



RULES
PUBLICATION 2/P

ALTERNATIVE SURVEY ARRANGEMENTS MACHINERY

July
2020

Publications P (Additional Rule Requirements) issued by Polski Rejestr Statków complete or extend the Rules and are mandatory where applicable.

GDAŃSK

Publication 2/P – Alternative Survey Arrangements for Machinery – July 2020 was approved by PRS Executive Board on 29 June 2019 and enters into force on 1 July 2020.

© Copyright by Polish Register of Shipping*, 2020

* *Polish Register of Shipping* means *Polski Rejestr Statków S.A.*, seated in Gdańsk, al. gen. Józefa Hallera 126, 80-416 Gdańsk, Poland, registered in the Register of Entrepreneurs of the National Court Register, under entry number 0000019880. Polish Register of Shipping, its affiliates and subsidiaries, their respective officers, employees or agents are, individually and collectively, referred to as Polish Register of Shipping or as PRS for short.

CONTENTS

| | Page |
|--|------|
| 1 General | 5 |
| 1.1 Scope of application | 5 |
| 1.2 Definitions | 5 |
| 1.3 General requirements | 5 |
| 2 Continuous machinery survey (CMS) | 5 |
| 2.1 General | 5 |
| 3 Survey arrangement based on approved planned maintenance scheme (PMS) | 6 |
| 3.1 General | 6 |
| 3.2 Survey of machinery covered by PMS | 6 |
| 3.3 Ship Owner's responsibility | 6 |
| 3.4 Procedures and conditions for approval of PMS and for approval validity | 7 |
| 3.5 Implementation audit and annual audits for machinery under PMS | 9 |
| 4 Condition monitoring system (CM) and condition based maintenance System (CBM) | 10 |
| 4.1 General | 10 |
| 4.2 Implementation and Maintaining of CM/CBM System | 13 |
| 4.3 Requirements for CM/CBM system documentation | 14 |
| 4.4 CM/CBM system certificate | 16 |
| 4.5 Condition monitoring methods | 16 |
| 4.6 Reference value measurements | 21 |
| 4.7 Condition monitoring survey scopes | 21 |

1 GENERAL

1.1 Scope of application

1.1.1 The requirements of *Publication 2/P – Alternative Survey Arrangements for Machinery*, hereinafter referred to as the *Publication*, are an extension of the requirements specified in *Part I – Classification Regulations of the Rules for Classification and Construction of Sea-going Ships* regarding PRS' survey of machinery where it has been referred to.

1.2 Definitions

Alternative machinery survey arrangements – classification survey arrangements in which direct machinery surveys, performed by PRS' Surveyor, are replaced, to a specified extent, by other methods of survey.

Maintenance work – overhauling and surveys of machinery performed by the crew, preservation, scheduled preventive maintenance or replacement of consumables.

Ship – any floating object classed with PRS to whom this *Publication* applies.

1.3 General requirements

1.3.1 At the Owner's request, Polski Rejestr Statków may adopt one of alternative machinery survey arrangements mentioned in this *Publication*, provided that the machinery maintenance practice, applied on board, ensures:

- maintaining machinery in satisfactory operational condition,
- providing documents necessary for verification of machinery technical condition and for planning repairs,
- providing documents useful in possible failures analysis.

1.3.2 Alternative survey arrangement may be implemented on each ship classed with PRS.

1.3.3 If an alternative survey arrangement has been implemented on the ship by a recognized Classification Society, PRS may continue such a survey arrangement, provided it fulfils the requirements of this *Publication*.

1.3.4 Generally, alternative survey arrangement documents shall be prepared and the documentation shall be kept in English. Upon PRS consent, the documents may be prepared in the flag state or other language subject to PRS consent in each particular case.

1.3.5 Alternative survey arrangement may cover particular machinery and electrical equipment components, installations and systems as well as control systems.

2 CONTINUOUS MACHINERY SURVEY (CMS)

2.1 General

2.1.1 Polski Rejestr Statków conducts surveys under CMS by:

- verification of the list of equipment, machinery, installations and systems indicated by the ship owner,
- conducting direct surveys of particular machinery items or recognising surveys performed by the Chief Engineer,
- entering records on the list of items covered by CMS provided on board.

2.1.2 The Owner may cancel CMS notifying PRS in writing thereon.

2.1.3 PRS may cancel CMS if it has been found that the condition of machinery, covered by CMS, requires surveys to be performed at intervals shorter than 5 years.

2.1.4 In the case CMS has been cancelled, the machinery shall be submitted to class renewal survey within the scope specified in *Part I – Classification Regulations*. Surveys performed under CMS may be credited for class renewal if they have been carried out during the last 12 months.

3 SURVEY ARRANGEMENT BASED ON APPROVED PLANNED MAINTENANCE SCHEME (PMS)

3.1 General

3.1.1 PRS survey of machinery based on the planned maintenance arrangement (hereinafter referred to as 'PMS arrangement') may be applied as an alternative to the CMS (described in Chapter 2).

3.1.2 PMS is limited to components and systems covered by CMS.

3.1.3 PMS arrangement may also cover other components and systems which are not subject to classification survey. In that case, they shall be properly indicated in the documentation of PMS (e.g. designated by a specific colour on the list of equipment covered by PMS arrangement).

3.1.4 Any items covered by PMS shall be surveyed and credited in the usual way.

3.1.5 Surveys within PMS are based on maintenance cycles recommended by the manufacturer, operator's experience.

3.1.6 PRS performs survey of PMS arrangement through:

- verification of the implementation and operation of the planned maintenance system at the PMS implementation, annual and additional audits,
- analysis of the Chief Engineer's reports,
- analysis of records of computer programs,
- surveys and tests of machinery performed in the presence of PRS Surveyor.

