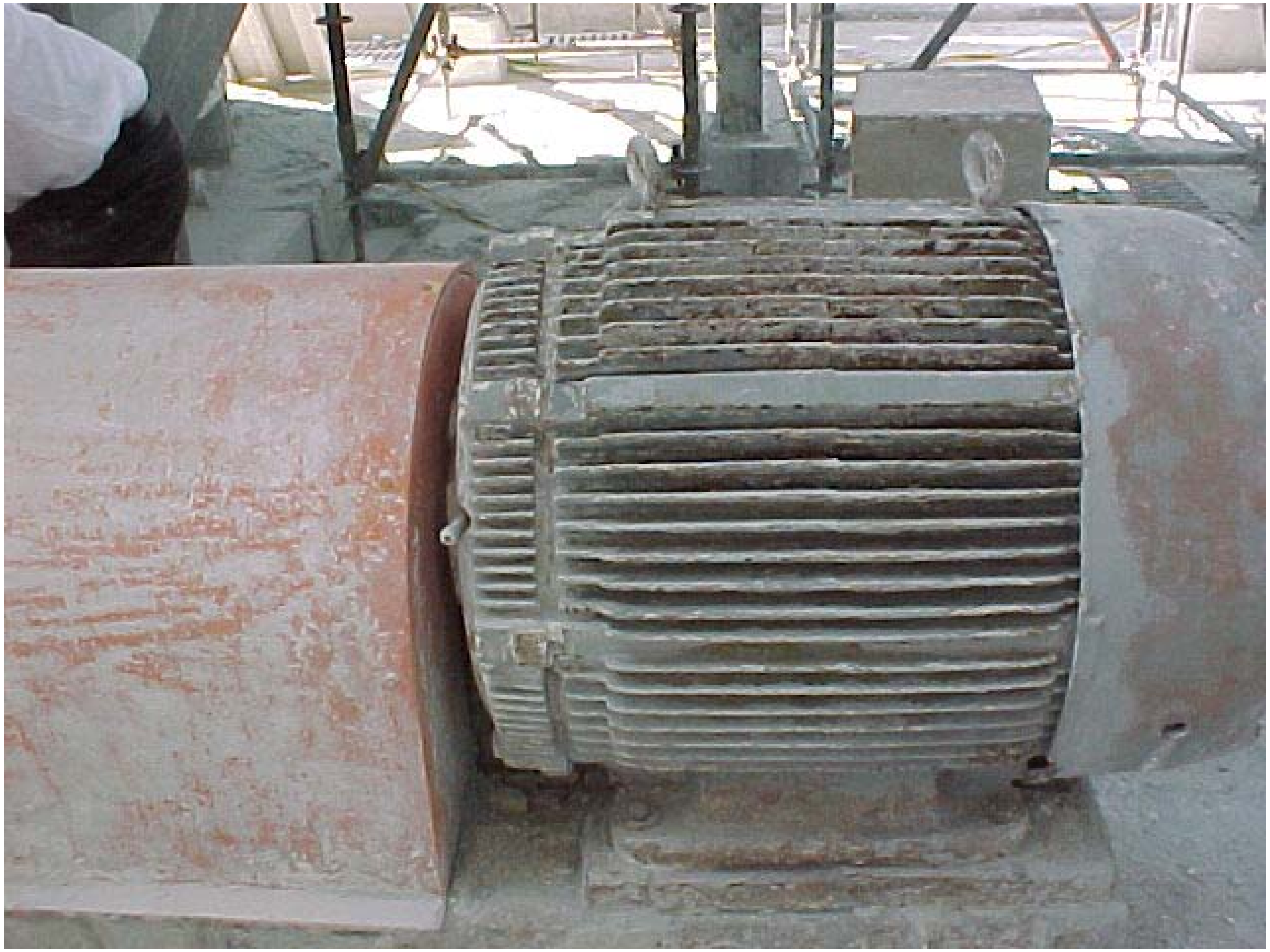
20 HP, 1800 rpm, frame class F (155ºF)

Dirty Motor

185 °F

<u>Rule of Thumb:</u>
An 18 °F Increase In Temperature Reduces Motor Life by 50%

Cleaner Motor



135 °F

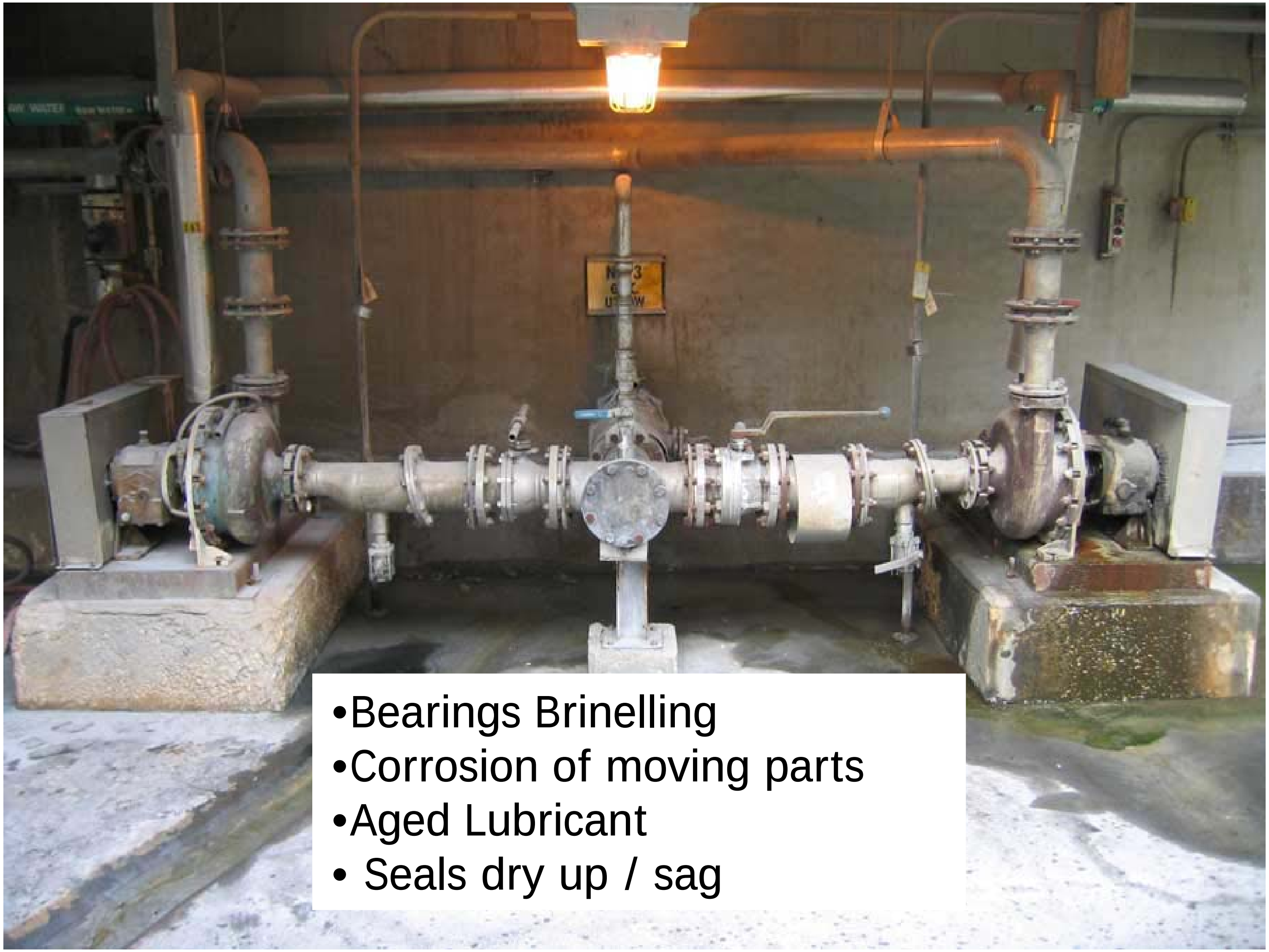
Make a Visible Change Early in the Project

Make a Visible Change Early in the Project

Operate Equipment with Reliability in Mind

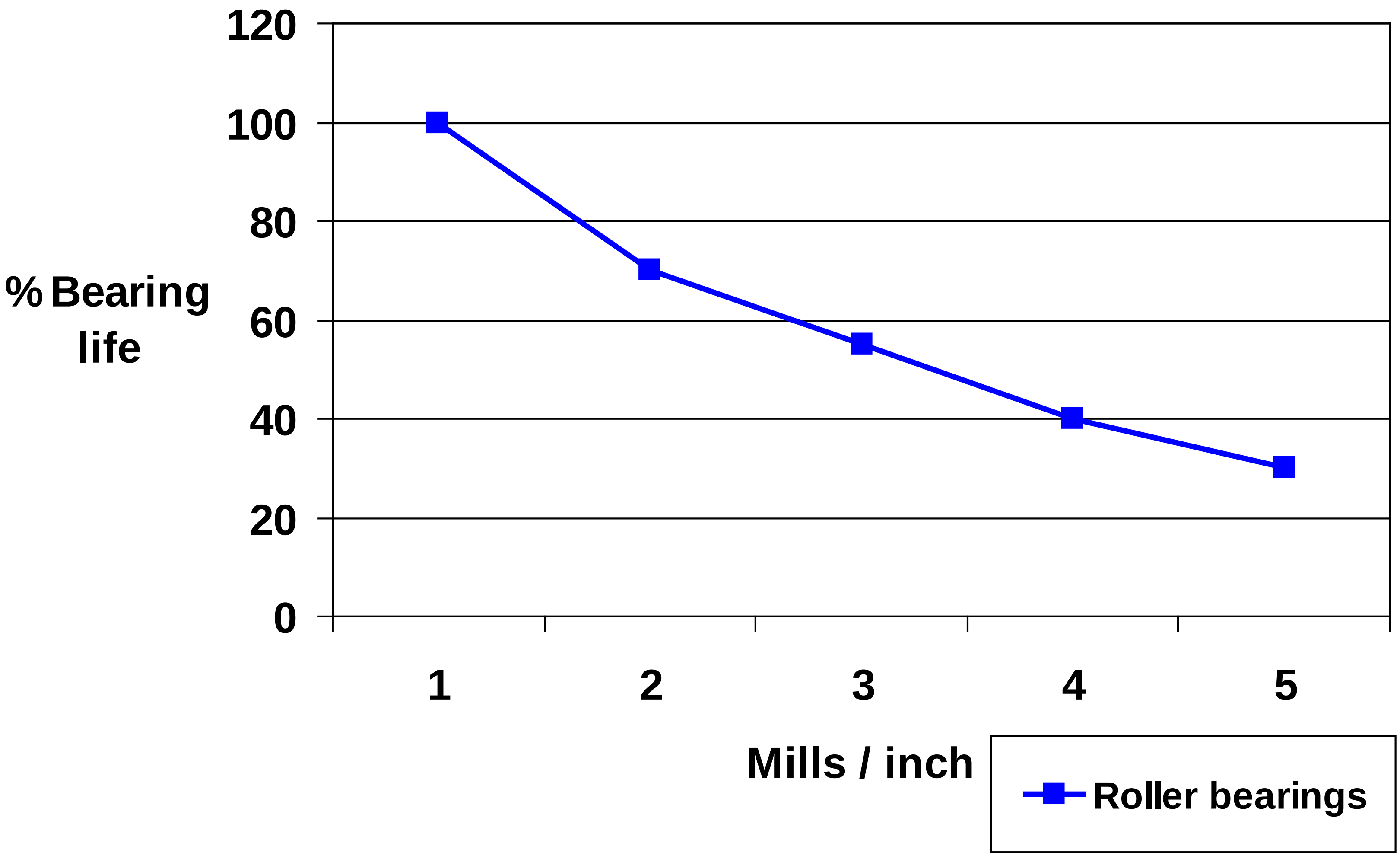
The current load is 4-7 times the full operating load at starting the motor. Operators should therefore not try to start Motors several times quickly together. It will burn the motor

Operating Procedures - Parallel Systems



- Bearings Brinelling
- Corrosion of moving parts
- Aged Lubricant
- Seals dry up / sag

