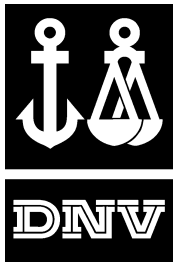

CLASSIFICATION NOTES

No. 10.2

GUIDANCE FOR CONDITION MONITORING

OCTOBER 2008

DET NORSKE VERITAS

Veritasveien 1, NO-1322 Høvik, Norway Tel.: +47 67 57 99 00 Fax: +47 67 57 99 11

FOREWORD

DET NORSKE VERITAS (DNV) is an autonomous and independent foundation with the objectives of safeguarding life, property and the environment, at sea and onshore. DNV undertakes classification, certification, and other verification and consultancy services relating to quality of ships, offshore units and installations, and onshore industries worldwide, and carries out research in relation to these functions.

Classification Notes

Classification Notes are publications that give practical information on classification of ships and other objects. Examples of design solutions, calculation methods, specifications of test procedures, as well as acceptable repair methods for some components are given as interpretations of the more general rule requirements.

A list of Classification Notes is found in the latest edition of Pt.0 Ch.1 of the ”Rules for Classification of Ships” and the ”Rules for Classification of High Speed, Light Craft and Naval Surface Craft”.

The list of Classification Notes is also included in the current “Classification Services – Publications” issued by the Society, which is available on request. All publications may be ordered from the Society’s Web site http://webshop.dnv.com/global/.

The Society reserves the exclusive right to interpret, decide equivalence or make exemptions to this Classification Note.

Main changes

A complete restructuring of the document has been made with the intent to clarify the content.

— The structure has been improved by letting the main document include general technical and document requirements, while each appendix specifies requirements for the separate components/survey arrangement schemes.
— The document has been aligned with the current DNV Rules for Classification of Ships (Pt.7 Ch.1 Sec.8 C300) and practice in that survey scheme and class requirements have been clearly specified. Further, that a clear division between a “company” approval and a “vessel” approval has been made.

Comments may be sent by e-mail to *rules@dnv.com*
For subscription orders or information about subscription terms, please use *distribution@dnv.com*
Comprehensive information about DNV and the Society's services is found at the Web site http://www.dnv.com

Computer Typesetting (FM+SGML) by Det Norske Veritas
Printed in Norway.

1. General

1.1 Introduction

This Classification Note is a supplement to DNV Rules for Classification of Ships Pt.7 Ch.1 Sec.8 C300 Machinery CM (Condition Monitoring). The information in this Classification Note is to be considered mandatory unless otherwise stated when preparing and maintaining the Machinery CM survey arrangement.

Guidelines for replacement of separate surveys by condition monitoring for rotating machinery, propulsion- and position thrusters (including podded propulsions), turbines and waterjets, are found in Appendix A-D.

It is emphasised that operating on Machinery CM described in the following paragraphs, does not replace either the normal daily surveillance or the chief engineer's responsibility for taking decisions in accordance with his judgement.

1.2 Approval process machinery CM programme

1) It is required that the ship/manager (hereinafter Manager) is operating according to a condition monitoring strategy before applying for Machinery CM.
2) The Manager submits documentation to DNV (Machinery Ships in Operation), as described in part 2 below. The documents will be compiled to a CM-manual. All outsourcing contracts/agreements, i.e. vibration measurement taking and/or analysis, oil analysis etc, shall be included in the documents sent for review.
3) The documentation is reviewed, and if found satisfactory, a CM company approval is granted. The CM company approval enables the manager to apply for vessel specific approval for vessels under their management. The documentation for the vessel specific approval must be prepared and submitted for review, prior to the initial survey on board.
4) When the vessel specific documentation has been reviewed and found satisfactory, an initial survey can be requested at any time by contacting DNV Høvik.
5) Once the initial survey has been carried out with satisfactory result, the vessel specific documentation will be approved and Machinery CM will be granted. A CM vessel certificate will be issued for the vessel accordingly and a CM-manual with the company and vessel approval documents will be compiled. The CM-manual is the approved CM programme.

