Guide for

Hull Condition Monitoring System

ABS

July 2020

GUIDE FOR

HULL CONDITION MONITORING SYSTEM
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Foreword *(1 July 2020)*

This Guide addresses the need for fitting of Hull Condition Monitoring Systems on vessels, describes the uses for the data they acquire, gives performance specifications for the various types of systems and outlines criteria against which ABS can award notations that will be entered in the ABS *Record*. It is applicable to all types and sizes of merchant vessels.

The scope of the system, the nature of the display and the form and aims of data processing are largely decisions to be made by the vessels' Owners in conjunction with the system suppliers. However, ABS is prepared and able to give advice and assistance in this respect.

The condition monitoring systems covered by this Guide extend from simple one-motion monitoring systems to sophisticated voyage data recorders covering a multitude of hull, systems and machinery parameters.

The overall Hull Condition Monitoring process is one of:

- Data measurement
- Data collection and conditioning
- Data processing and evaluation
- Results presentation and storage

Hull monitoring systems are fitted to acquire, display and/or record information and then use that information for decision making to improve operational efficiency and/or safety. As ABS is primarily interested in the enhanced safety aspects that can be obtained by the correct use of monitoring systems, any vessel fitted with a system and complying with the requirements of this Guide will be awarded appropriate notations for entry in the ABS *Record.*

The Performance Specification of a Hull Condition Monitoring system must depend to a large extent on the system's intended use. The focus of this Guide is what to do rather than how to do it.

Approved by an Administration, mandatory Voyage Data Recorders (VDRs) would be acceptable in partial fulfillment of the **HM3 VDR** notation, provided that additional requirements set by this Guide above those required by IMO Res. A.861(20) are met.

The July 2020 edition includes two newly proposed descriptive notations for **HM1**: **Sloshing Monitoring** and **HM2**: **Structural Temperature Monitoring**, and also provides one informative Appendix on sensor specification and signal processing.

The *Hull Condition Monitoring Guide* can accompany the ABS *Guide for Smart Functions for Marine Vessels and Offshore Units* and the ABS *Advisory on Structural Health Monitoring: The Application of Sensor-Based Approaches* to provide clients with guidance on implementing Hull Condition Monitoring and how to move to **SMART(SHM)** from Hull Condition Monitoring only.

SMART(SHM) as per the ABS *Guide for Smart Functions for Marine Vessels and Offshore Units* leverages operational data, sensor data, and other supporting data to provide structural health diagnostics and prognostics through the correlation of various data sources and physics-based or data driven algorithms and simulations. Compared to the hull condition monitoring summarized in this Guide that is mainly based on techniques such as parameter-based monitoring, alarming, and trending, **SMART(SHM)** is typically capable of generating structural insights for the holistic structures in addition to the sensed locations.

While the hull condition monitoring techniques summarized in this Guide are adequate for certain commercial implementations with optional class notations, the adoption of **SMART(SHM)** depends on various levels from the clients on implementation expectations, technical maturity, and commercial

considerations. The specification and requirements for sensor-based direct load and response monitoring listed in this Guide can supplement the sensor implementation for **SMART(SHM)** purposes as well.

This Guide becomes effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.

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HULL CONDITION MONITORING SYSTEM

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SECTION 1
General

1 Application

This Guide is applicable to classed vessels for which any of the hull monitoring system notations indicated in Subsection 1/3 have been requested.

2 Scope *(1 July 2020)*

This Guide covers hull monitoring systems used for motion monitoring, structural response monitoring and voyage data monitoring. Monitors covered include those for collection of data over a period of time for subsequent evaluation ashore, and those for immediate interpretation of processed data for use by vessels' operating personnel.

3 Notations *(1 July 2020)*

3.1 HM1, HM2, HM3 *(1 July 2020)*

At the request of the Owners or Shipyard, a hull condition monitoring system which complies with the requirements of this Guide will be distinguished in the *Record* by the notations **HM1**, **HM2**, **HM3**, as appropriate, followed by the appropriate descriptive notation such as **Slam Warning**, **Green Seas Warning**, **Ship Motion**, **Sea State**, **Hull Girder Stress**, **Local Load Monitoring**, **Fatigue Monitor**, **Sloshing Monitoring**, **Structural Temperature Monitoring**, **LC** (loading computer data link), **VDR**, **Enhanced VDR**, **Navigation**, **Wind**, **Shaft Monitoring**, and **SL** (shore data link). In addition, optional notations specifying the required type of monitoring devices of the monitoring system in compliance with this Guide, together with a digit specifying the number of devices installed or the number of measurements, will also be assigned as needed. The optional descriptive notations include: **MOT** (ship motion sensors), **ACS** (ship acceleration sensors), **PT** (pressure transducers), **ST** (sea state monitoring devices), **HS** (hull girder strain gauges), **LS** (strain gauges for local stress monitoring), **TEMP** (temperature sensors for structural temperature monitoring), **WD** (wind state monitoring devices), **TM** (shaft torque meters), and **RC** (shaft revolution counters). For example, the class notation **HM1 (Slam Warning: ACS1, Ship Motion: MOT2, Sea State: ST1)** is assigned to a vessel having the capability of slam warning with one accelerometer monitoring the acceleration along one axis, two devices monitoring ship motion and one device monitoring the sea state.