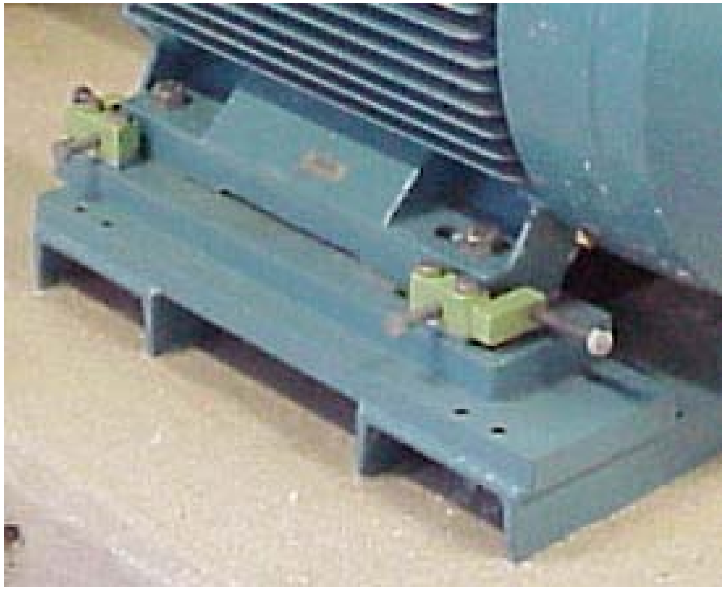
Bearing Life Reduction – An Example



Maintenance Technology Feb. 2000

Signs of Poor Alignment

Poorly aligned



Probably Well Aligned

Other Signs:

- **Hot bearings**
- **Hot Couplings**
- **Vibrating Equipment**

Measurement of Particle Size

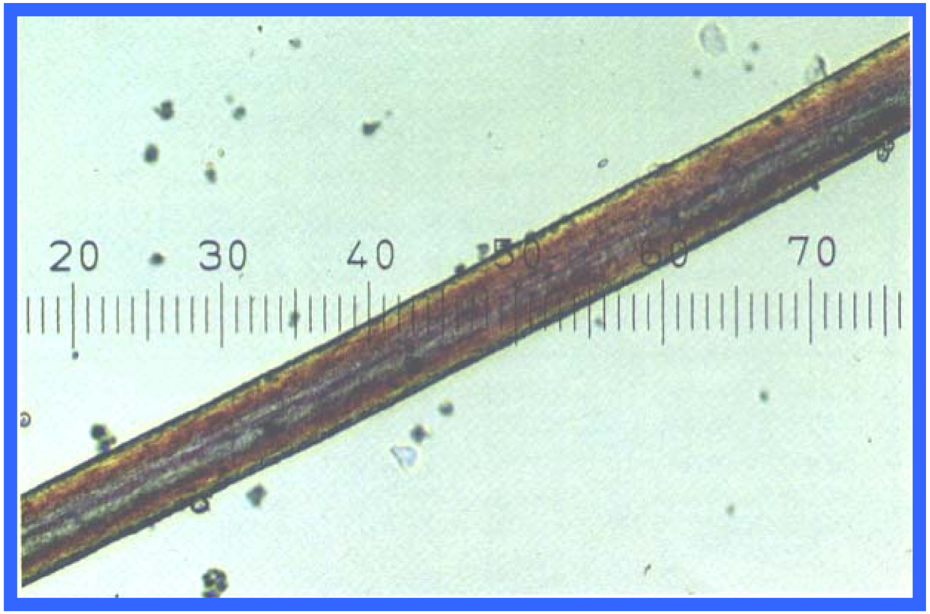
The Micrometer "µm"

"Micron" = Micrometer = 0.000001m

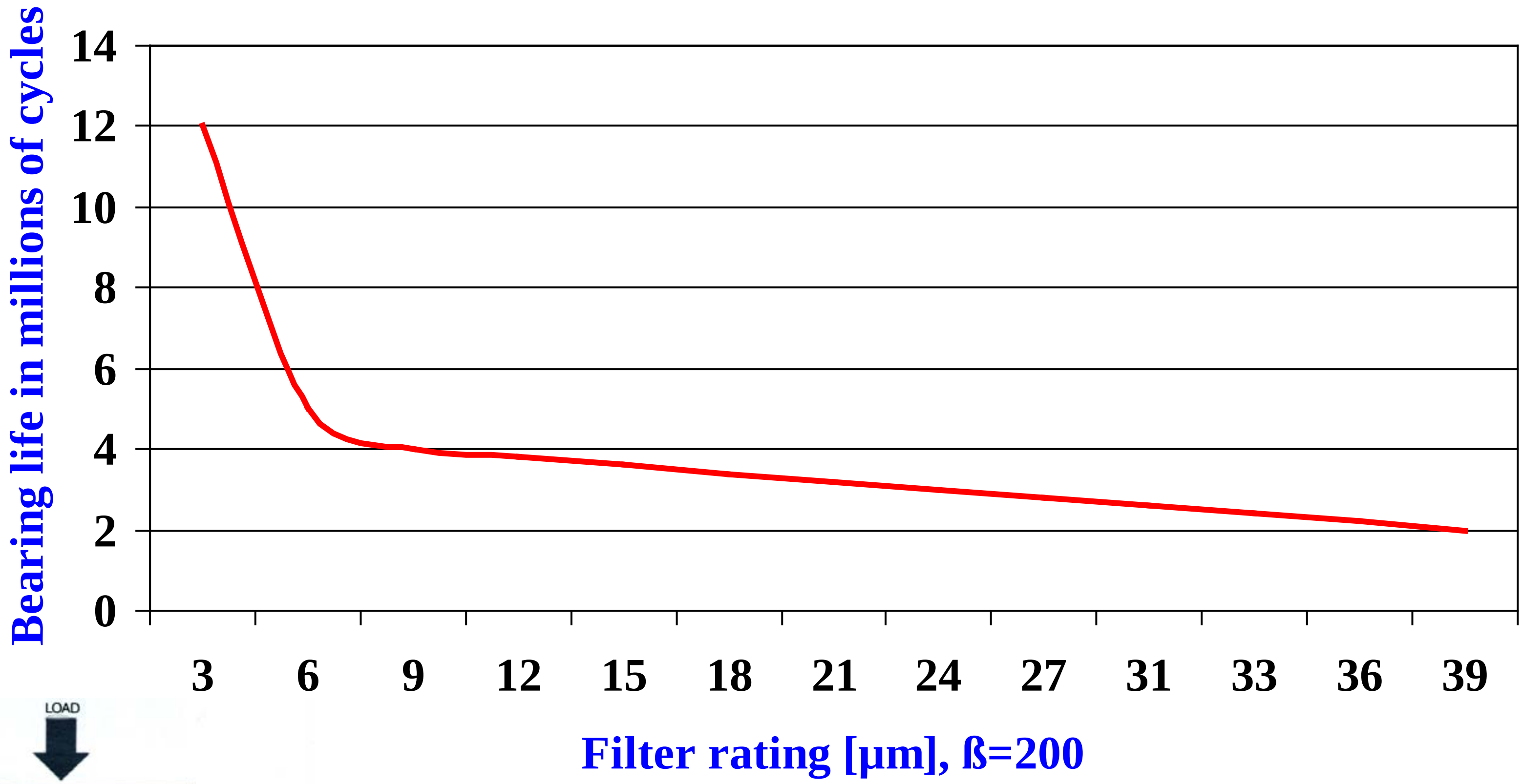
1 Micron = 0.000 039 inch

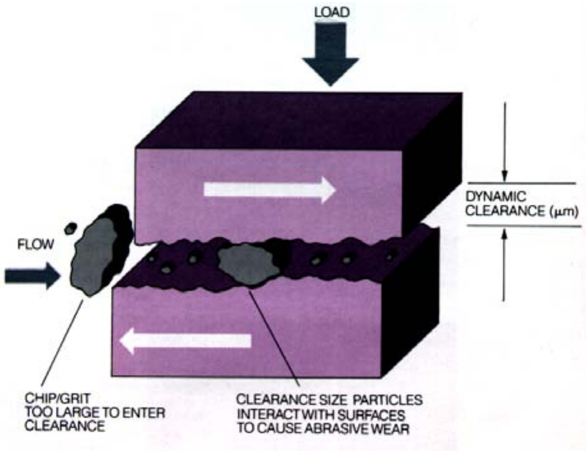
Grain of salt	**100 µm**
Thickness of paper	**75 µm**
Human hair	**70 µm**
Naked eye can see	**40 µm**
White blood cells	**25 µm**
Red blood cells	**8 µm**
Bacteria (cocci)	**2 µm**

Human Hair 75 µm particles 10 µm



Bearing Life & Filtration





Reference: Dr. P.B Macphereson, U.K


Maintainability

Design for Reliability

Design for Maintainability

Design For Maintainability

Motor Shelf

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Condition Monitoring – Finding Failures

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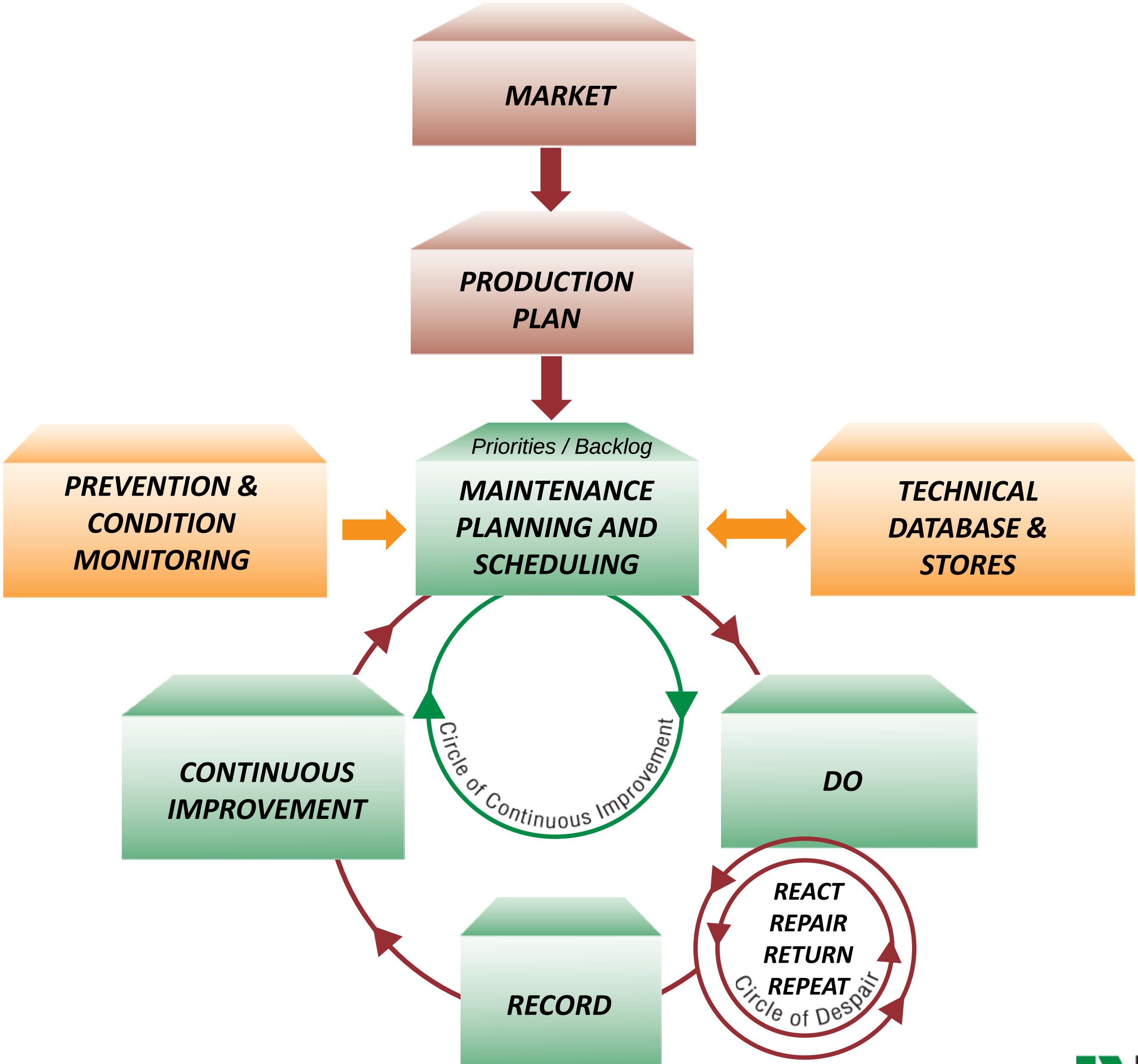
Reliability and Maintenance

