GUIDANCE NOTES
GD010-2026

INTERNATIONAL SHIP CLASSIFICATION

GUIDELINES FOR SURVEYS OF INTELLIGENT MACHINERY OF SHIPS

2026

Effective from 1 June 2026

Foreword

With the development of equipment manufacturing technology and the progress of science and technology, the structure of modern equipment is becoming more and more complex, the degree of automation is becoming higher and higher, the daily maintenance and trouble shooting of equipment is becoming more and more difficult, and the cost of equipment maintenance is becoming higher and higher. The implementation of condition monitoring of machinery installations and systems can diagnose various abnormal states or fault states timely and accurately, prevent or eliminate faults, provide necessary decision-making support for equipment and system operation and management, improve the reliability, safety and effectiveness of equipment operation.

International Ship Classification released the first Rules for Intelligent Ships in 2015, proposing the intelligent ship architecture of "one platform + N applications", among which the health management of machinery installations and systems is an important direction in the application of ship intelligent technology. It is intended to comprehensively utilize various information and data obtained by condition monitoring to analyze and evaluate the operating status and health status of machinery installations and systems, and provide support for decision-making in the use, operation and control, maintenance and management of equipment and systems. The Rules also specify basic functions and additional functions that intelligent machinery is to have.

In order to ensure the effective implementation and application of the rules requirements for intelligent machinery, International Ship Classification developed the Guidelines for Surveys of Intelligent Machinery of Ships in combination with the experience of the research and development of intelligent systems in the industry, on-board applications, drawing and document approval, survey etc. The Guidelines are an integral part of the ISC Rules for Intelligent Ships, covering the following additional contents: technical requirements for intelligent machinery systems, drawing and document approval, product approval and inspection, survey of intelligent machinery class notation.

The Guidelines are developed and updated by ISC and published on the web page http://www.isclass.com. The user may comment on the Guidelines by feedback to enquiry@isclass.com.

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Chapter 1 General

1.1 Purpose

1.1.1 The Guidelines supplement the technical requirements, approval and inspection requirements for condition monitoring and health assessment system, decision support system, condition-based maintenance system of ship machinery equipment and system (hereinafter referred to as “equipment and system”), which can be used as guidance documents for ISC surveyors, manufacturers, service suppliers and ship management companies.

1.2 Application

1.2.1 The Guidelines are applicable to ships for which the functional notation M(xi) for ISC 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 the intelligent system with functions of condition monitoring, health assessment and decision support.

1.3 Class notations

1.3.1 The functional notation M(xi) for intelligent machinery is given in 4.2 of Chapter 4 of ISC Rules for Intelligent Ships.

1.3.2 The class notation for condition-based maintenance of ship equipment CBM (X) may be assigned to a ship if condition monitoring and health assessment is implemented for one or more equipment and systems and a condition based maintenance plan of ship’s machinery equipment and system is developed in accordance with the assessment result upon voluntary application, where X is used to identify the equipment for which the condition based maintenance is implemented, e.g. CBM (Cargo Pumps) means that the condition based maintenance has been implemented on ship's cargo pumps.

Note: Equipment and system not covered by Chapter 4 of ISC Rules for Intelligent Ships may apply for the class notation CBM (X).

1.4 Definitions and abbreviations

1.4.1 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 equipment. 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 equipment or system). Failure is an event as distinguished from fault;

(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.

1.4.2 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.

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 ISC 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.

2.1.2 Appendices of the Guidelines show the main equipment and systems on board, typical malfunction/failure modes, and condition monitoring techniques which can be used as well as information on monitoring parameter for reference of users, detailed as follows:

(1) Appendix 1 Checklist for Equipment and System Condition Monitoring;

(2) Appendix 2 Checklist for Dredger Dredging Equipment and System Condition Monitoring;

(3) Appendix 3 Checklist for Tug Towing Equipment and System Condition Monitoring;

(4) Appendix 4 Checklist for Battery System and Equipment Condition Monitoring;

(5) Appendix 6 Checklist for Condition Monitoring of Geotextiles Laying Equipment and Systems of Geotextiles Layers;

(6) Appendix 7 Checklist for Condition Monitoring of Boilers and Systems.

2.1.3 For inland waterway ships applying for the function notation for intelligent machinery, the monitoring items and monitoring parameters/condition are to generally comply with the provisions of Appendix 5 of ISC Guidelines for Survey of Intelligent Machinery of Ships.

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 At present, the condition monitoring techniques used for ship power machinery mainly include vibration monitoring, oil analysis, non-destructive testing, mechanical structure parameter monitoring, performance parameter monitoring and instantaneous speed monitoring. The intelligent machinery is to use suitable 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 equipment and system 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

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

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.

2.2.7 Structure parameter monitoring: different equipment has different structure parameters, and the main parameters that can be monitored are stiffness and damping.

2.2.8 Performance parameter monitoring: the function of equipment and system 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 can reflect the operating state of equipment, 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 equipment and system 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 equipment.

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 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 portable 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 equipment 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 equipment 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 equipment as closely as possible, to ensure consistency and valid comparability of the data. When this is not possible, the characteristics of the equipment 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 equipment 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 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. For oil sampling and analysis, relevant requirements in Appendix 14 - Guidelines for Screwshaft condition Monitoring System and Appendix 15- Guidelines for Lubricating Oil Condition Monitoring System of Diesel Engines of Chapter 5 of PART ONE of ISC Rules for Classification of Sea-going Steel Ships may be referred to.

(3) The sampling time interval is mainly determined according to the characteristics of the monitored equipment, 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 requirements in 4.4.4, Chapter 4 of ISC 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 operation of equipment and system 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 equipment and system is to be accurately defined;

(4) The reliability of the measurement results 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 ISC 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.

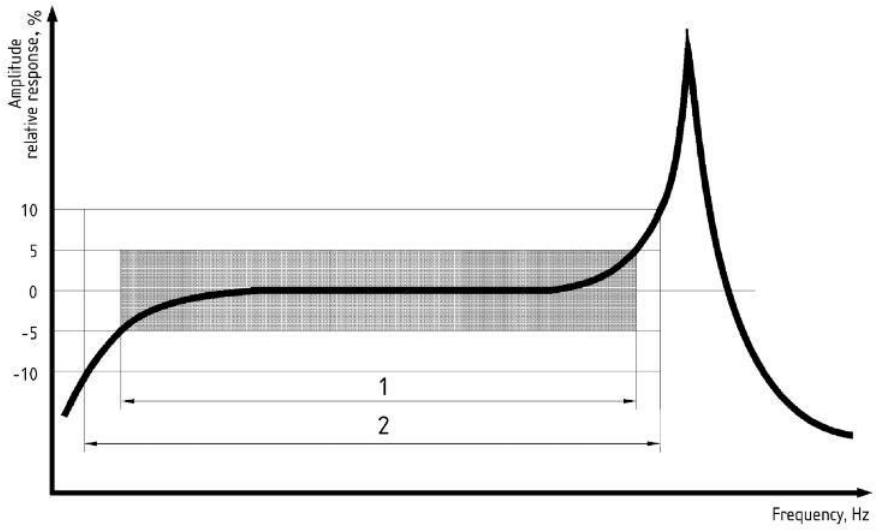
2.4.8 Technical requirements for vibration measuring equipment:

(1) The location of the vibration sensor depends on the specific equipment 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 ISC 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

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.

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 Relevant operators on board are to be familiar with and qualified for the operation and maintenance of intelligent systems.

2.5.2 If the supplier provides the condition monitoring and health assessment service of equipment and system, the training and qualification of the relevant personnel of the supplier are to comply with the requirements of ISC Guidelines for Management of Supplier Approval and Personnel Qualification.

Chapter 3 Requirements for 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 Figure 3.2.1.

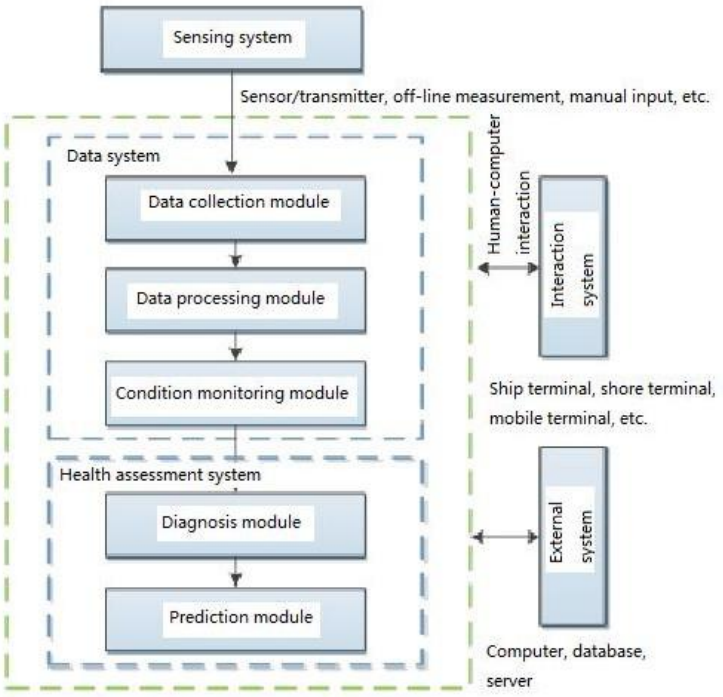


Figure 3.2.1 MCM&HAS System Framework Diagram

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 achieves 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 health condition and failure mode in future based on current condition assessment of equipment and system.

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 DSP[①] 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 Figure 3.3.9.