The notations are denoted in the following table.

Notations	*Descriptive Notations*	*Optional Descriptive Notations**
HM1	Slam Warning	ACS, PT, LS
	Green Seas Warning	---
	Ship Motion	ACS, MOT
	Sea State	ST
	Sloshing Monitoring	PT, LS
HM2	Hull Girder Stress	HS
	Local Load Monitoring	LS
	Fatigue Monitor	---
	LC	---
	Structural Temperature Monitoring	TEMP
HM3	VDR	---
	Enhanced VDR	---
	Navigation	---
	Wind	WD
	Shaft Monitoring	TM, RC
	SL	---

Note: * Optional descriptive notations are followed by a digit specifying the number of sensors (or devices) installed.

3.2 +R *(1 July 2020)*

At the request of the Owners or Shipyard, a hull condition monitoring system receiving any of the notations indicated in 1/3.1 which complies with the requirements of this Guide and has provisions for recording data for later evaluation will be distinguished in the *Record* by adding the notation **+R** directly after the notations indicated in 1/3.1 (e.g., **HM2+R**).

Additional requirements on the recorded data for notation **HM2+R** are specified in 2/2.2.4.

For vessels with the SL notation (2/3.7) and where it can be established that the data link to onshore facilities provides the capacity to record the measured data onshore for later evaluation, the **+R** notation will be awarded.

4 Information to be Submitted *(1 July 2020)*

The following plans and information are to be submitted:

- General Arrangement
- Structural plan with marked sensor or gauge installation locations and analysis appropriate to the purpose of the monitoring
- A block diagram and description illustrating the operation of the system.
- Details of the sensor accuracy, range, frequency response and any Type Approvals of the sensors.
- Description of the methods used to process the data for display.
- Description of the derivation of the display warning criteria.

- Description and visual simulation of the method of display of the output.
- Procedure for installing the sensors.
- Procedure for setting up and testing the sensors.
- Procedure for system testing.
- Description of the method and capability of the data recording system.
- The Operations Manual for the system.
- Operational verification procedure

Plans from designers and shipbuilders should generally be submitted electronically. However, hard copies will also be accepted. All plan submissions from manufacturers are to be made with the awareness of the shipbuilder. In some cases, ABS may request the submission of additional information when it is considered necessary to review particular features of a Hull Condition Monitoring system.

5 Alternatives *(1 July 2020)*

ABS will consider alternative arrangements which can be shown to be effective in meeting the overall intent of the Guide.

SECTION 2

System Type Requirements

1 HM1 - Motion Monitoring

1.1 Application *(1 July 2020)*

Where requested by the owner, the notation **HM1** and the appropriate descriptive notation such as **Green Seas Warning** will be assigned to vessels having hull condition monitoring systems for motion monitoring in compliance with this subsection. For the purposes of this subsection, motion monitoring systems measure rotational and/or translational movement using motion monitoring devices such as accelerometers, vertical reference gyroscopes, pitot and Doppler logs, wave height sensors and servo inclinometers.

Motion monitoring systems are to be identified by their main function or purpose, and it is this that will form the descriptive part of the notation awarded, as indicated in the following paragraphs. Requirements for the most common types of systems are provided in 2/1.2 to 2/1.6.

1.2 Slam Warning

1.2.1 System Requirements

The Slam Warning monitor is to warn the vessel's operating personnel in advance that the vessel is in sea or operating conditions approaching those that could induce wave slams that could lead to either local or hull girder structural damage. Slam warning monitors are to show the trend over time in relation to the slam wave impact that would exceed the selected warning levels.

1.2.2 Warning Levels *(1 July 2020)*

Structural damage warning levels on displays and alarm levels are to take into account the approved scantlings and their conditions of approval. The criteria to judge the occurrence of slams is to be derived from calculations, model tests or full-scale trial results, and are to be submitted for review. The method for deriving the criteria is to reflect the operations of the type of vessel being fitted.