3.2 Survey of machinery covered by PMS

3.2.1 The cycle of surveys of the machinery covered by PMS shall not exceed that specified for CMS. Upon the Owner's request, PRS may accept longer intervals of survey for specific components and installations based on the running hours' records taking into account the manufacturer's recommendations.

3.3 Ship Owner's responsibility

3.3.1 The Chief Engineer is the responsible person on board in charge of the PMS.

3.3.2 Documentation on overhauls of items covered by the PMS shall be prepared and signed by the Chief Engineer.

3.3.3 Access to computer programs for updating of PMS documentation and maintenance program shall only be permitted to the Chief Engineer or other authorised person(s).

3.3.4 In dual classed ships, PRS may restrict the Chief Engineer's right to perform overhauls of items covered by PMS.

3.4 Procedures and conditions for approval of PMS and for approval validity

3.4.1 Requirements for PMS

3.4.1.1 Records of PMS operation on board the ship shall be maintained using a computer system. This requirement, however, may be waived in the case of current schemes (provided that the requirements specified in 1.3.3 are applicable).

3.4.1.2 Computer programs applied are subject to PRS approval in accordance with the requirements specified in *Publication 9/P – Requirements for Computer Based Systems*. This requirement may be waived in the case where applications based on publicly available software are used.

3.4.1.3 Computer program shall enable making back-up copies, e.g. on CDs, which shall be updated at regular intervals.

3.4.1.4 PMS shall explicitly determine principles for maintaining records concerning:

- .1 machinery running hours,
- .2 basic operating parameters,
- .3 cases of defects, damage and repair,
- .4 maintenance,
- .5 test results for consumables and working media,
- .6 identification of persons in charge of PMS on board as well as the dates of assuming and relaying the duties,
- .7 identification of persons authorised to enter records on the list of items covered by PMS.

3.4.1.5 PMS shall be prepared and approved for a ship specified in the request mentioned in 3.4.4.1.

3.4.2 Documentation and additional information required for approval of PMS

3.4.2.1 Approval of PMS requires the following documentation and additional information to be submitted to PRS:

- .1 organization chart identifying areas of responsibility;
- .2 version of applied software;
- .3 listing of equipment to be considered by classification in PMS;
- .4 preventive maintenance sheets:
 - specifying listing and schedule of preventive maintenance procedures,
 - for the machinery and systems. It is recommended that the components connected functionally be provided with a common preventive maintenance sheet;
- .5 specification of basic technical data and operating parameters determining the normal running parameters for components and installations to be considered by classification in PMS.

3.4.3 Documentation and information to be available on board

3.4.3.1 The following documentation and information shall be available on board:

- .1 all up-to-date documents and information specified in sub-chapter 3.4.2;
- .2 maintenance instructions for the machinery and systems (manufacturer's and shipyard's);
- .3 information specified in 3.4.1.4.

3.4.4 PMS approval procedure

3.4.4.1 The Owner shall request, in writing, the approval of PMS from PRS. The documents and information specified in sub-chapter 3.4.2 shall be enclosed to the request.

3.4.4.2 Following the satisfactory result of the request verification, PRS enters – in the ship's survey status – acknowledgment of provisional implementation of PMS in addition to CMS and notifies the Owner thereof.

3.4.4.3 Where the Owner is unable to enclose the information specified in sub-chapter 3.4.2, such information shall be verified by PRS Surveyor during PMS Implementation Audit.

3.4.4.4 Within 12 months from provisional implementation of PMS on a ship, the Owner shall request PRS to perform the PMS Implementation Audit.

3.4.4.5 Following the satisfactory result of verification, by PRS Head Office, of report on the implementation audit, *Certificate of Approval for Planned Maintenance Scheme* (also referred to as PMS Certificate) is issued for the ship to confirm approval of PMS. PRS provides the Owner with the original and a copy of *PMS Certificate*. The original of *PMS Certificate* shall be available on board.

3.4.4.6 Upon the issuance of *PMS Certificate*, the CMS is replaced by PMS.

3.4.4.7 In the ship's survey status and *Certificate of Class*, PRS enters a record on PMS implementation.

3.4.4.8 PRS may condition the issuance of *PMS Certificate* on introduction of amendments to PMS.

3.4.5 Validity of PMS Certificate

3.4.5.1 *PMS Certificate* is issued without time limit.

3.4.5.2 To maintain *PMS Certificate*, the following conditions shall be fulfilled:

- .1 satisfactory result of PMS annual audit, which is a part of the machinery survey in accordance with the requirements specified in 3.5.2.2;
- .2 maintenance performed, by the authorised Chief Engineer or under his supervision, in accordance with the approved PMS;
- .3 PRS shall be immediately notified, by the Owner, of any machinery breakdown, damage or defect which cannot be repaired within normal maintenance work.
Breakdown, damage or defect, depending on their extent, shall be repaired by:
 - the Chief Engineer or crew under the Chief Engineer's supervision,
 - service supplier approved by PRS,
 - service supplier approved by other recognised Classification Society subject to PRS Head Office acceptance in each particular case;
- .4 **conditions of class**, issued by PRS as a result of the performed PMS audits or on the basis of the Chief Engineer's damage report, shall be implemented in due time. The **conditions** may require that the machinery item be submitted to PRS Surveyor's inspection prior to, during or after repair,
- .5 if practicable, any component which has been replaced due to damage, shall be retained on board until examined during PRS survey;
- .6 ongoing keeping up-to-date records mentioned in 3.4.1.4.

3.4.5.3 *PMS Certificate* is cancelled in the case when:

- .1 the Owner has changed,
- .2 software version has been replaced,
- .3 accepted overhaul intervals have been exceeded,
- .4 unsatisfactory condition of the machinery and systems under PMS has taken place,
- .5 PMS has been verified, during the Annual Audit, as not being correctly operated.