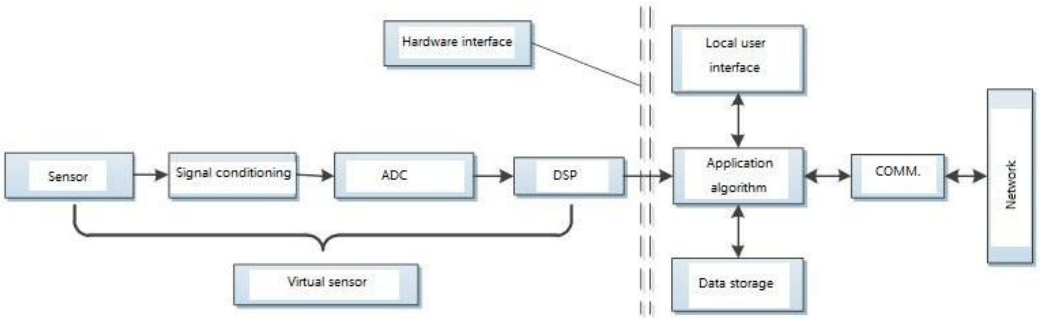


Figure 3.3.9 Normal Model of Intelligent Sensors

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.

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,

① DSP：Digital signal processing.

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 health assessment of equipment and system 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 indicator, threshold, severity of upward/downward deviation from the threshold, change of alarm level, intensity of abnormality, statistical analysis, etc.

3.5 Assessment system

3.5.1 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) Equipment and system 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 failure modes and trends of equipment and system 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 equipment and system 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 assessment system, expert knowledge, relevant configuration parameters, historical date to be stored, etc. Outputs mainly include performance evaluation results, explanations, related configuration parameters, and historical data to be saved.

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 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 Category II system data links in 2.6.6, Chapter 2, PART SEVEN of ISC 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 equipment and system based on the historical and current operation conditions of equipment and system 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 equipment and system.

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. for equipment and system.

4.2.3 Artificial DSS: ship/shore based technicians carry out analysis on conditions of equipment and system 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 equipment and system.

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 Figure 4.3.1.

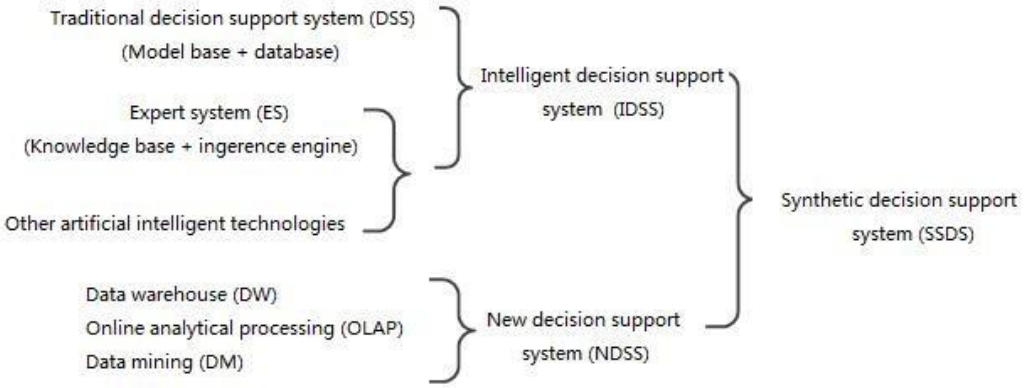


Figure 4.3.1 Typical DSS Categories

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

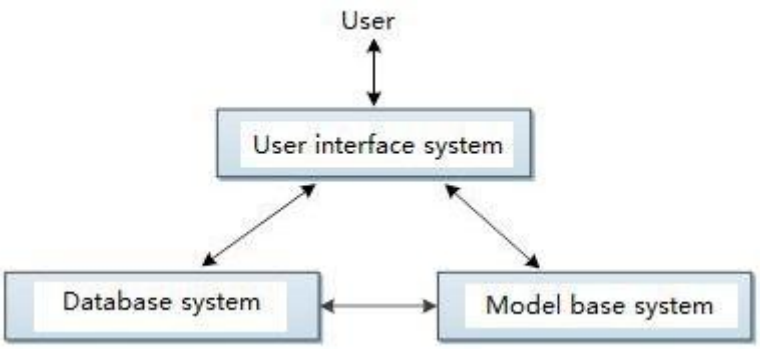


Figure 4.3.2 Basic Structural Diagram of Traditional DSS

4.3.3 IDSS integrates artificial intelligence technology into traditional DSS so as to compensate for the deficiencies 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 Figure 4.3.4.

(1) Knowledge base (KB) includes two basic elements: fact (such as situation in the field of related 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.

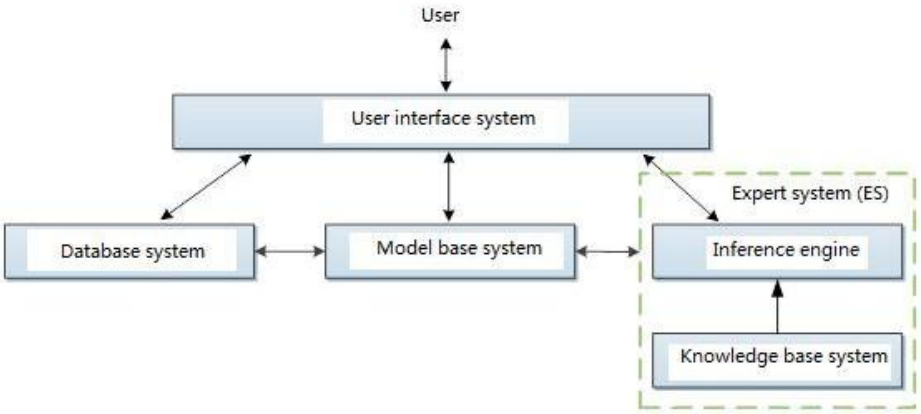


Figure 4.3.4 Basic Structural Diagram of IDSS

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 Figure 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.

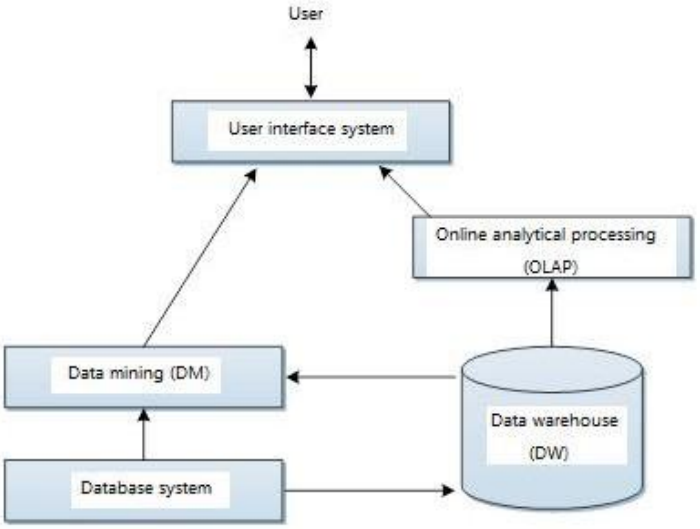


Figure 4.3.5 Basic Structural Diagram of NDSS

4.3.6 SDSS is composed of three main parts, as shown in Figure 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 part consisting of knowledge base system and data mining technology, carrying out knowledge reasoning, and providing decision support by use of data resources.

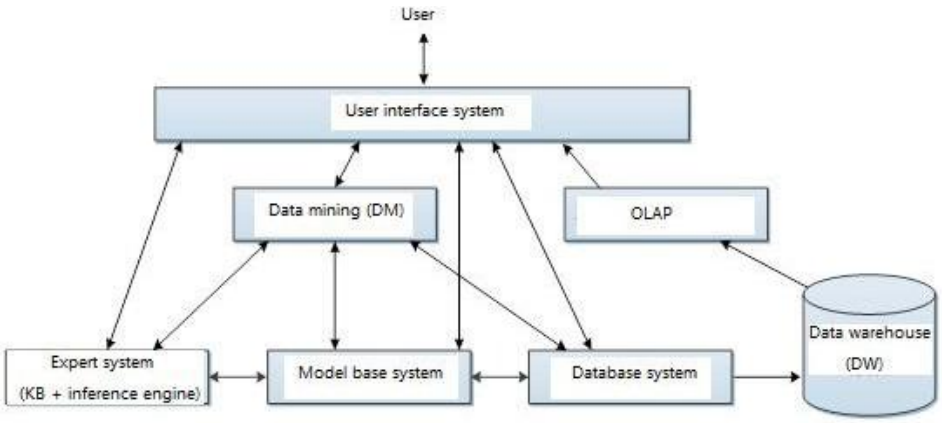


Figure 4.3.6 Basic Structural Diagram of SDSS

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 equipment and system, 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 operation and maintenance recommendations so as to optimize the running state of equipment and system.

4.4.3 For condition-based maintenance system, the recommended repair method is to be based on risk level of 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 equipment and systems, 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 equipment and system.

5.1.2 Condition-based maintenance plan is applicable to equipment and 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 equipment and system 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 and system 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 equipment 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 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 an equipment and system condition-based 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 maintenance;

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

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

(4) list and specification of equipment and system and their 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.

5.4 Requirements for service supplier of condition monitoring and health assessment

5.4.1 The supplier of condition monitoring and health assessment is to be approved in accordance with the requirements of ISC Guidelines for Management of Supplier Approval and Personnel Qualification.