1.2.3 Sensor Types *(1 July 2020)*

Slam warning is to be carried out using accelerometers measuring the vertical bow motion, or pressure transducers measuring the relative motions of the vessel and the sea surface or strain gauges measuring the response of the structure to identifiable slamming events. Acceptable methods of identifying impacts include:

1.2.3(a) Accelerometers. (1 July 2020)

Accelerometers are to be capable of identifying a decaying vibratory shape on the acceleration signal at the frequency of the 2-node mode of vibration of the vessel using spectral analysis or other techniques. The severity of the impact is to be indicated by the amplitude of the

vibration. Measurement signals are to be processed and displayed on the bridge for monitoring accelerations, including vibrations extractable from acceleration data. An optional descriptive notation **ACS**, with a digit can be assigned to indicate the installation of accelerometers monitoring acceleration along one axis for slam monitoring, and the number of accelerometers installed. For example, **ACS1** indicates that one sensor is installed monitoring acceleration along one axis.

1.2.3(b) Pressure Transducers. (1 July 2020)

The deployment of pressure gauges is to cover the slamming impact areas, such that gauges can emerge from the water. The severity of impact is indicated by the re-entry pressure. An optional descriptive notation **PT** together with a digit can be assigned to indicate the installation and the number of pressure transducers for slam monitoring purposes.

1.2.3(c) Strain Gauges. (1 July 2020)

The deployment of strain gauges is to cover the slamming impact areas, such that strain gauges are able to provide an alternative to measure the slamming pressure indirectly, in contrast to pressure transducers. Such deployment may not need penetration into the structure for the sensing element to contact the pressure medium. The slamming pressure can be estimated from the strain gauge readings via a conversion matrix, which can be established through the finite element method or similar approach. The methodology that is implemented to identify the slamming event using strain gauge signals is to be submitted for review. An optional descriptive notation **LS** together with a digit can be assigned to indicate the installation and the number of strain gauges for slam monitoring purposes.

1.3 Green Seas Warning

1.3.1 System Requirements *(1 July 2020)*

The Green Seas Warning monitor is to warn the operating personnel in advance that the vessel is in sea or operating conditions approaching those in which carrying of green seas could lead to damage of vessel or cargo. Green Seas Warning monitors are to show the trends of green seas over time in relation to the green seas that would exceed the selected warning levels.

1.3.2 Warning Levels *(1 July 2020)*

Structural damage warning levels on displays and alarm levels are to take into account the approved scantlings and their conditions of approval. Criteria to judge the approaching of levels of water on deck or bow acceleration that could cause damage to the vessel or cargo are to be derived from calculations, model tests or full scale trial data and are to be submitted for review.

1.3.3 Sensor Types *(15 December 2015)*

Monitoring of the carrying of green water is to be accomplished by sensors that measure the amount of water coming on deck or the vertical motions at the fore end of the vessel.

1.4 Ship Motion

1.4.1 System Requirements

The ship motion monitor is to warn the operating personnel that the vessel motions are approaching a level at which a specific problem condition is likely to occur. The specific problem being considered is to be clearly stated. Ship motion monitors are to indicate over time the possibility of the ship motion exceeding the selected warning levels.

1.4.2 Warning Levels

The levels of motion that will cause the specific problem are to be submitted for review. The levels at which warnings are given to the vessel's operating personnel are to reflect those levels and are to be submitted for review.

1.4.3 Sensor Types *(1 July 2020)*

Monitoring of ship motions is to be carried out by motion sensors, such as Motion Reference Units (MRUs), gyroscopes, and accelerometers. The sensors are recommended to be installed on rigid structures to reduce the effect from local structural vibration on ship motion measurements. The measurements (translations and/or rotations) and the installation locations are to be submitted for review.

Vessels equipped with ship motion monitoring devices other than accelerometers can be assigned an optional descriptive notation **MOT**, followed by a digit specifying the number of sensors installed.

As for accelerometers measuring acceleration along one axis for ship motion monitoring, measurement signals are to be processed and displayed on the bridge for monitoring accelerations, including vibrations extractable from acceleration data. Vessels equipped with such accelerometers can be assigned an optional descriptive notation **ACS**, followed by a digit specifying the number of sensors installed. For example, **ACS3** indicates three accelerometers each measuring accelerations along one axis are installed.