2. Documentation to be Submitted for Approval

2.1 General

Documentation for a CM programme shall be submitted to DNV for approval. The submitted CM programme shall contain information as described in this chapter (ref. DNV Rules for Classification of Ships Pt.7 Ch.1 Sec.8 C300). Upon completion of the company approval, a vessel specific approval including the documentation from the company approval must be submitted and approved prior to initial surveys.

If online system (continuous measurement) and outsourcing of measurement and/or analysis is chosen, some documentation requirements will be not applicable.

2.2 Company approval

2.2.1 The maintenance strategy

1) Description of the condition monitoring objective in the company (Why condition monitoring is considered beneficial, and how long it has been the preferred maintenance strategy within the company).
2) Description of the desired condition monitoring goals.
3) Documentation describing qualification of the crew and shore based personnel involved with CM in the daily operation of the ship with regards to condition monitoring equipment, measurements and analyses. If analysis and/or measurement taking is outsourced to a qualified 3rd party, the contract between the manager and the 3rd party to be submitted for review and acceptance.
4) Responsibility chart for the organisation showing dedicated personnel for condition monitoring, including 3rd party if applicable.
5) Workflow diagram/description of condition monitoring activities, including analysis and follow up of alarms.

2.2.2 Training programme and plan

It should be ensured that the vessel at all times is manned with personnel adequately trained in CM techniques. Plans, records and training for the responsible persons are to be established.

The following shall be submitted for approval:

1) A plan for qualification and training of future crewmembers.
2) A short description of the elements in the training programme.
3) A plan describing the crew rotation with regard to maintaining qualified personnel on board at all times.

2.3 Vessel specific approval

The approved documentation from the Manager's company approval should be included and part of the vessel specific approval for CM. In addition, the below items shall be submitted.

2.3.1 Monitoring methods for components including baseline data

For each component included in Machinery CM, the following information shall be submitted for approval:

1) Detailed description of condition monitoring technique used.
2) Component information that will contribute to forcing frequencies (excitation frequencies) for items where FFT analysis are required according to DNV Rules for Classification of Ships Pt.7 Ch.1 Sec.8 C303. (Such as r.p.m., bearing specification, couplings, number of fan or propeller blades, motor bars, gear teeth, aerodynamic or hydrodynamic frequencies, etc.).
3) Schematic sketch of each component with clearly marked measuring point(s).
4) Measured frequency range(s)
5) Baseline data.
6) Predefined alarm limits in cooperation with maker/ vibration specialist.
7) Measurement interval.
8) Relevant pre-defined actions based on condition monitoring results.

2.3.2 Condition monitoring equipment

The following shall be submitted for approval related to the equipment used onboard:

1) Equipment data sheets for condition monitoring equipment (sensors, vibration meters, collectors and analysing systems).

2.3.3 Implementation of condition monitoring in the planned maintenance system

All components in the DNV Machinery List shall be addressed in the vessels Planned Maintenance system, and the components credited based on Machinery CM shall be specially identified.

The following shall be submitted for approval:

1) Examples describing condition monitoring jobs in the planned maintenance system.
2) Procedures describing how the condition monitoring results are handled.
3) Procedures for handling of results close to or above predefined alarm limits.
4) The PMS shall be able to handle flexible maintenance intervals for CM based jobs.

2.3.4 Programme for lubricating and hydraulic oils analysis

The following shall be submitted for approval:

1) Description of programme for lubricating and hydraulic oils analyses.
2) Details on equipment and kit used for onboard water content testing.

For requirements see Section 7.

3. Technical Requirements for Condition Monitoring

3.1 Basic requirements for condition monitoring equipment

The requirements to the condition monitoring equipment are as follows:

1) Recordings, measurements and trends shall be presented in a simple and easily readable manner.
2) Historical data storage and trend presentation facilities shall be available so as to allow the surveyor access to all measurements since last survey.
3) The equipment and hardware shall be fit for operation in a marine environment and the intended use (Ref. DNV Rules for Classification of Ships Pt.4 Ch.9 Sec.5).

