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GUIDELINES FOR CONDITION BASED MAINTENANCE

NI684 – JULY 2024

GUIDANCE NOTE

BUREAU VERITAS

BUREAU VERITAS
RULES, RULE NOTES AND GUIDANCE NOTES

NI684 DT R01 July 2024 takes precedence over previous revision.

The PDF electronic version of this document available on the Bureau Veritas Marine & Offshore website https://marine-offshore.bureauveritas.com/ is the official version and shall prevail if there are any inconsistencies between the PDF version and any other available version.

These rules are provided within the scope of the Bureau Veritas Marine & Offshore General Conditions, enclosed at the end of Part A of NR467, Rules for the Classification of Steel Ships. The latest version of these General Conditions is available on the Bureau Veritas Marine & Offshore website.

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NI684

GUIDELINES FOR CONDITION BASED MAINTENANCE

July 2024

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Section 1 General

1 Scope

1.1 Introduction

1.1.1 When maintenance solutions (e.g. based maintenance, condition based maintenance…) are implemented on-board ships for the maintenance of machinery, ship Owners may apply for Planned Maintenance Survey (PMS) as an alternative to Continuous Survey scheme. In that case, Class surveys are no longer based on prescriptive inspection of the machinery, but on the audit of an approved maintenance program instead.

Amongst preventive maintenance strategies, is the Condition Based Maintenance (CBM). The CBM is the action of performing the maintenance of an equipment only when this maintenance is necessary, which mean in practice, to perform the maintenance as governed by the results of a Condition Monitoring System (CMS). Indeed, CMS are systems designed to identify the developing failures of an equipment, and to determine the corresponding maintenance action to be undertaken before this failure occurs.

It should be noted that under the definition “Condition Monitoring System” are gathered a wide variety of solutions, architectures or techniques. These technologies induce additional risks by the use of new methods, infrastructures or operational organization which should be assessed when implementing complex predictive CMS.

1.2 Application

1.2.1 This Guidance Note aims to provide guidelines for the implementation of Condition Based Maintenance (CBM) scheme on-board ships and for design and construction of Condition Monitoring Systems (CMS) under the scope of the following Rule Notes:

a) NR467 Rules for the Classification of Steel Ships; where:
   - Requirements for granting additional service feature **CBM** and **CBM-P** are given in NR467, Pt A, Ch 1, Sec 2, [4].
   - Approval of CBM scheme are given in NR467, Pt A, Ch 2, App 4.

Note 1: These Rules applied only to vessels operating on approved PMS survey scheme.

b) NR674 Approval of Condition Monitoring Systems.

These Rules apply either to new buildings or ships in-service.

1.2.2 This Guidance Note does not cover tailshaft monitoring system. Refer to NR467, Pt F, Ch 5, Sec 2 (**MON-SHAFT** notation).

1.2.3 Cyber security and cyber safety subjects are out of the scope of this document. Refer to NR659 Rules on Cyber Security for the Classification of Marine Units.

1.3 Class notation

1.3.1 In compliance with NR467, Pt A, Ch 2, App 4, and where a Planned Maintenance Survey (PMS) system for machinery is implemented on-board, the additional service feature **[CBM]** is assigned to the ship.

The additional service feature **[CBM]** is replaced by **CBM** when the implementation survey is carried out and found in order as described in NR467, Ch 2, App 4, [3.2].

The notations **[CBM-P]** and **CBM-P** are assigned in lieu of the notations **[CBM]** and **CBM** when the CBM scheme relies on at least one predictive condition monitoring system as defined in [2.2].

The requirements related to surveys for the assignment and maintenance of these additional service features are given in NR467, Pt A, Ch 2, App 4.

The detailed workflow is described in Article [3].

2 Definitions

2.1 General

2.1.1 The following general definitions are used in this Guidance Note:

- CMMS:
  Computerized Maintenance Management System.
- Component:
  Element making up an equipment item (e.g. sensors, transmitters, etc...).
- Condition Based Maintenance (CBM):
  Maintenance performed as governed by condition monitoring.

- Condition Monitoring (CM):

  Acquisition and processing of information and data that indicate the state of a machine over time. The machine state deteriorates if faults or failures occur.

- Equipment items:

  Element making up a system or subsystem, comprised various groups of components.

- Failure:

  Termination of the ability of an item to perform a required function.

- Failure mode:

  Observable manifestation of a system fault.

- Fault:

  Condition of a machine that occurs when one of its components, or assemblies, degrades or exhibits abnormal behavior, which may ultimately lead to the failure of the machine.

- Integrated system:

  System consisting of two or more subsystems having independent functions, connected by a data transmission network, and operated from one or more workstations.

2.2 Condition Monitoring System (CMS)

2.2.1 Condition Monitoring Systems (CMS) are computer based system or operational procedures designed to perform condition monitoring while providing an equivalent or a greater degree of confidence in the condition of the machinery than traditional survey techniques. A CMS generally consists of the following main functions (see Fig 1):

- Data Acquisition (DA):

  Provide the capability to collect data, generally from sensors.

- Data Processing (DP):

  Provide the capability to manipulate the data to a desired form of interest, and to ensure the transmission of data.

- Diagnostic Assessment (D):

  Examination of symptoms to determine the nature of faults or failures.

- Prognostic Assessment (P):

  In most advanced system, the Prognostic Assessment provide an estimation of future states, time to failure or risk for one or more incipient failure modes. This taking into account the current health state or historical conditions which enables maintenance optimization. For CMS for which Diagnostics are built on rule-based logic, the definition of a proper data acquisition time, defined with an acceptable confidence interval regarding the failure mode, can be considered as Prognostic Assessment.

- Health Management (HM):

  Integrate and consolidate information from the Diagnostic and Prognostic Assessment function to provide maintenance advisory or operational recommendations.

