財團法人驗船中心
CR CLASSIFICATION SOCIETY

GUIDELINES FOR SMART SHIPS

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GUIDELINES FOR SMART SHIPS

CONTENTS

CHAPTER 1 GENERAL

1.1 General

1.1.1 The Guidelines for Smart Ships ((hereinafter referred to as the Guidelines) provide requirements for the smart functions on ships classed with the CR Classification Society (hereinafter referred to as the Society). The notation **Smartship** will be assigned to ships upon request and where the applicable requirements in the Guidelines are complied with.

1.1.2 Smart functions are applications specific to certain object which are integrated by means of modern communication and information technology, computer network technology and intelligent control technology. Such applications generally include, but not limited to, assessment, diagnosis, prediction and decision making. Smart functions are generally characterized by:

(a) Perception, i.e. the ability to perceive the outside world and obtain outside information;

(b) Memory and thinking, i.e. the ability to store perceived outside information and knowledge arising from thinking, and at the same time analyze, calculate, compare, judge, associate and make decisions on information by making use of available knowledge;

(c) Learning and self-adaptability, i.e. the ability to continuously learn and accumulate knowledge by interacting with the environment so as to be adaptable to environmental changes;

(d) Behavioral decision making, i.e. the ability to respond to external stimulus, make decisions and convey relevant information.

1.1.3 Smart ships are those ships which automatically perceive and obtain information and data on ship itself, marine environment, logistics and port by making use of sensors, communication, the Internet of Things, the Internet and other technical means, and achieve intelligent operation in terms of ship navigation, management, maintenance and cargo transportation based on computer technology, automatic control technology and big data processing and analyzing technology, so that ships can become safer, more environmentally friendly, economical and efficient.

1.1.4 Base on a trend of development from local application to full ship application and from assistant decision-making to autonomous operation, the functions of smart ships normally consist of smart navigation, smart hull, smart machinery, smart energy efficiency management, smart cargo management, smart integration platform, remote control and autonomous operation.

1.1.5 Unless otherwise expressly provided in the Guidelines, ships, for which a **Smartship** class notation is requested, are also to comply with the relevant requirements of CR Rules and those of the Administration of the flag State.

1.2 Equivalence and Exemption

1.2.1 Any ship which embodies structure and features of a novel kind may be exempted from relevant requirement of CR Rules and Guidelines if the application of which might impede the incorporation of its features or its service, subject to approval by the Society.

1.2.2 Any fitting, material, appliance or apparatus, other than that required in CR Rules and Guidelines, may be allowed to be fitted in a ship, if it is satisfied by trial thereof or otherwise that such fitting, material, appliance or apparatus is at least as effective as that required in CR Rules and Guidelines.

1.2.3 Equivalence or substitution to those methods of calculation, criteria of evaluation, manufacturing procedures, materials, survey or test requirements specified by CR Rules and Guidelines may be accepted subject to approval by the Society, when relevant tests, theoretical basis or experience in application is provided, or recognized effective standards are available.

1.2.4 The Society encourages the application of new technologies. Where the new technologies are beyond the scope of the existing rules, risk assessment and tests are to be carried out to prove that the system and equipment adopting the new technologies can provide an equivalent level of safety to that required by CR Rules.

1.2.5 The risk assessment may be carried out in accordance with IMO MSC-MEPC.2/Circ.12 or a method given in relevant national or international standards.

1.2.6 The new technology may be approved in accordance with the Guidelines for the Approval of Alternatives and Equivalents as provided for in various IMO Instruments (MSC.1/Circ.1455).

1.3 Alterations and Repairs

1.3.1 A ship assigned **Smartship** class notation, which has undergone any alteration or repair of its equipment or system in association with smart ship functions, is to be subject to a survey, as appropriate, for confirming compliance with the technical requirements for the existing notation.

1.4 Class Notation for Smart Ships

1.4.1 A ship, which has, upon its request, undergone plan approval and surveys by the Society and its compliance with the requirements of the Guidelines in terms of smart navigation, smart hull, smart machinery, smart energy efficiency management, smart cargo management, smart integration platform is confirmed, may be assigned the following **Smartship** class notation according to the approaches specified below:

Smartship{Hx; Mx; Ex; Nx; Cx; Ix}

Where the letters in the curly-bracketed stand for functional notations of smart ships, which may be assigned in accordance with the functions possessed by the ship. Functional notations can be added based on the development of technology.

1.4.2 Functional notations are defined as follows:

Hx : Smart hull, for which the requirements of Chapter 2 of the Guidelines are to be satisfied;

Mx : Smart machinery, for which the requirements of Chapter 3 of the Guidelines are to be satisfied;

Ex : Smart energy efficiency management, for which the requirements of Chapter 4 of the Guidelines are to be satisfied;

Nx : Smart navigation, for which the requirements of Chapter 5 of the Guidelines are to be satisfied;

Cx : Smart cargo management, for which the requirements of Chapter 6 of the Guidelines are to be satisfied;

Ix : Smart integration platform, for which the requirements of Chapter 7 of the Guidelines are to be satisfied;

x : Annotation for the optional function. One small letter stands for an supplementary for a optional function. An optional functional notation may have several annotations. Detailed requirements are given in Chapters 2 to 7.

1.4.3 The assignment, maintenance, suspension, cancellation and reinstatement of **Smartship** class notation are to be in accordance with the relevant requirements of Chapter 1 of Part I of the Rules for Steel Ships.

1.5 Computer Systems

1.5.1 Relevant hardware and software of smart systems covered by the Guidelines are to satisfy the relevant requirements in 2.7 of Part VIII of the Rules for Steel Ships and to be subject to plan approval and survey by the Society.

1.5.2 Software development is to satisfy the requirements of IACS UR E22 On Board Use and Application of Computer based systems.

1.5.3 Risk assessment is to be carried out to the computer system. During system design and assessment, relevant failure conditions and system response to such failure conditions are to be determined. The interaction between faults is to be eliminated or restricted by means of design of software and hardware of relevant equipment while fault detection and tolerance are to be provided. In addition to the software testing within the normal range, the testing in abnormal range is also to be carried out, in order to ensure correct response ability of equipment and software under abnormal input and condition.

1.6 Personnel Requirements

1.6.1 The owner or ship management company is to develop corresponding management regulations, training plans and operational procedures for smart systems, in order to specify requirements such as responsibilities, qualifications and training of personnel operating and using smart systems.

1.6.2 Relevant personnel are to receive pre-post training, obtain qualification, and be familiar with the operation of smart system.

1.7 Cybersecurity Requirements

1.7.1 Ships assigned with notations as specified in the Guidelines for **Smartship** are to take measures to minimize the risks of cyber security during ship design and operation, in compliance with the requirements of the CR Guidelines on cyber security onboard ships.

CHAPTER 2 SMART HULL

2.1 General Requirements

2.1.1 The requirements of this Chapter apply to ships for which functional notation for smart hull is requested.

2.1.2 System software related to hull maintenance is to satisfy the requirements for category I computer software in IACS UR E22.

2.1.3 System software related to hull monitoring and assistant decision-making is to satisfy the requirements for category II computer software in IACS UR E22.

2.2 Functional Notation for Smart Hull

2.2.1 Upon request, the following functional notation for smart hull may be assigned subject to satisfactory plan approval and survey by the Society:

H_X

where:

H : the ship with the basic function of smart hull specified by 2.3;

x : Annotation for supplementary function, expressed by the following small letters:

h : hull maintenance;

m : hull monitoring and assistant decision-making.

2.3 Basic function of smart hull (H)

2.3.1 To conduct a ship-specific load and operation based structural health estimation, the following data and analysis are to be employed:

(a) Ship-specific environmental and sea loads and loading history. The wave loads can be either obtained through direct onboard measurements or derived from hindcast data with the assistance of ship routing or position history.

(b) Ship-specific operational data such as history of cargo and other payload and loading pattern, ship speed, heading, draft, and trim.

(c) Structural strength assessment and damage prediction using the ship-specific load and operation data.

(d) Accumulated fatigue damage and damage rate estimation using the ship-specific load and operation history.

2.3.2 Plans and documents

(a) The following plans and documents are to be submitted to the Society for approval:

(i) System composition and function explanation.

(b) The following documents are to be kept onboard the ship:
(i) The latest hull thickness measurement report;
(ii) The latest hull thickness measurement data analysis report;

2.4 Hull Maintenace (Hh)

2.4.1 General requirements

(a) To provide assistant decision-making for hull and deck machinery maintenance and structural renewal during in-service period of the ship based on the establishment and maintenance of hull database system and three-dimensional hull structural models.

(b) Hull maintenance includes the following functions:
(i) Development of hull inspection and maintenance scheme;
(ii) Development of deck machinery inspection and maintenance scheme;
(iii) Recording and assessment of hull structural conditions;
(iv) Development of structural renewal plan.

(c) Hull database system is to be able to integrate data of three-dimensional hull structural models, hull and deck machinery inspection and maintenance data, structural thickness measurement data and structural repair data.

2.4.2 Three-dimensional hull structural model

(a) A visual three-dimensional hull structural model is to be established to store and transmit data produced from the ship in service in standardized electronic data forms, which should be timely maintained and updated for the in-service period of ship.

(b) The three-dimensional hull structural model is to fully describe the actual hull structure, normally including at least plates (including properties such as thickness, materials), stiffeners (including properties such as structural scantling, material) and large brackets (including properties such as thickness, materials), etc.

(c) Thickness change of hull structure is recorded and corrosion trend is predicted based on the three-dimensional hull structural model.

(d) Hull structural repair data during ship in-service are recorded based on the three-dimensional hull structural model.

2.4.3 Development of hull inspection and maintenance scheme

(a) Hull inspection and maintenance scheme means to develop a periodical inspection and maintenance scheme for hull structure using computer system, based on classification/statutory survey requirements for ships in service and the request from the ship operator, for guiding the crew to carry out routine inspection, maintenance and repair. This system is to satisfy the requirements from (b) to (f) below.

(b) General inspection items, critical area and typical defect diagram are to be developed in accordance with the characteristics of hull structures.

(c) The inspection results of coating and structure in each structural area of ship compartments are to be recorded. The inspection results of coating and structure, structural corrosion condition, defects and repair history are to be shown intuitively, including the following:

(i) Inspection standards and grading principle are to be established for "coating, average corrosion, pitting corrosion, grooving corrosion, deformation and crack", generally consisting of GOOD, FAIR and POOR.

(ii) In accordance with the inspection results of each structural area of ship compartments, the condition of each structural area and the compartment as a whole is to be graded, generally consisting of GOOD, FAIR and POOR.

(iii) For structural areas graded as FAIR or POOR, the system is to provide necessary reminder and follow up.

(d) The survey history of hull structures, information on the size of structural members of hull structures, historical data of thickness measurement, defect and repair history are reviewed.

(e) The coating area and the weight of structural members during ship repair are calculated. The repair work amount is assessed.