3.2 Vibration meter (overall measurements)

The minimum instrumentation requirements for vibration measurements (suitable for e.g. centrifugal and screw pumps and ventilation equipment) is a vibration meter that complies with (ISO 10816) and the following requirements:

1) A vibration meter with an accelerometer with provisions for measuring the vibration level as velocity and preferably also acceleration or shock pulse.
2) Minimum measuring requirement shall be overall r.m.s. (Root Mean Square) values in two frequency ranges 10 - 1 000 [Hz] and 10 - 10 000 [Hz] and [mm/s]. Alternatively to 10 - 10 000 [Hz] velocity levels, the high frequency range as acceleration [g] or shock pulse readings is acceptable.
3) Sufficient memory to store at least one complete route/ round. In use, the overall level to be read on the instrument and then compared against the severity criteria, for an assessment of mechanical condition.

Note:

Vibration meter

It is of importance to realise that a vibration meter only displays the overall vibration level, including both internal and external vibration (Internal vibration is defined as the vibration excited by the actual component itself. External vibration is defined as the vibration excited by other equipment). This type of instrument is therefore not suitable for detecting and identifying specific problems in rotating machinery, except the general condition of roller and ball bearings (when shock pulse measurements or equivalent is utilised).

---e-n-d---of---N-o-t-e---

3.3 Data collector, (Frequency spectrum analyser)

For turbines, gears, piston pumps, piston compressors, water jets and thrusters, a spectrum analyser (Fast Fourier Transform, FFT analyser), is required. The measured results may be presented as either PEAK or r.m.s. (Root Mean Square) levels in respectively acceleration [g] or velocity [mm/s].

Note:

Frequency spectrum analyser

This kind of equipment is an analysis tool for extracting information to determine the origin of a problem as well as its severity. A spectrum analyser with a compatible computerised analysis program is a tool for both condition monitoring and troubleshooting on rotating machinery. However, it is important that performing analysis should only be carried out by specially qualified personnel/ vibration experts.

---e-n-d---of---N-o-t-e---

Note:

Overall measurements vs. spectrum analysis

The major benefit of selecting certain individual frequencies for each measuring point is that this will provide information, which helps identifying the type of fault causing a vibration problem.

In order to illustrate the difference in the two measuring methods, overall r.m.s. (vibration meter) and spectrum-based (FFT analyser) is measured. The same measurement, in the range 10 - 1 000 Hz is carried out in one position and one direction. The comparison of the two methods clearly shows that only measuring the overall level is more inaccurate than the spectrum method.

Example 1: Overall r.m.s. (vibration meter) velocity level:

The results are given as a numerical value on a display.

Baseline measurement: Overall r.m.s.-level = 5.1 mm/s.

Current measurement: Overall r.m.s.-level = 5.8 mm/s.

Example 2: Spectrum analyser velocity level:

Vibration measurement producing for instance a frequency spectrum with only two significant peaks V_1 and V_2, at the frequencies f_1 and f_2 respectively.

Baseline measurement:

V_1 = 5 mm/s (1st order of turbine rotor)

V_2 = 1 mm/s (2nd order of turbine rotor)

Calculation of overall r.m.s.-level = $\sqrt{(5^2 + 1^2)}$ = 5.1 mm/s

Current measurements:

V_1 = 5 mm/s, V_2 = 3 mm/s

Calculation of overall r.m.s.-level = $\sqrt{(5^2 + 3^2)}$ = 5.8 mm/s

The example illustrates the fact that although the increase of V_2 in example 2 (from 1 to 3 mm/s) is quite significant, the increase in overall r.m.s. is quite small and no suspicion would be aroused of a possible development of a fault condition if only overall r.m.s.- values were read.

---e-n-d---of---N-o-t-e---

3.4 Calibration procedure

For all equipment used for condition monitoring measurements, the calibration intervals shall be according to makers' specifications or recognised standards. If no such intervals are specified, the equipment should be calibrated at least every second year. A job shall be created in the Planned Maintenance System for calibration of the measuring equipment.

Test equipment shall be furnished by a suitable indicator (for example a tag or a label) to show calibration status.

4. Establishing of Measuring Positions

It is recommended that a professional engineering/vibration company carries out the installation.

For a total view of the mechanical condition, the vibration signal from an operating component should be identifiable, thus be measured as far as practical at each bearing. The measurements should be taken on the bearing support housing or other structural parts, which is in close contact with the bearings.