5.5 Requirements for system/product

5.5.1 On the basis of ISC 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 ISC 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 equipment and system, but also of the whole equipment and system 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 PART SEVEN of ISC Rules for Classification of Sea-Going Steel Ships or other applicable rules.

6.1.2 Chapters 4, 8, 9 and 10 of ISC Rules for Intelligent Ships and the Guidelines.

6.2 Plans and documents

6.2.1 For ships applying for the function notations for intelligent machinery and class notation CBM(X) 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	Intelligent machinery system diagram	Including the system power supply, input and output signal lines.	S	A
2	Shipboard installation arrangement of main equipment of intelligent machinery system	The installation and arrangement of sensors, data acquisition devices, servers and other main equipment of the system on board.	S	N
3	List and description of monitored equipment	(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
4	Detailed information on Intelligent machinery 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
5	Relevant information on implementing condition-based maintenance (applicable to function notation M(x2))	(1) list and description of equipment and parts included in the condition-based maintenance system; (2) content and plan of condition-based maintenance; (3) procedures for development and implementation of condition-based maintenance plan.	S	A
6	Detailed plan for measuring/acquiring	Including methods for measuring/acquiring data for criteria, plans for establishing effective criteria, and	P	A

	health assessment criteria	methods for evaluating the effectiveness of the criteria, etc.		
7	Type test program	Including testbed, test equipment, test items, test methods, test result judgment, etc.	Survey unit	A
8	Risk analysis report	According to 4.1.6 of Chapter 4 of ISC Rules for Intelligent Ships, if the condition monitoring scope is different from that specified in the Rules, condition monitoring scope and monitoring purpose may be determined according to the results of risk analysis.	P	N
9	Operation manual	According to 1.9 of Chapter 1 of ISC Rules for Intelligent Ships, at least the following aspects are to be considered in the operating manual: (1) Procedures and instructions related to system operation, inspection, testing and maintenance; (2) Working conditions and restrictions related to system operation; (3) Emergency procedures.	P	N
10	Procedures and schedules	(1) onboard testing procedures, including testing plan, technical index, sea trial outline; (2) procedures and schedules for data collection, including real-time continuous/periodic data collection, personnel arrangement (if applicable), sampling frequency, sampling duration, data collection working conditions/conditions, relevant implementation records, etc.; (3) procedures and schedules for data storage/backup, including real-time/periodic storage/backup mechanisms, duration, personnel arrangements (if applicable), relevant implementation records, etc.; (4) procedures and schedule s for data analysis, including monitoring data processing, real-time/periodic analysis mechanisms, personnel arrangements (if applicable), relevant implementation records, etc.; (5) output of assessment result/report, including regular/periodic output mechanism, output format, personnel arrangement (if applicable), relevant implementation records, etc.; (6) procedures and schedules for calibration of monitoring devices, including periodic calibration mechanism, calibration method, personnel arrangement, relevant implementation records, etc..	S where (1) is to be submitted to the survey unit	A
11	Intelligent machinery system instruction	Including descriptions of system functions, software and hardware, and installation requirements.	S	N
12	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 of equipment and system.

7.2 Approval/survey basis

7.2.1 Chapter 3 of PART ONE and Chapters 1 to 3 of PART SEVEN of ISC Rules for Classification of Sea-Going Steel Ships or other applicable rules.

7.2.2 Chapters 1, 4, 8, 9 and 10 of ISC 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, ISC 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 Certification of the intelligent machinery system and its components is to comply with the relevant provisions of 1.10.1 of Chapter 1of the Rules for Intelligent Ships.

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 ISC. Refer to ISC Guidelines for Approval of Testing Organization for Marine Products 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	ISC Guidelines for Type Approval Test of Electric and Electronic Products	
4	Electromagnetic compatibility test	ISC 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 ISC. 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			

No.	Test items	Requirements for test result	Remarks
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	
Condition monitoring and health assessment function			
5	Inspection of data acquisition function	The operation condition of major equipment and system of the engine room is to be monitored and the data acquired 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 monitoring parameters	Records of monitored parameters are to include at least the following information: (1) description of basic data of equipment ans system; (2) measurement location; (3) method for processing measurement data; (4) date and time information	
8	Recording of benchmark data	To record the benchmark data measured under the original state of equipment and system or the condition monitoring is acquired	
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	To be capable of implementing the data trend analysis and indicating the analysis result visually	
13	Analysis and assessment function	To be capable of outputting analysis and assessment report for operation condition and health condition of equipment and system. To check whether the false detecting rate and missed detecting rate comply with the	This test may be carried out by means of data simulation and the assessment result is to be consistent with the simulation environment.

No.	Test items	Requirements for test result	Remarks
		requirements of the Guidelines. (Neither the false detecting rate nor the missed detecting rate is to be over 30%)	At least 10 failure events are to be simulated
Decision support function			
14	Knowledge base function	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	To be capable of outputting decision making suggestions corresponding to the above analysis and assessment report	
16	History data query function	To facilitate the query of history data and output relevant records necessary for the inspection	
Condition-based maintenance 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 equipment and system and their components	
18	Updating of condition-based maintenance plan function	To constantly update the maintenance plan based on condition monitoring information	
19	Record generating function	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 ISC Guidelines for Security and Reliability Assessment of Marine Software and the requirements of the standard are to be met.

7.5.5 The intelligent machinery system is at least to meet the SL0 level cyber security requirements in Chapter 2 of ISC Guidelines for Ship Cyber Security, and the products are to be inspected in accordance with Chapter 3 of the Guidelines for Ship Cyber Security.

7.6 Unit/batch inspections

7.6.1 After type approval, unit-by-unit inspection of products is to be carried out by ISC 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 ISC Guidelines for Type Approval Test of Electric and Electronic Products	
4	Voltage resistance test	Regulation 2.14 of ISC 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(xi) and CBM(X).

8.2 Document approval

8.2.1 The requirements for submitting plans and documents in 4.3, Chapter 4 of ISC 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 ISC 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 ISC class notation M(x1) for intelligent machinery are to keep documents such as Decision support suggestion adoption and feedback records, Decision support correction record and knowledge updating record;

(6) In addition to keeping documents mentioned in above (1) to (4), ships applying for ISC class notation M(x2) 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 (if any);

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

(9) Other records as required by procedures and plans.

8.4 Survey and test

8.4.1 Relevant requirements for survey and test in 4.5, Chapter 4 of ISC 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 relation 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 checked. For ships initially assigned with ISC class notations for intelligent machinery and/or class notation CBM(X), implementation survey is to be carried out in accordance with the requirements in 1.4.8, Chapter 1 of ISC Rules for Intelligent Ships.

8.4.4 If there is condition of alteration, damage and failure affecting maintenance of class notation, the ship owner is to notify ISC 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 After the intelligent machinery related systems and equipment are installed on board, an initial survey is to be carried out in accordance with the requirements in 4.5.1, Chapter 4 of ISC Rules for Intelligent Ships, and the functional validity is to be verified by tests. The function test is generally to cover those specified in Table 8.4.5.

List of Test Items for Initial Survey **Table 8.4.5**

No.	Test items	Requirements for test result	Remarks
	General functions		
1	Data communication function	To confirm the validity of data communication.	
2	Data communication failure alarming function	To confirm that 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	To confirm that the system is to be capable of shifting automatically to the backup power in the case of power loss during normal power supply.	
4	Power failure alarm	To confirm that audio and visual alarms are to be initiated while the system power failure occurs	
	Machinery Condition monitoring and health assessment function		
5	Inspection of data acquisition function	To check the integrity, accuracy and validity of the collected data in accordance with the approved monitoring equipment and parameter list.	
6	Signal loss alarming function	To check that the system is to initiate the alarm in the case of loss of signal to be collected	
7	Recording of baseline data	To confirm that the system is to measure or acquire the baseline data of the condition monitoring.	
8	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.	
9	Inspection of data storage function	To confirm that the data measured by the system is to be stored according to specified procedures and plans and that the data content is to be consistent with the original input data.	
10	Inspection of data backup capability	To confirm that equipment necessary for database backup is to be provided and backup is to be conducted according to specified procedures and plans.	
11	Trend analysis of condition monitoring data	To check that the system is to be capable of implementing the data trend analysis and indicating the analysis result visually	
12	Analysis and assessment result output function	To check that the system is to be capable of outputting analysis and assessment report for operation condition and health condition of equipment and system according to specified procedures and plans.	
13	History data query function	To check that the system is to facilitate the query of history data and information.	
	Decision support function		
14	Decision support output function	To check that the system is to be capable of outputting decision making suggestions corresponding to the above analysis and assessment report	
Condition-based maintenance function (applicable to the functional notation M(x2) or the class notation CBM(X))			
15	Development of condition-based maintenance plan function	To check that the system is to be capable of developing condition-based maintenance plan for monitored equipment and components based on the health assessment results of equipment and system and their components	
16	Record generating function	To check that the system is to generate two records: list of inspection items of condition-based maintenance equipment and system, record for service, inspection and repairing of condition-based maintenance	

8.4.6 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 ISC Rules for Intelligent Ships.

Survey requirements are as follows:

(1) The ship owner or ship management company is to submit an annual report on class notations M(xi) and/or CBM(X) to ISC units carrying out survey. The report is at least to include system maintenance record, general operation record, failure condition of monitored equipment and system, cause analysis, equipment replacement condition as well as operation and maintenance record of renewed equipment and system 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 ISC is to be submitted. The portable 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 portable 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 ISC Rules and Guidelines.

8.4.7 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.