1.5 Sea State *(15 December 2015)*

1.5.1 System Requirements

The sea state monitors are to provide direct measurements such as the encounter wave height, wave period and wave direction of the dominant wave and wave frequency spectrum. The monitors are to demonstrate over time the possibility of sea state endangering the safe operation of the vessel.

1.5.2 Warning Levels

The levels of sea states that will pose a danger to vessel operation are to be submitted for review. The levels at which warnings are given to the vessel's operating personnel are to reflect those levels and are to be submitted for review.

1.5.3 Devices *(1 July 2020)*

Vessels equipped with direct sea state monitors, such as radar, acoustic and laser/optic wave meters in compliance with 2/1.5.1 to 2/1.5.2 can be assigned an optional descriptive notation **ST**, followed by the number of devices used.

1.6 Sloshing Monitoring *(1 July 2020)*

1.6.1 System Requirements

Tanks holding liquids may be exposed to sloshing loads, which are a form of impact load acting on the inner surface of the tank. The sloshing monitoring is to warn the vessel's operating personnel that particular liquid cargo tanks are being subjected to unwanted sloshing loads on the critical structural area locally to levels approaching the limits of their approval, and that corrective action is advisable. Sloshing monitoring is to indicate over time the approaching possibility of the structural load/response exceeding the selected warning levels. ABS is to be consulted prior to the design of sloshing monitoring systems as the detailed requirements of such systems are dependent upon their function.

1.6.2 Warning Levels

Warning levels on displays and alarm levels are to be set taking into account the approved scantlings and their conditions of approval. Warning level settings are to be submitted for approval along with the criteria used in determining those settings.

1.6.3 Sensors

Sloshing monitoring may be carried out by the use of strain gauges measuring the sloshing induced strains in structures or pressure transducers measuring the liquid pressure in tanks. Acceptable methods of sloshing monitoring include but are not limited to:

1.6.3(a) Strain Gauges.

The deployment of strain gauges is to cover the sloshing suspect areas, such that strain gauges are able to provide an alternative to measure the sloshing loads indirectly. Proper signal processing and signal pattern recognition techniques can be employed to identify the transient sloshing event from the strain gauge signals associated with other evidence from additional means (e.g., liquid level sensors, Motion Reference Units, accelerometers and/or pressure sensors). The methodology that is implemented to interpret the sloshing loads/responses using strain gauge signals is to be submitted for review. An optional descriptive notation **LS** together with a digit can be assigned to indicate the installation and the number of strain gauges for sloshing monitoring purposes.

1.6.3(b) Pressure Transducers.

The deployment of pressure gauges is to cover the sloshing suspect areas, such that gauges are able to contact the pressure medium and to capture the sloshing loads directly. An optional descriptive notation **PT** together with a digit can be assigned to indicate the installation and the number of pressure transducers for sloshing monitoring purposes.

2 HM2 – Structural Response Monitoring *(1 July 2020)*

2.1 Application *(1 July 2020)*

Where requested by the Owner, the notation **HM2** and the appropriate descriptive notation such as **Hull Girder Stress** will be assigned to vessels having systems to monitor stresses in compliance with this subsection. For the purposes of this Subsection, stress monitoring usually involves fitting a number of strain gauges to the hull structure.

Structural response monitoring systems are to be identified by their main function or purpose, and it is this that will form the descriptive part of the notation awarded, as indicated in the following paragraphs. Requirements for the most common types of systems are provided in 2/2.2 to 2/2.6, below.

2.2 Hull Girder Stress

2.2.1 System Requirements

The Hull Girder Stress monitor is to warn the vessel's operating personnel that the hull girder stresses are approaching a level at which corrective action is advisable. Hull Girder Stress monitors are to indicate over time the possibility of the hull girder stresses exceeding the selected warning levels. Hull girder monitors are to show the still water bending moment and wave bending moment and how they vary with time and longitudinal position along the length of the vessel.

2.2.1(a) Still Water Loads. (1 July 2020)

Information is to be collected and presented to help prevent of overloading, buckling and collapse of the hull during cargo and ballast operations and to confirm that the required strength for wave loading remains in the hull girder when at sea. A display for the still water loads is to be available in the area from which cargo loading and unloading operations are controlled.

2.2.1(b) Wave Loads.

The display is to show the effects of change of speed or heading on the wave loads and, thereby, on the possibility of damage within a short time of the change. In general, this time is to be less than ten minutes.

2.2.2 Warning Levels *(1 July 2020)*

ABS provides Rule criteria for both static and dynamic load and stress components which are to be used to set the warning levels of monitoring systems. When installed as global hull girder response indicators, the warning levels are to be set with reference to the approved scantlings and their conditions of approval. Warning level settings are to be submitted for review along with the criteria used in determining settings.