(f) In addition to the periodical inspection and maintenance scheme, based on structural thickness records and assessment, the practical condition and reliability of the ship are analyzed comprehensively and an interim inspection and maintenance scheme of hull structures is developed.

2.4.4 Development of deck machinery inspection and maintenance scheme

(a) Deck machinery inspection and maintenance scheme means to develop a periodical inspection and maintenance scheme for deck machinery using computer system, considering the characteristics of deck machinery, based on classification/statutory survey requirements for ships in service and the request from the ship operator, for guiding the crew to carry out routine inspection, maintenance and repair.

2.4.5 Recording and assessment of hull structural conditions

(a) For hull structural thickness recording and assessment, the data of structural thickness is recorded within the in-service period of ship from completion of construction to decommissioning by using computer systems and based on the three-dimensional hull structural model, for which the requirements of (b) to (c) below are to be satisfied.

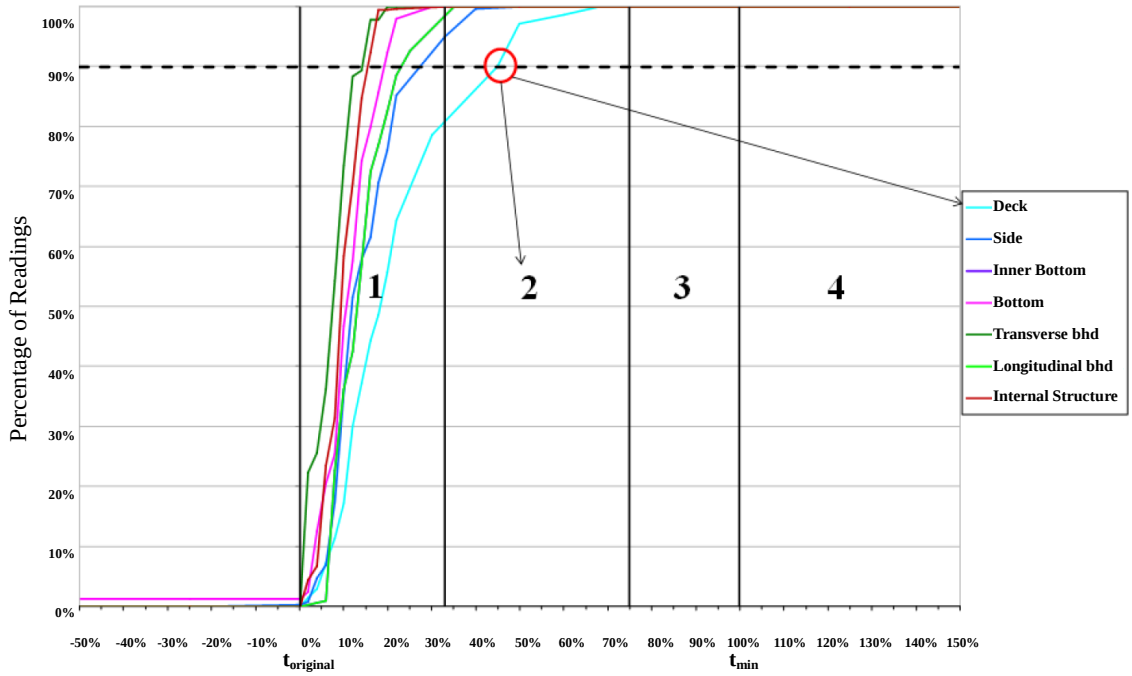
(b) Previous thickness measurement data and renewal history of structural members are recorded. Statistical analysis is carried out to previous thickness measurement data. Grading of corrosion condition of hull structures is shown intuitively and the trend of corrosion is predicted based on the change of thickness of structural members and the environment. Thickness measurement data analysis report is output.

(c) The thickness measurement data is analyzed and graded in accordance with the following requirements or other equivalent methods based on collected thickness measurement data:

(i) The hull structure is divided into several compartments/spaces/areas, e.g. ballast tanks, cargo tanks (including void spaces, pump rooms etc.) and external structures (exposed strength deck and shell plating). For the thickness measurement data of each compartment/space/area, the statistical analysis method of 90% reliability (S-Curve method) is used for analysis.

(ii) The grading result of thickness measurement is determined based on the grading section where the intersection point of 90% horizontal line (e.g. the horizontal dotted line in the figure below) and thickness measurement curve is located (e.g. the thickness measurement of deck is assessed as grade 2 in the figure below).

Cumulative Distribution Curve of Thickness Diminutions (Example)



Diminution Percentage (Relative to Class Allowable Margin)

(iii) For the boundary and structural members of each compartment/space/area, they are in general divided into several structural elements (including plates and attached stiffeners), e.g.: deck structure, side structure, bottom structure, inner bottom structure, transverse bulkhead structure, longitudinal bulkhead structure and internal structure (hatch cover and coaming are also to be included where applicable). Each structural element is divided into grade 1 to 4 as follows:

	Grade			
	1	2	3	4
Diminution percentage, r	$r \leq 33\%$	$33\% < r \leq 75\%$	$75\% < r \leq 100\%$	$r > 100\%$

(iv) For compartments/spaces with common boundaries, the thickness measurement data of the common boundary is to be included in the compartment/space on both sides respectively.

2.4.6 Development of structural renewal plan

(a) The report on structural renewal plan is to be developed and output based on thickness measurement data and corrosion trend prediction results, including renewal scope, calculation of renewed steels, workload assessment, etc.

2.4.7 Plans and documents

(a) In addition to 2.3.2, the following plans and documents are to be submitted to the Society for approval:

(i) Composition and description of three-dimensional hull structural model;

(b) In addition to 2.3.2, the following documents are to be kept onboard the ship:

(i) Documents related to hull and deck machinery inspection and maintenance schemes.

2.4.8 Survey and test

(a) Prior to completion of construction of ship, the initial survey at least includes the following items:

(i) Examining the approval certificate of system software.

(ii) The systems for hull and deck machinery inspection and maintenance schemes have been installed on board the ship and operate normally.

(iii) General inspection items, critical areas and inspection interval of hull inspection and maintenance scheme satisfy requirements.

(iv) Personnel carrying out hull and deck machinery inspection and maintenance on board the ship have been trained by the Society or an organization accepted by the Society.

(b) The annual/intermediate/special survey is at least to include the following items:

(i) The information specified by above 2.4.7(b) is to be kept on board the ship.

(ii) The thickness data of structural members and renewal history recorded in the hull database are consistent with practical conditions.

(iii) The analysis report of hull thickness measurement data satisfies the requirements of above 2.4.5(c).

(iv) Personnel carrying out hull and deck machinery inspection and maintenance on board the ship have been trained by the Society or an organization accepted by the Society.

(v) Witnessed by the Surveyor, personnel on board the ship randomly select at least two ballast tanks for internal inspection, correctly determine the coating and structural conditions of the structural area under inspection and correctly enter the identified problem and assessed grade into the computer system.

(vi) The records in the computer system of hull and deck machinery inspection and maintenance scheme are complete and consistent with practical conditions.

2.5 Hull Monitoring and Assistant Decision-Making System (Hm)

2.5.1 General requirements

(a) The hull monitoring and assistant decision-making system collects, stores, analyzes and displays data such as hull structural stress, ship motion, ship loading, sea state, course and speed, which gives warning in case the change of such data exceeds the preset critical value and provides assistant decision-making on operation of ship.

(b) The hull monitoring and assistant decision-making system is to include the following functions:

(i) Collecting and monitoring important parameters related to the safety of hull;

(ii) Storing collected data;

(iii) Carrying out calculation and abnormal analysis in accordance with the data collected by the monitoring system;

(iv) Capable of giving alarms in a timely manner in case the analytical result is abnormal;

(v) Providing decision-making suggestions on ship operation in accordance with alarm parameters;

(vi) Analyzing and recording sea state information and navigation parameters by link to the loading computer, gyro-compass and anemorumbometer, etc.

(c) Hull monitoring system is to comply with appropriate techniques or recognized standards accepted by the Society.

2.5.2 Parameter monitoring

(a) The following data are to be obtained from hull monitoring:
  (i) Sea environment data, e.g. wind force, wind direction, wave;
  (ii) Ship navigation parameters, e.g. course, speed;
  (iii) Ship motion and acceleration, at least including pitch, roll and heave;
  (iv) Ship floating condition, including draught of bow, midship and stern (port and starboard).

(b) Hull structural monitoring parameters normally including the following according to the stress distribution feature of ship types:
  (i) The longitudinal strength of the hull structure;
  (ii) Stress in the critical structural areas;
  (iii) Temperature of the structural members affected by high or low temperature;
  (iv) Bow slamming pressure (for applicable ship types);
  (v) Liquid sloshing in tanks (for applicable ship types);
  (vi) Structural stress of ice belt region of ice-reinforced ships;
  (vii) Relevant monitoring parameters may be determined or further added in accordance with practical conditions of ship and safety needs.

(c) Ship loading state is to be obtained from hull monitoring, normally including:
  (i) Cargo hold loading volume (where applicable);
  (ii) Ballast tank loading volume (where applicable);
  (iii) Fuel oil, fresh water.

2.5.3 Assistant decision-making

(a) Based on alarms from hull monitoring during navigation, cargo loading and unloading at docks and ballast water exchange, hull monitoring and assistant decision-making system is to be capable of providing appropriate assistant decision-making. Normally the following requirements are to be considered:
  (i) during navigation, monitoring the hull’s:
    (1) longitudinal strength;
    (2) local strength (including critical structural areas) strength ;
  (ii) during cargo loading and unloading at docks and during ballast water exchange:
    (1) carrying out ship stability calculation (or obtain it from the loading instrument);
    (2) monitoring the hull’s longitudinal strength ;
  (iii) In case of an abnormal situation, an alarm is to be timely activated, cause analysis will be carried out and appropriate operational suggestions will be provided, such as to adjust ballast water, loading/unloading, course, speed, etc. so as to ensure that the ship's longitudinal strength and stability are in safe condition;
  (iv) Relevant safety assessment and analysis and assistant decision-making requirements may be added in accordance with practical conditions of ship and safety needs.

2.5.4 Plans and documents

(a) In addition to 2.3.2 and 2.4.7, the following plans and documents are to be submitted to the Society for approval:
  (i) Arrangement of sensors.

(b) In addition to 2.3.2 and 2.4.7, the following plans and documents are to be submitted to the Society for information:

(i) System diagram;

(ii) System operating manual;

(iii) System hardware specification;

(iv) System instructions;

(v) System testing procedure.

(c) The following documents are to be kept onboard:

(i) The operating manual of hull monitoring and assistant decision-making system, which is at least to include description of the following:

(1) operation;

(2) setting and calibration of sensors and the system;

(3) failure identification;

(4) repair;

(5) system maintenance and functional tests (showing testing methods for the components and the system and what is to be observed during tests);

(6) explanations of test results.

(ii) Maintenance and calibration log of hull monitoring and assistant decision-making system.

