GUIDANCE NOTES
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CHINA CLASSIFICATION SOCIETY

GUIDELINES FOR SURVEYS OF INTELLIGENT MACHINERY OF SHIPS

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CONTENTS

Chapter 1 General

1.1 Purpose

1.1.1 The Guidelines specify the technical requirements, approval and inspection requirements for condition monitoring and health assessment system, decision support system, condition-based maintenance system of ship machinery installations, as well as the inspection requirements for class notations M①, Mx② for intelligent machinery and class notation CBM(X)③ for condition-based maintenance of ship equipment and also provides for the relevant procedures and technical requirements for condition-based maintenance system of ship machinery installations implementation based on condition monitoring, which can be used as guidance documents for CCS surveyors, manufacturers, service suppliers and ship management companies.

1.2 Application

1.2.1 The Guidelines are applicable to ships for which the class notations M and Mx for CCS intelligent machinery and the class notation CBM(X) for ship equipment condition-based maintenance are requested.

1.2.2 The Guidelines are applicable to the approval and inspection of condition monitoring and health assessment system, decision support system and condition-based maintenance system of ship machinery installations.

1.2.3 The Guidelines are applicable to the approval of suppliers which provide condition monitoring and health assessment, assistant decision support system and condition-based maintenance service for ship machinery installations.

1.2.4 Ship machinery installations applicable to the Guidelines are given in Appendix 1.

1.3 Definitions and abbreviations

1.3.1 Definitions

(1) Diagnostics: examination of symptoms and syndromes of equipment to determine the nature of faults or failures (kind, situation, extent);

(2) Fault: condition of a component that occurs when one of its components or assemblies degrades or exhibits abnormal behavior, which may lead to the failure of the machine. A fault may be the result of a failure, but can exist without a failure. Planned actions or lack of external resources are not a fault;

(3) Failure: termination of the ability of an item to perform a required function (the action and activity assigned to, required of, or expected of a machine or system). Failure is an event as distinguished from fault;

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① Refer to the part of intelligent machinery in Chapter 4 of CCS Rules for Intelligent Ships.
② Refer to the part of intelligent machinery in Chapter 4 of CCS Rules for Intelligent Ships.
③ CBM(X): Class notation for condition-based maintenance of ship equipment. This notation may be assigned if a condition based maintenance plan of ship's machinery installations or systems is developed in accordance with the analysis and assessment result of the operating condition and health condition of machinery installations or systems of a ship, with one or more notations X affixed to identify the equipment for which the condition based maintenance is implemented, e.g. CBM (Cargo Pumps) is the condition based maintenance notation of cargo pumps. Equipment not marked * in Appendix 1 to the Guidelines and other equipment required by the shipowner (not listed in Appendix 1) may apply for this class notation.

(4) Prognostics: analysis of the symptoms of faults to predict future condition and trend of equipment;

(5) Refer to ISO 13372 for other related terms.

1.3.2 Abbreviations

(1) Planned Maintenance System: PMS;

(2) Machinery Condition Monitoring and Health Assessment System: MCM&HAS;

(3) Decision Support System: DSS;

(4) Condition-Based Maintenance: CBM.

1.4 References

1.4.1 References

(1) CCS Rules for Intelligent Ships 2015;

(2) ISO 13372 Condition Monitoring and Diagnostics of Machines – Vocabulary;

(3) ISO 17359 Condition Monitoring and Diagnostics of Machines -- General Guidelines;

(4) ISO 13374-1 Condition Monitoring and Diagnostics of Machines -- Data Processing, Communication and Presentation -- Part 1: General Guidelines;

(5) ISO 13379-1 Condition Monitoring and Diagnostics of Machines -- Data Interpretation and Diagnostics Techniques -- Part 1: General Guidelines;

(6) ISO 13379-2 Condition Monitoring and Diagnostics of Machines -- Data Interpretation and Diagnostics Techniques -- Part 2: Data-driven Applications;

(7) ISO 18436-2 Condition Monitoring and Diagnostics of Machines -- Requirements for Qualification and Assessment of Personnel -- Part 2: Vibration Condition Monitoring and Diagnostics;

(8) IEC 61672-1 Electroacoustics - Sound level meters - Part 1: Specifications;

(9) MIMOSA①-CBM related standards;

(10) IACS UR Z17 Procedural Requirements for Service Suppliers;

(11) CCS Guidelines for Planned Maintenance Scheme of Ship Machinery;

(12) CCS Rules for Classification of Sea-Going Steel Ships and 2017 Amendments

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① MIMOSA: Machine Information Management Open System Alliances.

Chapter 2 Technical Requirements for Monitoring and Measurement

2.1 General requirements

2.1.1 The relevant requirements of 4.4.4, Chapter 4 of CCS Rules for Intelligent Ships are to be complied with. Fixed measuring equipment/sensors can be used for monitoring and measurement,and portable measuring equipment are also acceptable.

2.2 Monitoring techniques

2.2.1 The condition monitoring procedure is to consider the feasibility of monitoring and data acquisition, including easy access, complexity of data acquisition system, level of data processing, safety requirements and whether the parameters required for health assessment are included.

2.2.2 For common monitoring techniques, please refer to Appendix 1 of CCS Rules for Intelligent Ships. At present, the condition monitoring techniques used for ship power machinery mainly include vibration monitoring, oil analysis, non-destructive testing, mechanical structure parameter monitoring, mechanical performance parameter monitoring and instantaneous speed monitoring. The intelligent machinery is to use certain monitoring techniques, but not limited to one or more of the above, and other monitoring techniques, such as thermography, can also be used for the purpose of realizing functions.

2.2.3 The main monitoring parameters for ship machinery installations are given in Appendix 1 to the Guidelines, but are not limited to those in Appendix 1. For certain parameters, such as current, voltage and vibration, simple monitoring may not be sufficient to show the occurrence of a fault/ failure, then the spectral or phase value of the parameter is to be monitored.

2.2.4 Vibration monitoring: vibration condition monitoring is conducted to assist in the evaluation of the “health” of the machine during sustained operation. Depending on the machine type and the critical components to be monitored, one or more monitoring parameters and a suitable monitoring system are to be selected. Vibration monitoring mainly includes time domain analysis, FFT① spectrum analysis, envelope analysis, spectrum radiation energy analysis, phase measurement, high frequency detection and other methods.

2.2.5 Oil analysis: by analyzing different information of abrasive and grain in oil samples, different condition information of equipment can be obtained. Oil analysis technique in machinery condition monitoring mainly refers to spectral analysis, ferrographic analysis, physical and chemical analysis, magnetic chip detection, particle counting, etc. The detection indexes, advantages and limitations of each method are different, and appropriate analysis methods can be selected according to different demands in practical application.

2.2.6 Non-destructive testing (NDT) refers to the method of examining and testing the structure, nature, condition and defect of the internal and surface of the tested object and type, nature, quantity, shape, position, size, distribution and changes of defect without damaging or affecting the performance of the tested object and destroying the internal organization of the tested object. The main testing methods are radiographic testing, ultrasonic testing, magnetic particle testing, penetration testing, eddy current testing, acoustic emission testing, and so on.

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① FFT: Fast Fourier transform (FFT), is a general term for the efficient and fast calculation method of calculating discrete fourier transform by computer.

2.2.7 Mechanical structure parameter monitoring: different machinery installations have different structure parameters, and the main parameters that can be monitored are stiffness and damping.

2.2.8 Mechanical performance parameter monitoring: the function of machinery installations can be measured by certain indexes, such as displacement, speed, power, pressure, output torque, flow rate, temperature, etc.

2.2.9 Instantaneous speed monitoring: speed signals of rotating machinery can reflect the operating state of machinery, and the operating state and related fault information can be obtained by analyzing the fluctuation of rotating speed. It is conducted by extracting the characteristic value of the signal, finding the change rule of the characteristic value when the fault occurs, setting the fault characteristic parameter threshold under each state, and finally realizing the state detection, which mainly includes waveform analysis method, torque estimation method, harmonic analysis method and multi-feature information fusion method.

2.3 Measurement

2.3.1 Consideration is to be given to the interval between measurements whether continuous or periodic sampling is required. The measurement interval primarily depends on the type of fault/failure, its rate of progression and the rate of change of the relevant parameters. The influence of factors such as operating condition of ship machinery and fault/failure criticality is to be taken into account for measurement interval. The interval of data acquisition need not be constant. It depends on the current condition of the machine.

2.3.2 For steady-state conditions, the data acquisition rate is to be able to capture a complete set of data before conditions change. For transient conditions, the data acquisition rate is to be able to monitor the change of transient state in time.

2.3.3 Measurements of different parameters are to be taken wherever possible at the same time or under the same operating conditions. For variable duty or variable speed machines, it may be possible to achieve similar measurement conditions by varying speed, load or some other parameter.

2.3.4 Measurement locations are to be chosen to give the best possibility of fault/failure detection. Measurement points are to be identified uniquely by using a permanent label or identification mark. Factors to be taken into consideration for setting measurement points are safety, sensor installation, signal transmission, attenuation or loss of signal, sensitivity to change in fault/failure condition, repeatability of measurements, accessibility, and environment.

2.3.5 The monitored raw data is to be preprocessed, including filtering, compression and related operations, so as to filter noise and interference and improve signal to noise ratio.

2.3.6 In order to ensure the reproducibility of the measurement, the same measurement sensor/instrument is be generally used for the measurement. However, if it is necessary to replace the measurement sensor/instrument, the measurement sensor/instrument is to be not less than the same type, the same sensitivity and the same calibration method.

2.3.7 Consideration is to be given to the feasibility of acquiring the measurement, including easy access, complexity of data acquisition system, level of data processing, safety requirements, cost, and whether monitoring or control systems exist that are already measuring parameters of interest.

2.3.8 The following requirements are to be satisfied for vibration measurement:

(1) Insulation must be performed between the sensor and the measuring point;

(2) Except in special cases, the measurement quantity for vibration condition monitoring on stationary parts of machinery is vibration velocity or vibration acceleration. For monitoring the relative position and motion of rotating parts, the measurement quantity is vibration displacement. Vibration acceleration is the measurement quantity for vibration monitoring of rolling element bearings and gears;

(3) In order to ensure the reliability of vibration monitoring, the frequency range of measurement is to be suitable for the monitored machine;

(4) In order to ensure the transmission of high-frequency signals and reduce signal loss, the fixed and reliable connection mode is to be adopted for the installation of vibration sensor to prevent the failure of the sensor due to the normal operation of the equipment;

(5) Where permanently mounted sensors are impractical, hand-held probes are available. Hand-held probes are frequency-limited and are not normally recommended for use above 500Hz, unless there are special instructions for the hand-held measuring instrument;

(6) Refer to Appendix D to ISO 13373-1 for the information of vibration measurement locations;

(7) Vibration measurement period is to be determined according to historical analysis experience and the type, quality and quantity of data collected;

(8) Measuring points are usually selected at sensitive points of equipment vibration, key points closest to the core of equipment and points prone to degradation, which are generally rigid supporting points, and environmental factors are to be taken into account;

(9) The number of measurement points is to be moderate, and appropriate measurement directions are to be selected according to the deterioration types of different parts. For example, the imbalance of rotating machine usually occurs in the horizontal direction, while the loosening of anchor bolts takes place in the vertical direction;

(10) Clear descriptions of operating conditions, such as speed, load or temperature, are to accompany any vibration data collected. As a minimum, such descriptions are to include shaft speed and machine load (power, flow, pressure, etc.) and any other operating parameter that can affect the measured vibration;

(11) During data acquisition it is strongly emphasized that the operating conditions are to approximate the normal operating conditions of the machine as closely as possible, to ensure consistency and valid comparability of the data. When this is not possible, the characteristics of the machine must be well known in order to evaluate any differences in the data;

(12) The magnitude range to be measured is to be selected on the basis of previous experience or the criteria applied for evaluation of the particular machine being monitored, covering the lowest to the highest anticipated amplitude. In the absence of previous experience, refer to the applicable International Standard (e.g. the ISO 10816 or ISO 7919 series) for the magnitude range recommended for vibration measurements;

(13) For reliable condition monitoring, measuring equipment is to be capable of covering a wide frequency range in order to encompass not only shaft rotational frequencies and harmonics, but also frequencies due to other components, but it is normally not to be greater than the maximum sensor linear range;

(14) According to the different characteristics of the equipment, measurement of vibration baseline data may include all or part of the data listed below: broadband vibration magnitude (displacement, velocity and/or acceleration), rotational frequency, amplitude at once-per-revolution, vibration vector (vibration amplitude and phase), frequency spectrum analysis of the vibration signals at steady state, run-up/coast-down frequency response data (e.g. Bode plots, waterfall plots, polar plots, etc.), shaft orbit analysis, shaft centerline position, etc.

2.3.9 In temperature monitoring, the installation position, power supply and cable of the measuring device/instrument are all factors affecting the accuracy of temperature measurement. The following factors are to be taken into account in the selection, arrangement and installation of the measuring device/instrument:

(1) When selecting the sensor, attention is to be paid to whether the linear characteristics, reproducibility, hysteresis (especially bimetal instrument) and drift of the sensor are applicable to the measurement environment;

(2) The influence of thermal gradient on measurement is to be taken into account in temperature measurement, especially for objects with poor thermal conductivity, such as air, most liquids, insulators and other non-metallic solids;

(3) The influence of thermal radiation on the measurement is to be taken into account in temperature measurement. If necessary, in order to reduce the influence of thermal radiation, the measuring device/instrument is to be coated or bandaged or treated with thermal shielding;

(4) Good thermal contact between the measuring device / instrument and the object to be measured is to be ensured during temperature measurement;

(5) If the temperature of the measured object changes rapidly during temperature measurement, the device/instrument with low thermal time constant is to be considered;

(6) The influence of electrical noise or electronic interference on the measurement is to be taken into account in temperature measurement. The following methods can effectively avoid such influence: adopting twisted pair cables with shielding functions, installing cables of measuring devices/ instruments away from power cables, transformers and other electrical equipment, installing the measuring device of low pass filter and avoiding the grounding loop;

(7) The influence of atmospheric condensation and evaporation on the measurement is to be taken into account in the temperature measurement. The measuring device/instrument and its cables are to be isolated from the condensation environment or effectively sealed/bandaged, etc.;

(8) The influence of mechanical stress on measurement is to be considered in temperature measurement. Measuring devices/instruments such as resistance temperature detectors are susceptible to mechanical stress and are to be protected from deformation after installation. Using adhesives for installation is to be avoided. The measuring device/instrument which is similar to the linear expansion coefficient of the measured object is to be used. The device that is not too sensitive to mechanical stress, such as a thermocouple, is to be used.

