GUIDANCE NOTES
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CHINA CLASSIFICATION SOCIETY

GUIDELINES FOR IMPLEMENTATION OF OFFSHORE FPSO STATUS MONITORING AND DIGITAL TWIN SYSTEM CERTIFICATION

2024

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Beijing

Contents

Chapter 1 General

Section 1 General Provisions

1.1.1 Purposes

1.1.1.1 China Classification Society (hereinafter referred to as CCS) has prepared the *Guidelines for Implementation of Offshore FPSO Status Monitoring and Digital Twin System Certification* (hereinafter referred to as the Guidelines) for the purpose of providing implementation basis for inspection of FPSO status monitoring and digital twin system.

1.1.2 General Requirements

1.1.2.1 The Guideline applies to the FPSO status monitoring and digital twin systems. The FPSO status monitoring system refers to the monitoring systems for marine environment, structural status and equipment, and the FPSO digital twin system refers to the digital twin systems for hull, process flow and equipment.

1.1.2.2 The FPSO status monitoring and digital twin system (hereinafter referred to as "the system") means a system that adopts sensor technology, modern communication and information technology, computer network technology, artificial intelligence and other digital technologies in FPSO to realize the FPSO status monitoring and digital twin functions.

1.1.2.3 The FPSO structural status monitoring system mainly monitors ship hull motion attitude, structural corrosion, structural force, mooring and riser, liquid tank, etc., to obtain the state of FPSO.

1.1.2.4 The FPSO equipment monitoring system mainly monitors the status of electromechanical equipment, process flow, transportation system, gas leakage and fire system, and can use their original monitoring data, but cannot interfere with the original monitoring systems of the equipment.

1.1.2.5 On the basis of status monitoring system, the FPSO digital twin system can realize real-time management, risk assessment and auxiliary decision-making of FPSO by establishing digital twin of the ship hull, process flow or equipment, and by mapping and cooperating between digital twin and physical entity. Figure 1.1.2.5 shows the reference architecture of the system.

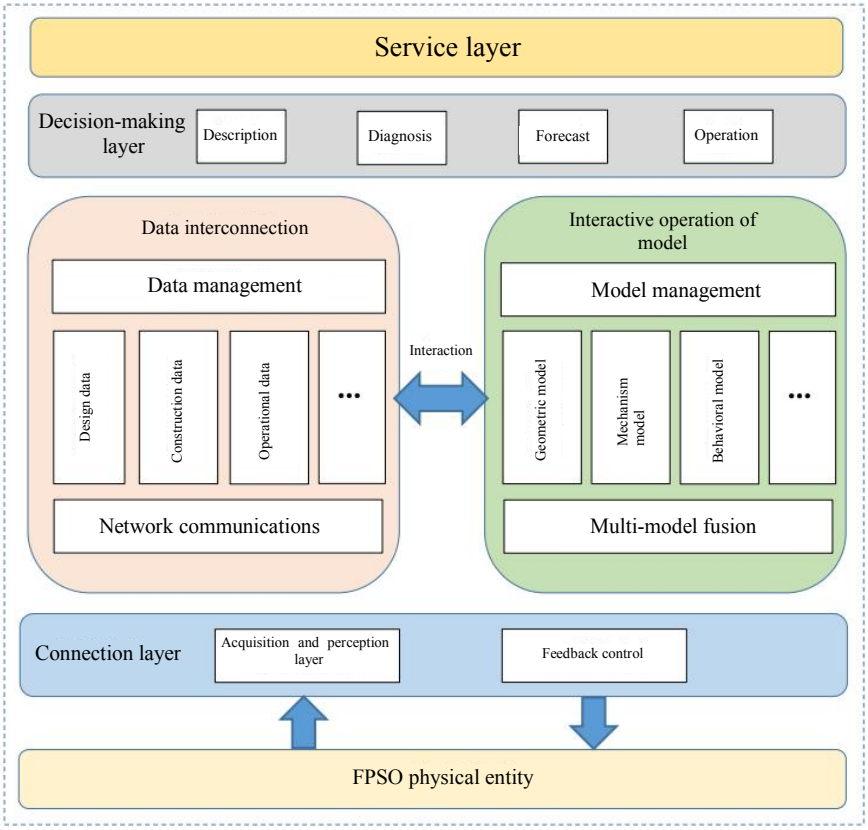

Figure 1.1.2.5 Schematic Diagram of Functional Framework of FPSO Status Monitoring and Digital Twin System

Section 2 Rules and Standards

1.2.1 General Requirements

1.2.1.1 The design, manufacture, installation and inspection of the system shall meet the requirements of the relevant laws and regulations of the competent authority of the sea area and the national specifications and standards of the industry and classification societies. Generally, the following specifications and standards shall be referred to (if not dated, the latest version shall prevail) :

(1)	State Administration of Work Safety	*Safety Rules for Floating Production Storage and Offloading Units (FPSO)*
(2)	IMO A.830(19)	Code on alarms and indicators
(3)	CCS	*Rules for Classification of Sea-Going Steel Ships*
(4)	CCS	*Rules for Classification of Offshore Floating Installation*
(5)	CCS	*Rules for Materials and Welding*
(6)	CCS	*Rules for Classification of Offshore Single Point Moorings*
(7)	CCS	*Guidelines for Surveys of Monitoring Systems for Structures and Equipment of Mobile Units and Offshore Installations*
(8)	CCS	*Guidelines for Digital Twin Systems for Ships and Offshore Installations*
(9)	CCS	*Guidelines for Verification of Digital Systems for Ships and Offshore Installations*

(10)	CCS	*Guidelines for Quality Assessment of Ship Data*
(11)	CCS	*Guidelines for Ship Cyber Security*
(12)	CCS	*Guidelines for Type Approval Test of Electric and Electronic Products*
(13)	CCS	*Guidelines for Safety and Reliability Assessment for Shipboard Software*
(14)	IEC 60092-504	*Electrical Installations in Ships-part 504: Special Features-Control and Instrumentation*
(15)	ISO 21451-2010	*Standard for Information technology - Smart Transducer Interface for Sensors and Actuators*
(16)	JJF 1804-2020	*Specifications for Calibration of Bragg Fiber Grating Sensor Network Analyzer*

Section 3 Equivalence and Exclusion Clauses

1.3.1 Where status monitoring and digital twin technologies with novel structures and features are beyond the scope specified in the Guidelines and are validated by risk assessment and tests or other methods to prove that the systems and equipment using the new technologies can achieve the same level of safety as required by the Guidelines, these technologies may be accepted as alternative and equivalent methods with the consent of CCS.

