ShipRight

Design and construction

Machinery Planned Maintenance and Condition Monitoring

Linked Supporting Service

March 2013
ShipRight

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Document History

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<th>Document Date</th>
<th>Notes</th>
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<tr>
<td>July 2002</td>
<td>Major review involving the merger of Chapters 9 and 10 of the January 1997 Version</td>
</tr>
<tr>
<td>July 2002 – Notice 1</td>
<td>Revisions as identified in ‘History of Development up to January 2004’.</td>
</tr>
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**MACHINERY PLANNED MAINTENANCE AND CONDITION MONITORING**  

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Machinery Planned Maintenance and Condition Monitoring

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### Section 1: Introduction

#### 1.1 Summary

These procedures describe how a Machinery Planned Maintenance Scheme approved by Lloyd’s Register can be accepted as an integral part of the Continuous Survey Machinery (CSM) cycle. The basis of an approved Machinery Planned Maintenance Scheme is that maintenance and inspection carried out by Chief Engineers according to an approved plan can be used to modify the extent of traditional survey requirements. The procedures also describe how condition monitoring of machinery can be incorporated.

Approved Machinery Planned Maintenance Schemes are based on the use of Chief Engineers who undertake planned maintenance activities on a continuous basis. Lloyd’s Register Surveyors confirm satisfactory operation of the scheme at an Annual Audit. Condition monitoring of machinery may be applied either as part of the planned maintenance scheme or independently for specific screwshaft and steam turbine procedures.

The main business benefits of operating an approved Machinery Planned Maintenance Scheme are:

(a) Selected machinery systems and components can be credited for survey based on examinations by the ship’s Chief Engineer without the need for a Lloyd’s Register Surveyor to be present, thus reducing:
   - duplication of the Operator’s own planned maintenance and inspection programme with the requirements of classification surveys,
   - the overall number of visits by a Lloyd’s Register Surveyor to a ship,
   - the extent of opening out required for formal survey, subject to confirmatory audits and the optional use of condition monitoring,

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1 Operator may be the Owner or Manager responsible for the day-to-day operation and maintenance of the ship, i.e. the company who has assumed the responsibility for operation of the ship as defined by the International Safety Management Code (ISM Code).
SECTION 1

- the risk of delay resulting from these surveys,
- the overall cost of ship operations.

(b) An increase in:
- utilisation of existing planned maintenance systems,
- the revenue earning potential of a ship through increased availability.

(c) Recognition of the Operator’s commitment to maintaining a high quality ship by the assignment of a descriptive note in Lloyd’s Register’s Register of Ships.

The remaining parts of this Chapter present an overview of the various schemes, their operation and the notations available together with details of how to apply for them. General guidance on planned maintenance is given in Annex A.

1.2 Overview of schemes and notations

Approved Machinery Planned Maintenance Scheme (ShipRight MPMS Descriptive Note)

When a machinery planned maintenance scheme approved by Lloyd’s Register is in use, Chief Engineers may carry out the examination of selected machinery items, without the need for a Lloyd’s Register Surveyor to be present. An Annual Audit is required, at which time a Lloyd’s Register Surveyor will undertake confirmatory surveys on those items to be credited which have been examined by the Chief Engineer during the preceding year.

Machinery Condition Monitoring (ShipRight MCM Descriptive Note)

Where machinery condition monitoring is in use, those monitored machinery items need only be opened out for examination and survey when readings of condition and performance parameters indicate deterioration beyond manufacturer’s recommended limits. Condition records are examined at the Annual Audit to verify that they are within specified limits and confirmatory readings may be taken to compare with the ship’s records. The Operator decides the number of machines to be included in the scheme, the remaining items not subject to condition monitoring are dealt with under MPMS/CSM. The ship must be operating an approved Machinery Planned Maintenance Scheme.

Machinery Condition Based Maintenance (ShipRight MCBM Descriptive Note)

Operators may wish to base their machinery maintenance procedures on a Condition Based Maintenance scheme (CBM), which will incorporate all classed CSM machinery items assessed on the basis of criticality and probability of failure. Lloyd’s Register will accept this approach for survey purposes providing certain requirements for operation of the scheme are met. The ship must be operating an approved Machinery Planned Maintenance Scheme.

Reliability Centred Maintenance (ShipRight RCM Descriptive Note)

Operators may wish to base their machinery maintenance procedures on the results of a Reliability Centred Maintenance study. Lloyd’s Register will accept this approach for survey purposes providing certain requirements for operation of the scheme are met. The ship must be operating an approved Machinery Planned Maintenance Scheme.

Screwshaft Condition Monitoring (ShipRight SCM Descriptive Note)

For screwshafts there is a specific procedure based on the use of condition monitoring which provides an alternative method of survey. With the SCM procedure, the screwshaft need not be withdrawn from the stern bearing at the normal survey intervals if condition monitoring data is found to be within permissible limits. It should be noted that fixed pitch propellers are still required to be removed and controllable pitch propellers opened up for examination. It is not necessary for the ship to be operating an approved Machinery Planned Maintenance Scheme.

Turbine Condition Monitoring (ShipRight TCM Descriptive Note)

For steam turbines for direct main propulsion there is a specific procedure based on the use of condition monitoring and performance measurements. With the TCM procedure, the turbine top casings need not be lifted for examination of the rotors and diaphragms if vibration measurements and a performance trial indicate satisfactory condition. It is not necessary for the ship to be operating an approved Machinery Planned Maintenance Scheme.

Assignment of Notations

Compliance with the procedures may, upon application, lead to descriptive notes being assigned for inclusion in Lloyd’s Register’s Register of Ships. Where applicable, an appropriate Memoranda item will be entered on the ship’s survey status.
Machinery Planned Maintenance and Condition Monitoring

For example:

ShipRight MPMS, MCM, SCM indicates that the ship is using an approved Machinery Planned Maintenance Scheme, with Machinery Condition Monitoring and Screwshaft Condition Monitoring.

Section 2: Approved Machinery Planned Maintenance Schemes

2.1 Introduction

The following improved facilities for dealing with machinery surveys are provided through adoption of the Machinery Planned Maintenance Scheme:

- A more flexible approach to dealing with classification surveys of selected machinery items. Opening out for classification inspection is restricted to the service overhauls generally specified by the equipment manufacturers or, where agreed by the equipment manufacturers, to overhauls based on documented operator’s experience. The condition as observed and reported by Chief Engineers will, subject to Annual Audit, be sufficient to credit the items for survey.

- The Operator can operate a single system, covering maintenance, spare parts supply and survey requirements. The level of documentation and control will demonstrate a commitment to International Safety Management Code requirements.

The Machinery Planned Maintenance Scheme will operate by allowing Chief Engineers to carry out examinations of selected machinery items to an approved schedule over a five year period corresponding to the existing classification cycles. Ships currently undertaking, or transferring to, classification surveys by the Continuous Survey Machinery (CSM) regime may be accepted onto the scheme. In order to implement the scheme, however, it will be necessary to divide the items selected for Chief Engineer examination such that approximately 20 per cent of machinery master list items are examined each year. In preparing this schedule of examinations, due account should be taken of the items still required to be surveyed by a Lloyd’s Register Surveyor such that these may be conveniently carried out at the time of the Annual Audit or on completion of the CSM cycle.