2.5.5 Survey and tests

(a) Prior to completion of construction of the ship, the initial survey for hull monitoring and assistant decision-making system is at least to include the following items:

(i) Confirming that relevant plans have been examined;

(ii) Confirming that system hardwares (including sensors) are furnished with relevant certificates;

(iii) Confirming that software systems are approved;

(iv) After completion of installation of the system and equipment, survey and test are to be carried out in accordance with testing procedures to verify system function and effectiveness.

(b) During annual/intermediate/special surveys, at least the following items are to be examined for the hull monitoring and assistant decision-making system:

(i) Examining whether the system operates effectively;

(ii) Examining the detailed working record of the system;

(iii) Examining the repair record of system equipment;

(iv) Confirming that the historical and analytical data are complete and carrying out random examination of report contents;

(v) Confirming that operators are familiar with the hull monitoring and assistant decision-making system and confirming the implementation condition;

(vi) Examining and confirming that relevant instrumentation of the hull monitoring and assistant decision-making system has been calibrated in accordance with specified procedures and plans.

(c) In case of any fault of the hull monitoring and assistant decision-making system, or any damage, repair or renewal of equipment, or any major change to the means of monitoring, the owner or ship management company is to apply for an occasional survey.

CHAPTER 3 SMART MACHINERY

3.1 General Requirements

3.1.1 The requirements of this Chapter apply to ships for which functional notation for smart machinery is requested.

3.1.2 Smart machinery is capable of carrying out analysis and assessment of the operating condition and health condition of the equipment and systems in machinery space by comprehensively using various information and data collected by the condition monitoring, thus providing support for decision-making on the usage, operation and control, servicing and repair, and management, etc. of the equipment and systems.

3.1.3 Smart machinery is to have the following basic functions:

(a) Carrying out monitoring of the operating condition of the equipment and systems related to main propulsion in machinery space;

(b) Carrying out analysis and assessment of the operating condition and health condition of the equipment and systems based on the condition monitoring data;

(c) Providing reasonable suggestions based on the result of analysis and assessment, in order to provide support for decision-making on the usage, operation and control, servicing and repair, and management, etc. of the equipment and systems;

(d) Main propulsion machinery is to be capable of being remotely controlled from bridge control station, and machinery space including machinery centralized control station is periodically unattended.

(e) During the unattended period, the equipment and systems in machinery space are to be capable of continuous and normal operation.

3.1.4 In addition to the basic functions of 3.1.3, relevant condition-based maintenance plan may be developed based on the result of analysis and assessment of the operating condition and health condition of the equipment and systems, which is used as the supplementary function of smart machinery .

3.1.5 For small ships or other ships not engaged in transport of cargoes, designers may consult the Society to agree on the basic functions and associated requirements for smart machinery.

3.1.6 The condition monitoring scope of the equipment and systems may be determined through risk analysis, subject to the agreement by the Society.

3.1.7 For a ship directly propelled by conventional main propulsion diesel engine applying for smart machinery functional notation **M**, at least the following equipment and systems shown in Table 3-1 is to be monitored:

Table 3-1
List of Equipment and Systems Being Monitored

No.	Name of equipment/systems	Monitoring Scope (e.g. equipment/parts/performance, etc.)	Monitooring Purpose (e.g. condition, function, performance, etc.)
1	Main diesel engine (direct propulsion)		
1.1		Cylinder combustion	Combustion condition
1.2		Cylinder liner	Sealing, heat transfer
1.3		Piston head (including piston ring)	Sealing, heat transfer
1.4		Cylinder cover (including intake valve and exhaust valve)	Sealing, heat transfer
1.5		Fuel nozzle/valve	Injection, atomization
1.6		Friction parts, e.g. main bearings, crankpin bearings, crosshead bearings (if fitted) and camshaft bearings, etc.	Wear, lubrication condition
1.7		Crankcase	Explosion-proof
1.8		Turbocharger	Turbocharging performance
2	Diesel engine for propulsion and/or auxiliary power generation		
2.1		Cylinder cover (including intake valve and exhaust valve)	Sealing, heat transfer
2.2		Cylinder liner	Sealing, heat transfer
2.3		Fuel nozzle/valve	Injection, atomization
2.4		Friction parts, e.g. main bearings	Wear, lubrication
2.5		Turbocharger	Turbocharging performance
3	Shafting for propulsion		
3.1		Gearbox (if any), e.g. bearings	Wear
3.2		Shaft and bearings	Wear, sealing condition
4	Auxiliary system		
4.1	Fuel (oil) system		
4.1.1		Fuel (oil) pump	Fuel (oil) supply capacity
4.1.2		Filter	Filtering of impurities
4.1.3		Heat exchanger (if fitted)	Heat exchange performance
4.2	Lubricating oil system		
4.2.1		Lubricating oil pump	Oil supply capacity
4.2.2		Filter	Filtering of impurities
4.2.3		Heat exchanger	Heat exchange performance
4.3	Cooling system		
4.3.1		Pump	Cooling medium supply capacity
4.3.2		Heat exchanger	Heat exchange performance
4.3.3		Filter	Filtering of impurities
4.4	Hydraulic (servo) oil system		
4.4.1		Hydraulic oil pump	Oil supply capacity
4.4.2		Filter	Filtering of impurities
4.5	Starting and control air system		Air supply capacity
4.6	Air intake (four-strooke)/Scavenging (two-stroke) system		Quality of cylinder combustion air
4.7	Exhaust gas system		Exhaust perforomance
4.8	Power supply for control-safety-alarm system (electrical, pneumatic, hydraulic)		Power supply capacity

3.1.8 For an electric propelled ship applying for smart machinery functional notation **M**, the diesel engine for propulsion or auxiliary power generation as well the auxiliary systems are to be monitored according to the applicable requirements specified in Table 3-1. In addition, the following equipment and systems shown in Table 3-2 are to be monitored:

Table 3-2
List of Equipment and Systems Being Monitored (Electric Propulsion)

No.	Name of equipment/systems	Monitoring Scope (e.g. equipment/parts/performance, etc.)	Monitooring Purpose (e.g. condition, function, performance, etc.)
1	Generator		Overall working condition
1.1		Stator	Condition of stator, e.g. winding inter-turn insulation
1.2		Rotor	Condition of rotor, e.g. rotor balance, inter-turn condition, eccentricity condition
1.3		Bearing	Wearing condition
1.4		Excitation and AVR	Excitation and voltage regulating condition
2	Switchbooard		Overall working condition Quality of power supply Insulation status
2.1		Main bus bar and circuit breaker	Condition of circuit breaker and bus bar overcurrent capacity etc.
3	Transforomer		
3.1		Winding	Working condition of winding
4	Motor driver		
4.1		Power electronics	Overall working condition
4.2		Braking resistance	Overload condition
5	Propulsion motor		
5.1		Stator	Condition of stator, e.g. winding inter-turn insulation
5.2		Rotor	Condition of rotor, e.g. inter-turn condition (synchronous motor), balance condition, eccentricity condition, broken rotor (induction motor)
5.3		Bearing	Wearing condition
6	Auxiliary system		
6.1		Cooling system (water-cooling, air-cooling)	Cooling condition
7	Propeller		
7.1		Sealing device	Sealing condition
7.2		Bearing device	Wearing condition

3.1.9 The condition monitoring and health assessment system is to be approved by the Society.

3.1.10 Where the health assessment result is intended to be used for the development of the maintenance plan for the equipment and systems in machinery space, the applicant is to provide sufficient evidence to demonstrate that the condition determined by condition monitoring is at least equivalent to that determined by direct inspection, and the implementation of condition-based maintenance may be carried out after approval by the Society.

3.1.11 For the equipment and systems already covered by the condition-based maintenance, their items subject to overhaul examination may be handled in accordance with the condition-based maintenance plan. For equipment and parts not included in the condition-based maintenance, maintenance and survey are still to be carried out in accordance with the Planned Maintenance System (PMS).

3.1.12 Condition monitoring, health assessment and assistant decision-making (including condition-based maintenance) are to comply with, in addition to the requirements in this Chapter, relevant requirements in 1.6.4(h) of Part I of the Rules for Steel Ships and IACS Z27.

3.1.13 Upon completion of installation of the condition monitoring and health assessment system on board the ship, an initial survey is to be carried out in accordance with the provisions of 3.5.1 of this Chapter to verify that the condition monitoring and health assessment is carried out in accordance with approved procedures and plans, and that the relevant system can operate effectively as intended.

3.1.14 For the purpose of this Chapter:

(a) Condition monitoring (CM) means the process of acquiring and processing of information and data that indicate the state of equipment. The equipment state deteriorates if faults or failures occur.

(b) Health assessment means a process of analyzing and assessing of the operating conditions and health conditions of the equipment and systems basing on the condition monitoring data.

(c) Assistant decision-making means proposing suggestions based on the condition monitoring and health assessment results of the equipment and systems, in order to provide support for decision-making on the usage, operation and control, servicing and repair, and management, etc. of the equipment and systems.

(d) Condition-based maintenance (CBM) means to carry out maintenance in accordance with the results of condition monitoring and health assessment of the equipment and systems.

(e) Baseline data means the data measured and obtained when the performance of equipment and their parts reaches or at the initial healthy condition, which is used as the baseline for the analysis and comparison of health condition of equipment and their parts, and which is generally measured on board the ship.

(f) Reference conditions means the specified conditions for acquisition of monitoring data, including the operating conditions of monitored equipment (e.g. temperature, pressure, rate of revolution etc.), the operating conditions of ship (e.g. ship speed and draft) and relevant environmental conditions (e.g. temperature, pressure, sea state, wind speed etc.).

3.2 Functional Notation for Smart Machinery

3.2.1 Upon request, the following functional notation for smart machinery may be assigned subject to satisfactory plan approval and survey by the Society:

M_X

where:

M : the ship with the basic function of smart machinery specified by 3.1.3;

x : Annotation for supplementary function, expressed by the following small letters:

m : the condition-based maintenance is implemented for main propulsion engine(s) and parts;

a : the condition-based maintenance is implemented for engines used for auxiliary power generation and its parts;

p : the condition-based maintenance is implemented for propulsion shafting.

3.2.2 For ships applying for smart machinery functional notation **M**, the following prerequisites are to be satisfied:

(a) Relevant requirements for **CAU**, **CAB** notation in Part VIII of the Rules for Steel Ships;

(b) Relevant systems and equipment for condition monitoring, health assessment and assistant decision-making are provided.

3.2.3 For ships applying for smart machinery functional notation **Mx**, in addition to complying with the requirements of 3.2.2, the following prerequisites are to be satisfied:

(a) Relevant requirements for survey of the Planned Maintenance Scheme (PMS) of 1.6.4(g) of Part I of the Rules for Steel Ships are satisfied;

(b) Condition-based maintenance is applied for relevant equipment and systems.