2.2.2(a) Still Water Loads.

Still Water hull girder stress warning levels are to reflect both 'At Sea' and 'In Harbor' criteria, as well as any others that may be appropriate. Stresses resulting from the static (or Still Water) loads are to be calculated using the loading manual or loading instrument.

2.2.2(b) Wave Loads. (1 July 2020)

See Appendix A1/6.1ii) for guidance.

2.2.3 Sensors *(1 July 2020)*

Measurements of hull girder stresses are generally made with several long base strain gauges distributed along the length of the vessel and around its girth. Strain gauges for monitoring Hull Girder stresses are to be located as close as possible to locations at which the loading manual and loading instrument give bending moment results. Where the gauges cannot be sited at these locations, the method for correlating the strain gauge output to the loading manual and loading instrument locations is to be submitted to ABS for review and included in the operating manual. Where strain gauges are located in areas subject to multiple load mechanisms, means are to be provided for separating out the different stress components. For those gauges located in areas subject to shear lag, compensation is to be made for determining the primary hull girder stresses without shear lag.

Measurement signals are to be processed and displayed on the bridge for monitoring hull girder loading and whipping and springing for fatigue damage and extreme loading.

The minimum required number and approximate position of the strain gauges are indicated below.

2.2.3(a) Tankers, Bulk Carriers, General Cargo Ships and Container Ships (1 July 2020)

- 2 at midships (one port, one starboard on deck)
- 1 at 25% of the length from the bow (on deck)
- 1 at 25% of the length from the stern (on deck)

Additional strain gauges can be provided at the discretion of the Owner or system supplier.

Vessels equipped with strain gauges for hull girder stress monitoring in compliance with Sections 2/2.2.1 to 2/2.2.3 can be assigned an optional descriptive notation **HS**, followed by the number of gauges used. For example, **HS4** indicates four strain gauges are installed for the hull girder stress monitoring.

2.2.4 +R Notation

Data showing the distribution of the extremes of the hull girder stresses are to be collected and recorded for the award of the **+R** notation. ABS will advise on the exact data required, depending on vessel type and size. In general, the data will be the frequency distribution of the dynamic stress component in 50 microstrain intervals.

2.3 Local Stress Monitoring

2.3.1 System Requirements *(1 July 2020)*

The local stress monitor is to warn the vessel's operating personnel that components of the vessel's structure are being locally stressed to levels approaching the limits of their approval and

that corrective action is advisable. Local stress monitors are to indicate over time the approaching possibility of local stresses exceeding the selected warning levels and the subsequent trend of local stresses in relation to the selected warning levels. ABS is to be consulted prior to the design of local stress monitors as the detailed requirements of such systems will be dependent upon their function.

2.3.2 Warning Levels

Warning levels on displays and alarm levels are to be set taking into account the approved scantlings and their conditions of approval. Warning level settings are to be submitted for approval along with the criteria used in determining settings.

2.3.3 Sensors *(1 July 2020)*

Various types of sensors can be installed for local stress monitoring purposes, but the most common type of devices are strain gauges (either long based or short based depending on the purpose and installation locations). Vessels equipped with strain gauges for local stress monitoring in compliance with 2/2.3.1 to 2/2.3.2 can be assigned an optional descriptive notation **LS**, followed by the number of gauges used.

2.4 Fatigue Monitor *(1 July 2020)*

Fatigue monitors are applicable to areas of possible deterioration and designated fatigue prone areas. Usually, fatigue monitors adopt sensors to monitor the local stresses of fatigue prone areas directly (refer to 2/2.3.3).

Fatigue monitors are to indicate over time the amount of usage of the initial fatigue strength relative to the approved scantlings and their conditions of approval. Miner's sum techniques, in conjunction with rainflow counting, are to be used for fatigue life estimation. Other schemes may also be approved. It is recommended that the measured data also be used for crack growth calculations using a method submitted for review.

2.5 Loading Computer Data Link

2.5.1 System Requirements *(1 July 2020)*

The vessel's loading computer is to be able to provide information on the actual calculated still water bending moments, metacentric height (GM) and drafts of the vessel under different loading conditions. The hull monitoring system is to be able to access the above information available from the loading computer and retrieve the still water bending moments at locations where hull girder stress monitors are located. If the still water bending moments from the loading computer are not available at the locations of the monitoring devices, the method used in the hull monitoring system to determine the actual calculated still water bending moments at sensor locations is to be submitted for review.

