Optimization of Preventive Maintenance and Operator Essential Care
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
Exercise!

How is Preventive Maintenance Defined?

How is Operator Essential Care Defined?
“All actions to prevent a failure or detect a failure early”
Failure & Break Down

When the equipment condition reaches an unacceptable level, the failure has developed to the point that the equipment is unable to operate. The failure is detected and reported.

Failure

Break Down

Source

Event that initiate Failure developing
### IDCON Definition - Preventive Maintenance / Essential Care and Condition Monitoring (PM/ECCM)

#### Essential Care

- 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
Motor Life in Relation to Cleanliness

20 HP, 1800 rpm, frame class F (155°F)
Dirty Motor

185 °F

Rule of Thumb:
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
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

% Bearing life vs. Mills / inch

- Roller bearings
Signs of Poor Alignment

Poorly aligned

Probably Well Aligned

Other Signs:
- Hot bearings
- Hot Couplings
- Vibrating Equipment
**The Micrometer "µm"**

"Micron" = Micrometer = 0.000001 m  
1 Micron = 0.000 039 inch

<table>
<thead>
<tr>
<th>Substance</th>
<th>Particle Size (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain of salt</td>
<td>100</td>
</tr>
<tr>
<td>Thickness of paper</td>
<td>75</td>
</tr>
<tr>
<td>Human hair</td>
<td>70</td>
</tr>
<tr>
<td>Naked eye can see</td>
<td>40</td>
</tr>
<tr>
<td>White blood cells</td>
<td>25</td>
</tr>
<tr>
<td>Red blood cells</td>
<td>8</td>
</tr>
<tr>
<td>Bacteria (cocci)</td>
<td>2</td>
</tr>
</tbody>
</table>

Human Hair 75 µm particles 10 µm
Bearing Life & Filtration

Filter rating [µm], β=200

Reference: Dr. P.B Macphereson, U.K
Maintainability
Design for Reliability
Design for Maintainability
Design For Maintainability
Motor Shelf
Condition Monitoring – Finding Failures

Results Oriented
Reliability and Maintenance
Consulting and Training
How would you inspect the Zinc anodes?
Solution?

NEW ANODE

DRILLED HOLE

OLD ANODE

SLIGHT LEAKAGE
Exercise 8-B

Heat Exchanger

- Oil In
- Oil Out
- Water in
- Water out
- Temp. gauge
Heat Exchanger Valve
Expensive Ratio 200:1
Cheap Ratio 3:1

Infrared Temperature “Guns”

\[ \text{RATIO} = \frac{L}{D} = \frac{400}{20} = 20:1 \]
Possible Inspection Tools

- IR Gun
- Flashlight
- Vibration Pen
- Inspection Mirrors
- Stroboscope
- Industrial Stethoscope
Flashlight

285 Lumens, size of a Marker

218 Lumens / 4D Batteries about a foot long
Temperature Crayons
Infrared Camera
Leaking Steam System – Relief Valve
Wet Insulation - Saturated with Water Due to Leak
The Basics of Reliability and Document tasks

Results Oriented
Reliability and Maintenance
Consulting and Training

WWW.IDCON.COM
### Paper Inspection Route Example

<table>
<thead>
<tr>
<th>Equip.No: Route No: Doc No:</th>
<th>Equipment Name</th>
<th>Int. Pos. Vol.</th>
<th>Comments STX.No Activity M.Type UoM</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>899-316-3111-801 530</td>
<td>CAUSTIC - KILN EAST GLC RAKE LIFTING DEVICE 1</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>899-316-3210-021 550</td>
<td>CAUSTIC - KILN WEST GREEN LIQUOR CLARIFIER 1</td>
<td>7</td>
<td></td>
<td></td>
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<tr>
<td>899-316-3211-801 600</td>
<td>CAUSTIC - KILN WEST GLC RAKE LIFTING DEVICE 1</td>
<td>7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Pump – Double-Suction Single Stage Centrifugal**

CMS (100 Available)

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**Loose and Piping**

Check for visible leaks at pump mating surfaces, connections, and flanges. Also check condition of flanges supporting the pump group. Pipes and pipe supports are covered in CMS TSR. If you experience unusual amount of flange gasket failure, it may be caused by misaligned piping, lack of "bell snapping", high flow, too high level of liquid in the pipe, incorrect selection or installation of the gasket.