3.3 Plans and Documents

3.3.1 For ships applying for the functional notation for smart machinery, the following applicable plans and documents are to be submitted:

(a) Condition monitoring and health assessment system diagram;

(b) Onboard installation and arrangement of main equipment of the condition monitoring and health assessment system

(c) List and description of monitored equipment and systems, at least including the following information of each equipment and part:
  (i) monitoring condition and/or fault, e.g. combustion condition in the cylinder, wear condition of bearing and performance of turbocharger;
  (ii) monitoring parameters and normal range, e.g. temperature, pressure, flow and vibration;
  (iii) monitoring devices/sensors;
  (iv) monitoring procedures;
  (v) condition analysis/assessment method;
  (vi) acceptance criteria.

(d) Detailed information on condition monitoring and health assessment system, generally including the following:
  (i) system principle, functions, operating and maintenance description;
  (ii) system hardware description, e.g. sensor, data acquisition device, data storage/backup device;
  (iii) software description, e.g. data processing and analysis method, fault diagnosis method and condition assessment method;

(iv) type and content of output data/information.

(e) List and descriptions of systems and equipment subject to condition-based maintenance;

(f) Procedures and schedules related to implementation of condition monitoring, health assessment and auxiliary decision-making, including:
(i) onboard testing procedures;
(ii) procedures and schedules for data collection;
(iii) procedures and schedules for data storage/backup;
(iv) procedures and schedule s for data analysis;
(v) output of assessment result/report;
(vi) procedures and schedules for calibration of monitoring devices.

(g) Relevant information on the company (if applicable), at least including:
(i) structure diagram of relevant posts (responsibilities) of company;
(ii) working flow, including goal, method and strategy;
(iii) training plan and qualification requirements for relevant personnel carrying out assistant decision making and condition-based maintenance.

3.4 System Requirements

3.4.1 General requirements

(a) Computer systems covered by this Chapter are to be designed, manufactured, surveyed and tested in accordance with the requirements for category II computer systems in IACS UR E22.

(b) Relevant parameters necessary for condition monitoring and health assessment are to be collected by selecting appropriate measurement technology/method. Such parameters are to be appropriate for displaying the trend of condition change of the equipment and systems within a period of time. The measurement data is to be documented in a standard format to be suitable for read and use.

(c) The trend analysis based on condition monitoring data is to be feasible and convenient. The obtained trend data is to display condition change clearly. The analysis and assessment result is to be described intuitively.

(d) Sensors used in condition monitoring are in general to be a fixed type. Where it is impracticable to fit fixed sensors, other equivalent means of measurement may be used subject to the agreement of the Society. Where portable instruments are used, the position of relevant measurement points and the direction of measurement (parameters related to direction) are to be permanently marked. For the connection of sensors to measurement points, the influences of any human factor are to be excluded. The measurement results are to be entered into the condition monitoring system according to a specified procedure and plan so as for health assessment.

(e) The condition monitoring data may be collected via the ship alarm system provided that the normal function of ship alarm and safety system is not affected.

(f) The data of condition monitoring is to be stored according to a specified procedure and plan, which may be replayed and displayed at any time as necessary.

(g) Necessary data backup equipment is to be provided.

(h) For a condition monitoring and health assessment system of novel design, the designer may consult with the Society to determine the requirements for system design, installation, measurement, test and survey, etc.

3.4.2 Assistant decision-making

(a) Analysis and assessment of operation state and health condition of the equipment and systems in machinery space is to be carried out based on monitoring data, and reasonable suggestions are to be provided as a foundation for decision-making on operation and management of the equipment and system, taking into account the knowledge base that has been established for the system.

(b) The knowledge base used in decision-making is to be updated and improved continuously with the accumulation of experience in system operation and the update of knowledge.

(c) The assessment report of operating and health condition of the equipment and systems as well as suggestions on decision-making are to be output.

(d) Historical data on operating and health condition of the equipment and systems are to be easily searchable and relevant records required by survey can be output.

(e) Where the shore-based supporting method is used for analysis, assessment and decision-making, etc., the related shore-based system is also to be considered as part of the decision support system, and the submitted plans and documents are to include information on the function, design, operation and maintenance of the related shore-based system.

3.4.3 Condition-based maintenance

(a) The condition-based maintenance plan is to be capable of being developed based on the health assessment results of equipment and systems.

(b) For the ship implementing condition-based maintenance, the maintenance plan is to be capable of being updated bases on the monitoring information during ship in-service.

(c) Spare parts on board the ship are to consider the needs of the condition-based maintenance plan.

(d) The system related to condition-based maintenance is to be capable of producing the following records:

List of check items of equipment conducting condition-based maintenance;

Records of condition-based maintenance service, examination and repair of fault.

(e) Data and information related to condition-based maintenance are to be stored, and relevant information required by survey can be output.

(f) The historical data of condition-based maintenance plan can be queried at any time as necessary.

(g) Where the shore-based supporting method is used for condition-based maintenance, relevant plans and procedures are to be submitted to the Society for approval.

3.4.4 Condition monitoring

(a) One or more applicable monitoring techniques are to be selected based on the monitored object, goal and purpose. Detailed instructions are to be provided for each monitoring technique that is selected.

(b) Where the oil analysis technique is used for condition monitoring and health assessment of diesel engines and propeller shafts, the requirements of appropriate techniques or recognized standards accepted by the Society and 2.3.4 of Part I of the Rules for Steel Ships are to be satisfied respectively.

Where the oil analysis technique is used for condition monitoring of other equipment, the implementation may refer to the requirements above and the following requirements are at least to be considered:

(i) All oil samples are collected by designated personnel.

(ii) Representative oil samples are normally taken during normal operation period of equipment.

(iii) The sampling period is determined in accordance with type, rate of revolution, working condition and performance of equipment.

(iv) Sampling points are to be clearly identified and permanently marked.

(v) The oil analysis report is to be provided by a company approved by the Society. In case the analytical result exceeds the range allowed by standards, the ship manager or ship owner is obligated to report to the Society in a timely manner.

(c) In order to ensure the normal function of monitoring equipment and correct measurement result, functional test and periodical calibration are to be carried out in accordance with approved procedures and plans. Test and calibration are to be recorded.

(d) The monitoring data is to be measured in accordance with an appropriate time internal and sampling frequency. Data are in general to be measured in the reference condition. Where the reference condition cannot be met during practical measurement, the measured value is to be corrected to the value in the reference condition. The correction method and other related information are to be submitted to the Society for approval.

(e) The record of monitoring parameters is at least to include the following information:

(i) General information describing the equipment and systems;

(ii) Measurement position;

(iii) The unit and processing method of the measured data;

(iv) Information on measurement date and time.

(f) The baseline data of the equipment and systems are to be measured in the initial healthy condition (after the run-in period) or obtained by other means. The reference condition during measurement is to be documented.

(g) The baseline data are in general to be measured during shipboard trials and the following requirements are to be complied with:

(i) Baseline data are to be measured by designated personnel;

(ii) The measured baseline data are to cover the expected operating conditions of the equipment and systems;

(iii) The effectiveness of the measured baseline data used for fault diagnosis and health assessment is to be assessed.

(iv) For new equipment or equipment after major conversion, the baseline data is to be measured after a period of running in.

(h) The maintenance and/or repair of the equipment and systems are to be recorded and identified on the condition trend curve. After the repair of equipment, relevant monitoring parameters are to be measured, and the newly measured data is to be compared with the historical data (before repair) for examination of any deviation. The measurement data and deviation are to be documented.

(i) Any fault/failure of the condition monitoring system is to be recorded in the annual report specified in 3.5.2(b) of this Chapter. Any major fault /failure which affects the trend analysis of measurement data is to be repaired immediately. In case parameters cannot be measured as planned due to such fault/failure, the Society is to be notified.

3.5 Survey and Test

3.5.1 Initial survey

(a) The initial survey is at least to include the following items:

(i) Confirming that plans and documents have been examined.

(ii) Confirming that the condition monitoring and health assessment system has been approved.

(iii) Confirming that the designated operating personnel have completed relevant training as required and are able to perform duties correctly.

(iv) After completion of installation of relevant systems and equipment, tests are carried out in accordance with the approved testing procedures.

(v) Checking the condition-based maintenance plan and implementation procedures (if applicable) to ensure that the contents are consistent with real ship.

(vi) Confirming that relevant plans and documents, manuals, procedures and relevant records are kept on board the ship.

3.5.2 Survey after construction

(a) For ships which are assigned the functional notation for smart machinery, the survey is to be carried out in connection with the annual/intermediate/special survey of ship, in order to verify the normal function of systems related to smart machinery.

(b) Prior to the annual survey, the owner or ship manager is to submit to the Society an annual report on systems related to smart machinery, which at least is to include the following items from last annual survey:

(i) Maintenance records of systems related to smart machinery;

(ii) General operating condition of systems related to smart machinery;

(iii) Fault/failure conditions and cause analysis of the monitored equipment;

(iv) Repair records and replacement of spare parts of the monitored equipment.

(c) At annual survey, in addition to examining the annual report submitted by the owner (ship), the Surveyor is also to examine the following items on board the ship:

(i) Examining whether the systems related to smart machinery operate effectively;

(ii) Examining detailed working records of the systems related smart machinery;

(iii) Examining repair records of the equipment and systems which are monitored. For replacement of important components and parts, the spare parts are to satisfy the certification requirements of CR Rules;

(iv) Confirming that the historical data, trend analysis data, lubricating oil analysis report and vibration analysis report of systems related to smart machinery are complete and carrying out random examination of report contents;

(v) Confirming that operators are familiar with systems related to smart machinery and confirming the implementation condition;

(vi) Some testing and analysis processes need to be verified if deemed necessary by the Surveyor;

(vii) Examining and confirming that relevant instrumentation have been calibrated in accordance with specified procedures and plans;

(viii) The maintenance of equipment included in the condition-based maintenance is to be confirmed.

CHAPTER 4 SMART ENERGY EFFICIENCY MANAGEMENT

4.1 General Requirements

4.1.1 The requirements of this Chapter apply to ships for which functional notation for smart energy efficiency management is requested.

4.1.2 Smart energy efficiency management means to evaluate ship energy efficiency condition, navigation and loading condition based on the monitoring data and information on ship navigational condition and energy-consuming condition, and provide evaluation results and solutions for speed optimization and optimal stowage based on trim optimization, so as to realize real-time monitoring, evaluation and optimization of ship energy efficiency, and continuously improve level of energy efficiency management of ship.

4.1.3 Smart energy efficiency management is to have following basic functions:

(a) Online monitoring and automatic data collection of ship navigational condition, energy efficiency and energy-consuming condition;

(b) Providing evaluation, report and alarm on ship energy efficiency and energy-consuming condition;

(c) Providing assistant decision-making recommendations for energy efficiency management according to analysis and evaluation results.

4.1.4 In addition to basic functions specified in above 4.1.3, smart energy efficiency management may also have following additional functions:

(a) Providing speed optimization plan based on different objectives and in combination with evaluation results of route characteristics, fuel oil consumption and cost effectiveness;

(b) Providing optimal stowage plan based on trim optimization according to initial loading and ship's optimal navigation state analysis.