An Approved Machinery Planned Maintenance Scheme is also a pre-requisite for ships operating under the ShipRight MCM, MCBM and RCM descriptive notes.
<table>
<thead>
<tr>
<th>Item</th>
<th>Component</th>
<th>Key:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C/E: Chief Engineer item</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LR: Lloyd’s Register Surveyor item</td>
</tr>
<tr>
<td>Main propulsion diesel engines</td>
<td>Cylinder covers</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Valves and valve gears</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Cylinder liners</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Pistons and piston rods</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Connecting rods, crossheads, top end bearings, guides, gudgeon pins and bushes</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Crankshafts and bearings in multiple engine installations</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Crankshafts and bearings in single engine installations</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Fuel injection pumps and fuel booster pumps</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Scavenge pumps, blowers and air coolers</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Turbocharger</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Detuners, dampers and balancer units</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Camshaft and camshaft drive</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Main engine thrust bearing</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Crankcase doors, crankcase and scavenge relief devices</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Governor</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Engine trial</td>
<td>LR</td>
</tr>
<tr>
<td></td>
<td>First start arrangement trial</td>
<td>LR</td>
</tr>
<tr>
<td></td>
<td>Auxiliary diesel engines</td>
<td>Complete unit including coolers and pumps</td>
</tr>
<tr>
<td>Main steam turbines</td>
<td>Complete unit</td>
<td>LR Unless special arrangements have been agreed. See Table 3.4.3</td>
</tr>
<tr>
<td>Auxiliary steam turbines</td>
<td>Complete unit including coolers and pumps</td>
<td>C/E See Note 3 and Table 3.4.3</td>
</tr>
<tr>
<td>Gas turbines</td>
<td>Complete unit</td>
<td>LR Unless special arrangements have been agreed. See Table 3.4.4</td>
</tr>
<tr>
<td>Reduction gearing</td>
<td>Reduction/increase gearing, flexible couplings and clutches</td>
<td>LR</td>
</tr>
<tr>
<td>Shafting</td>
<td>Intermediate shafts</td>
<td>C/E LR Modified survey procedures may be applicable. See Table 3.4.6</td>
</tr>
<tr>
<td></td>
<td>Screwshafts</td>
<td>LR</td>
</tr>
<tr>
<td></td>
<td>Stern bearings</td>
<td>LR</td>
</tr>
<tr>
<td>Propellers</td>
<td>Complete unit</td>
<td>LR</td>
</tr>
<tr>
<td>Auxiliary machinery</td>
<td>Main engine driven pumps, e.g., bilge, lubricating oil and cooling water</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Independently driven pumps (and associated motors and cables where insulation resistance readings are supplied), e.g., bilge, ballast, fresh water cooling, sea-water cooling, lubricating oil and oil fuel transfer pumping arrangements</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Sea connections</td>
<td>LR</td>
</tr>
<tr>
<td></td>
<td>Main engine fresh water and lubricating oil coolers</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Low pressure heaters used in high viscosity fuel systems of internal combustion engines</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Main and auxiliary condensers/drain coolers</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Air compressors and their safety devices</td>
<td>C/E</td>
</tr>
<tr>
<td></td>
<td>Forced or induced draught fans</td>
<td>C/E</td>
</tr>
<tr>
<td>Pressure plant</td>
<td>Boilers and other pressure vessels</td>
<td>LR</td>
</tr>
<tr>
<td></td>
<td>Boiler fuel oil heaters</td>
<td>LR</td>
</tr>
<tr>
<td></td>
<td>Steam pipes</td>
<td>LR</td>
</tr>
<tr>
<td></td>
<td>Adjustment of exhaust gas boiler safety valves under steam</td>
<td>LR</td>
</tr>
<tr>
<td></td>
<td>Manoeuvring valves and bulkhead stop valves</td>
<td>LR</td>
</tr>
<tr>
<td></td>
<td>Starting air pipes</td>
<td>LR</td>
</tr>
</tbody>
</table>
Table 2.2.1 List of applicable machinery items (conclusion)

<table>
<thead>
<tr>
<th>Item</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical equipment</td>
<td>Electrical equipment other than auxiliary motors</td>
</tr>
<tr>
<td>Control equipment</td>
<td>Main engine controls and controls associated with class notations, e.g., UMS, CCS, ICC, IP and DP</td>
</tr>
<tr>
<td>Steering machinery</td>
<td>Steering gear pump</td>
</tr>
<tr>
<td></td>
<td>Other surveyable items</td>
</tr>
<tr>
<td>Deck machinery</td>
<td>Windlass and windlass machinery</td>
</tr>
<tr>
<td>Refrigerated cargo</td>
<td>Refrigerant compressors</td>
</tr>
<tr>
<td>Installations</td>
<td>Brine pumps</td>
</tr>
<tr>
<td></td>
<td>Condenser cooling pumps</td>
</tr>
<tr>
<td></td>
<td>Liquid refrigerant circulating pumps</td>
</tr>
<tr>
<td>Ships for liquefied gases</td>
<td>Refrigerant compressors</td>
</tr>
<tr>
<td></td>
<td>Cargo gas compressors</td>
</tr>
<tr>
<td></td>
<td>Condenser cooling pumps</td>
</tr>
<tr>
<td></td>
<td>Circulating pumps (where fitted)</td>
</tr>
<tr>
<td>Ships fitted with</td>
<td>Scrubber units</td>
</tr>
<tr>
<td>approved inert gas systems</td>
<td>Blowers</td>
</tr>
<tr>
<td></td>
<td>Independent gas generators</td>
</tr>
<tr>
<td></td>
<td>Remaining components of inert gas systems</td>
</tr>
<tr>
<td>General</td>
<td>Holding down bolts and chocks</td>
</tr>
<tr>
<td></td>
<td>Machinery damage, repairs and alterations</td>
</tr>
</tbody>
</table>

NOTES
1. Special arrangements for the Chief Engineer to survey the main engine crankshaft and bearings are applicable when torsional vibration characteristics indicate that there is no susceptibility to damage as a result of uneven firing and when the condition monitoring requirements specified in Table 3.4.1 are complied with. Where special arrangements have been agreed to carry out the examination of the main engine crankshaft and bearings, the inspections are to proceed as follows:
   • The top and bottom halves of the main bearings are to be removed for inspection. Bridge gauge readings before removal and after replacement of bottom halves are to be recorded where facilities are provided, otherwise the crown thickness of the bearings are to be measured and compared with the engine designer’s recommended limits.
   • Crankpin bearing top and bottom halves are to be examined and clearances recorded, or crown thicknesses compared with the designer’s recommended limits. Crankpins, journals and webs are to be carefully examined for cracks, especially at the fillets and in the vicinity of oil holes.

The Confirmatory Survey carried out by Lloyd’s Register at the time of the Annual Audit will comprise:
   • A review of the condition monitoring records specified in Table 3.4.1.
   • A check of bearing clearances, where possible.
   • A check for signs of wiped or broken white metal in the crankcase and at the edges of bearings.
   • A check of shrink fit reference marks, if applicable.
   • A check of the bedplate structure, inside and out.