3.4.5.4 The Owner may cancel the survey arrangement under PMS by informing PRS in writing thereon. The Owner shall declare whether they wish to have CMS reinstated or abandon the alternative survey arrangement for machinery.

3.4.5.5 PRS may refuse to reinstate CMS.

3.4.5.6 In the case of CMS being reinstated, surveys performed by the Chief Engineer since the latest Annual Audit may be credited – by PRS – as completed provided that the requirements specified in 2.3.1 are fulfilled.

3.4.5.7 In the cases mentioned in 3.4.5.3 and 3.5.2.10, PRS Head Office follows the requirements specified in 3.4.5.4 and 3.4.5.8, depending on the ascertained non-conformities.

3.4.5.8 In the case an alternative survey arrangement for machinery has been cancelled, the machinery shall be submitted to class renewal survey within the scope specified in *Part I – Classification Regulations*. Surveys performed under PMS arrangement may be credited for class renewal if they have been performed during the last 12 months and found satisfactory as a result of verification, by PRS Surveyor, of the relevant survey reports.

3.4.5.9 In special cases, PRS Surveyor may, subject to satisfactory clarification by the Chief Engineer, postpone the survey of a machinery component or system covered by PMS.

3.5 Implementation audit and annual audits for machinery under PMS

3.5.1 PMS implementation audit

3.5.1.1 PMS Implementation Audit aims at verifying that:

- .1 PMS fulfils the requirements specified in this *Publication*,
- .2 PMS is suitable for the type and complexity of the machinery and installations on board,
- .3 within PMS, records specified in 3.4.1.4 are collected and maintained,
- .4 persons authorised to keep records within PMS (in accordance with the requirements specified in 3.3.3) are familiar with PMS principles.

3.5.1.2 PRS Surveyor performing PMS Implementation Audit makes a report and transfers it to PRS Head Office for verification.

3.5.1.3 PRS Head Office follows the procedure specified in paragraphs 3.4.4.5 to 3.4.4.8.

3.5.2 PMS Annual Audit

3.5.2.1 PMS Annual Audit aims at verify in that the PMS is being correctly operated.

3.5.2.2 PMS Annual Audit is performed concurrently with the annual, intermediate and class renewal surveys of the ship in compliance with their schedule specified in *Part I – Classification Regulations*.

3.5.2.3 PMS Annual Audit is performed by PRS Surveyor.

3.5.2.4 In the case of dual classed ships, PRS may request the other Classification Society that the ship is classed with to perform PMS audit on PRS behalf.

3.5.2.5 The following information and documents shall be prepared for verification by PRS Surveyor within PMS Annual Audit:

- .1 performance and maintenance records concerning overhauls and running repairs to the machinery and systems covered by PMS since the previous PMS audit. The records shall include the list of spare parts used,
- .2 written details of any breakdown or malfunction of machinery and systems or installations covered by PMS, including the breakdown cause – if known,
- .3 *Certificate of Approval for Planned Maintenance Scheme,*
- .4 *Software Approval Certificate.*

3.5.2.6 PRS Surveyor verifies the submitted information and documents specified in 3.5.2.5.

3.5.2.7 As a part of PMS Annual Audit, PRS Surveyor examines the machinery and installations which have been overhauled and repaired since the last PMS Annual Audit and performs their function tests as far as practicable and reasonable.

3.5.2.8 PRS Surveyor may require to dismantle a machinery component or installation to be submitted to inspection where they raise doubts concerning their reasonable technical condition.

3.5.2.9 Where minor non-conformities in PMS operation are shown during PMS Annual Audit, PRS Surveyor may recommend that an additional PMS audit be conducted. In that case, an appropriate **condition of class** including the list of non-conformities is entered in the ship's survey status.

3.5.2.10 After verification of PMS Annual Audit report, PRS Head Office may cancel *PMS Certificate*. In that case, PRS notifies the Owner thereof and enters an appropriate record in the ship's survey status and in the *Certificate of Class*.

3.5.2.11 Additional audit is performed in the scope of PMS Annual Audit with special attention paid to the non-conformities entered in the **condition of class** mentioned in 3.5.2.9.

4 CONDITION MONITORING SYSTEM (CM) AND CONDITION BASED MAINTENANCE SYSTEM (CBM)

4.1 General

4.1.1 CM/CBM System is an alternative system for PRS survey of ship machinery based on the approved and implemented Condition Monitoring Programme (CMP). The system allows for the Owner's ongoing analysis of the technical condition of the machinery covered by such a system and for determining the individual machinery components' repair dates or their overhaul in the opened up condition.

4.1.2 CM/CBM System implementation process includes the approval of both the Owner's CM/CMB and Ship's CM/CBM. The Ship's CM/CBM approval process includes the approval of CMP and the correct implementation of the approved CMP on board the ship – to be confirmed by the implementation survey performed on board the ship.

4.1.3 CM/CBM System may cover the following:

- pumps,
- electrical rotating machinery (motors, generators)

- turbines,
- reduction gearing,
- compressors,
- bearings,
- other equipment subject to PRS consent in each particular case, **i.e. components and systems covered by CMS.**

4.1.4 Where the Owner has changed, CM/CBM System is cancelled automatically, i.e. both the Owner's CM/CBM and Ship's CM/CBM are cancelled.

4.1.5 Definitions

Cepstrum – inverse Fourier transform.

CM System Handbook – approved CMP.

Condition monitoring programme (CMP) – Owner-developed technical survey plan for the components covered by CM/CBM System.

Annual audit – audit aiming to confirm that the approved CMP is operational on board the ship.

Equipment maintenance strategy – document covering all the Owner's operations and activities focused on maintaining the machinery in the required technical condition.

FFT Analysis – fast Fourier transform analysis.

Implementation survey – initial survey aiming to verify that the approved CMP is implemented and operational on board the ship.