4.1.5 If the smart energy efficiency management functions provided in the above 4.1.3 and 4.1.4 do not apply to some ships not engaged in transport of cargoes, designers may consult the Society to agree on the functions and associated requirements for smart energy efficiency management.

4.1.6 Relevant definitions and abbreviations in this Chapter are as follows:

(a) EEOI means ship's energy efficiency operation index, i.e. the ratio of mass of CO_2 emitted per unit of transport work.

(b) MRV means monitoring, reporting and verification of CO_2 emissions from maritime transport.

(c) Emission control area (ECA) means the area requiring special compulsory measures to be taken to ship emission so as to prevent, reduce and control atmospheric pollution due to NOx or SOx and particulate matters or all three emission types, which will then cause adverse effect on human health and environment.

(d) Main energy-consuming equipment means main energy-consuming equipment including main engine, auxiliary engine, boiler and gas turbine and inert gas generator, etc.

(e) Transportation work means product by multiplying the distance travelled with the amount of cargo carried.

4.2 Functional Notation for Smart Energy Efficiency Management

4.2.1 Upon request, the following functional notation for smart energy efficiency management may be assigned subject to satisfactory plan approval and survey by the Society:

Ex

where:

E : the ship has basic functions of smart energy efficiency management as specified in 4.1.3;

x : annotation for supplementary function, expressed by the following small letters:

s : speed optimization;

t : optimal stowage based on trim optimization.

4.2.2 Ships applying for the functional notation for smart energy efficiency management are to satisfy requirements for basic functions required by 4.1.3 of this Chapter. If relevant requirements for speed optimization and/or optimal stowage based on trim optimization are also satisfied, corresponding supplementary functional notations may be assigned.

4.3 Plans and Documents

4.3.1 The following plans and documents are to be submitted to the Society:

(a) Composition and explanation of energy efficiency on-line monitoring system, which is to include the following information:
  (i) explanation of equipment composition;
  (ii) monitoring method and parameters;
  (iii) special explanation on installation processes and positions of monitoring equipment (if necessary);
  (iv) method for analyzing and evaluating energy efficiency/energy consumption;
  (v) (initial) set value of energy efficiency/energy consumption evaluation criteria;
  (vi) type and contents of output data/information.

(b) Electrical system plan of energy efficiency on-line monitoring system (including system power supply, system input and output signal circuit and parameter list);

(c) Electrical system plan and arrangement plan of shaft power measurement device (if fitted);

(d) Arrangement plan of fuel oil flowmeter;

(e) Procedure and plan, including:
  (i) Procedure and plan for data collection/storage;

(ii) Procedure and plan for relevant evaluation results/report output;

(iii) Plan for calibration of monitoring device(s);

(f) Principle, function and instructions of speed optimization system;

(g) Principle, function and instructions of optimal stowage system based on trim optimization;

(h) Test program of energy efficiency management system.

4.4 Ship Energy Efficiency On-Line Smart Monitoring

4.4.1 General requirements

(a) Energy efficiency on-line smart monitoring is to be able to monitor main energy-consuming equipment and ship navigational condition, collect, transmit, store and analyze data, and carry out evaluation and alarm on relevant technical index such as ship's energy efficiency and energy consumption.

(b) It is to be able to carry out periodic general evaluation on ship's energy efficiency condition and provide assistant decision-making recommendations on energy efficiency optimization and improvement.

(c) It is to be able to provide relevant data or analysis evaluation report according to demand and based on the results of monitoring, analysis and evaluation of energy efficiency and energy consumption data.

(d) Computer system of energy efficiency on-line smart monitoring is to satisfy requirements for category I computer system in IACS UR E22, and monitoring device and system are to be approved by the Society.

4.4.2 Monitoring and measurement

(a) It is to be able to carry out real-time collection of relevant data of main energy-consuming equipment, shaft power measurement device (if fitted), electronic fuel oil flowmeter, wind speed and direction indicator, global positioning system, log, electronic clinometer, sounding instrument and ship draft measuring equipment, etc.

Note: The above equipment may be adjusted based on ship types and ship propulsion types.

(b) Monitoring parameters of ship's main energy-consuming equipment, metering equipment and navigational equipment include, but not limited to:

(i) Parameters of power, pressure and temperature of main energy-consuming equipment;

(ii) Parameter of fuel oil consumption of main energy-consuming equipment;

(iii) Parameter of main engine shaft power*;

(iv) Parameter of wind speed and direction;

(v) Parameters of ship position, course and speed;

(vi) Parameter of speed through the water;

(vii) Ship inclination angle;

(viii) Water depth value;

(xi) Ship draft value.

*: Output power of generators for propulsion and/or auxiliary power generation is permitted to be obtained by alternative methods.

(c) Considering the effect of ship deformation and local vibration on measurement of shaft power, the stator installation foundation for shaft power meter (if fitted) is to be welded tight, generally welded on ship's strong components, and welding on hull plating is not allowed.

4.4.3 Data transmission and storage

(a) The system may receive and store equipment parameter data periodically, and the receiving period may be adjusted according to minimum period set of the equipment and management demands.

4.4.4 Energy efficiency and energy consumption calculation

(a) The system is to be able to calculate following energy efficiency and emission index automatically:
(i) EEOI;
(ii) Fuel oil consumption per sea mile;
(iii) Fuel oil consumption per transport work;
(iv) CO_2 emission per sea mile;
(v) CO_2 emission per transport unit.

Note: The above indexes may be adjusted based on ship types and ship propulsion types.

(b) The system is to be able to calculate following index of main energy-consuming equipment automatically:
(i) Fuel oil consumption per hour;
(ii) Fuel oil consumption per day;
(iii) Summary of fuel oil consumption per voyage (leg).

4.4.5 Energy efficiency and energy consumption evaluation

(a) Real-time evaluation of energy consumption of main energy-consuming equipment
(i) Automatically judging ship's navigational status such as mooring, maneuvering navigation and constant speed navigation according to actual operational condition of ship equipment;
(ii) Using real-time data of ship's energy consumption, carrying out comparison and analysis according to set energy consumption evaluation method and criteria, automatically judging energy-consuming condition and outputting evaluation conclusion.

(b) Evaluation of ship energy efficiency and emission index
(i) It is to be able to carry out automatic real-time monitoring of energy efficiency and emission indexes specified in 4.4.4(a). These evaluation indexes may be adjusted based on ship types and comparative analysis with energy efficiency evaluation criteria can be carried out.
(ii) It is to be able to automatically generate yearly, quarterly, monthly and voyage-related index data report according to demands and carry out inquiry when necessary.

(c) Ship's energy consumption distribution analysis
(i) It is to be able to obtain energy consumption distribution proportion and energy utilization efficiency of main energy-consuming equipment by analysis and according to ship's design parameters and relevant plans and information or real ship navigation data;
(ii) It is to be able to output energy consumption distribution data and analysis result of energy utilization efficiency.

(d) Reminding that index exceeds limit

(i) If real-time value of ship's energy efficiency and energy consumption index exceeds set value, the system is to give alarm.

4.4.6 Assistant decision-making on energy efficiency management

(a) General evaluation on ship's energy efficiency and energy consumption condition may be carried out according to voyage and natural period (not exceeding one year).

(b) It is to be able to propose assistant decision-making recommendations on energy efficiency optimization and improvement according to results of comprehensive evaluation.

4.4.7 Assistant management of energy efficiency

(a) Carbon emission monitoring and reporting required by MRV: system is able to monitor carbon emission data required by MRV, and generate relevant report and evidence satisfying verification requirements.

(b) Emission control area (ECA) early warning: system is able to provide early warning for residual nautical miles and residual time within certain area away from ECA according to current ship voyage plan.

(c) Fuel oil information management: management of fuel oil replacement during fuel oil bunkering and navigation, including information management on types of bunkered fuel oil and types of fuel oils before and after fuel replacement.

4.5 Speed Optimization

4.5.1 General requirements

(a) It is to be able to provide speed optimization plan based on different objectives according to voyage plan, fuel oil consumption and general cost effectiveness analysis.

(b) Speed optimization analysis is to generate speed optimization plan according to ship's navigational data and in combination with voyage plan, route characteristics and ship efficiency, fuel oil consumption evaluation results, etc., as well as with navigational cost accounting and analysis results.

(c) Speed optimization function based on different objectives is to include speed optimization based on voyage plan and speed optimization based on cost effectiveness.

(d) Computer system of speed optimization is to satisfy requirements for Category I computer system in IACS UR E22.

4.5.2 Speed optimization based on voyage plan

(a) It is to automatically calculate navigated distance and navigated time based on voyage and leg management functions and according to information including ship's departure port, destination port, departure time, and predicted navigation distance, etc., and forecast arrival time according to residual voyage and current speed.

(b) It is to automatically calculate specific fuel oil consumption under current speed according to parameters such as speed, main propulsion equipment power and fuel oil consumption, calculate oil consumption according to current speed and residual navigation distance and calculate fuel oil consumption for navigated miles and fuel oil necessary for residual miles.

(c) It is to evaluate effect on speed according to set indexes which can reflect ship performance and efficiency during operation and considering the factors such as weather and sea conditions.

(d) During navigation, it is able to provide speed optimization plan according to the analysis of fuel oil consumption rate, ship efficiency, etc.

4.5.3 Speed optimization based on cost effectiveness

(a) Cost management and benefit index evaluation

(i) The system is to provide management functions for all cost involved in ship operation, including freight charge, port charge, fuel price, ship depreciation, material input, crew wages, shore-based personnel wages and management charges;

(ii) The system may check each cost during ship operation and establish evaluation indexes on voyage benefits.

(b) It is to be able to provide speed optimization plan based on cost effectiveness according to evaluation results of benefit index.

4.6 Optimal Stowage Based on Trim Optimization

4.6.1 General requirements

(a) Optimal stowage system based on trim optimization is to have functions such as trim optimization and automatic stowage optimization, and can be used for calculating optimal trim condition under each loading condition.

(b) Optimal stowage system is to satisfy relevant requirements for loading instruments in Appendix 1 of Part I and Chapter 3, PART II of the Rules for Steel Ships.

(c) Optimal stowage system may provide optimal energy-saving stowage plan according to initial loading and target trim by adjusting cargo and ballast water with computer simulating automatic iteration.

(d) Optimal stowage computer system based on trim optimization is to satisfy requirements for Category I computer system in IACS UR E22.

4.6.2 Requirements for trim optimization and stowage optimization

(a) Trim optimization system usually includes device collecting voyage data, basic database for trim performance and analysis system which can carry out trim optimization.

(b) Database for trim performance can be established by means of model test and numerical calculation, or by model analysis on serial data obtained from real-time voyage data collected from ship.

(c) Database for trim performance established by means of model test and numerical calculation is to at least cover conditions included in loading manual, and each condition is to include draft, speed and trim. Database for trim performance established by means of collecting ship's real-time voyage data is to include operational and navigational condition data such as trim, draft, speed, propulsive power and speed, wind speed and wind direction.