For the hull monitoring system with direct data link to the loading computer that is capable of continuously updating the loading conditions to the hull monitoring system, an optional descriptive notation **LC** will be assigned. The data link to the loading computer is not to interfere with the functionalities of the loading computer. Any failure or malfunction of the hull monitoring system is not to affect the normal operations of the loading computer.

2.6 Structural Temperature Monitoring *(1 July 2020)*

2.6.1 System Requirements

Structural temperature monitoring is to warn that particular components of the vessel's structure are being subjected to unwanted temperature variations to levels approaching the limits of their approval and that corrective action is advisable. Structural temperature monitoring is to indicate over time the approaching possibility of structural temperature exceeding the selected warning

levels. ABS is to be consulted prior to the design of structural temperature monitoring systems as the detailed requirements of such systems will be dependent upon their function.

2.6.2 Warning Levels

Warning levels on displays and alarm levels are to be set taking into account the approved scantlings, materials, and their conditions of approval. Warning level settings are to be submitted for approval along with the criteria used in determining those settings. Proper thermal stress analysis can be used to estimate the warning levels with reference to ABS *Guidance Notes on Thermal Analysis of Vessels with Tanks for Liquefied Gas*.

2.6.3 Sensors

Various sensors can be installed for structural temperature monitoring purposes. The most commonly used sensors for measuring temperature are thermocouples, thermistors, resistance temperature detectors (RTDs), and fiber-optic sensors.

Vessels equipped with temperature sensors for structural temperature monitoring in compliance with 2/2.6.1 to 2/2.6.2 can be assigned an optional descriptive notation **TEMP**, followed by the number of temperature sensors used.

3 HM3 – Voyage Data Monitoring

3.1 Application *(1 July 2020)*

Where requested by the Owner the notation **HM3** and the appropriate descriptive notation, such as **VDR**, will be assigned to vessels having voyage data monitoring systems in compliance with this subsection. For the purposes of this Subsection, Voyage Data Recording systems record data for later analysis.

Voyage data recorders are to be identified by the extent of their recording capability, the time scale of their recording and the survivability of their recordings, and it is this that will form the descriptive part of the notation, as indicated in the following paragraphs.

The Voyage Data Recorder (VDR) systems required by SOLAS Chapter V, as amended, Regulation 20; and approved by an Administration in accordance with the IMO Resolution A.861(20); fulfill the requirements of this subsection for Voyage Data Recording systems, providing the additional conditions in 2/3.2 below are satisfied.

When the vessel is equipped with an operational data monitoring system, appropriate descriptive notations will be assigned, such as **Navigation** (2/3.4) for monitoring the ship's navigation information, **Wind** (2/3.5) for monitoring wind data and **Shaft Monitoring** (2/3.6) for monitoring the shaft torque and evolutions.

Vessels with data link to shore facilities will be awarded the **SL** descriptive notation, detailed requirements of which are specified in 3/3.7.

3.2 HM3 – VDR

3.2.1 System Requirements

Approved systems will generally monitor and record all bridge functions, fire and gas alarms, principal main engine and auxiliary operating parameters and alarms, environmental conditions, radar and Hull Monitor data, when fitted.

It is recommended that Hull Girder Stress monitors (as described in Section 2/2.2 above) be fitted in conjunction with Voyage Data Recorders for vessels in excess of 200 meters.

3.2.2 Recorded Data *(1 July 2020)*

Recorded data is to be provided in a format that allows the original signal from the sensor to be reconstructed. This requirement can be waived for radar signals.

The minimum acceptable recording rate for the radar is for the information from one complete sweep to be recorded per minute. Data recorded is to be kept for at least 24 hours before it is overwritten, with statistical data being kept for at least a year. For vessels with the **SL** descriptive notation, the one year storage requirement for statistical data can be waived, while the data recording time may be reduced to 12 hours when the onshore data link and onshore storage can provide equivalent storage capacity of at least one year of statistical data and 24 hours of recorded data. The proposal to waive the one year statistical data storage and reduce recorded data storage to 12 hours onboard is to be submitted to ABS for review and approval.

3.2.3 Power Supply *(1 July 2020)*

Voyage Data Recorders are always to operate from an uninterruptable power supply (UPS) with at least four hours backup. The power supply time may be reduced to two hours for vessels with the **SL** descriptive notation and of which the hull monitoring system is capable of onshore remote maintenance. The proposal to reduce power supply hours is to be submitted and approved by ABS. Loss of power from the UPS is to result in an audible and visual alarm on the bridge. After shutting down due to loss of power from its UPS, the Voyage Data Recorder is to start up on resumption of power without any intervention from the vessel's operating personnel. See also Subsection 4/2.