2. In general, the top and bottom halves of the main bearings and crankpin bearings should be removed at intervals that do not exceed the five year survey interval. Where special arrangements have been agreed, longer intervals may be accepted for large bore slow speed engines if they are based on the engine designer’s recommendations for running hours and condition monitoring. In such cases the Lloyd’s Register Surveyor may credit these items at the end of the five year cycle on the basis of a satisfactory Confirmatory Survey at the time of the Annual Audit, as described in Note 1. Requests to survey main bearings and crankpin bearings in this manner should be made in writing.

3. When used for power generation, the number of generating sets is to be such that all services essential to the propulsion and safety of the ship, also the preservation of refrigerated cargo, can be supplied when any two sets are not working. One of these sets can then be overhauled while the other remains as ‘stand-by’.
2.3 Scheme approval

It is recognised that planned maintenance schemes may take various forms. The type of maintenance control, the scheduling, reporting and recording methods can only be decided by the Operator, having due regard to all the factors involved.

However, there are some basic features that Lloyd’s Register requires when approving a planned maintenance scheme, as specified below. It should be noted that approval of the planned maintenance scheme involves approval of the Operator’s overall approach to maintenance for each installation, not just approval of the planned maintenance software. However, the amount of information to be submitted can be reduced, if the planned maintenance software has been approved using Lloyd’s Register’s Software Conformity Assessment (SCA) system. Further details of SCA can be obtained from Lloyd’s Register local offices.

Operational requirements:

**NOTE**
The approval checklist in Annex C can be used for guidance.

(a) Ship to be operating on the Continuous Survey Machinery (CSM) cycle.

(b) The language of the scheme is to be English.

(c) The scheme is to be based on a computerised system with arrangements for backing up data at regular intervals. Access to computerised systems for updating of the maintenance documentation and maintenance programme is to be only be permitted by the Chief Engineer or other authorised person(s).

(d) Approval of the scheme will be withdrawn if:
   - the Operator of the ship changes,
   - the type of computerised system changes,
   - deficiencies in the operation of the scheme are identified.

Details to be submitted:

- A general description of the scheme.
- Details and version number of the planned maintenance software.*
  This should include details of how access is controlled and the arrangements for backing-up data.
- A numbered index of the items is to be included in the scheme. This index is to include at least all CSM items which appear on the ‘Master List of Surveyable Items’. The scheme may also cover items that are not required for classification. There is to be a method of indicating those items to be dealt with by preventive maintenance and, if applicable, those by condition based maintenance. *(See also Section 3, Machinery Condition Monitoring and Section 4, Machinery Condition Based Maintenance).*
- Details of the method by which the numbered index can be cross-referenced to the master list numbers.*
- Sample maintenance job descriptions. These descriptions are to cover at least the minimum opening out necessary to demonstrate that a satisfactory examination of the item will be made. The extent of the work to be undertaken is to be indicated but it is not necessary for approval purposes to include every detailed job description. A selection of sample job descriptions will suffice to demonstrate how the system works.
- Maintenance intervals for each item. In general, the maintenance intervals should not exceed those specified for CSM. However, for components where the maintenance is based on running hours, longer intervals may be accepted as long as the intervals are based on the manufacturer’s recommendations.
- Examples of the reporting and recording procedures.* These procedures are to be sufficiently comprehensive to demonstrate that correct operation of the scheme can be verified at the time of the Annual Audit.
  Reports are to include:
  - details of inspections and maintenance carried out on a specific item over a specified time interval:
    - the condition as found;
    - any repairs effected;
    - a list of spare parts used.

**NOTE**
Items marked with an asterisk need not be submitted if the planned maintenance software has been approved using Lloyd’s Register Software Conformity Assessment (SCA) system.

2.4 Roles and responsibilities

**Operator**
The Operator should make a request for approval of the planned maintenance scheme either through a local Lloyd’s Register office or direct to the London office. The information detailed in 2.3 should be submitted. Requests for approval of planned maintenance software, in accordance with Lloyd’s Register Software Conformity Assessment system, should be made to a local Lloyd’s Register office or direct to the London office. Re-approval will be required if the Operator of the ship changes or if the type of computerised planned maintenance system is changed.
Machinery Planned Maintenance and Condition Monitoring

Lloyd’s Register
Details of the scheme will be reviewed and if acceptable a Certificate of Operation of an approved Machinery Planned Maintenance Scheme will be issued to the Operator. A specimen copy of this document is given in Annex C. A copy of the Certificate is to be retained on board the subject ship for the information of the Master, Chief Engineer and Lloyd’s Register Surveyors. The ShipRight MPMS descriptive note will be assigned to the ship if requested and an appropriate memoranda item entered on the ship’s survey status.

Chief Engineer
Chief Engineers may carry out the examination of selected machinery items, in accordance with the applicable requirements of Lloyd’s Register’s Rules and Regulations. Chief Engineers are reminded that overhaul of machinery items whilst at sea must not compromise the redundancy/standby functions which are requirements of Classification Rules.

2.5 Annual audit

The Chief Engineer or Operator should arrange for Lloyd’s Register Surveyors to carry out an Annual Audit of the Machinery Planned Maintenance Scheme. Annual Audits are to be held within three months before or after the due date and are to be harmonised with the classification annual survey. Confirmatory surveys will be carried out on those items to be credited which have been examined by the Chief Engineer during the preceding year. In the case of new ships on their first survey cycle, approximately 20 per cent of the total number of machinery master list items are to be selected for completion in each year of the survey cycle.

The Chief Engineer is to make the following information available:

- Inspection and maintenance records for each item to be credited for Class. These records should give details of any repairs carried out and spare parts used.
- Written details of any defect, breakdown or malfunction of essential machinery. Such details should include the main cause of failure, if known. Any machinery part that has been replaced due to damage should be retained on board, where possible, and examined by the Lloyd’s Register Surveyor.
- A Lloyd’s Register Certificate of Operation of an approved Machinery Planned Maintenance Scheme.
- Confirmation that the type of planned maintenance software in use is the same as that specified in the Certificate of Operation.

The machinery records and documentation will be examined in sufficient depth by the Lloyd’s Register Surveyors to ensure that the scheme has been operated correctly and that the machinery has functioned satisfactorily since the previous Audit. The records should indicate that all scheduled maintenance has been carried out. Any items not dealt with as per the schedule will be discussed with the Chief Engineer.

As part of each Audit the Lloyd’s Register Surveyor will carry out a general examination of the machinery and, as far as is practical, machinery to be credited for survey will be examined under working conditions. If the Surveyor is not satisfied with the operating condition or any aspect of the scheme’s operation he may request that items be opened out for inspection.

If deficiencies in the operation of the scheme are identified, either from the maintenance records or from the general condition of the machinery, the Surveyors may advise that a further Audit will be required and impose a suitable Condition of Class. In the event of serious deficiencies, a report will be forwarded to the Classification Committee in London recommending that approval of the scheme be withdrawn.

An Audit Checklist is available to assist Surveyors and a specimen copy is given in Annex C.

2.6 Reporting

Machinery master list items may be credited towards the ship’s survey status according to one of the following methods and/or frequencies to suit the Operator’s preference for recording assigned dates:

- Examined items credited by the attending Surveyor at the Annual Audit (i.e., as a single batch of items once per year). Assigned dates will be aligned with the Annual Audit date.
- Examined items reported by the Chief Engineer or Operator using the PMS Interactive facility. Assigned dates will be aligned with the Chief Engineer’s or Operator’s report date.
- Examined items reported by the Chief Engineer or Operator using the PMS Direct facility. Assigned dates will be aligned with the Chief Engineer’s or Operator’s report date.