Note:

Avoid bearing housing and electrical motor caps, which are of thin metal and are thus poor conductors of vibration energy.

---e-n-d---of---N-o-t-e---

To define the vibration behaviour at each measuring point, measurements should preferably be taken in three directions: horizontal, vertical and axial. For single direction measuring equipment, the requirement for condition monitoring is usually met by performing the measurements in the horizontal or the vertical direction. If possible, these should be supplemented by measurement of axial vibration, ref. Table 6-1 misalignment. The latter is normally of significance on thrust bearing locations where direct axial dynamic forces are transmitted.

The position should be clearly marked and uniquely identified so that all periodic readings are taken in the exact same position and direction every time.

For velocity measurements (up to approximately 2 kHz) the sensor can be attached by magnetic mounting to the machines bearing/casing if the position makes a good contact between the sensor and the surface. However, for acceleration measurement (above 2 kHz) sensors are required to be connected by means of quick click or bolt connection.

A hand-held sensor (accelerometer) is not accepted for any type of measurements.

Note:

In order to avoid possible unfortunate affects by magnetic mounting (old/ deteriorated magnets, painted/ rusty surfaces) it is advised to use quick click or bolted sensor connection at all times.

---e-n-d---of---N-o-t-e---

5. Baseline Measurements

5.1 General

The following general requirements apply to establishment of all baseline measurements:

1) The baseline measurements shall be carried out by qualified personnel.
2) The measurements shall normally be obtained at a clearly defined operating condition representative for future in-service operation, see below chapters for specific details.
3) Steady state conditions shall be obtained before the measurements are carried out.
4) A proper evaluation of the measurement results have to be made in order to detect any fault conditions. The faults should be corrected before the baseline is settled.

New baseline measurements shall be taken when a component is overhauled/ renewed. For establishment of baseline on components between overhaul periods, the baseline measurements and linked alarm levels must be evaluated by the society and vibration expert.

Note:

Baseline measurement with a vibration meter (overall r.m.s. value) will include both types (internal and external) of excitation in one single value. If the measured level for a component exceeds an acceptable level, the vibration environment should be checked in accordance with ISO 3954. That implies, for all measuring positions the overall r.m.s. level from 10 to 1 000 Hz has to be measured for two conditions:

1) r.m.s.r is the overall level with the actual machinery item running
2) r.m.s.nris the overall level with the actual machinery stopped.

According to ISO 3954, a non-active vibration environment is said to exist when: r.m.s.r / r.m.s.nr ≥ 3.

If the ratio ≤ 3, actions should be taken to correct the situation. Probably most of the excitation is coming from the main engine. Therefore in this situation, the baseline and future vibration measurements have to be carried out with the propulsion machinery stopped.

---e-n-d---of---N-o-t-e---

6. Performance and Evaluation of Vibration Measurements

6.1 Operating Conditions and General Requirements

The periodic measurements are to be carried out by qualified personnel. The general rule is that machinery operating continuously when the ship is at sea shall be controlled minimum once a month or on a continuous basis. Machinery used only periodically (i.e. standby or backup machinery) to be controlled with 1 to 3 months interval.

It is essential that the periodic measurements are carried out under load conditions as near as possible to the baseline measurement obtained for the same machinery component (The propeller r.p.m. and pitch, the load on the drive motor, and other performance conditions must be as close as possible to the baseline condition).

Of particular importance is similarity in shaft rotational speed. Differences in power load, suction conditions, exhaust conditions, and fluid medium, can have a significant influence of the vibration levels recorded.

Measurements shall not be started until stable running conditions have been obtained.

These guidelines are applicable only for the vibration produced by the component itself and not for vibration which is transmitted to the component from external sources.

6.2 Evaluation of Overall Measurements

The component condition can be evaluated according to ISO 10816-3 standard (10 - 1 000 Hz) for acceptable vibration level of rigidly and resiliently mounted machinery. The following guidance applies to the velocity overall vibration measurement of machinery with, for instance, steam turbine or other rotating machinery driven by separate electrical motor with power above 15 kW:

Grade A: Good < 1.8 mm/s r.m.s.
Grade B: Acceptable 1.8 mm/s to 4.5 mm/s r.m.s.
Grade C: Still acceptable, but improvements desirable to necessary 4.5 mm/s to 11.2 mm/s r.m.s.
Grade D: Risk of breakdown > 11.2 mm/s r.m.s.

