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How to design, deliver and run successful Condition-Based Maintenance?

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CBM Dreamer at Amaziograph Ltd

CBM CONNECT™ CONFERENCE AUSTRALIA 2019
Powered by Mobius Institute

Co-located with RELIABILITY CONNECT™ CONFERENCE

WWW.THECBMCONFERENCE.COM

Who's That Dreamer?



Svetoslav (Sveto)

CBM Dreamer and Senior Advisor

- Master of Science, Marine Mechanical Engineer
- VA Category III certified
- 25 years experience in the CM world
- Advising "analog" companies how to survive in the digital world

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// And still an SW developer…



Observations

312 000 000

Results appear in Google when you look for condition-based maintenance

Back to basics

Document	Definition of the Condition-based maintenance (CBM)
ISO 13372	Maintenance performed as governed by **condition monitoring programms**
DNVGL-CG-0052	CBM is a predictive maintenance form, based on and utilizing the information of an established **condition monitoring programme**
ABS Rules for survey After construction	A maintenance plan, conducted on a frequent or real-time basis, which is based on the use of **Condition Monitoring** to determine when part replacement or other corrective action is required.
Lloyd's Register Machinery Planned maintenance and Condition Monitoring	A systems approach to asset management which will include assessment of an asset's criticality and probability of failure, assessment of the consequences of asset failure and development of a strategy to minimise the risks associated with asset failure. This may include, for example, the **condition monitoring tools deployed**, company policy for spares procurement.

Back to basics

Document	Definition of the Condition Monitoring (CM) programme
ISO 13373-1	After selection of the equipment to be monitored, and determining the type of measurement system that is appropriate, it is recommended that a condition monitoring programme flowchart be developed. However, since each plant and each system is unique, the data flow should be customized to provide the maximum benefits.
DNVGL-CG-0052	A CM programme is the result of an evaluation of what and how machinery shall be monitored. It contains comprehensive information about all relevant parameters, components and personnel, related to condition monitoring.
ABS Rules for survey After construction	Preventative Maintenance Program (PMP) – A program that consists of Planned Maintenance and/or Condition Monitoring plans. CM - The use of various technologies to determine the condition of equipment, at a specific moment in time, using minimal or non-invasive means.

Why Marine industry?

7 600 000

Rotating machines on board ships worldwide

Why Marine industry?

The Marine Industry is one of the most very heavily regulated industries with very well defined and controlled maintenance practices.

Why Marine industry?

The Marine Industry recognizes the **CM techniques** as a tool to define the **maintenance intervals**.

CBM rules in the Marine industry

Classification society (Class)

(https://en.wikipedia.org/wiki/Classification_society)

ABS

Lloyd's Register

DNV·GL

BUREAU VERITAS

IACS International Association of Classification Societies (http://www.iacs.org.uk)

No.74

No. 74 (Apr 2001) (Rev.1 May 2008) (Rev.2 Aug 2018)

A GUIDE TO MANAGING MAINTENANCE IN ACCORDANCE WITH THE REQUIREMENTS OF THE ISM CODE

INTRODUCTION

The ISM Code makes it clear that the ship operator (the "Company") is responsible for ensuring the safe and pollution-free operation of the ship. In particular, the Company is required to ensure that the ship's hull, machinery and equipment are maintained and operated in accordance with the applicable rules and regulations and any additional requirements that may be established by the Company.

IMO INTERNATIONAL MARITIME ORGANIZATION

https://www.imo.org



Ship (near to 76000 ships worldwide)

Singapore, 2017

CBM rules in the Marine industry

Maintenance intervals

...

ii) condition monitoring techniques (i.e. lube oil analysis, vibration analysis), where used as part of an approved condition monitoring or condition based maintenance scheme.

Maintenance intervals

Maintenance intervals should be established based on the following:

i) manufacturers' recommendations and specifications;
ii) condition monitoring techniques (i.e. lube oil analysis, vibration analysis), where used as part of an approved condition monitoring or condition based maintenance scheme.
iii) practical experience in the operation and maintenance of the ship and its machinery, including historical trends in the results of routine inspections, and in the nature and rates of failures;
iv) the use to which the equipment is put - continuous, intermittent, stand-by, or emergency;
v) practical or operational restrictions, e.g. maintenance that can be performed only in dry-dock;
vi) intervals specified as part of class, convention, administration and company requirements;
vii) the need for regular testing of standby arrangements.

Inspections

Procedures for planned inspection routines should be written to include the following:

i) acceptance criteria (e.g. pass/fail, tolerances);
ii) the use of suitable measuring and testing equipment of the required accuracy;
iii) the calibration of the measuring and testing equipment to the appropriate standards.

Inspections

...

ii) vibration

No. 74 (cont)

The following are examples of the types of inspection and test that may be employed:

i) visual
ii) vibration
iii) pressure
iv) temperature
v) electrical
vi) load
vii) water tightness

Why to have CM program?

According ISO 13373-1:2002:

Vibration condition monitoring can provide information for the following purposes:

- to increase equipment protection;
- to improve safety for personnel;
- to improve maintenance procedures;
- to detect problems early;
- to avoid catastrophic failures;
- to extend equipment life;
- to enhance operations.

The operational manager needs

Tell me:

- Which machines are not OK?
- What I need to do, and how urgent is it?

ACT ON TIME

The maintenance manager needs

Tell me:

- Which equipment does need to be repaired, the electric motor or the pump?
- What is the reason this fault to appear?

REPAIR QUICKLY

How many successful CBM implementations have you seen?



My experience is 1 out of 10 is truly successful, 3 out of 10 are relatively successful, and the rest pretend to have CBM.

Why did the CBM fail?

My top five reasons are:

- Implementation
- Factory Management
- Maintenance culture
- CM service and product companies
- Complexity of the existing technology

Creating a company's CBM standard (CBM Handbook)

Have you heard one of these questions:

- What is the benefit of having CBM?
- How much money do we spend on CM?
- Should we continue to follow the CM schedule, all our machines are good?
- Why did the machine in the CM scope fail?

Why do we need a CBM Handbook?

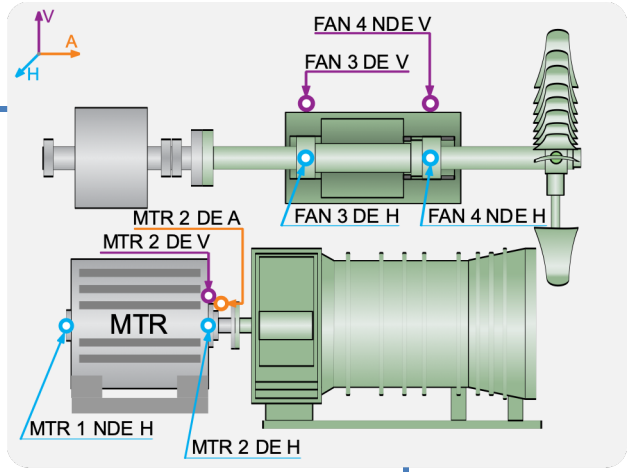
The CBM Handbook:

- Documents the CM program
- Provides rules to control
- Sustain the CM and CBM during the changes in the company

The CBM Handbook – Starting point

- Collect
- Transfer
- Store

DATA



- Machine Status
- Discovered Faults
- Recommendations to mitigate the risk of machine to fail.

DATA ANALYSIS

- Accept / Reject recommendations
- Create notifications in CMMS
- Plan and execute

MAINTENANCE

FEEDBACK

- Recommendation's status
- Findings

How to create the CBM Handbook?

Lessons from experience:

- The CBM Handbook is a set of documents.
- It should give answers to all questions about CM program, and the link to CMSS.
- Create responsibilities around roles, not around people.
- Put yourself in the shoes of freshmen. Think, if you start a new job, what you want to find as information, what is going to help you.
- Classification Societies rules are a good starting point

The CBM Handbook

2.2 Approval of condition monitoring programme

The applicable programme shall be approved for each individual vessel and shall be prepared by the manager. It shall contain (but is not limited to) the following information:

- all machinery/components to be monitored
- component information and CM contributing parameter(s) (e.g. forcing frequencies for vibration monitoring)
- measurement method(s)
- measurement points (drawings, sketches & unique marking)
- sampling points (drawings & unique marking)
- all applicable equipment used for monitoring purposes, including installation diagrams
- how and when baseline data is obtained
- reference conditions/values
- measurement/sampling intervals
- warning- and alarm levels
- work procedure(s) for all relevant CM tasks
- analysis responsibilities
- follow up of analysis results - responsibilities

3 Vessel approval

The vessel approval shall verify that the CM programme is implemented onboard a dedicated vessel successfully. It shall be carried out for each individual vessel of an approved manager. After a successful vessel approval the applicable initial survey can be requested.