8.4.8 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.

Appendix 1 Checklist for Equipment and System Condition Monitoring

Description:

(1) This appendix lists the ship's major equipment and systems, typical failures, and parameters that may be used for condition monitoring, for user reference only.

(2) For ships applying for the function notations for intelligent machinery, the monitored equipment and system scope is at least to comply with the requirements in Chapter 4 of ISC Rules for Intelligent Ships.

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
1	Diesel engine for main propulsion		
1.1	Combustion condition	Single cylinder dynamic pressure, single cylinder exhaust gas temperature; single cylinder cooling water outlet temperature, vibration	(1) Abnormal exhaust temperature; (2) Insufficient output power; (3) Misfire, knocking, combustion instability, etc. (gas /low flash point fuel engine).
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, piston picture (two-stroke diesel engine), cylinder oil parameter	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, piston ring groove and wear ring; (3) Scale of water jacket space
1.4	Piston ring (if applicable)	Vibration, temperature, piston ring picture (two-stroke diesel engine), cylinder oil parameter	(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, cylinder oil parameter	(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	Transmission	Vibration	(1) Abnormal clearance of roller.

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
	mechanism of intake valve Transmission mechanism of exhaust valve		
1.12	Engine bracket & engine foundation	Vibration	(1) Crack, deformation, damage, corrosion, etc; (2) Fracture, loosening of connecting bolt
1.13	Crankcase & safety device (if applicable)	Oil mist concentration, crankcase pressure	(1) Explosion
1.14	Bearing of crank pin	Vibration, temperature, bearing wear	(1) Bearing crack, breakaway, overheat, scotch, wear; (2) Abnormal clearance of bearing
1.15	Holding –down bolt & packing block	Vibration	(1) Holding –down bolt is loose or fractured, etc; (2) Loosening of packing block
1.16	Main bearing	Vibration, temperature, bearing wear	(1) The bearing has crack, breakaway, overheat, scotch, wear; (2) Abnormal bearing clearance
1.17	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
1.18	Camshaft (if applicable), camshaft bearing (if applicable)	Vibration, temperature, bearing wear	(1) Loosening of cam; (2) Surface of cam shaft has crack, corrosion hole, scotch and excessive wear
1.19	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
1.20	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.
1.21	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
1.22	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
1.23	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
1.24	Through bolt	Vibration	(1) Loose, breaking
1.25	Vibration damper or antivibrator	Vibration	(1) Flexible base: damage of vibration isolating rubber and spring (2) Back balance antivibrator: loosening of back balance

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
			and bolt (3) Hydraulic spring-type antivibrator: failure of the spring unit, loosening of locating pin and blockage of oil hole
1.26	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
1.27	Reversing arrangement	Vibration	(1) Failure of reversing cam, reversing valve, reversing servo mechanism, etc.
1.28	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
1.29	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
1.30	Engine-driven diesel oil booster pump	Vibration, temperature, pressure, flow	
1.31	Engine-driven fuel oil booster pump	Vibration, temperature, pressure, flow	
1.32	Engine-driven diesel oil delivery pump	Vibration, temperature, pressure, flow	
1.33	Engine-driven fuel oil delivery pump	Vibration, temperature, pressure, flow	
1.34	Engine-driven freshwater pump	Vibration, temperature, pressure, flow	
1.35	Engine-driven cooling pump of fuel injector	Vibration, temperature, pressure, flow	
1.36	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
1.37	Engine-driven reduction gear lub. oil pump	Vibration, temperature, pressure, flow	
1.38	Engine-driven seawater circulating pump	Vibration, temperature, pressure, flow	
1.39	Engine-driven seawater cooling pump	Vibration, temperature,	

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
		pressure, flow	
1.40	Engine-driven freshwater cooler	Temperature, pressure,	(1) Filth blockage of seawater jacket space, fresh water jacket space; (2) Leakage
1.41	Engine-driven lub. oil cooler	Temperature, pressure,	(1) Filth blockage of seawater jacket space; (2) Leakage
1.42	Partial pipeline of starting air system	Pressure	(1) Corrosion, damage, leakage; (2) Poor sealing
1.43	Pilot fuel nozzle (dual fuel engine)	Exhaust temperature, oil injection pressure, oil injection temperature	Filth blockage, poor atomization, insufficient ignition ability
1.44	Ignition device (single gas /low flash point fuel only engine)	Voltage	Insufficient ignition ability
1.45	Crankcase (applicable to trunk piston type gas /low flash point fuel engines)	Flammable gas concentration, crankcase pressure	Leakage of gas/low flash point fuel
1.46	Piston underside space (two-stroke gas/low flash point fuel engine) (if applicable)	Flammable gas concentration, lower space pressure of piston	Leakage of gas/low flash point fuel
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) Abnormal bearing clearance
2.7	Bearing of crank pin	Lub. Oil temperature	(1) Bearing crack, breakaway, overheat, scotch, wear; (2) Abnormal clearance of bearing
2.8	Camshaft bearing (if applicable)	Lub. oil into camshaft pressure, lub. oil into camshaft	(1) Loosening of cam; (2) Crack, pitting corrosion, scotch, excessive wear

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
		temperature,	
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, vibration	(1) Sooting; (2) Low temperature corrosion, high temperature corrosion; (3) Misfire, knocking, combustion instability, etc. (gas /low flash point fuel engine)
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.;
2.16	Pilot fuel nozzle (dual fuel engine)	Exhaust temperature, oil injection pressure, oil injection temperature	Filth blockage, poor atomization, insufficient ignition ability
2.17	Ignition device (gas only/low flash point fuel engine)	Voltage	Insufficient ignition ability
2.18	Crankcase (applicable to trunk piston type gas /low flash point fuel engines)	Flammable gas concentration, crankcase pressure	Leakage of gas/low flash point fuel
2.19	Piston underside space (applicable to crosshead gas/low flash point	Flammable gas concentration, lower space pressure of	Leakage of gas/low flash point fuel

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
	fuel engines)	piston	
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 white alloy; (6) Poor sealing of bearing casing
3.3	Stern tube and bearing (if applicable) ①	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	**Auxiliary system**		
4.1	Fuel oil (fuel) system (including pilot fuel system for dual fuel engine)		
4.1.1	Fuel oil (fuel) pump	Inlet and outlet pressures	Insufficient fuel oil (fuel)supply capacity
4.1.2	Filter	Inlet and outlet pressure (differential pressure)	Filth blockage
4.1.3	Heat exchanger (if fitted)	Inlet and outlet pressures, temperature	Poor heat exchange performance
4.1.4	Ventilated double wall gas/low flash point fuel piping	Ventilation flow/pressure/flow rate, gas concentration/low flash point fuel flow	Insufficient ventilation capacity, gas/low flash point fuel leakage
4.1.5	Inert gas pressurized double wall gas/low flash point fuel piping	Inert gas pressure, gas concentration/low flash point fuel flow	Insufficient inerting capacity, gas/low flash point fuel leakage
4.2	Lubricating oil system		
4.2.1	Lubricating oil pump	Inlet and outlet pressures	Insufficient lubricating oil supply capacity
4.2.2	Filter	Inlet and outlet pressure (differential pressure)	Filth blockage
4.2.3	Heat exchanger	Inlet and outlet pressures, temperature	Poor heat exchange performance
4.2.4	Lubricating oil piping (applicable to gas/low	Flammable gas concentration	Gas/low flash point fuel leakage

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
	flash point fuel engine) ②		
4.3	Water lubrication system		
4.3.1	Pump	Water supply pressure, flow, etc.	Lubrication water supply capacity
4.3.2	Filter	Inlet and outlet pressure or differential pressure	Impurity filtration
4.3.3	Heat exchanger (if provided)	Inlet and outlet temperature, pressure	Heat exchange performance
4.4	Cooling system		
4.4.1	Pump	Inlet and outlet pressures	Insufficient cooling medium supply capacity
4.4.2	Filter	Inlet and outlet pressure (differential pressure)	Filth blockage
4.4.3	Heat exchanger	Inlet and outlet pressures, temperature	Poor heat exchange performance
4.4.4	Cooling water piping (applicable to gas/low flash point fuel engine) ②	Flammable gas concentration	Gas/low flash point fuel leakage
4.5	Hydraulic (servo) oil system		
4.5.1	Hydraulic oil pump	Inlet and outlet pressures	Insufficient oil supply capacity
4.5.2	Filter	Inlet and outlet pressure (differential pressure)	Filth blockage
4.6	Starting and control air system	Pressure	Insufficient air supply capacity
4.7	Air intake (four stroke)/scavenging (two stroke) system	Pressure, temperature	Insufficient pressurization, high air intake/scavenging temperature
4.8	Exhaust gas system	Back pressure	Insufficient exhaust capacity
4.8.1	Exhaust pipe (applicable to methanol/ammonia fuel engine)	Toxic gas concentration	The residual toxic gas in the exhaust gas impact to safety
4.8.2	Purging fan (if provided)	Ventilation flow/pressure/flow rat, fan working condition	Insufficient purging ability
4.9	Power source of control safety alarm system (electric, pneumatic, hydraulic)	Voltage, gas/liquid pressure	Insufficient energy supply capacity
4.10	Sealing oil system (when serving gas/low flash point fuel engine)		
4.10.1	Sealing oil pump	Oil pressure, oil	Insufficient oil supply ability