Consulting and Training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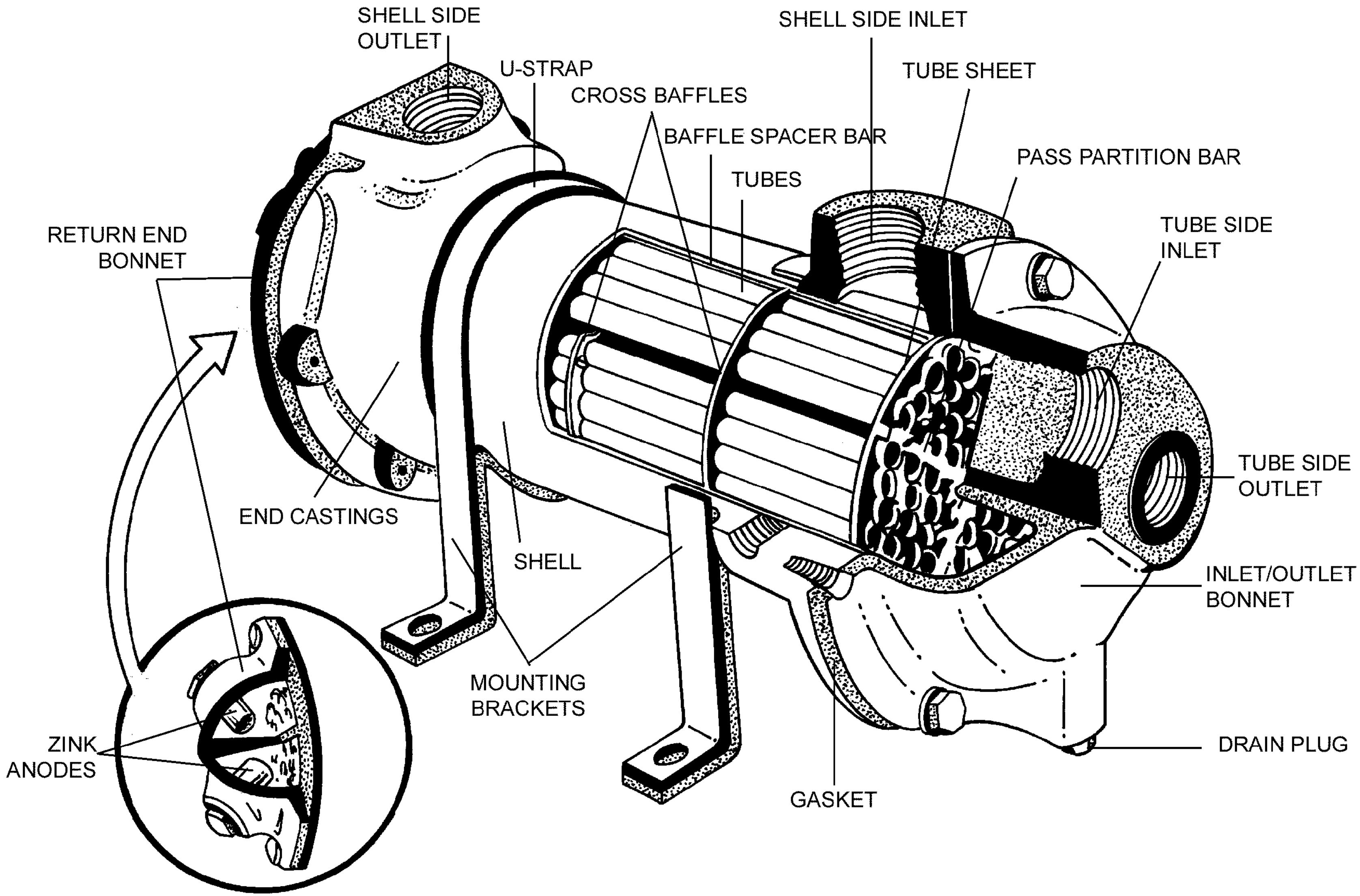
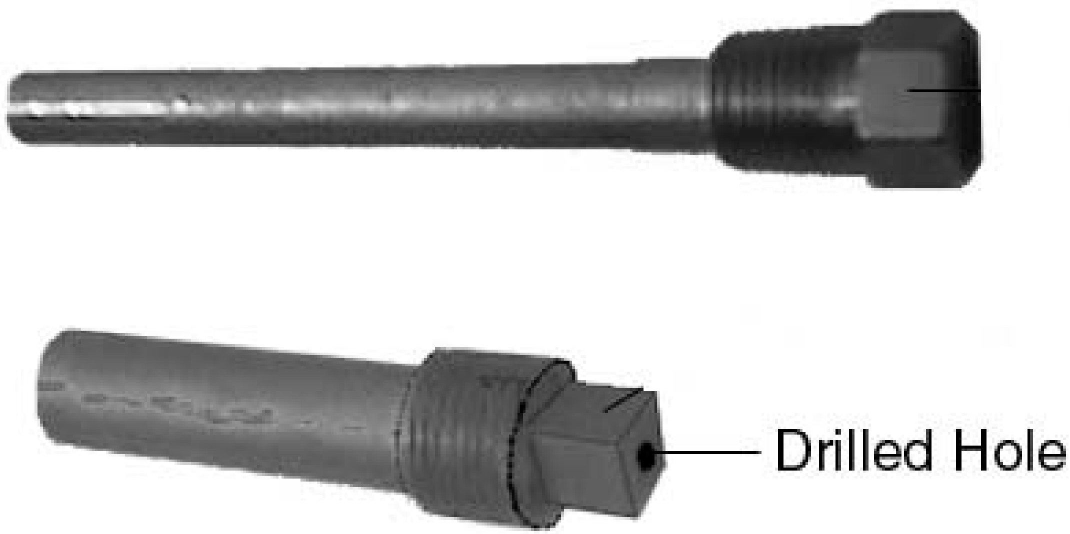
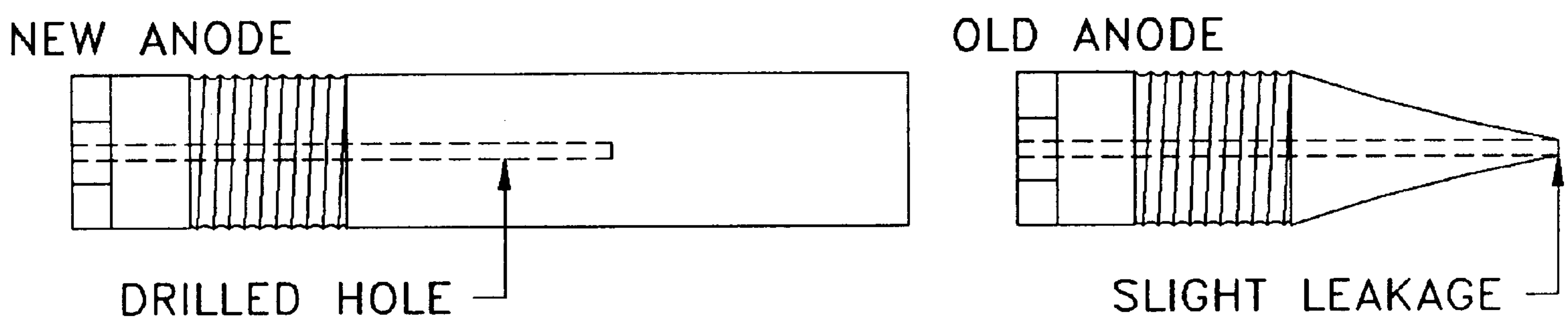
How would you inspect the Zinc anodes?

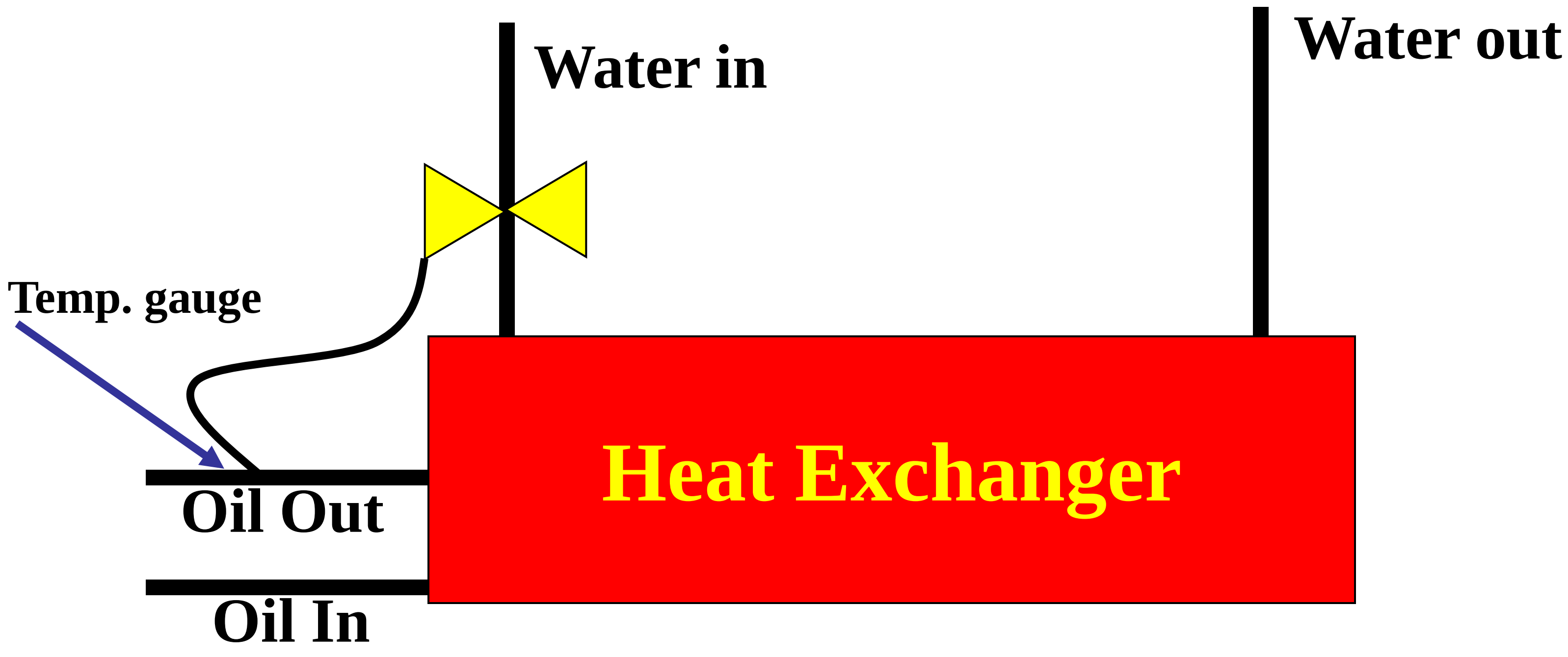


Solution?


Drilled Hole

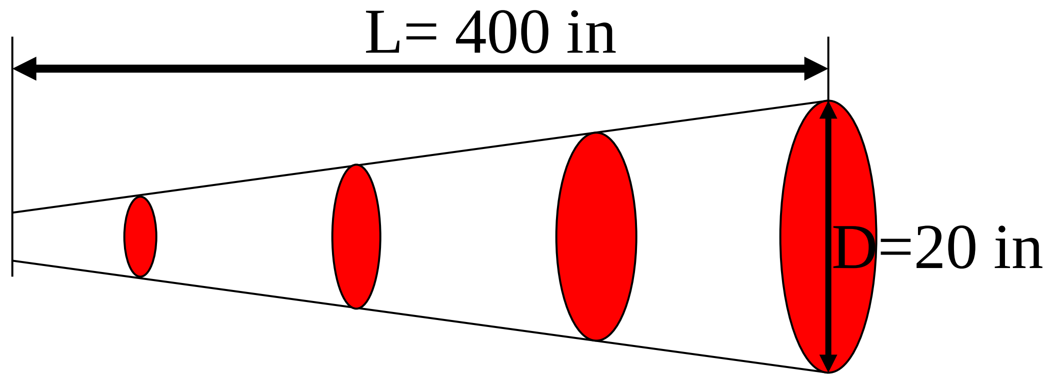

NEW ANODE
OLD ANODE
DRILLED HOLE
SLIGHT LEAKAGE

Exercise 8-B

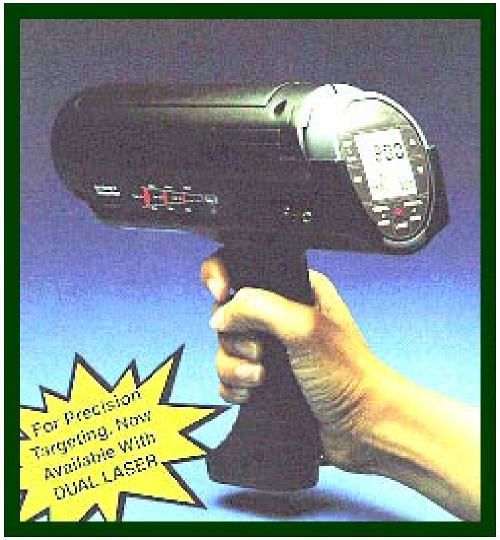


Heat Exchanger Valve

Infrared Temperature "Guns"