2.3.10 Requirements to be complied with in oil analysis:

(1) Information on the current condition of the monitored equipment is to be input before oil analysis, including machine structure, lubrication mode, friction pair material and performance, lubricating oil performance and so on;

(2) The oil sampling position, usually in front of the filter, is to contain the wear condition and fault information as much as possible, and it can flow through all the friction pair wear surfaces of the machine system, usually the oil tank and the return pipeline;

(3) The sampling time interval is mainly determined according to the characteristics of the monitored machinery installations, operation stage and the degree of fault diagnosis accuracy required by monitoring;

(4) The oil sample is to be treated accordingly before analysis, such as heating and dilution.

2.3.11 Requirements to be complied with for noise measurement:

(1) When there is a large reflecting surface near the measurement location, it is to be explained;

(2) Weather conditions are not to affect the measurement and are to be duly recorded;

(3) Noise from external sources (such as people, construction work, wind, wave, other equipment, etc.) is not to affect the sound pressure level of the measurement location;

(4) Taking into account the uncertainty of measurement, the measurement time is to be long enough, at least 10 seconds, to complete the equivalent continuous A weight sound pressure level measurement at a specified time interval;

(5) Relevant noise reduction measures (mufflers, acoustic cabins, etc.) may be taken if necessary.

2.3.12 In addition to meeting the monitoring and measurement requirements in 4.4 of the Rules for Intelligent Ships, the measurement of baseline data is also to meet the following requirements:

(1) Baseline data is to be measured when the machine operation is known to be acceptable and stable;

(2) The measurement of baseline data is to be carried out under clearly defined operating conditions, and corresponding correction methods are to be provided;

(3) The baseline data is to be established early in the life of the equipment, and the initial stable condition of the machine is to be accurately defined;

(4) The reliability of the measurement results of the condition monitoring is to be ensured before measuring the baseline data. If any fault occurs in the condition monitoring system, it is to be corrected first before the measurement of baseline data;

(5) The baseline data is to be verified and evaluated by relevant technical personnel and submitted to CCS for examination.

2.4 Measuring equipment/sensor

2.4.1 The selection of measuring equipment/sensor is to take into account such factors as range, precision, sensitivity, frequency response characteristics, linear range, stability and ease of disassembly and assembly.

2.4.2 The metrology department that is qualified to carry out inspections, tests or calibration services` is to be entrusted to conduct regular calibration or verification for the sensors, equipment, instruments and meters used in the measurement and analysis process of condition monitoring in order to keep the precision of the instruments and meters within the specified range. All calibrated sensors, equipment, instruments and meters are to bear calibration labels or hold calibration certificates.

2.4.3 The selection of range and precision of the equipment, instruments and instruments used in the measurement process of condition monitoring is first to protect the equipment from reducing its reliability or causing damage during the measurement process. The second is to meet the minimum measurement error and improve the reliability of the measurement results.

2.4.4 The sensor is to be installed firmly and reliably without any movement during the entire measurement process. Ensure that the sensor works properly to ensure the accuracy of the data provided by the sensor.

2.4.5 The sensor components used to detect fault warning information is to be of durability, robustness, high precision and high sensitivity, and be able to respond in a timely manner to measured parameters/variables that vary within the actual dynamic range.

2.4.6 The sensor layout is to be targeted at meeting the needs of control and feature detection.

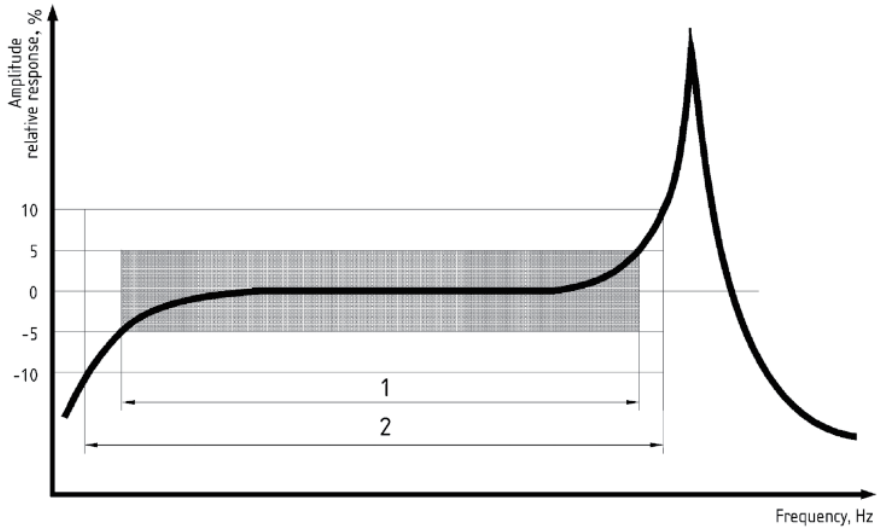
2.4.7 The optimal sensor layout for fault diagnosis is to take detectability, identifiability, reliability of fault detection and uncertainty of sensor into consideration.

2.4.8 Technical requirements for vibration measuring equipment:

(1) The location of the vibration sensor depends on the specific machine to be measured and the specified parameters. Before determining the “location”, the parameters to be monitored must first be determined. In general, it is to be located where maximum vibration value is most likely to be provided and where friction or fault indication is most likely to be provided at an early stage. It is best to select a specific location based on the experience of the machine manufacturer and the user;

(2) Vibration measurement accuracy: Type1: measurements will have an allowable tolerance of ±5% of the calibration sensitivity for the required amplitude and frequency range of the measurement. Type 2: measurements will have an allowable tolerance of ±10% of the calibration sensitivity for the required amplitude and frequency range of the measurement. Measurements with greater than 10% variations in calibration sensitivity over the required amplitude and frequency range are not in accordance with this procedure, unless special precautions are taken to return them to within the required tolerances. Measurements made in accordance with this procedure are to be stated as such using the appropriate Type 1 or Type 2 designation, as shown in figure 2.4.8;

(3) The vibration measurement and calibration equipment are to comply with the relevant requirements of 14, Annex 1, Appendix 8, Chapter 5, PART ONE of the Rules for Classification of Sea-Going Steel Ships.



1 Type 1 linear range
2 Type 2 linear range

Figure 2.4.8 System frequency response

2.4.9 Technical requirements for noise measurement equipment:

(1) Noise measurement equipment, commonly used measuring instruments include sound level meter, sound power meter, frequency analyzer and recording and display instruments. The sound level meter is to comply with the relevant requirements of IEC 61672-1①. When frequency interval filter is used alone or in combination with sound level meter (as the case may be), it is to meet the relevant requirements of IEC 61260;

(2) Before and after each measurement, the microphone is to be calibrated with a sound calibrator of 0.3db accuracy to verify that the entire measurement system is calibrated within one or more relevant frequency ranges;

(3) The sound calibrator is to comply with the IEC 60942 standard and to be approved by the manufacturer of the sound level meter used. The sound calibrator and sound level meter are to be validated at least every two years by the national standard laboratory or by an appropriate laboratory approved in accordance with ISO 17025.

2.5 Personnel

2.5.1 Operators and supervisors engaged in mechanical condition monitoring and health assessment are to have at least 2 years of relevant working experience and to be familiar with the operation of necessary equipment. Supervisors are mainly responsible for the management of actual work, as well as the examination of reports, materials and documents.

2.5.2 Relevant operators and supervisors are to receive at least 1 year of on-the-job training and regular internal and/or external training.

① The sound level meter in this part is used to measure the sound in the hearing range of human ears. In order to measure the audible sound in the case of ultrasound, the AU weight specified in IEC 61012 can be used.

2.5.3 The qualification of relevant operators and supervisors is to comply with the requirements of ISO 18436-2, ISO 18436-4~8, and the operator is to obtain the qualification level of grade I and above, and the supervisor is to obtain the qualification level of grade II. However, the qualification requirements of operators and supervisors engaged in mechanical condition monitoring and health assessment in condition-based maintenance system are to be higher than those of decision support system.

Chapter 3 Requirements for Mechanical Condition Monitoring and Health Assessment System

3.1 General requirements

3.1.1 The main functions of MCM&HAS include: sensing and data acquisition, data processing and feature extraction, producing a warning, fault/failure diagnosis and condition assessment, predicting future health trends, managing and controlling data flow and test sequence, storage of historical data and stores management, system configuration management, human-computer system interface, etc.

3.2 System composition

3.2.1 MCM&HAS is generally composed of sensing system, data system, health assessment system, external system, communication system and interaction system, as shown in Fig.3.2.1.

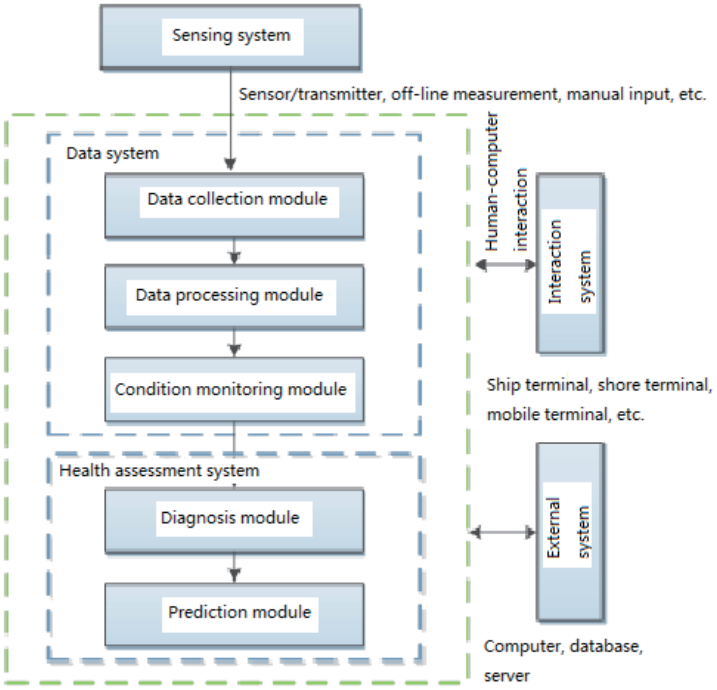


Fig.3.2.1 MCM&HAS System Framework Diagram

3.2.2 The sensing system may realize the condition signal acquisition by means of continuous on-line monitoring, off-line monitoring, manual input, etc.

3.2.3 The data system may include data collection module, data processing module and condition monitoring module.

(1) Data collection module: transforming the inputs of sensors to digital parameters indicating physical quantity and relevant information (such as time, calibration, data property, configuration of data collector and detector to be used, etc.);

(2) Data processing module: performing signal analysis, calculating meaningful descriptors, extracting the feature of original measurement data, carrying out algorithm calculation, etc. with the results used for condition monitoring module;

(3) Condition monitoring module: retrieving if the new collected data are abnormal and determining abnormal ranges and attribution for data (such as early warning or alarm). It mainly achievs the function of comparison between outputs of sensing system and data processing system and limit values in the system, as well as the simple alarm function.

3.2.4 The health assessment system may include diagnosis module and prediction module.

(1) Diagnosis module: analyzing the condition information, diagnosing the fault/failure of equipment;

(2) Prediction module: predicting the mechanical health condition and failure mode in future based on current condition assessment.

3.2.5 The external system is to achieve the functions of data storage, backup, access, management, etc.

3.2.6 The communication system is to perform the reliable and secure communication between sensing system and data system, among the internal data systems, between the data system and interaction system, and between the ship terminal and shore terminal.

3.2.7 The interaction system is to achieve the display and information expression functions of ship terminal, shore terminal and mobile terminal systems (if any). There may be physical overlap between the interaction system and the external system.

3.3 Sensing system

3.3.1 Hardware system is to have the ability to detect multiple parameters, and finally achieve the purpose of reducing noise and interference through information integration technology, such as statistical characteristic analysis, principal component analysis, filtering, etc.

3.3.2 Measurement equipment/sensor components are to have durability, robustness, high precision and appropriate sensitivity, and be capable of making response to the measured parameters/variations to be changed within the real dynamic range in time.

3.3.3 Sensors are to be marked according to uniform rules so as to facilitate easy identification.

3.3.4 Measurement equipment/sensors are to have a certain grade of protection and electromagnetic interference shielding ability so as to be normally operated in the installation spaces or environment onboard the ships.

3.3.5 Three factors, detectability, identifiability and reliability are to be taken into account for measurement equipment/sensors. In addition, the uncertainty of sensors is to be considered to ensure the measurement abilities.

3.3.6 The dynamic characteristic measurement system is to be undistorted, and the system is to have higher frequency bandwidth, high reliability and be convenient for operation.

3.3.7 The wireless sensor network is to complete the transmission of information and achieve the expected information transmission and service quality.

3.3.8 Fault/failure detection ability of measurement equipment/sensors means the capability of sensors to detect the existing specific fault/failure. It depends on the following indexes: signal-to-noise ratio of sensors, ratio of detection time to failure time, fault detection sensitivity, ratio of symptom duration to failure time.

(1) The signal-to-noise ratio may be evaluated by means of random distribution of all possible noise signal sources which have been constructed and use of uncertainty transfer law;

(2) The detection time means the duration from the beginning of fault to the time when the sensor detects, and the failure time means the duration from the beginning of fault to the time when the failure occurs;

(3) Definition of sensor fault detection sensitivity is the ratio of measured fault/failure variation to sensor output variation.

3.3.9 Intelligent sensors are to be easily installed, and have the functions of self-identification, self-diagnosis, reliability and time consistency, as well as certain software functions and DSP① functions. The sensors are to have standard control agreement and network interface (IEEE 1451) so as to raise the intelligence of measuring points, reduce the costs of composing and maintaining distribution-type sensor system, integrate sensing, control, computation and communication and correctly connect the sensors with different types. A normal model is shown in Fig.3.3.9.