Owner's CM/CBM – the process of verification of the Owner's office ability to maintain the CM/CBM System confirmed by the *Certificate of Owner's CM/CBM* issue.

Reference value – value of diagnostic parameter determining the machinery component condition assessment result.

Ship's CM/CBM – the process of verification of the equipment and crew preparation to maintain CM/CBM System; to be confirmed by the issue of the *Certificate of Ship's CM*.

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.

Diagnostic – examination of symptoms and syndromes to determine the nature of faults or failures.

Condition Based Maintenance (CBM) – maintenance performed as governed by condition monitoring programmes.

4.1.6 Condition Monitoring (CM)

4.1.6.1 Where an approved condition monitoring system is fitted, credit for survey may be based on acceptable condition monitoring results. The condition monitoring results are to be reviewed during the annual audit.

4.1.6.2 Limiting parameters are to be based on the Original Equipment Manufacturers guidelines (OEM), or a recognised international standard.

4.1.6.3 The condition monitoring system is to provide an equivalent or greater degree of confidence in the condition of the machinery to traditional survey techniques.

4.1.6.4 The condition monitoring system shall be approved in accordance by PRS.

4.1.6.5 A condition monitoring system may be used to provide a greater understanding of equipment condition, and a condition based maintenance scheme may be used to obtain maintenance efficiency. Class approval is required where owners wish to change the survey cycle based on CM/CBM.

4.1.6.6 Software systems can use complex algorithms, machine learning and knowledge of global equipment populations/defect data in order to identify acceptability for continued service or the requirement for maintenance. These systems may be independent of the OEM recommended maintenance and condition monitoring suggested limits. Approval of this type of software is to be based on OEM recommendations, industry standards and PRS experience.

4.1.6.7 PRS retains the right to test or open-up the machinery, irrespective of the CM results, if deemed necessary.

4.1.7 Condition Based Maintenance (CBM)

4.1.7.1 Where an owner wishes to base their equipment maintenance on a CBM approach, this is to meet the requirements of the *ISM Code*.

4.1.7.2 Where an agreed planned maintenance and CBM scheme is in operation, the CMS and other survey intervals may be extended based on OEM maintenance recommendations and acceptable condition monitoring results.

4.1.7.3 Limiting parameters (alarms and warnings) are to be based on the OEM guidelines, or a recognised international standard.

4.1.7.4 The CBM scheme is to provide an equivalent or greater degree of confidence in the condition of the machinery to traditional maintenance techniques.

4.1.7.5 The scheme shall be approved in accordance with each Member Society's procedures.

4.1.7.6 Software systems can use complex algorithms, machine learning and knowledge of global equipment populations/defect data in order to identify acceptability for continued service or the requirement for maintenance. These systems may be independent of the OEM recommended maintenance and condition monitoring suggested limits. Approval of this type of software is to be based on OEM recommendations, industry standards and PRS experience.

4.1.8 Onboard responsibility

4.1.8.1 The chief engineer shall be the responsible person on board in charge of the CM/CBM.

4.1.8.2 Documentation on the overhaul of items covered by CM/CBM schemes shall be reported by the chief engineer.

4.1.8.3 Access to computerized systems for updating of the maintenance documentation and maintenance program shall only be permitted by the chief engineer or other authorized person.

4.1.8.4 All personnel involved in CM/CBM shall be appropriately qualified.

Note: CM does not replace routine surveillance or the chief engineer's responsibility for taking decisions in accordance with his judgement.

4.1.9 Equipment and system requirements

4.1.9.1 CM equipment and systems shall be approved by PRS.

4.1.9.2 The CM/CBM scheme and its extent, are to be approved by the PRS.

4.1.9.3 The CBM scheme is to be capable of producing a condition report, and maintenance recommendations.

4.1.9.4 A system is to be provided to identify where limiting parameters (alarms and warnings) are modified during the operation of the scheme.

4.1.9.5 Where CM and CBM schemes use remote monitoring and diagnosis (i.e. data is transferred from the vessel and analysed remotely), the system is to meet the applicable standards for Cyber Safety and Security. The system shall be capable of continued onboard operation in the event of loss of the communication function.

4.1.9.6 CBM schemes are to identify defects and unexpected failures that were not prevented by the CM system.

4.1.9.7 Systems shall include a method of backing up data at regular intervals.

4.2 Implementation and Maintaining of CM/CBM System

4.2.1 Before the request for CM/CBM System implementation has been submitted, the following conditions shall be fulfilled:

- ship machinery shall be covered by the *Planned Maintenance Scheme* (PMS) for machinery,
- Owner-developed CMP shall be a part of PMS,
- the installation survey is to take place, the equipment and software shall be installed and surveyed in accordance with PRS rules and the set of base line readings is to be taken.

4.2.2 The information contained in the following documents is the base for CM System implementation process:

- equipment maintenance strategy developed and used by the ship Owner,
- list of machinery components covered by CM System,
- descriptions of the methods for machinery components' condition diagnosing,
- reference values,
- records of the incorporation of CM System elements into PMS.

4.2.3 Implementation survey

4.2.3.1 The Implementation Survey shall be carried out by the Society's surveyor no earlier than 6 months after installation survey and no later than the first class annual survey.

4.2.3.2 During the Implementation survey the following shall be verified by a surveyor:

- the CM/CBM scheme is implemented according to the approval documentation, including a comparison with baseline data;
- by the scheme is producing the documentation required for the annual audit and the;
- requirements of surveys and testing for the maintenance of class are complied with;
- the onboard personnel are familiar with operating the scheme;
- records of any limiting parameters (alarms and warnings) that have been modified;
- during the operation of the scheme;
- records of any failures of monitored equipment are to be reviewed to ensure that the condition monitoring scheme is effective/sufficient.