Note 1: CMS functions may be supported by a wide variety of CMS solutions or architectures. Especially, for some CMS, all the functions may be performed by the same Computer Based System, from Data Acquisition, to Diagnostic and Health Management. Whereas other CMS will only rely on Computer Based System for the Data Acquisition and Processing, and fulfill the remaining functions with dedicated procedures. Nevertheless, independently of the chosen CMS solution, final CMS data and information (e.g. results of diagnostics, health management...) should be communicated and implemented into the CMMS supporting the scheme, to ensure proper management of the CBM scheme and traceability of the operations.

This document differenciates CMS of predictive type from other types of CMS based on their complexity and the solutions implemented to support prognostic and diagnostic (D & P) functions:

- When CMS use rule base logic (e.g. threshold between monitored values and limiting parameters / baseline value) to provide a diagnostic they will be named “CMS”. Moreover, CMS are categorized into three categories in the scope of this document
  - Type A:

    On-line, permanently installed systems.

  - Type B:

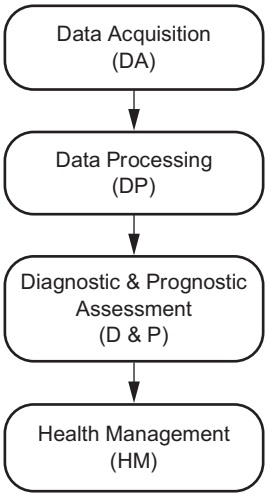
    On-site testing and detection. It involves the operation of a qualified person on-site with portable measurement equipment and usually the installation of a portable sensor, but the sensor can also be permanently installed.

  - Type C:

    Sampling systems which involve off-site analysis (e.g. oil sampling and analysis).

- When CMS software systems use complex algorithms, machine learning and knowledge of global equipment populations/ defect data in order to provide a diagnostic and a prognostic they will be named “predictive CMS”. Predictive CMS requires to be fed by an important amount of quality data, and therefore are usually supported by dedicated data infrastructure.

Figure 1 : Condition monitoring system - Main functions



2.3 Data acquisition and data processing

2.3.1 The following definitions are used in this Guidance Note for data acquisition and data processing functions:

- Off-line:

  Periodic or intermittent collection of data, usually using a portable data collector (e.g. vibration analysis, oil analysis…). A sensor or collection system is temporarily connected to the machine to collect the data.

- On-line:

  Use of permanently mounted sensors to collect and transfer data automatically for processing and visual display. Data can be collected on a defined interval that suits the application. Data can also be collected continuously if desired.

- Permanently mounted sensors:

  Sensors permanently fixed to data collection points for the purpose of transferring data automatically.

Note 1: For off-line system, permanently mounted sensors can be terminated in a remote junction box. Data collection extension cables are then used to manually collect data from the remote junction box. This is commonly applicable where direct manual off-line access to data collection points is restricted or not possible due to safety issue arising from nearness to rotating machinery parts.

- Sampling time (data acquisition):

  Frequency or period at which data collection tasks are performed.

- Time interval for data analysis:

  Time interval at which diagnostics or prognostics tasks are performed.

Note 2: Sampling time for data acquisition and time interval for data analysis may differ for a given CMS. For example for an on-line CMS, the data acquisition may be performed in real time (e.g. every minute) whereas the data analysis may be performed at different time (e.g. every hours). In that case, data processing may be performed on monitored data (e.g. maximum, averaging...).

2.4 Diagnostic and prognostic assessment

2.4.1 The following definitions are used in this Guidance Note for the prognostic assessment function:

- Baseline data:

  Descriptor or group of descriptors which provide a criterion of the normal behavior of a machine under various process states.

- Descriptor:

  Data item derived from raw, or processed parameters, or external observations.

- Mean Time Between Failures (MTBF):

  Estimation of the average time between failures of a reparable system.

- PF-interval:

  Interval between the potential detection of an item failure and when the functional failure itself occurs (see Fig 2).

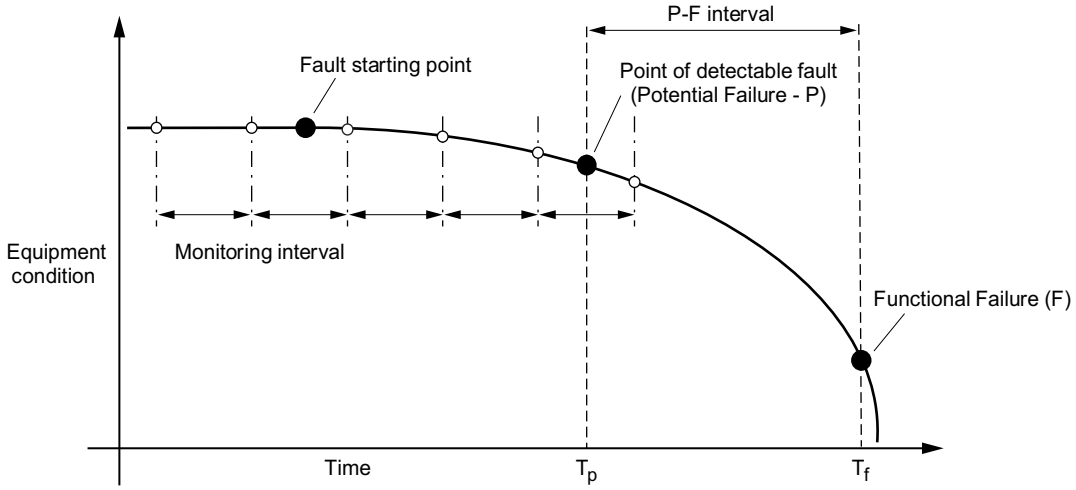
- Prognostic:

  Estimation of future state, time to failure, trending and risk for one or more incipient failure modes according to current or historical conditions.

- Mean Time To Failure (MTTF):

  Estimation of the average time before the first failure of a system (equivalent to the mean life of non reparable systems).