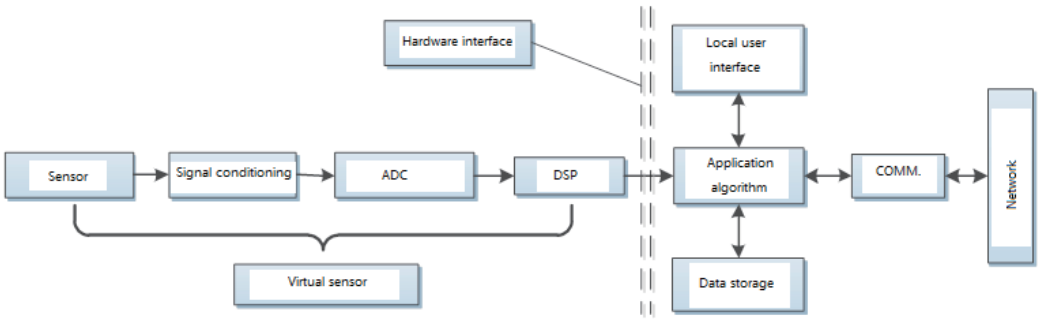


Fig.3.3.9 Normal Model of Intelligent Sensors

3.3.10 Inputs are mainly to include historical information, data collected from the lower-layer equipment, associated configuration parameters, etc. Outputs are mainly to include the collected and collated data, configuration parameters, control command, etc.

3.3.11 The input source of sensing system may be sensor, transmitter or manual input, and the output information is to include digitalized data (floating point values for scalar data, dynamic data replication and time series, test result for lubricating oil/air/water sample data), timing data/time baseline data, data quality index.

① DSP：Digital signal processing.

3.4 Data system

3.4.1 The data collection module is to have the functions to collect analog data, digital data and manual data, and transform the analog data to digital data.

3.4.2 The data system is to be suitable for the acquisition and processing of various communication modes or analog/switching signals.

3.4.3 The data collection module is intrinsically a calibrated digital sensor data record server. Data collection module may be represented as a software module through which the access to automatic input or manual input digital data is provided by the system or as a specific data collection module with analog input from legacy sensor, or sensor signals which are collected and merged from data bus. In addition, the data collection module may be shown as the software interface of intelligent sensors.

3.4.4 The outputs of data collection module are to include digital data, timing data/time baseline data (normally by reference of UTC or local time zone) and data quality index (such as good, poor, unknown, in the process of examination, etc.).

3.4.5 The data processing module is to have the functions of carrying out signal processing (such as filtering, fenestration, FFT, etc.), synchronous or asynchronous averaging, algorithm calculation, feature extraction, etc.

3.4.6 The condition monitoring module is to have the functions of making comparison between outputs of data collection module and/or data processing module and expected value or operating limit so as to produce the enumeration state indexes with their respective boundary exceedances.

3.4.7 The indexes output by condition monitoring module may be used as a reference for mechanical health assessment to produce alarm and warning.

3.4.8 The data collection module is to be capable of self-inspection on its hardware, and giving functional fault or false alarm.

3.4.9 The output of data system is mainly include enumeration state indictor, threshold, severity of upward/downward deviation from the threshold, change of alarm level, intensity of abnormality, statistical analysis, etc.

3.5 Health assessment system

3.5.1 Health assessment system are to carry out automatic diagnosis and predict current and potential fault/failure conditions by means of certain algorithm and analysis technologies. If conditions are limited, artificial means may be used to assist in the diagnosis and prediction.

3.5.2 The diagnosis module is to carry out fault/failure detection, identification, positioning and early isolation. Diagnosis information is to include the followings as a minimum:

(1) Machineries and their components of which fault/failure is possibly to occur, and the associated fault/failure modes;

(2) Potential symptoms of fault/failure;

(3) Relevant condition monitoring parameters;

(4) Diagnosis method, basis and interpretation.

3.5.3 The diagnosis algorithm is to meet the following requirements:

(1) Having the abilities to detect the system performance and degradation grade;

(2) Having the abilities to detect the fault/failure based on physical characteristics changes through measurable phenomena;

(3) Identifying the mechanism of a specific system or component and its fault/failure;

(4) Giving the diagnostic conclusions for potential impact of fault/failure on the integrity of the system operation.

3.5.4 Diagnostic performance indexes:

(1) Timeliness: means the ability of system to detect fault/failure of monitored system/equipment immediately after the occurrence;

(2) Sensitivity: means ability of system to detect the micro fault/failure signal, the smaller the detected fault/failure signal, the higher the sensitivity of early detection;

(3) False alarm: means fault/failure is mistakenly detected where there is no fault/failure of the monitored system/equipment;

(4) False alarm rate (r_{FA}): means the ratio of the number of false alarms in a prescribed period of time to the total number of fault/failure indications in the same period of time. The formula is: $r_{FA} = N_{FA} / (N_F+N_{FA})$, where: N_{FA} — the number of false alarms in a prescribed period of time; N_F — the number of correct fault/failure alarms in the same period of time;

(5) Miss alarm: means the fault/failure of monitored system/equipment is not detected;

(6) Miss alarm rate (r_{MA}): means the ratio of the number of miss alarms in a prescribed period of time to the total number of fault/failure in the same period of time. The formula is: $r_{MA} = N_{MA} / (N_F+N_{MA})$, where: N_{MA} — the number of miss alarms in a prescribed period of time; N_F — the number of correct fault/failure alarms in the same period of time;

(7) Fault/failure isolating ability: means the ability of system to distinguish the different faults/failures, the stronger isolation capability, the more accurate the positioning of fault/failure;

(8) Fault/failure identification ability: means the ability of system to identify the fault/failure size and time-varying characteristics;

(9) Robustness: means the ability of system to correctly carry out fault/failure diagnosis in the case of noise, interference, etc., and maintain low false alarm rate and miss alarm rate simultaneously;

(10) Adaptive ability: means the system is adaptive to the monitored system/equipment in a changeable state, and is capable of improving itself by use of new information due to changes.

3.5.5 Measures to reduce false alarm and miss alarm:

(1) Ensuring the effectiveness of monitoring data;

(2) Optimal feature selection/extraction;

(3) Optimal selection for fault detection/identification algorithms;

(4) Evidence synthesis/fusion (D - S theory);

(5) Fault/failure classification algorithm fusion;

(6) Declaring fault/failure only when confidence level/certainty exceeds the set threshold.

3.5.6 The prediction module is to be applied to estimate the mechanical failure modes and trends in the future.

3.5.7 The prediction information is at least to include the followings:

(1) Operating conditions, monitoring parameters, etc. of the monitored machineries in the process of prediction;

(2) Prediction conclusion, including all identified failure modes;

(3) Confidence level, effective condition and risk assessment;

(4) Additional test/verification required to improve confidence level;

(5) Prediction method, basis and interpretation.

3.5.8 Inputs mainly include outputs and historical information of data system, outputs and historical information of other health assessment system, expert knowledge, relevant configuration parameters, historical date to be stored, etc.

3.6 External system

3.6.1 The system is to be equipped with a server/database of sufficient capacity so as to realize data storage, backup and management, and is capable of maintaining the data for a survey cycle as a minimum (at least 5 years for ship terminal to set up data backup system).

3.6.2 Any access, acquisition, storage and application of data for conditions are to be allowed and authorized by the shipowner in advance, by taking consideration of his privacy.

3.6.3 Historical operation data may be retrieved and applied at any time by other functional modules such as health assessment.

3.6.4 Historical data trends may be applied to carry out analysis related to statistics, and for the sake of accuracy, the existing health assessment and root cause information are to be checked.

3.7 Communication system

3.7.1 The communication system is to meet the relevant requirements of Categories II and III of system data links in 2.6.6, Chapter 2, PART SEVEN of CCS Rules for Classification of Sea-going Steel Ships.

3.7.2 The communication system of intelligent sensors/transmitters is to comply with the IEEE1451 series standard.

3.7.3 The communication system is to ensure the effectiveness, reliability, adaptability, security, standardization and maintainability of digital transmission and maintain the safe and reliable bidirectional data exchange between ship terminal and shore terminal, shore terminal and mobile terminal (if any).

3.7.4 In order to integrate the modules which are from different platforms, manufacturers, and in different programming languages into one integrated part, so as to achieve the health assessment function, a set of communication standard is to be formulated to realize the exchange of modules. System structure of the standard may be classified into three parts, such as data exchange interface, hierarchy interface and communication agreement. Data exchange interface is to provide application programming interfaces for each module and set up the communication foundation among modules; Hierarchy interface is to provide the communication information description of modules and are the essential conditions for communication among modules; Communication agreement is directly to face the application, which is a contract of information exchange among executors in the system and is an essential condition to realize the communication of modules.

3.8 Interaction system

3.8.1 The interaction system is to have a user friendly human-computer interface and be convenient for operation, and may display overall images of all machinery and sub-system/component images. Multi-level alarm values may be set for machinery, and various statistical information can be simultaneously output, including alarm information, measurement information, abnormal signal information, health assessment result, etc.

3.8.2 The output data and information are at least to include the followings:

(1) Identification code or number: to describe identification of the tested machinery by historical records such as equipment number, component number, data of evaluation, etc.;

(2) Condition monitoring: to display specific condition information and trend data of the monitored machinery;

(3) Health assessment: to display diagnosis conclusions of current or potential fault/failure for the monitored machinery and failure prediction information.

3.8.3 The interaction system is to be capable of transforming data to a format which can be clearly expressed and is necessary for proper decision-making, such as text description form, digital form to express amplitude value, diagram form to express trend or the combination of these three forms.

3.8.4 In order to facilitate the senior personnel to carry out analysis, relevant technical display is required to show the trends and relevant information within abnormal zone and provide the abnormal condition data to be identified, confirmed or understood for the analysts.

3.8.5 For most users, display may be classed into five zones so as that the conditions may be rapidly understood, and the specific additional data may be displayed by subsequent multi-windows. The five different zones are condition monitoring, health assessment, prediction, recommended measures and identification. Customer display format may be developed for specific application in a special case.

3.8.6 Different authority is to be set for operators with different demands so as to prevent misoperation and ensure the safety and security of system.

Chapter 4 Decision Support System Requirements

4.1 General requirements

4.1.1 DSS is to be constructed on the basis of MCM&HAS, and meet the requirements of Chapter 3.

4.1.2 DSS may be regarded as a component of CBM system and is to provide rational and effective maintenance plan for ship's machinery equipment based on the historical and current operation conditions of machinery installations in engine rooms and the comprehensive consideration of future trend prediction; it may also be combined with MCM&HAS to form an independent system to provide implementation measures and decision support recommendations on operation and maintenance for ship's machinery equipment.

4.2 DSS categories

4.2.1 According to the different subjects providing decision support, DSS may be grouped into computer DSS and artificial DSS.

4.2.2 Computer DSS: computer independently carries out analysis and evaluation by combining human judgment with computerized information so as to provide operational decision-making recommendations or maintenance plan, etc.

4.2.3 Artificial DSS: ship/shore based technicians carry out analysis on mechanical conditions output by MCM&HAS and/or analysis and evaluation results so as to provide implementation measures and decision-making recommendations on operation and maintenance for ship's machinery equipment.

4.2.4 If conditions are limited, artificial DSS may provide assistance to computer DSS to complete the analysis and evaluation of decision support.

4.3 Compositions of computer DSS

4.3.1 Based on the different structures, DSS may be classed into traditional DSS, intelligent decision support system (IDSS), new decision support system (NDSS) and synthetic decision support system (SDSS), refer to the typical DSS categories shown in Fig.4.3.1.

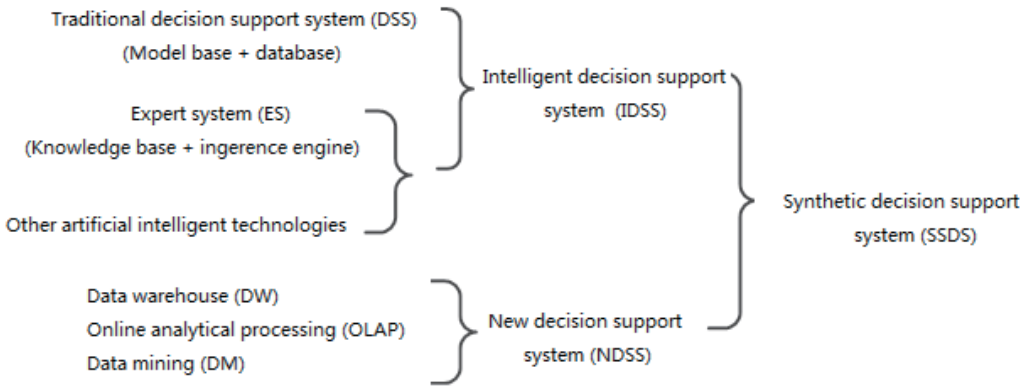


Fig.4.3.1 Typical DSS Categories

4.3.2 The traditional DSS is mainly composed of database system, model base system, user interface, etc., as shown in Fig.4.3.2.

(1) Database system: including database and database management system (DBMS). Data related to physical issues are stored in database, which is managed by DBMS;

(2) Model base system: including model base and other quantitative models providing decision-making analysis ability. The model base management system (MBMS) is to provide users with modeling language and functions, and the model base management function;

(3) User interface system: interface between DSS and users, and DSS is to provide decision-making recommendation to users; Users may feedback information to DSS for error correction and self-learning. Human-computer interaction may be carried out by means of menu, questions and answers, forms, natural language, windows, etc.

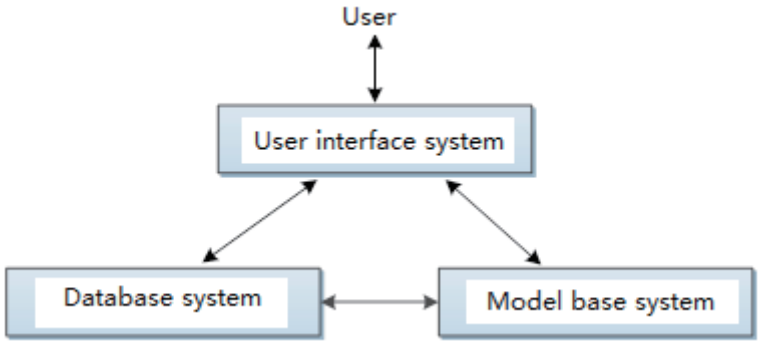


Fig. 4.3.2 Basic Structural Diagram of Traditional DSS

4.3.3 IDSS integrates artificial intelligence technology into traditional DSS so as to compensate for the dificiencies of traditional DSS relying solely on model technology and data processing technology and intentional deviation due to users highly involving. The artificial intelligent technologies related to decision support is mainly to include expert system (ES), neural network, genetic algorithm, machine learning, intelligent agent technology, natural language understanding, etc.