(d) It is to be at least able to carry out optimal trim optimization calculation under any condition included in loading manual, and output optimized trim range which can be used for adjusting navigational floating condition.

(e) When automatically optimizing loading plan based on target trim, operation is to be simple and convenient with acceptable calculation efficiency.

(f) When optimal energy-saving loading plan is outputted automatically, the plan is to comply with objective of optimal navigational state and satisfy requirements for hull strength, intact stability, grain stability, damaged stability and serial safety index of initial navigation.

(g) It is to be able to set several target trim for loading plan optimization according to user demand.

(h) It is to fit optimal navigational state target selected by users as far as possible. The user is to be notified if data exceed limit and fitting is impossible, and output a plan which is nearest to the target.

4.7 Survey

4.7.1 Initial survey

(a) The initial survey is at least to include the following items:
  (i) Confirming that plans and information specified in this Chapter have been examined and approved.
  (ii) Confirming that computer system of smart energy efficiency management is furnished with relevant certificates.
  (iii) Confirming that system hardware has been approved.

(b) In addition to satisfying relevant statutory and class survey requirements, the following equipment within statutory and class ranges are to be inspected according to following requirements:
  (i) Shaft power measurement device (if fitted):
    (1) Examining that it is installed according to the approved plans and/or manufacturer's instructions;
    (2) Witnessing check process and result of shaft power measurement device.
  (ii) Flowmeter:
    (1) Checking verification report of flowmeter;
    (2) Examining that it is installed according to the approved plans and/or manufacturer's instructions;
  (iii) Electronic clinometer:
    (1) Examining that it is installed according to the approved plans and/or manufacturer's instructions;
    (2) Confirming that electronic clinometer has been calibrated and confirming output results of inclination angle during functional test.
  (iv) Wind speed and direction indicator, sounding instrument, global positioning system, log, remotely draft measuring equipment:
    (1) Examining that it is installed according to the approved plans and/or manufacturer's instructions;
    (2) Inspection on functional test.

(c) For signal-collecting equipment, the following items are to be checked:

(i) Integrity of parameter input to system;

(ii) Consistency of parameter data of software system receiving end and parameter data of sending end of signal-collecting equipment.

(d) Test and inspection are to be carried out according to test program.

(e) It is to be confirmed that relevant plans and documents, manuals, procedures and relevant records are kept on board.

4.7.2 Survey after construction

(a) Annual, intermediate and special surveys are to include the following items:

(i) Checking the service condition of systems within the latest survey cycle to confirm that they are in normal condition;

(ii) Confirming that monitoring equipment have been calibrated according to the relevant provisions.

(b) For a ship assigned with the functional notation for smart energy efficiency management, if its monitoring equipment is damaged, repaired and renewed, or monitoring means are substantially changed, a request needs to be sent to the Society for interim survey.

CHAPTER 5 SMART NAVIGATION

5.1 General Requirements

5.1.1 The requirements of this Chapter apply to ships for which functional notation for smart navigation is requested.

5.1.2 Smart navigation means to obtain and perceive the status information necessary for ship navigation by means of advanced perception technology and sensing information fusion technology, and makes use of computer technology and control technology to carry out analysis and processing, so as to provide decision-making suggestions for optimization of ship's route and speed. If feasible, the ship can realize autonomous navigation in open water, narrow channel, entering and leaving port, berthing and unberthing, and various navigation scenarios and complex environmental conditions.

5.1.3 The basic function of smart navigation is route and speed design and optimization.

5.1.4 In addition to the basic function specified in 5.1.3, smart navigation may also have the following advanced functions:

(a) Autonomous navigation in open water;

(b) Autonomous navigation during entire voyage.

5.2 Functional Notation for Smart Navigation

5.2.1 Upon request, the functional notation for smart navigation may be assigned subject to satisfactory plan approval and survey by the Society:

Nx

where:

N : the ship with the function of route and speed design and optimization;

No : based on the function of route and speed design and optimization, the ship is with the function of autonomous navigation in open water under the supervision of the personal onboard;

Nn : based on achieving the function of **No**, the ship is with the function of autonomous navigation and automatic berthing and unberthing in narrow channel and complex environmental conditions, so as to realize autonomous navigation during entire voyage.

5.3 Functional Requirements

5.3.1 Route and speed design and optimization (**N**)

(a) For route and speed design and optimization, the route and ship speed are designed and optimized to achieve the voyage optimization goal, which is continuously optimized throughout the navigation period, in accordance with the technical condition and performance of the ship itself, specific navigation task, draft, cargo characteristics and sailing schedule and by taking into consideration such factors as wind, wave, current and swell, provided that the safety of ship, personnel and cargo is guaranteed.

(b) Route and speed design and optimization are generally achieved by shipborne systems and shore-based supporting center.

(c) Performance calculation model is to be built on the practical design parameters of the ship. The following data (if available) are in general to be considered:

(i) Ship general arrangement drawing;

(ii) Ship lines plan and midship section with bilge keel details;

(iii) Hydrostatic curves;

(iv) Main engine particulars and shaft generator (if fitted) details;

(v) Main engine shop test results;

(vi) Model test or ship trial reports;

(vii) Typical past voyage reports showing ship speed, rate of revolution, power and fuel oil consumption (such data may be obtained from relevant systems of Chapter 4);

(viii) Ship's performance of resistance against wind and wave.

(ix) Ship loading manual.

Where such data is unavailable, the model may be established by means of theoretical analysis and empirical curves, and improvement may be made continuously based on data obtained from real ship.

(d) Ship performance calculation model is to be provided with the function of dynamic adjustment. The model can be adjusted according to the practical operation conditions, so as to reflect actual performance of the ship and ensure the effect of route and speed design and optimization.

(e) The short-term and long-term weather data is to be considered and updated for route and speed design and optimization. The following data is to be obtained periodically:

(i) Wind direction and speed;

(ii) Significant wave height;

(iii) Wave height and mean period;

(iv) Swell height, direction and mean period;

(v) Current speed and direction;

(vi) Tropical cyclone (or typhoon): maximum wind speed, gust speed, radius of moderate gale, etc.;

(vii) Extratropical cyclone: central pressure, moving path and speed, etc.;

(viii) Warning of strong cold high pressure (cold wave and gale);

(ix) Ice condition (where applicable).

(f) Meteorological data are to be real-time and sufficiently accurate. The accuracy of short-term meteorological data (the weather forecast data within 1-5 days) is not to be less than 1.5deg*1.5deg, while the accuracy of long-term meteorological data (the weather forecast data within 6-14 days) is not to be less than 3deg*3deg.

(g) The time span of meteorological data is to be able to cover the remaining navigation time period of the intended voyage of the ship. If the time span cannot completely cover the voyage days of the ship, a reasonable method for handling such situation that navigation days exceed the weather forecast period is to be described.

(h) Route and speed design and optimization is to achieve one or more of the following functions in the highest sea scale for the set voyage and under the restriction of the navigation time period of the voyage:

(i) Optimization of navigation period;

(ii) Optimization of fuel oil consumption;

(iii) Optimization of total cost.

(i) Sea scale set for the voyage is not to exceed the design resistance level of the ship against wind and wave.

(j) Navigation safety of the ship is to be the prerequisite for route and speed design and optimization. The optimized route is to avoid obstacles and shoals and other hazardous areas for navigation.

(k) Ship's propulsion and steering capability is to be taken into consideration in route and speed design and optimization. Turning point and speed of the optimized route should match the propulsion and steering performance of the ship.

(l) The following route and speed design and optimization results are to be output and displayed: route, turning point and speed of each voyage segment.

(m) The ship is to be able to store the result of route and speed design and optimization and the actual navigational condition of the ship, for analysis and assessment of the optimized result.

5.3.2 Autonomous navigation in open water (**No**)

(a) The ship is capable of autonomous navigation in open water. During such period, onboard personnel will supervise the navigational operation of the ship and can intervene at any time where necessary to obtain the control of navigation and maneuver the ship.

(b) The ship is to fulfill basic functional requirements of smart navigation.

(c) In a situation of open water navigation, the ship is to make analysis and decision-making based on the perceived and obtained navigational information, control the propulsion and steering system according to the intended route, and achieve autonomous navigation. The ship is to be capable of implementing collision prevention decisions and operations in accordance with the International Regulations for Preventing Collisions at Sea, 1972.

(d) The ship autonomously navigating in open water is to be capable of perceiving and obtaining the following situation information at all times and using such information for autonomous decision-making:

(i) Real-time perception of environmental and meteorological data during navigation, including:

(1) wind speed and direction;

(2) sea surface visibility.

(ii) Real-time perception of the information on the ship itself:

(1) information on position, speed and heading;

(2) ship motion response, at least including pitch, roll and yaw;

(3) bow, amidship and stern draught, port and starboard draught.

(iii) AIS data of surface objects;

(iv) Data of electronic charts and information updated;

(v) Information on other objects at sea as follows:

(1) other ships, including position, motion direction, motion speed, size, actual distance and intersection angle with the ship itself, navigation signals and navigation status;

(2) information on other fixed obstacles and mobile objects on surface.

(vi) Measured water depth of ship's position.

(e) The situation awareness system and autonomous navigation system are to have self-check and alarm functions, capable of providing continuous monitoring during the normal operation of equipment. When equipment failure is detected, it is to be capable of sending an alarm and failure message to the navigation control system and remote control station and generating a record.

(f) The equipment and components of the situation awareness system and the autonomous navigation system are to be sufficiently reliable so as to minimize the failure probability. The equipment is to be so provided and arranged to ensure that the ship's perception, communication and navigation control capabilities are not affected or can be restored as soon as possible in case of single point failure of equipment.

(g) When the failure of the situation awareness system and the autonomous navigation system finally leads to the damage of autonomous navigation capability of the ship, an alarm is to be activated and the personnel onboard are to intervene and take over the operation of navigation of the ship.

(h) The ship is to be provided with data server for the storage of information on condition and operation of the equipment and system related to navigation. The capacity of the data server is to be such that at least the data generated by a single voyage but not less than 30 days can be continuously stored. When the server capacity reaches its limit, the oldest data can be replaced by the latest data.

(i) Where the design or equipment selection related to the autonomous navigation control and situation awareness function fails to meet the requirements of this Chapter, alternative or equivalent design may be accepted by the Society, provided that any risk existing in the design of smart navigation system in all scenarios is fully identified and analyzed by means of risk assessment method (e.g. FMEA), the risk control measure is proposed and the design of system is improved upon verification.

5.3.3 Autonomous navigation during entire voyage (**Nn**)

(a) The ship is to fulfil all requirements of autonomous navigation in open water (**No**).

(b) The ship is capable of autonomous navigation in all scenarios including open water, narrow channel and entering/leaving port and of automatic berthing and unberthing. During such period, onboard personnel will supervise the navigational operation of the ship and can intervene at any time where necessary to obtain the control of navigation and maneuver the ship.