RATIO = L/D = 400/20 = 20:1



Expensive	**Ratio 200:1**
Cheap	**Ratio 3:1**

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Possible Inspection Tools

Inspection Mirrors

IR Gun

Flashlight

Vibration Pen

Stroboscope

Industrial Stethoscope

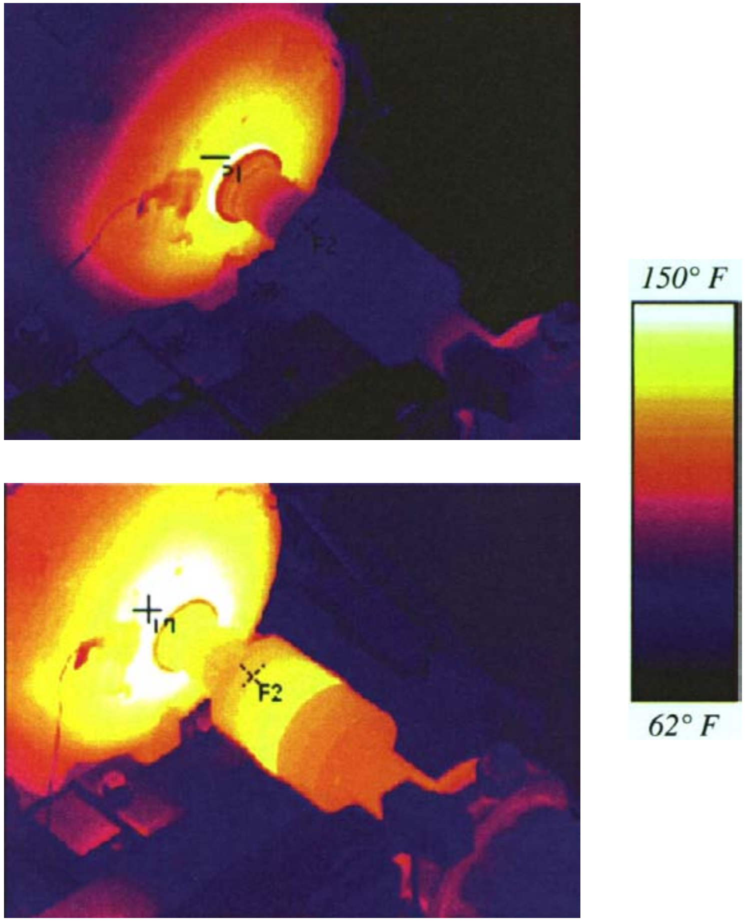
Flashlight

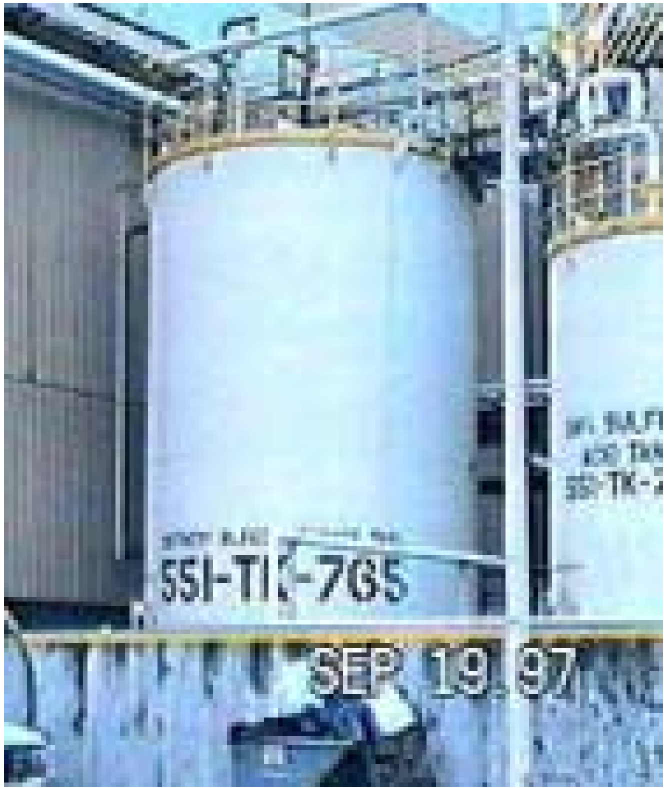
285 Lumens, size of a Marker

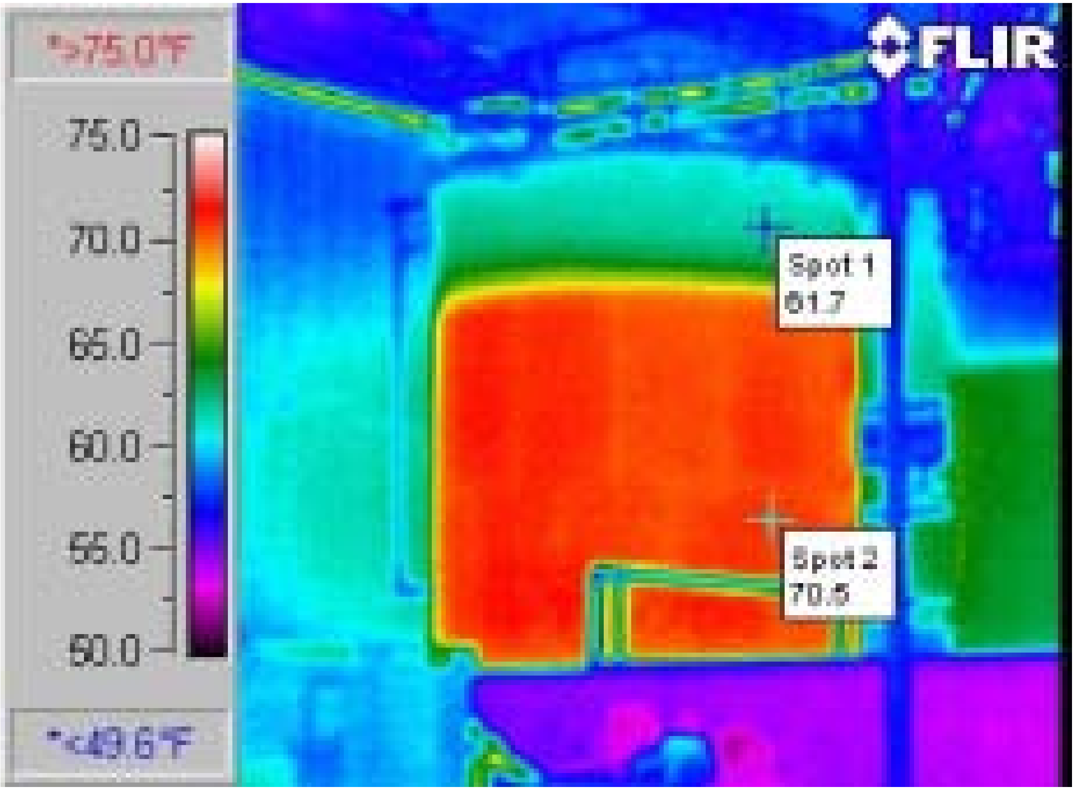
218 Lumens / 4D Batteries about a foot long