Section 4 Class Notation and Certificate of Compliance

1.4.1 Class Notation

1.4.1.1 The owner of classified FPSO can submit applications to CCS for the following class notations:

(1) Class notation of hull monitoring system for FPSO: HMS(X);

Refer to the *Guidelines for Surveys of Monitoring Systems for Structures and Equipment of Mobile Units and Offshore Installations* by CCS for the technical requirements.

(2) Class notation of equipment monitoring system for FPSO: EMS(X);

Refer to the *Guidelines for Surveys of Monitoring Systems for Structures and Equipment of Mobile Units and Offshore Installations* by CCS for the technical requirements.

(3) Class notation of intelligent FPSO: i-Installation (PPS(Od), APS(CI(ox, gx, wx)), ILS, ISS, US, DC);

Refer to CCS *Rules for Classification of Offshore Floating Installation* and its first Technical Change Notice in 2023 for the technical requirements.

(4) Class notation of digital twin of FPSO hull structure: SDT(d). The meanings of the class notations are as follows:

SDT - the notation of digital twin functions for FPSO hull structure, which shall meet the relevant requirements of Section 1.4.1.2 and the *Guidelines for Digital Twin System of Ships and Offshore Installations* by CCS.

d - the additional notations of digital twin function, including d1, d2, d3, d4 and d5, which respectively indicate five functions of digital twins: mirroring, attribution, forecast, preference and autonomy.

1.4.1.2 The requirements for the digital twin functions of FPSO hull structure are as follows:

(1) Mirroring:

① Establish the digital twin of FPSO hull structure, and keep the appropriate synchronization frequency with the stress state of FPSO hull structure;

② Be able to visualize the digital twin of FPSO hull structure and simulate different working conditions;

③ The precision of simulation shall meet the design requirements of the system digital twin;

④ If this function is met, the additional notation d1 can be granted.

(2) Attribution

① Realize real-time monitoring of the stress state of FPSO hull structure through the digital twin of FPSO hull structure;

② Judge the current structural response of FPSO hull structure and its cause based on the monitoring/calculation data and historical information;

③ If this function is met, the class notation d2 can be granted.

(3) Forecast:

① Through the digital twin of FPSO hull structure, simulate and verify the stress state of FPSO hull structure in the digital space, and forecast the future stress state of FPSO hull structure, so as to judge its potential defects and risks and give early warning;

② If this function is met, the additional notation d3 can be granted.

(4) Preference:

① Through the digital twin of FPSO hull structure, simulate and compare the performance, defects and risks of FPSO hull structure under various decision schemes on the basis of forecast;

② The digital twin of FPSO hull structure can choose decision scheme or make suggestions according to the actual demand, including decision support and automated decision;

③ If this function is met, the additional notation d4 can be granted.

(5) Autonomy:

① It refers to the dynamic interaction between the digital twin of FPSO hull structure and the FPSO hull. The digital twin sends control instructions to the FPSO hull, and after the FPSO hull executes the instructions, the execution results are fed back to the digital twin, thus realizing the automatic operation of the system;

② When necessary or in an emergency, the operator can take over the system control authority and switch to manual control;

③ If this function is met, the additional notation d5 can be granted.

1.4.1.3 After the completion of the system inspection and test, the surveyor on site shall issue the corresponding survey report, grant the corresponding class notations, and notate it in the FPSO classification certificate in accordance with the requirements of the Guidelines, the *Rules for Classification of Offshore Floating Installation* by CCS and Section 3 of Chapter 2 of Title 1 in the first Technical Change Notice of 2023.

1.4.2 Certificate of Compliance

1.4.2.1 Based on the application or contract/agreement of the owner, the designer or the builder, the surveyor may issue a certificate of compliance for systems used on non-CCS FPSO upon completion of the inspection and testing of the system. Any survey-related documents issued only reflect the status at the time when the survey is carried out.

Chapter 2 Technical Requirements for System

Section 1 General Provisions

2.1.1 General Requirements

2.1.1.1 The system should support the fusion of multi-source heterogeneous data, structured data and unstructured data, including the data of text, picture, video, audio and other common formats.

2.1.1.2 The system shall have a certain degree of extendibility and a perfect data interface scheme to facilitate the access of new modules. The data collected through the new modules can be centrally stored in the system database.

2.1.1.3 The system should reserve communication connectors with external systems to provide necessary data sharing services based on requirements of external systems.

2.1.1.4 The system should have the functions of data feedback and feedback confirmation. When necessary, the system may return data back to the specified server database on the land end accurately and completely.

2.1.1.5 For FPSO capable of typhoon production mode[①], the data generated by the system shall at least be fully stored locally in typhoon production mode.

2.1.1.6 For the data synchronization process between the FPSO and the land end, complete log records shall be kept, and it shall be possible to locate problems through log backtracking.

2.1.1.7 The system shall have a process monitoring program, which can automatically restart the program when it terminates unexpectedly, and ensure that the data record is not interrupted.

2.1.1.8 The installation of the system shall not reduce the original structural safety of the FPSO and shall not interfere with the normal operation of the electromechanical equipment.

2.1.1.9 The system shall be easy to use and not significantly increase the workload of FPSO operators or lead to new safety risks due to excessive diversion of the operators' attention.

2.1.1.10 The system shall not interfere with the data of the FPSO central control system, and such data shall be independent.

2.1.1.11 The power supply of the system shall meet the requirements of 9.1.1 of Chapter 9 of Title 9 of the first Technical Change Notice in 2023 of CCS *Rules for Classification of Offshore Floating Installation*.

2.1.1.12 The data quality assessment of the system shall meet the relevant requirements of CCS *Guidelines for Quality Assessment of Ship Data*.

2.1.1.13 The data security of the system shall meet the relevant requirements in Appendix 8 of CCS *Guidelines for Quality Assessment of Ship Data*.

2.1.1.14 The cyber security of the system shall meet the relevant requirements of CCS *Guidelines for Ship Cyber Security*.

2.1.1.15 Unless otherwise specified in this Chapter, the system shall meet the relevant requirements in CCS *Guidelines for Surveys of Monitoring Systems for Structures and Equipment of Mobile Units and Offshore Installations*.