6.3 Evaluation of Spectrum Measurements

Evaluation of spectrum measurements is dependent on type of component. The following includes both general and specific guidelines. Table 6-1 summarises the relationship between dif-

ferent sources of vibration (mostly fault condition) and the corresponding frequencies at which significant vibration velocity peaks are likely to show up. The frequencies are specified in terms of the fundamental frequency referred to in the table as r.p.m., i.e. the unit used for frequency is r.p.m. rather than Hz (Hertz). Please be informed that Table 6-1 is for information only.

Table 6-1 Relationship between sources of vibration and common corresponding peak frequencies

Vibration cause	*Frequency*	*Remarks*
Unbalance	1 × r.p.m	Vibration proportional to rotor unbalance. Position and size of balancing holes or weights may be determined by vibration measurement
Misalignment of couplings or bearings and bent shaft	1 × r.p.m. usually 2 or 3 × r.p.m. some times	Usually severe axial vibration Realign until minimum vibration
Mechanical looseness	2 × r.p.m.	Usually accompanied by unbalance or misalignment. Higher harmonics peaks can be expected.
Defective ball or roller bearings	Erratic, many times r.p.m., Shocks and transients	Vibration signature is significantly different from similar bearing Positive detection by SPM shock pulse meter
Defective plain bearings	Erratic, Shocks and transients	Vibration signature is significantly different from similar bearings
Oil whirl. oil whip	0.5 × r.p.m. critical r.p.m. of rotor	Resonance of oil film in journal bearings
Defective or damaged gears	Number of gear teeth × r.p.m. = gear mesh frequency and harmonics (2, 3, etc. times) and in any frequency from r.p.m. to mesh frequency. E.g. single tooth damage = 1 × r.p.m.	Constant gear "whine" may be ignored Change of pitch or erratic signal indicates defects. These signals may occur at gear mesh frequency (all teeth damaged) or by 1…Z × r.p.m. (Z is number of teeth)
Drive belt problems	1, 2 and higher × r.p.m.	Easily confused with unbalance. Belt resonance with no relationship to rotational r.p.m. Can increase bearing wear
Electric Motor problems	2 × slip × No. of Poles	Sometimes causes 2 × slip sidebands around 120 Hz
Reciprocating forces	1, 2 and higher × r.p.m.	Inherent in reciprocating machinery
Combustion forces	0.5 × N × r.p.m. 1 × N × r.p.m. N = number of cylinder units	4 cycle Also higher orders 2 cycle Load dependent
Aerodynamic or hydrodynamic forces (cavitations)	Number of blades × r.p.m. and higher orders.	Variable, depends on throttle position, suction, pressure, etc
Forced vibration	Depends on vibration source	Vibrations caused by other (machinery, propeller, hull) vibration source may be identified by narrow band spectrum analysis. Critical in cases of resonance. May also cause damage to machinery out of use especially roller bearings.

6.3.1 Reduction gears

Gears typically generate a dominant vibration peak at the gear mesh frequency (gear rotating speed × number of teeth) and its harmonics (harmonics series are peaks of a spectrum which are integral multiples of the fundamental frequency). The mesh frequency may be a single vibration peak, or it may be surrounded by sidebands spaced on either side of the mesh frequency at intervals of the shaft running frequencies. Sidebands may indicate a gear defect. If sidebands occur around a tooth mesh, it may be determined which gear is defective by the sideband spacing.

Typical values of the amplitude at mesh frequency will generally be within the range from 0.5 - 6.0 [g] acceleration. However, it is not uncommon and may not be abnormal to observe gears with amplitude at mesh frequency well above this value.

6.3.2 Ball and Roller bearings

The first stages of ball or roller bearing defects will produce non-synchronous vibration frequencies called *bearing tones* and their harmonics (non-synchronous vibration peaks are not exact multiples of 1 × the fundamental frequency). Depending on the instrumentation, the first indication will most likely be high frequency bearing tones with 1st order sidebands. The existence of non-synchronous vibration peaks in a spectrum is a red flag to the analyst that bearing problems may exist.