The CBM Handbook

- Document the scope
- CM techniques
- CM Points
- Data collection (inspection) schedule
- Connection to the CMMS
- Responsibilities
- KPIs

Ship CM program handbook

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Example of Ship CBM Handbook

The CBM Handbook - The Scope

Which machines do we need to monitor?

Criteria for including in the scope:

- Criticality to the process
- Criticality to safety
- Probability of failing
- Time for repair

The CBM Handbook - The Scope

40-60%

Between 40% to 60% of all rotating equipment should be in the scope of CM program.

The CBM Handbook - The Scope

Example 1: Tanker fleet with an average of 120 rotating machines on board:

- 18% High Critical – OEM & CBM
- 47% Medium Critical – Only CBM
- *35% Low Critical – Only Watchkeeping, no CM*

Example 2: Site with an average of 465 rotating machines:

- 44.5% (207) machines are in CBM scheme

The CBM Handbook – Inspection Intervals

How often to collect data?

Advice about establishing aa data collection plan:

- The data collection (vibration inspection) intervals need to be part of the PMS (planned maintenance system)
- Recommended data collection intervals: 1M, 2M or 3M
- Use the RoF index to define data collection intervals.
- Start with monthly data collection and adjust after six months.
- Data collection intervals can vary from the intervals in the PMS for the time being, from the time when the fault appears to when it disappears.
- Data collection intervals of 6M and above do not make sense for vibration data.
- Calculate the time required for data collection to adjust the inspection plan and the necessary resources.

The CBM Handbook - The Scope

Example

Machine	Risk rank	CoF rank	PoF rank
No.1 ME Aux Blower	6 (3x2)	3	2
No.1 Bilge, Fire & GS Pump	4 (2x2)	2	2

RoF	In the scope of CM program	
Low (≤3)	Medium (3-6)	High (≥ 6)

Machine	RoF	Vibration data collection interval	Note
Accommodation A/C Compressor	Medium	2M	
Aft Power Pack Pump	Medium	2M	
Air Conditioning Hot Water Reheat Pumps	Low	6M	Excluded from the CM program
Central Cooling FW Pumps	High	1M	

CoF – Consequence of failure; PoF – probability of failure; RoF – Risk of Failure

all machinery/components to be monitored

The CBM Handbook - CM techniques

Monitoring data sources:

- Human Senses
- Performance
- Corrosion
- Motor Current
- Thermal
- Tribology (Lubrication)
- Acoustic Emission
- Ultrasonic
- Vibrations

- ○ Well known process available data, one scalar value (parameters), trend and limits, well define by OEMs.
- ● Complex data computed from one source . The data require multi-parameter trend analysis, spectral analysis, time waveform analysis.

Table A.1 — Examples of condition monitoring parameters by machine type

Parameter	Machine type								
	Electric motor	Steam turbine	Aero gas turbine	Industrial gas turbine	Pump	Com-pressor	Electric generator	RIC engine	Fan
○ Temperature	•	•	•	•	•	•	•	•	•
Pressure		•	•	•	•	•		•	•
Pressure (head)					•				
Pressure ratio			•	•		•			
Air flow			•	•		•		•	•
Fuel flow			•	•				•	
Fluid flow		•			•	•			
Current	•						•		
Voltage	•						•		
Resistance	•						•		
Input power	•				•	•	•		•
Output power	•	•	•	•			•	•	
○ Noise	•	•	•	•	•	•	•	•	•
● Vibration	•	•	•	•	•	•	•	•	•
● Acoustic techniques	•	•	•	•	•	•	•	•	•
○ Oil pressure	•	•	•	•	•	•	•	•	•
○ Oil consumption	•	•	•	•	•	•	•	•	•
● Oil (tribology)	•	•	•	•	•	•	•	•	•
Torque	•	•		•		•	•	•	
○ Speed	•	•	•	•	•	•	•	•	•
Length		•							
Efficiency (derived)		•	•	•	•	•		•	

• Indicates condition monitoring measurement parameter is applicable.

Source: Appendix A, ISO 17359

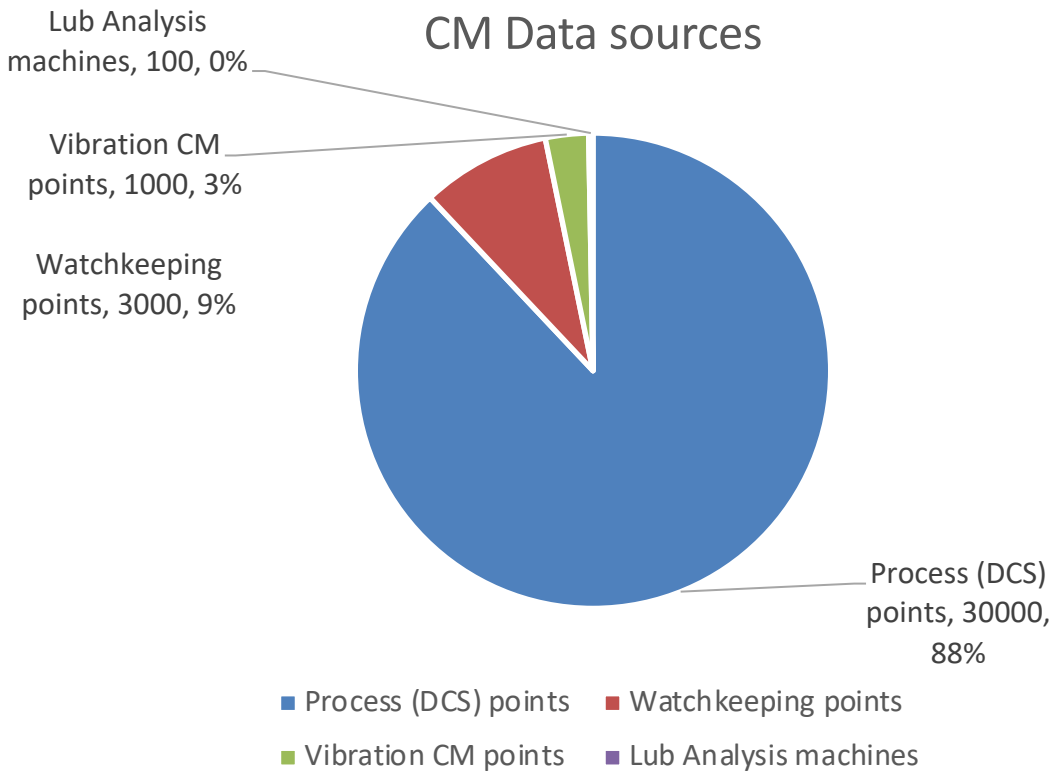
The CBM Handbook - Inspection Plan

Example of an Inspection plan that must be part of the CBM Handbook and integrated in the maintenance management system (PMS, CMMS).

Machine	RoF	Watch Keeping	Performance	VIB	LUB	UT	THERMAL (IR)	MCA	AE
Accommodation A/C Compressor	Medium	24H	1m	2M	6M	2M	6M	1Y	N/A
Aft Power Pack Pump	Medium	24H	12H	2M	N/A	2M	N/A	1Y	N/A
Air Conditioning Hot Water Reheat Pumps	Low	1W	1W	6M	N/A	N/A	N/A	N/A	N/A
Central Cooling FW Pumps	High	12H	1m	1M	N/A	2M	6M	1Y	N/A