2.1.1.16 Except as otherwise provided in this Chapter, the system shall meet the relevant requirements of CCS *Rules for Classification of Offshore Floating Installation* and the its first Technical Change

[①] The typhoon production mode refers to the continuous production of oil and gas by remotely operating the offshore platform through the land central control system after all the personnel on the offshore platform are evacuated to the land when the typhoon comes, so as to achieve little or no suspended production during the typhoon.

Notice in 2023.

Section 2 Technical Requirements for Status Monitoring System

2.2.1 General Requirements

2.2.1.1 The FPSO status monitoring system shall be able to accurately reflect the real status of the monitored object.

2.2.1.2 According to different monitoring function requirements, the selection of sensors shall at least consider the following factors:

(1) Data collection frequency;

(2) The range and accuracy of the collected data;

(3) Adaptability to the working environment, such as waterproof, anti-oil mist, anti-salt spray, anti-corrosion, high temperature resistance, explosion-proof, shock-proof and other capabilities;

(4) Construction convenience;

(5) Service life.

2.2.1.3 The quality assessment of data collected by sensors shall meet the relevant requirements of CCS *Guidelines for Quality Assessment of Ship Data*.

2.2.1.4 The monitoring data quality assessment results can be divided into good, medium and poor grades, as shown in Table 2.2.1.5. Monitoring data rated as poor quality shall not be used for later warning and/or forecasting.

2.2.1.5 The following factors shall be considered in the quality assessment of monitoring data:

(1) The proportion of invalid data formats;

(2) The proportion of data loss;

(3) The proportion of the value beyond the normal range;

(4) The ratio of data signal duration to total duration.

Monitoring Data Quality Assessment **Table 2.2.1.5**

Quality assessment indexes	Quality assessment grades		
	Good	Medium	Poor
Proportion of invalid data formats	<0.1%	0.1% ~ 0.5%	>0.5%
Proportion of data loss	<0.1%	0.1% ~ 0.5%	>0.5%
Proportion of the value beyond the normal range	<0.1%	0.1% ~ 0.2%	>0.2%
Ratio of data signal duration to total duration	>90%	80% ~ 90%	<80%

Note: At least 3 random samples should be taken during testing or operation, with a recommended duration of 30 minutes for each sample.

2.2.2 Marine Environmental Monitoring

2.2.2.1 Marine environmental monitoring parameters include water depth, meteorological parameters, wave parameters and ocean current parameters.

2.2.2.2 Generally, the following meteorological parameters (including but not limited to) should be obtained:

(1) Temperature;

(2) Humidity;

(3) Atmospheric pressure;

(4) Wind speed;

(5) Wind direction.

2.2.2.3 In the measurement of wind speed and direction, the influence of structure on the measurement results shall be reduced. The measuring instruments should be installed in area with no shelter, stable wind field, long windward path and stable turbulence coefficient.

2.2.2.4 In the meteorological parameter monitoring, the weather station is generally installed on the top of FPSO for long-term continuous monitoring.

2.2.2.5 The layout of environmental monitoring sensors/equipment shall avoid adverse effects on the structure and equipment of the FPSO.

2.2.2.6 The appropriate wave parameter measuring equipment shall be selected according to the application occasions and on-site working conditions.

2.2.2.7 Generally, the following wave parameters shall be obtained (but not limited to):

(1) Significant wave height;

(2) Maximum wave height;

(3) Average zero-crossing period;

(4) Peak spectral period;

(5) Wave direction.

2.2.2.8 The installation position of wave measuring equipment shall take into account the weathercock effect and hull safety of FPSO.

2.2.2.9 The installation position of the ocean current meter shall not affect the structural safety of the FPSO.

2.2.2.10 The monitoring parameters of ocean currents shall include but be not limited to flow direction and flow velocity profile.

2.2.2.11 The statistical algorithm of environmental condition parameters shall be set up for marine environmental monitoring to obtain the data of long and short period monitoring.

2.2.2.12 The collection and transmission of marine environmental data shall comply with the relevant requirements of the *Data Security Law of the People's Republic of China*.

2.2.3 Motion Attitude Monitoring

2.2.3.1 The FPSO motion attitude monitoring data include but are not limited to ship bow direction, hull position coordinates, six degrees of freedom motion components of hull, safe distance from adjacent facilities, draft, and distance between ship bottom and seabed.

2.2.3.2 The attitude monitoring of a single point mooring system includes but is not limited to single point rotation direction and single point position coordinates.

2.2.3.3 The inclination sensor, inertial navigation sensor, acceleration sensor, GPS or Beidou positioning sensor installed on the FPSO hull and mooring system shall be used to monitor the attitude and position information of the FPSO hull and mooring system.

2.2.3.4 The inclination sensor installed on the FPSO hull shall be corrected according to its position, and the reference axis shall be parallel to the coordinate system where the hull is located to ensure the measurement accuracy.

2.2.3.5 The FPSO motion attitude data should be fused and associated with field environmental data to evaluate the data reliability of attitude monitoring sensors.

2.2.3.6 The FPSO motion attitude monitoring system shall have early warning function, so that it can timely send alarm information when the FPSO hull motion trajectory deviates from the set parameters.

2.3.3.7 The FPSO motion attitude monitoring system shall provide effective data for the digital twin system to give an alarm or an early warning.

2.2.4 Monitoring of Structural Corrosion and Anti-corrosion

2.2.4.1 FPSO structural corrosion monitoring is mainly used to monitor the plate thickness.

2.2.4.2 FPSO anti-corrosion monitoring generally includes cathodic protection potential monitoring, sacrificial anode current monitoring and coating monitoring.

2.2.4.3 A reasonable alarm threshold shall be set, and an alarm shall be given when the corrosion degree of the monitored area exceeds the threshold. For corrosion limits, the requirements of Table 3.2.2.2, Chapter 3, Part 2 of the *Rules for Classification of Offshore Floating Installation* shall be referred to.

2.2.5 Structural Stress Monitoring

2.2.5.1 The structural stress monitoring of FPSO shall meet the technical requirements of sensors, quality of collected data, user interface and test outline in Chapter 3 of the *Guidelines for Surveys of Monitoring Systems for Structures and Equipment of Mobile Units and Offshore Installations* by CCS.

2.2.5.2 The overall stress monitoring of FPSO is used to obtain the stress state of the ship hull girder, such as still water bending moment/shear force and wave bending moment/shear force, as well as their changes over time and along the ship length/width direction.