4.2.3.3 When this survey is carried out and the implementation is found in order, a report describing the scheme shall be submitted to PRS HO and the scheme may be put into service.

4.2.4 Annual audit

4.2.4.1 An annual audit of the CM and CBM scheme shall be carried out a PRS surveyor concurrently with the class annual survey.

4.2.4.2 The purpose of this audit shall be to verify that the scheme is being correctly operated and that the machinery has been functioning satisfactorily since the previous audit. This is to include any limiting parameters (alarms and warnings) that have been modified since the last audit. A general examination of the items concerned shall be carried out.

4.2.4.3 The performance, condition monitoring and maintenance records shall be examined to verify that the machinery has functioned satisfactorily since the previous survey, or action has been taken in response to machinery operating parameters exceeding acceptable tolerances.

4.2.4.4 Written details of break-down or malfunction shall be made available.

4.2.4.5 At the discretion of the surveyor, function tests, confirmatory surveys and random check readings, where Condition Monitoring/Condition Based Maintenance equipment is in use, shall be carried out as far as practicable and reasonable.

4.2.4.6 The familiarity of the chief engineer and other personnel involved with the CM system shall be verified.

4.2.4.7 Calibration status of sensors and equipment shall be verified.

4.2.4.8 Verification that the suitability of the CM/CBM scheme has been reviewed following defects and failures shall be carried out.

4.2.5 Damage and repairs

4.2.5.1 Damage to components or items of machinery is to be reported to the PRS. The repairs of such damaged components or items of machinery are to be carried out to the satisfaction of the Surveyor.

4.2.5.2 Details of repairs and maintenance carried out shall be examined. Any machinery part, which has been replaced by a spare one, due to damage, is to be retained on board where possible until examined by the Society's Surveyor.

4.2.5.3 Defect and failure data is to be reviewed in order to ensure the system output is appropriate. Where necessary, following review of the failure data, there is to be a method of amending the CM and CBM scheme.

4.3 Requirements for CM/CBM system documentation

4.3.1 General

4.3.1.1 Before the request for CM/CBM System approval has been submitted to PRS, the Owner shall follow the *Equipment Maintenance Strategy* developed by themselves.

4.3.1.2 The scope of documentation to be submitted to PRS is specified in paragraphs 4.3.2 and 4.3.3. The documentation shall include all the contracts for the outsourced measurements, i.e. the measurements and/or vibration analysis, oil analysis, etc.

4.3.1.3 After the submitted documentation has been approved, the *Owner's Certificate of CM/CBM* is issued to enable the ship Owner to request the approval of Ship's CM/CBM for the specific ship. Individual *Condition Monitoring Programme* (CMP) shall be developed for the specific ship and submitted for approval before the implementation survey has been performed.

4.3.1.4 Subject to the implementation survey positive result, the *Ship's Certificate of CM/CBM* is issued with the conditions for subsequent annual audit endorsed.

4.3.1.5 The approved CMP is the base for annual audits performed to confirm the *Ship's Certificate of CM/CBM* validity.

4.3.2 Documentation required for Owner's CM/CBM approval

4.3.2.1 *Equipment Maintenance Strategy* which shall include:

- documentation containing the description of the qualifications of the crew and shore personnel who perform daily activities within CM/CBM System regarding the available equipment for the condition monitoring, measurement and analysis. Where a competent third party has been commissioned for the analysis and/or measurement, the relevant contract shall be submitted for acceptance;
- responsibility file indicating the persons designated for the condition monitoring, including the third person's staff, if applicable;
- flow diagram/description of work organisation and activities connected with the condition monitoring including the analysis and actions taken after a critical condition alarm has been given.

4.3.2.2 Training curriculum and schedule

The ship shall be constantly manned by the crew duly trained in CM/CBM System techniques. Relevant plans, records and training courses for the persons responsible shall be provided.

The following documents shall be submitted for approval:

- crew qualification and prospective crew training plans,
- training curriculum outline,
- descriptive plan of the turnover of crew involved in CM/CBM System operation considering constant manning of the ship by duly qualified staff,
- copies of the relevant documents to confirm the qualifications necessary for the Ship's CM/CBM operation.

4.3.3 Documentation required for ship's CM/CBM approval

4.3.3.1 Condition Monitoring Programme (CMP)

The approved Owner's CM/CBM is an integral part of CMP documentation. Furthermore, CMP shall include the following documents to be approved by PRS:

Documents available on board:

- maintenance instructions (manufacturer's and shipyard's),
- condition monitoring data including all data since last opening of the machine and the original base line data,
- reference documentation (trend investigation procedures etc.),
- records of maintenance including repairs and renewals carried out.

Detailed information:

- detailed description of the condition monitoring techniques applied,
- arrangement sketch of measurement points,

- alarm triggering values agreed with the equipment manufacturer,
- the schedule of diagnostic check-ups,
- condition monitoring result-based actions,
- condition monitoring equipment data files (sensors, vibration meters, data collectors and analytical systems),
- set of calibration and functional certificates for measuring instrumentation.

4.3.3.2 Information on CM/CBM system incorporation into ship's PMS

All the equipment covered by CM/CBM System shall also be covered by PMS. Furthermore, PMS shall enable determining of the testing schedule for specific machinery components depending on the condition monitoring results.

4.3.3.3 Condition monitoring result follow-up procedures

4.3.3.4 Operating procedures for results nearly, or exceeding, alarm triggering values

4.4 CM/CBM system certificate

4.4.1 The *Certificate of Owner's CM/CBM* is issued for the period not exceeding 5 years. The issue of such a Certificate for further 5 years is subject to the positive result of the implemented CM System analysis performed by PRS.

4.4.2 The *Certificate of Ship's CM/CBM* is issued for the period of 5 years, however not beyond the class renewal survey date. The Certificate validity is confirmed during periodical classification surveys of ship. The issue of such a Certificate for further 5 years is subject to the positive result of annual audits.