**NOTE**
All assigned dates derived from reports except those items credited by the attending Surveyor at the Annual Audit are subject to confirmatory credit at the Annual Audit.
It should be noted that when items become due for survey between Annual Audits but have not been credited by one of the methods above, they will be shown as ‘OVERDUE’ on the survey status until the Annual Audit has been held and reported or the items have been reported directly by the Chief Engineer or Operator.

The Chief Engineer should report to Lloyd’s Register without delay, any defect or damage identified during an examination which could invalidate the Conditions of Class for which the ship has been assigned. In such cases, a Lloyd’s Register Surveyor should be requested to attend the ship to carry out an appropriate survey in accordance with normal practice. All repairs that may be required in order for the ship to maintain her class are to be carried out to the satisfaction of a Lloyd’s Register Surveyor. When repairs are effected at a port, terminal or location where the services of a Lloyd’s Register Surveyor are not available, the repairs are to be surveyed by a Lloyd’s Register Surveyor at the earliest opportunity thereafter.

Section 3: Machinery Condition Monitoring

3.1 Introduction

These procedures describe the application of condition monitoring where it forms part of an approved Machinery Planned Maintenance Scheme.

Selected machinery may be credited for survey on the basis of condition data without the need for opening out, if they remain in a satisfactory condition.

3.2 Applicability

The Operator decides the extent to which condition monitoring is applied. For guidance, Tables 3.4.1 to 3.4.7 give a list of typical shipboard machinery, together with suitable condition monitoring techniques. However, the application of condition monitoring to machinery not on the list and the use of alternative monitoring techniques will be considered.

3.3 Details required for approval

The information to be submitted should include the following:

- Description of the monitoring methods to be used, the frequency of monitoring and the limiting values of acceptable condition. The limiting values should be derived from the manufacturer’s recommendations, applicable severity criteria as defined in recognised Standards, or the Operator’s required limits when these are more severe. Further guidance is given in Annex B.
- Details and version number of condition monitoring software.
- Details of condition monitoring hardware.
- Method and frequency of calibration for any instrumentation used.

Specific requirements for vibration monitoring systems:

- The system should be able to display trends of overall vibration level over time.
- The system should be able to display an FFT frequency spectrum for each vibration signal.
- Details of the training given to the personnel undertaking measurements are to be submitted.

3.4 Condition monitoring techniques

The use of the condition monitoring techniques listed in Tables 3.4.1 to 3.4.7 are the normal minimum requirement to avoid the need for a fully opened out inspection of components at a Periodical Survey.

Alternative arrangements to those given in the Tables, which provide an equivalent level of confidence in the condition of the machinery, will be considered. Similarly, the application of condition monitoring to machinery not included will also be considered.
### Table 3.4.1  Diesel engines for direct main propulsion
(for survey of crankshaft and bearings on single engine installations)

<table>
<thead>
<tr>
<th>Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance monitoring</td>
<td>Continuous or periodic monitoring of:</td>
</tr>
<tr>
<td></td>
<td>• Shaft horsepower</td>
</tr>
<tr>
<td></td>
<td>• Engine and screwshaft rpm</td>
</tr>
<tr>
<td></td>
<td>• Cylinder pressure – time curves</td>
</tr>
<tr>
<td></td>
<td>• Charge air pressure</td>
</tr>
<tr>
<td></td>
<td>• Exhaust gas temperatures</td>
</tr>
<tr>
<td></td>
<td>• Engine cooling system temperatures and pressures</td>
</tr>
<tr>
<td></td>
<td>• Engine lubricating oil system temperatures and pressures</td>
</tr>
<tr>
<td></td>
<td>• Turbo-charger rpm and vibration</td>
</tr>
<tr>
<td></td>
<td>• Main bearing temperatures and/or crankcase oil mist densities</td>
</tr>
<tr>
<td>Lubricant analysis</td>
<td>Regular sampling, laboratory testing, analysis and assessment of lubricant</td>
</tr>
<tr>
<td>Visual inspection</td>
<td>• Periodic inspection of crankcase and at the edges of the bearings for signs</td>
</tr>
<tr>
<td></td>
<td>of wiped or broken white metal</td>
</tr>
<tr>
<td></td>
<td>• Periodic inspection of shrink fit reference marks (if applicable)</td>
</tr>
<tr>
<td></td>
<td>• Periodic inspection of bedplate structure, inside and out</td>
</tr>
<tr>
<td>Physical measurement</td>
<td>• Periodic measurement of crankweb deflection readings</td>
</tr>
<tr>
<td></td>
<td>• Periodic measurement of bearing clearances</td>
</tr>
</tbody>
</table>

### Table 3.4.2  Diesel engines for electric power generation

<table>
<thead>
<tr>
<th>Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance monitoring</td>
<td>Continuous or periodic monitoring of:</td>
</tr>
<tr>
<td></td>
<td>• Engine cooling system temperatures and pressures</td>
</tr>
<tr>
<td></td>
<td>• Exhaust gas temperatures</td>
</tr>
<tr>
<td></td>
<td>• Engine lubricating oil system temperatures and pressures</td>
</tr>
<tr>
<td></td>
<td>• Turbo-charger rpm and vibration</td>
</tr>
<tr>
<td>Lubricant analysis</td>
<td>Regular sampling, laboratory testing, analysis and assessment of lubricant</td>
</tr>
</tbody>
</table>

### Table 3.4.3  Steam turbines

<table>
<thead>
<tr>
<th>Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance monitoring</td>
<td>Continuous or periodic monitoring of:</td>
</tr>
<tr>
<td></td>
<td>• Shaft horsepower</td>
</tr>
<tr>
<td></td>
<td>• Shaft and turbine rotor rpm</td>
</tr>
<tr>
<td></td>
<td>• Plant performance data, e.g., steam conditions at the inlet and outlet of</td>
</tr>
<tr>
<td></td>
<td>each turbine, boiler performance data, condenser vacuum, sea temperature and</td>
</tr>
<tr>
<td></td>
<td>steam conditions of other major steam consuming auxiliaries</td>
</tr>
<tr>
<td>Vibration monitoring</td>
<td>Continuous or periodic monitoring of turbine bearing housing vibration</td>
</tr>
<tr>
<td>Visual inspection</td>
<td>• Inspection at survey of rotor bearings, thrust bearings, couplings and</td>
</tr>
<tr>
<td></td>
<td>casing axial expansion arrangements</td>
</tr>
<tr>
<td></td>
<td>• Inspection at survey of final low pressure and astern stage blading</td>
</tr>
<tr>
<td>Physical measurement</td>
<td>• Periodic measurements of rotor axial position using permanent indicators</td>
</tr>
<tr>
<td></td>
<td>• Analysis of boiler water</td>
</tr>
<tr>
<td>Lubricant analysis</td>
<td>Regular sampling, laboratory testing, analysis and assessment of lubricant</td>
</tr>
</tbody>
</table>
Method Requirement

Visual inspection
Periodic inspection of intakes and exhaust ducts, inlet guide vanes, compressor 1st stage, compressor and gas generator casings and auxiliary components and systems. The running clearances and dimensional changes where practicable