Figure 2 : PF-interval



2.5 Roles and responsibilities

2.5.1 The following definitions are used in this Guidance Note to describe roles and responsibilities:

- Chief Engineer:

  The Chief Engineer is the responsible person on board in charge the CBM scheme and CMS operations, therefore sufficient information and instrumentation are to be available on board for his use. In no case, the presence of a CMS is to replace routine surveillance, operator rounds or the chief engineer's responsibility for taking decisions in accordance with his judgment.

- Ship Owner:

  The Ship Owner is responsible for contracting the ship, and owns the systems at vessel delivery. After vessel delivery, the Owner may delegate some responsibilities to the ship management company.

- Supplier:

  The supplier is any contracted or subcontracted provider of system components or equipment (hardware or software). The supplier is responsible for providing programmable devices, sub-systems or systems to the shipyard.

- Approved Service Supplier:

  Service supplier means a person, or a company, not employed by the Society who, at the request of an equipment manufacturer, a shipyard, a Shipowner or another client, acts in connection with inspection work and provides services for a ship or a mobile offshore unit such as measurements, tests or maintenance of safety systems and equipment, the results of which are used by surveyors, taking decisions affecting classification or statutory certifications and services

- Original Equipment Manufacturer (OEM):

  Original equipment manufacturer refers to equipment manufacturer who may propose CMS for their equipment, and work with ship's personnel to collect and analyse data from such systems.

- Qualified Personnel:

  Person who has been trained (with the required knowledge, skills and /or experience), and is competent and qualified to carry out CBM related tasks.

Note 1: All training records are to be made available, upon request, during the application and future audit periods. This includes on-board personnel, and shore technical team, for carrying out data collection tasks and/or data interpretation and analysis related tasks respectively.

3 Workflow

3.1 General

3.1.1 An effective CBM scheme should be built on reliable Condition Monitoring Systems, which provide accurate information on the state of monitored equipments by performing trustworthy diagnostics and prognostics. CMS should be operated by qualified personnel.

To ensure the success of a CBM program, sustainment procedures should be implemented to assess, through feedback loops, when CMS or CBM scheme provide inaccurate results repetitively. Corrective actions should be carried out through change management.

Note 1: Records of training should be verifiable as with any other standard training records in line with ISM Code requirements.

The general process for the approval and issuance of additional service feature **CBM** and **CBM-P** is described in [3.2] and [3.3].

3.1.2 When CMS are permanently installed on-board, components or subsystems are usually provided by System Suppliers, and integrated by a System Integrator, who are to comply with requirements of NR674 Condition Monitoring Systems. The corresponding workflow is described in [3.4].

3.1.3 The Society recognize that CMS Data Collections or CMS Data Analysis can be performed either by:

- Qualified personnel, when trained crew member or trained ship's shore side technical management team performs CBM activities, such as data collection or analysis.

Note 1: qualification and competence of ship's personnel are to be covered by ISM code requirements.

- OEM, when CMS is developed and implemented by OEM to monitor parameters specific to their own equipment.

Note 2: OEM services for data analysis, if not part of the TAC process, are to be approved as Approved Service Supplier by the Society.

- Approved Service Supplier, recognized by the Society.

3.2 In-service workflow for ship already under PMS

3.2.1 The following workflow should be followed by the Owner in order to be granted the additional service feature **CBM** for a ship in service already under PMS (see Fig 3):

- Apply to CBM for a list of PMS items and provide general documentation (see Tab 1).

  Once the general documentation has been received, the Society may assign the ship with the notation **[CBM]**.
- Provide CMS Inventory documentation (Sec 2, [3]).
- Provide CBM Handbook documentation (Sec 2, [4]).
- Provide CBM Operation documentation (Sec 2, [5]).
- Request an Installation Survey.

An Implementation Survey is to be carried out, no earlier than 6 month after the Installation Survey, and no later than the first Class annual survey, to grant the ship with the notation **CBM**.

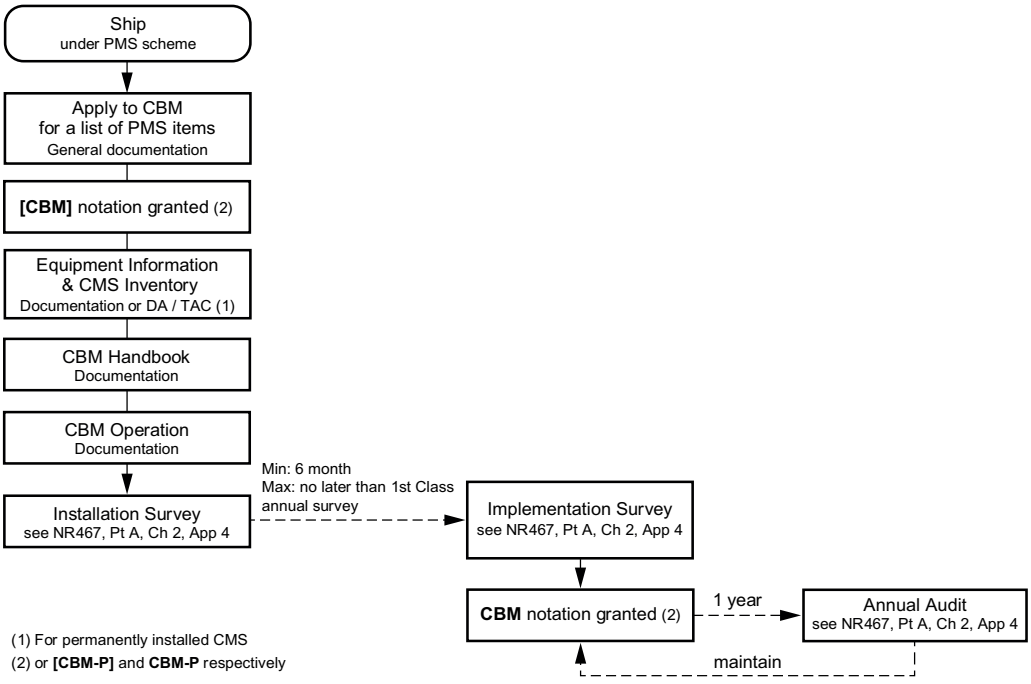
Note 1: Consideration may be given by the Society, on a case by case basis, to withdraw **[CBM]** in case of significant delay for the Owner's request for the Installation Survey.