measurement method(s)
measurement/sampling intervals

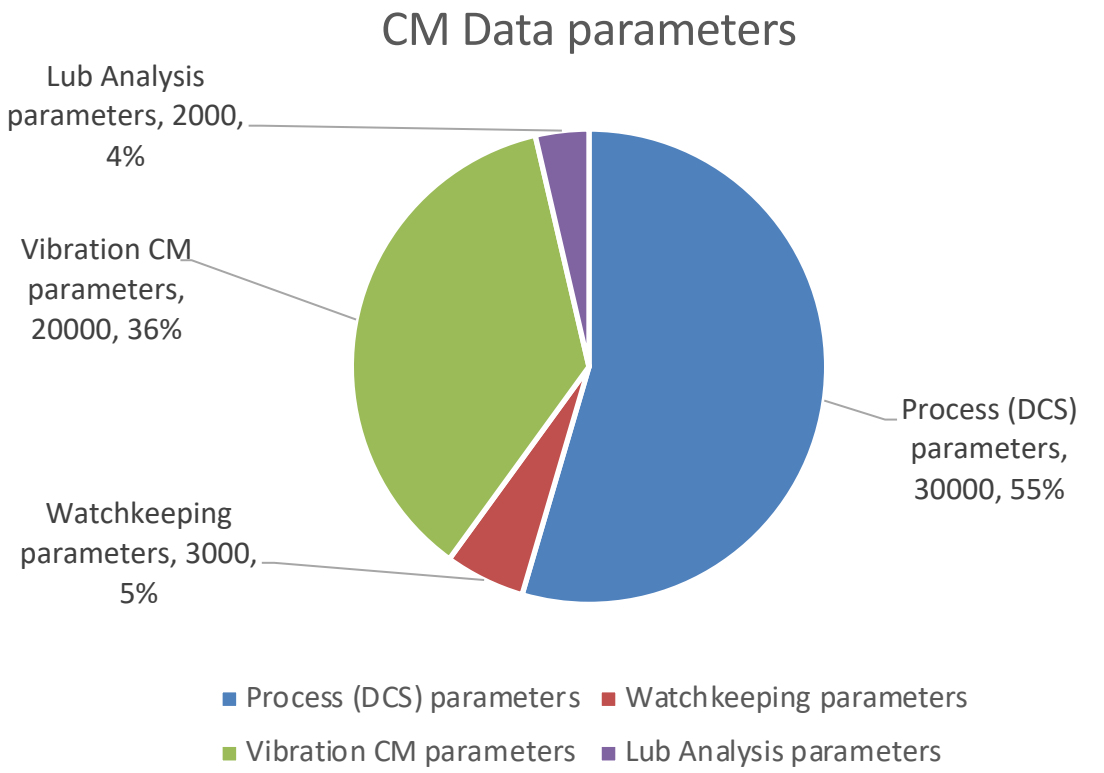
The CBM data - Sources



34 100

Source:
Site with 465 rotating machines (functional locations).
207 (44.5%) are in CM vibration program.

The CBM data - Parameters



55 000

Source:
Site with 465 rotating machines (functional locations).
207 (44.5%) are in CM vibration program.

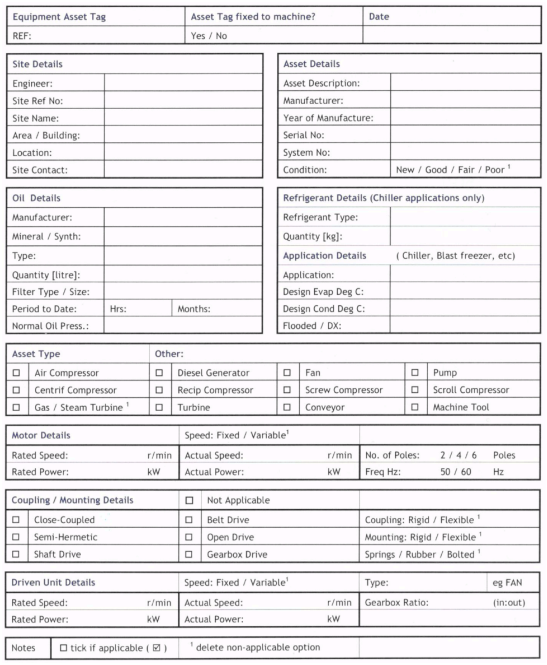
The CBM Handbook – Vibration part

The vibration monitoring is one of the most sophisticated techniques that require special attention due to:

- Data collection must provide reliable data (from the right source, from the same location and secured sensor attachment to the CM Point)
- Data analysis requires certified CM specialists (with valid certification according to ISO 18436-2 and understanding the machines and the maintenance)
- 3% of the CM data sources generate 36% of data to be analyzed

The CBM Handbook - Machine CM Data

It is going to take an enormous amount of time if you use some of the available “Machinery or Asset data sheet” and it will be challenging to analyze the machines CM data.



Equipment Asset Tag	Asset Tag fixed to machine?	Date
REF:	Yes / No	

Site Details		Asset Details	
Engineer:		Asset Description:	
Site Ref No:		Manufacturer:	
Site Name:		Year of Manufacture:	
Area / Building:		Serial No:	
Location:		System No:	
Site Contact:		Condition:	New / Good / Fair / Poor [1]

Oil Details			Refrigerant Details (Chiller applications only)	
Manufacturer:			Refrigerant Type:	
Mineral / Synth:			Quantity [kg]:	
Type:			Application Details	(Chiller, Blast freezer, etc)
Quantity [litre]:			Application:	
Filter Type / Size:			Design Evap Deg C:	
Period to Date:	Hrs:	Months:	Design Cond Deg C:	
Normal Oil Press.:			Flooded / DX:	

Asset Type	Other:						
☐	Air Compressor	☐	Diesel Generator	☐	Fan	☐	Pump
☐	Centrif Compressor	☐	Recip Compressor	☐	Screw Compressor	☐	Scroll Compressor
☐	Gas / Steam Turbine [1]	☐	Turbine	☐	Conveyor	☐	Machine Tool

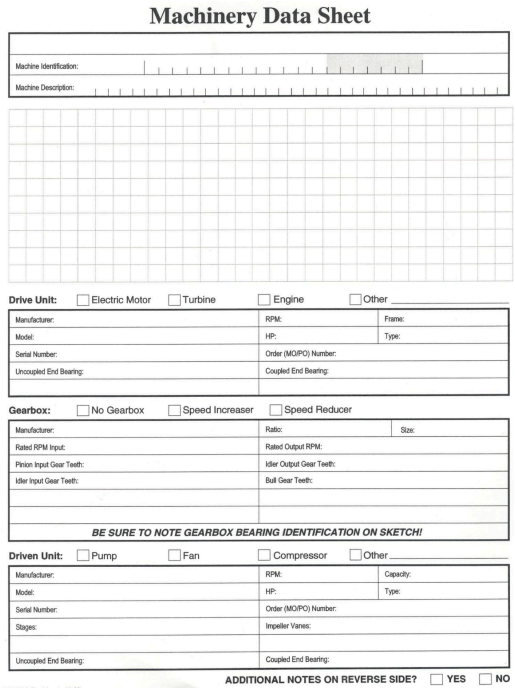
Motor Details		Speed: Fixed / Variable [1]			
Rated Speed:	r/min	Actual Speed:	r/min	No. of Poles: 2 / 4 / 6	Poles
Rated Power:	kW	Actual Power:	kW	Freq Hz: 50 / 60	Hz

Coupling / Mounting Details		☐	Not Applicable	
☐	Close-Coupled	☐	Belt Drive	Coupling: Rigid / Flexible [1]
☐	Semi-Hermetic	☐	Open Drive	Mounting: Rigid / Flexible [1]
☐	Shaft Drive	☐	Gearbox Drive	Springs / Rubber / Bolted [1]

Driven Unit Details		Speed: Fixed / Variable [1]		Type:	eg FAN
Rated Speed:	r/min	Actual Speed:	r/min	Gearbox Ratio:	(in:out)
Rated Power:	kW	Actual Power:	kW		

Notes	☐ tick if applicable (☑)	[1] delete non-applicable option

Vibration Monitoring and Analysis Handbook, BINDT



Machinery Data Sheet

Machine Identification:

Machine Description:

Drive Unit: ☐ Electric Motor ☐ Turbine ☐ Engine ☐ Other

Manufacturer:	RPM:	Frame:
Model:	HP:	Type:
Serial Number:	Order (MO/PO) Number:	
Uncoupled End Bearing:	Coupled End Bearing:	

Gearbox: ☐ No Gearbox ☐ Speed Increaser ☐ Speed Reducer

Manufacturer:	Ratio:	Size:
Rated RPM Input:	Rated Output RPM:	
Pinion Input Gear Teeth:	Idler Output Gear Teeth:	
Idler Input Gear Teeth:	Bull Gear Teeth:	

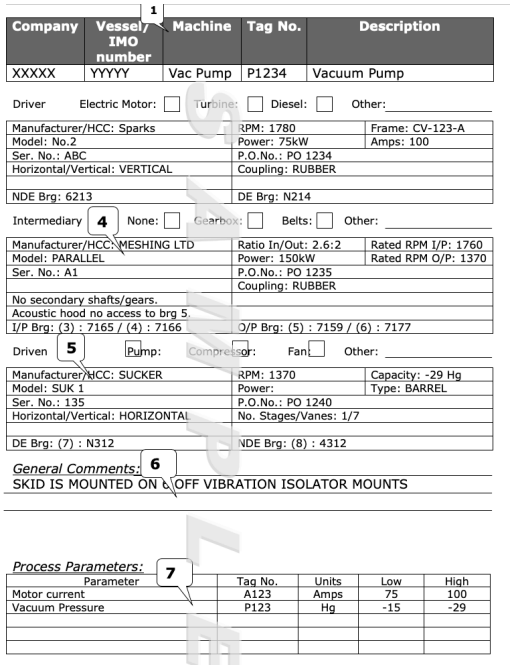
BE SURE TO NOTE GEARBOX BEARING IDENTIFICATION ON SKETCH!