Visual inspection by borescope/endoscope
Periodic inspection of compressor stators, guide vanes and blades, combustion chambers, turbine nozzles and blades and power turbine

Vibration monitoring
Continuous monitoring and trend analysis of gas turbine rotor vibration. The equipment used for vibration measurement should be capable of determining vibration throughout the operating range of the gas turbine

Lubricant analysis
- Periodic inspection of magnetic particle detectors (manual records and/or automatic recording via debris counters in oil scavenge lines)
- Periodic inspection of oil filters
- Regular sampling, laboratory testing, analysis and assessment of lubricant
- Periodic testing of oil cleanliness

Fuel analysis
- Maintenance of fuel bunker/marine gas oil analysis records
- Periodic sampling and laboratory analysis of fuel quality

Performance monitoring
Continuous monitoring and trend analysis of critical gas turbine operating parameters including:
- Compressor conditions (inlet and exit temperature, delivery pressure and speed)
- Power turbine (inlet entry temperature and speed)
- Engine breather temperature
- Low cycle fatigue counter
See Note

NOTE
Manual recording and trend analysis methods may also be acceptable.

Table 3.4.5 Intermediate shafting

Method Requirement

Visual inspection
- Inspection at survey of shaft surface, shaft bearings and shaft bearing securing arrangements
- Periodic inspection of shaft earthing device

Physical measurement
Periodic measurement of shaft bearing temperatures

Lubricant analysis
Regular sampling, laboratory testing, analysis and assessment of lubricant for self contained shaft bearings

Table 3.4.6 Screwshafts

Method Requirement

Lubricant analysis
- Sampling, laboratory testing, analysis and assessment of lubricant at regular intervals not exceeding six months
- Periodic recording of oil consumption

Physical measurement
- Periodic measurement of sterntube bearing wear down
- Periodic recording of sterntube bearing temperatures
Machinery Planned Maintenance and Condition Monitoring

### Table 3.4.7 Auxiliary machinery

<table>
<thead>
<tr>
<th>Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coolers</td>
<td>Periodic recording of cooler inlet and outlet temperatures</td>
</tr>
<tr>
<td>Heaters</td>
<td>Periodic recording of heater inlet and outlet temperatures</td>
</tr>
<tr>
<td>Pumps, fans and compressors</td>
<td>Periodic recording of vibration and pressures</td>
</tr>
<tr>
<td>Filters</td>
<td>Periodic recording of differential pressures across filters</td>
</tr>
</tbody>
</table>

#### 3.5 Roles and responsibilities

**Operator**
The Operator should submit the condition monitoring details as specified in 3.3 at the time of the request for approval of the machinery planned maintenance scheme.

**Lloyd’s Register**
The planned maintenance scheme will be reviewed with particular reference to the condition monitoring proposals. If acceptable, a Certificate of Operation of an Approved Planned Maintenance Scheme for Machinery will be issued to the Operator indicating that the scheme includes condition monitoring. A copy of the Certificate is to be retained on board the subject ship for the information of the Master, Chief Engineer and Lloyd’s Register Surveyors. The ShipRight MCM descriptive note will be assigned if requested and an appropriate memoranda item entered on the ship’s survey status.

**Chief Engineer**
The Chief Engineer should ensure that the condition monitoring parameters are recorded at the agreed intervals. This should include an initial or ‘baseline’ set of readings, against which further data can be compared.

#### 3.6 Annual audit

The requirement for an Annual Audit of the machinery maintenance and monitoring records is the same as that given in Section 2. At the Annual Audit the Chief Engineer is to make available the following maintenance and monitoring records, in addition to those specified in 2.4:

- Condition monitoring records for each item to be credited for class. The records should indicate where acceptable limits have been exceeded and what action was taken.
- Calibration certificates for instrumentation used to take measurements, if applicable.

The responsibilities of Lloyd’s Register Surveyors at the Annual Audit are similar to those described in Section 2. The machinery and monitoring records will be examined in sufficient depth to ensure that the scheme has been operated correctly and that the machinery has functioned satisfactorily since the previous survey.

The condition monitoring records will be examined to verify that vibration levels, oil analysis results, performance criteria, etc., are, for example, within the specified limits. Baseline condition data will be compared with subsequent readings and the trend characteristics reviewed. The Lloyd’s Register Surveyor may require confirmatory readings on available running machinery to be taken for comparison with the ship’s records. Calibration certificates for condition monitoring instrumentation will be examined.

---

### Section 4: Machinery Condition Based Maintenance (MCM)

#### 4.1 Introduction

These procedures describe how a Machinery Condition Based Maintenance (MCM) Scheme approved by Lloyd’s Register can be accepted as a method for demonstrating compliance with the Classification requirements of a Continuous Survey Machinery (CSM) cycle where it forms part of an approved Machinery Planned Maintenance Scheme.

These procedures may be modified following experience with their implementation and application in service.

The objective of the ShipRight MCBM descriptive note is to increase assurance that shipboard machinery assets are maintained to the highest standards while minimising the need for intervention by invasive opening up of machinery for survey.
The MCBM process utilises a systems approach to asset management which will include assessment of an asset’s criticality and probability of failure, assessment of the consequences of asset failure and development of a strategy to minimise the risks associated with asset failure. This may include, for example, the condition monitoring tools deployed, company policy for spares procurement.

The office based system is required to hold records of maintenance carried out on board each ship as well as records which support the shipboard MCBM processes. These records are to be maintained on a continuous basis, limited only by the means of communication between ship and shore, and subject to a Periodical Audit by Lloyd’s Register.

The shipboard system should contain records of maintenance carried out to each item within the scheme, including condition monitoring records, where applicable, in accordance with the approved MCBM plan.

4.2 Applicability

For assignment of the ShipRight MCBM descriptive notation to a ship the following are required:

- Ship to be operating on the Continuous Survey Machinery (CSM) cycle.
- Machinery maintenance being carried out under an approved Machinery Planned Maintenance Scheme.
- The ship must be assigned the ShipRight Descriptive Notes MPMS and TCM (if applicable).
- The language of the scheme to be English.

MCBM schemes are to be based on a computerised system with arrangements for backing up data at regular intervals. Access to computerised systems for updating of the maintenance documentation and maintenance programme shall only be permitted by the Chief Engineer or other authorised person(s).

If the software system operating the scheme is changed, the scheme will be required to be reapproved.

Approval of the scheme will be withdrawn if:

- The Operator of the ship changes.
- Deficiencies in the operation of the scheme are identified.
- The Operator no longer wishes to maintain the descriptive note ShipRight MCBM.

4.3 Details required for approval

It is recognised that Machinery Condition Based Maintenance Schemes may take various forms. The type of maintenance control, the scheduling, reporting and recording methods can only be decided by the Operator, having due regard to all the factors involved.

However, there are some basic features that Lloyd’s Register requires when approving a Machinery Condition Based Maintenance scheme, as specified below. It should be noted that approval of the Machinery Condition Based Maintenance scheme involves approval of the Operator’s overall approach to maintenance for each ship operating the scheme (The amount of information to be submitted can be reduced if the planned maintenance software has been approved using Lloyd’s Register’s Software Conformity Assessment (SCA) system – see 2.3). Further guidance information on condition monitoring can be found in Section 3 Machinery Condition Monitoring, and in the Annex to this document.