Note 2: Implementation survey can be synchronized with other periodic ship's surveys.

Note 3: Class surveys are described in NR467, Pt A, Ch 2, App 4.

Note 4: **[CBM-P]** and **CBM-P** are assigned in lieu of the notations **[CBM]** and **CBM** when the CBM scheme relies on at least one predictive condition monitoring system.

Figure 3 : In Service workflow - ship under PMS



3.3 In-service workflow for ship not under PMS

3.3.1 The following workflow should be followed by the Owner in order to be granted the additional service feature **CBM** to a ship in service not under PMS (see Fig 4):

- Apply to PMS with respect to NR467, Pt A, Ch 2, App 1 and to CBM for a list of machinery items and provide general documentation (see Article [4]). Equipment enrolled in the scheme are subject to Class agreement.

  Once the general documentation has been received, the Society may assign the ship with the notation **[CBM]**.
- Provide CMS Inventory documentation (Sec 2, [3]).
- Provide CBM Handbook documentation (Sec 2, [4]).
- Provide CBM Operation documentation (Sec 2, [5]).
- Request an Installation Survey.

An Implementation Survey is to be carried out, no earlier than 6 month after the Installation Survey, and no later than the first Class annual survey, to grant the ship with the additional service feature **CBM**.

Note 1: Consideration may be given by the Society, on a case by case basis, to withdraw **[CBM]** in case of significant delay for the Owner's request for the Installation Survey.

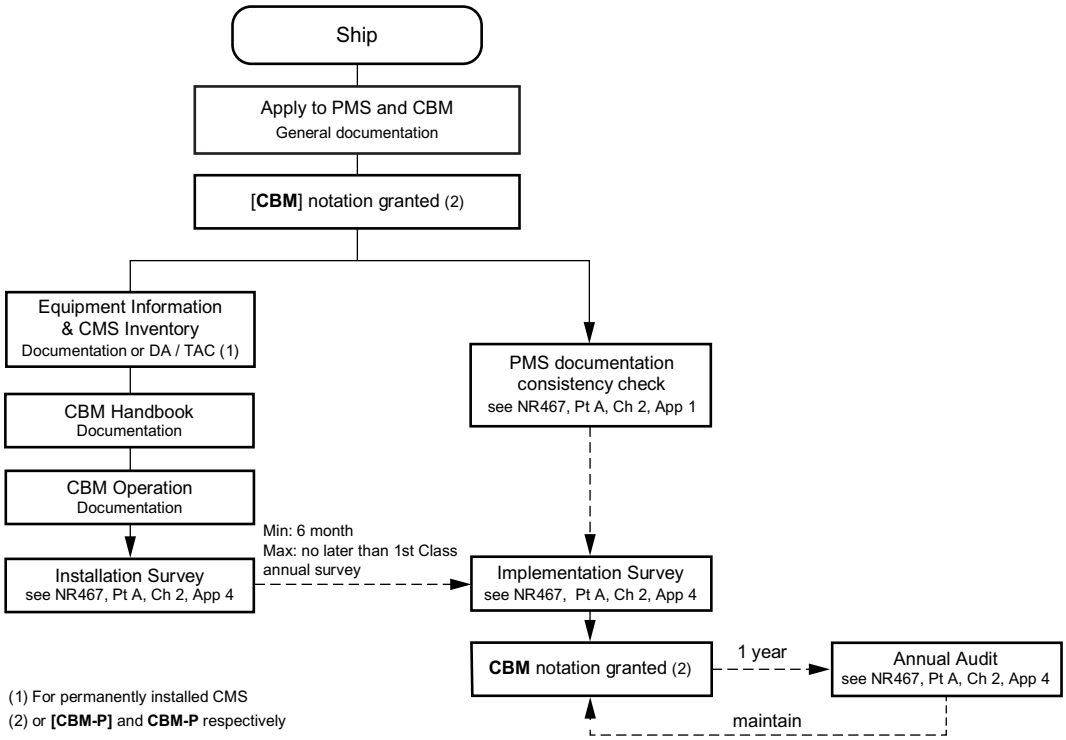
Note 2: PMS should have been granted before the additional service feature **CBM** is granted.

Note 3: Implementation Survey can be synchronized with other periodic surveys.

Note 4: Class Surveys are described in NR467, Pt A, Ch 2, App 4.

Note 5: **[CBM-P]** and **CBM-P** are assigned in lieu of the notations **[CBM]** and **CBM** when the CBM scheme relies on at least one predictive condition monitoring system.

Figure 4 : In Service workflow - ship not under PMS



3.4 Design assessment or type approval of condition monitoring systems

3.4.1 Suppliers of permanently installed CMS are to comply with requirements of NR674 to grant Type Approval of their systems hardware and software. They should provide documentation of Sec 2, [3] and should be compliant with Sec 2.

Note 1: Prior to the review, a request is to be made to the Society in order to confirm that the equipment on which the CMS is installed can be part of CBM scheme.