4.4.3 Where the *Certificate of Owner's CM* has been cancelled, all the certificates of ship's CM are cancelled automatically.

4.4.4 Approval validity

4.4.4.1 An annual audit shall be carried out to maintain the validity of the CM/CBM scheme.

4.4.4.2 The survey arrangement for machinery under CM/CBM can be cancelled by the PRS, if the scheme is not being satisfactorily carried out either from the maintenance records or the general condition of the machinery.

4.4.4.3 The case of sale or change of management of the ship or transfer of class shall cause the approval to be reconsidered.

4.4.4.4 The ship owner may, at any time, cancel the survey arrangement for machinery under the scheme by informing the PRS in writing and for this case the items which have been inspected under the scheme since the last annual audit can be credited for class at the discretion of the attending surveyor.

4.5 Condition monitoring methods

4.5.1 Vibration and acoustic diagnostics

4.5.1.1 Technology review

4.5.1.1.1 For the shipborne equipment testing, ultrasonic instruments may be used. Their typical applications are: testing of bearings, gears, pumps, electric motors, valves, leakage

detection in pressure or vacuum equipment, such as boilers, heat exchangers, condensers, piping, hydraulic systems as well as arcing tests in the electrical apparatus.

4.5.1.1.2 There are a lot of ultrasound sources. In normal operation condition, bearings generate different sounds from those generated after the defect occurrence. Ultrasound propagation is different from a regular sound wave as it has a circular form which enables accurate measurement and easy determining of the location abnormality source location.

4.5.1.1.3 Ultrasound measurement is focused on the following four basic parameters: RMS, MAX RMS, PEAK and CREST FACTOR. These parameters determine the signal energy and amplitude thus providing information on various irregularities in operation of, for instance, a bearing.

4.5.1.1.4 The parameters may be divided into statical and dynamical. The above mentioned parameters are statical, whereas the dynamic ones are represented by the diagram dB μ V versus time.

4.5.1.1.5 The methods of measurement and analysis of results are subject to PRS verification in each particular case.

4.5.1.2 Technical documentation

The following documentation shall be submitted to PRS for the ultrasonic testing method acceptance:

- measuring instrument specifications or system overview;
- functional description, user's manual,
- parameters and data collection method;
- calibration certificate and/or other certificates, including conformity certificates;
- measurement points;
- electrical installation diagrams (including power supply circuits), if applicable;
- calculation method;
- testing/analysis procedure;
- list of equipment components (including their present condition).

4.5.2 Thermal imaging diagnostics

4.5.2.1 Technology overview

4.5.2.1.1 Thermal analysis technology enables quick detection of operations irregularities of various equipment components as well as both machinery and electrical installations. Variance in the object's thermal condition reflect the changes in their internal and external temperature. Slow thermal changes may testify to the wear and tear progress whereas fast changes will signify imminent damage.

4.5.2.1.2 Continuous or as frequent as possible measurement within thermal analysis is the condition of the measurement effectiveness. Within that method, the diagnostics may be divided into two stages where the first consists in the analysis of individual thermal photos (thermograms), and the second consists in the analysis of the changes in the selected parameters in microintervals (dynamic changes) and macrointervals (functional changes).

4.5.2.1.3 Thermal imaging techniques are commonly used in that method. They enable infrared radiation measurement. They convert the infrared radiation signal into the thermal image (thermogram). They enable the selection of many functions and continuous analysis of thermal

changes, consequently they provide for early detection of the incorrect operation of an object or its component.

4.5.2.1.4 Thermal image investigation may be included in the shipborne machinery installations' CM System for early detection of the equipment operation irregularities.

4.5.2.1.5 Measurement/analysis methods are subject to PRS verification in each particular case.

4.5.2.2 Technical documentation

The following documentation shall be submitted to PRS for the thermal imaging method acceptance:

- measuring instrument specifications or system overview;
- functional description, user's manual,
- parameters and data collection method;
- calibration certificate and/or other certificates, including conformity certificates;
- recording and storage of measurements taken;
- measurement points;
- electrical installation diagrams (including power supply circuits), if applicable;
- calculation methods used for the assessment of measurements taken;
- testing/analysis procedure;
- list of equipment components (including their present condition).

4.5.3 Oil analysis

4.5.3.1 Technology overview

4.5.3.1.1 Variation of physical and chemical properties of oil is a machinery component technical condition diagnostic parameter. As oil is an environment easily communicating on the emergency occurrence, the changes of its properties are a significant indicator enabling early detection of the equipment component damage.

4.5.3.1.2 Physical and chemical analysis is performed for the samples of physical and chemical:

- hydraulic oil,
- lubrication oil,
- thermal oil,
- other types of oil, as necessary.

4.5.3.1.3 Oil samples shall be taken and transferred to be analysed at intervals specified by the Owner, taking account of the manufacturer's recommendations and PRS requirements.

4.5.3.1.4 Representative sample of the whole volume of oil in the installation shall be taken through the drain cock at the oil outlet (before the oil filter) while the equipment is in operation, after some oil has been drained to avoid the sample contamination which might result in the wrong assessment of further usefulness of oil.

4.5.3.1.5 The oil is delivered to the ship together with the sample containers protected against unauthorised opening and provided with labels for the sample description as well as envelope/packaging for the sample shipment by post.

4.5.3.1.6 Oil description shall include the following information:

- Owner's particulars,
- ship name,

- name of the equipment component from which the sample has been taken,
- oil type,
- sampling date,
- oil running hours since the installation was filled,
- volume of oil in the installation,
- supplementary notes, if necessary,

and shall be immediately transferred together with the sample to the oil manufacturer's laboratory or to another manufacturer-authorized laboratory.