2.2.5.3 The overall stress monitoring of the FPSO shall have a real-time indication of whether the hull girder stress is approaching the design limit value, so as to warn the operator and recommend mitigation measures. For the allowable stress, reference shall be made to the relevant requirements of Chapter 9, Part 2 of the *Rules for Classification of Offshore Floating Installation*.

2.2.5.4 Local stress monitoring of FPSO is used to obtain the change of stress level over time at key locations such as the hull, equipment and their bases. For the allowable stress, reference shall be made to the relevant requirements of Chapter 9, Part 2 of the *Rules for Classification of Offshore Floating Installation*.

2.2.5.5 FPSO local stress monitoring shall have the ability to indicate in real time the possibility of local stress exceeding the warning level, and to give an indication of the corresponding consequence trend at the warning level, to give a warning to the operator if the local stress level of the corresponding structural component of ship is approaching the approved limit, and to recommend mitigation measures.

2.2.5.6 For ship type offshore FPSO, the following structures should be considered as the monitored positions for structural stress:

(1) Main deck and side structures at the center of the ship;

(2) Main deck and side structures at 1/4 of a ship's length from the bow and stern;

(3) Crane base and its strengthening structure;

(4) The base of the upper module and its strengthening structure;

(5) The base of the burner boom and its strengthening structure;

(6) Transportation system;

(7) Other structures subject to large concentrated loads or/and large alternating loads.

2.2.5.7 For non-ship type offshore FPSO, the structural stress monitoring devices shall be positioned to reflect the overall structural response to obtain the overall stress, or placed in the positions of high stress to detect local stress.

2.2.5.8 The sampling frequency of the sensor used for local structural stress monitoring may be adjusted according to the natural frequency of the local structure, but shall not be less than 3 times the natural frequency of the local structure of order 1 (or potentially excited mode).

2.2.5.9 The derivation of fatigue hot spot stress data from the fatigue stress data at the monitoring point shall use the calculation method corresponding to the fatigue assessment and shall be approved by CCS.

2.2.5.10 As a vulnerable device, the structural strain sensor shall be provided with a compensation algorithm for device damage (that is, a numerical compensation algorithm based on historical data or results near the monitoring point) or quick repair measures.

2.2.5.11 The strain sensor used for structural stress monitoring of FPSO should meet the following specific requirements:

Requirements of Strain Sensor for FPSO Structural Stress Monitoring Table 2.2.5.11

Characteristics		Recommended values
Measuring range		$\geq \varepsilon_{\text{still-water}} + \varepsilon_{\text{d ynamic-load}} \pm 2000$ με (for steel)
Uncertainty (minimum requirement)		3% of the measured value or $20\mu\varepsilon$, whichever is greater
Resolution ratio		$5\mu\varepsilon$
Motion and wave load	Bandwidth (Hz)	0~5
	Frequency (Hz)	3 times the required frequency, 20 recommended
Slamming	Bandwidth (Hz)	5~100
	Frequency (Hz)	3 times the required frequency, 300 recommended
Sloshing	Bandwidth (Hz)	30~1200
	Frequency (Hz)	3 times the required frequency, 2000 recommended
Note 1: ε indicates strain, that is, the amount of deformation per unit length. Note 2: με indicates micro strain, $1\varepsilon = 10^6$ με.		

2.2.6 Mooring System Monitoring

2.2.6.1 For single-point mooring offshore FPSO, the mooring device monitoring should consider the following equipment or parameters:

(1) Mooring system;

(2) Main mooring load force transfer members (such as bearing support structure, mooring rope and single point connection members, fixation system, etc.);

(3) Tension of the anchor chain;

(4) Angle of inclination of the anchor chain;

(5) Main bearing;

(6) Torque arm;

(7) Liquid temperature and pressure in the liquid slip ring;

(8) Slip ring video surveillance;

(9) Hose support structure.

2.2.6.2 For offshore FPSO with distributed mooring, the mooring device monitoring shall adopt the reliable methods to monitor the stress state of the mooring rope, so as to provide effective data for the digital twin system to evaluate the safety state of the mooring rope.

2.2.6.3 Monitoring equipment with high reliability and long service life should be selected for the mooring rope stress monitoring system.

2.2.6.4 For the shallow water mild steel arm mooring system, the stress state of the mild steel arm shall be monitored through data collection or calculation analysis.

2.2.6.5 For mooring systems with fixation system, priority shall be given to monitoring the stress state of the fixation system.

2.2.6.6 For the mooring system using main self-lubricating sliding bearings, the number of relative rotation turns of bearings, bearing temperature, lubricating oil temperature and pressure can be monitored, and the bearing wear can be determined by a reasonable calculation model.

2.2.6.7 For the mooring system using main ball bearings, the composition of lubricating oil can be monitored to determine the working state of the main bearings.

2.2.7 Riser System Monitoring

2.2.7.1 The tension and bending radius of the riser at the top and bottom and the riser motion of the riser system should be monitored, and the corresponding warning threshold should be set.

2.2.7.2 The annular state of the flexible riser should be monitored.

2.2.7.3 The layout of sensors/monitoring equipment shall be considered in the monitoring of riser system, and the monitoring point data can be used to establish the overall state monitoring model or digital twin model for riser.

2.2.7.4 The monitoring of the riser system shall consider the requirements of information transmission and meet the requirements of wireless or wired transmission.

2.2.8 Liquid Tank Status Monitoring

2.2.8.1 The liquid tank status monitoring mainly refers to the continuous status monitoring of liquid level, temperature, pressure, etc.

2.2.8.2 The liquid tank status monitoring system shall have alarm function. When the liquid level, temperature, pressure or other parameters exceed the preset range, it should send alarm in time to remind the operator to take measures.

2.2.8.3 The liquid tank status monitoring system shall have the function of data recording and analysis to record the historical monitoring data and perform data analysis and trend prediction.

2.2.8.4 The liquid tank status monitoring system shall have remote monitoring function, which can monitor the liquid tank state in real time through the network to facilitate remote operation and management.

2.2.9 Process Flow Monitoring

2.2.9.1 The FPSO process flow monitoring shall meet the functional requirements specified in Chapter 6 and Chapter 10 of the *Safety Code For Floating Production Storage And Offloading Units (FPSO)*.

2.2.9.2 The process flow monitoring of FPSO shall meet the signal acquisition requirements for production process control.

2.2.9.3 For FPSO process system with digital twin function, its monitoring parameters shall meet the requirements of process system simulation and twin.