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**Breather**

A breather is an air filter, located on pumps or piping bearings, and has the purpose of removing any moisture from the piping and also the equipment. The breather should not be clogged, and be kept clear of debris. On older equipment, the breather may have been replaced with inappropriate parts of the wrong type or size. It is therefore important that you visually inspect the condition of the breather.

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**Leakage**

Leakage is a problem that can occur due to high temperatures, high piped temperatures, or problems such as corrosion, the internal wearing of parts, incorrect packing adjustment, improper lubrication, overload, misalignment, existence of foreign material within the pump or faulty bearings.

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**CMMS**

CMMS is an acronym for Computerized Maintenance Management System.

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**Key**

<table>
<thead>
<tr>
<th>WHAT</th>
<th>WHY</th>
</tr>
</thead>
<tbody>
<tr>
<td>... Continued</td>
<td></td>
</tr>
</tbody>
</table>

**Pumps**

Pumps are machines that move fluids or gases from one place to another. They are used in many applications, such as: water supply, sewage treatment, heating and cooling systems, and more.

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**IDCON**

IDCON is a company that provides services in the field of facility management and maintenance. They offer services such as: computerized maintenance management systems (CMMS), training, consulting, and more.

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**FETY FIRST**

FETY FIRST is a software application that helps facility managers to optimize their maintenance operations. It provides real-time data and analytics to improve decision-making.

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**WWW.IDCON.COM**

IDCON's website where you can find more information about their services and products.

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**CMS TSR**

CMS TSR is a document that provides technical specifications and instructions for the CMS pump system.

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**CMS 1754L – On-The-Roll Inspection**

CMS 1754L is a standard for on-the-roll inspection of CMS pumps.

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**CMS 1759L**

CMS 1759L is a standard for CMS pumps in the lubrication system.
Handheld Example

Description

Temperature front bearing of motor

<table>
<thead>
<tr>
<th>Type</th>
<th>UoM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp.</td>
<td>Fahrenheit</td>
</tr>
</tbody>
</table>

Latest Reading

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>09/06/01</td>
<td>15:33:35</td>
<td>158</td>
</tr>
</tbody>
</table>

New Reading

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>09/06/01</td>
<td>15:34:15</td>
<td>175</td>
</tr>
</tbody>
</table>
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
Work Order PM

Check for cavitation damage TMP Low Pressure White water Pump

Purpose
Use this document to check for cavitation damage on the TMP/PM Low Pressure White Water Pump. Service Number: 746344.

The estimated total time to check for cavitation damage is 2.8 hours using 1 filter.

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

The suction head to this pump is too low causing a large amount of cavitation and impeller damage. The suction head should be 8m high but it is only 3.8m and it is not economic to increase the height of the chest so the impeller is inefficient.

This check is undertaken on a 2 yearly basis.

Hazard
Refer to procedure # XXXXXX for hazards, changing valve casing.

Pre-checks
Things to check before starting this procedure.

Check Operations schedule.
Confirm availability of materials and tools.
Confirm maintenance crew availability.
Visual check for dings and cracks for damage before size.

Time Line

<table>
<thead>
<tr>
<th>Step</th>
<th>Procedure Overview</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>For Pump Removal Re-assembly and Reinstall</td>
<td>Week</td>
</tr>
<tr>
<td>2</td>
<td>Check impeller for cavitation damage and replace if required</td>
<td>1 hr</td>
</tr>
</tbody>
</table>

Labour Required

<table>
<thead>
<tr>
<th>Quantity &amp; Description</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Filter</td>
<td>1/2</td>
</tr>
</tbody>
</table>

Materials Required

<table>
<thead>
<tr>
<th>Quantity &amp; Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Impeller 415mm diameter R# 26464A (don't remove from stock, check that available if required)</td>
</tr>
<tr>
<td>(1) Impeller 415mm R# 26464A (don't remove from stock, check that available if required)</td>
</tr>
</tbody>
</table>

Activity

1. For Pump Removal, Re-assemble and Reinstall – see procedure # XXXXXX includes seating impeller clearance

2. Check pump impeller for cavitation damage

2.1. When the pump head and impeller have been removed from the valve.

2.2. Check the back side of the six blades (See Fig 1) for cavitation damage.

2.3. If 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 impeller. (See example Fig 2).

2.4. If the structural integrity of the impeller is compromised by the damage and parts of the impeller could break away while in operation then replace the impeller.