4.3.4 The most mature ES-based IDSS in the mechanical field is to integrate ES on the basis of traditional DSS so as to make traditional DSS to fully apply the human knowledge or intelligent knowledge, such as descriptive knowledge of decision-making, procedural knowledge in the process of decision-making, detective knowledge for solving problems, etc., and assist to solute the complex decision-making issues by logical reasoning. ES is mainly composed of knowledge base, knowledge acquisition subsystem, inference engine and dynamic database. Refer to basic structural diagram of IDSS shown in Fig.4.3.4.

(1) Knowledge base (KB) includes two basic elements: fact (such as situation in the field of releated issues), special heuristic knowledge or regulations;

(2) Knowledge acquisition subsystem: knowledge acquisition is a process to extract the knowledge used to solve issues in the specialized field from the sources of the knowledge and transform it to computer program so as to establish or extend the knowledge base. The source of knowledge may be experts, science books, databases, research reports, cases, etc.;

(3) Inference engine: in the case of fault/failure of diagnostic objects, detection is to be carried out for the objects through relevant knowledge called from knowledge base by certain strategy, analysis and isolation are to be conducted based on premonition data till the fault/failure source is positioned. The performances of inference engine and transparency of detective process will directly affect the result and efficiency of reasoning results;

(4) Database in traditional DSS may be regarded as a relative static database, which provides initial data for dynamic database in ES, upon the conclusion of ES reasoning, the results in dynamic database are to return to DSS database.

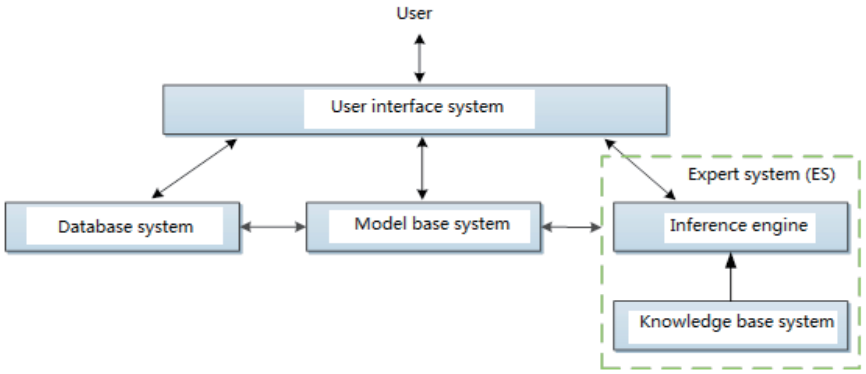


Fig.4.3.4 Basic Structural Diagram of IDSS

4.3.5 NDSS: the data warehouse-based DSS is combined of three technologies: data warehouse, online analytical processing and data mining, as shown in Fig.4.3.5.

(1) Data warehouse (DW): reorganizing a large number of historical data, real-time data, synthetic data according to decision-making demands, storing the data in the form of DW and providing users with random queries, synthesized data, trend analysis information, etc. which can assist in decision-making;

(2) Online analytical processing (OLAP): sharing multidimensional information and providing a rapid information technology for online data access and analysis of specific issues;

(3) Data mining (DM): extracting useful information hidden in data from large amounts of data and providing decision support.

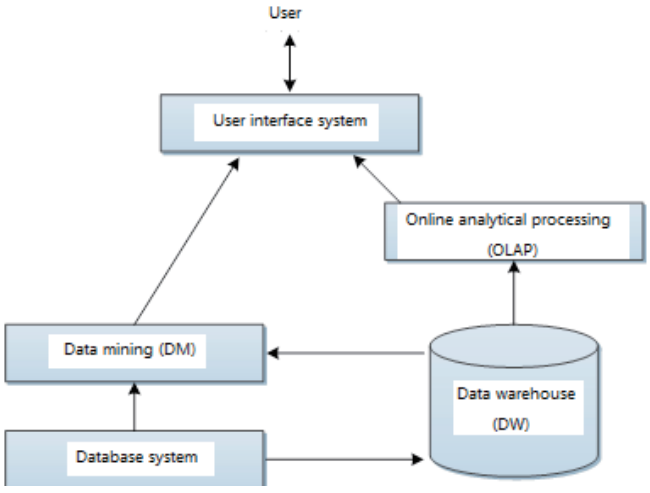


Fig.4.3.5 Basic Structural Diagram of NDSS

4.3.6 SDSS is composed of three main parts, as shown in Fig.4.3.6:

(1) a main part consisting of model base system and database system, completing combination of multiple models and processing large amounts of shared data, and providing decision support by use of model resources;

(2) a main part consisting of data warehouse and online analytical processing, carrying out data synthesis, prediction and multidimensional data analysis in data warehouse, and providing decision support by use of data resources;

(3) a main parts consisting of knowledge base system and data mining technology, carrying out knowledge reasoning, and providing decision support by use of data resources.

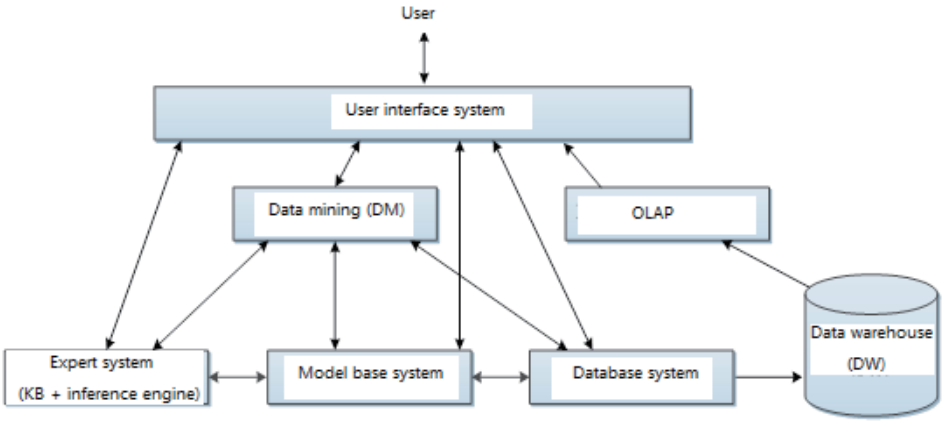


Fig.4.3.6 Basic Structural Diagram of SDSS

4.3.7 For DSS in a network environment, its data warehouse, model resource and knowledge resource are to provide concurrence, shared model services and knowledge services on the network in the form of a server, such as model server, knowledge server, database server, OLAP and data mining server, data warehouse server, etc.

4.4 DSS technical requirements

4.4.1 DSS is to be easy for operation and adaptable, with rapid and friendly-interface for users.

4.4.2 For alarming/early warning information and current and predicted fault/failure information of machinery equipment, DSS is to output hazards and their effects, causes, recommended measures and alternatives (ranking based on recommended grades), basis and interpretation, etc.. Alternatively, DSS is to provide mechanical operation and maintenance recommendations so as to optimize the running state of machinery equipment.

4.4.3 For condition-based maintenance system, the recommended repair method is to be based on risk level of machinery equipment or components, operation costs, maintenance costs, availability of spare parts and other elements.

4.4.4 Computer DSS is at least to meet the following requirements:

(1) Self-learning/self-improvement;

(2) User interface system is to have the human-computer interaction function;

(3) Full completion of knowledge necessity to solve the storage and key issues;

(4) Sufficient capacity of database/data warehouse;

(5) Providing the means of knowledge acquisition, machine learning, database maintenance, such as modification, extension and improvement, etc. for IDSS;

(6) Information automatically recorded by the system based on time sequence and information on adoption, implementation, error correction and manual supplementation (if any) of backup decision recommendations, if necessary, the operators of ship terminal may provide assistance to complete the working.

4.4.5 Artificial DSS is to provide continuous and full-functional assistant decision support for machinery equipment, and at least one detailed decision support recommendation or report is to be given each month.

4.4.6 Ship companies are to regularly provide feedback reports on the application of artificial DSS, including the information on adoption, implementation, error correction, etc. of decision support recommendations.

Chapter 5 Condition-Based Maintenance System and System Requirements

5.1 Application

5.1.1 This Chapter applies to ships applying for approval of condition-based maintenance plan for machinery and system.

5.1.2 Condition-based maintenance plan is applicable to equipment or system covered in appendix 1 to the Guidelines and other equipment or system required by the shipowner.

5.2 Composition and functions of CBM system

5.2.1 CBM system is established on the basis of MCM&HAS (see Chapter 3 of the Guidelines for details) and develops targeted reasonable and effective machinery maintenance plan combining the decisions and suggestions for maintenance given by DSS (see Chapter 4 of the Guidelines for details).

5.2.2 CBM system diagnoses and predicts remaining useful life and arranges future maintenance scheduling of equipment reasonably through the real-time monitoring of the working condition and environment of equipment by means of artificial intelligence. A complete CBM system architecture is to cover a series of functions from data acquisition to detailed maintenance plan and the major functions of CBM system include:

(1) sensing and data acquisition;

(2) data manipulation and feature extraction, early warning;

(3) failure/fault diagnosis;

(4) condition monitoring;

(5) prediction of future physical condition and form of failure;

(6) maintenance plan or appraisal of availability of equipment in specific operational environment;

(7) management of the storage and access of history data;

(8) management of system configuration;

(9) man-machine interaction;

(10) safe and reliable bidirectional data exchange between shore ends;

(11) automatic recording and backup of information on the adoption, implementation, correction and manual replenishing (if any) of CBM plan according to the time order and the ship end operational personnel may assist to complete the work where necessary.

5.2.3 Maintainability and security of the CBM system must be ensured and the usage/maintenance cost of key system/process within the whole life circle is to be reduced.

5.2.4 The structure of CBM is to be designed as and open type which may be easy to use in case of change, updating and replacement of external system or sub-system and component and the change of system/process interfaces is to be minimized.

5.2.5 The requirements for reliability, availability, maintainability and durability of CBM system are to be met.

5.2.6 The knowledge base of CBM system comes mainly from design (the original data and information and other components of system) and operation (including record of operation data, maintenance history and material consumption history).

5.3 Requirements for the organization and personnel managing condition-based maintenance system

5.3.1 The management party applying for CBM system for machinery is to establish a dedicated unit to manage the CBM system and structure. Such unit may undertaken by maintenance department concurrently or a dedicated department. In any case, the unit is to be charged by dedicated personnel. Furthermore, this unit is responsible for development of documents of CBM system, and daily management of CBM system. This unit is to give the equipment list for implementing CBM plan according to the specifications of equipment manufacturer.

5.3.2 The shore end is to establish a mechanism to look up and update machinery condition monitoring and diagnosis data, assessment report, CBM information etc. e.g.: server, management system.

5.3.3 The management party of condition-based maintenance system is to establish a condition-based machinery maintenance quality management system, which is to comply with ISO 9000 quality management system certification standard or equivalent standard and requirements of ISM code and IACS. The quality management system is to include at least the following items:

(1) post functions and authorities of the dedicated unit implementing condition-based machinery maintenance;

(2) working procedures, daily management and document management of condition-based machinery maintenance;

(3) management of personnel implementing condition-based machinery maintenance, including qualification and training management;

(4) list and specification of machinery equipment and components implementing condition-based maintenance;

(5) condition-based maintenance plan and the backup plan in case the former can not be implemented;

(6) condition-based maintenance engineering management, including maintenance standard, inspection and quality control;

(7) continuous analysis and monitoring plan;

(8) contents and interval of process record;

(9) maintenance support, including spare part, technical support,etc.;

(10) internal review, correction, improvement procedures of quality management system.

5.3.4 The management party of condition-based maintenance system is to provide management and technical support such as personnel training, spare part supply, maintenance equipment and tools necessary for the implementation of condition-based maintenance.

5.3.5 All personnel engaged in condition-based maintenance are to undertake sufficient training and to be qualified. Chief engineer is the responsible person implementing CBM onboard the ship. He is responsible for the implementation of CBM plan, storage of necessary maintenance and measurement records and check or confirmation and endorsement of related servicing report. Only the chief engineer or other authorized persons is allowed to get access to CBM system so as to update the maintenance documents and maintenance plan.

The chief engineer is to submit the report of implementation of CBM of each month of the season to the management unit of the company at least every season. The management unit is responsible for summary and management and the report may be transmitted to CCS by E-mail.

5.4 Requirements for service supplier of machinery condition monitoring and health assessment

5.4.1 The supplier of machinery condition monitoring and health assessment is to be approved by CCS. Details of approval requirements are given in Chapter 9.

5.5 Requirements for system/product

5.5.1 On the basis of CCS rules and extensiveness of the definition of computer system in the acceptable standard, the systems/products involved in the Guidelines may all be categorized as computer system despite of different levels of complexity, except for some individual equipment.

5.5.2 According to the requirements for categories of computer system specified in Section 6, Chapter 2 of PART SEVEN of Rules for Classification of Sea-Going Steel Ships, computer systems/ products involved in the Guidelines are to be categorized as category II equipment the system fault of which will finally endanger personnel safety, ship safety and environment.

5.5.3 The system/product involved in the Guidelines is to comply with the requirements of CCS Guidelines for Security and Reliability Assessment of Marine Software for computer system.

5.5.4 System independence requirements

(1) CBM system is to be designed or rendered to function independently of each other so that a failure or malfunction in one or two of these systems or modules will not prevent the other system(s) from operating.

(2) Sub-systems of CBM system are to be independent. Failure in one of the sub-systems is not to interfere with the operation of another sub-system.

5.5.5 System fail-safe requirements

(1) CBM system is to be designed on the fail-safe principle. The fail-safe principle is to be applied on the basis not only of the CBM system itself and its associated machinery, but also of the whole machinery installation and the safety of the ship and personnel.

(2) The design of CBM system is to be such that a failure in the operation will not cause other failures and will, so far as possible, lead to the least dangerous condition of the controlled process.