2.2.9.4 The process system should monitor the following process parameters:

(1) Pressure;

(2) Temperature;

(3) Flow rate;

(4) Oil, gas and water content;

(5) Liquid level;

(6) Interface;

(7) Rotational speed;

(8) Power;

(9) Vibration displacement;

(10) Vibration frequency;

(11) Voltage;

(12) Valve opening.

2.2.10 Monitoring of Oil (Gas) Discharge System

2.2.10.1 The oil (gas) discharge system shall be equipped with instruments to continuously monitor the following parameters:

(1) Oil (gas) discharge pressure;

(2) The connection status of hoses and ropes;

(3) The tension of connecting equipment (such as hose winch);

(4) Tension of ropes (if applicable).

2.2.11 Electromechanical Equipment Monitoring

2.2.11.1 The data of the electromechanical equipment sensors of FPSO should be used to realize the monitoring or digital twin function.

2.2.12 Gas Leakage Monitoring

2.2.12.1 The data of the gas leakage sensors of FPSO should be used to realize the monitoring or digital twin function.

2.2.13 Fire Detection Monitoring

2.2.13.1 The data of the fire detection sensors of FPSO should be used to realize the monitoring or digital twin function.

Section 3 Technical Requirements for Digital Twin System

2.3.1 General Requirements

2.3.1.1 The FPSO digital twin system shall include the physical entity, digital twin, digital twin data and digital twin service of FPSO. A digital twin shall be established for physical entities such as the FPSO hull, process flow, mooring system, equipment, etc. The digital twin receives information from the FPSO physical entities and evolves at an appropriate frequency to maintain consistency with the FPSO physical entities, and then assist in early warning, diagnosis, decision-making, or control of the FPSO physical entity, thus achieving full life cycle management and operational optimization of FPSO.

2.3.1.2 FPSO digital twin system needs to collect data from various sensors, monitoring equipment

and instruments in the FPSO production process, process the data through algorithms, and form a complete production data model to realize real-time monitoring and prediction of various indicators of FPSO.

2.3.1.3 The FPSO digital twin shall be able to dynamically and accurately map the real-time state of FPSO, and predict the future state of FPSO to a certain extent through simulation or data processing methods.

2.3.1.4 The FPSO digital twin system shall be able to display the state and operation process of FPSO digital twin in an intuitive and visual manner.

2.3.1.5 The interaction time delay between the FPSO physical entity and the digital twin shall be guaranteed to be within an acceptable range.

2.3.1.6 The FPSO digital twin and the physical entity shall be able to exchange information and instructions through a compatible interface.

2.3.1.7 The FPSO digital twin and the digital twin service layer shall be able to exchange data through a compatible interface.

2.3.1.8 The accuracy, integrity and consistency of the data interaction between the FPSO physical entity and the digital twin shall be guaranteed. Data during the interaction process shall not be missed, mistransmitted, or transmitted repeatedly.

2.3.1.9 FPSO digital twin system shall have data cleaning function, including correction of wrong data, filtering of invalid data, merging and eliminating of duplicate data, filling of incomplete data and other effective methods.

2.3.1.10 The FPSO digital twin system should adopt an efficient database design scheme to support the distributed storage and horizontal scaling to avoid performance bottlenecks caused by data surge.

2.3.1.11 The FPSO digital twin service shall be modular, callable, combinable, reusable and reconfigurable.

2.3.1.12 Real-time simulation shall be performed using a digital twin updated to the state consistent with the current FPSO physical entity.

2.3.1.13 Where the FPSO digital twin system has autonomous decision-making and automatic control functions, risk analysis shall be performed and security measures shall be developed to ensure the safety of the FPSO physical entity. Relevant documents shall be submitted to CCS for review.

2.3.1.14 Unless otherwise specified in this chapter, the FPSO digital twin system shall meet the relevant requirements in the *Guidelines for Digital Twin Systems of Ships and Offshore Installations* and the *Guidelines for Verification of Digital Systems of Ships and Offshore Installations* by CCS.

2.3.2 Digital Twin Model

2.3.2.1 The time system of FPSO digital twin model should adopt Gregorian calendar and UTC/GMT standard time.

2.3.2.2 The FPSO digital twin model shall accurately reflect the structural characteristics of the FPSO physical entity.

2.3.2.3 The construction of FPSO digital twin model shall fully consider the practicality and scalability to adapt to the expansion and change of business requirements.

2.3.2.4 The FPSO digital twin model shall have an unique identifier in the system.

2.3.2.5 The FPSO digital twin system shall be able to preview, search, import, export and modify the FPSO digital twin model.

2.3.2.6 The FPSO digital twin model shall be able to attach the dynamic information such as state and behavior of FPSO.

2.3.2.7 The FPSO digital twin model shall have the structural and semantic characteristics to be able to participate in simulation analysis.

2.3.2.8 Lightweight processing should be carried out for FPSO digital twin model to ensure model accuracy, improve the efficiency of model simulation calculation, improve the redundancy of system computing resources, and reduce the computing pressure.

2.3.2.9 The real-time simulation running time of the FPSO digital twin model shall be similar to the original data acquisition cycle, or follow a preset reference time threshold.

2.3.2.10 The off-line simulation running time of FPSO digital twin model shall follow the preset reference time threshold.

2.3.2.11 The simulation results of FPSO digital twin model shall be able to be visualized, and different alarm levels shall be clearly distinguished.

2.3.2.12 The FPSO digital twin model, after being constructed, shall be reviewed and verified.

2.3.2.13 A model update mechanism shall be established to timely update the model when the physical entity of FPSO changes.

2.3.2.14 Consistency of model, attribute data and metadata shall be ensured during system operation.

2.3.2.15 The version management mechanism for model update shall be established, and the model can be switched between versions according to requirements.

2.3.2.16 The creation, storage, transmission and update of the model shall comply with the provisions of the national information security and confidentiality management.

2.3.2.17 Evaluation indicators of model accuracy shall be formulated, such as deviations between model simulation results and measured data. Evaluation indicators shall meet the design requirements and be submitted to CCS for review.

2.3.3 Digital Twin Data

2.3.3.1 FPSO digital twin data includes attribute data, configuration data, system running state data, control data, derivation data, knowledge data, simulation data, etc.

2.3.3.2 The FPSO digital twin system shall be able to manage the collected data, including data parsing, de-duplication, synchronization, aggregation, sorting and matching, and classify and store the data according to reasonable rules.