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 impeller 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.

Prepared: G Handcock
Authorised: J Hoogstraten
Date: 12-06-2006

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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
Reliability Basics

- 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).

![Graph showing failure rates]

**Picture Courtesy: www.weibull.com**
Component Life

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

$L_{10}$  

$L_{90}$
Component Life

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

A belt will show signs of deterioration before breaking down

Change in Condition

Have FDP

Break Down

FDP
Failure/ Break Down

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

BREAK DOWN

The failure is detected and reported

FAILURE

When the equipment condition reaches an unacceptable level

SOURCE

Event that initiate
Failure developing

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
Preventing Problems

• 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)

99%
• Obvious

ANSWER BY:
• 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?

Check:

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

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

• CMS 127R
Who

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

- Is it practical? [Y/N]
  - N: Go to next group
  - Y: Do they know how? [Y/N]
    - N: Can they be trained in < X min? [Y/N]
      - Y: Implement Task
      - N: Go to next group
    - Y: Implement Task
**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
<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>ON-THE-RUN INSPECTION</th>
<th>Frequency</th>
<th>SHUTDOWN INSPECTION/ FTM</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coupling Gear</td>
<td>Operators: Look for grease outside coupling ___ If grease is present the seals may be blown. Check for unusual noise ___. Check housing and bolts for looseness 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 looseness with stroboscope ___. Check temp. with IR-gun ___, misaligned coupling gets hot, if coupling can’t be seen, modify guard at earliest convenience.</td>
<td>Weekly</td>
<td>Lubricator: Take apart, inspect, clean all parts, change seals, re lubricate, check alignment.</td>
<td>Monthly</td>
</tr>
<tr>
<td>Motor AC</td>
<td>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.</td>
<td>Weekly/monthly</td>
<td>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.</td>
<td>Yearly</td>
</tr>
<tr>
<td>Pump Centrifugal Packing</td>
<td>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 ___, 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.</td>
<td>Twice weekly</td>
<td>Lubricator: Oil change yearly for mineral oil, every 3 years for synthetic oil.</td>
<td>1-3 years</td>
</tr>
</tbody>
</table>

Ref: CMS106R
Ref: CMS100R
Ref: CMS127R
Hydraulic Cylinder
### Consequence of Break Down Analysis

<table>
<thead>
<tr>
<th>Maintenance Procedure</th>
<th>Failure Rate</th>
<th>Direct MAINT. Cost (Repairs + Material = Cost)</th>
<th>Cost / Year</th>
<th>DOWNTIME Cost / Year</th>
<th>Damages</th>
<th>Maintenance Cost/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTB</td>
<td>0.2</td>
<td>$640 (16h * $40 = Parts)</td>
<td>$728</td>
<td>0.2*$4,000*10 = $8,000</td>
<td>1,000*0.2 = $200</td>
<td>728+8,000+200 = $8,928</td>
</tr>
<tr>
<td>FTM</td>
<td>1</td>
<td>$400 (10h *$40 = Parts)</td>
<td>3,400</td>
<td>0</td>
<td>0</td>
<td>$3,400</td>
</tr>
<tr>
<td>CBM</td>
<td>0.2</td>
<td>$400 (10h *$40 = Parts)</td>
<td>680</td>
<td>0</td>
<td>0</td>
<td>$680</td>
</tr>
</tbody>
</table>
Summary of Documentation Setup
Results Oriented Maintenance

Most Organizations KNOW What to do

Best Organizations Do it.
Lost opportunity - actual example

Example 1- Kiln bricks
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!?