Driven Unit: ☐ Pump ☐ Fan ☐ Compressor ☐ Other

Manufacturer:	RPM:	Capacity:
Model:	HP:	Type:
Serial Number:	Order (MO/PO) Number:	
Stages:	Impeller Vanes:	
Uncoupled End Bearing:	Coupled End Bearing:	

ADDITIONAL NOTES ON REVERSE SIDE? ☐ YES ☐ NO

SKF Condition monitoring Machinery Data Sheet



1 Company	Vessel IMO number	Machine	Tag No.	Description
XXXXX	YYYYY	Vac Pump	P1234	Vacuum Pump

Driver Electric Motor: ☐ Turbine: ☐ Diesel: ☐ Other: _____

Manufacturer/HCC: Sparks	RPM: 1780	Frame: CV-123-A
Model: No.2	Power: 75kW	Amps: 100
Ser. No.: ABC	P.O.No.: PO 1234	
Horizontal/Vertical: VERTICAL	Coupling: RUBBER	
NDE Brg: 6213	DE Brg: N214	

Intermediary 4 None: ☐ Gearbox: ☐ Belts: ☐ Other: _____

Manufacturer/HCC: MESHING LTD	Ratio In/Out: 2.6:2	Rated RPM I/P: 1760
Model: PARALLEL	Power: 150kW	Rated RPM O/P: 1370
Ser. No.: A1	P.O.No.: PO 1235	
	Coupling: RUBBER	
No secondary shafts/gears.		
Acoustic hood no access to brg 5		
I/P Brg: (3) : 7165 / (4) : 7166	O/P Brg: (5) : 7159 / (6) : 7177	

Driven 5 Pump: ☐ Compressor: ☐ Fan: ☐ Other: _____

Manufacturer/HCC: SUCKER	RPM: 1370	Capacity: -29 Hg
Model: SUK 1	Power:	Type: BARREL
Ser. No.: 135	P.O.No.: PO 1240	
Horizontal/Vertical: HORIZONTAL	No. Stages/Vanes: 1/7	
DE Brg: (7) : N312	NDE Brg: (8) : 4312	

General Comments: 6

SKID IS MOUNTED ON RUBBER OFF VIBRATION ISOLATOR MOUNTS

Process Parameters: 7

Parameter	Tag No.	Units	Low	High
Motor current	A123	Amps	75	100
Vacuum Pressure	P123	Hg	-15	-29

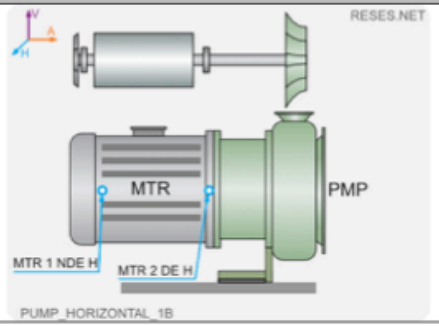
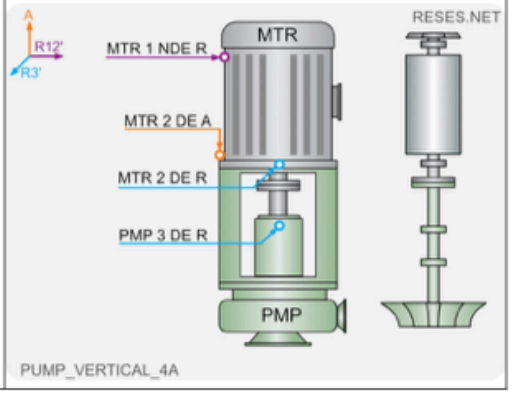
Machinery Data Sheet modification for Marine Industry

The CBM Handbook - Machine CM Data

Advice: Be agile

- Collect first the machinery data that is easy to find and will allow configuring your CM database correctly. (Speed, Power and Machine type/arrangement).
- Use machine templates to define the number of CM points and their locations on the machines.
- During installation of the studs collect nameplate data
- Systemize the machine CM data

The CBM Handbook - Machine CM Data

FL ID	Description	Photos	RPM	KW	RQ-S	FLs	RQs	Cat	Model ID
BW Discharge PUMP 1 AM_0008344 **BW Discharge PUMP 2** AM_0008345	Black water pumps Compartment 09 Accessibility: High MTR: VEM KPER 132 PMP: Herborner 7.5/ HK80-1-130-F-W1		3460	6.6	2	2	4	Shor t	
FIRE PUMP 1 Motor AM_0009286 PP AM_0009286	Fire pump Compartment 10 Accessibility: High MTR: VEM K11R 315S NDE: Q 316 M C3 DE: 6317 M C3 PMP: Behrens VNF 5/420		1785	110	4	1	4	Avg	

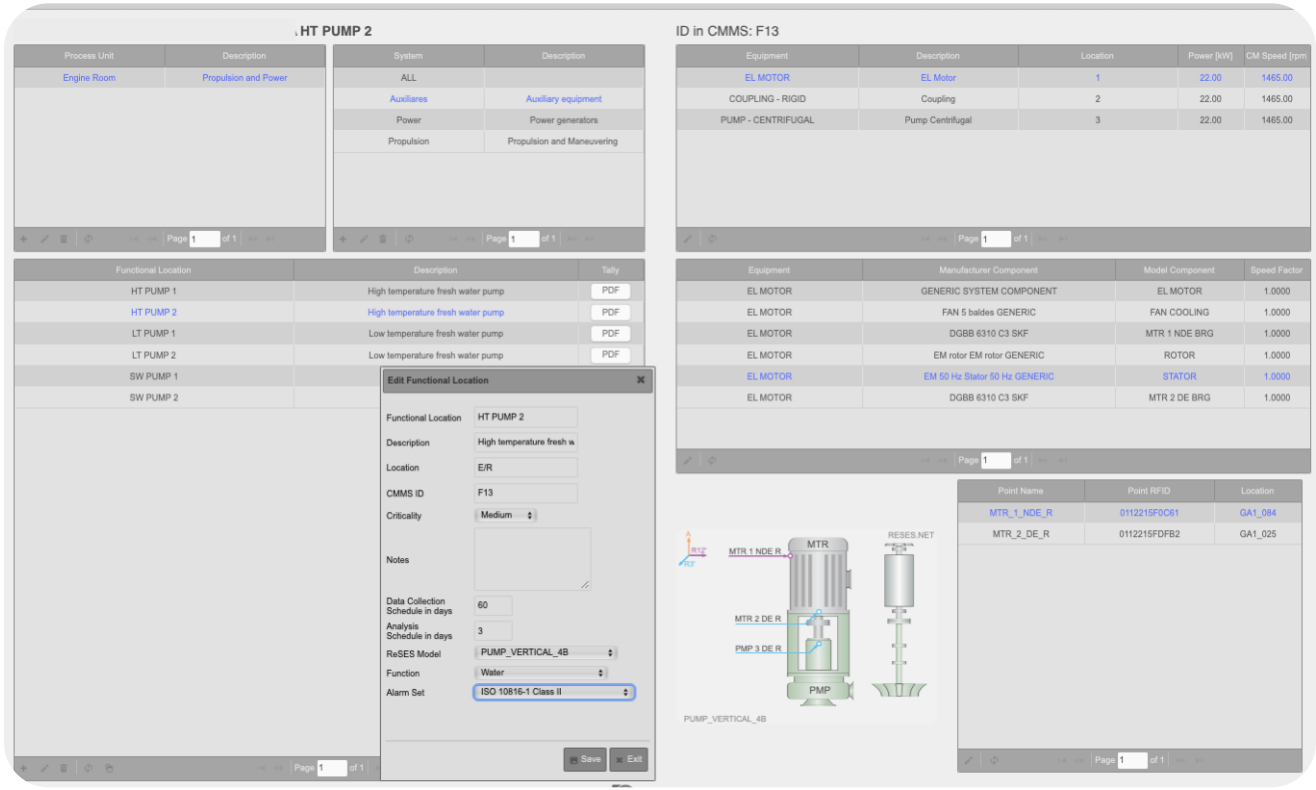
Source: Relianeering AB form, Cruise vessel CM Handbook appendix, First Draft

First draft: Machine Name & Type, Speed, Power, CM Points. Equipment type and manufacturers, bearings, gear teeth, impeller vanes/blades etc.