3.3 HM3 – Enhanced VDR

To qualify for the descriptive notation **Enhanced VDR**, the following requirements are to be met in addition to those of 2/3.2.

3.3.1 Recording Time

A full accident investigation system is to record the data for the following time spans:

Vessels > 100 000 tdwt	45 days
Vessels between 40 000 and 100 000 tdwt	30 days
Vessels < 40 000 tdwt	15 days

Vessels on dedicated short sea trades will be given special consideration. These times can be reduced if satellite transmission of the data ashore is adopted.

3.3.2 Survivability *(1 July 2020)*

On all vessels other than oil tankers and gas carriers, the VDR recordings are to be able to survive and be readable after being in a cellulose type fire for 30 minutes.

On tankers and gas carriers, the VDR recordings are to be able to survive being in a hydrocarbon type fire for four (4) hours and are to be released into the sea if their temperature reaches that at which they would be damaged.

The VDR recording devices are to be buoyant and float free if the vessel sinks, and an Emergency Position Indicating Radio Beacon (EPIRB) is to be automatically activated.

3.4 Navigation

3.4.1 System Requirements *(1 July 2020)*

Ship's navigation information, such as vessel position, speed over ground, speed through water, vessel's course over ground and rudder angle is to be recorded continuously in the hull monitoring system. If the ship has a separately installed navigation system, instead of installing additional

sensors, the hull monitoring system can be directly linked with the navigation system and retrieve the data, such as Global Navigation Satellite System (GNSS) for position, speed over ground and course over ground from the installed navigation system in a non-intrusive way. The data link to the ship's navigation system is not to affect the normal operations of the navigation system. Any failure or malfunction of the hull monitoring system is not to affect the navigation system.

3.5 Wind *(15 December 2015)*

3.5.1 System Requirements *(1 July 2020)*

Wind monitors are to measure the relative speed and direction to the vessel's longitudinal direction of the dominant wind. Wind speed and wind direction are to be corrected based on GNSS signals to obtain the true wind speed and direction and the Beaufort wind scale. Wind sensor installation location is to be selected such that there is the least effects on the measurements from other ship structures, such as the deck house and the distance from the sea level. Locations atop the mast are recommended as much as practical, and the installed location of the wind sensor is to be submitted for review.

3.5.2 Warning Levels

The levels of wind speed and direction at which warnings are given to the vessel's operating personnel are to reflect those levels that will pose a danger to the vessel's operations and are to be submitted for review.

3.5.3 Sensors *(1 July 2020)*

Vessels equipped with wind measurement devices in compliance with Sections 2/3.5.1 and 2/3.5.2 can be assigned an optional descriptive notation **WD**, followed by the number of devices used.

3.6 Shaft Monitoring *(15 December 2015)*

3.6.1 System Requirements

The power output in term of torsional moment or shaft torque on the rotating propulsion shaft and the shaft revolutions are to be directly measured and monitored continuously. For vessels with twin screws, shaft output and revolutions are to be measured on both shafts.

3.6.2 Warning Levels

Warning levels on displays and alarm levels are to be set taking into account the approved maximum output power and allowed revolutions and their conditions of approval. Warning level settings are to be submitted for review.

3.6.3 Sensors *(1 July 2020)*

The installation location of shaft torque meters are to be documented and submitted for review.

Vessel equipped with shaft torque meters and shaft revolution counters can be assigned optional descriptive notational **TM** and **RC**, followed by the number of devices used, respectively.

3.7 Shore Data Link

3.7.1 System Requirements *(1 July 2020)*

When the hull monitoring system has the capacity to be connected to an onshore system via a data link to allow the exchange of data between the onboard and onshore systems and the remote operations for maintenance and data transfer, the descriptive notation **SL** will be assigned. Details of the data transfer intervals and storage capacity of the exchange of data, especially where reductions of onboard storage (2/3.2.2) and power supply (2/3.2.3) have been applied, are to be submitted for review. The data link security is to be fully considered and the security plan is to be submitted for review.

SECTION 3

System Requirements

1 General *(1 July 2020)*

Hull Condition Monitoring systems are to possess a processing and display function to provide information to the vessel operators. The critical elements of these systems are to comply with the following.