(3) The CBM system is to ensure continuous, effective and reliable operation, updating and maintenance.

5.5.6 System redundancy design

(1) Duplicated sources of power are adopted by CBM system. The backup power will undertake all loads immediately while the main source of power failures.

(2) In the case of failure of the system or its module, the component of redundant configuration will get involved and undertake the work so as to reduce the failure period of system.

Chapter 6 Requirements for Approval of Plans and Documents

6.1 Approval basis

6.1.1 Chapters 3&4 of PARTSEVEN of CCS Rules for Classification of Sea-Going Steel Ships.

6.1.2 Chapter 4 of Rules for Intelligent Ships and the Guidelines.

6.2 List of plans and documents to be submitted for approval

6.2.1 For ships applying for the class notations in the Guidelines, applicable plans and documents as specified in Table 6.2.1 are to be submitted.

List of plans and documents and requirements Table 6.2.1

No.	Plans and documents	Main contents	Submission phase	Detailed requirements
1	List and description of monitored machinery installations	(1) list of monitored equipment, method for description of health condition, diagnosable failure; (2) monitoring parameters and normal range, e.g. temperature, pressure, flow and vibration; (3) monitoring plan, including monitoring devices/sensors; (4) monitoring procedures, including monitoring method/ technology, monitoring means (on-line, off-line monitoring and periodical measurement, measurement period is to be specified for periodical measurement), reference measurement procedures, equipment condition monitoring procedures; (5) condition analysis/assessment method, including description of principles, examples, verification plan, technical index; (6) assessment criteria, including health assessment index, failure diagnose index.	P/S	A
2	Detailed information on condition monitoring and fault diagnosis system	(1) system principle, functions, operating and maintenance description, including network of condition monitoring system, communication and database design of condition monitoring system; (2) system hardware description, e.g. sensor, data acquisition device, data storage/backup device; (3) software description, e.g. data processing and analysis method, fault diagnosis method and condition assessment method; (4) type and content of data/information output.	P	A
3	Relevant information on decision support system	(1) system functions, use and maintenance description; (2) list and description of equipment and system included in Assistant decision making; (3) implementation procedures, including system operation and maintenance plan, plans for updating of knowledge base.	P	A
4	Relevant information on condition-based maintenance system	(1) system functions, use and maintenance description; (2) list and description of equipment and parts included in the condition-based maintenance system; (3) content and plan of condition-based maintenance; (4) procedures for development and implementation of condition-based maintenance plan (5) redundancy design and analysis of condition-based maintenance system.	P	A

No.	Plans and documents	Main contents	Submission phase	Detailed requirements
5	Procedures and schedules	(1) onboard testing procedures, including testing plan, technical index, sea trial outline; (2) procedures and schedules for data collection; (3) procedures and schedules for data storage/backup; (4) procedures and schedule s for data analysis; (5) output of assessment result/report; (6)procedures and schedules for calibration of monitoring devices.	S where (1) is to be submitted to the survey unit	A
6	Relevant information on the company	(1) structure diagram of relevant posts (responsibilities) of company; (2) working flow, including goal, method and strategy; (3) training plan and qualification requirements for relevant personnel carrying out Assistant decision making and condition-based maintenance.	Survey unit	N

Symbols:

1) Submission phase: P—product plan approval stage, S—ship plan approval stage;
2) Detailed requirements: A—submission for approval, N—submission for information.

Chapter 7 Technical Requirements for System Approval and Test

7.1 Application

7.1.1 This Chapter applies to the approval and test of Machinery Condition Monitoring and Health Assessment System (MCM&HAS), Decision Support System (DSS) and Condition-Based Maintenance system.

7.2 Approval/survey basis

7.2.1 Chapter 3 of PART ONE and Chapters 1, 2 &3 of PART SEVEN of CCS Rules for Classification of Sea-Going Steel Ships.

7.2.2 Chapters 1 & 4 of CCS Rules for Intelligent Ships.

7.3 Selection of typical sample

7.3.1 The selection of test samples is to be representative and to cover the products the type approval of which is applied.

7.3.2 Where the major elements (e.g. computer, display) of products are provided by different manufacturers, CCS may consider to take the samples for type test (including test for marine environment, electromagnetic compatibility test etc.) respectively according to the above principles.

7.4 Certification requirements for products

7.4.1 For products to be approved/surveyed, the certification requirements in Table 7.4.1 are to be met.

Certification Requirements for System/Products Table 7.4.1

No.	Product name	Type of certificate		Approval mode				Plan approval	Remarks
		C/E	W	DA	TA-B	TA-A	WA	PA	
1	Machinery condition monitoring and health assessment system (MCM&HAS)	X	—	—	X	—	—	X	Apply for class notation M, or Mx or CBM (X)
1.1	Computer	—	X	—	X[3]	—	—	X	
1.2	Display	—	X	—	X[3]	—	—	X	
1.3	Uninterrupted Power Supply (UPS)	—	X	—	X[3]	—	—	X	
1.4	Programmable controller	—	X	—	X[3]	—	—	X	
1.5	Sensor/monitoring equipment	O	X	—	O	—	—	X	

No.	Product name	Type of certificate		Approval mode				Plan approval	Remarks
		C/E	W	DA	TA-B	TA-A	WA	PA	
2	Decision support system (DSS)	X	—	—	X	—	—	X	Apply for class notation M
2.1	Computer	—	X	—	X^3	—	—	X	
2.2	Display	—	X	—	X^3	—	—	X	
2.3	Uninterrupted Power Supply (UPS)	—	X	—	X^3	—	—	X	
2.4	Programmable controller	—	X	—	X^3	—	—	X	
2.5	Sensor/monitoring equipment	O	X	—	O	—	—	X	
3	Condition-based maintenance system (CBM)	X		—	X	—	—	X	Apply for class notation Mx, CBM (X)
3.1	Computer	—	X	—	X^3	—	—	X	
3.2	Display	—	X	—	X^3	—	—	X	
3.3	Uninterrupted Power Supply (UPS)	—	X	—	X^3	—	—	X	
3.4	Programmable controller	—	X	—	X^3	—	—	X	
3.5	Sensor/monitoring equipment	O	X	—	O	—	—	X	

Symbols:

1) C – Marine Products Certificate; E – Equivalent document; W – Manufacturer's document; X – Applicable; O – Optional.
2) DA – Design approval; TA-B – Type approval B; TA-A – Type approval A; WA – Works approval; PA – Plan approval.
3) X^3: If certification requirements for purchased parts can not be satisfied, complete type test is to be carried out with integral product.

7.5 Type approval

7.5.1 The type test programme is to be submitted to the surveyor in advance for approval, including preparation basis, test items, selection of sample, test location, etc. The test organization and its testing capability are to be approved by CCS. Refer to Guidelines for Approval of Testing Organization for Marine Products (GD08-2015) for requirements for approval.

7.5.2 Type test is to cover the test items listed in Table 7.5.2.

Type Test Items **Table 7.5.2**

No.	Test items	Requirements for test result	Remarks
1	Inspection of appearance, identification and completeness	To confirm that there is no damage of the appearance of product, the identification is clear and modules of product are complete	
2	Function test	See Table 6.5.3 for details	
3	Marine environment test	CCS Guidelines for Type Approval Test of Electric and Electronic Products	
4	Electromagnetic compatibility test	CCS Guidelines for Type Approval Test of Electric and Electronic Products	

7.5.3 The function test is to be capable of confirming that the system complies with the technical requirements of the approved drawing/information and the Guidelines. The function test is to cover those specified in Table 7.5.3.

Detailed test method is to be developed combined with the product technical documents (technical conditions, specifications) approved by CCS. Decision support function may be verified by means of environmental simulation and the testing plan is to be confirmed by the surveyor.

Items of Function Test **Table 7.5.3**

No.	Test items	Requirements for test result	Remarks
General functions			
1	Tamper resistance function	Protective measures are to be provided to prevent the operator making unwitting or unauthorized amendments to the procedure	
2	Data communication failure alarming function	The system is to be capable of making continuous self-examination of communication lines and alarm is to be initiated once abnormal situation occurs	
3	Power shifting function	The system is to be capable of shifting automatically to the backup power in the case of power loss during normal power supply. The storage battery maybe used as backup power and the capacity is to maintain the power supply for at least 30 minutes	
4	Power failure alarm	Audio and visual alarms are to be initiated while the system power failure occurs	
Machinery condition monitoring and health assessment system (MCM&HAS) function			
5	Inspection of data acquisition function	The system is to monitor the operation condition of major machinery of the engine room and the data acquired through analysis is to be in consistent with the original data inputted actually	To provide data acquisition interfaces with access to standard signal (e.g. current signal, voltage signal, serial port signal) and to observe the data indication; data acquisition interfaces of the same type may be verified by sampling if the number of interfaces is large
6	Signal loss alarming function	The system is to initiate the alarm in the case of loss of signal to be collected	
7	Inspection of format of machinery monitoring parameters	Records of monitored parameters are to include at least the following information: (1) description of basic data of machinery; (2) measurement location; (3) method for processing measurement data; (4) date and time information	
8	Recording of benchmark data	The system is to record the benchmark data measured under the original state of machinery or the condition monitoring is acquired	

No.	Test items	Requirements for test result	Remarks
9	Inspection of ship-shore communication function	If shore-based support is adopted to implement condition-based maintenance or decision support function, the effectiveness of ship-shore data communication is to be confirmed	
10	Inspection of data storage function	The measured data is to be recorded in a standard form and stored periodically; history data may be checked from the stored data and the content is to be consistent with the original input data	
11	Inspection of data backup capability	Equipment necessary for database backup is to be provided and verified effective	
12	Trend analysis of condition monitoring data	The system is to be capable of implementing the data trend analysis and indicating the analysis result visually	
13	Analysis and assessment function	The system is to be capable of outputting analysis and assessment report for machinery operation condition and health condition. To check whether the false detecting rate and missed detecting rate comply with the requirements of the Guidelines. (Neither the false detecting rate nor the missed detecting rate is to be over 30%)	This test may be carried out by means of data simulation and the assessment result is to be consistent with the simulation environment. At least 10 failure events are to be simulated
Decision support system (DSS) function			
14	Knowledge base function	The system is to establish a knowledge base which is capable of being constantly updated and completed with the accumulation of operation experience and updating of knowledge.	
15	Decision support output function	The system is to be capable of outputting decision making suggestions corresponding to the above analysis and assessment report	
16	History data query function	Decision support system is to facilitate the query of history data and output relevant records necessary for the inspection	
Condition-based maintenance system function			
17	Development of condition-based maintenance plan function	To develop condition-based maintenance plan for monitored equipment and components based on the health assessment results of machinery and components	
18	Updating of condition-based maintenance plan function	The system is to constantly update the maintenance plan based on condition monitoring information	
19	Record generating function	The system is to generate two records: list of inspection items of condition-based maintenance equipment, record for service, inspection and repairing of condition-based maintenance	
20	History data query function	The history data of condition-based maintenance plan is to be available for query	

7.5.4 The software of the product is to be assessed as category II system in accordance with CCS Guidelines for Security and Reliability Assessment of Marine Software and the requirements of the standard are to be met.

7.5.5 The cyber system of the product is to be assessed in accordance with CCS Guidelines for Requirement and Security Assessment of Ship Cyber System and the requirements of the standard are to be met.

7.6 Unit/batch inspections

7.6.1 After type approval, unit-by-unit inspection of products is to be carried out by CCS surveyor.

7.6.2 Unit/batch product inspection is to be carried out according to the test items listed in Table 7.6.2.

Test items of unit/batch inspection Table 7.6.2

No.	Test items	Requirements for test result	Remarks
1	Inspection of appearance, identification and completeness	To confirm that there is no damage of the appearance of product, the identification is clear and modules of product are complete	
2	Check of information on sensors	To confirm that the accuracy of sensor complies with the system requirements by checking of certificate/evidence	
3	Measurement of insulance	Regulation 2.3 of CCS Guidelines for Type Approval Test of Electric and Electronic Products	
4	Voltage resistance test	Regulation 2.14 of CCS Guidelines for Type Approval Test of Electric and Electronic Products	
5	Function test	Applicable test items in Table 7.5.3 are to be included: (1) Machinery condition monitoring and health assessment system (MCM&HAS): items 1 to 13 (2) Decision support system (DSS): items 1 to 16 (3) Condition-based maintenance system: items 1 to 20	

Chapter 8 Class Notation Survey

8.1 Application

8.1.1 This Chapter is applicable to ships applying for class notations M and Mx for intelligent machinery and class notation CBM(X) for ship equipment condition-based maintenance.

8.2 Document approval

8.2.1 The requirements for submitting plans and documents in 4.3, Chapter 4 of CCS Rules for Intelligent Ships and relevant requirements for plan and document list in 6.2, Chapter 6 of the Guidelines are to be complied with.

8.3 Document on board ships

8.3.1 The following documents are to be kept on board ships:

(1) Relevant plans and documents mentioned in 4.3, Chapter 4 of CCS Rules for Intelligent Ships;

(2) Records relating to class notation since last survey, e.g. records of equipment overhaul, maintenance, repair or replacement;

(3) Approval certificate for system relating to class notations in the Guidelines;

(4) All monitoring data (including original reference data) and alarm record of monitored machinery since last survey;

(5) In addition to keeping documents mentioned in above (1) to (4), ships applying for CCS class notation M for intelligent machinery are to keep documents such as records of suggestions adopted and feedbacks provided by DSS, DSS correction record and knowledge updating record;

(6) In addition to keeping documents mentioned in above (1) to (4), ships applying for CCS class notation Mx for intelligent machinery and class notation CBM(X) are to keep documents such as record of implementing condition-based maintenance plan and record of feedbacks and suggestions;

(7) Evaluation report provided by intelligent machinery service supplier;

(8) Calibration record/certificate of monitoring equipment/sensor.

8.4 Survey and test

8.4.1 Relevant requirements for survey and test in 4.5, Chapter 4 of CCS Rules for Intelligent Ships are to be complied with.

8.4.2 Test procedures to be kept on board ship are at least to include items such as system integrity inspection, function inspection and communication inspection.

8.4.3 Survey in relaciton to the request for class notation for intelligent machinery and/or class notation CBM(X) is to be carried out simultaneously with initial classification, annual, intermediate and special survey, and documents kept on board ship as required by 8.3 of this Chapter are to be verified.