Building CM DB

Building the CM DB follow the rules:

- Have a consistent and easy to navigate the site's hierarchy.
- Use the same taxonomy as CMMS.
- Store your Inspection plan, as a data collection schedule.
- CM Points names should bring information and match the machine CM scheme.
- Store machinery data that are useful for the analysis process.



Source: ReSES.net, Functional location (machine) CM data setup

Building CM DB – Initial Alarm levels

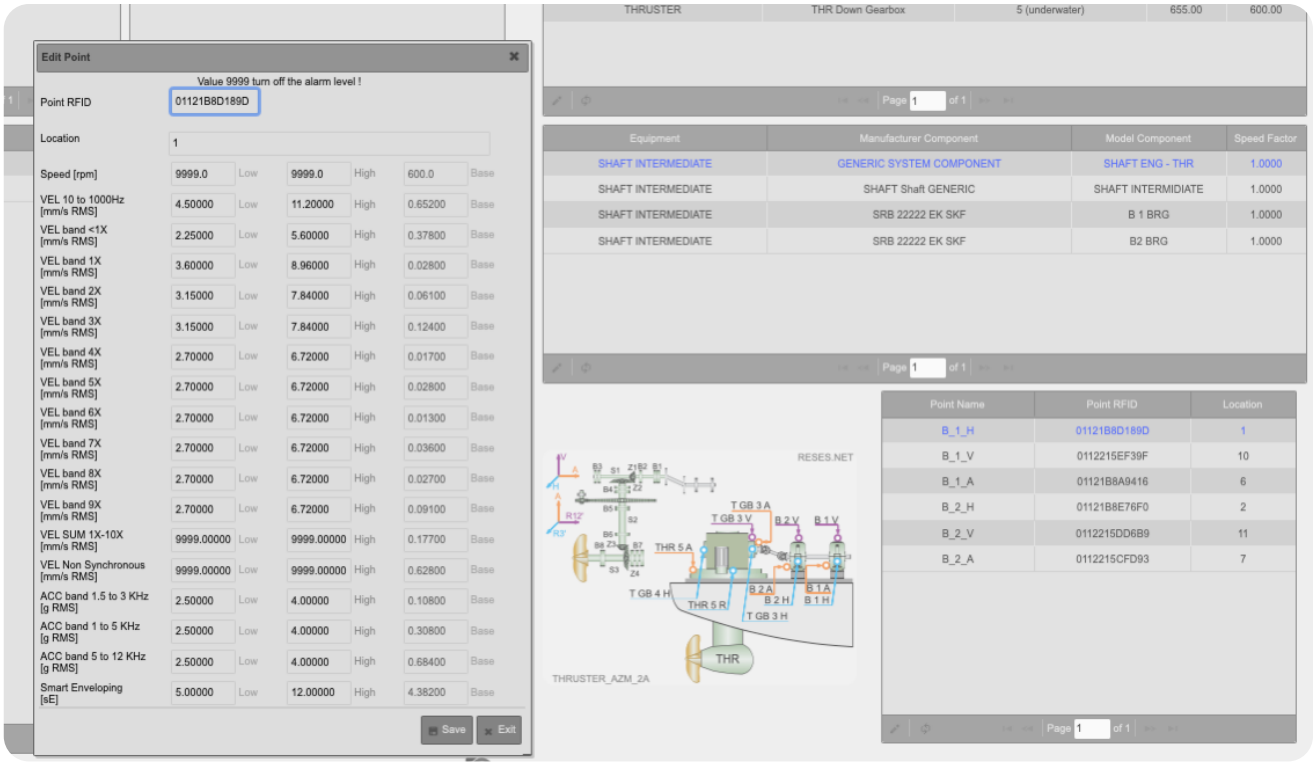
Initial alarms and baseline setup rules:

- The purpose of the alarm levels is to trigger attention of the CM specialist.
- Prepare alarm sets based on OEM, ISO, or other organization standards.
- Define deviation alarms from the Baseline readings and the previous readings. Over time the statistical alarms become most useful.
- Describe the operating regimes for data collection and alarm sets. Example: Load above 75%, speed between 900-1100 rpm.
- Adjust the alarm levels after a certain period and after repair of the machine.
- The Baseline should be reset whenever a machine's component or equipment is changed, or the normal operating regime is modified.

how and when baseline data is obtained reference conditions/ values

Building CM DB – Initial Alarm levels

Initial alarms and baselines must be documented in the CM SW



warning- and alarm levels

ReliReSES.net, Propulsion thruster CM Point alarm set

The CBM Handbook - Machine CM Data

component information and CM contributing parameters

Using proper tools you will:

- Know machine components.
- Have fault frequencies.
- Know the missing data.
- Do more accurate analysis.

Components - all	2346
Unknown	505 (22%)
Rolling bearings	1015 (43%)
Unknow rolling bearings	96 (9.5%)

EqID	Process Unit	System	FL Name	FL CMMS ID	Equipment Name	EQ CMMS ID	Comnent Type name	Component Type	Speed Factor	Component Name	Component Designation	Component Manufacturer	Freq. 1	Freq. 2	Freq. 3	Freq. 4	Freq. 5
226	1	01HCC	01HCC01AP001	01HCC01AP001	EL MOTOR		EL MOTOR	GENERIC	1.0000	GENERIC	SYSTEM	COMPONENT	1.0000	2.0000	3.0000	4.0000	0.5000
226	1	01HCC	01HCC01AP001	01HCC01AP001	EL MOTOR		COOLING FAN	Impeller	1.0000	FAN	9 blades	GENERIC	9.0000	18.0000	21.0000	1.0000	0.0000
226	1	01HCC	01HCC01AP001	01HCC01AP001	EL MOTOR		MTR 1 NDE BRG	Bearing Rolling (Anti-friction)	1.0000	DGBB	6313 C3	SKF	0.3838	2.0361	3.0708	4.9292	4.0722
226	1	01HCC	01HCC01AP001	01HCC01AP001	EL MOTOR		ROTOR	EM Rotor	1.0000	EM rotor	EM rotor	GENERIC	1.0000	2.0000	0.0000	0.0000	0.0000
226	1	01HCC	01HCC01AP001	01HCC01AP001	EL MOTOR		STATOR	EM Stator	1.0000	EM 50 Hz	Stator 50 Hz	GENERIC	-50.0000	-100.0000	-200.0000	-300.0000	-116.6670
226	1	01HCC	01HCC01AP001	01HCC01AP001	EL MOTOR		MTR 2 DE BRG	Bearing Rolling (Anti-friction)	1.0000	DGBB	6313 C3	SKF	0.3838	2.0361	3.0708	4.9292	4.0722
227	1	01HCC	01HCC01AP001	01HCC01AP001	COUPLING		GENERIC COUPLING	GENERIC	1.0000	GENERIC	SYSTEM	COMPONENT	1.0000	2.0000	3.0000	4.0000	0.5000
227	1	01HCC	01HCC01AP001	01HCC01AP001	COUPLING		COUPLNG	Coupling	1.0000								
228	1	01HCC	01HCC01AP001	01HCC01AP001	PUMP - CENTRIFUGAL		PMP CENTR MULTI ST/	GENERIC	1.0000	GENERIC	SYSTEM	COMPONENT	1.0000	2.0000	3.0000	4.0000	0.5000
228	1	01HCC	01HCC01AP001	01HCC01AP001	PUMP - CENTRIFUGAL		PMP SHAFT	Shaft	1.0000	SHAFT	Shaft	GENERIC	1.0000	2.0000	3.0000	1.5000	0.5000
228	1	01HCC	01HCC01AP001	01HCC01AP001	PUMP - CENTRIFUGAL		PMP 3 DE BRG	Bearing Rolling (Anti-friction)	1.0000	DGBB	6308-2Z	SKF	0.3840	2.0390	3.0719	4.9218	4.0780
228	1	01HCC	01HCC01AP001	01HCC01AP001	PUMP - CENTRIFUGAL		PMP IMPELLERS	Impeller	1.0000								
228	1	01HCC	01HCC01AP001	01HCC01AP001	PUMP - CENTRIFUGAL		PMP 4 NDE BRG	Bearing Rolling (Anti-friction)	1.0000	DGBB	6308-2Z	SKF	0.3840	2.0390	3.0719	4.9218	4.0780

Source: ReSES.net, Components data export

The CBM Handbook - CM Points

measurement points (drawings, sketches & unique marking)

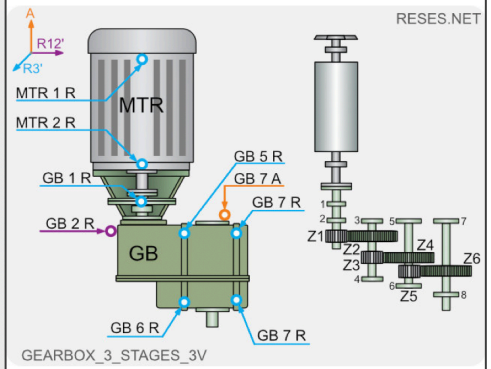
Advice: Use studs and CM point tagging

Document the location of the CM Points.
Have an instructions for studs installation and replacing.