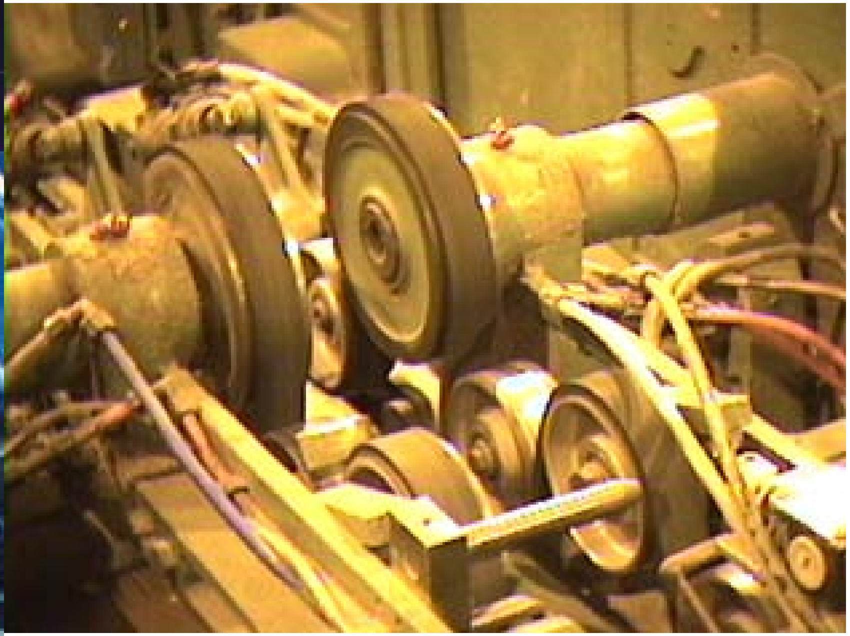
Temperature Crayons

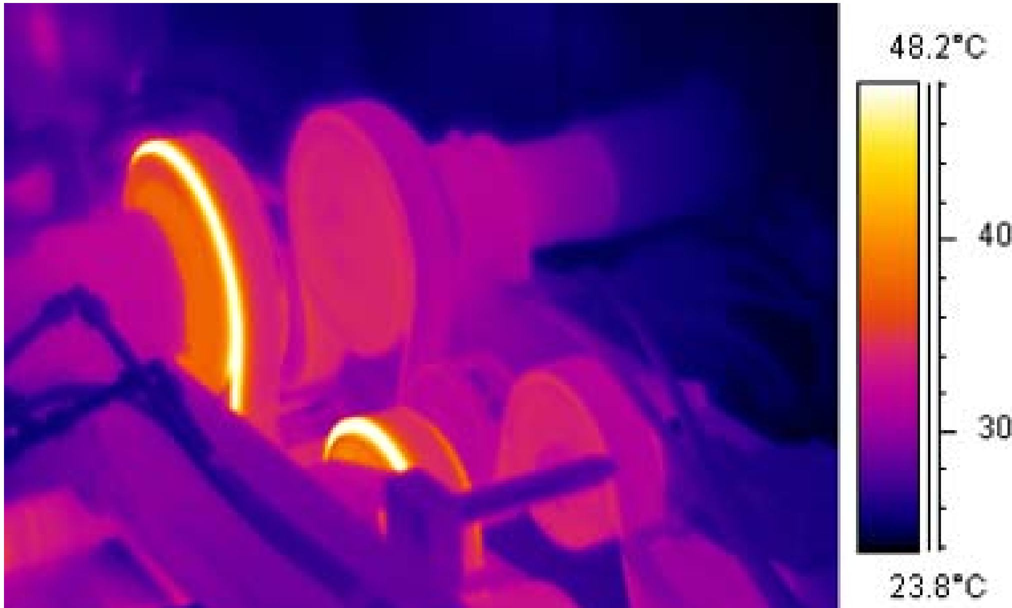
Infrared Camera



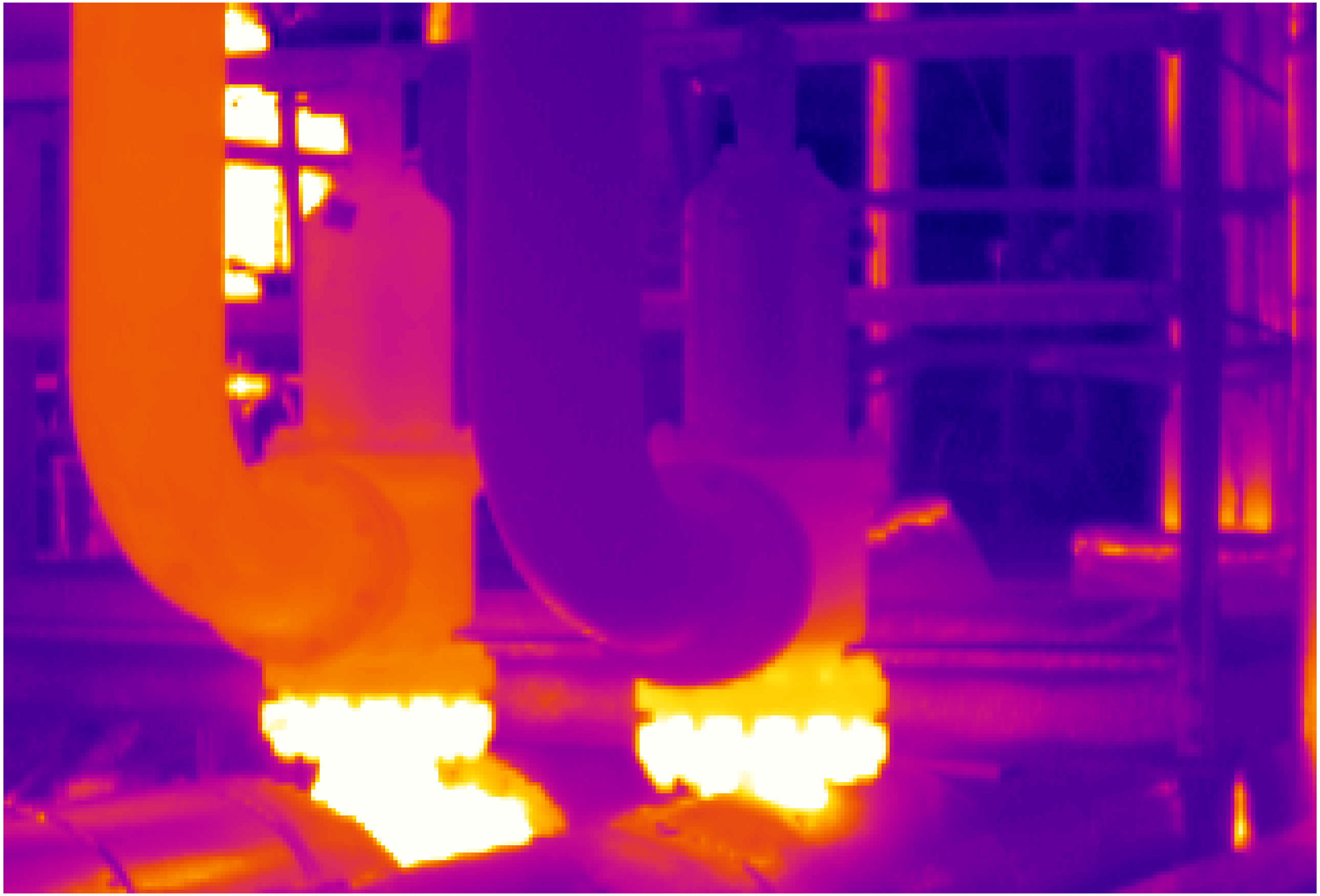

SSI-TK-705
SEP 19 97


*>75.0°F
75.0
70.0
65.0
60.0
55.0
50.0
*<49.6°F
FLIR
Spot 1
61.7
Spot 2
70.5

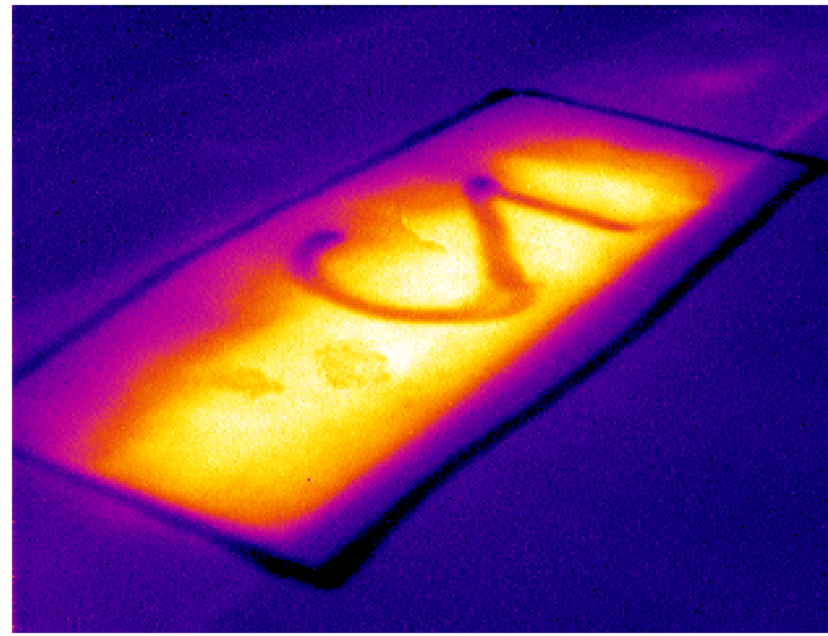



48.2°C
40
30
23.8°C

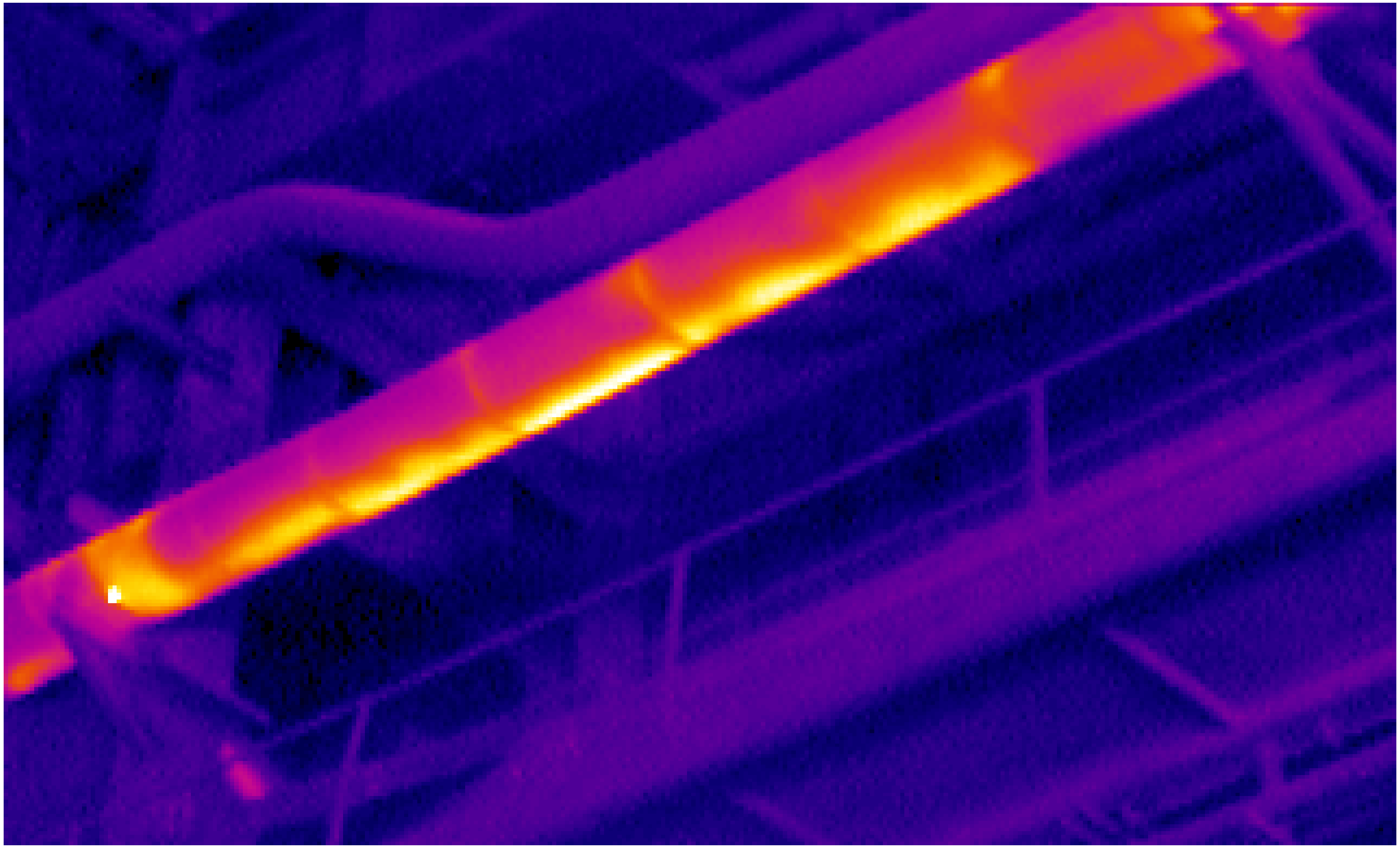
Leaking Steam System – Relief Valve




*>31.2°C
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
*<13.9°C



Wet Insulation –Saturated with Water Due to Leak



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The Basics of Reliability and Document tasks