4.5.3.1.7 The assessment made by the laboratory to be sent to the Owner shall include the following characteristics (as appropriate to the specific oil type):

- viscosity,
- mass density,
- water content,
- chlorides' content (where sea water penetration is possible),
- insoluble contaminants' content,
- total basicity number (TBN),
- total acidity number (TAN),
- chemical composition of contaminants/wear products,
- flash point,
- other parameters, where necessary,
- oil assessment and recommendations (the Owner is responsible for decision-making in respect of further use or taking other measures).

4.5.3.2 Technical documentation

The following documentation shall be submitted to PRS for the lubrication oil testing method acceptance:

- equipment description (user's manual);
- parameters and data collection method;
- measurement points;
- testing/analysis procedures;
- list of approved laboratories.

4.5.4 Mechanical vibration analysis

4.5.4.1 Technology overview

4.5.4.1.1 Vibration measurement is the method of machinery condition monitoring. Vibration is a harmful consequence of loads due to mechanical energy transmission which leads to the equipment wear and an increase in its failure frequency.

4.5.4.1.2 Periodically taken measurements facilitate detection of the deterioration of specific machinery component condition.

4.5.4.1.3 Measurements taken are compared with the parameters specified in standards or reference values set for each equipment component. The reference value shall be determined through the measurements taken by duly qualified personnel in specified operation conditions representative in view of further operation of such equipment.

4.5.4.1.4 The tendencies confirmed by regular vibration measurement readings enable the identification of defects, tracking their development and repair schedule planning.

4.5.4.1.5 The measurement of vibration intensity, i.e. its velocity and amplitude increase, is the base for the equipment component vibration assessment. The minimum requirements for measuring instruments are specified in standard ISO 10816 and they refer to the root mean square value and velocity [mm/s].

4.5.4.1.6 For turbines, gears, piston pumps and compressors fast Fourier transform analysis is required. This analysis shall be performed by personnel duly trained in vibration or vibration experts. Such specialists shall define, in agreement with PRS, measurement points considering the tested equipment manufacture's recommendations. The measurement points shall be permanently marked so that subsequent measurements be taken in the same locations.

4.5.4.1.7 Periodical vibration measurements shall be taken by duly trained personnel. As a rule, machinery being in operation permanently shall be checked at intervals not exceeding one month, whereas the machinery being in operation periodically – at intervals not exceeding three months. It is recommended that periodical measurements be taken in the loaded condition as close to the reference values as possible.

4.5.4.1.8 Measurement/analysis methods are subject to PRS verification in each particular case.

4.5.4.2 Technical documentation

The following documentation shall be submitted to PRS for the vibration testing method acceptance:

- measuring instrument specifications or system overview;
- functional description, user's manual;
- parameters and data collection method;
- measurement points;
- calculation methods;
- testing/analysis procedure;
- list of equipment components (including their present condition).

4.5.4.3 Relations between the exemplary defects and vibration occurring:

| Defect type | Predominant vibration component frequency [Hz] | Direction | Notes |
|--------------------------------------|--|------------------|---|
| Revolving elements unbalanced | 1 × rev./s | Radial | Common reason for excessive vibration level in the equipment |
| Misalignment and deflection of shaft | usually 1 × rev./s; often 2 × rev./s occasionally 3 and 4 × rev./s | Radial and axial | Typical defect |
| Bearing rolling element damaged | Impact frequency of single element of bearing. Also high-frequency vibration (2 to 60 kHz) often related to radial resonances of bearings | Radial and axial | Unstable vibration level, often with impacts. Impact frequency f (Hz): for damaged outer track of bearing $f = n/2 f_r (1 - BP/PD \cos \beta)$ for damaged inner track of bearing $f = n/2 f_r (1 + BP/PD \cos \beta)$ for damaged rolling element $f = PD/BD f_r [1 - (BD/PD \cos \beta)^2]$ where: β – contact angle, BD – rolling element diameter (ball, roller), PD – pitch diameter, |

| Defect type | Predominant vibration component frequency [Hz] | Direction | Notes |
|--|---|----------------------|--|
| | | | n – number of rolling elements (balls, rollers), f_r – number of revolutions per second of inner track in relation to outer track |
| Slide bearing clearance in its housing | Subharmonic rev./s of shaft, $\frac{1}{2}$ or $\frac{1}{3} \times$ rev./s | Predominantly radial | Clearance may manifest only at the operational speed and temperature (e.g. turbine machinery). |
| Oil whirl or run-out in slide-bearing | Slightly lower than half of shaft's rev./s | Predominantly radial | Occurs in high-speed machinery (e.g. turbines) |
| Hysteresis whirl | Critical shaft speed rev./s | Predominantly radial | Vibration excited at exceeding critical shaft speed lasts at higher shaft speeds. |
| Gear damaged | Meshing frequency (shaft's rev./s \times number of teeth) and harmonics | Radial and axial | Side bands around meshing frequencies testify to modulations (e.g. eccentric) at frequency equal to the spacing of side bands. Usually detectable only by means of narrow-band analysis and cepstrum |
| Clearances | $2 \times$ rev./s | | Both subharmonics and interharmonics, like at slide bearing slackness |
| Belt transmission damaged | 1, 2, 3 and $4 \times$ rev./s of belt | Radial | The problem may usually be identified visually by means of stroboscope |
| Electrically-excited vibration | $1 \times$ rev./s or 1 or $2 \times$ synchronisation frequency | Radial and axial | Should fade after power supply shut-off |

4.6 Reference value measurements

4.6.1 Reference values shall be measured by duly trained personnel.

4.6.2 Measurements shall be taken in accurately defined operational conditions.

4.6.3 Prior to the commencement of measurements, care shall be taken to ensure stable conditions for measurements.

4.6.4 The obtained results shall be assessed to detect defective states. Defects shall be rectified before the reference value has been determined. Where the equipment is subjected to survey in opened up condition or it has been replaced, new reference values shall be determined. New alarm triggering values of diagnostic parameters shall be defined to be applied between surveys in opened up condition.