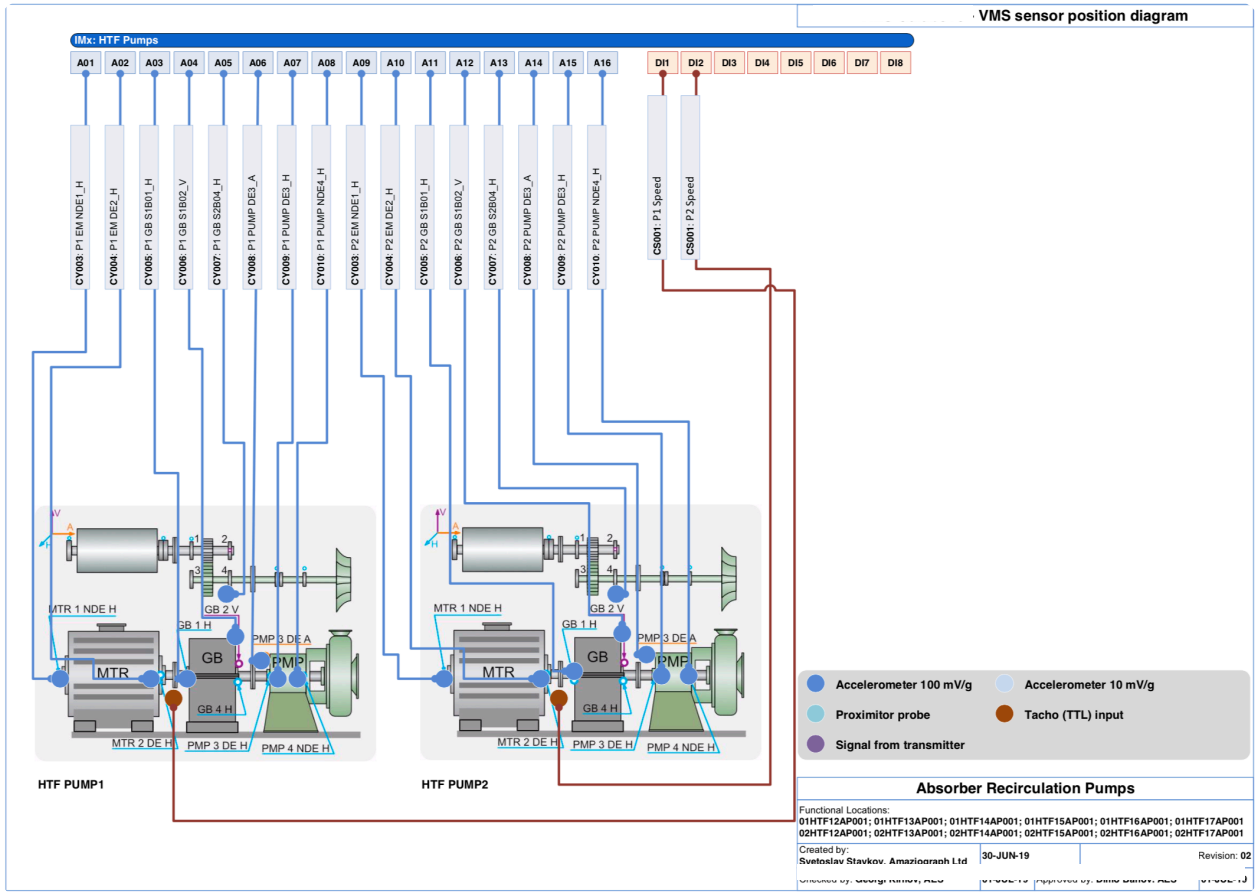


CM program | FLs (KKS) and CM Points | Page 5 of 13

FL ID	Description	Photos	Model ID
01HLD10AE001 01HLD10AE002 02HLD10AE001 02HLD10AE002	Motor-Gearbox 1-2 RB		

Source: Amaziograph Ltd, CM Handbook, CM Points location appendix

The CBM Handbook - CM Points





all applicable equipment used for monitoring purposes, including installation diagrams

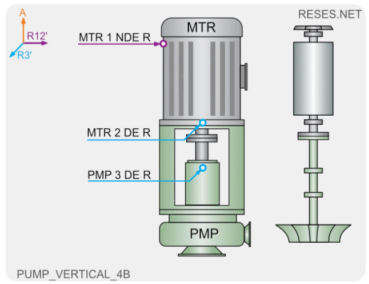
Source: Amaziograph Ltd, TPP absorber recirculation pumps online vibration monitoring system drawings

Document the location of the CM Points of your online system.

The CBM Handbook

- all machinery/components to be monitored
- component information and CM contributing parameter(s) (e.g. forcing frequencies for vibration
  monitoring)
- measurement method(s)
- measurement points (drawings, sketches & unique marking)
- sampling points (drawings & unique marking)
- all applicable equipment used for monitoring purposes, including installation diagrams
- how and when baseline data is obtained
- reference conditions/values
- measurement/sampling intervals
- warning- and alarm levels
- work procedure(s) for all relevant CM tasks
- analysis responsibilities
- follow up of analysis results - responsibilities

Source: DNVGL-CG-0052, Survey arrangement for machinery condition monitoring

Engine Room Auxiliares / HT PUMP 1	CM Point	Cup ID	RFID tag
	MTR_1_NDE_R MTR_2_DE_R PMP_3_DE_R	GA1_083 GA1_023 GA1_024	0112215E6408 011221601A48 011221609ECC

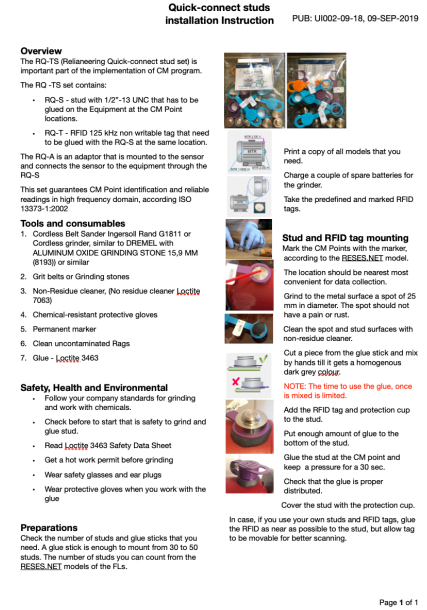
Source: ReSES.net PDF export, Machine CM Points ID label

The CBM Handbook – Work procedures

The minimum work instructions:

- Data Collection
- Data Transfer
- Data Backup
- CM Points installation
- Tools and sensors calibration

work procedure(s) for all relevant CM tasks



Quick-connect studs installation Instruction PUB: UI002-09-18, 09-SEP-2019

Overview
The RQ-TS (Relaneering Quick-connect stud set) is important part of the implementation of CM program.

The RQ -TS set contains:

- RQ-S - stud with 1/2"-13 UNC that has to be glued on the Equipment at the CM Point locations.
- RQ-T - RFID 125 kHz non writable tag that need to be glued with the RQ-S at the same location.

The RQ-A is an adaptor that is mounted to the sensor and connects the sensor to the equipment through the RQ-S

This set guarantees CM Point identification and reliable readings in high frequency domain, according ISO 13373-1:2002

Tools and consumables
1. Cordless Belt Sander Ingersoll Rand G1811 or Cordless grinder, similar to DREMEL with ALUMINUM OXIDE GRINDING STONE 15,9 MM (8193)) or similar
2. Grit belts or Grinding stones
3. Non-Residue cleaner, (No residue cleaner Loctite 7063)
4. Chemical-resistant protective gloves
5. Permanent marker
6. Clean uncontaminated Rags
7. Glue - Loctite 3463

Safety, Health and Environmental
- Follow your company standards for grinding and work with chemicals.
- Check before to start that is safety to grind and glue stud.
- Read Loctite 3463 Safety Data Sheet
- Get a hot work permit before grinding
- Wear safety glasses and ear plugs
- Wear protective gloves when you work with the glue

Preparations
Check the number of studs and glue sticks that you need. A glue stick is enough to mount from 30 to 50 studs. The number of studs you can count from the RESES.NET models of the FLs.