4 Documentation

4.1 General

4.1.1 The documentation that should be submitted, by the Owner and shipyard, for a ship to be granted the additional service feature **CBM** is described in Tab 1

Table 1 : Documentation to be submitted

	New construction		In service		CMS supplier	ASS (**1**)	I/A (**2**)	Reference
	Shipyard	Owner	Shipyard	Owner				
GENERAL								
CBM application letter	X	X	-	X	-	-	I	-
PMS application letter	-	X	-	X	-	-	I	NR467, Pt A, Ch 2, App 1, [2.2.1]
List of equipment included in CBM scheme	-	X	-	X	-	-	I	-
CBM SCHEME								
Equipment information	X	X	-	X	-	-	I	Sec 2, [2.2]
CMS inventory:	X(**3**)	-	-	X(**3**)	X(**4**)	X(**4**)	A	
• CMS information table	X	-	-	X	-	X	I	Sec 2, [3]
• CMS definition	X	-	-	X	X	X	I	NR674
• permanently installed CMS.	-	-	-	-	X	-	A	
CBM Handbook	-	X	-	X	-	X	I	Sec 2, [4]
CBM Operation	-	X	-	X	-	-	I	Sec 2, [5]

(1) ASS : Approved Service Supplier
(2) I: for Information ; A: for Approval
(3) At ship level
(4) At CMS level

Section 2 CBM Scheme

1 General

1.1 Scope

1.1.1 A ship operating under a CBM scheme should comply with the requirements of this Section.

2 Documentation

2.1 General

2.1.1 Documentation listed in Tab 1 should be provided.

The Society reserves the right to ask for the submission of additional documents in case of non-conventional design, or if it is deemed necessary for the evaluation of systems or components.

Table 1 : CBM scheme

Deliverable	I/A **(1)**	Reference
EQUIPMENT INFORMATION		
Equipment information table	I	[3.2]
CMS INVENTORY		
CMS information table	I	[3.2]
CMS definition	I	[3.3]
Documentation for permanently installed CMS	A	NR674
CBM HANDBOOK		
General	I	[4.1]
Organization	I	[4.2]
Scheme operation procedures	I	[4.3]
Sustainment procedures	I	[4.4]
CBM OPERATION		
Annual report template	I	[5.4.1]
(1) I: for Information ; A: for Approval		

2.2 Equipment information table

2.2.1 An equipment information table, which gather information on equipments involved in the CBM scheme should be provided, including:

- reference number (and BV reference number)
- Original Equipment Manufacturer (OEM)
- on-board location (e.g. Engine Room #2)
- equipment use (normal / occasional)
- machine rating (e.g. nominal rpm, horsepower...).

3 CMS inventory

3.1 Scope

3.1.1 The CMS Inventory should gather information for all CMS implemented on-board on eligible equipments, through an inventory of assets including:

- CMS information table, which provides an overview of all CMS with an identification of the equipment item and failure modes addressed as explained in [3.2].
- CMS definition as defined in [3.3].

Note 1: CMS included in the inventory, can be either:

- Already type approved CMS. In that case, information approved in the scope of the Type Approval should be gathered and presented within the scope of the current CBM scheme.
- CMS carried out by Approved Service Supplier. In that case, information approved in the scope of the Approved Service Supplier should be gathered and presented within the scope of the current CBM scheme.
- Other CMS implemented in the CBM scheme operated by qualified personnel.

Note2: For off-line manual data collection for technologies such as Vibration Analysis and Oil Analysis, ensure that data is collected from designated points as per schematics or marked up locations on the equipment.

3.2 CMS information table

3.2.1 The following information should be provided in the CMS information table, and listed for each physical parameter monitored, or equipment item covered:

- reference for CMS identification within the scheme (e.g. #ME004)
- name of the equipment (e.g. Main Engine)
- name of equipment item covered by CMS (e.g. bearing #3)
- failure mode covered by CMS (e.g. wear out)
- CMS categories (e.g. CMS type A)
- general description of the CM technique used (e.g. oil analysis)
- indication if the CMS, or some sub-system or components such as sensors, are permanently installed on-board
- indication if the CMS is covered by a Type Approved certificate.

Note 1: When the reliability of a CM technique is considered insufficient with regards to the criticality of the equipment item failure, different CMS may be implemented to monitor the condition of this item. Reciprocally, a CM technique may be used to monitor different equipment items or failure modes.

Example of CMS information table is provided in Tab 2.

3.3 CMS definition

3.3.1 Scope

Permanently installed CMS of type A and type B and predictive CMS should be approved and comply with requirements of NR674.

In addition, for CMS of type A, B or C, information detailed in [3.3] should be provided.

3.3.2 Functional scheme

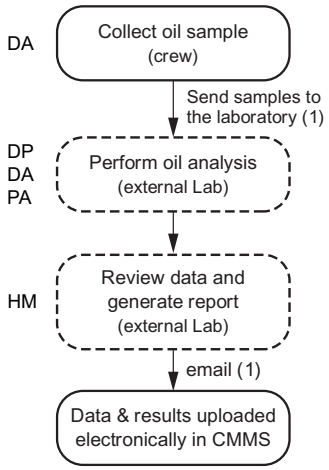
Diagrams and functional schemes (e.g. bloc diagram) describing the CMS should be provided, with (see examples in Fig 1 and Fig 2):

- General description of the CMS, along with the monitoring techniques and the different CMS functions (DA, DP, D & P, HM). For off-line systems, manual operations achieving CMS functions should be identified.
- When applicable, a clear definition of the interfaces between different systems (e.g. between CMS and existing ship network infrastructure), or organizations (e.g. between crew and approved service supplier) should be provided.

Table 2 : Example of CMS information table

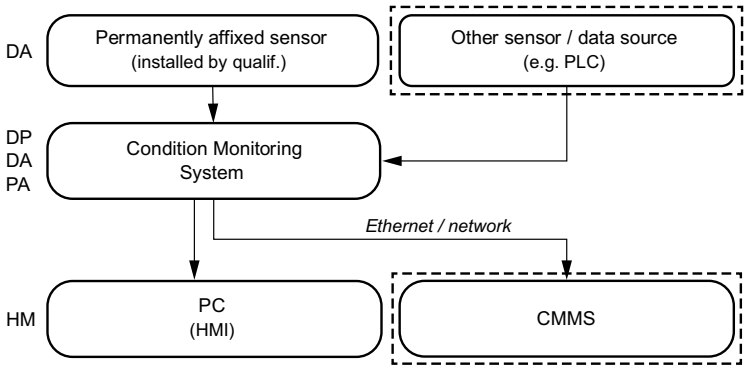
Reference Equipment	Equipment	Equipment sub-system	Equipment item	Reference CMS	Failure mode (optional)	CMS General Description	CMS Type	Permanently installed on board	TAC **(1)** (if any)
#ME001	Main Diesel Generator	Diesel Engine							
			Turbo rotor imbalance	#GS001	Wear/ misalign	Surface vibration	A	yes	yes
			Bearing damage	#GS002	Blockage	Lube oil analysis	C	no	no
		Generator							
			Rotor Shaft	#GS003	Wear / misalign	Bearing temperature	B	yes	no
(1) Type Approval Certificate									

Figure 1 : Example of CMS Type C functional scheme



(1) Data exchange format and naming are compliant with documentation (e.g. naming convention) provided in the CBM Handbook

Figure 2 : Example of CMS Type A functional scheme



3.3.3 Data acquisition

Permanently installed CMS of type A or B should be approved and comply with requirements of NR674.