4.7 Condition monitoring survey scopes

4.7.1 Machinery components

4.7.1.1 General

Every machinery component included in the list of equipment covered by PMS System may be covered by CM System. Positive result of the component condition monitoring may allow the equipment component internal examination to be waived.

4.7.1.2 Implementation survey

Reference value measurements for all the equipment covered by CM System shall be verified in its normal operation conditions.

Subject to survey and testing, where necessary, are the following:

- apparatus measuring functions and condition monitoring software,
- equipment/procedures for oil sampling and service,
- vibration measurement installation equipment,
- personnel skills at the operation of condition monitoring instrumentation,
- planned maintenance system and/or the documentation for equipment maintenance in accordance with the manufacturer's instructions.

4.7.1.3 Pumps

Pump reference value measurements shall include, where applicable, the following parameters:

- vibration parameters (vibration spectrum or complete) of all the relevant bearings,
- electric motor power consumption (record shall be entered during the pump operation in normal service conditions) and rotation rate,
- suction head and discharge pressure,
- rotor axial displacement, if applicable.

For installations with pump rotation rate control, all the reference values, including vibration measurements, shall be recorded at the maximum rotation rate.

4.7.1.4 Compressors

Compressor reference value measurements shall include, where applicable, the following parameters:

- vibration parameters (vibration spectrum) of all the relevant bearings,
- electric motor power consumption (measurement shall be taken at the discharge pressure of 2 bar below the design pressure or below the recommended shut-off pressure, whichever is lower) and rotation rate,
- lubrication oil pressure.

Lubrication oil pressure shall be measured at the same discharge pressure.

4.7.1.5 Generators

Generator value measurements shall include, where applicable, the following parameters:

- vibration parameters (vibration spectrum) of all the relevant bearings,
- rotation rate and power.

Measurements shall be taken at idle speed to avoid interference in the interesting part of vibration spectrum by motor forces' induction.

4.7.1.6 Annual audit

Essentially, the annual audit covers:

- review of planned maintenance system and equipment maintenance documentation,
- crediting those equipment components which were subjected to survey in opened up condition,
- the review of analyses and trends of vibration measurements' data and lubrication oil analyses obtained from the recent annual audit,

- verification of crew skills at the operation of condition monitoring equipment,
- equipment calibration status verification.

PRS Surveyor may require that other specific tests be performed.

4.7.2 Turbines

4.7.2.1 General

Monitoring of the condition of turbine and the associated equipment covered by CM System allows the internal examination to be waived. CM System aims to monitor the power transmission system (i.e. bearings, gearing) condition.

4.7.2.2 Implementation survey

Subject to survey and testing, where necessary, are the following:

- apparatus measuring functions and condition monitoring software,
- equipment/procedures for oil sampling and service,
- vibration measurement installation equipment,
- personnel skills at the operation of condition monitoring instrumentation,
- planned maintenance system and/or the documentation for equipment maintenance in accordance with the manufacturer's instructions.

4.7.2.3 Steam turbines

Reference values shall be measured in normal service conditions and shall include the following parameters:

- vibration parameters (spectrum) induced by all the relevant bearings,
- vibration parameters measured by permanently fixed monitoring equipment, if applicable,
- axial displacement of rotor, where applicable,
- steam pressure, flow rate and temperature between the inlet and outlet segments and the turbine gland,
- condenser pressure,
- lubrication oil pressure and controller oil pressure,
- rotation rate and torque.

4.7.2.4 Gas turbines

Reference values shall be measured in normal service conditions and shall include the following parameters:

- atmospheric air temperature, pressure and humidity,
- fuel calorific value,
- vibration parameters (spectrum) of all the relevant bearings,
- parameters of vibration measured by permanently fixed monitoring equipment, where applicable,
- axial displacement of rotor(s),
- air temperature and pressure at the compressor inlet and outlet,
- combustion temperature,
- fuel flow rate,
- exhaust gas temperature and pressure at the inlets and outlets of the exhaust gas generator turbine and power turbine,
- lubrication oil pressure and oil pressure in the controller,
- rotation rate and torque.

4.7.2.5 Reduction gearing

Reduction gearing reference value measurements shall cover, where applicable, the following parameters:

- vibration parameters (vibration spectrum) of all the relevant bearings to be measured at the sampling frequency at least twice the meshing frequency,
- shaft axial displacement (by means of built-in equipment), where applicable,
- lubrication oil pressure in bearings,
- rotation rate and torque.

4.7.2.6 Turbine-driven generators

Reference value measurements shall cover:

- vibration parameters (spectrum) of all the relevant bearings,
- load (not less than 80% of rated power), and
- rotation rate.

4.7.2.7 Annual audit

Essentially, the annual audit covers:

- review of planned maintenance system and equipment maintenance documentation,
- review of analyses and trends of vibration measurements' data and lubrication oil analyses obtained from the recent annual audit,
- verification of crew skills at the operation of condition monitoring equipment,
- equipment calibration status verification.

PRS Surveyor may require that other specific tests be performed.

List of amendments effective as of 1 January 2020

| <i>Item</i> | <i>Title/Subject</i> | <i>Source</i> |
|---------------------------|---|-----------------------------|
| Chapter 4 | Condition monitoring system (CM) and condition based maintenance system (CBM) | IACS.UR Z27 (new July 2018) |

List of amendments effective as of 1 July 2020

| <i>Item</i> | <i>Title/Subject</i> | <i>Source</i> |
|---------------|---|--------------------------|
| various items | Substitution of the term "recommendation" by the term "condition" | IACS decision (KDZ 3581) |