(c) In all navigation scenarios, the ship is to make analysis and decision-making based on the perceived and obtained navigational information, control the propulsion and steering system according to the intended route, and achieve autonomous navigation. The ship is to be capable of implementing collision prevention decisions and operations in accordance with the International Regulations for Preventing Collisions at Sea, 1972.

(d) In addition to the situation awareness requirements in 5.3.2(d), the ship is to be capable of obtaining the following situation information for decision-making in navigational operation:

(i) Real-time perception of the distance between the bow and stern and the shore as well as the angle between the ship and the shore;

(ii) Information on changes of tide, flow velocity and direction at port and channels, and other relevant environmental information.

5.4 Equipment Provision and Performance Requirements

5.4.1 General requirements

(a) Systems and equipment related to smart navigation are to be subject to type approval and product inspection by the Society.

5.4.2 Route and speed design and optimization

(a) The ship applying for the functional notation of route and speed design and optimization is to be provided with:
  (i) Data communication equipment: communication connection is to be established to the shore base to facilitate exchange of information;
  (ii) Electronic chart display and information system;
  (iii) Electronic positioning equipment;
  (iv) Anemorumbometer;
  (v) Gyro-compass or other ship heading systems;
  (vi) Speed and distance measuring device;
  (vii) Echo sounder;
  (viii) Route and speed design and optimization system.

(b) Route and speed design and optimization systems are to be at least supplied by the main source of electrical power.

(c) Route and speed design and optimization systems are to comply with the requirements for category II computer systems in IACS UR E22 and satisfy applicable provisions of Part VIII of the Rules for Steel Ships.

5.4.3 Autonomous navigation

(a) The ship applying for the functional notation for autonomous navigation is to be at least provided with the following:
  (i) Autonomous navigation system;
  (ii) Situation awareness equipment, including:
    (1) marine radars with ARPA function;
    (2) ship's automatic identification system (AIS);
    (3) position, navigation and timing (PNT) systems;
    (4) electronic chart display and information systems;
    (5) independent gyro compasses or other ship heading systems;
    (6) echo sounder;
    (7) speed and distance measuring device;
    (8) ship motion sensor;
    (9) anemorumbometer;
    (10) visibility sensors.

(b) For ships applying for functional notation for autonomous navigation during entire voyage, close range detection equipment, e.g. laser radar, is also to be provided.

(c) The situation awareness system and autonomous navigation system are to be supplied by two independent sources of electrical power and to realize automatic change-over in the event of failure of one power supply.

(d) Autonomous navigation systems are to comply with the requirements for category III computer systems in IACS UR E22 and satisfy applicable provisions of Part VIII of the Rules for Steel Ships.

(e) The measurement range, accuracy and delay of close range detection equipment are to satisfy the decision-making requirements for berthing and unberthing and realize continuous monitoring.

(f) The radars are to have the detection capability of identifying marine hazardous objects on the water within 2.5 nautical miles.

5.5 Survey and Test Requirements

5.5.1 Ships applying for the functional notation for smart navigation are to submit the following plans and documents to the Society for approval:

(a) Route and speed design and optimization
  (i) Route and speed design and optimization system diagram (including metrological data list);
  (ii) Route and speed design and optimization system arrangement;
  (iii) Plan to realize route and speed design and optimization function;
  (iv) Route and speed design and optimization system specifications (for information);
  (v) Other drawings and documents as necessary.

(b) Autonomous navigation
  (i) Autonomous navigation design plan and explanations, including perception system design plan, autonomous control plan;
  (ii) Perception equipment system diagram;
  (iii) Equipment arrangement of perception system;
  (iv) Autonomous navigation system diagram;
  (v) Equipment arrangement of autonomous navigation system;
  (vi) Emergency response plan for failure of autonomous navigation function;
  (vii) Risk assessment report on ship autonomous navigation, the risk assessment range of which should cover all autonomous navigation and operation scenarios;
  (viii) Equipment installation procedures;
  (ix) Equipment maintenance plan;
  (x) Situation awareness and autonomous navigation system specifications (for information);
  (xi) Other drawings and documents as necessary.

5.5.2 Initial survey

(a) Confirming that relevant plans have been examined.

(b) Confirming that the system related to smart navigation is furnished with relevant certificate.

(c) Confirming, for different smart navigation functions, that a navigation officer has finished corresponding training and is competent to properly perform his duty.

(d) Confirming the input, output and communication functions of smart navigation system.

(e) Based on different input conditions, verifying navigation assistant decision-making function through simulation testing of route and speed design and optimization function.

(f) Confirming that relevant charts have been updated as appropriate.

(g) For autonomous navigation in open water and autonomous navigation during entire voyage, verifying through real ship test the functions of situation awareness, navigation control and autonomous collision prevention, and intervention and taking over by personnel.

5.5.3 Survey after construction

(a) For ships assigned with smart navigation functional notation, the actual effect of route and speed design and optimization is to be verified through ships in service. During the first annual survey, a report is to be submitted based on the operation data from the previous year, describing in detail the effect of using route and speed optimization function, and verifying the effectiveness of assistant decision-making function.

(b) Previous service conditions of the systems are to be reviewed in combination with annual, intermediate and special surveys to confirm that they are in normal condition. It is also to be checked that the route and speed design and optimization system, situation awareness system and autonomous navigation system involved in smart navigation are in normal function.

(c) Functions of the equipment and system are to be re-verified after their repair and renewal. Sea trial is to be carried out after renewal of the autonomous navigation system or repair or renewal of its core parts.

CHAPTER 6 SMART CARGO MANAGEMENT

6.1 General Requirements

6.1.1 Smart cargo management carries out automatic collection of parameters of cargo, cargo hold and cargo related system by using sensing equipment such as sensors, and based on computer technology, automatic control technology and big data processing and analysis, to realize monitoring, early warning/alarm, assistant decision-making and control of cargo hold, cargo and cargo related system conditions, and at the same time, carry out optimization of cargo loading/unloading plan and automatic loading and unloading based on monitoring and obtained data to realize smart management of ship cargo.

6.1.2 Smart cargo management is to have following basic functions:

(a) parameter monitoring of cargo, cargo hold and cargo related system;

(b) optimization of cargo loading/unloading plan;

(c) early warning/alarm and assistant decision-making.

6.1.3 Smart cargo management may also have following supplementary functions:

(a) automatic cargo loading and unloading.

6.1.4 Smart cargo management system software is to satisfy the requirements for category II computer system in IACS UR E22. Automatic cargo loading and unloading system software is to satisfy the requirements for category III computer system in IACS UR E22.

6.2 Functional Notation for Smart Cargo Management

6.2.1 Upon request, the following functional notation for smart cargo management may be assigned subject to satisfactory plan approval and survey by the Society:

Cx

where:

C : ship has functions related to monitoring of cargo, cargo hold and cargo related system, optimization of cargo loading/unloading plan and assistant decision-making;

x : Annotation for supplementary function, expressed by the following small letters:

l : ship with function of automatic cargo loading and unloading.

6.3 Monitoring of Parameters

6.3.1 General requirements

(a) The smart cargo management system is to monitor or obtain the following data based on the specific condition of loaded cargoes:
  (i) sea environment data, e.g. wind force, wind direction, wave;
  (ii) ship navigation parameters, e.g. course, speed;
  (iii) ship motion and acceleration;
  (iv) ship's floating condition;
  (v) cargo type and capacity;
  (vi) ballast tank liquid level;
  (vii) temperature in the tank;
  (viii) humidity in the tank;
  (ix) flammable gas, harmful gas and oxygen content in the tank;
  (x) water ingress in the cargo hold.

(b) For ships with automatic loading and unloading functions, the tension of mooring lines also needs to be monitored.

(c) Relevant monitoring parameters may be added in accordance with practical conditions of ship and safety needs.

6.3.2 Dry bulk carriers

(a) In general the following parameters also need to be monitored:
  (i) condition of cargo (e.g. cargo movement, liquefaction of ore in bulk, etc.);
  (ii) securing of cargo (whether the lashing is loose);
  (iii) open and closed condition of hatch cover of cargo hold.

6.3.3 Container ships

(a) Each container is to have an independent identification number and provided with basic information such as its size, weight, type (general, reefer, dangerous goods container, etc.), loading and unloading port and location on board.

(b) In general the following parameters also need to be monitored:
  (i) position of the container;
  (ii) condition of the reefer container (temperature, power supply, status of temperature control device);
  (iii) condition of the cargo hold of containers carrying dangerous goods (ventilation, temperature, flammable gas, etc.);
  (iv) lashing of each stack on the deck (whether the lashing rods are loose).

6.3.4 Oil tankers/chemical tankers/liquefied gas carriers

(a) In general the following parameters also need to be monitored for oil tankers/chemical tankers:
  (i) cargo tank pressure and liquid level height;
  (ii) oxygen content in the cargo tank;
  (iii) operating status of liquid cargo pump;
  (iv) operating status of inert gas system;

(v) remote control valve position / opening;

(vi) temperature of structural members adjacent to the independent cargo tank support block (where applicable).

(b) In general the following parameters also need to be monitored for liquefied gas carriers:

(i) cargo tank pressure and liquid level height;

(ii) oxygen content in the cargo tank;

(iii) operating status of deep well pumps;

(iv) operating status of inert gas system;

(v) remote control valve position / opening;

(vi) temperature and pressure in the secondary barrier (if applicable);

(vii) condition of the reliquefaction device;

(viii) condition of the vapor compressor;

(ix) temperature of structural members adjacent to the independent cargo tank support block (where applicable).

6.4 Optimization of Cargo Loading/Unloading Plan

6.4.1 General requirements

(a) Monitoring and technical analysis of relevant parameters in the process of cargo loading and unloading are carried out by considering various constraints such as ships and docks, so as to develop an optimized loading / unloading (including operations before and after loading and unloading) plan.

6.4.2 Constraints

(a) An optimized loading and unloading plan is generally to consider the following factors in terms of safety, environmental protection and efficiency:

(i) cargo type and quantity;

(ii) floating condition, stability and strength of the ship;

(iii) cargo hold capacity and stowage factor;

(iv) cargo loading and unloading sequence, speed and time;

(v) ballast water operation;

(vi) emergency stop procedure;

(vii) cargo hazard property;

(viii) ship maneuvering, port and dock;

(ix) cargo long-distance identification and tracking;

(x) route, weather and hydrology;

(xi) residual water depth limit.

(b) The following factors also need to be considered for oil tankers/chemical tankers/liquefied gas carriers:

(i) pipes and pumps to be used;

(ii) ventilation requirements;

(iii) emergency procedure for oil spill and recovery of oil spill;

(iv) preventing static electricity;

(v) initial loading and unloading rates;

(vi) temperature control procedure;

(vii) stripping;
(viii) crude oil tank cleaning procedure;
(ix) special precaution against cargo.