For CMS of type B and type C, procedures for Data Acquisition and Data Processing should be provided, especially:

- For temporary installed sensors, procedures for sensor installation, positioning, and instrumentation should be provided along with sensor specifications and calibration. Representation of sensor location on the equipment and with spatial orientation should be provided.
- For oil analysis, sampling procedures should be provided, with indication on sampling point locations.
- When a portable equipment is used for data collection, it should be maintained and calibrated in accordance with recognized national or international industrial standards, and calibration should be specified. For vibration analysis, system should be capable of frequency spectra analysis.

Note 1: When manual actions are part of Data Acquisition or Data Processing, it should be ensured that those functions are performed similarly every time, to ensure effective Condition Monitoring and reliable conclusions.

Note 2: For data quality concerns, CMS should be preferably fitted with data sharing capabilities and means to export data (e.g. USB, emails…). For example, reports for oil data analysis should be preferably uploaded electronically from the analysis laboratory. Machine readable format (e.g. csv format), in opposite to text format, should be preferred from for data exchange.

3.3.4 Processing, diagnostic, prognostic and health management

For CMS of type A, B or C the following information on the Processing, Diagnostic, Prognostic and Health Management should be provided:

- Original baseline data recorded during the Installation Survey.
- Listing of acceptable condition monitoring parameters. Limiting parameters are to be based on the Original Equipment Manufacturers (OEM) guidelines, or on a recognized international standard.

A minimum of 2 thresholds, which define the 3 following Condition Indicators (Traffic light system), should be provided:

- satisfactory (good condition of the equipment)
- alert (probable deficiency, monitor at a more frequent interval during the next data collection interval or carry out further checks and minor adjustments)
- alarm (major deficiency, schedule repair immediately).

- Maximum time interval for data collection and sampling time (when different from time interval). Maximum sampling time should be documented, for example by the mean of consideration to PF-interval, MTTF, MTBF or any other indicator of the time between failure and detection, and provided by OEM, or by a recognized international standard.
- Data processing performed on collected raw data. Especially, when CMS sampling time and time interval for data acquisition differ, data processing performed on sampled data (e.g maximum, average...) should be specified.
- If any, identification of alternative data sources used for diagnostic (e.g. baseline defined as an aggregation of baseline data coming from similar machine).

Example of CMS definition table is provided in Tab 3.

Table 3 : Example of CMS definition table

Reference CMS	CMS General Description	Original baseline	Acceptable CM parameters	Alternative Data Source	Max. time interval	Sampling time	Sensor ID	Sensor location / sampling point	Sensor Characteristics	Sensor Calibration
#GS001	Surface Vibration	3	warning: +/- 1 alarm: +/- 2	0.3 (aggregation)	1 month	30 min	#s_vib_043	pdf	pdf	annually (pdf)
#GS002	Lube oil analysis	approved lab	approved lab	approved lab	2 months	–	–	pdf	–	–
#GS003	Bearing surface temperature	50°C (ASS)	warning: +/-4°C alarm: +15°C (ASS)	40°C (aggregation)	1 month	–	N.A.	pdf	N.A. (scope ASS)	N.A. (scope ASS)

(1) ASS = Approved Service Supplier

4 CBM Handbook

4.1 General

4.1.1 The CBM Handbook should gather and present the procedures which should be applied within the CBM scheme. Procedures can be either related to the overall scheme operation, to CMS maintenance or to the implementation of risk mitigation procedures for predictive CMS.

The procedures can be within the scope of:

- Type approved CMS. When CMS are type approved and when procedures are part of the type approval, they are to be gathered and presented within the scope of the CBM scheme.
- Procedures of Approved Service Supplier. In that case, procedures approved in the scope of the Approved Service Supplier are to be gathered and presented within the scope of the CBM scheme.
- Other CMS implemented in the CBM scheme.

4.2 Organization

4.2.1 The Chief Engineer is the responsible person on-board in charge of CMS and the CBM scheme.

4.2.2 CMS are to be operated by qualified personnel (crew, skilled personnel and approved service supplier), either on board or on shore (e.g. remote data analysis). An organization chart, or any equivalent document, should be provided with identification of area of responsibility of the different parties involved in CBM scheme operation.

4.2.3 General description of the people in charge of CMS operation should be provided with the following information:

- reference of the CMS in the CBM scheme (e.g. #ME004)
- CMS type (e.g. type A)
- person in charge of data collection (e.g. crew)
- person in charge of data analysis (e.g. Approved Service Supplier).

Example of CMS operation table is provided in Tab 4.

Table 4 : Example of CMS operation table

CMS Reference	CMS Type	Data collection	Data Analysis
#GS001	A	N.A. (online)	M.Engineer 1
#GS002	C	M.Foreman 1	Company 1
#GS003	B	ASS 1	ASS 1
#CP00_pred1	A	N.A. (online)	ASS 2

4.2.4 All the personnel involved in the CBM scheme operation are to be properly qualified with regard to their action in the scheme, and following document should be submitted:

- Detail of qualification of authorized personnel involved in the CBM scheme (with applicable training plan):
  - in charge of data collection
  - in charge of data analysis.
- Qualification of company responsible for analyzing CM results, if applicable (e.g. ISO 18436 certification).
- Certificate of approval for Approved Service Supplier involved in the scheme, if applicable.