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
		temperature	
4.10.2	Filter	Pressure before and after the filter, the pressure drop	Filth blockage of filter
4.11	Inert gas purging system (if provided, when serving gas/low flash point fuel engine)		
4.11.1	Purging piping system	Inert gas pressure, flow rate	Insufficient purging ability
4.12	Water purging system (if provided, when serving gas/low flash point fuel engine)		
4.12.1	Purging piping system	Purging water pressure and flow rate	Insufficient purging ability
4.13	Fuel recovery and treatment system (if provided, applicable to methanol/ammonia fuel engine)		
4.13.1	Gas liquid separation device	Liquid level, pressure	Insufficient gas-liquid separation ability
4.13.2	Water sealing device	Liquid level, pressure, concentration of methanol/ammonia solution, concentration of methanol/ammonia gas in vent pipe	Insufficient methanol/ammonia absorption ability
5	**Alternating current electric propulsion related equipment and systems**		
5.1	Generator		
5.1.1	Stator	Voltage, current, temperature	Abnormal current/voltage harmonics Unbalanced current/voltage, high winding temperature
5.1.2	Rotor (Not applicable to permanent magnet motor)	Current, vibration	Abnormal dynamic eccentricity, abnormal mixed eccentricity, turn-to-turn short circuit of rotor
5.1.3	Bearing	Temperature, vibration	High bearing temperature, abnormal bearing wear and clearance, abnormal vibration peak-peak/vibration peak factor
5.1.4	Excitation device and automatic voltage regulator (AVR)	Voltage, current	Uneven reactive power distribution, overexcited, underexcited
5.1.5	Permanent magnet (applicable to permanent magnet synchronous generator)	Stator current, voltage and temperature	Loss of excitation
5.2	Switchboard		

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
5.2.1	All panel circuit breakers	Current, temperature	Abnormal connection, aging switch, and high temperature of lap joint
5.2.2	Busbar power quality	Frequency, voltage	Harmonic abnormity, frequency overrun, unbalance between phases, voltage fluctuation, over-voltage, voltage sag
5.2.3	Busbar insulation	Zero sequence voltage, zero sequence current	Single phase earthing, low insulation of a single specific load
5.3	Power transformer		
5.3.1	Winding	Current, temperature, vibration	Phase-to-phase /turn-to-turn short circuit, high winding temperature, excessive vibration
5.4	Frequency convertor		
5.4.1	Power device module	Voltage, current, temperature	Failure shutdown
5.4.2	Braking resistor (if applicable)	Temperature	High braking resistor temperature
5.5	Main propulsion motor		
5.5.1	Stator	Voltage, current, temperature	Abnormal current/voltage harmonics (excessive harmonic coefficient), unbalanced current/voltage, high winding temperature
5.5.2	Rotor	Current, vibration, temperature	Abnormal dynamic eccentricity, abnormal mixed eccentricity, turn-to-turn short circuit of rotor, loss of excitation(permanent magnet motor)
5.5.3	Bearing	Temperature, vibration	High bearing temperature, abnormal bearing wear and clearance, abnormal vibration peak-peak/vibration peak factor
5.6	Auxiliary system		
5.6.1	Cooling system (water cooling, air cooling)	Water cooling: flow rate, pressure, temperature Air cooling: air volume, pressure	High/low cooling water pressure, cooling medium leakage, high/low cooling water temperature, insufficient air volume
5.7	Propeller		
5.7.1	Sealing device	Liquid level	Poor sealing, leakage
5.7.2	Bearing	Temperature, vibration	Abnormal bearing wear
6	**Direct current electric propulsion related equipment and systems**		
6.1	Generator		
6.1.1	Stator	Current, temperature, vibration	Stator state, e.g. winding turn-to-turn insulation
6.1.2	Rotor (Not applicable to permanent magnet motor)	Current, temperature, vibration	Rotor state, e.g. rotor balance, turn-to-turn insulation state, eccentric state
6.1.3	Bearing	Temperature, vibration	Wear
6.1.4	Excitation device and automatic voltage	Voltage, current	Excitation and voltage regulation capacity

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
	regulator (AVR)		
6.1.5	Permanent magnet (applicable to permanent magnet synchronous generator)	Stator current, voltage, temperature	Loss of excitation
6.2	Switchboard		
6.2.1	Busbar break solid state switch	Voltage, current, solid state switch on/off command/status, voltage and current before and after the action moment	Operation state, such as switch on/off command, switch on/off status, voltage and current before and after switch on/off, etc.
6.2.2	All panel circuit breakers	Current	switch on/off command, switch on/off status
6.2.3	Busbar	Voltage, current, power, harmonics, zero sequence voltage, zero sequence current	Power quality (such as voltage deviation, voltage fluctuation and flicker, ripple, transient voltage drop, transient recovery time, etc.) System insulation Pre-charge state (if applicable)
6.2.4	Inhibit capacitance and resistance, inductance (if provided)	Charge/discharge action, temperature	Operation state, e.g. charge/discharge action, temperature
6.3	Power transformer of DC distribution board to AC distribution board		
6.3.1	Winding	Temperature, current, vibration	Operation state of winding
6.4	Current converter		
6.4.1	Power device module	Voltage, current, temperature	Operation state
6.5	Main propulsion motor		
6.5.1	Stator	Current, temperature, vibration	Stator state, e.g. winding turn-to-turn insulation
6.5.2	Rotator	Current, temperature, vibration	Rotor state, such as turn-to-turn state (synchronous motor), balance state, eccentricity state, rotor bar break (asynchronous motor), loss of excitation (permanent magnet motor)
6.5.3	Bearing	Vibration, temperature	Wear
6.6	Auxiliary system		
6.6.1	Cooling system (water cooling, air cooling)	Water cooling: flow rate, pressure, temperature Air cooling: air volume, pressure	High/low cooling water pressure, cooling medium leakage, high/low cooling water temperature, insufficient air volume
6.7	Propeller		
6.7.1	Sealing device	Liquid level	Sealing

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
6.7.2	Bearing	Temperature, vibration	Wear
7	Water jet propulsion system		
7.1	Water jet propulsion pump	Speed, flow, head	Water jet propulsion performance
7.1.1	Impeller	Vibration	Impeller operation state, e.g. impeller balance state, wear state, corrosion state, etc.
7.1.2	Impeller shaft and bearing	Vibration, temperature	Wear
7.2	Inlet duct system		
7.2.1	Inlet duct	Pressure, vibration	Through-flow condition
7.2.2	Grille/intake screen	Pressure, differential pressure	Impurity filtration
7.3	Hydraulic system		
7.3.1	Hydraulic oil pump	Pressure, flow	Oil supply capacity
7.3.2	Heat exchanger (if provided)	Pressure, temperature	Heat exchange performance
7.3.3	Filter	Pressure, differential pressure	Impurity filtration
7.4	Lubricating oil system		
7.4.1	Lubricating oil pump	Pressure	Oil supply capacity
7.4.2	Heat exchanger	Pressure, temperature	Heat exchange performance
7.4.3	Filter	Pressure, differential pressure	Impurity filtration
7.5	Power source of control system (electric, pneumatic, hydraulic)	Voltage, pressure	Energy supply capacity
8	Propelling system		
8.1	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
8.2	Clutch	Vibration, temperature, pressure	(1) Poor connection and slip; (2) Leakage of box; (3) Loosening of hold-down bolts
9	Essential auxiliary machinery		
9.1	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
9.2	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;

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
			(4) Poor lubricating; (5) Filth blockage and poor sealing of piping
9.3	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
9.4	Essential pumps and motors		
9.4.1	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
9.4.2	Seawater pump and motor for berthing	Vibration, noise, temperature, pressure, flow	
9.4.3	Fresh water pump & motor for main engine	Vibration, noise, temperature, pressure, flow	
9.4.4	Fresh water pump & motor for berthing	Vibration, noise, temperature, pressure, flow	
9.4.5	Feed pump & motor for boiler	Vibration, noise, temperature, pressure, flow	
9.4.6	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 Ejector pumps: (1) Wear of nozzle holes; (2) Corrosion of diffuser cone Driving motors of various pumps: (1) Abnormal insulance; (2) Wear of ball bearing or roller bearing
9.4.7	Circulating water pump & motor for exhaust boiler	Vibration, noise, temperature, pressure, flow	
9.4.8	Fuel pump & motor for boiler	Vibration, noise, temperature, pressure, flow	
9.4.9	Fuel pump & motor for main engine	Vibration, noise, temperature, pressure, flow	
9.4.10	Fuel pressure pump & motor for main engine	Vibration, noise, temperature, pressure, flow	
9.4.11	Lub. oil pump & motor for main engine	Vibration, noise, temperature, pressure, flow	
9.4.12	Oil pump & motor for main engine camshaft	Vibration, noise, temperature, pressure, flow	
9.4.13	Fire pump & motor	Vibration, noise, temperature, pressure, flow	
9.4.14	Emergency fire pump	Vibration, noise,	