The shipboard MCBM plan is to be submitted for approval and is to include:
1. A description of the Machinery Condition Based Maintenance system.
2. A numbered index of items included in the scheme. The index is to include at least all CSM items which appear on the ‘Master List of Surveyable Items’, and should cross reference all masterlist item numbers. The scheme may also cover items that are not required for classification. There is to be a method of indicating those items dealt with by planned maintenance, those dealt with by condition based maintenance and those items which remain to be dealt with by Lloyd’s Register Surveyors under conventional CSM.
3. For each Master List Item, the MCBM plan must provide clear guidance as to the acceptance criteria required by the shipboard authorised persons when making a judgment about the continued service of the machinery asset. Recommended actions are to be included for the likely conditions in which the item is found.
4. Where Essential Machinery is not subject to Condition Based Maintenance then a system of planned maintenance to prevent failure is to be included in the plan. Frequency and extent of planned maintenance are to be included in the Machinery Condition Based Maintenance Plan (MCBM).
5. Examples of decision making processes, the basis of decisions and responsibilities, when deviating from the approved plan.
Machinery Planned Maintenance and Condition Monitoring

6. Means and frequency of measuring equipment calibration used as part of the condition based maintenance scheme.

7. Spare Parts purchasing policy and policy for holding essential spares.

8. The MCBM Plan is to include a description of the interface between ship and office, and means of contingency if the interface becomes unavailable.

9. The MCBM Plan is to contain the procedure for withdrawing from the MCBM descriptive note and re-instatement of Conventional Surveys. This should include an arrangement for the attendance of a Surveyor for the updating of credit dates for items dealt with under the scheme.

The following supporting information is also required for approval:

(a) Details and version numbers of all maintenance software in use. This should include details of how access is controlled and the arrangements for backing-up data.

(b) A description of what the essential machine or equipment is required to do and the expected performance standards required.

(c) An assessment of failure modes and an analysis for each Master List Item.

(d) Evidence of FMEA/FMECA assessment is to be provided to support the plan appraisal process. This assessment is to be carried out in accordance with a recognised International Standard such as IEC60812.

(e) Definitions of the Machine’s Criticality as a product function of failure severity and probability of failure.

(f) Supporting evidence of the criticality, probability of failure analysis and the assumptions underpinning this analysis. This criticality assessment is to be carried out in accordance with a recognised International Standard such as IEC60812. [These will be reviewed and comments will be made using a Design Appraisal Document (DAD) as necessary].

(g) The minimum training standards for the monitoring and maintenance operators. Details of the training given to the personnel undertaking measurements and interpretation of Condition Monitoring Data are to be submitted.

(h) Sample maintenance job descriptions. These descriptions are to cover at least the minimum opening out necessary to demonstrate that a satisfactory examination of the item will be made. The extent of the work to be undertaken is to be indicated but it is not necessary for approval purposes to include every detailed job description. A selection of sample job descriptions will suffice to demonstrate how the system works.

(j) Maintenance intervals for each item. In general, the maintenance intervals should not exceed those specified for CSM. However, for components where the maintenance is based on running hours, longer intervals may be accepted as long as the intervals are based on the manufacturer’s recommendations. The equipment manufacturer’s recommendations and supporting documentation are to be available.

(k) Examples of the reporting and recording procedures. These procedures are to be sufficiently comprehensive to demonstrate that correct operation of the scheme can be verified at the time of the Annual Audit (aboard) and Office Audits. Reports are to include:
   - details of inspections and maintenance carried out on a specific item over a specified time interval;
   - the condition as found;
   - any repairs effected;
   - a list of spare parts used.

(l) Examples of records of spares purchased, supplied to the ships and used by the ships staff to maintain the ship in accordance with Lloyd’s Register Rules.

(m) Examples of training records and authorisations necessary to support the Condition Based Maintenance Plan.

4.4 Roles and responsibilities

Operator

The Operator should make a formal request for assignment of the ShipRight MCBM descriptive note to Lloyd’s Register. The information detailed in 4.3 should be submitted for review.

Lloyd’s Register Office

Details of the scheme will be reviewed and if acceptable a Certificate of Operation of an approved Machinery Condition Based Maintenance Scheme will be issued to the Operator. A specimen copy of this document is given in Annex C. A copy of the Certificate is to be retained on board the subject ship for the information of the Master, Chief Engineer and Lloyd’s Register Surveyors. The ShipRight MCBM descriptive note will be assigned to the ship if requested and an appropriate memorandum entered on the ship’s survey status.

A Certificate of Operation (Office) will be issued, to be retained in the Operator’s office.
Survey due dates will be removed from CSM Master List items. The due dates will remain absent from the Master List while the MCBM descriptive note remains assigned. In order to facilitate this a notional Engine Survey (ES) will replace the CSM for ships on the scheme. The Machinery 5 year cycle will be credited upon the basis of a satisfactory Annual Audit in the 5th year of the cycle.

Chief Engineer
Chief Engineers are responsible for implementing the approved Machinery Condition Based Maintenance Plan on board the ship. Chief Engineers are reminded that overhaul of machinery items whilst at sea must not compromise the redundancy/standby functions which are requirements of Classification Rules.

The Chief Engineer should ensure that the condition monitoring parameters are recorded at the agreed intervals. This should include an initial or ‘baseline’ set of readings, against which further data can be compared.

The requirements of the relevant ShipRight Procedures and the conditions listed on the Certificate of Operation of an Approved Machinery Condition Based Maintenance Scheme are applicable.

Lloyd’s Register’s Surveyors
The Lloyd’s Register Surveyor will carry out the annual shipboard audit of the Approved Machinery Condition Based Maintenance Scheme. The Surveyor is responsible for crediting the essential machinery Master List items at the Annual Audit. For those items subject to condition monitoring where the control limits are being approached, the Surveyor is to verify that a system is in place to take timely maintenance action.

4.5 Annual Audit

The Chief Engineer or Operator should arrange for Lloyd’s Register Surveyors to attend aboard to carry out an Annual Audit of the MCBM Scheme. Annual Audits are to be held within three months before or after the due date and are to be harmonised with the Classification Annual Survey.

Confirmatory surveys and audit of ships records will be carried out. In the case of new ships the Initial Audit will be carried out at the first Annual Survey. The Chief Engineer is to make the following information available:

The Lloyd’s Register Certificate of Operation of an approved Machinery Condition Based Monitoring Scheme is to be made available along with a verified copy of the Certificate of Operation (Office).

The Surveyors will confirm that the type of planned maintenance software in use is the same as that specified in the Certificate of Operation. The machinery records and documentation will be examined in sufficient depth by the Lloyd’s Register Surveyors to ensure that the scheme has been operated correctly and that the machinery remains functioning satisfactorily.

Inspection, maintenance and monitoring records are to be made available to the Surveyor for the items selected for audit by the Surveyor. These records should give details of any repairs carried out and spare parts used.

Written details of any defect, breakdown or malfunction of essential machinery are to be included in the ship’s record. Such details should include the cause of failure, if known. Any machinery part that has been replaced due to damage should be retained on board, where possible, and examined by the Lloyd’s Register Surveyor.

The records should indicate that all scheduled maintenance and monitoring have been carried out. Any items not dealt with as per the schedule will be discussed with the Chief Engineer. The decisions taken and the information needed to defer scheduled activities will be reviewed.