Note 1: Records of training and competence should be verifiable as with any other standard training records in line with ISM code requirements.

Example of qualification table is provided in Tab 5.

Table 5 : Example of qualification table

Crew / skilled personnel / ASS	Person identification	Measure / analysis	CM technique	Certification / training plan
INTERNAL				
M.Foreman 1	crew	measure	oil and thermal	ISO 18436-1 (certif.)
M.Engineer 1	crew	measure & analysis	vibration	ISO 18436-2 (certif.)
M.Engineer 2	skilled personnel	analysis	thermal	ISO 18436-2 (certif.)
EXTERNAL				
Company 1	-	analysis	oil analysis	pdf
ASS 1	-	measure & analysis	vibration & thermal	N.A. (ASS)

4.3 Scheme operation procedures

4.3.1 Following procedures related to CBM scheme operation should be provided in the CBM Handbook, when applicable:

- General procedures for CBM scheme Management (e.g. integration of CM tasks in PMS...).
- Procedures for changes to software system (e.g. CMMS, data acquisition software...), or changes to CM parameters (thresholds, baselines...). Especially, when the operational condition of a machinery is modified (e.g. modification of speed, loads...) new baseline readings should be recorded. Access to computerized systems for updating maintenance documentation and maintenance program shall only be permitted by the chief engineer or other authorized person
- Maintenance instructions (manufacturer's and shipyard's).
- Procedures for condition report and maintenance recommendation.
- Procedures for communication between parties involved in the scheme (crew, ship operator, approved service supplier, class society).
- For CMS type A, procedures for validation of alerts and anomalies by qualified personnel. Especially, procedures to ensure management of false positive for on-line systems should be provided.

- Procedure and related documentation (e.g. naming convention) related to data format and naming, and in line with specifications of [5.2], should be provided.

Note 1: Data format and naming should be common for Owner and Approved Service Suppliers involved in the scheme.

- Procedure for data reporting, data storage and back-up.
- Procedures for reporting CMS faults and malfunctions, and the implementation of corresponding corrective actions.
- Maintenance procedures for CMS.
- Additional procedures related to predictive CMS operation (refer to NR674, Sec 3, "predictive CMS Handbook")

Note 2: In no case, the presence of a CMS is to replace routine surveillance, operator rounds, or the chief engineer's responsibility for taking decisions in accordance with his judgment.

4.4 Sustainment procedure

4.4.1 Where an Owner wishes to base their equipment maintenance on a CBM approach, this is to meet the requirements of the IMO International Safety Management (ISM) Code.

4.4.2 A sustainment process should be implemented on-board to identify faults and unexpected failures that were not prevented by the CM system and to ensure continuous improvement of the CBM scheme through assessment of the real condition of the equipment. Especially processes should be provided to ensure that, for each faults or failures, an examination is carried out and that the corresponding CMS outputs are challenged accordingly:

- If no defect is found, or if a defect has developed that CM has failed to detect, investigations have to be undertaken (e.g. root cause analysis…) to improve CM strategy. When necessary, corrective actions should be implemented through change management. Results and possible modifications should be communicated to the OEM, the Owner, the Society and the CMS supplier when relevant
- If the defect was diagnosed correctly and that appropriate maintenance has been carried out it should be indicated to assess success of the CBM scheme.

Evidence that a sustainment process is implemented on board should be provided with description of how the CMS takes advantage of the experience to improve its performances.

5 CBM scheme operation

5.1 Computerized Maintenance Management System (CMMS)

5.1.1 Maintenance activities should be programmed and maintained in a Computerized Maintenance Management System (CMMS) as required by PMS program. CMMS should comply with specifications of NR496 Approval of Computerized Maintenance Management Systems Used on Board Ships.

Note 1: All data collection or analysis tasks should be scheduled from the CMMS. Reciprocally, all CMS final data or information (e.g. final diagnostics, health management data...) should be uploaded with indication of the maintenance performed.

5.1.2 CBM scheme (e.g. supporting CMMS) is to be able to provide a condition report and maintenance recommendations.

5.1.3 Access to computerized systems for updating maintenance documentation or the maintenance program should be restraint to the Chief Engineer or other authorized person (e.g. username/ password). Users should be logged to ensure traceability of actions.

5.2 Data format and naming

5.2.1 Data types, format and naming should be clearly specified to ensure proper data management of the scheme (e.g. data traceability, data availability, audit...).

Note 1: For improvement of data quality and to enable to share data with third parties, it is recommended to manage data in accordance with predefined standard, which provide specifications on data structure (e.g. data, metadata...), data format (e.g. string, timestamp...), data exchange format (e.g. XML)...

Refer to ISO 19848 "Standard data for shipboard machinery and equipment".

5.2.2 When exchanging data with other CBM scheme parties (e.g. Approved Service Supplier, Class...), open, non-proprietary, machine readable data format (e.g. XML, CSV, JSON...) with standard character encoding (e.g. UTF-8, ASCII...) should be preferred.

5.2.3 The Owner should define a naming convention to provide rules for the naming of files, or email subject. It is recommended that naming follow, as a minimum, the following principles:

- consistency of naming across file names, or email subjects
- descriptive naming
- less than 25 characters
- avoid special character, or space
- uses capital and underscore instead of period or slashes
- follow ISO 8601 specifications on DateTime format
- specify the version number of naming convention.

5.2.4 When data sharing is performed through emails exchanges, email objects should follow naming convention so that data traceability can be ensured for all parties involved in the CBM scheme. When data sharing is performed through files exchanges, files name should follow naming convention.

5.2.5 Naming convention used for email or file naming should be the same for the Owner and Approved Service Suppliers involved in the CBM scheme.