Print a copy of all models that you need.

Charge a couple of spare batteries for the grinder.

Take the predefined and marked RFID tags.

Stud and RFID tag mounting
Mark the CM Points with the marker, according to the RESES.NET model.

The location should be nearest most convenient for data collection.

Grind to the metal surface a spot of 25 mm in diameter. The spot should not have a pain or rust.

Clean the spot and stud surfaces with non-residue cleaner.

Cut a piece from the glue stick and mix by hands till it gets a homogenous dark grey colour.

NOTE: The time to use the glue, once is mixed is limited.

Add the RFID tag and protection cup to the stud.

Put enough amount of glue to the bottom of the stud.

Glue the stud at the CM point and keep a pressure for a 30 sec.

Check that the glue is proper distributed.

Cover the stud with the protection cup.

In case, if you use your own studs and RFID tags, glue the RFID as near as possible to the stud, but allow tag to be movable for better scanning.

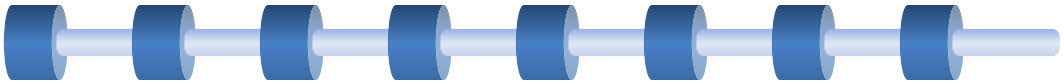
Page 1 of 1

Source: Amaziograph Ltd, Power plant CBM Handbook Work instructions

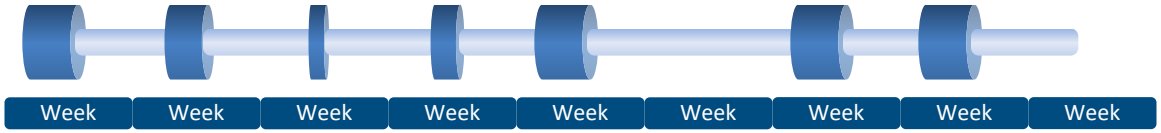
The CBM Handbook – Work procedures

Data collection Routes:

- Static Routes – mostly for watchkeeping data
  - Fixed data collection schedule: Every shift, Every week etc.



- Dynamic Routes – suitable for vibration data
  - Driven by last data collection date and interval
  - List of CM tasks for the week



The CBM Handbook – Dynamic Route

Process Unit	FL Name	Location	Due in days	Number of points
01	01ETP01AN002	L1	-35d	10
01	01HCC01AP001	L2	-2d	7
01	01HFC20AJ001	L3	-5d	6
01	01HFC20AJ002	L3	-5d	4
01	01HFC20AS001	L3	-5d	5
01	01HFC60AJ001	L3	1d	6
01	01HTF10AM001	L9	2d	4
01	01HTF10AM002	L9	2d	4
01	01HTF10AM003	L9	2d	4
01	01HTF10AM004	L9	3d	4
01	01HTF10AM005	L9	3d	4
01	01LCM10AP001	L1-1	-32d	7

Site: XYZ
Period: October,07 +7 days
Summary for the week:

- You have to collect 70 Functional Locations
- In total there are 391 CM Points
- Estimated time for data collection 05:00 h

Source: ReSES.net, Data Collection Remainder e-mail

The CBM Handbook – Work procedures

Providing information:

- Less is More:
  - Machine Status
  - Discovered Faults
  - Recommendations
- Consider:
  - Using catalogues for faults and recommendations
  - Always to provide recommendations for machines with bad status

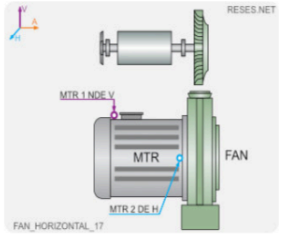
FUNCTIONAL LOCATION CM STATUS REPORT

Company	Site
p	åd

Process Unit	System	Functional Location	Description	CMMS ID
282	049	U3-F1	Cirkulationsfläkt	

Analysed on	CM Status	Analysed by
2019-05-05 15:53:22	ATENTION	S.Staykov

Equipment	CM Status	CMMS ID
EL MOTOR	ATENTION	
FAN - CENTRIFUGAL	GOOD	



Equipment	Component	Fault	Sev	Recommended Action	Pri
EL MOTOR	MTR 2 DE BRG	Bearing - Lubrication fault - High sE with spectrum typical for lubrication fault.	Med	Replace - Plan to replace the bearing.	Med
EL MOTOR	MTR 1 NDE BRG	Bearing- Rolling bearing fault - sE spectrum with peaks wit harmonics. Could be bearing fault signature.	Low	Other - Confirm the bearing designation and manufacturer.	Low

CM STATUS REPORT Page 1 of 1

Source: ReSES.net, Automatically generated report

The CBM Handbook - Responsibilities

One of the most important parts of the CM program.

It is very important to clarify the process from data, through information to maintenance actions and providing feedback:

- Who does Data Collection?
- Who does Data Analysis?
- Who does a review of the Analysis?
- Who does use the Analysis results?
- Who does control execution of CBM triggered maintenance actions?

The CBM Handbook - Responsibilities



Document in a simple way Roles and Responsibilities and connect to real people:

Activity	Role in the Site	Person / Company	Contact
Watchkeeping Data Collection	Operators	Shift Leader	Senior.operator@abcd.com (+1 73737638)
Vibration Data Collection	Operators	Team Leader	Supervisor.operator@abcd.com (+1 73737638)
Oil samples	Maintenance technician	Tech One	Tech.one@abcd.com (+1 73737638)
Vibration analysis	CM Specialist	Como One	Como.one@abcd.com (+1 73737638)
Lubrication Analysis	External	Lube Prediction	support@lubepredict.com (+1 12345678)
Review results and issue CMMS notifications	Unit 1 Maintenance manger	Maint Man	Maint.man@abcd.com (+1 73737638)
Provide Feedback to CM Specialists	Maintenance technician Operators		

The CBM Handbook – Mission completed

- Collect
- Send
- Store

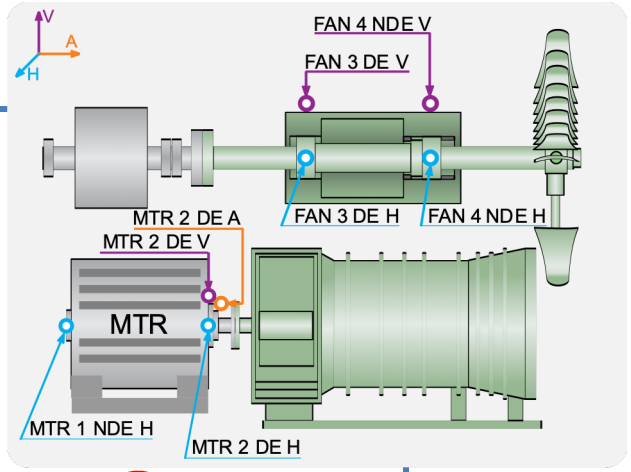
DATA

- Machine Status
- Discovered Faults
- Recommendations to mitigate the risk of machine to fail.

DATA ANALYSIS

- Accept / Reject recommendations
- Create notifications in CMMS
- Plan and execute

MAINTENANCE



Ready to ACT ON TIME

FEEDBACK

- Recommendation's status
- Findings

CM program outsourcing

Why to outsource the CM program?

- Better ROI
- Flexibility

What to outsource from the CM program?

- Data Analysis
- Data Storage

Requirements to CM suppliers

Challenges when you outsource the CM program:

- **Select a CM platform:** CM platform that will allow switching quickly from one to another CM Supplier
- **Find a reliable CM Supplier:** There is no certification process for CM Suppliers that work offshore.
- **Organize data collection:** Technology that allows easy and reliable data collection from people with no experience.
- **Integrate the recommendations into CMMS:** Create a culture and habits the responsible roles in turning recommendations into actions.

Requirements to CM suppliers

DNV·GL

CLASS PROGRAMME

DNVGL-CP-0484 Edition March 2018

DNV GL approval of service supplier scheme

Companies **providing condition monitoring** services of machinery and equipment, in order to offer an **alternative to calendar based renewal surveys**, shall be approved by the Society.

Appendix B

5 Service suppliers firms engaged in condition monitoring of machinery on board ships and mobile offshore units

5.1 General

5.1.1 Scope

Companies providing condition monitoring services of machinery and equipment, in order to offer an alternative to calendar based renewal surveys, shall be approved by the Society. The companies shall be approved in accordance with this programme and applicable DNV GL rules. In the following, such companies are referred to as the supplier.

5.1.2 Objective

The objective of this approval programme is to ensure that the supplier of condition monitoring services is using appropriate procedures, has qualified and certified personnel and has implemented written procedures for training, performance, application, control, verification and reporting.