Bearing tones at 0.15 mm/s r.m.s. (0.0025 g r.m.s.) or higher are considered significant.

An example of simple calculations of the bearing tone frequencies for most common bearings are as follows:

Outer race fault = No. of rollers × r.p.m. × 0.4
Inner race fault = No. of rollers × r.p.m. × 0.6
Fundamental Train Frequency (FTF) = 0.4 × r.p.m.

7. Requirements for Oil Analysis

7.1 Lubricating and hydraulic oil analysis

The basic requirements to the lubricating/hydraulic oil samples are as follows:

— A complete round of oil samples shall at a minimum be submitted for analysis twice a year.
— Last laboratory analysis report and documentation of follow- up of recommended actions shall be made available to the attending surveyor.
— The oil sampling point should be clearly identified and positioned to ensure that the sample is taken at the same position each time.

If possible samples should be acquired from the return flow, usually this will mean immediately downstream from the component in question.

— Oil samples are always to be acquired while the equipment is operating and the oil is circulating.
— Before sampling, a sufficient draining is required to ensure representative oil samples.

— Wherever samples intended for particle counting are acquired, special ultra-clean particle free equipment and bottles are to be used. Both the sampling point and the procedure are to be designed so as to minimise the risk of contamination.

Lubricating and hydraulic oil samples shall be submitted to the delivering oil company or an independent oil analysis laboratory.

When submitted to an independent laboratory, one should ensure that the analyses of lubricating oil for combustion engines are performed in accordance with guidelines put down by CIMAC (the International Council on Combustion engines).

For other samples, recommended values from the manufacturer of the system or the oil supplier should be followed.

For lubricating oils the scope of work should, as a minimum, be:

— water content
— sodium content (salt)
— flash point
— wear particles
— viscosity
— base number
— insoluble material.

For hydraulic oils the scope of work should, as a minimum, be:

— water content
— viscosity
— wear particles
— acid number.

For hydraulic systems with high cleanliness demands specified by manufacturer, particle counting should be performed.

Appendix A
Machinery CM

A.1 General

Any rotating machinery component in the DNV machinery list can be part of the Machinery CM programme. Monitoring analysis will give an assessment of the components, which are credited by Class when main overhaul has been performed.

A.2 Initial Survey

Initial survey shall be carried out by a DNV surveyor, ref Section 1.2 4). Baseline measurements for all components included in the Machinery CM programme shall be verified, taken at normal running conditions.

The following will generally be reviewed and may also be tested if found necessary:

- The functionality of instrumentation and analysis program for condition monitoring.
- Equipment/Procedures for oil sampling and handling.
- The installation of vibration measurement equipment.
- Verify the crew's ability to operate the condition monitoring arrangement.
- Verify planned maintenance system and/or documentation for maintenance in accordance with maker's instructions.

A.2.1 Pumps

Baseline measurements for pumps shall contain the following parameters, as far as applicable:

- Vibration measurements (spectrum or overall) from all relevant bearings.
- Power consumption of centrifugal pump's electrical motor (to be recorded when the pump is running under normal operating conditions) and speed (r.p.m.).
- Corresponding suction and discharge pressure.
- The axial displacement of the rotor, if applicable.

For systems with speed regulation of pumps, all baseline data including vibration measurements shall be recorded at maximum pump speed.

A.2.2 Compressors

Baseline measurements for compressors shall contain the following parameters, as far as applicable:

- Vibration measurements (spectrum) from all relevant bearings.
- Power consumption of compressor’s electrical motor (to be measured at a discharge pressure of 2 bars below maker's design pressure or recommended tripping pressure whichever is lower) and r.p.m.
- The lubricating oil pressure.

Later measurements shall be taken at the same discharge pressure.

A.2.3 Generators

Baseline measurements for diesel driven generators shall contain the following parameters, as far as applicable:

- Vibration measurements (spectrum) from all relevant bearings.
- Measurements to be taken at idling running conditions, in order to avoid masking of interesting part of the vibration spectra due to excitation from engine forces.