Considering importance and safety of condition-based maintenance, condition-based maintenance system is to be subject to trial operation on completion of initial installation, and the trial period is to be at least 6 months. During trial period, if significant problems occur, feedback is to be provided to service supplier and CCS in time. Condition-based maintenance system is to give class memorandum on completion of initial installation survey, requiring the surveyor to carry out survey during annual survey not earlier than 6 months on completion of initial installation survey of condition-based maintenance system.

During survey, the surveyor is to:

(1) verify that condition-based maintenance system is implemented according to approved documents, including comparison with reference data;

(2) verify the implementation of system survey requirements and maintenance test by consulting documents required by annual survey;

(3) verify that operators are familiar with system operation and check implementation condition;

(4) check revision record of equipment limit parameter (alarm and warning) during trial operation of condition-based maintenance plan;

(5) consult failure record of equipment applicable to condition-based maintenance and check reasonability of condition monitoring and condition-based maintenance plan.

8.4.4 If there is condition of alteration, damage and failure affecting maintenance of class notation, the ship owner is to notify CCS in time and apply for interim survey. For ship transaction, alteration of management company or class transfer, ship condition-based maintenance system is to be reapproved. Any replaced machinery parts is to be kept on board ship for inspection by surveyor.

8.4.5 Annual and intermediate survey carried out on board ship is at least to meet relevant requirements for survey after construction in 4.5.2, Chapter 4 of CCS Rules for Intelligent Ships. Survey requirements are as follows:

(1) The ship owner and ship management company are to submit an annual report on class notations M, Mx and/or CBM(X) to CCS units carrying out survey. The report is at least to include system maintenance record, general operation record, failure condition of monitored machinery equipment, cause analysis, equipment replacement condition as well as operation and maintenance record of renewed equipment since last annual survey;

(2) To check detailed work record of system;

(3) To confirm system's historical data, trend analysis data, lubricating oil analysis report, vibration analysis report and system operation analysis report of last year;

(4) To confirm that the operators are familiar with system operation and implementation condition;

(5) To examine and confirm that relevant instruments such as system condition monitoring sensors are calibrated according to the requirements of Chapter 2 of the Guidelines;

(6) To check test procedures to be kept on board ship, and test procedures are at least to include items such as system integrity check, functional examination and communication check;

(7) If the ship owner or ship management company entrusts the third party to submit annual evaluation report of system, approval certificate sufficient to satisfy condition monitoring system and health assessment system approved by CCS is to be submitted. The handheld condition monitoring equipment is maintained and calibrated according to recognized international and national standards to ensure accuracy of reading data, and copy of calibration certificate is to be submitted. The handheld equipment used for hazardous area is to meet the requirements for division of ship hazardous area. The surveyor is to check that system installation, alarm and installation comply with relevant provisions of manufacturer's manual and CCS Rules and Guidelines.

8.4.6 For special survey of class notation, in addition to complying with above survey and test requirements, following survey need to be carried out:

(1) The surveyor needs to check maintenance and inspection record of ship condition monitoring and health assessment system within the period of special survey since last initial/special survey;

(2) Maintenance plan is to be updated based on system operation condition within the period of special survey and approved.

8.4.7 Ship condition monitoring and health assessment system is to be subject to maintenance, inspection and data collection at specified survey interval; diagnosis information based on condition monitoring will lead to update maintenance plan continuously; ship condition monitoring and health assessment system is capable of outputting system test information, condition monitoring and diagnosis information so as to receive inspection and survey results and output condition monitoring data.

8.5 Class notations

8.5.1 If upon request and subjected to plan approval, approval and survey by CCS it is confirmed that a ship complies with requirements for intelligent machinery specified in CCS Rules for Intelligent Ships and relevant requirements of the Guidelines, it can be assigned with class notation mentioneds in Table 8.5.1.

8.5.2 For ships assigned with class notations M and Mx for intelligent machinery and class notation CBM(X) for ship equipment condition-based maintenance, machinery equipment survey items included in condition-based maintenance plan may substitute relevant PMS survey items. In addition, if deemed necessary, CCS reserves the right to test monitoring equipment and carry out survey.

8.5.3 If machinery equipment included in condition-based maintenance plan cannot get satisfactory maintenance, CCS is to cancel survey arrangement for machinery equipment in condition-based maintenance plan. Moreover, the ship owner may also notify CCS in written form to cancel survey arrangement for machinery equipment in condition-based maintenance plan.

Explanations of class notations **Table 8.5.1**

Class notation	Explanation	Technical requirements to be satisfied
M	See CCS Rules for Intelligent Ships	(1) Monitored machinery (including monitoring parameters) includes relevant system/equipment in Appendix 1; (2) The ship has computer DSS, and if condition is limited, manual analysis may be adopted to assist the computer to complete decision support analysis.
Mx	See CCS Rules for Intelligent Ships	(1) Monitored machinery (including information such as monitoring parameter and typical failure) includes relevant system/equipment in Appendix 1; (2) The ship has CBM system.
CBM(X)	To prepare ship machinery equipment or system condition-based maintenance plan according to certain ship machinery equipment or system operation status and health condition analysis and evaluation result	(1) The ship has CBM system.

Chapter 9 Approval Requirements for Service Supplier Providing Ship Condition Monitoring and Health Assessmewnt

9.1 General requirements

9.1.1 For the company providing services such as ship condition monitoring, health assessment, decision support, condition-based maintenance technology and technical consultation for intelligent machinery of intelligent ships, product service and measurement, test and system maintenance involving above service, CCS is to carry out approval according to the requirements of this Chapter and procedures mentioned below.

9.2 Purpose

9.2.1 The purpose of this Chapter is to set minimum requirements for approval and certification of service supplier which are applicable to initial audit, renewal audit and additional audit.

9.3 Definitions

9.3.1 Manufacturer means a company providing intelligent system equipment, periodical service and/or maintenance for intelligent machinery.

9.3.2 Service supplier (service supplier or service supplier of different type can be referred to as "supplier") means a company which is required by equipment manufacturer, shipyard, ship owner or other clients relating to inspection work and provides services such as ship condition monitoring, health assessment, decision support, condition-based maintenance technology and technical consultation for intelligent machinery of intelligent ship, product service and measurement, test and system maintenance involving above service, the result of which will affect surveyors' survey certification of class notations of intelligent ship and decisions made on service.

9.3.3 Branch means a company partly or fully owned by the manufacturer or an approved service supplier.

9.4 Application

9.4.1 This Chapter is applicable to approval of service suppliers (hereinafter referred to as "suppliers") providing ship condition monitoring and health assessment, and/or decision support, and/or condition-based maintenance technology consultation and product service.

9.5 Approval and certification procedure

9.5.1 The following documents are to be submitted to CCS for review:

(1) Business license and brief introduction of company (including subsidiary company being approved/certified), including company organization, management diagram and responsibility, etc.;

(2) Requirements of quality system approval certificate, quality manual or regime for implementing effective quality control, documented procedures and quality management system;

(3) Ship condition monitoring and health assessment, decision support and condition-based maintenance plan and implementation procedure;

(4) Successful case of company in ship condition monitoring, health assessment, decision support and condition-based maintenance domain;

(5) Training procedure for operators and supervisors engaged in ship condition monitoring, health assessment, decision support and condition-based maintenance work, supervisors' namelist, training record and working experience, and compliance with relevant international, national or industry-recognized standards;

(6) List of main devices, equipment and standard instruments for measurement, including equipment name, type, technical indexes, manufacturer, verification period, verification condition and responsible person of testing and analysis instrument;

(7) Detailed description of strategy used for ship condition monitoring, health assessment, decision support and condition-based maintenance, including method, means and monitoring technology, etc.;

(8) Contents, form or template of report, record or other output result;

(9) Flow diagram of subcontractor (if any) and responsibility;

(10) Condition of other activities which may cause conflict of interests;

(11) Record of customer complaints and corrective measures required by the certification organization;

(12) The supplier needs to provide promise of confidentiality to technical service.

9.5.2 General requirements

(1) Approval scope: In addition to documents mentioned in 9.5.1, the supplier is to be able to prove its capability of implementing the service for which it is applying for approval as well as its capability of necessary control;

(2) Personnel training: The supplier is to be responsible for personnel qualification and training to comply with applicable and recognized international, national or industrial standards and CCS relevant requirements. Personnel are to have sufficient experience and be familiar with operation of necessary equipment. Operator/technician/inspector is to have at least one year on-post training. CCS accepts relevant qualifications obtained from external training;

(3) Supervision: The supplier is to supervise all service provided and set a post of supervisor. The supervisor in charge is to have work experience of at least one year operator/technician/inspector in approval supplier;

(4) Personnel record: The supplier is to keep record of operator/technician/inspector approved by CCS, including age, education background as well as training and experience related to approved service;

(5) Equipment and facilities: The supplier is to provide necessary equipment and facilities for service provided. The record of equipment used is to be maintained and available. The record is to include information relating to maintenance as well as calibration and verification results. When it is found that the equipment is not in compliance with relevant requirements for measurement equipment and sensor as specified by the Guidelines, CCS is to evaluate and record effectiveness of last measurement result. CCS is to take appropriate action on affected equipment, e.g. replacing equipment complying with requirements within specified time limit or suspending relevant class notation of intelligent ship;

(6) Data control: When computer is used to carry out data collection, processing, record, report, storage, measurement evaluation and monitoring, service supplier is to demonstrate capability of satisfying intended computer software①. It is to be confirmed that it is carried out prior to initial use and meets requirements of CCS updated Guidelines for Maritime Software Safety and Evaluation;

(7) Procedure: The supplier is to establish working procedure covering all service provided and form documents;

(8) Subcontractor: If part of the service provided is subcontracted, the supplier is to provide information on agreement and arrangement. The supplier is to pay attention to quality control during subcontracting;

(9) Verification: The supplier is to verify that the service provided complies with the provisions of approval procedure in the Guidelines;

(10) Report: The report is to be prepared in the format accepted by CCS, describing the result of inspection, measurement, test, maintenance and/or repair in detail.

9.5.3 Supplier audit: After satisfactory audit, the documents submitted are to be subject to supplier audit to confirm that its organization and management comply with the provisions in the documents and the supplier has capability of providing approval/certification service.

9.5.4 Certification depends on evidence of supplier's practical implemention of specific service and compliance with CCS relevant provisions. During renewal audit, evidence of implementing service is to be verified by CCS surveyor.

9.5.5 For audit of quality management system, the supplier is to have a documented system at least covering following elements:

(1) Code of conduct for relevant activity;

(2) Work preparation:

(3) Work procedure;

(4) Internal audit procedure;

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① Note: The existing commercial software which is widely and commonly used in the design application scope (e.g. word processing, database and statistical procedure) can be deemed as having been subject to sufficient verification and no any subsequent confirmation is required.

(5) Equipment maintenance and calibration;

(6) Training plan for operator/supervisor;

(7) Supervision and audit to ensure compliance with work procedure;

(8) Record and report information;

(9) Quality management of subsidiary company and subcontractor (if any);

(10) Workflow of periodic audit;

(11) Document issuance, maintenance and control procedure;

(12) Customer complaints and feedback, corrective and improvement measures.

9.5.6 A documented system complying with the updated current ISO9000 quality management system certification standard and including elements mentioned in 9.5.5 may be accepted.

9.5.7 If the equipment manufacturer (and/or service supplier) applies to CCS for approval covering designated agent and/or branch, quality management system is to be certified according to updated ISO9000 series standard. The quality management system must cover effective control of agent and/or branch of manufacturer (and/or service supplier), and the designated agent and/or branch also must have equivalent quality management system complying with updated ISO9000 series quality management system certification standard. Such approval is to be based on quality management system evaluation carried out by the parent company according to updated ISO9000 series quality management system certification standard, and CCS may require follow-up audit of agent and/or branch according to updated ISO9000 series quality management system certification standard to confirm compliance with quality management system.

9.6 Certification

9.6.1 On completion of audit of the supplier, CCS may issue approval certificate to demonstrate that supplier's service operation system is in a satisfactory condition, and the service result under the control of this system is acceptable, which can be used as basis for CCS surveyor to assign class notations for classed intelligent ships.

9.6.2 It is to be verified through audit that the approved conditions are maintained and interval of certificate renewal or issuance is not more than 5 years, and intermediate audit is to be carried out, or, if applicable, audit is to be carried out at the time of expiration of approval by equipment manufacturer, whichever is earlier, to verify maintenance of approval condition. For the latter case, service supplier is to notify CCS at proper time.

9.7 Information on alteration of approved service operation system

9.7.1 If there is alteration of approved supplier service operation system, CCS is to be notified immediately, and if necessary, reaudit is to be carried out.

9.8 Cancellation of approval

9.8.1 CCS reserves the right of cancelling approval.

9.8.2 Approval can be cancelled under following conditions:

(1) Service is not properly carried out or result report is inappropriate;

(2) The surveyor finds that there are defects in service operation system approved by the supplier, and no proper corrective measure is taken;

(3) CCS is not notified in writing of alteration of relevant service supplier certificate in company quality system;

(4) It is confirmed that there is deliberate conduct or misconduct destroying service quality;

(5) Any deliberate false statement of service supplier;

(6) Intermediate audit required in 9.6.2 is not carried out.

9.8.3 After approval is cancelled, if nonconformities leading to cancellation are corrected which can make CCS confirm that corrective measures have been effectively implemented, the supplier for which approval is cancelled can apply for reapproval.

9.8.4 After approval of parent company of supplier is expired or cancelled, approval of all agents and/or branches is deemed as invalid automatically.