2.3.3.3 Fusion of multi-channel and multi-sensor data is recommended.

2.3.3.4 Remote communication between the local database and the land-based database shall be supported, and the integrity, consistency and accuracy of data transmission shall be ensured.

2.3.3.5 The returned data should be compressed before being sent back to the land-based database to save network bandwidth resources.

2.3.3.6 When a network or service fault occurs during data transmission and the fault is recovered, the data transmission shall be able to be resumed from the break point.

2.3.3.7 Guided transmission medium and unguided transmission medium can be selected as transmission medium for FPSO digital twin data according to specific requirements. The guided transmission medium includes twisted pair cable, coaxial cable, optical fiber and other conductors. The unguided transmission medium includes radio waves such as short wave, microwave, Bluetooth, satellite and light waves.

2.3.3.8 Structured information (such as geometry information and attribute information) of FPSO digital twin data should be stored in database mode. Unstructured information, such as files, should be stored in a distributed file management system.

2.3.3.9 The FPSO digital twin system shall support standard, open and secure data access interfaces for data manipulation.

2.3.3.10 The FPSO digital twin system shall have a data security mechanism, allowing only authorized users to access and modify data through user identity authentication, permission control, data encryption, etc.

2.3.3.11 The FPSO digital twin system shall have data fault tolerance and high availability mechanism, including data backup and quick recovery functions.

2.3.3.12 Data backup and recovery functions shall be able to support database-level full backup, and save and view the backup and recovery progress, backup and recovery history records.

2.3.3.13 Backup data should be compressed to reduce disk space occupied by backup data.

2.3.3.14 Necessary measures shall be taken to ensure that the data backup procedure does not affect the normal operation of the FPSO digital twin system.

2.3.4 Digital Twin Service

2.3.4.1 The digital twin service refers to the service interface required by the digital twin system to provide users (people, organizations, or systems) with services.

2.3.4.2 The digital twin services should include monitoring, diagnosis, prediction and decision-making functions.

2.3.4.3 In the software architecture design, the principles of single responsibility, interface isolation and dependency inversion should be followed, and the stability and high availability of FPSO digital twin service should be guaranteed through microservice, redundancy design, stateless design, system fault tolerance, disaster recovery backup and various overload protection mechanisms.

2.3.4.4 The page of FPSO digital twin service shall be simple, easy to use, flexible, uniform in style, and complete with user help documents.

2.3.4.5 After the FPSO digital twin service is upgraded, the compatibility of previous versions shall be ensured, and the versions can be switched as required.

2.3.4.6 The FPSO Digital twin service should have an audit mechanism to record important behaviors of users, abnormal use of system resources, and use of important system commands that affect the security and stability of the FPSO digital twin system.

Chapter 3 Surveys of Products

Section 1 General Provisions

3.1.1 General Requirements

3.1.1.1 The system and related products shall undergo product inspection in accordance with the requirements of this chapter, including product design drawings review, product survey and testing, and product certificate issuance.

3.1.1.2 The manufacturer, agent, or designer of the product shall submit an application for product survey to CCS and submit the drawings specified in Section 2 of this chapter to CCS for review.

3.1.1.3 The product survey of the system shall not only comply with the provisions of the Guidelines, but also comply with the provisions of the *Rules for Classification of Offshore Floating Installation* by CCS, the *Rules for Classification of Sea-Going Steel Ships* and the *Rules for Materials and Welding.*

Section 2 Design Review

3.2.1 General Requirements

3.2.1.1 The list of survey and test items and process documents of the system, such as welding process, equipment installation process, test outline and test procedure, shall be submitted to the surveyor on site of CCS.

3.2.1.2 The development and testing process of the system and the development quality system shall comply with the requirements of the CCS specification documents and the owner's technical documents.

3.2.1.3 If design changes are made to the approved drawings, the modified drawings shall be re-submitted for review.

3.2.2 Scope of Drawings to Be Submitted for Review

3.2.2.1 The following drawing materials (but not limited to) shall be submitted according to the applicable situation of the system:

(1) System technical specifications (software and hardware);

(2) System schematic diagram;

(3) Power system diagram and layout diagram;

(4) Sensor/monitoring equipment installation layout (including equipment information and installation requirements);

(5) Test outline and test procedures for sensor/monitoring equipment;

(6) Instructions of software design (including algorithms, models, data quality and network security);

(7) Digital twin algorithm test report (including the correctness, integrity, availability, fault tolerance and recoverability of the algorithm);

(8) Software test outline;

(9) Software test report;

(10) System test procedures;

(11) System operation manual.

Section 3 Certification Requirements for Products

3.3.1 General Requirements

3.3.1.1 The certification requirements for classified FPSO products are detailed in the *Rules for Classification of Offshore Floating Installation* by CCS and 3.1.6, Section 1, Chapter 3, Part 1 of its First Technical Change Notice in 2023.

3.3.1.2 The certification requirements for non-classified FPSO products are detailed in the *Rules for Classification of Offshore Floating Installation* by CCS, 3.1.6, Section 1, Chapter 3, Part 1 of its First Technical Change Notice in 2023, and Section 3, Chapter 2 of the *Offshore Oil and Gas Handling Code*.

Section 4 Equipment Survey

3.4.1 Equipment Test

3.4.1.1 The equipment for status monitoring and digital twin system of the classified FPSO shall be surveyed according to the product certification requirements in 3.3.1 of the Guidelines, and the environmental reliability and EMC (electromagnetic compatibility) of the product shall meet the relevant test requirements of the CCS *Guidelines for Type Approval Test of Electric and Electronic Products*.

3.4.1.2 Test items and requirements shall meet the relevant requirements of 4.2.2.2, Section 2, Chapter 4 of the *Guidelines for Surveys of Monitoring Systems for Structures and Equipment of Mobile Units and Offshore Installations* by CCS.

3.4.1.3 Cable tests shall meet the relevant requirements of Part 6 of the *Rules for Classification of Offshore Floating Installation* by CCS.

3.4.1.4 The survey of equipment for status monitoring and digital twin system of non-classified FPSO shall be carried out in accordance with the requirements of this section.

Section 5 System Test

3.5.1 General Requirement

3.5.1.1 The model constructed by the system shall be confirmed to ensure the consistency between the system model and the physical entity.

3.5.1.2 The system functions shall be tested to confirm the reliability and stability of the system.

3.5.1.3 The system functional tests shall include:

(1) The degree of realization of the function;

(2) Safety response caused by internal fault or external system equipment fault;

(3) Secure interconnections with other systems;

(4) To confirm the normal implementation of the system's data collection, storage, transmission, display and application.