5.1.3 Extent of approval

The approval programme defines the requirements for obtaining the Society's approval for carrying out condition monitoring of machinery and equipment, normally subject to renewal and annual survey on vessels classed by the Society.

Condition monitoring of machinery and equipment is in this program limited to the following standardised methods:

— vibration condition and diagnostics
— lubricant analysis (oil).

5.1.4 References

DNVGL-RU-OU-0101	=	Rules for classification of offshore drilling and support units
DNVGL-RU-OU-0102	=	Rules for classification of floating production, storage and loading units
DNVGL-RU-OU-0103	=	Rules for classification of floating LNG/LPG production, storage and loading units
DNVGL-RU-SHIP Pt.7	=	Rules for classification of ships, Part 7
ISO 17359	=	*Condition monitoring and diagnostics of machines - General guidelines*
ISO 13379-1	=	*Condition monitoring and diagnostics of machines- Data interpretations and diagnostics techniques*
ISO 13372	=	*Condition monitoring and diagnostics of machines - Vocabulary*
ISO 18436-2	=	*Condition monitoring and diagnostics of machines - Requirements for training and certification of personnel* - Part 2: *Vibration condition monitoring and diagnostics.*
ISO 18436-4	=	Condition monitoring and diagnostics of machines - Requirements for qualification and assessment of personnel - Part 4: Field lubricant analysis
ISO 18436-5	=	Condition monitoring and diagnostics of machines - Requirements for qualification and assessment of personnel - Part 5: Lubricant laboratory technician/analyst
ISO 9000 series	=	*Quality management*

Requirements to CM suppliers

- Quality System:
  - Work Procedures:
    - Monitoring methods (Vibration, lubrication, UT, etc.)
    - Data collection and analysis
    - Determine maintenance actions
    - Reporting
  - Audits: Internal and External
  - Training of the personnel
  - Continues improvement
  - Customer support
- CM Specialist Certification
- Supervisor control

Requirements to CM suppliers

Check list for CM suppliers:

- QMS integration of CM process
- Organizational chart
- CM quality manual that describes the system
- Code of conduct for the activity
- Work procedures and instructions:
- Internal Audits
- Preparation, issuance, maintenance and control of documents
- Maintenance and/or calibration of the equipment
- Job preparation (check lists)
- Periodic review of work process procedures
- Corrective and preventive action
- Feed back and continuous improvement (how it is done)
- Handle customer complaints
- Training and certification of condition monitoring personnel
- Records for the CM personnel
- Records for Equipment and Calibrations

Requirements to CM suppliers

Check the supplier's procedure for:

- Setup Maintenance strategy
- Monitoring methods per equipment type
- Alarm criteria
- Condition and acceptable criteria for applicable machinery and equipment
- Collection of sensor data - identification, how to control quality data collection
- Security mechanisms to assure data transfer and storage
- Clearly defined prerequisites, sensibility and performance requirements of algorithms part of any predictive maintenance
- Required Machinery information to perform CM
- Documenting the installation - diagrams, points etc.
- Obtain and use Baseline readings
- Maintenance task in CMMS: measurement, sampling, recordings, recommendations
- Continues improvement
- Communication and reporting between supplier and owner of the machines

Contract Management

Why is the contract management crucial for delivering long term Condition Monitoring services?

- The root cause for cancelation of CM service contracts is a lack of contract management.
- Detects on time deviation from the agreed scope of services.
- Mitigate the risk of for both parties in case of employees and organizational changes

Contract Management

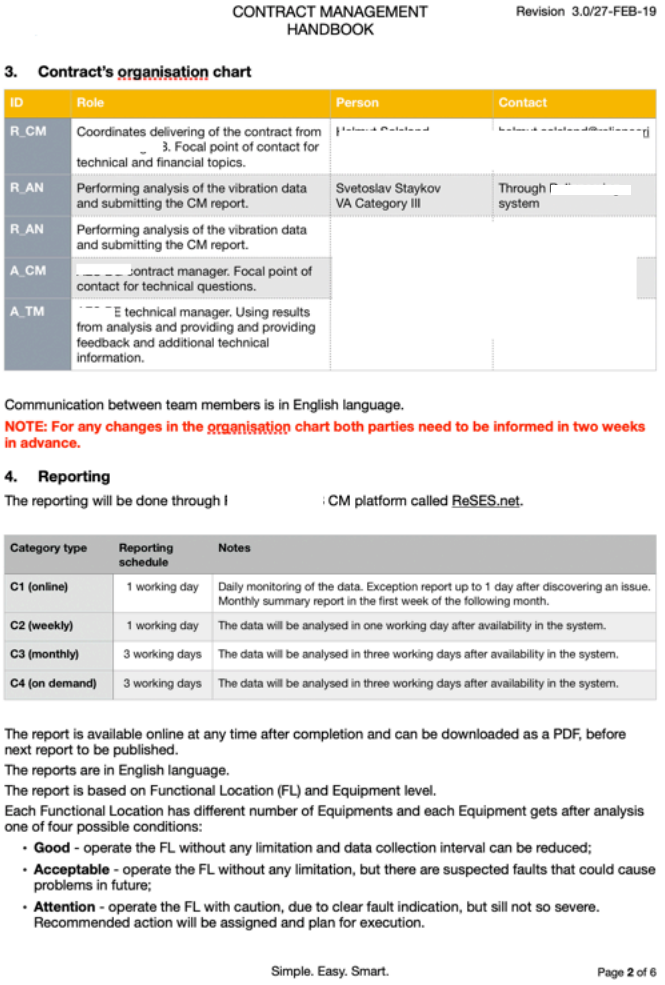
The key factors for success are:

- Proper documented contract management procedures (rules) in a Contract Management handbook.
- Appointed Contract Managers in both companies
- Regular Contract Management review meetings
  - At least every six months, preferably quarterly

Contract Management Handbook

Contract management handbook:

- Overview
- Scope of the contract
- Contract's organization chart
- Reporting and reporting schedule
- Contract Review meetings
- Failure and faults notification
- Data exchange protocol
- Contract invoicing schedule
- Contract's KPIs
- Improvements plan



CONTRACT MANAGEMENT HANDBOOK — Revision 3.0/27-FEB-19

3. Contract's organisation chart

ID	Role	Person	Contact
R_CM	Coordinates delivering of the contract from 3. Focal point of contact for technical and financial topics.		
R_AN	Performing analysis of the vibration data and submitting the CM report.	Svetoslav Staykov VA Category III	Through system
R_AN	Performing analysis of the vibration data and submitting the CM report.		
A_CM	contract manager. Focal point of contact for technical questions.		
A_TM	E technical manager. Using results from analysis and providing and providing feedback and additional technical information.		

Communication between team members is in English language.

NOTE: For any changes in the organisation chart both parties need to be informed in two weeks in advance.

4. Reporting

The reporting will be done through I CM platform called ReSES.net.

Category type	Reporting schedule	Notes
C1 (online)	1 working day	Daily monitoring of the data. Exception report up to 1 day after discovering an issue. Monthly summary report in the first week of the following month.
C2 (weekly)	1 working day	The data will be analysed in one working day after availability in the system.
C3 (monthly)	3 working days	The data will be analysed in three working days after availability in the system.
C4 (on demand)	3 working days	The data will be analysed in three working days after availability in the system.

The report is available online at any time after completion and can be downloaded as a PDF, before next report to be published.

The reports are in English language.

The report is based on Functional Location (FL) and Equipment level.

Each Functional Location has different number of Equipments and each Equipment gets after analysis one of four possible conditions:

- **Good** - operate the FL without any limitation and data collection interval can be reduced;
- **Acceptable** - operate the FL without any limitation, but there are suspected faults that could cause problems in future;
- **Attention** - operate the FL with caution, due to clear fault indication, but sill not so severe. Recommended action will be assigned and plan for execution.

Simple. Easy. Smart. Page 2 of 6

Source: Contract management Handbook

CM Contract KPIs

- Analysis completed on time - **above 90%**
  (CM Supplier responsibility)
- Machines in data collection overdue - **below 10%**
  (Owner responsibility)
- Percentage of wrong diagnoses - **below 2%**
  (CM Supplier responsibility)
- Completeness of required technical data - **above 80%**
  (Owner responsibility)
- Overall user satisfaction - **above Satisfy**

Final Advice

- Design the CBM scheme in a way to achieve "**ACT on TIME**".
- Initial efforts to create the CBM Handbook are foundations of your CBM scheme and success.
- Without well-systemized data, you can't apply Machine Learning afterward.
- Consider CM technology or service supplier carefully.

Simplify the Complexity