Appendix 1 Checklist for Ship Machinery Condition Monitoring

No.	Equipment/ performance	Primary parameters for monitoring	Typical malfunction/failure
1	**Diesel engine for main propulsion**		
1.1	* Combustion performance	Single cylinder dynamic pressure, single cylinder exhaust gas temperature; single cylinder cooling water outlet temperature	(1) Abnormal exhaust temperature; (2 Insufficient output power
1.2	* Cylinder cover	Cooling water temperature, cooling water pressure	(1) Defects, e.g. crack, ablation, of each connected flange around cylinder cover and valve hole; (2) Scale and corrosion of cooling water jacket space
1.3	*Piston	Temperature of cooling liquid	Trunk piston: (1) Crack and ablation of piston head, piston ring groove, piston pin hole, piston skirt, etc. ; Crosshead type engine piston (2) Crack, ablation, excessive wear, loosening of piston head, suspension lug, piston ring groove and wear ring; (3) Scale of water jacket space
1.4	*Piston ring	Vibration, temperature	(1) Wear, blow-by, deformation, bruise, breaking, seizure, oil expelling, etc.
1.5	Connecting rod	Vibration , stress (if applicable)	(1) Crack of connecting rod; (2) Crack, deformation, looseness, thread damage of bolt
1.6	Piton rod Stuffing box	Vibration, temperature	(1) Eccentric; (2) Wear and blow-by of oil scraping ring, sealing ring, etc.
1.7	* Cylinder liner	Temperature, cooling water pressure	(1) Crack, scotch and excessive wear, etc.
1.8	Intake valve *Exhaust valve Safety valve Indicator valve Starting valve	Vibration, temperature, pressure	(1) Crack of casing, core and spring; the working face between valve and valve seat not in normal order
1.9	* Fuel nozzle/valve	Exhaust temperature, vibration	(1) Filth blockage, wear, leakage, poor atomization
1.10	*Crosshead bearing (if applicable)	Lubricating oil temperature	(1) Crack and scotch of crosshead pin, etc.; (2) Crosshead pin, bearing and white metal of guide plate have crack, overheat, scotch, breakaway. The connection is not in order;
1.11	Bearing of connecting rod	Vibration , temperature	(1) Crack, breakaway, overheat, scotch, shed, wear, etc. ; (2) Abnormal clearance of bearing
1.12	Transmission mechanism of intake valve Transmission mechanism of exhaust valve	Vibration	(1) Abnormal clearance of roller.

No.	Equipment/ performance	Primary parameters for monitoring	Typical malfunction/failure
1.13	Engine bracket & engine foundation	Vibration	(1) Crack, deformation, damage, corrosion, etc; (2) Fracture, loosening of connecting bolt
1.14	* Crankcase& safety device (if applicable)	Vibration	(1) Fracture of spring of explosion-proof door; loosening of valve;
1.15	* Bearing of crank pin(if applicable)	Lubricating oil temperature	(1) Crack, breakaway, overheat, scotch, shed, wear, etc. ; (2) Abnormal clearance of bearing
1.16	Holding –down bolt & packing block	Vibration	(1) Holding –down bolt is loose or fractured, etc; (2) Loosening of packing block
1.17	*Main bearing & shaft journal	Vibration, lubricating oil temperature, bearing clearance	(1) The bearing has crack, breakaway ,overheat, scotch, wear; (2) Shaft journal has scotch and corrosive hole (3)Ablation, wear down of bearing and bearing bush
1.18	Transmission mechanism of crankshaft	Vibration	(1) Tooth gear: the gear has crack, erosion, collapse, excessive wear , improper gear engagement; (2) Chain gear: the link and roller have crack. erosion, wear and tear
1.19	Camshaft (if applicable), *camshaft bearing (if applicable)	Vibration, temperature	(1) Loosening of cam; (2) Surface of cam shaft has crack, corrosion hole, scotch and excessive wear
1.20	Scavenging fan, emergency air blower	Vibration, temperature, flow, pressure	(1) Abnormal vibration; (2) Bearing temperature is too high; (3) Current of the motor is too high, temperature rise too high; (4) Moving and slip of belt
1.21	Scavenging pump	Vibration, temperature, pressure, flow	(1) Piston –type scavenging pump: piston, piston rod, cylinder, intake valve, exhaust valve have crack, scotch and excessive wear. (2) Revolving scavenging pump: pump shell, impeller or gear, shaft, bearing and components of transmission gear have crack, deformation, excessive wear, etc.
1.22	High- pressure oil pump	Vibration, temperature, pressure, flow	(1) Pump spring have defects such as crack, deformation, etc.; (2) Precise couplings such as plunger/sleeve have too big clearance or are jammed
1.23	* Exhaust-gas turbocharger (if applicable)	Revolving speed, pressure, vibration, temperature, inlet and outlet pressure difference	(1) Crack of casing, scale and the corrosion of the cooling water jacket space; (2) Defects such as crack, bending, deformation, collapse, corrosion of rotor, blades, guide blade and diffuser; (3) Defects of bearing
1.24	Air cooler	Temperature, pressure, pressure difference	(1) The pipe and tube plate have deformation, damage, scale, corrosion, poor sealing, etc.; (2) Deficiency of corrosion-proof zinc
1.25	Through bolt	Vibration	(1) Loose, breaking

No.	Equipment/ performance	Primary parameters for monitoring	Typical malfunction/failure
1.26	Vibration damper or antivibrator	Vibration	(1) Flexible base: damage of vibration isolating rubber and spring (2) Back balance antivibrator: loosening of back balance and bolt (3) Hydraulic spring-type antivibrator: failure of the spring unit, loosening of locating pin and blockage of oil hole
1.27	Scavenging air receiver & safety device	Temperature, pressure	(1) Blockage of the internal of scavenging receiver and manifold; (2) Blockage of nozzles of emergency fire-extinguishing appliances; (3) Failure of explosion-proof door of scavenging receiver and valves
1.28	Reversing arrangement	Vibration	(1) Failure of reversing cam, reversing valve, reversing servo mechanism, etc.
1.29	Carriage turning gear (jacking engine)	Vibration	(1) Wear of worm wheel and worm; (2) Failure of carriage turning gear and interlocked valve; (3) Failure of the coupling of motor and carriage turning gear
1.30	Engine-driven air compressor	Vibration, pressure, temperature	Engine-driven air compressor: (1) Filth blockage of valve hole and water hole; (2) Scale and corrosion of Cooling water jacket; (3) Excessive wear of crank journal and bearing; (4) Poor lubricating; (5) Filth blockage and poor sealing of piping Where engine-driven pump is a reciprocating pump: (1) Failure of engine-driven transmission mechanism; (2) Crack, scotch and excessive wear of piston, piston rod, cylinder liner, air inlet valve, exhaust air (water, oil) valve and spring
1.31	Engine-driven bilge pump	Vibration, temperature, pressure, flow	
1.32	Engine-driven diesel oil booster pump	Vibration, temperature, pressure, flow	
1.33	Engine-driven fuel oil booster pump	Vibration, temperature, pressure, flow	
1.34	Engine-driven diesel oil delivery pump	Vibration, temperature, pressure, flow	
1.35	Engine-driven fuel oil delivery pump	Vibration, temperature, pressure, flow	
1.36	Engine-driven freshwater pump	Vibration, temperature, pressure, flow	
1.37	Engine-driven cooling freshwater pump	Vibration, temperature, pressure, flow	
1.38	Engine-driven cooling pump of fuel injector	Vibration, temperature, pressure, flow	

No.	Equipment/ performance	Primary parameters for monitoring	Typical malfunction/failure
1.39	Engine-driven lub. oil pump	Vibration, temperature, pressure, flow	Where engine-driven pump is a rotating-type pump: (1) Failure of engine-driven transmission mechanism; (2) Crack, deformation, excessive wear of casing, impeller or gear or worm, bearing, shaft, shaft gland and components
1.40	Engine-driven reduction gear lub. oil pump	Vibration, temperature, pressure, flow	
1.41	Engine-driven seawater circulating pump	Vibration, temperature, pressure, flow	
1.42	Engine-driven seawater cooling pump	Vibration, temperature, pressure, flow	Where engine-driven pump is a rotating-type pump: (1) Failure of engine-driven transmission mechanism; Crack, deformation, excessive wear of casing, impeller or gear or worm, bearing, shaft, shaft gland and components
1.43	Engine-driven freshwater cooler	Temperature, pressure,	(1) Filth blockage of seawater jacket space, fresh water jacket space; (2) Leakage
1.44	Engine-driven lub. oil cooler	Temperature, pressure,	(1) Filth blockage of seawater jacket space; (2) Leakage
1.45	Partial pipeline of starting air system	Pressure	(1) Corrosion, damage, leakage; (2) Poor sealing
1.46	Crankshaft	Vibration, temperature, pressure	(1) Scotch, pitting corrosion, mechanical damage and wear of shaft journal; (2) Loosening or offset of cylinder liner or press fit; (3) Crack of rounded angle and oil hole
2	**Diesel engine for electric power generation**		
2.1	* Supercharger	Revolving speed, inlet exhaust temperature, outlet exhaust temperature, lub. oil inlet pressure, lub. oil outlet temperature, inlet air temperature, inlet air strainer pressure difference	(1) Crack of casing, scale and the corrosion of the cooling water jacket space; (2) Defects such as crack, bending, deformation, collapse, corrosion of rotor, blades, guide blade and diffuser; (3) Defects of bearing
2.2	* Fuel nozzle/valve	Exhaust temperature, vibration	(1) Filth blockage, wear, leakage, poor atomization
2.3	*Cylinder liner	Temperature, cooling water pressure	(1) Crack, scotch and excessive wear, etc.
2.4	* Cylinder cover	Cooling water temperature, cooling water pressure	(1) Defects, e.g. crack, ablation, of each connected flange around cylinder cover and valve hole; (2) Scale and corrosion of cooling water jacket space
2.5	* Intake valve, * exhaust valve	Vibration , temperature, pressure	(1) Crack of casing, core and spring; the working face between valve and valve seat not in normal order
2.6	*Main bearing	Temperature, lub. oil outlet temperature, bearing wear sensor (capable of obtaining bearing wear loss)	(1) The bearing has crack, breakaway ,overheat, scotch, wear; (2) Shaft journal has scotch and corrosive hole; (3)Ablation, wear down of bearing and bearing bush

No.	Equipment/ performance	Primary parameters for monitoring	Typical malfunction/failure
2.7	* Bearing of crank pin	Lub. Oil temperature	(1) Crack, breakaway, overheat, scotch, shed, wear, etc. ; (2) Abnormal clearance of bearing
2.8	* Camshaft bearing (if applicable)	Lub. oil into camshaft pressure, lub. oil into camshaft temperature,	(1) Loosening of cam; (2) Crack, pitting corrosion, scotch, excessive wear
2.9	Air cooler	Air inlet temperature, air outlet temperature, air inlet/outlet pressure difference, cooling water inlet temperature, cooling water outlet temperature, cooling water inlet pressure, cooling water in let/outlet pressure difference(or outlet pressure)	(1) The pipe and tube plate have deformation, damage, scale, corrosion, leakage, etc.; (2) Deficiency of corrosion-proof zinc
2.10	Combustion chamber	Single cylinder dynamic pressure, single cylinder exhaust gas temperature; single cylinder cooling water outlet temperature	(1) Sooting; (2) Low temperature corrosion, high temperature corrosion
2.11	Fuel oil	Inlet pressure, inlet temperature/viscosity (before oil injection pump), common rail fuel oil pressure (if applicable), common rail servo oil pressure (if applicable)	(1) Abnormal pressure; (2) Abnormal temperature; (3) Abnormal viscosity
2.12	Lubricating oil	Inlet pressure, inlet pressure	(1) Abnormal pressure; (2) Abnormal temperature
2.13	Cooling water	Inlet pressure or flow, inlet temperature	(1) Abnormal pressure; (2) Abnormal temperature; (3) Abnormal flow
2.14	Air	Starting air pressure, control air pressure	(1) Abnormal pressure
2.15	Lubricating oil cooler	Temperature, pressure difference, pressure	(1) The pipe and tube plate have deformation, damage, scale, corrosion, leakage, etc.;
3	**Shafting**		
3.1	* Intermediate shaft and bearing (if applicable)	Vibration, temperature	(1) Wear, crack, high temperature and poor alignment of shaft; (2) High temperature and crack of bearing; (3) Ablation and wear of bearing bush; (4) Poor lubricating; (5) Loosening of bearing seat
3.2	Thrust shaft and bearing	Vibration, temperature	(1) Wear, crack, high temperature and poor alignment of shaft; (2) High temperature and crack of bearing; (3) Ablation and wear of bearing bush; (4) Poor lubricating; (5) Wear and loosening of thrust pad alloy; (6) Poor sealing of bearing casing

No.	Equipment/ performance	Primary parameters for monitoring	Typical malfunction/failure
3.3	* Stern tube and bearing (if applicable)	Vibration, temperature	(1) Wear, crack, high temperature and poor alignment of shaft; (2) High temperature, ablation, wear and crack of bearing ; (3) Poor lubricating; (4) Loosening of bearing seat; (5) Bearing clearance is too big
4	**Propelling system**		
4.1	*Reduction/ increasing Gear (if applicable)	Vibration, temperature, pressure	(1) Wear of gear shafting and scotch of shaft journal; (2) Poor engagement of gear and pinion, crack of root; (3) Wear of tooth face; (4) Poor lubricating; (5) Leakage and crack of gear box
4.2	Clutch	Vibration, temperature, pressure	(1) Poor connection and slip; (2) Leakage of box; (3) Loosening of hold-down bolts
5	Essential auxiliary machinery		
5.1	Main air compressor Auxiliary air compressor Accessory safety device	Vibration, noise, temperature, pressure, flow	(1) Filth blockage of valve hole and water hole; (2) Scale and corrosion of cooling water jacket; (3) Excessive wear of crank journal and bearing; (4) Poor lubricating; (5) Filth blockage and poor sealing of piping
5.2	Emergency air compressor and air bottle	Vibration, noise, temperature, pressure, flow	(1) Filth blockage of valve hole and water hole; (2) Scale and corrosion of cooling water jacket; (3) Excessive wear of crank journal and bearing; (4) Poor lubricating; (5) Filth blockage and poor sealing of piping
5.3	Ventilator set, ventilator in cargo hold, ventilator in engine room (including ventilators for auxiliary engine room and oil separator room), forced ventilation for boiler, ventilator in pump room, ventilator in CO_2 room	Vibration, noise, flow, temperature	(1) Abnormal noise; (2) Surge, abnormal vibration; (3) Local damage of rotor; (4) Too big current or too high temperature rise; (5) Bearing wear or abnormal temperature
5.4	Essential pumps and motors		