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
	& driving device	temperature, pressure, flow	
9.4.15	Ballast pump & motor	Vibration, noise, temperature, pressure, flow	
9.4.16	Bilge pump & motor	Vibration, noise, temperature, pressure, flow	
9.4.17	Equalizing pump & motor	Vibration, noise, temperature, pressure, flow	
9.4.18	General service pump & motor	Vibration, noise, temperature, pressure, flow	
9.4.19	Seawater pump and motor for fresh water generator	Vibration, noise, temperature, pressure, flow	
9.4.20	Condensate pump and motor for fresh water generator	Vibration, noise, temperature, pressure, flow	
9.4.21	Fuel transfer pump and motor	Vibration, noise, temperature, pressure, flow	
9.4.22	Diesel oil transfer pump and motor	Vibration, noise, temperature, pressure, flow	
9.4.23	Residual fuel pump & motor	Vibration, noise, temperature, pressure, flow	
9.4.24	Daily service fresh water pump & motor	Vibration, noise, temperature, pressure, flow	
9.4.25	Heat water circulating pump & motor	Vibration, noise, temperature, pressure, flow	
9.4.26	Sanitary pump & motor	Vibration, noise, temperature, pressure, flow	
9.4.27	Drinking water pump & motor	Vibration, noise, temperature, pressure, flow	
9.4.28	Cooling pump & motor of fuel injector for main engine	Vibration, noise, temperature, pressure, flow	
9.4.29	Cooling pump & motor of piston for main engine	Vibration, noise, temperature, pressure, flow	
9.4.30	Fresh water transfer pump and motor	Vibration, noise, temperature, pressure, flow	
9.4.3l	Vacuum pump set of fresh water generator	Vibration, noise, temperature, pressure, flow	

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
9.4.32	Salt water pump & motor for fresh water generator	Vibration, noise, temperature, pressure, flow	
9.4.33	Vacuum air pump	Vibration, noise, temperature, pressure, flow	
9.4.34	Feed water jet pump	Vibration, noise, temperature, pressure, flow	
9.4.35	Bilge water jet pump	Vibration, noise, temperature, pressure, flow	
9.4.36	All other engine-driven pumps	Vibration, noise, temperature, pressure, flow	
9.4.37	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
9.4.38	Diesel oil separator & motor	Vibration, temperature, pressure, flow, insulance	
9.4.39	Lub. oil separator & motor	Vibration, temperature, pressure, flow, insulance	
10	Air bottles and various pressure vessels and accessories		
10.1	Main & auxiliary air bottle, working air bottles and accessories such as safety valves	Pressure	(1) poor airtightness of valves; (2) Failure of safety valves
10.2	Fresh water pressure tank, sanitary tank (seawater pressure tank) and potable fresh water tank	Pressure	(1) Leakage
11	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
12	Windlass		
12.1	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
13	Bilge pipe, strainer, bilge well suction,	Pressure	(1) Filth blockage of suction screen and mud box; (2) Failure of emergency bilge suction in engine room

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
	sludge pipe		
14	Ballast pipe, valve and ballast operating system	Pressure	(1) Failure of remote control valve
15	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
16	Additional requirements for oil tankers		
16.1	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
16.1.1	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
16.1.2	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
16.1.3	Segregated ballast pump	Vibration, pressure, temperature, insulance	(1) Leakage of shaft gland; (2) Abnormal insulance of motor; (3) Wear of bearing, abnormal temperature
16.1.4	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
16.1.5	Sealing device for pump drive assembly	Temperature	(1) Damage of sealing device, jam of pump shaft
16.1.6	Piping and fittings	Pressure	(1) Leakage
16.2	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
16.3	Crude oil washing machine Washing heater		
16.3.1	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
16.3.2	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
16.4	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;

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
			(3) Loosening of heating pipe
16.5	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
16.6	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
16.7	Inert gas system		
16.7.1	Inert gas system	Pressure, other concentration	(1) Serious corrosion, water and oil leakage of pipeline and components; (2) Oxygen concentration is above standard
16.7.1.1	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; (7) Excessively low gas pressure in IGS manifold
16.7.1.2	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
16.7.1.3	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;
17	Liquid cargo system (ships carrying liquefied gases in bulk)		
17.1	Liquid cargo pump	Vibration, noise, flow, pressure	(1) Abnormal vibration, noise, temperature; (2) Leakage; (3) Abnormal flow, pressure
17.2	Prime mover	Insulance, temperature, current	(1) Abnormal insulance; (2) Excessive current, too high temperature rise
17.3	pump room shaft gastight device	Pressure	(1) Poor sealing

No.	Equipment/performance	Primary parameters for monitoring	Typical malfunction/failure
17.4	Compressor room shaft gastight device	Pressure	(1) Poor sealing
17.5	Liquid cargo piping	Pressure	(1) Filth blockage, corrosion
17.6	Valve	Vibration, noise, pressure	(1) Leakage, corrosion, erosion; (2) Abnormal vibration, noise
18	Liquid cargo system (ships carrying dangerous chemicals in bulk)		
18.1	Liquid cargo pump	Vibration, noise, pressure, flow	(1) Abnormal vibration, noise, temperature; (2) Leakage; (3) Abnormal flow, pressure
18.2	Liquid cargo piping	Pressure	(1) Filth blockage, corrosion
18.3	Valve	Pressure, vibration, noise	(1) Leakage, corrosion, erosion; (2) Abnormal vibration, noise
18.4	Tank	Liquid level	(1) Abnormal liquid level

Note:

① For open water lubrication shafting, it is not necessary to monitor the sealing of the aft end of the stern tube.

② In accordance with the provisions of 4.1.6 of Chapter 4 of the Rules for Intelligent Ships, the monitoring requirements do not apply if the risk analysis shows that there is no risk of gas/low flash point fuel leakage into the relevant auxiliary systems (such as lubricating oil systems, cooling water systems).

Appendix 2 Checklist for Dredger Dredging Equipment and System Condition Monitoring

Description:
(1) This appendix lists the major dredging equipment and systems of cutter suction dredgers and trailing suction hopper dredgers, typical malfunction/failures, and parameters that may be used for condition monitoring, for user reference only.
(2) For dredgers applying for the function notations for intelligent dredging, the monitored equipment and system scope is at least to comply with the requirements in 10.3 of Chapter 10 of ISC Rules for Intelligent Ships.

No.	Equipment and system	Primary parameters for monitoring	Typical malfunction/failure
1	Cutter and drive system (cutter suction dredger)		
1.1	Gear box	Revolving speed, vibration, temperature, pressure and oil analysis parameters	Gear shaft wear, poor meshing of gear, gear surface wear, poor lubrication
1.2	Drive shaft bearing	Revolving speed, vibration, temperature, oil analysis parameters, sealing fluid level	Wear, abnormal bearing clearance, poor sealing
1.3	Cutter shaft bearing	Revolving speed, vibration, temperature, oil analysis parameters, sealing fluid level	Wear, abnormal bearing clearance, poor sealing
2	Dredge pump and drive system		
2.1	Dredge pump	Revolving speed, pressure, flow rate	Insufficient mud transmission capacity
2.2	Impeller, lining plate, inner liner	Vibration	Severe wear
2.3	Dredge pump bearing	Revolving speed, vibration, temperature, oil analysis parameters, sealing fluid level	Wear, abnormal bearing clearance, poor sealing
2.4	Gear box	Revolving speed, vibration, temperature, pressure, oil analysis	Gear shaft wear, poor meshing of gear, gear surface wear, poor lubrication

		parameters	
2.5	Drive shaft bearing	Revolving speed, vibration, temperature, oil analysis parameters, sealing fluid level	Wear, abnormal bearing clearance, poor sealing
3	Hydraulic system		
3.1	Hydraulic oil pump	Hydraulic oil tank level, revolving speed, pressure, temperature	Insufficient oil supply
3.2	Filter	Inlet and outlet pressures, differential pressure	Blockage
4	Seal water system		
4.1	Seal water pump	Pressure, flow rate, revolving speed	Insufficient or excessive water supply
4.2	Filter	Inlet and outlet pressures, differential pressure	Blockage
5	Flushing system		
5.1	Flush water pump	Pressure, flow rate, revolving speed, power	Insufficient water supply
5.2	Filter	Inlet and outlet pressures, differential pressure	Blockage
6	Lubricating oil system		
6.1	Lubricating oil pump	Pressure, temperature	Insufficient oil supply
6.2	Filter	Inlet and outlet pressures, differential pressure	Blockage
6.3	Heat exchanger	Pressure, temperature	Insufficient heat exchange capacity
7	Cooling system		
7.1	Pump	Pressure, temperature	Insufficient water supply
7.2	Heat exchanger	Pressure, temperature	Insufficient heat exchange capacity
7.3	Filter	Inlet and outlet pressures, differential pressure	Blockage

8	Compressed air system	Pressure	Insufficient air supply capacity
9	Motor		
9.1	Stator	Current, temperature, vibration	State of stator, such as winding turn-to-turn insulation
9.2	Rotor	Current, temperature, vibration	Rotor state, such as turn-to-turn state (synchronous motor), balance state, eccentricity state, rotor bar break(asynchronous motor), loss of excitation (permanent magnet motor)
9.3	Bearing	Vibration, temperature	Wear
10	Winch		
10.1	Bearing	Vibration, temperature, oil analysis	Wear, abnormal bearing clearance

Appendix 3 Checklist for Tug Towing Equipment and System Condition Monitoring

Description:
(1) This appendix lists the towing equipment and systems of tugs, typical malfunction/failures, and parameters that may be used for condition monitoring, for user reference only.
(2) For tugs applying for the function notations for intelligent towing operation, the monitored equipment and system scope is at least to comply with the requirements in 10.4.6 of Chapter 10 of ISC Rules for Intelligent Ships.