Results Oriented

Reliability and Maintenance

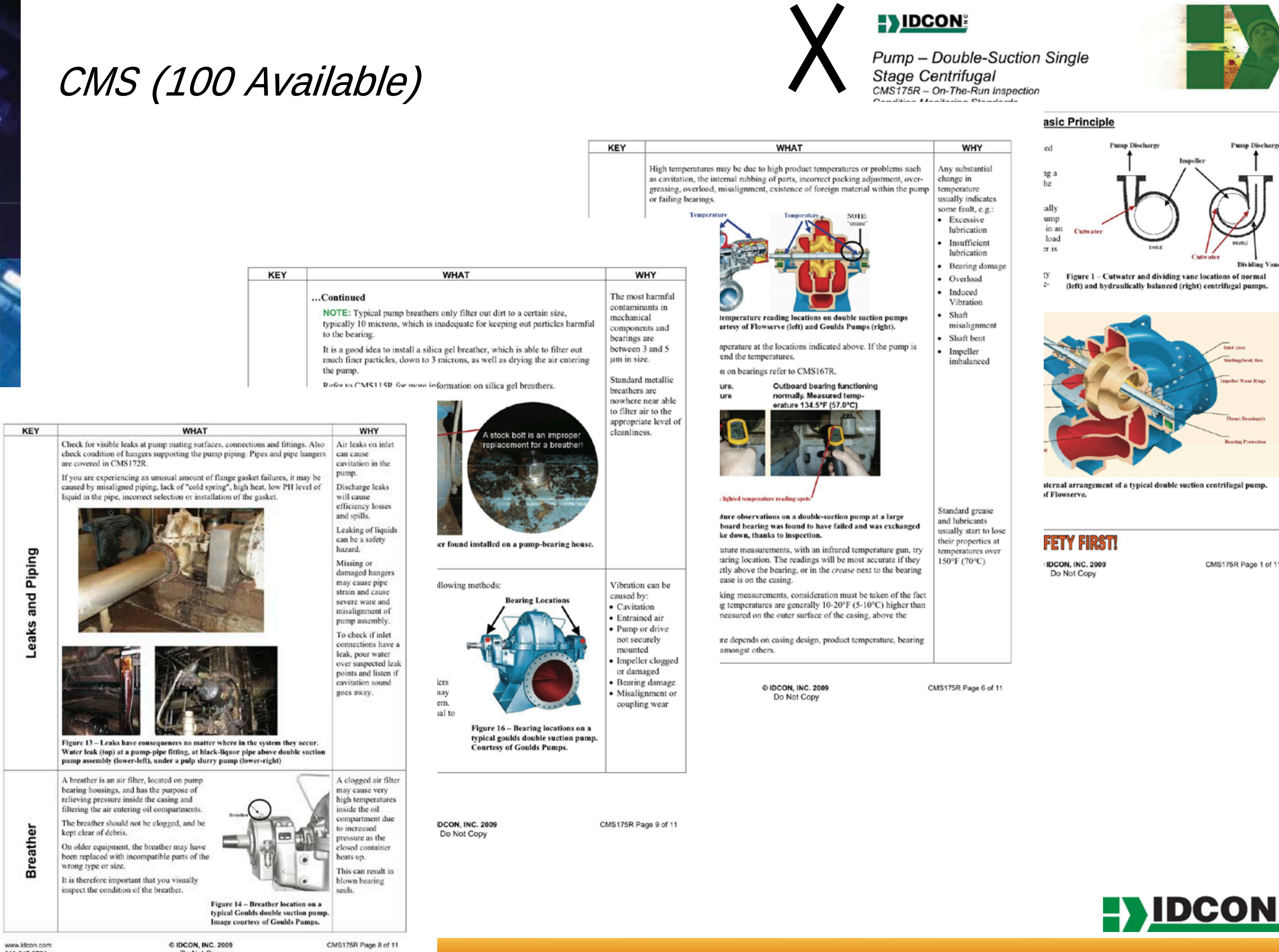
Consulting and Training

Paper Inspection Route Example

X

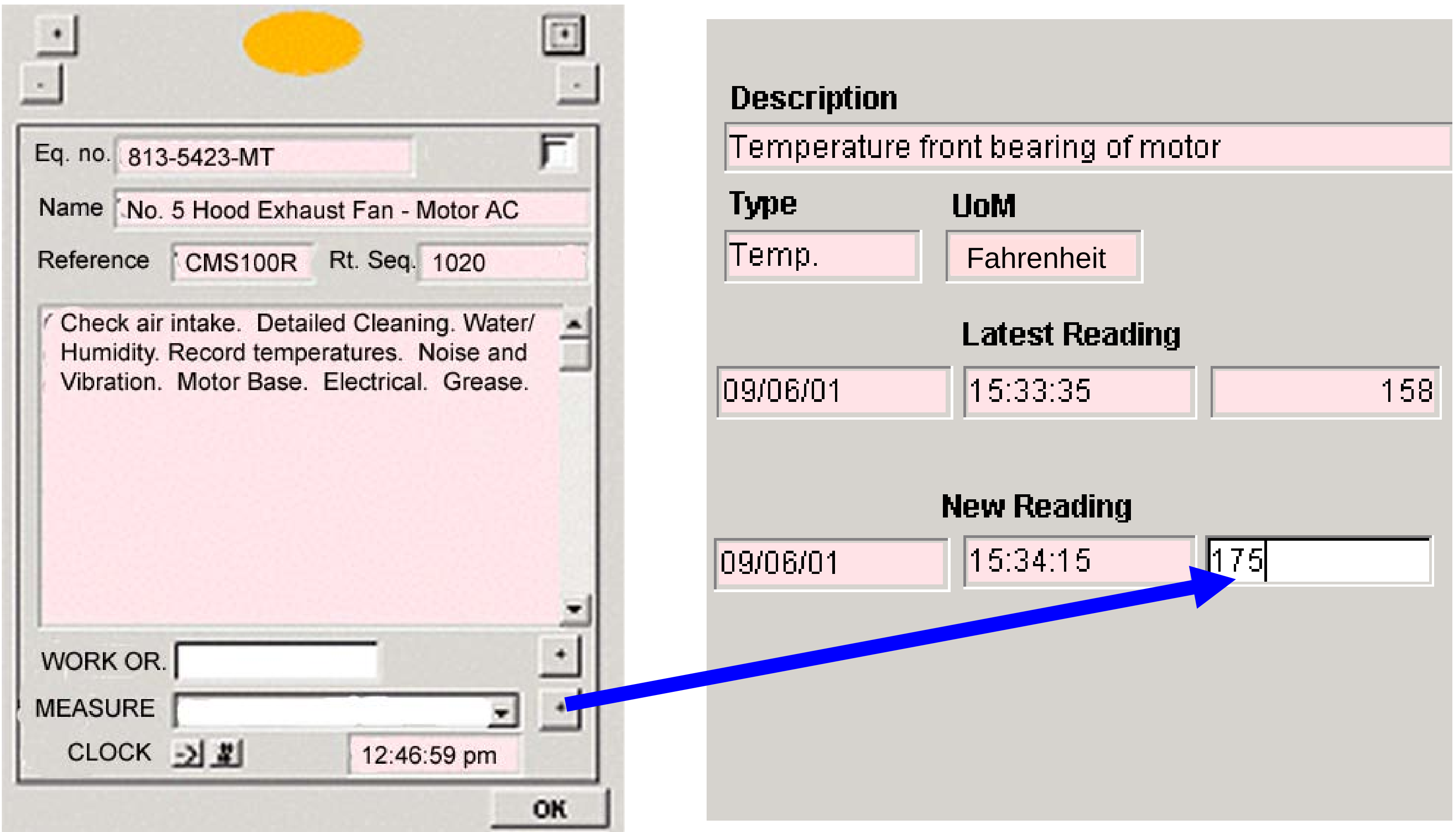
Equip.No: Route No: Doc No:	Equipment Name	Int. Pos. Vol.	Comments STX.No Activity M.Type UoM Description
899-316-3111-801 530	CAUSTIC - KILN EAST GLC RAKE LIFTING DEVICE	7 1	
899-316-3210-011 540 CMS100R	CAUSTIC - KILN WEST GREEN LIQUOR CLARIFIER MOTOR 1745 RPM	7 1 0	Air Intake. Temperature_________ Noise and Vibration___________ Bolts. Base. Foundation. Electrical. Detailed Cleaning. Junction Box. Comments:____ TEMP ° F WINDINGS ___________ VIB IN/S INBOARD BEARING ___________
899-316-3210-021 550	CAUSTIC - KILN WEST GREEN LIQUOR CLARIFIER	7 1	
899-316-3210-022 560 CMS117R	CAUSTIC - KILN WEST GREEN LIQUOR CLARIFIER REDUCTION GEAR	7 1 0	Noise. Vibration. Temperature. Lubrication Level. Leakage. Detailed Cleaning. Visual Breather. Visual Seals. TEMP ° F BEARING HOUSINGS ___________ VIB IN/S BEARING HOUSINGS ___________
899-316-3210-027 570 CMS121R	CAUSTIC - KILN WEST GREEN LIQUOR CLARIFIER RAKE	7 1 0	Seal Water. Packing. Belts. Bolts. Foundation. Bearings. Overload.
899-316-3211-011 580 CMS100R	CAUSTIC - KILN WEST GLC RAKE LIFTING DEVICE MOTOR 1745 RPM	7 1 0	Air Intake. Temperature_________ Noise and Vibration___________ Bolts. Base. Foundation. Electrical. Detailed Cleaning. Junction Box. Comments:____
899-316-3211-022 590 CMS117R	CAUSTIC - KILN WEST GLC RAKE LIFTING DEVICE REDUCTION GEAR	7 1 0	Noise. Vibration. Temperature. Lubrication Level. Leakage. Detailed Cleaning. Visual Breather. Visual Seals.
899-316-3211-801 600	CAUSTIC - KILN WEST GLC RAKE LIFTING DEVICE	7 1	
899-318-1071-011 610 CMS100R	TRS COLLECTION AND INCINERA TRS HEADERS FOUL CONDENSA MOTOR 3450 RPM	7 1 0	Air Intake. Temperature_________ Noise and Vibration___________ Bolts. Base. Foundation. Electrical. Detailed Cleaning. Junction Box. Comments:____
899-318-1071-021 620 CMS175R	TRS COLLECTION AND INCINERA TRS HEADERS FOUL CONDENSA FOUL CONDENSATE PUMP	7 1 0	Temperature. Bolts. Seal. Noise. Vibration. Oil Level. Oil Condition. Leaks and Piping. Pressure Gauge. Detailed Cleaning. Breather. Cavitation.

CMS (100 Available)



X

Handheld Example



Common Mistakes – (A Few Examples)

- Make a route for only one component or equipment type, for example “pumps routes” or “valve routes”
  - Because inspector will have to walk around the plant 30-50 times to reach all equipment
- No use of standard job plans for inspections
  - Makes maintenance of inspection lists very cumbersome if a new inspection tool or new technique is established
- Separate routes for different inspection intervals
  - Often a daily, a weekly, a monthly, a semi annually route for each trade make scheduling cumbersome and maintenance of routes very maintenance intensive.
- Set up of too many measuring points that are collected but not analyzed
- We don’t fix what we find

X

Work Order PM

Check for cavitation damage TMP Low Pressure White water Pump

Target: 1/2 hrs

Mandatory PPE: Safety Footwear, Eye Protection, Gloves, & Hearing Protection

Recommended PPE:

Purpose

Use this document to check for cavitations damage on the TMP/RMP Low Pressure White Water Pump. Service Number: 740244

The estimated total time to check for cavitations damage is 0.5hrs using 1 fitter.

This procedure must be used in conjunction with procedure # XXXXXX? for changing the volute casing for the removal and reinstating procedure.

The suction head to this pump is too low causing a large amount of cavitation and impellor damage. The suction head should be 8m high but it is only 3-4m and it is not economic to increase the height of the chest so the impellor is sacrificial.

This check is undertaken on a 2 yearly basis.

Hazards

Refer to procedure # XXXXX for hazards, changing volute casing.

✓ Pre-Checks (Things to check before starting this process)

- ☑ Check Operations schedule
- ☑ Confirm availability of materials and tools
- ☑ Confirm maintenance crew available
- ☑ Visually inspect slings and chain blocks for damage before use

Time Line

Step	Procedure Overview	Time
1	For Pump Removal, Re-assemble and Reinstate	See procedure #XXXX
2	Check impellor for cavitation damage and replace if required	½ hour

Labour Required

Quantity & Description	Hours
☑ 1 Fitters	1/2

Materials Required

Quantity & Description
☑ (x1) Impellor 444mm diameter P/N 23448 (don't remove from stock, check that available incase it is required)
☑ (x1) Impellor o-ring P/N 23637 (don't remove from stock, check that available incase it is required)

Isolations

Electrical Drive:

Refer procedure # XXXXX for isolations, changing volute casing.

Environmental

- ☐ Refer procedure # XXXXX for environmental considerations. changing volute casing.

High Temperature Work

Working environment not extreme. Drinking plenty of water will reduce the effects

Permits

- ☐ Refer procedure # XXXXX for environmental considerations, changing volute casing

References:

Document Name & Description
☑ AC Pump PS Plus™ Model 100/150 (F23A2, F23B2 and F23C2) Process/Slurry Centrifugal pump. Installation & Operations Manual (internet) and TMP pumps file.

STOP Read Hazards

Activity	Inspection Task
Remove pump	1. **For Pump Removal, Re-assemble and Reinstate – see procedure # XXXXXX** **Includes setting impellor clearance**
Check impellor for cavitation damage	2. **Check pump impellor for cavitation damage** 2.1. When the pump head and impellor have been removed from the volute. 2.2. Check the back side of the six blades (See Fig 1) for cavitation damage. 2.3. If evident the cavitation damage will be present on the back side (mechanical seal side) of the six blades and will be close to the eye of the impellor. See example Fig 2. 2.4. If the structural integrity of the impellor is compromised by the damage and parts of the impellor could break away while in operation then replace the impellor. 2.5. The acceptable level of wear or damage is a discretionary call if you are unsure get a second opinion from a mechanical engineer. 2.6. Figure 2 shows previous cavitation damage, at this level of damage the impellor was replaced on 25/06/2008. 2.7. Make sure - if the pump is returned to service with some damage evident that you are confident it will run for the next two years. It is likely to sustain further damage and must still hold together.

Fig 1: Area for inspection

Fig 2: Example of cavitation damage

Prepared: G Handcock	Authorised: J Hoogstraten	Date: 12-06-2008
Page: 1 of 1	250-CMSTD-1004	Version: 01

Uncontrolled copy printed on 23/03/10 @ 14:41 – out of date in 3 days! Check the version before use

What is the Final Documentation Product of OEC and PM

Usually

- Inspection Routes for on-the-run PM/OEC
  - Usually less than 5 minutes per equipment number
- Work orders for off line PM/OEC
  - Often longer jobs 30 min – 16 hrs

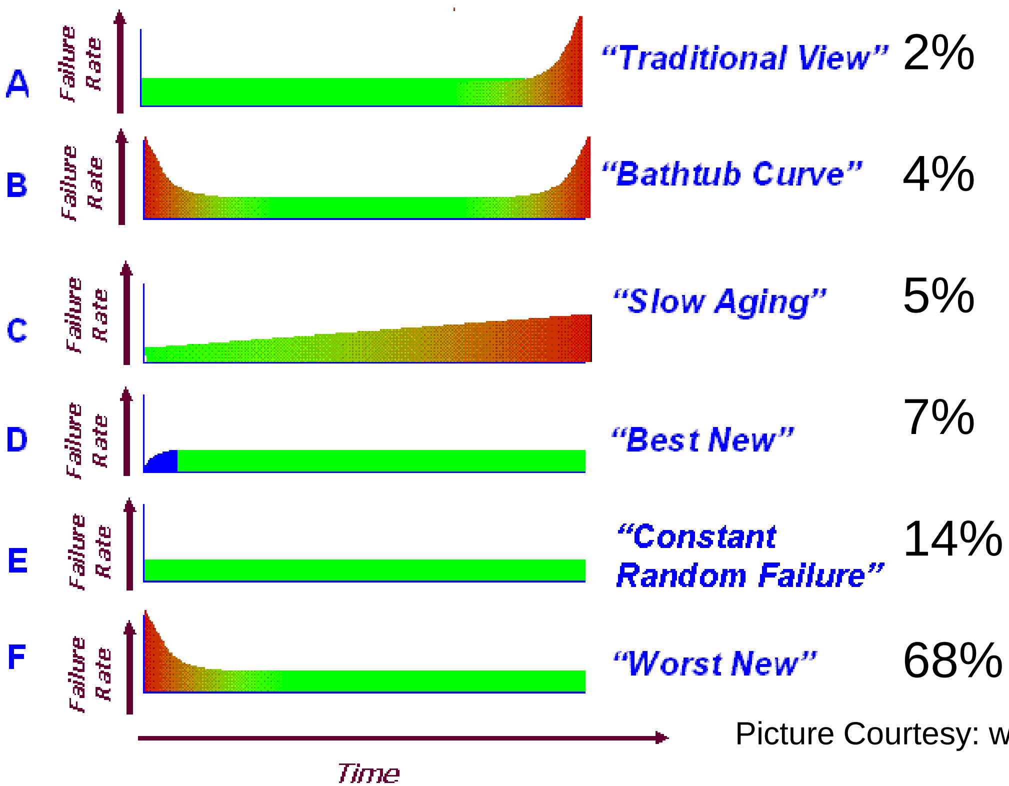
- **Maintenance Methods Available**
- **Life of Components**
- **Failure Developing Period (FDP)**

Maintenance Methods – Existing Equipment

- OTB – Operate To Break-Down
  - Often Too Expensive
- FTM - Fixed Time Maintenance
  - Don’t Know Life Most of the Time
- CBM – Condition Based Maintenance
  - 70-85% Will Therefore Need CBM

Random or not?