As part of each Annual Audit the Lloyd’s Register Surveyor will carry out a general examination of the machinery and, as far as is practical, machinery will be examined under working conditions. If the Surveyor is not satisfied with the operating condition or any aspect of the scheme’s operation he may request that items be opened out for inspection. The predicted performance characteristics of the system are to be made available to the Surveyor.

Note that items of machinery examined/tested as part of the Classification Annual Survey, for example steering gear, bilge pumping, etc., will continue to be surveyed as part of the Annual Survey.

If deficiencies in the operation of the scheme are identified, either from the maintenance records or from the general condition of the machinery, the Surveyors may advise that a further Audit will be required and impose a suitable Condition of Class. In the event of serious deficiencies, a report will be forwarded to the Classification Committee in London recommending that approval of the scheme be withdrawn. An Audit Checklist is available to assist Surveyors and a specimen copy is given in Annex C.
Machinery Planned Maintenance and Condition Monitoring

Condition monitoring records and trend data for each item to be credited for class are to be reviewed. The records should indicate where acceptable limits have been exceeded and what action was taken.

The MCBM plan must include a ship specific calibration plan to ensure the monitoring instrumentation remains calibrated in accordance with the manufacturer’s recommendations. The calibration process will be audited by the attending Surveyor.

4.6 Office audits

A Lloyd’s Register Surveyor will carry out the initial, intermediate and renewal office audits, at the request of the Owners based on a 5 year renewal period, with the intermediate audit being held between the second and third years after renewal.

The Surveyor will review the Company’s established and documented procedures which ensure that the ships classed machinery items are maintained in conformity with Lloyd’s Register’s Rules and Regulations and with any additional requirements which may be established by the Company.

In meeting these requirements the Company should ensure that inspections, maintenance and monitoring are held at appropriate and planned intervals and in accordance with the MCBM Plan. Records of these activities are to be maintained ashore for audit. Support documentation such as delivery notes, job control records, purchase requisitions and details of deferment decisions are be made available for the audit.

The Auditor will expect to find quality control and documentation control standards defined and for the purpose of maintaining classed machinery in accordance with the Rules. These controls may be subjected to the auditor’s scrutiny.

4.7 Reporting

Machinery Master List items may be credited towards the ships survey status according to one of the following methods and/or frequencies to suit the Operator’s preference for recording assigned dates:

Examined items credited by the attending Surveyor at the Annual Audit (i.e., as a single batch of items once per year). Assigned dates will be aligned with the Annual Audit date.

Items which are subject to Condition Based monitoring only will be assigned a date based on the trend information provided by the ship.

The Chief Engineer should report to Lloyd’s Register without delay, any defect or damage identified during an examination which could invalidate the conditions of classification for which the ship has been assigned. In such cases, a Lloyd’s Register Surveyor should be requested to attend the ship to carry out an appropriate survey in accordance with normal practice. All repairs that may be required in order for the ship to maintain her class are to be carried out to the satisfaction of a Lloyd’s Register Surveyor. When repairs are effected at a port, terminal or location where the services of a Lloyd’s Register Surveyor are not available, the repairs are to be surveyed by a Lloyd’s Register Surveyor at the earliest opportunity thereafter.

Section 5: Reliability Centred Maintenance (RCM)

5.1 Introduction

These procedures describe the use of Reliability Centred Maintenance techniques as part of an approved Machinery Planned Maintenance Scheme.

These procedures may be modified following experience with their implementation and application in service.

5.2 The RCM approach

RCM may be defined as:

‘A process used to determine what must be done to ensure that any physical asset continues to do what its users want it to do in its present operating context.’

The RCM process entails asking seven basic questions about the asset or system under review:

- What are the functions and associated performance standards of the asset in its present operating context?
  This covers not only an asset’s primary function but also any secondary functions.

- In what ways does it fail to fulfil its functions?
  This involves defining what circumstances amount to a failed condition.

- What causes each functional failure?
  Events that can cause the failed condition are identified. These events are known as failure modes.

- What happens when each failure occurs?
  This describes the effect of each failure mode.
In what way does each failure matter?
The consequences of failure are identified and categorised as those where there are hidden (for example a protective device which is not fail-safe), safety, environmental, operational or non-operational consequences.

What can be done to predict or prevent each failure?
Tasks are identified that can be undertaken before a failure occurs. Such proactive tasks cover predictive and preventive maintenance techniques.

What should be done if a suitable proactive task cannot be found?
Default actions are identified where there are no effective proactive tasks. Default actions include failure finding, redesign and run-to-failure.

5.3 Details required for approval

The following information is to be submitted to Lloyd’s Register for review:
(a) The RCM Study documentation in paper or electronic form, which should include details of the study team members.
(b) Details of system/equipment covered by the study.
(c) Copy of acceptance letter from equipment manufacturers confirming their review of the study details.

Lloyd’s Register will verify by audit that the following items have been complied with:
(a) Study has been undertaken in full compliance with the methodology embodied in an acceptable and applicable standard for RCM, e.g., SAE Standard JA1011; ‘Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes’.
(b) Study team members have adequate experience both of undertaking RCM studies and the systems/equipment under review.
(c) Study team members have been present during the study for sufficient time to properly contribute to the study.
(d) No ‘Mandatory Redesign’ requirements are outstanding.
(e) Where spares have been identified as ‘Critical’, they have been properly identified in the management systems on board.
(f) Procedures for collection of condition monitoring information have been established and reporting procedures for submission of this as part of the approved Machinery Planned Maintenance Scheme are clearly documented.
(g) Where changes to operating procedures have been identified, an adequate management system is in place to ensure that they are complied with.
(h) A Failure Modes, Effects and Criticality Analysis (FMECA) may be undertaken as part of the RCM process. In this case the FMECA is to be in compliance with an acceptable standard, good marine engineering practice and the application of valid reliability data.

Lloyd’s Register will undertake a technical audit of selected parts of the RCM study. The following methodology will be used:
(a) Verification that the study covers the entire function being addressed.
(b) For each individual study (sub function) within a group function, verification that there is a list that includes the individual asset items, including controls, instrumentation and protective/emergency devices.
(c) Verification that an expected maintenance task list has been drafted, based on typical tasks that would be expected for the relevant item, under any maintenance regime. These would include, but may not be limited to:
   • system performance analysis checks;
   • standard condition monitoring checks (vibration, lubricant analysis, electrical characteristics, thermography, etc.);
   • inspections of items liable to wear or other age related degradation, i.e., fouling;
   • periodic tests of protective devices;
   • correct functioning of alternative modes of operation and control.
(d) Confirmation that standard tasks have been identified for each sub function.
(e) Where standard tasks have not been identified, review the study for justification.
(f) Review any inconsistencies in periodicity for tasks included in the maintenance schedule.
(g) Carry out a review of RCM logic applied for one sub function. If the review is acceptable and in accordance with the standard for RCM, others will not be fully reviewed. If considered unacceptable, a review of another sub function will be carried out for confirmation. If this review is also unacceptable, Lloyd’s Register will require a complete review of all other sub functions.
(h) Review the maintenance programme for machinery included in Lloyd’s Register’s Master List of Surveyable items.