A.3 Annual Survey

Main objective of survey:

- Review of planned maintenance system and maintenance documentation.
- Crediting of components that have been overhauled.
- Review historic and trend analysis of the vibration measurement data and lube oil analysis, recorded since the last annual survey.
- Verify the crew's ability to operate the condition monitoring arrangement.
- Verify equipment calibration status.
- Other special tests may be required if deemed necessary by the attending DNV surveyor.

Appendix B
Thruster CM
(Propulsion and Position Thrusters)

B.1 General

As stated in the Class Rules, this condition monitoring program is intended to replace visual internal inspection of the thrusters and is thus intended to monitor condition of the mechanical power transmission train (i.e. bearings and gears). This program may also be implemented for podded type thrusters, i.e. thrusters equipped with integrated electric drive motor, instead of gear transmission, to monitor shaft bearings and sealing condition.

B.2 Special Conditions

For propulsion thrusters, oil analyses are to be carried out at least once a month.

For position thrusters, oil analyses are to be carried out minimum quarterly.

B.3 Initial Survey

Initial survey shall be carried out by a DNV surveyor, ref Section 1.2 4). Baseline measurements for thrusters are advised to be taken at 50 - 75% power (at higher output unwanted noise and vibration may mask the interesting parts of the spectra due to possible propeller cavitations), and shall contain the following parameters:

— Vibration measurements (spectrum) from all relevant bearings.
— Vibration measurements (spectrum) from shafting, gear and propeller.
— Corresponding load for the prime mover and speed (r.p.m.).

The DNV surveyor will carry out or monitor vibration measurements and oil analysis similar to those carried out when the baseline measurement data were established. This is to confirm that the baseline data and the equipment are operated as intended and in accordance with the CM programme.

The following will generally be reviewed and may also be tested if found necessary:

— The functionality of instrumentation and analysis program for condition monitoring.
— Equipment/Procedures for oil sampling and handling.
— The installation of vibration measurement equipment.
— Verify the crew's ability to operate the condition monitoring arrangement.
— Verify planned maintenance system and/or documentation for maintenance in accordance with maker's instructions.

B.4 Annual Survey

Main objective of survey:

— Review of planned maintenance system and maintenance documentation
— Review historic and trend analysis of the vibration measurement data and lube oil analysis, recorded since the last annual survey
— Verify the crew's ability to operate the condition monitoring arrangement
— Verify equipment calibration status
— Other special tests may be required if deemed necessary by the attending DNV surveyor.

B.5 Overhaul survey/Crediting of thrusters

Crediting of thrusters shall be done when overhauled. Overhaul to be witnessed by DNV surveyor. See DNV Rules for Classification of Ships Pt.7 Ch.1 Sec.5 D/E.

Appendix C
Turbine CM

C.1 General

This condition monitoring program is intended to replace the scope for turbine and reduction gear survey; visual inspection by opening up fully or partly, and is thus intended to monitor condition of the mechanical power transmission train (i.e. bearings and gears). As the turbine and reduction gear is listed in the DNV Machinery list, the systematics will follow Machinery CM.

C.2 Initial Survey

Initial survey shall be carried out by a DNV surveyor, ref. 1.2 4).

Baseline measurements shall be verified- see below chapters for conditions.

The following will generally be reviewed and may also be tested if found necessary:

— The functionality of instrumentation and analysis program for condition monitoring.
— Equipment/Procedures for oil sampling and handling.
— The installation of vibration measurement equipment.
— Verify the crew's ability to operate the condition monitoring arrangement.
— Verify planned maintenance system and/or documentation for maintenance in accordance with maker's instructions.

C.2.1 Main steam turbines

Initial survey shall be carried out by specially qualified DNV surveyor. Baseline measurements for main turbines shall be taken at normal running conditions (usually at MCR), and contain the following parameters:

1) Vibration measurements (spectrum) from all relevant bearings.
2) Axial displacements of HP and LP turbine rotor shaft (turbine safety system).
3) Axial displacement of main gear shaft (turbine safety system), if applicable.
4) Vibration levels of the HP and LP turbines continuously monitoring and remotely read vibration sensors installed by the turbine manufacturer.
5) Steam pressure and temperatures at the inlet and the bleeder sections. Gland seal pressure regulating valve set point and position to be logged.
6) Condenser vacuum, atmospheric pressure and sea water temperature.
7) Governor oil pressure.
8) Bearing lubricating oil pressure.
9) Propeller shaft torque and r.p.m.
10) Manoeuvre valve (ahead) position.