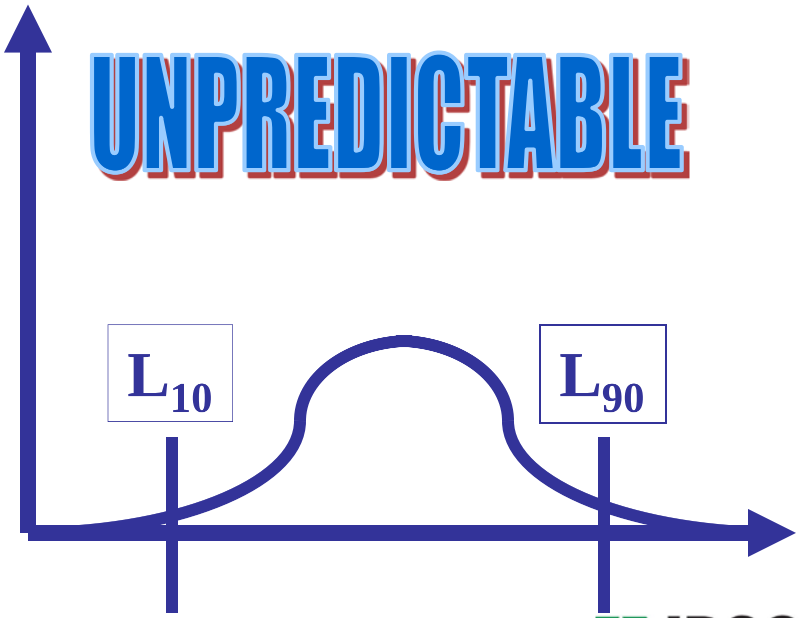
- It is unnecessary to know which of the traditional six life expectancy. You need to estimate if the failure IS Random or NOT. All failures are somewhat random and 5 – 11% somewhat predictable (C & possibly A & B).



Picture Courtesy: www.weibull.com

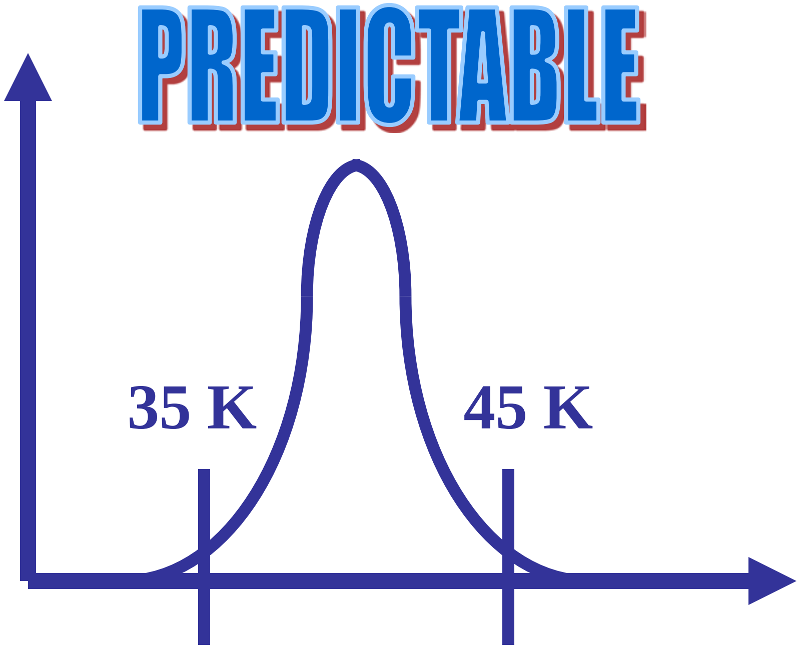
Component Life

Bearing life under the same operating conditions, can vary from 1 to 25 years



Component Life

Car tires life under the same operating conditions, may vary from 35,000 to 45,000 miles (6000-6500 mil)



Back

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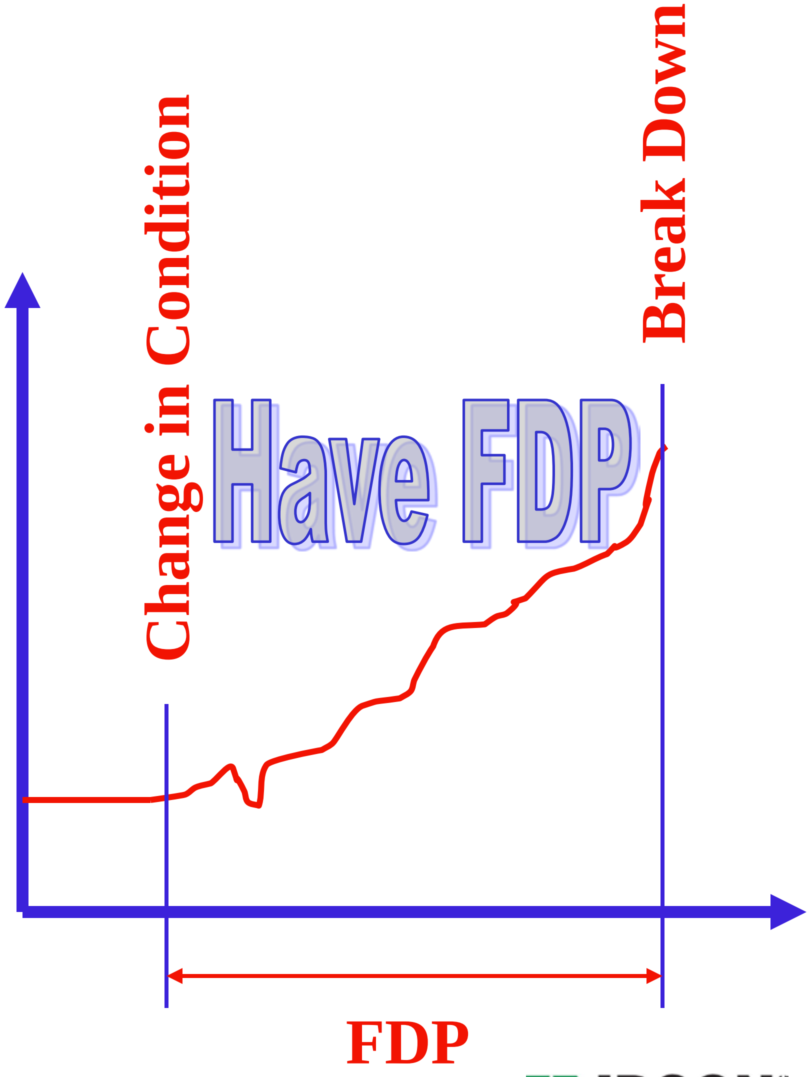
Failure Developing Period

A belt will show signs of deterioration before breaking down



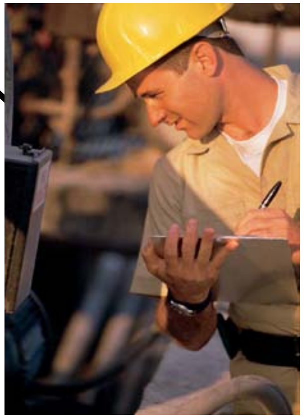
Failure/ Break Down

When the failure has developed
to the point that the equipment is unable
to operate
<u>BREAK DOWN</u>

<u>FAILURE</u>
When the equipment condition
reaches an unacceptable level

<u>SOURCE</u>
Event that initiate
Failure developing

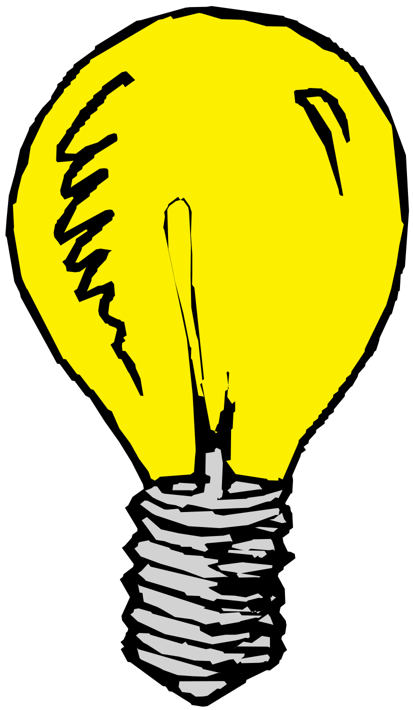
The failure is detected
and reported

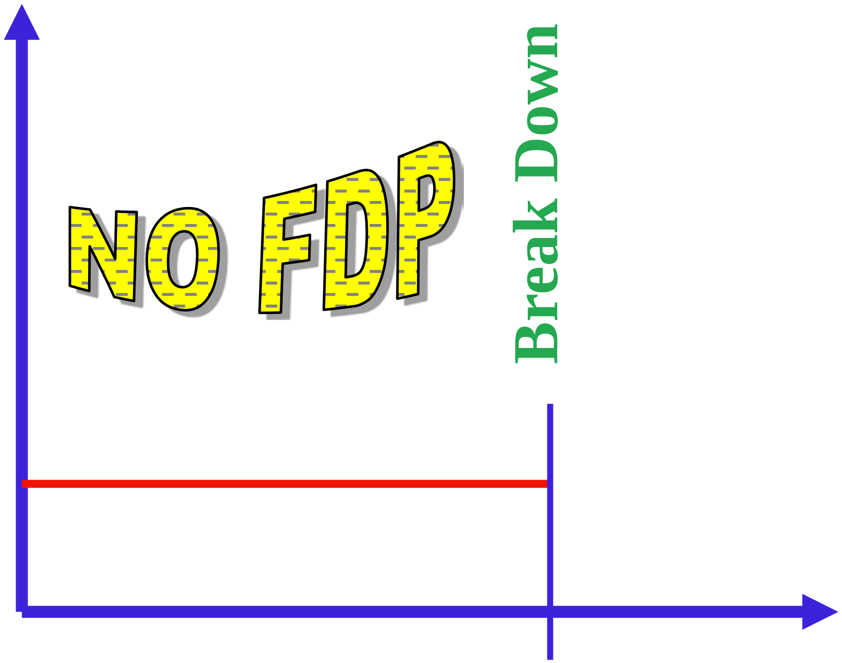


Source: källa till felet
Break down: Haveri

Failure Developing Period

A light bulb will break instantaneously without any signs of deterioration





Selecting Maintenance Method

1. **Prevent failures**
2. **Most cost effective maintenance method**
3. **Implement the most cost effective method**

- **Detailed Cleaning**
- **Lubrication**
- **Alignment**
- **Adjustment**
- **Operating Procedures**
- **Filtration**
- **Balancing**
- **Installation Procedures**

Maintenance Methods – Existing Equipment

- OTB – Operate To Break-Down
  - Often Too Expensive
- FTM - Fixed Time Maintenance
  - Don’t Know Life Most of the Time
- CBM – Condition Based Maintenance
  - 70-85% Will Therefore Need CBM

Selecting Maintenance Method

What is the Function?

What will happen if the function Break down?

1. **Environmental damage or personal injury**
2. **High cost (lost production or damages)**
3. **Preserve value (Life)**

ANSWER BY:

99%

- **Obvious**
- **P & ID**
- **Ask operator**

For Existing Equipment

ESSENTIAL CARE (EC)

lubrication
alignment
balancing
detailed cleaning
operating procedures
filtration

CBM

Inspection lists on component level

1. Running objective
2. Running subjective
3. Shutdown objective
4. Shutdown subjective

Decide What, Who, and When

- Decide what inspections/ PM to Do
- Decide who Should do the tasks
- How often should the task be done?

Alternative to RCM (Reliability Centered Maintenance)

How does this component work?

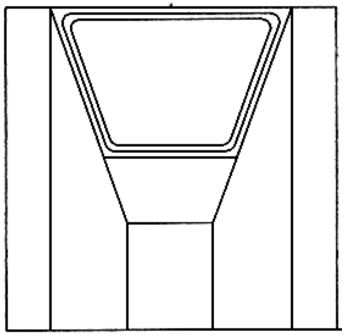
↓

How can this component fail?