No.	Equipment/ performance	Primary parameters for monitoring	Typical malfunction/failure
5.4.1	Seawater pump & motor for main engine	Vibration, noise, temperature, pressure, flow	(1) Wear and leakage of pump shaft gland; (2) Corrosion and imbalance of impeller; (3) Abnormal clearance between impeller and pump case; (4) Wear of blade and tooth face; (5) Wear of shaft gland; (6) Wear of bearing
5.4.2	Seawater pump and motor for berthing	Vibration, noise, temperature, pressure, flow	
5.4.3	Fresh water pump & motor for main engine	Vibration, noise, temperature, pressure, flow	
5.4.4	Fresh water pump & motor for berthing	Vibration, noise, temperature, pressure, flow	
5.4.5	Feed pump & motor for boiler	Vibration, noise, temperature, pressure, flow	
5.4.6	Circulating water pump & motor for boiler	Vibration, noise, temperature, pressure, flow	Centrifugal pump: (1) Corrosion and failure of self-priming of suction pipeline; (2) Cavity corrosion of impeller and blades; Gear pump: (1) Wear and pocked oil of gear; (2) Leakage, abnormal flow Reciprocating pump: (1) Wear of piston ring; (2) Abnormal sound and flow, etc. Screw pump: (1) Abnormal noise, imbalance; (2) Abnormal flow Sled (vane) pump: (1) Jam of vane in chute; (2) Abnormal sound and flow Driving motors of various pumps: (1) Abnormal insulance; (2) Wear of ball bearing or roller bearing
5.4.7	Circulating water pump & motor for exhaust boiler	Vibration, noise, temperature, pressure, flow	
5.4.8	Fuel pump & motor for boiler	Vibration, noise, temperature, pressure, flow	
5.4.9	Fuel pump & motor for main engine	Vibration, noise, temperature, pressure, flow	
5.4.10	Fuel pressure pump & motor for main engine	Vibration, noise, temperature, pressure, flow	
5.4.11	Lub. oil pump & motor for main engine	Vibration, noise, temperature, pressure, flow	
5.4.12	Oil pump & motor for main engine camshaft	Vibration, noise, temperature, pressure, flow	
5.4.13	Fire pump & motor	Vibration, noise, temperature, pressure, flow	
5.4.14	Emergency fire pump & driving device	Vibration, noise, temperature, pressure, flow	
5.4.15	Ballast pump & motor	Vibration, noise, temperature, pressure, flow	
5.4.16	Bilge pump & motor	Vibration, noise, temperature, pressure, flow	

No.	Equipment/ performance	Primary parameters for monitoring	Typical malfunction/failure
5.4.17	Equalizing pump & motor	Vibration, noise, temperature, pressure, flow	Centrifugal pump: (1) Corrosion and failure of self-priming of suction pipeline; (2) Cavity corrosion of impeller and blades; Gear pump: (1) Wear and pocked oil of gear; (2) Leakage, abnormal flow Reciprocating pump: (1) Wear of piston ring; (2) Abnormal sound and flow, etc. Screw pump: (1) Abnormal noise, imbalance; (2) Abnormal flow Sled (vane) pump: (1) Jam of vane in chute; (2) Abnormal sound and flow Driving motors of various pumps: (1) Abnormal insulance; (2) Wear of ball bearing or roller bearing
5.4.18	General service pump & motor	Vibration, noise, temperature, pressure, flow	
5.4.19	Seawater pump and motor for fresh water generator	Vibration, noise, temperature, pressure, flow	
5.4.20	Condensate pump and motor for fresh water generator	Vibration, noise, temperature, pressure, flow	
5.4.21	Fuel transfer pump and motor	Vibration, noise, temperature, pressure, flow	
5.4.22	Diesel oil transfer pump and motor	Vibration, noise, temperature, pressure, flow	
5.4.23	Residual fuel pump & motor	Vibration, noise, temperature, pressure, flow	
5.4.24	Daily service fresh water pump & motor	Vibration, noise, temperature, pressure, flow	
5.4.25	Heat water circulating pump & motor	Vibration, noise, temperature, pressure, flow	Ejector pumps: (1) Wear of nozzle holes for wear; (2) Corrosion of diffuser cone
5.4.26	Sanitary pump & motor	Vibration, noise, temperature, pressure, flow	
5.4.27	Drinking water pump & motor	Vibration, noise, temperature, pressure, flow	
5.4.28	Cooling pump & motor of fuel injector for main engine	Vibration, noise, temperature, pressure, flow	
5.4.29	Cooling pump & motor of piston for main engine	Vibration, noise, temperature, pressure, flow	
5.4.30	Fresh water transfer pump and motor	Vibration, noise, temperature, pressure, flow	
5.4.31	Vacuum pump set of fresh water generator	Vibration, noise, temperature, pressure, flow	
5.4.32	Salt water pump & motor for fresh water generator	Vibration, noise, temperature, pressure, flow	
5.4.33	Vacuum air pump	Vibration, noise, temperature, pressure, flow	

No.	Equipment/ performance	Primary parameters for monitoring	Typical malfunction/failure
5.4.34	Feed water jet pump	Vibration, noise, temperature, pressure, flow	Ejector pumps: (1) Wear of nozzle holes for wear; (2) Corrosion of diffuser cone
5.4.35	Bilge water jet pump	Vibration, noise, temperature, pressure, flow	
5.4.36	All other engine-driven pumps	Vibration, noise, temperature, pressure, flow	
5.4.37	Fuel oil separator & motor	Vibration, temperature, pressure, flow, insulance	(1) Bending and wear of vertical spindle; (2) Wear of bearing; (3) Poor engagement of worm wheel and worm, wear of teeth; (4) Abnormal insulance of motor; (5) Wear of ball bearing or roller bearing, abnormal temperature
5.4.38	Diesel oil separator & motor	Vibration, temperature, pressure, flow, insulance	
5.4.39	Lub. oil separator & motor	Vibration, temperature, pressure, flow, insulance	
6	Air bottles and various pressure vessels and accessories		
6.1	Main & auxiliary air bottle, working air bottles and accessories such as safety valves	Pressure	(1) poor airtightness of valves; (2) Failure of safety valves
6.2	Fresh water pressure tank, sanitary tank (seawater pressure tank) and potable fresh water tank	Pressure	(1) Leakage
7	Main & auxiliary steering gear and accessory equipment and control system	Vibration, noise, temperature, insulance	(1) Abnormal noise, vibration; (2) Abnormal temperature of pump and motor; (3) Bypassing or severe leakage of main oil system; (4) Blockage of main oil system or obstruction of steering; (5) Steering time cannot meet the requirements; (6) Lagged steering, oversteering and deviated steering; (7) Severe error of rudder indicator; (8) Abnormal insulance of motor; (9) Wear of bearing, abnormal temperature
8	**Windlass**		
8.1	Prime motor, driving and control units, operating and braking devices of windlass	Vibration, temperature, insulance	(1) Failure of gear, chain sprocket, brake ribbon (shoe); (2) Failure of hydraulic cylinder, rotor, blade, bearing, sealing device; (3) Loosening of windlass base; (4) Abnormal insulance of motor; (5) Wear of bearing, abnormal temperature
9	Bilge pipe, strainer, bilge well suction, sludge pipe	Pressure	(1) Filth blockage of suction screen and mud box; (2) Failure of emergency bilge suction in engine room
10	Ballast pipe, valve and ballast operating system	Pressure	(1) Failure of remote control valve

No.	Equipment/ performance	Primary parameters for monitoring	Typical malfunction/failure
11	Pressure strainers, heaters, coolers and various strainers of fuel oil, lub. oil, cooling water, boiler water	Pressure	(1) Filth blockage of screen, piping; (2) Tubular heater or cooler: filth blockage, poor watertight riveting of tube plate; (3) Plate-type heater or cooler: corrosion of plate, poor sealing
12	**Additional requirements for oil tankers**		
12.1	Cargo oil pump, bilge pump, stripping pump, segregated ballast pump in pump room	Vibration, noise, insulance	(1) Loosening of bedplate, locating pins or binding bolts; (2) Abnormal noise and vibration; (3) Abnormal insulance of motor; (4) Wear of bearing, abnormal temperature
12.1.1	Cargo oil pump	Vibration, pressure, temperature, insulance	(1) Corrosion, deformation, wear of components; (2) Leakage of shaft gland; (3) Poor shafting alignment; (4) Failure of remote shutdown; (5) Abnormal insulance of motor; (6) Wear of bearing, abnormal temperature
12.1.2	Stripping pump	Vibration, pressure, temperature, insulance	(1) Corrosion, deformation, wear of components; (2) Leakage of shaft gland; (3) Poor shafting alignment; (4) Failure of remote shutdown; (5) Wear of bearing, abnormal temperature
12.1.3	Segregated ballast pump	Vibration, pressure, temperature, insulance	(1) Leakage of shaft gland; (2) Abnormal insulance of motor; (3) Wear of bearing, abnormal temperature
12.1.4	Bilge pump	Vibration, pressure, temperature, insulance	(1) Leakage of shaft gland; (2) Failure of remote shutdown; (3) Abnormal insulance of motor; (4) Wear of bearing, abnormal temperature
12.1.5	Sealing device for pump drive assembly	Temperature	(1) Damage of sealing device, jam of pump shaft
12.1.6	Piping and fittings	Pressure	(1) Leakage
12.2	Venting system of cargo oil tank	Pressure	(1) Filth blockage of venting system (including breathing valve) in cargo oil tank and slop tank; (2) Filth blockage of breathing valve in cargo oil tank; (3) Filth blockage of quick venting valve in cargo oil tank fitted with IGS
12.3	Crude oil washing machine Washing heater		
12.3.1	Crude oil washing machine	Temperature, pressure, insulance	Washing pump: (1) Abnormal temperature; (2) Abnormal flow and pressure; (3) Abnormal insulance of motor; (4) Wear of bearing, abnormal temperature

No.	Equipment/ performance	Primary parameters for monitoring	Typical malfunction/failure
12.3.2	Washing heater	Pressure, temperature	(1) Leakage of heating pipe; (2) Abnormal temperature; (3) Corrosion of tube plate; (4) Failure of safety valve; (5) Failure of the valve or other mechanisms separating the heater from crude oil washing piping
12.4	Cargo oil heating system	Pressure, temperature	(1) Failure of safety valve, reducing valve, automatic pressure regulator valve, regulator, etc. of pipeline; (2) Corrosion and leakage of heating pipe; (3) Loosening of heating pipe
12.5	Ventilation system of cargo oil pump tank	Vibration, noise, temperature	Ventilator: (1) Abnormal noise; (2) Surge, abnormal vibration; (3) Local damage of rotor; (4) Too big current or too high temperature rise; (5) Wear of bearing or abnormal temperature; (6) Poor sealing of shaft drive assembly for ventilator in cargo oil pump tank that penetrates bulkhead; (7) Failure of emergency shutdown of ventilator, filth blockage of emergency vent; (8) Failure of the interlock of ventilator and illumination of pump room
12.6	Relevant instruments of cargo oil & ballast control stations	Pressure, level, gas concentration	(1) Failure of relevant instruments: steam inlet pressure gauge of steam turbine, tachometer of cargo oil pump, cargo outlet pressure gauge, cargo outlet thermometer, seawater outlet thermometer of washing heater, outlet pressure gauge of ballast pump, hydro-oil outlet pressure gauge of hydraulic pump station, and voltmeter, ammeter and control air pressure gauge of control station; (2) Failure of the remote control valve and valve position indicator of cargo oil system for hydro-oil leakage and correct indication; (3) High level of pump room bilge; (4) Combustible gas concentration is above standard
12.7	Inert gas system		
12.7.1	Inert gas system	Pressure, other concentration	(1) Serious corrosion, water and oil leakage of pipeline and components; (2) Oxygen concentration is above standard
12.7.1.1	Monitoring device of inert gas system	Pressure, temperature, gas concentration	(1) Excessive oxygen content in IGS manifold; (2) Excessively low gas pressure in IGS manifold; (3) Excessively low feed pressure of deck water seal; (4) Excessively high gas temperature in IGS manifold; (5) Excessively low feed pressure of scrubber; (6) Failure of interlocking with outlet pressure parameters of cargo oil pump

No.	Equipment/ performance	Primary parameters for monitoring	Typical malfunction/failure
12.7.1.2	Inert gas generator, scrubber, fan, deck water seal	Pressure, vibration, noise	(1) Filth blockage of nozzle and screen in scrubber; (2) Abnormal noise and vibration, surge of fan, wear of bearing or abnormal temperature; (3) Severe corrosion of the internal of pressure vacuum breaker
12.7.1.3	Cooling pump	Pressure, vibration	(1) Wear and leakage of pump shaft gland; (2) Corrosion and imbalance of impeller; (3) Abnormal clearance between impeller and pump case (4)Wear of blade, tooth; (5) Wear of shaft gland; (6) Wear of bearing;
13	**Liquid cargo system (ships carrying liquefied gases in bulk)**		
13.1	Liquid cargo pump	Vibration, noise, flow, pressure	(1) Abnormal vibration, noise, temperature; (2) Leakage; (3) Abnormal flow, pressure
13.2	Prime mover	Insulance, temperature, current	(1) Abnormal insulance; (2) Excessive current, too high temperature rise
13.3	pump room shaft gastight device	Pressure	(1) Poor sealing
13.4	Compressor room shaft gastight device	Pressure	(1) Poor sealing
13.5	Liquid cargo piping	Pressure	(1) Filth blockage, corrosion
13.6	Valve	Vibration, noise, pressure	(1) Leakage, corrosion, erosion; (2) Abnormal vibration, noise
14	**Liquid cargo system (ships carrying dangerous chemicals in bulk)**		
14.1	Liquid cargo pump	Vibration, noise, pressure, flow	(1) Abnormal vibration, noise, temperature; (2) Leakage; (3) Abnormal flow, pressure
14.2	Liquid cargo piping	Pressure	(1) Filth blockage, corrosion
14.3	Valve	Pressure, vibration, noise	(1) Leakage, corrosion, erosion; (2) Abnormal vibration, noise
14.4	Tank	Liquid level	(1) Abnormal liquid level

Note: 1. For a ship applying for the class notation M or Mx, its machinery subject to monitoring is at least to include the items marked with *.

2. The primary monitoring parameters may be one or more parameters listed above. Operational status of equipment may be obtained through online monitoring or offline testing or indirect means.