Note 1: Naming convention, data exchange format and related procedures are in the scope of the CBM Handbook, and should therefore be communicated to the Society.

5.2.6 The minimum information which should be provided in the naming scheme (or identification scheme) are:

- date of data acquisition (e.g. YYYYMMDD, YYYY-MM-DDTHH:MM:SSZ...)
- identification of the equipment (e.g. main diesel generator, #ME001...)
- identification of the equipment sub-system (e.g. generator)
- identification of equipment item (e.g. rotor shaft)
- data quantity name (e.g. temp).

Note 1: For example, an acceptable file name could be “20211104_MainDieselGeneratorA36_GeneratorB4_RotorShaft01_temp”.

5.3 Data storage and backup

5.3.1 CBM scheme should be capable to store scheme management data, and data of CMS implemented on-board (refer to [6.2.3]).

Note 1: For quality purpose, it is preferred that data of the different CMS included in the CBM scheme are centralized in a unique data support (e.g. data server) dedicated to maintenance.

Note 2: For quality purpose, automatic (in contrary of manual) transmission of data from CMS to the storage are preferred whenever possible. Procedures for data recording and transfer are in the scope of the CBM Handbook.

5.3.2 CBM scheme should to be able to store on board CMS Inventory and CBM Handbook in an up to date fashion.

5.3.3 Data should be available on board in an up to date fashion, through on-board (e.g. maintenance server) or remote storage (e.g. ship network, Cloud...), or documentation. Data should be kept available for a minimum period of 5 years.

Note 1: CBM scheme data storage aims at supporting operations, sustainment and audit of the scheme.

5.3.4 When applicable, the following should be stored as a minimum:

- Record of changes to software systems and parameters.
- Original baseline data.
- All baseline and limiting parameters that have been modified since the beginning of the program.
- All data used for condition monitoring since last opening of the machine.
- All condition monitoring data (e.g. Diagnostics Assessments results) and the corresponding actions carried out when required by Health Assessment, with detail of the repairs and renewal carried out on the equipment since the beginning of the program.
- All other records of maintenance including repairs and renewals carried out that were not predicted by CMS.
- CMS alarm log with detail of CMS breakdown or malfunction (e.g. sensor malfunctions or damage, power interruption...) should be stored in the system with a short explanation of the problem. The time of interruption between detected failure and repair should be specified. The time of interruption should not be above 90 days.
- Sensors calibration records, certification and status.
- Calibration record for portable data collection system. For on-line systems, firmware updates should be stored.
- Reference documentation (trend investigation procedures...).
- Additional data related to predictive CMS operation (refer to NR674, Sec 3, “predictive CMS operation data”).

5.3.5 CBM scheme data (Management data and CMS data) should be backed up at regular interval, to prevent loss of data in case of failure.

5.4 Annual report template

5.4.1 An annual report is to be provided to the Society to support the annual audit, and enable the surveyor to have an overview of the scheme operation on the period.

Note 1: Rules for class survey are provided in NR467, Pt A, Ch 2, App 4.

The annual report should be schematic, easily understandable for the Surveyor and indicate the results presented for each CMS of the CBM scheme.

The template of the annual report should be presented to the Society during the scheme approval process. Following information should be presented as a minimum in the report:

- Each machinery included in the CBM scheme should be separately listed.
- For each machinery, the list of items and components enrolled in CBM scheme, and procedures for their identification.
- CMS reference with general description of the CM technique and the preventive maintenance sheets. Calibration status of sensors and equipment should be indicated.
- Original reference data of the machinery checked through Condition Monitoring.
- The results of the Condition Monitoring diagnostic should be presented on the form of Condition Indicators (CI) with three levels of criticality: 'good condition', 'caution', 'critical'. The following information should be provided as a minimum:
  - A summary table of Condition Monitoring performed on the past year should be presented to the Surveyor. In this table should be presented the worst Condition Indicator recorded for each quarter of the year prior to the annual review (see Tab 6).
  - For Condition Indicators which are exceeding acceptable thresholds and presenting 'caution' or 'critical' level, detailed data should be provided. Especially:

    Full trend analysis (including spectrum analysis for vibrations) of machinery displaying operating parameters exceeding acceptable tolerances should be carried out in the case of exceeding acceptable threshold

    The time window represented should be sufficient to represent the initial 'good condition' of the item, and degradation of the failure mode

    Baseline value and thresholds

  Note 2: The baseline value and thresholds presented are to be the data effectively used by the CMS during the time window (and not the last values).

  Example of CMS summary diagnostic table is provided in Tab 6.
- Description of repairs carried out during the period, with written details of breakdown and malfunctions. When applicable, indication when CMS or the CBM scheme fail to manage the developing failures should be explicitly provided, with details of the corrective action undertaken.
- Indication of CMS failures with time of interruption.
- Indication of any change to the CBM Handbook, CMS Inventory or documentation listed in NR467, Pt A, Ch 2, App 4, [2.3].

Note 3: The Annual Report is made available by the Owner to support to CBM scheme Annual Survey, as described in NR467, Pt A, Ch 2, App 4.

Note 4: In addition, all condition monitoring data, including all data since the last dismantling and the original reference data of the machinery checked through condition monitoring should be available for on the Surveyor's request as stated in NR467, Pt A, Ch 2, App 4.

Table 6 : Example of CMS Diagnostic summary table

Reference Equipment	Equipment	Equipment sub system	Equipment item	Reference CMS	Failure mode (optional)	Condition Indicator (CI) **(1)**				Next calibration
						Current	Q1	Q3	Q4	
#ME001	Main diesel generator	Diesel Engine								
			Turbo rotor imbalance	#GS001	Wear / misalign	GC	GC	C	GC	DD/MM/YY (overdue)
			Bearing damage	#GS002	Blockage	C	W	GC	GC	DD/MM/YY
		Generator								
			Rotor Shaft	#GS003	Wear / misalign	C	GC	GC	GC	DD/MM/YY

(1) GC: Good conditions; C: Caution; W: Warning

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