6.5 Assistant Decision-Making

6.5.1 General requirements

(a) The monitored data is analyzed based on the specific design of the ship, the specific cargo loaded and comprehensive consideration of the trend of current condition. Reminders / warnings on possible abnormal situations that might occur in a short period of time are given. Reasonable recommendations and operational plans are given.

(b) An alarm is given in case any abnormal condition is detected. The data is analyzed and processed in detail. Reasonable recommendations and operational plans are given.

6.5.2 Dry bulk carriers

(a) The following scenarios are in general to be considered:
(i) water ingress in cargo hold;
(ii) cargo movement or liquefaction of ore in bulk;
(iii) change of cargo hold temperature, humidity, flammable gas concentration and harmful gas concentration;
(iv) loose lashing, any change of the lashing force or support force (where applicable);
(v) scenarios deemed necessary based on the practical condition of the ship.

6.5.3 Container ships

(a) The following scenarios are in general to be considered:
(i) shift or dropping of container;
(ii) temperature change of reefer container;
(iii) change of cargo hold temperature and flammable gas concentration;
(iv) change of the environment surrounding dangerous goods containers;
(v) scenarios deemed necessary based on the practical condition of the ship.

6.5.4 Oil tankers/chemical tankers/liquefied gas carriers

(a) The following scenarios are in general to be considered:
(i) change of cargo tank level;
(ii) change of cargo tank pressure;
(iii) change of flammable gas, harmful gas and oxygen content in cargo tanks;
(iv) temperature change of secondary barrier of cargo containment system;
(v) scenarios deemed necessary according to the type of ship, the structure of the cargo tank and the cargo loaded.

6.6 Automatic Cargo Loading and Unloading

6.6.1 General requirements

(a) Based on the optimized loading / unloading plan, the relevant systems can be automatically controlled to realize automatic loading and unloading of ships.

(b) The smart cargo management system is to be able to deal with and control sudden failures of equipment, external environmental changes and other factors in a timely manner

6.6.2 Dry bulk carriers/container ships

(a) Automatic loading and unloading generally includes:
  (i) operation of cargo loading and unloading equipment on board (where applicable);
  (ii) operation of cargo hold ventilation, tightness, opening and closing cargo hold hatches (where applicable);
  (iii) control of cargo loading and unloading process, generally including:
    (1) cargo hold capacity;
    (2) ballast water in ballast tank.

6.6.3 Oil tankers/chemical tankers/liquefied gas carriers

(a) Automatic operations of oil tankers/chemical tankers generally include:
  (i) cargo tank inerting;
  (ii) cargo loading;
  (iii) cargo unloading;
  (iv) cargo tank stripping;
  (v) gas-freeing of cargo tank ;
  (vi) ballast, deballast and ballast water transfer.

(b) Automatic operations of liquefied gas carriers generally include:
  (i) cargo tank dehumidification
  (ii) cargo tank inerting;
  (iii) inerting of secondary barrier of cargo containment system;
  (iv) cargo tank inflation;
  (v) cargo tank cooling;
  (vi) cargo loading;
  (vii) cargo unloading;
  (viii) cargo tank stripping;
  (ix) cargo tank warming;
  (x) gas–freeing of cargo tank ;
  (xi) ballast, deballast and ballast water transfer.

6.7 Plans and Documents

6.7.1 The following plans and documents are to be submitted to the Society for approval:

(a) Arrangement plan of sensors.

6.7.2 The following plans and documents are to be submitted to the Society for information:

(a) System composition and function explanation;

(b) System hardware specifications;

(c) System test procedure.

6.8 Survey

6.8.1 Initial survey

(a) Relevant plans have been examined.

(b) It is to be confirmed that the system has relevant certificate.

(c) System design, system input and output as well as communication function are to be confirmed.

(d) According to application for different functional notations for smart cargo management, different conditions are inputted for simulation operation to verify software function.

(e) Capability of treating emergency situation is to be verified.

6.8.2 Survey after construction

(a) Previous service condition of systems are reviewed at annual, intermediate and special surveys to confirm that they are in normal condition.

(b) Functions of the equipment and system are to be re-verified after their repair and renewal. Test is to be carried out as necessary after repair or renewal of the smart cargo management system.

CHAPTER 7 SMART INTEGRATION PLATFORM

7.1 General Requirement

7.1.1 The requirements of this Chapter apply to ships for which functional notation for smart integration platform is requested.

7.1.2 If a ship is assigned with the basic functional notation (**I**) for smart integration platform, it is to be provided a unified integration platform of data acquisition/collection, storage, integration, interaction, sharing and demonstration and control command transmission (where applicable).

7.1.3 If a ship is assigned with the functional notation (**Ip**) for smart integration platform, in additiona to 7.1.2, integration platform is to be open and be able to integrate existing information management system on board ship and subsequent newly-added system to realize all-round monitor, control and smart management for ship as well as data exchange with shore base.

7.2 Functional Notation for Smart Integration Platform

7.2.1 Upon request, the following functional notation for smart integration platform may be assigned subject to satisfactory plan approval and survey by the Society:

Ix

where:

I : the ship has basic functions of smart integrationas specified in 7.1.2;

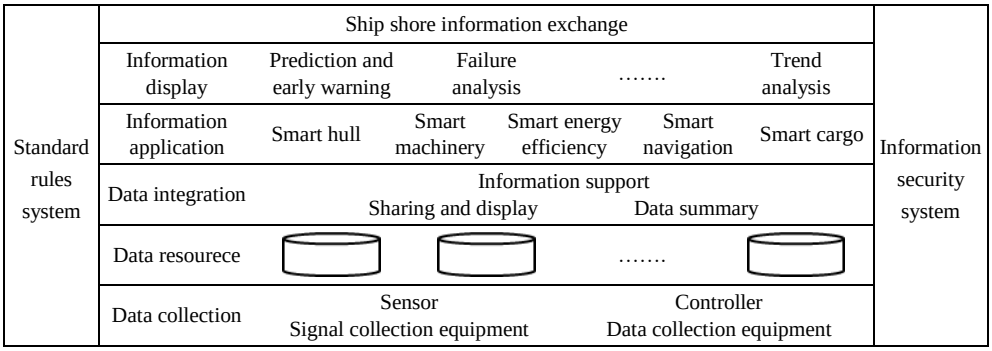
x : annotation for supplementary function, expressed by the following small letters:

p : represents that the ship can at least integrate data of two systems, the platform is open, having capability of accessing newly-added system.

7.2.2 Ships applying for functional notation **Ip** for smart integration platform are to have at least two functional notations among **Hx**, **Mx**, **Ex**, **Nx**, **Cx**. Where the ship has more than two smart applications, the integration platform is to be able to provide services for all applications.

7.3 System Layer

7.3.1 Overall structure of system



(a) Data collection, i.e. using sensing equipment (e.g. sensor), control, signal collecting equipment and data collecting equipment to collect required data, collecting data, defining data standard, including standard relating to data definition, data description, data quality, data transmission and data handling, and realizing data traceability.

(b) Data storage, i.e. establishing subject-oriented, integrated and stable data set supporting decision-making and management process and reflecting historical change, carrying out storage as well as safety and evaluation management for data collected to ensure accuracy, integrity and availability of data; in case of single failure, the data stored on board will not be lost.

(c) Data integration and exchange, i.e. carrying out system processing, aggregation, analysis integration and exchange based on necessary selection and cleaning of existing data, using multi-dimensional analysis method, analyzing and comparing from different angle, and extracting information hidden within data to provide information support for service application and assistant decision-making as well as play a role of information integration.

(d) Ship shore information exchange, i.e. realizing ship shore information exchange through communication equipment to achieve remote failure diagnosis and data mining.

(e) Information display, i.e. by means of human-computer interaction and according to customization, providing excavating results of relevant data, expressing failure cause in proper form and providing prediction and early warning for user operational decision-making by using data trend.

(f) Standard rules system, which is to be observed during system integration process.

(g) Information security system, i.e. based on requirements for information security (information confidentiality, authenticity, integrity, unauthorized copy and security of parasitic system) and from computer operation system, security agreement and mechanism (digital signature, message authentication and data encryption) to safety system, proposing design thinking and protection strategy to ensure continuous, reliable and normal operation of system and uninterrupted information service as well as final continuous service.

7.4 System Requirements

7.4.1 General requirements

(a) System integration is to adopt unified input and output standard.

(b) Stable and reliable communication agreement and system data transmission mechanism is to be adopted for communication between ship and shore.

(c) Data collection is to have fault-tolerant mechanism.

(d) Database of integration platform is to have valid integration process, i.e. screening necessary data according to data quality of each system and functional requirements for integration platform.

(e) The system is to support multi-terminal (PC and mobile device) access.

(f) The system is to provide external data transmission interface and have capability of sharing data with relevant parties.

(g) The system is to realize multi-department and multi-user cooperative management according to company's relevant requirements for management system.

(h) A redundant design is to be used for the network providing data communication for different nodes, i.e. the failure of any node or network will not affect the communication between other nodes.

(i) A redundant design is to be used for the data storage and hot backup is to be achieved to ensure the continuity of functions.

(j) Where the integration platform has the function of transmitting control commands, it is to ensure the timeliness and accuracy of the transmission of commands.

(k) The integration platform providing support for assistant decision-making is to comply with the requirements for category II computer system in IACS UR E22, and the integration platform providing support for control is to comply with the requirements for category III computer system in IACS UR E22, as well as satisfying applicable requirements of Part VIII of the Rules for Steel Ships.

7.4.2 System integration requirements

(a) Smart integration platform is to integrate existing information resource of smart system on board ship. Data collected through smart system can be stored in integration platform database, or establish effective call relation with it.

(b) Smart integration platform can integrate functions relating to ship information management system and realize management for relevant ship information by ship and company, e.g. equipment maintenance management, crew delivery and basic information management, security management, system management, cost management and electronic management of maritime information.

(c) Smart integration platform is to be able to integrate newly-added system (e.g. video monitoring system, integrated navigation system) according to conventions, rules as well as company management and operation needs. The system is to have certain expandability and complete data interface plan to facilitate access of other newly-added system. Data collected through newly-added system may be stored in smart integration platform database, or establish effective call relation with it.

7.5 Survey

7.5.1 Initial survey

(a) It is to be confirmed that plans have been examined.

(b) Ships applying for the functional notation for smart integration platform is to be subject to initial survey to verify following items:

(i) confirming that smart integration platform has relevant certificates;

(ii) confirming that process of data collection, storage, transmission, display and application of smart integration platform is implemented properly;

(iii) inspecting relevant functions according to requirements for each integration system.

7.5.2 Survey after construction

(a) Following items are to be examined at annual survey, intermediate survey and special survey:

(i) examining former service condition record of smart integration platform and confirming normal operation of smart integration platform;

(ii) system data can be exchanged normally between ship and shore, and conforming historical record of data exchange;

(iii) checking system backup record randomly and confirming system has implemented effective backup;

(iv) inspecting relevant functions according to requirements for each integration system.