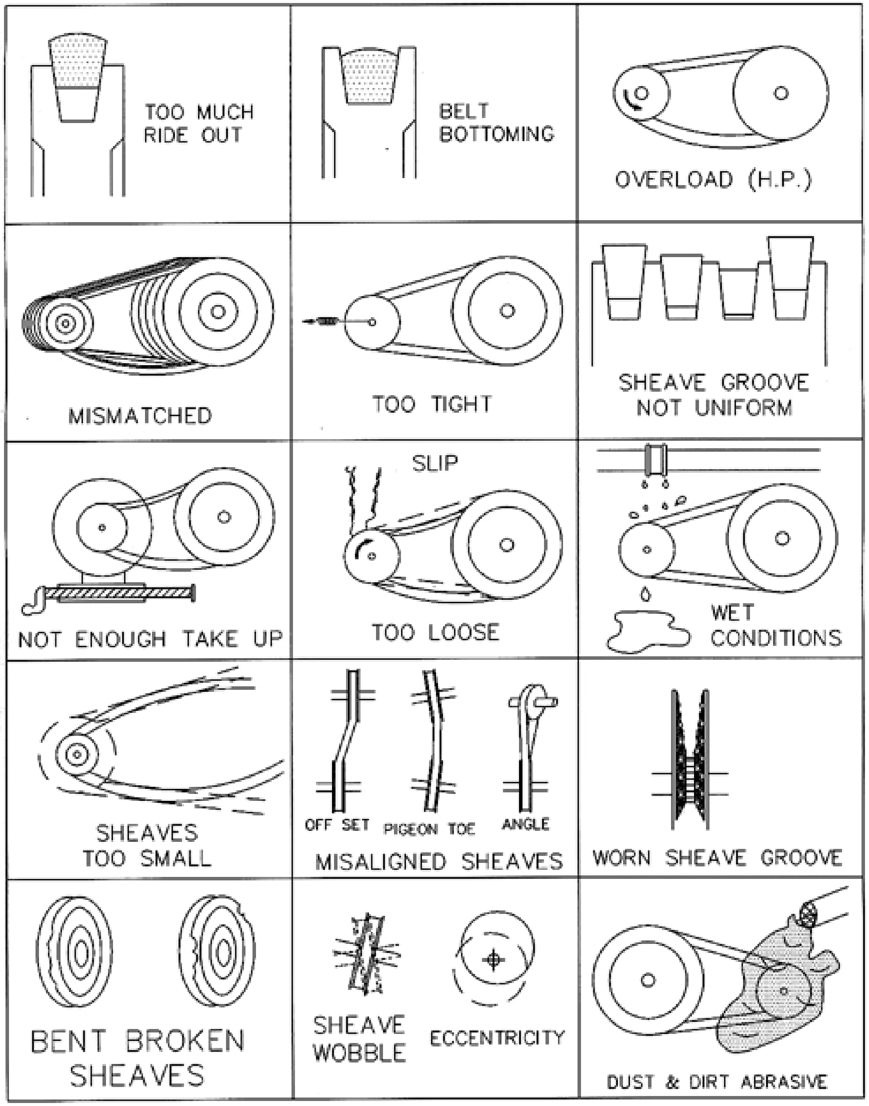
↓

How can I predict the failure?

How does it work?



How does it fail?



E!

Check:

Slippage/ oil, water
Belt tightness
Alignment of Belt
Sheave Wear
Noise

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Motor Inspection

On-The-Run

- Cleanliness (fins, plugged airflows, etc)
- Fan with strobe
- Temperatures with (IR Temperature - Max? 170F (75C)
- Vibration (feel or with Pen – Alarm 0.25 in/sec 6.35 mm/sec?)
- Hold down bolts
- Base
- Condition of Junction Box and wires
- Noise
- Load (Current Reading)

Shutdown

Winding test

CMS 100 R

Exercise 5-B

Exercise 5-B

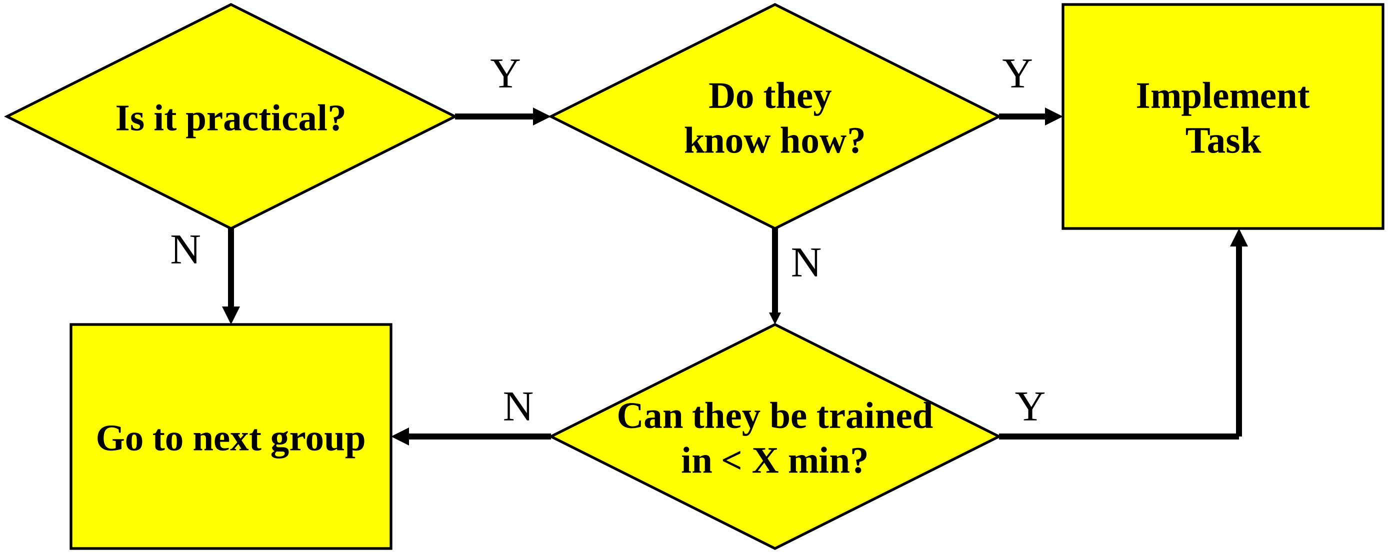
- Temperatures
- Bolts and Fasteners
- Noise and Vibration & cavitation
- Oil - Level and Condition
- Leaks
- Pressures
- Cleaning
- Breather
- Piping to and from Pump

- CMS 127R

Who

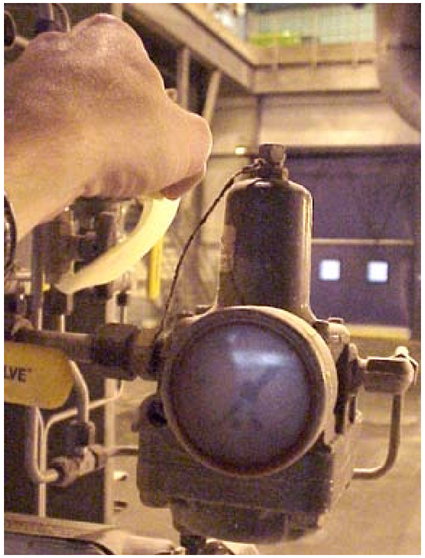
<u>*GROUPS*</u>

1. **Operator**
2. **Area Maintenance**
3. **In house maintenance expert**
4. **Outside expert**



Typical Operator Inspections

Motor Temperature



Weep Hole Regulator

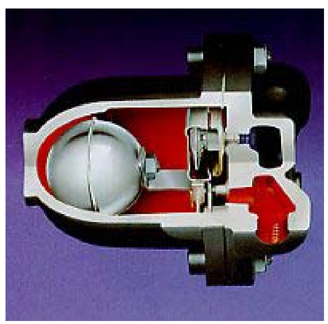
Belt and Coupling Condition with Stroboscope

Typical Maintenance Inspections

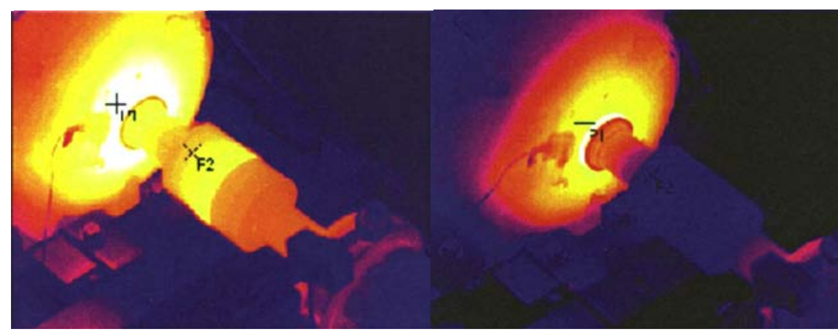
Places Impractical for Operators to Get To

Complex Systems

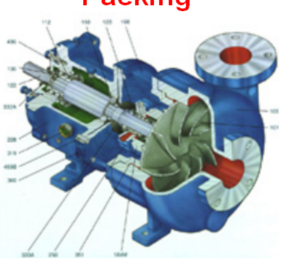
Vibration Analysis



Components that Require Experience



Infrared Camera

COMPONENT	ON-THE-RUN INSPECTION	Frequency	SHUTDOWN INSPECTION/ FTM	Frequency
Coupling Gear  Ref: CMS106R	**Operators:** Look for grease outside coupling ___. If grease is present the seals may be blown. Check for unusual noise ___. Check housing and bolts for loosens with stroboscope ___.Check temp. with IR-gun ____, misaligned coupling gets hot. If coupling can't be seen, modify guard at earliest convenience **Mech. Maint.:** Look for grease outside coupling ___. If grease is present the seals may be blown. Check for unusual noise ___. Check housing and bolts for loosens with stroboscope ___. Check temp. with IR-gun ____, misaligned coupling gets hot. If coupling can't be seen, modify guard at earliest convenience	Weekly Monthly	**Lubricator**: Take apart, inspect, clean all parts, change seals, re lubricate, check alignment.	X 2 years
Motor AC  Ref: CMS100R	**Operations:** Clean if needed, check temperature (alarm 175°F), listen for unusual noise. Damaged electric junction box and condition of cables ___. Check bolts/ foundation/ base for cracks, corrosion and looseness ___. Make sure the motor isn't exposed to unnecessary water or moisture ___. Check vibration: Check vibration (middle of bearings in horizontal plane) coupling side ___in/s, back side ___in/s. Check fan condition with strobe light. **Mech. Maint.:** Detailed cleaning of cooling fins and air intake if needed ___. Scan motor and record highest temperature ___F. Check for unusual noise __, damaged electric junction box and condition of cables ___. Check bolts/ foundation/ base for cracks, corrosion and looseness ___. Make sure the motor isn't exposed to unnecessary water or moisture ___. Check vibration: Check vibration (middle of bearings in horizontal plane) coupling side ___in/s, back side ___in/s. Check fan condition with strobe light. Vibration analysis Lubrication (if applicable). Frequency depends on rpm and grease.	Weekly Weekly-monthly 2-3 Weeks 3 months	**E/I Maint.** For critical motors, it's suggested to run a winding test. A winding test can be done with a number of different tools, use the mill standard tool. If there is a maintenance opportunity, do detailed cleaning of unit, remove junction box cover and inspect connections. Follow required safety procedures.	Yearly
Pump Centrifugal Packing  Ref: CMS127R	**Operations:** Needs cleaning ___. Check for vibration, noise ___. Check for signs if cavitation ___. Check piping to / from pump for leaks ___. Check packing tubing for damage ____. Check packing for excessive leakage ____. Packing gland gap ____. Check for right amount of seal water (30-60 drops/min). **Mech Maint.** Record temp. bearings IB___. OB___ . Check oil level and condition ___, clean oil glass ___. Check for vibration, noise ____. Listen for cavitation ____. Record discharge pressure if gauge is installed ___. Check foundation / base /bolts for corrosion, cracks and looseness ____. Check piping to / from pump ___. Check tubing for loose fittings, corrosion, damage ____. Check packing for excessive leakage ____. Packing gland gap ____. Check for right amount of seal water (30-60 drops/min)___. Tighten packing if needed.	Twice weekly	**Lubricator**: Oil change yearly for mineral oil, every 3 years for synthetic oil.	1-3 years

Hydraulic Cylinder

X

Consequence of Break Down Analysis

MAINTENANCE PROCEDURE	FAILURE RATE	DIR. MAINT. COST REPAIR TIME + MATERIAL = COST	COST / YEAR	DOWNTIME COST / YEAR	DAMAGES	MAINTENANCE COST/YEAR
OTB	0.2	16h * $40 = $640 Parts 3,000	$728	0.2*$4,000*10 = $8,000	1,000*0.2 =$200	728+8,000+200 =$8,928
FTM	1	10h *$40 = $400 Parts 3,000	3,400	0	0	$3,400
CBM	0.2	10h *$40 = $400 Parts 3,000	680	0	0	$680

Summary of Documentation Setup

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Most Organizations
KNOW
What to do

Best Organizations
Do it.

Lost opportunity – actual example

<u>Example 1- Kiln bricks</u>

Operate To Breakdown - OTB	$500,000
If responded to Inspection	$60,000

Accounting


Why do we spend so much on Preventive Maintenance when we never have any breakdowns!?
???
ACCOUNTANT
MAINTENANCE