3.5.1.4 System power supply test: when the main power supply for the system is lost, the standby power supply shall be able to automatically switch to the system power supply.

3.5.1.5 The system fault alarm tests shall include:

(1) Failure of power supplies;

(2) Fault in sensor/monitoring equipment;

(3) The monitoring data of the sensor/monitoring equipment exceeds the system alarm threshold;

(4) Fault in alarm (or measuring) line grounding;

(5) Communication system fault.

3.5.1.6 The system failure tests shall include:

(1) The functions of the system shall be independent of each other, when one or more systems fail, it shall not affect the normal work of other systems;

(2) The fault of one sensor/monitoring device signal channel (or a module, which may include multiple channels) shall not affect other non-associated channels (modules).

3.5.1.7 In addition to the provisions in this section, the test of the system shall also meet the requirements of relevant specifications and guidelines such as the *Guidelines for the Safety and Reliability Assessment of Marine Software*, the *Guidelines for Requirements of Ship Cyber Security*, the *Guidelines for Digital Twin System for Ships and Offshore Installations*, and the *Guidelines for Verification of Digital System for Ships and Offshore Installations* by CCS.

3.5.2 FPSO Digital Twin System Test

3.5.2.1 The test items of FPSO digital twin system include FPSO digital twin model test, FPSO digital twin data test and FPSO digital twin service test.

3.5.2.2 The FPSO digital twin model test mainly includes:

(1) The quality check of FPSO digital twin model includes data integrity, expression precision, logical consistency, attribute accuracy, time accuracy, etc.;

(2) Verify the functions of viewing, searching, editing, modifying, importing and exporting model elements;

(3) Verify the three-dimensional display, enlargement, reduction, drag, rotation and other operations of the model, and each operation shall be smooth without obvious delays, page crashes and other abnormalities;

(4) Check whether the online or offline simulation running time of the model meets the expected time threshold;

(5) Check whether the deviation between the model simulation results and the measured data meets the expected indicators;

(6) Check whether the simulation results of the model are displayed differently according to different levels, and whether the colors of different levels can be clearly distinguished;

(7) Check whether the function of the model to switch between different versions is normal (if applicable).

3.5.2.3 The FPSO digital twin data test mainly includes:

(1) Carry out data accuracy debugging to check whether the data is correct at all stages from collection, cleaning, storage, processing to final display;

(2) Check whether the data collection frequency is consistent with the threshold set by the system;

(3) Check the integrity, consistency, accuracy, continuity and recoverability of system data backup;

(4) Check the fault tolerance of the system for abnormal data. For example, if the original data collection or the user input data is abnormal, the stable operation of the system will not be affected. The system shall be able to effectively eliminate the impact of abnormal data to ensure that there is no dirty data/invalid data;

(5) Check whether the system has effective measures to restrict access to confidential data;

(6) Check whether the system has effective measures to restrict access to backup data;

(7) If there is an external data access interface, check the integrity and accuracy of the data provided by the interface and check whether the interface has effective measures to restrict access;

(8) The quality assessment of FPSO digital twin data shall meet the relevant requirements of CCS *Guidelines for Quality Assessment of Ship Data*.

3.5.2.4 The FPSO digital twin service test mainly includes:

(1) Check each function of FPSO digital twin service according to the list of functions to confirm that each function meets the requirements;

(2) Debug the early warning function of FPSO digital twin service to check whether the early warning function at all levels is as expected;

(3) Debug the compatibility of FPSO digital twin service to ensure that when the operating system version, screen resolution and other related configurations are changed, the system is able to provide services normally;

(4) Verify the prediction algorithm if a prediction function is provided by the FPSO digital twin service;

(5) If an audit function is provided by the FPSO digital twin service, check the audit logs for completeness and correctness;

(6) Check whether the resources consumed during service running are stable, including server CPU, memory, hard disk, and network bandwidth resources. The server shall not run at full capacity for a long time;

(7) Check whether the loading performance of the front-end page is within an acceptable time range;

(8) Check whether permission control policies are developed for the operating environment of the system. Check to make sure that the user account with low permission cannot perform unauthorized operations;

(9) Check whether permission control policies are developed for the configuration files of the system. Check to make sure that the user account with low permissions cannot modify or delete the system configuration files at will.

Chapter 4 Survey during Construction

Section 1 General Provisions

4.1.1 General Requirements

4.1.1.1 Prior to the installation of the system on the FPSO, the applicant shall submit to CCS a written request for survey during construction and class notation.

4.1.1.2 In order to ensure the smooth and timely survey of the system and related equipment, the applicant shall provide the surveyor with necessary survey conditions and safety measures.

4.1.1.3 The surveyor shall confirm the product certificate of the system or equipment.

4.1.1.4 The installation process requirements for the equipment approved by CCS shall be met.

4.1.1.5 The applicant shall submit the system test outline to CCS for approval. CCS shall survey and test the system according to the technical requirements of the approved test outline.

4.1.2 Surveys of system installing and commissioning

4.1.2.1 Requirements for System Construction and Installation

(1) The construction and installation of the system shall be appropriate to the specific application of the FPSO installations. Among them, the specific functional content used for the system shall meet the requirements of the technical agreement or specifications of the system project, and the equipment installed on the FPSO installations shall meet the requirements of the *Rules for Classification of Offshore Floating Installation* and its first Technical Change Notice in 2023.

(2) The system shall be designed for site installation on the FPSO installations, with initial setup of the system according to approved drawings. After the initial setup is completed and confirmed by CCS, the system shall have appropriate protection measures to ensure that the computer is only used for system functions such as monitoring data display, digital model display, simulation and alarm.

(3) The construction of the system shall meet the following requirements:

① The material selection for the system equipment shall meet the requirements of structural and environmental working conditions in 3.1.1, Chapter 3 of the *Guidelines for Surveys of Monitoring Systems for Structures and Equipment of Mobile Units and Offshore Installations* by CCS;

② The building and installation of the accessory devices of the system shall not affect the safety of the main structure, and construction shall be conducted based on the drawings approved by CCS;

③ The interface between the system and other systems, such as the control system, safety system, etc., shall be clearly defined, and the specific interface requirements shall meet the requirements of the FPSO installations drawings approved by CCS.