No.	Equipment and system	Primary parameters for monitoring	Typical malfunction/failure
1	Towing winch		
1.1	Hydraulic motor	Vibration, oil analysis, temperature	Wear, abnormal clearance
1.2	Gear box	Vibration, temperature, pressure, oil analysis	Gear shaft wear, poor meshing of gear, gear surface wear, poor lubrication
1.3	Winch drum shaft and bearing	Vibration, temperature, oil analysis	Wear, abnormal clearance
2	Hydraulic system (hydraulic driven towing winch)		
2.1	Hydraulic oil pump	Pressure, temperature	Insufficient oil supply
2.2	Filter	Inlet and outlet pressures, differential pressure	Blockage
2.3	Heat exchanger	Inlet and outlet pressures, temperature	Poor heat exchange performance
3	Control system		
3.1	Power source (electric, pneumatic, hydraulic)	Voltage, gas/liquid pressure	Insufficient energy supply capacity
4	Towline	Tension, cumulative service time	Tow rope broken and badly damaged
5	Power transformer (motor driven towing winch)		
5.1	Winding	Current, voltage, temperature, vibration	Phase-to-phase /turn-to-turn short circuit, high winding temperature, excessive vibration
6	Frequency convertor (motor driven towing winch)		

6.1	Power device module	Voltage, current,temperature	Failure shutdown
6.2	Braking resistor (if applicable)	Temperature	High braking resistor temperature
7	Motor(motor driven towing winch)		
7.1	Stator	Current, temperature, vibration	State of stator, such as winding turn-to-turn insulation
7.2	Rotor	Current, temperature, vibration	Rotor state, such as turn-to-turn state (synchronous motor), balance state, eccentricity state, rotor bar break(asynchronous motor), loss of excitation (permanent magnet motor)
7.3	Bearing	Vibration, temperature	Wear
8	Auxiliary system		
8.1	Cooling system (water cooling, air cooling)	Pressure, temperature, flow rate	Insufficient cooling capacity

Appendix 4 Checklist for Battery System and Equipment Condition Monitoring

Description:
(1) This appendix lists the lithium battery/super capacitor systems and equipment, typical malfunction/failures, and parameters that may be used for condition monitoring, for user reference only.
(2) For ships applying for the function notations for intelligent machinery, the monitored lithium battery/super capacitor equipment and system scope is at least to comply with the requirements in Chapter 4 of ISC Rules for Intelligent Ships.

No.	Equipment and system	Primary parameters for monitoring	Typical malfunction/failure
1	Battery (lithium battery/super capacitor)		
1.1	Battery system	Voltage, temperature, battery series circuit current, intermodule voltage, system insulation resistance, SOC, SOH, charge/discharge current	Abnormal working status, imbalance between battery cells, aging insulation, insufficient remaining battery level, attenuation of battery performance, and heating of battery pack
1.2	Battery pack cooling system (if fitted)	Pressure, ventilator failure, flow rate, temperature	Insufficient cooling capacity
2.1	Charging device	Current, voltage, charging interface temperature, connection status	Unable to charge normally, charging slowly, heating of connector
3	Auxiliary system for battery box/cabinet/compartment		
3.1	Cooling system	Pressure, temperature, flow rate	Insufficient cooling capacity
3.2	Emergency exhaust system	Ventilator power supply status, operation status, failure	Abnormal operation status
3.3	Battery	Flammable gas	Flammable gas accumulation, explosion

No.	Equipment and system	Primary parameters for monitoring	Typical malfunction/failure
	box/cabinet/compartment	concentration	

Appendix 5 Checklist for Intelligent Machinery Monitoring of Inland Waterway Ships

Description:
(1) This appendix specifies the equipment and systems that need to be monitored and the monitoring parameters/status when an inland waterway ship applies for the function notation for intelligent machinery.

Monitoring item	Monitoring parameter/status	Notes
1 Main diesel engine (including diesel engine with electric propulsion generator set)		
1.1Fuel (oil) system(including the pilot fuel system of dual fuel engine)		
★Fuel (oil) inlet pressure	Pressure	After filter
★Fuel (oil) temperature (before fuel injection pump)	Temperature	
★Leakage of high pressure fuel pipe	Leakage	Applicable to cargo ships of 500 GT and over and all passenger ships; For electronically controlled diesel engines, external data is to be provided.
★Liquid level of fuel oil service tank	Liquid level	If there is no appropriate overflow device, a high level alarm is to be added.
★Common rail fuel (oil) pressure (if applicable)	Pressure	External data is to be provided for electronically controlled diesel engines.
★Ventilated double wall gas/low flash point fuel piping (if applicable)	Ventilation flow rate or pressure or velocity	
★Inert gas pressurized double wall gas/low flash point fuel piping (if applicable)	Pressure	
★Gas/low flash point fuel piping (including double walls) (if applicable)	Flammable gas concentration	
1.2 Lubricating oil system		
★Lubricating oil inlet pressure	Pressure	
★Lubricating oil inlet temperature	Temperature	
★Oil level of lubricating oil circulation tank	Oil level	
1.3 Turbocharger system		
★Lubricating oil inlet pressure of turbocharger	Pressure	
★Revolving speed of turbocharger	Revolving speed	Applicable to engines with cylinder bore above 200mm
★Turbocharger vibration②	Abnormal	Applicable to engines with cylinder bore above 200mm
1.4 Seawater cooling system		
★Seawater cooling pressure	Pressure	

1.5 Fresh water cooling system			
★Cooling water inlet pressure		Pressure	
★Cooling water outlet temperature (per cylinder) or cooling water outlet temperature (manifold)		Temperature	
★Water level of cooling water expansion tank		Water level	
1.6 Starting and control air system			
★Starting air pressure before main shutoff valve (if applicable)		Pressure	
★Control air pressure (if applicable)		Pressure	
★Starting battery level or voltage (if applicable)		Battery level or voltage	
1.7 Exhaust gas system			
Exhaust gas temperature before entering the turbocharger		Temperature	Applicable to engines with cylinder bore above 200mm
★Exhaust gas temperature after the turbocharger		Temperature	
1.8 Rotating speed/direction			
★Rotating speed		Rotating speed	
1.9 Others			
★Turbocharger performance	★ Each cylinder exhaust temperature	Temperature	Applicable to engines with cylinder bore above 200mm
★Combustion performance①	★Cylinder head vibration	Vibration	Applicable to engines with cylinder bore above 200mm
	★Camshaft top dead center signal	Abnormal	Applicable to engines with cylinder bore above 200mm，including at least the first cylinder
	★ Flywheel end instantaneous speed or angle signal	Abnormal	Applicable to engines with cylinder bore above 200mm
★Pilot fuel nozzle (dual fuel engine)	★Exhaust gas temperature, oil injection pressure, oil injection temperature	Temperature, pressure	Applicable to engines with cylinder bore above 200mm
★ Ignition device (single gas/low flash point fuel engine)		Abnormal	Applicable to engines with cylinder bore above 200mm
★Control - safety - alarm system power source (electric, pneumatic, hydraulic)		Voltage, air pressure, hydraulic pressure	
2 Auxiliary diesel engine (prime mover of generator set)			
Lubricating oil inlet pressure		Pressure	
Lubricating oil inlet temperature		Temperature	
Cooling water outlet temperature		Temperature	
Cooling water pressure (if applicable)		Pressure	

Rotating speed		Rotating speed	
Starting air pressure (if applicable)		Pressure	
High pressure fuel pipe		Leakage	Applicable to diesel engines above 500kW; for electronically controlled diesel engines, external data is to be provided.
Liquid level of fuel oil service tank (if fitted)		Liquid level	
Water level of cooling water expansion tank (if fitted)		Water level	
Common rail fuel (oil) pressure (if applicable)		Pressure	External data is to be provided for electronic control diesel engines.
Cylinder block vibration②		Vibration	
Camshaft top dead center signal		Abnormal	Applicable to engines with cylinder bore above 200mm，including at least the first cylinder
Flywheel end instantaneous speed or angle signal		Abnormal	Applicable to engines with cylinder bore above 200mm
Rotating speed of turbocharger		Rotating speed	Applicable to engines with cylinder diameter above 200mm
Turbocharger vibration②		Abnormal	Applicable to engines with cylinder bore above 200mm
Pilot fuel nozzle (dual fuel engine)	Exhaust gas temperature, oil injection pressure, oil injection temperature	Temperature, pressure	Applicable to engines with cylinder bore above 200mm
Ignition device (single gas/low flash point fuel engine)		Abnormal	
Control - safety - alarm system power source (electric, pneumatic, hydraulic)		Voltage or air pressure or hydraulic pressure	
3 Generator			
Automatic unloading device		Action	
4 Power station			
★Bus bar voltage		Voltage	
★Bus bar frequency		Frequency	
★Automatic unloading		Action	
★Automatic switching-on of circuit breaker		Action	
★Automatic tripping of circuit breaker (generator set circuit breaker tripping)		Action	
★Load distribution failure		Action	

★Multiple sets start in sequence and one set fails to start	Action	
★Power station loses power and the generator set fails to start	Action	
★The diesel engine of the generator set is overspeed	speed	
★Lubricating oil pressure	Pressure	
★ If the power station has an emergency power supply function, the power station loses power, the diesel engine of the generator set is shutdown due to overspeed or lower lubricating oil pressure, the standby generator set is started and goes into the grid for more than 15S	Action	
5 Auxiliary boiler (if fitted)		
Boiler water level	Water level	
Fuel oil pressure to burner	Pressure	
Burner flame and ignition	Extinction/failure	
Control - safety - alarm system power source (electric, pneumatic, hydraulic)	Voltage, air pressure, hydraulic pressure	
6 Gear box (for main propulsion)		
★Gear box inlet pressure of lubricating oil	Pressure	
★Gear box inlet temperature of lubricating oil or cooling water temperature	Temperature	
★Working oil pressure	Pressure	
Gear box vibration②	Abnormal	
7 Clutch		
★Clutch state (rotating direction of main engine or clutch)	State	
★Clutch control power source (electric, pneumatic, hydraulic)	Electric, pneumatic, hydraulic	
★Reversing indication of navigation bridge to remotely control the main engine and clutch	Ahead	
	Astern	
8 Thrust bearing		
★Thrust bearing lubricating oil temperature	Temperature	
9 Stern tube bearing		
★Oil lubricated stern tube bearing temperature	Temperature	
★Oil level of stern tube lubricating oil tank	Liquid level	
★Water lubricated bearing flow rate	Flow rate or pressure	
10 Exhaust gas boiler (if any)		
Circulation feed pump outlet pressure or flow rate	Pressure or flow rate	Only applicable to forced circulation water pipe exhaust gas boilers
Fire in exhaust gas pipe	Fire alarm	
Steam pressure	Pressure	