As an alternative to carrying out post study audits as specified above, Lloyd’s Register can, if requested, provide direct input and advice to the study team(s) on either a full or part-time basis to supplement the technical/survey requirement input. If this is undertaken, the scope of the audit will be reduced accordingly.
5.4 Roles and responsibilities

**Operator**
The Operator should make a formal request for assignment of the ShipRight RCM descriptive note to Lloyd’s Register. The information detailed in 6.3 should be submitted for review.

**Lloyd’s Register Office**
The scope of audit required will be decided and further information obtained from the Operator if necessary. The audit will be completed and if the RCM study is considered to be acceptable the ShipRight RCM descriptive note will be assigned if requested.

**Chief Engineer**
The Chief Engineer should carry out maintenance in accordance with the agreed schedule.

**Lloyd’s Register’s Surveyors**
The maintenance records will be reviewed at the Annual Audit of the Machinery Planned Maintenance Scheme. The scope of the Audit will be as described in 2.5. In addition, Surveyors will check that any breakdown or malfunction of essential machinery is being reviewed so that assumptions made during the RCM study can be verified.

6.2 Applicability

Screwshaft Condition Monitoring can only be applied to oil lubricated screwshafts fitted with an approved oil sealing gland which is capable of being replaced without withdrawal of the screwshaft. The stern bearing may be lined with a metallic or non-metallic, composite material. The stern bearing is to have a facility for the measurement of bearing wear down and two temperature sensors or other approved arrangements are to be fitted. Regular analysis of the lubricating oil to trend the amount of bearing surface wear particles in the oil and to monitor the basic oil condition is required. Care is needed when analysing the lubricating oil from bearings lined with a metallic or non-metallic composite material.

6.3 Details required for approval

Details of the oil sealing gland.
Details of the arrangements for taking bearing weardown measurements.

It is to be confirmed that there is a system on board the ship for recording the following:
- Lubricating oil analysis carried out at regular intervals not exceeding six months. Each analysis is to include the following minimum parameters:
  - water content;
  - bearing material, metal particles content and external contaminants;
  - oil ageing (resistance to oxidation).
- The oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube. A written procedure for the sampling of screwshaft lubricating systems should be kept with the analysis records and should be available for inspection by the Lloyd’s Register Surveyor. See Annex B for guidance on lubricating oil sampling procedures and the interpretation of lubricating oil analysis results.
- Sterntube lubricating oil consumption.
- Sterntube bearing temperature (two temperature sensors or other approved arrangements).
- Sterntube bearing wear down.

■ Section 6: Screwshaft Condition Monitoring

6.1 Introduction

These procedures define the parameters to be measured, frequency of measurement and methods for recording and evaluating data in order to determine the physical and operational condition of screwshaft bearings.

Where all condition monitoring data is found to be acceptable and the Lloyd’s Register Surveyors are in all other respects satisfied that the procedures have been properly followed, then the screwshaft need not be withdrawn from the stern bearing at the normal five-yearly survey.
6.4 Roles and responsibilities

Operator
The Operator should make a formal request to Lloyd’s Register for assignment of the ShipRight SCM descriptive note, submitting the information detailed in 6.3. For existing ships, a full tailshaft survey is normally required so that the initial condition of the shaft and bearing can be assessed. Where an application for an existing ship is received prior to the tailshaft survey, a memorandum noting that the descriptive note has been applied for and that the requirements are to be verified at the next tailshaft survey, will be added to the ship’s survey record.

Lloyd’s Register Office
The information will be reviewed and if acceptable the ShipRight SCM descriptive note will be assigned if requested.

Chief Engineer
The Chief Engineer should ensure that records of the condition parameters defined in 6.3 are maintained on board.

Lloyd’s Register’s Surveyors
The condition records are to be inspected and audited annually by Lloyd’s Register Surveyors, normally at the time of the Annual Survey.

Section 7: Turbine Condition Monitoring

7.1 Introduction
These procedures describe special arrangements for the survey of steam turbines for direct main propulsion. Where the requirements detailed in this document are complied with and the Lloyd’s Register Surveyors are satisfied that the procedures have been properly followed, then the steam turbine top casings need not be lifted for examination of the rotors and diaphragms at five-yearly surveys.

7.2 Applicability
The alternative survey arrangements for steam turbines are applicable where:
- The rotor bearings, thrust bearings and couplings can be opened out without lifting the top turbine casing.
- Access to visually examine the final low pressure and astern stage blading is provided.
- Indicators for determining the axial position of rotors relative to their casings and for showing the longitudinal expansion of casings at the sliding feet are fitted.

7.3 Details required for approval
The information required should include the following:
- Sufficient details are to be submitted to determine that the requirements given in Table 3.4.3 are met.
- The Operator is required to keep vibration and performance records for the turbines. Ideally, these records should be available from the date of build, but in the case of existing ships Lloyd’s Register may accept a vibration history of at least 12 months prior to assignment of the notation. These vibration records are to be retained on the ship and be available to the Lloyd’s Register Surveyor for assessment at the time of the survey.

7.4 Roles and responsibilities

Operator
The Operator should make a formal request to Lloyd’s Register for assignment of the ShipRight TCM descriptive note, submitting the information detailed in 5.3. For existing ships, a full tailshaft survey is normally required so that the initial condition of the shaft and bearing can be assessed. Where an application for an existing ship is received prior to the tailshaft survey, a memorandum noting that the descriptive note has been applied for and that the requirements are to be verified at the next tailshaft survey, will be added to the ship’s survey record.

Lloyd’s Register Office
The information will be reviewed and if acceptable the ShipRight TCM descriptive note will be assigned if requested.

Chief Engineer/Operator
Measurements of turbine bearing vibration and other data as specified in Table 3.4.3 are required at regular intervals not exceeding two months. Vibration is to be recorded on the forward and aft bearings of the low pressure and high pressure rotors in the vertical, horizontal and axial directions, i.e., three sets of readings for each bearing. Readings for each bearing should either be taken simultaneously or with a short interval between each reading and at a similar speed. Ideally, readings should always be recorded at the normal maximum operational power. The propeller shaft/rotor speeds are also to be recorded at the same time as the vibration measurements.

Lloyd’s Register Surveyors
The following condition and performance records will be reviewed annually by the Lloyd’s Register Surveyor, normally at the time of the Annual Survey:
- Vibration measurements taken by the ship’s crew.
- Calibration of vibration measurement instrumentation.
- Plant performance data and records of propeller shaft/rotor speeds.
- Readings of turbine rotor position indicators.
7.5 **Periodical survey every five years**

In addition to a review of the data presented at Annual Audits, confirmatory vibration measurements are to be taken in the presence of the Surveyor during a short sea passage. The measurements are to be at the same, and possibly additional, locations to those used by the crew and shall be recorded at full power and at least one at reduced power, e.g., 50 to 60 per cent.

In addition to the vibration readings it is necessary to carry out a full power trial to demonstrate to the Lloyd’s Register Surveyor that the turbines are in good working order. During this trial sufficient plant performance data shall be recorded in order to make an adequate assessment of operating conditions.

At a convenient date, either before or on completion of the vibration monitoring survey, a visual examination of the LP rotor final stages and astern rotor is to be carried out, as far as practical, through the inspection ports in the turbine casing. The rotor bearings, thrust bearings and flexible couplings are also to be opened out and examined.