(4) The installation of the system shall meet the following requirements:

① A convenient installation mode shall be supplied for the system equipment, so that they can be installed and disassembled quickly;

② Under no circumstances shall the installation of the system (including sensors, monitoring equipment) damage the structure of the FPSO installations and affect the performance of the FPSO installations, cause any safety hazards, or replace the correct judgment and responsibility of the personnel on the FPSO installations;

③ The installation of the system (including sensors and monitoring equipment) shall meet the technical requirements of fire prevention, explosion-proof and anti-corrosion of the FPSO installations, and the surveyor shall survey the installation of the system;

④ The equipment in the system shall be installed in accordance with the drawings and the equipment installation process requirements approved by CCS;

⑤ The installation of sensors/monitoring equipment in the system shall consider the structural layout of the facility, the location of the monitored installations, the maintenance of the sensor/monitoring equipment and its operation mode, etc.;

⑥ Protective measures such as necessary sealing and wave blocking shall be taken for sensors/monitoring equipment to prevent damage caused by waves;

⑦ For the equipment placed underwater in the system, the ease of installation, recovery and replacement shall be considered;

⑧ For the system equipment, cables that meets the environmental conditions shall be selected according to their installation locations, and all cables and wiring other than the equipment shall be at least flame retardant. When the cable runs through the watertight bulkhead or deck, a separate watertight stuffing box or a watertight stuffing box of multiple cables can be used, and the watertight integrity of the bulkhead or deck shall be maintained after cable penetration. Similarly, cables running through bulkhead and deck with certain fire protection requirements shall not affect the fire integrity of the deck and bulkheads;

⑨ The auxiliary devices of the system should meet the requirements of moisture, salt spray, oil spray and mold prevention, and their installation positions shall not interfere with other equipment or affect the safety and reliability of the main structure;

⑩ The equipment in the system shall be commissioned with standalone debugging after installation to test the connectivity of the system.

4.1.2.2 The site survey of system installation shall include:

(1) Check whether the layout of the sensors/monitoring equipment is in accordance with the approved drawings;

(2) Check whether the packaging of the sensor/monitoring equipment is in accordance with the approved drawings;

(3) Check the calibration value of the sensor/monitoring equipment after installation, and confirm that the error with the factory value meets the requirements;

(4) Check that the welding loss value of the optical fiber connector meets the requirements;

(5) Check the installation position of the anemometer and confirm that the surrounding structure will not affect the wind speed and direction. The installation position of the wave radar shall be a certain distance above sea level to avoid damage to the radar by waves. The installation of the motion sensor shall take into account the impact of vibration. If the elastic support is used, it shall be proved that its natural frequency will not affect the signal of the frequency band measured by the sensor;

(6) The welding and installation survey of the monitoring system equipment or the fixed installations of the sensor/monitoring equipment shall be completed in accordance with the *Rules for Materials and Welding* by CCS (if applicable);

(7) The laying of system cables shall meet the requirements of fire prevention, explosion prevention and electromagnetic compatibility, and the technical requirements for the integrity of corresponding bulkheads shall be met when the cables penetrating watertight or fire resistant bulkheads;

(8) Installation survey of other accessory equipment of the system;

(9) Functional testing of the system equipment after installation shall be carried out to verify the connectivity of single sensor/monitoring equipment or system equipment;

(10) Check that the system is grounded properly.

4.1.2.3 The functional test of the monitoring system after installation shall include:

(1) Verify whether the quantity, accuracy and other parameters of data collection for monitoring system sensors/monitoring equipment meet the design requirements;

(2) Verify whether the data collection, data storage and other functions of the monitoring system meet the design requirements;

(3) Verify whether the joint debugging results of the monitoring system meet the design requirements;

(4) Verify whether the normal and emergency operation functions of the monitoring system meet the design requirements;

(5) Verify whether the other functions and performance of the monitoring system meet the design requirements.

4.1.2.4 The functional test after the digital twin system is installed shall include:

(1) Review the system function and performance to verify that the architecture, function and performance of the digital twin system meet the requirements of the CCS specification guidelines and the owner's technical documents;

(2) Review the data management to verify that the multi-source data storage methods, analysis and processing methods, data fusion methods, data management and application of static data in construction and installation of digital twin system and dynamic data in service comply with the requirements of CCS specification guidelines and the owner's technical documents;

(3) Review the twin model to verify that the intelligent method applicability and model synchronization reliability of the implementation of the twin model in each stage of the digital twin system meet the requirements of the CCS specification guidelines and the owner's technical documents;

(4) Review the data to confirm the security policy of data activities, determine the data retention period, and determine the conformity of the characteristics, measures and weights of the evaluation using data for the data meets the retention period.

4.1.2.5 The system switch test shall include:

(1) Conduct system switch test to perform normal switching operation or emergency shutdown; Confirm that all equipment indicators are in normal status;

(2) Conduct the shutdown test for some equipment in the system to ensure the independence of equipment and confirm the normal state indication of other equipment;

(3) Confirm that the automatic shutdown caused by unexpected events (such as high pressure, high temperature and flame failure) has been completed and meets the requirements;

(4) Test the shutdown of equipment of the whole system one by one and confirm their compliance with the design requirements.

Chapter 5 Post-construction Survey

Section 1 General Provisions

5.1.1 **General Requirements**

5.1.1.1 After system survey and certification according to this Guideline, if any of the following changes occur, the applicant shall promptly notify CCS and apply for a new survey.

(1) Replacement or repair of main equipment damaged;

(2) Changes in main functions of the software;

(3) Addition of subsystem or module.

5.1.1.2 After system survey and certification, the validity of the certificate can be maintained in accordance with the requirements of this chapter.

Section 2 Survey of Class Notation

5.2.1 **General Requirements**

5.2.1.1 For survey requirements for class notation of the system, refer to the *Rules for Classification of Offshore Floating Installation* and the requirements set out in 5.13.4, Section 13, Chapter 5, Part 1 of the first Technical Change Notice in 2023.

5.2.1.2 When replacing parts that are required to be certified, certificates of the relevant parts shall be provided, and records of debugging and functional tests of related items shall be recorded.

5.2.1.3 The owner may apply for occasional survey if necessary.

5.2.1.4 The survey cycle of the class notation shall be coordinated with that of the installations.

Section 3 Survey of Certificate of Compliance

5.3.1 General Provisions

5.3.1.1 For systems with CCS certificate of compliance, if the owner applies for a survey to maintain the validity of the certification, the specific survey requirements can be found in Section 2 of this chapter.

5.3.1.2 The survey cycle of the system should be consistent with that of the installations.