11 Air compressor		
Air compressor lubricating oil pressure (if applicable)	Pressure	Except for splash lubrication
12 Computer system		
★Computers in the running state	Failure	For host computer of automation system only
★Computer system	Failure	Including local area network controller failure, local area network overload, running stop due to overflow, etc.
★Computer system power supply	Voltage	
13 Sludge tank		
Sludge tank oil level	Oil level	
14 Steering gear		
★Steering gear power	Loss of power	
★Steering gear overload	Overload	
★Oil level of hydraulic oil tank	Oil level	
★Electric and hydraulic power of steering gear control system	Failure	
15 Bilge water		
★Bilge water level	Water level	
Bilge pump	Operation instruction	Only applicable to automatically controlled bilge pump
16 Engine room fire detection		
Fire signs or in case of fire	Fire signs or fire	
Failure of fire detection system itself	Failure	
17 Electrically propelled ship		
17.1 Generator		
★Bearing temperature	Temperature	
Bearing vibration②	Vibration	
★Voltage current	Abnormal	
★Exciting current	Abnormal	
Winding temperature	Temperature	
Insulation monitoring	Abnormal	
17.2 Motor		
★Voltage current	Abnormal	
★Exciting current (applicable type)	Abnormal	
★Lubricating oil temperature of thrust bearing	Temperature	
Bearing vibration②	Vibration	
17.3 Switchboard		
★Busbar temperature	Temperature	
★Switch state	State	
★Insulation monitoring	Abnormal	

★Voltage and current of busbar	Abnormal	
17.4 Frequency convertor		
★Braking resistor temperature rise	Temperature rise	
★Cooling water inlet and outlet temperature (if applicable)	Temperature	
★Air pressure and temperature of ventilator outlet (if applicable)	Temperature	
★Power device module	Abnormal	
17.5 Power transformer		
Winding temperature	Temperature	
17.6 Propeller		
★Bearing temperature	Temperature	
★Bearing seal	Abnormal	
Bearing vibration②	Vibration	
18 Others		
★Override function	State	
Controlled environmental conditions (if applicable)	Abnormal	Where controlled environment is required for equipment, this item is to be complied with.
Power of monitoring and alarm system (electrical, pneumatic, hydraulic)	Failure	
Note: Items marked with "★" are compulsory. For the items not marked with "★", it is recommended to set according to the actual situation of the ship. ① For combustion performance of the engine, monitoring the cylinder pressure of a single cylinder or other equivalent means may be used as alternatives; ② Other equivalent means may be used as alternatives for the vibration condition monitoring of equipment and components.		

Appendix 6 Checklist for Condition Monitoring of Geotextiles Laying Equipment and Systems of Geotextiles Layers

Description:
(1) This appendix lists the geotextiles layer systems and equipment, typical malfunction/failures, and parameters that may be used for condition monitoring, for user reference only.
(2) For ships applying for the function notation for intelligent geotextiles laying, the monitored geotextiles laying equipment and system scope is at least to comply with the requirements in 10.7.4, Chapter 10 of ISC Rules for Intelligent Ships.

No.	Equipment and system	Primary parameters for monitoring	Typical malfunction/failure
1	Mooring positioning winch		
1.1	Gear box	Vibration, temperature, pressure, oil analysis parameters	Gear shaft wear, poor meshing of gear, gear surface wear, poor lubrication
1.2	Drive shaft bearing	Vibration, temperature, oil analysis parameters	Wear, abnormal bearing clearance
2	Tipping winch		
2.1	Gear box	Vibration, temperature, pressure, oil analysis parameters	Gear shaft wear, poor meshing of gear, gear surface wear, poor lubrication
2.2	Drive shaft bearing	Vibration, temperature, oil analysis parameters	Wear, abnormal bearing clearance
3	Coil drum driven winch		
3.1	Gear box	Vibration, temperature, pressure, oil analysis parameters	Gear shaft wear, poor meshing of gear, gear surface wear, poor lubrication
3.2	Drive shaft bearing	Vibration, temperature, oil analysis parameters	Wear, abnormal bearing clearance
4	Motor (mooring positioning winch, tipping winch, coil drum driven winch, (trussed) crane)		
4.1	Stator	Current, temperature, vibration	Stator state, e.g. winding turn-to-turn insulation
4.2	Rotor	Current, temperature, vibration	Rotor state, such as turn-to-turn state (synchronous motor), balance state, eccentricity state, rotor bar break (asynchronous motor), loss of excitation (permanent magnet motor)

No.	Equipment and system	Primary parameters for monitoring	Typical malfunction/failure	
4.3	Bearing	Vibration ,temperature	Wear	
5	Power transformer (mooring positioning winch, tipping winch, coil drum driven winch, (trussed) crane)			
5.1	Winding	Current, voltage, temperature, vibration	Phase-to-phase /turn-to-turn short circuit, high winding temperature, excessive vibration	
6	Frequency convertor (mooring positioning winch, tipping winch, coil drum driven winch, (trussed) crane)			
6.1	Power device module	Voltage, current,temperature	Failure shutdown	
6.2	Braking resistor (if applicable)	Temperature	High braking resistor temperature	
7	Control system			
7.1	Power source (electric)	Voltage	Insufficient energy supply capacity	
8	Auxiliary system (where applicable)			
8.1	Cooling system (water cooling, air cooling)		Pressure, temperature, flow rate	Insufficient cooling capacity

Appendix 7 Checklist for Condition Monitoring of Boilers and Systems

Description:
(1) This appendix lists the boilers and systems, typical malfunction/failures, and parameters that may be used for condition monitoring, for user reference only.

(2) For ships applying for the functional notation for intelligent machinery M(bi), the monitored boiler and system scope is at least to comply with the requirements of Chapter 4 of ISC Rules for Intelligent Ships.

Steam Boiler and System **Table 1**

No.	Equipment and system	Primary parameters for monitoring	Typical malfunction/failure
1	Oil-fired boiler		
1.1	Combustion chamber	Flame monitoring	Ignition failure, misfire, poor combustion
1.2	Combustion unit	Vibration, temperature, oil analysis	Wear, abnormal bearing clearance
2	Exhaust gas boiler	The exhaust gas pressure before and after the boiler and the pressure difference	Ash accumulation, high flow resistance
3	Feed water system	Temperature, salinity, and oil content monitoring	High water salinity leads to scaling, low temperature results in excessive oxygen content, and leakage of the heating pipe causes oil contamination
3.1	Feed water pump	Pump operating condition, water supply pressure, flow rate	Insufficient water supply and water supply interruption
4	Steam system	Steam pressure, steam temperature	Insufficient supply of heating steam
5	Flue gas system (oil-fired boiler)	Flue gas back pressure, temperature, fire detection	Poor ventilation and fire
6	Exhaust gas system (exhaust gas boiler)	Exhaust gas temperature, fire detection	Fire, abnormal exhaust temperature
7	Power source of control, safety and alarm system (electrical, pneumatic, hydraulic)	Voltage/gas pressure/hydraulic pressure, power supply/gas supply/liquid supply condition	Insufficient energy supply, supply failure

Thermal Oil Heater and System **Table 2**

No.	Equipment and system	Primary parameters for monitoring	Typical malfunction/failure
1	Oil-fired thermal oil heater		
1.1	Combustion chamber	Flame monitoring	Ignition failure, misfire, poor combustion
1.2	Combustion unit	Vibration, temperature, oil analysis	Wear, abnormal bearing clearance
1.3	Cylindrical shells	Leakage detection, liquid level	Leakage of thermal oil
2	Exhaust gas thermal oil heater	The exhaust gas pressure before and after the boiler and the pressure difference	Ash accumulation, high flow resistance.
2.1	Cylindrical shells	Leakage detection, liquid level	Leakage of thermal oil
3	Thermal oil supply system		
3.1	Thermal oil expansion tank	Liquid level, detection of flammable liquid cargo vapor	Insufficient supply of thermal oil and contamination of thermal oil
3.2	Thermal oil supply pump	Pump operating condition, supply pressure, flow rate	Insufficient thermal oil supply and supply interruption
4	Thermal oil heating system	Thermal oil pressure, temperature	Insufficient supply of heating thermal oil
5	Flue gas system (oil-fired boiler)	Flue gas back pressure, temperature, fire detection	Poor ventilation and fire
6	Exhaust gas system (exhaust gas boiler)	Exhaust gas temperature, fire detection	Fire, abnormal exhaust gas temperature
7	Power source of control, safety and alarm system (electrical,	Voltage/gas pressure/hydraulic pressure, power supply/gas	Insufficient energy supply, supply failure

No.	Equipment and system	Primary parameters for monitoring	Typical malfunction/failure
	pneumatic, hydraulic)	supply/liquid supply condition	