C.2.2 Auxiliary steam turbines

Baseline measurements for auxiliary turbines shall be taken at normal running conditions (Turbo generators to be taken at minimum 80% load) and contain the following parameters:

1) Vibration measurements (spectrum) from all relevant bearings.
2) Vibration measurement from fixed monitoring equipment, if applicable.
3) Axial displacements of the rotor, if applicable.
4) Steam pressure between the inlet and exit sections and gland seal of the turbine.
5) Lubricating- and governor oil pressure.
6) Output (speed and power).

C.2.3 Reduction gears

Baseline measurements for reduction gear shall contain the following parameters:

— Vibration measurements (spectrum) from all relevant bearings with a max frequency of at least 2 times the gear mesh frequency.
— Axial displacements of shaft, if applicable (by means of integrated equipment).
— Bearing lube. oil pressure.
— r.p.m. and power.

C.2.4 Turbine generators

Baseline measurements for generators shall contain the following parameters:

— Vibration measurements (spectrum) from all relevant bearings.
— Corresponding load for the prime mover (not less than 80% of maximum continuous rating) and speed (r.p.m.).

C.3 Annual Survey

Main objective of survey:

— Review of planned maintenance system and maintenance documentation.
— Review historic and trend analysis of the vibration measurement data and lube oil analysis, recorded since the last annual survey.
— Verify the crew's ability to operate the condition monitoring arrangement.
— Verify equipment calibration status.
— Other special tests may be required if deemed necessary by the attending DNV surveyor.

C.4 Overhaul survey/Crediting of turbines and gears

Crediting of turbines and gears shall be done when overhauled. Overhaul to be witnessed by DNV surveyor. See DNV Rules for Classification of Ships Pt.7 Ch.1 Sec.4 Table E1 and Pt.7 Ch.1 Sec.8 C.

Appendix D
Water Jet CM

D.1 General

The condition monitoring arrangement described in this Appendix is an alternative to the traditional survey method for water jets.

D.2 Initial Survey

Initial survey shall be carried out by a DNV surveyor. Baseline measurements for thrusters are advised to be taken at 50 - 75% power (at higher output unwanted noise and vibration may mask the interesting parts of the spectra due to possible propeller cavitations), and shall contain the following parameters:

— Vibration measurements (spectrum) from all relevant bearings.
— Vibration measurements (spectrum) from shafting and impeller.
— Corresponding load for the prime mover and speed (r.p.m.).

The DNV surveyor will carry out or monitor vibration measurements and other condition monitoring measurements similar to those carried out when the baseline measurement data were established.

This is to confirm that the baseline data and the equipment are operated as intended and in accordance with the CM programme.

The following will generally be reviewed and may also be tested if found necessary:

— The functionality of instrumentation and analysis program for condition monitoring.
— Equipment/Procedures for oil sampling and handling.
— The installation of condition monitoring equipment.
— Verify program for lubricating and hydraulic oils analysis, see Section 7.
— Verify the crew's ability to operate the condition monitoring arrangement.

D.3 Annual Survey

Main objective of survey:

— The extent of annual survey, reference is made to the DNV Rules for Classification of HSLC and NSC: Pt.7 Ch.1 Sec.5 A Table A1.
— Review of planned maintenance system and maintenance documentation.
— Review of historic and trend analysis of the condition monitoring data.
— Review of lubricating and hydraulic oil analysis. Records since the last annual survey have to be presented to a DNV surveyor.
— Verify the crew's ability to operate the condition monitoring arrangement.
— Verify calibration status of the measuring equipment
— Other special tests may be required if deemed necessary by the attending DNV surveyor.

D.4 Overhaul survey/Crediting of water jets

Crediting of water jets shall be done when overhauled. Overhaul to be witnessed by DNV surveyor. See Rules for Classification of HSLC and NSC Pt.7 Ch.1 Sec.5 F.