2 Sensors

2.1 All Sensors *(1 July 2020)*

There is no restriction on the type of sensor that can be used in a hull condition monitoring system. Sensor selection is to consider environmental condition, installation location of the sensor, and the protective treatment (e.g., hazardous area, ambient temperature, pressure, humidity, noise, vibration, corrosive acid, abrasive action, and electromagnetic, neutron, and radiation fields). Care is to be taken when selecting sensors to confirm that they are suitable for the marine environment. It is recommended that ABS Type Approved sensors be used wherever possible.

The frequency response of sensors is to be suitable for the signal being measured. Accuracy of sensors is to be suitable for the use to which the signal is put.

2.2 Strain Gauges *(1 July 2020)*

Each individual strain gauge is to have a measurement uncertainty better than ±5 microstrain, and the strain gauge instrument is to be capable of measuring in the 0–5 Hz frequency range for wave-induced responses.

In general, strain gauges intended to measure global hull girder loads are to be of the long base type to avoid including local effects in their measurements.

Strain gauges can be either electrical-resistance type or fiber-optic type (e.g., Fiber Bragg Grating (FBGs) strain gauge).

2.3 Accelerometers *(1 July 2020)*

Each individual accelerometer is to have a measurement uncertainty better than ±0.01 g.

3 Output

3.1 Derivation

3.1.1 Accuracy *(1 July 2020)*

When measuring hull girder stresses and corresponding loads, the effects of temperature variations due to daily environmental changes are to be considered. Where possible, these effects are to be

removed from any display of still-water loads. The accuracy of derived hull girder stresses and loads is to be within ±2% of the Still-Water Allowable (at sea) value.

Thermal loads due to cargo temperatures are to be considered separately. Consideration is to be given, taking into account the type of vessel and cargo and the approved scantlings and their conditions of approval, as to whether or not these loads are to be included in the still-water or wave loading.

3.1.2 Sampling Rates

Digital sampling rates are to be suitable for the frequency response of the transducer and the use of the signal. In general, the sampling rate is not to be less than three (3) times the required frequency response. Special attention is to be paid to the sampling rate if it is intended to capture transient components of signals.

3.1.3 Filtering *(1 July 2020)*

Anti-aliasing filtering is to be used when frequency domain processing is performed. The cutoff frequency is to be arrived at in conjunction with the sampling rate. The anti-aliasing filter is to be placed before the analog-to-digital converter and subsequent data processing.

3.1.4 Calculation Period

Statistical parameters of wave-induced signals are to be calculated over a period of between twenty and thirty minutes. It is acceptable for the statistical parameters to be calculated on a rolling basis.

3.1.5 Fatigue Counting

The bin sizes for fatigue counting and extreme frequency counting is not to exceed 50 microstrain. Details of the fatigue counting algorithm are to be submitted for review.

3.2 Displays *(1 July 2020)*

Display of the relative parameters on the bridge in real time or near real time is to be provided.

With assigned **ACS** optional descriptive notation, the acceleration measurement signals are to be processed and displayed on the bridge to monitor accelerations, including vibrations extractable from acceleration data.

With assigned **HS** optional descriptive notation, the strain measurement signals are to be processed and displayed on the bridge to monitor hull girder loading and whipping and springing for fatigue damage and extreme loading events.

When the display is fitted in the wheelhouse, a nighttime display with reduced light intensity and colors that are conducive to night vision are to be made available.

3.3 Recording

3.3.1 All Systems *(1 July 2020)*

All systems are to possess a minimum capability of verifying that all sensors are working under sea-going conditions. Data recording is to be of the mean, standard deviation, maximum peak to peak, average zero crossing period of the dynamic part of the signal, the date and the time. This information is to be calculated over a period of twenty to thirty minutes and recorded at least once per week on semi-permanent data storage medium which maintains data in the event of power loss. Where manual input (for example, via a computer keyboard) is used, the input procedures are to be included in the operating manual for the guidance of the operating personnel and are to be submitted for review. This data is to be checked regularly against the criteria described in the Verification Procedure. Facilities are to be available onshore or on the vessel to enable the data to

be evaluated. Proposals will be considered for recording to be replaced by sending the data ashore via satellite on a regular basis.

3.3.2 +R Notation *(1 July 2020)*

Recording is to be of processed data rather than raw data as far as is possible. The data to be recorded is to include all of the data displayed.

Recordings are to be sent for analysis on a regular basis. The recording period is to take into account the ability of the system to display system failures to operating personnel for resolution. Thus, a period of less than three months is recommended. Proposals will be considered for recording to be replaced by sending the data ashore via satellite on a regular basis.

4 Alarms *(1 July 2020)*

Caution is to be exercised to avoid fitting overly sensitive full alarms with audible warning to Hull Condition Monitoring systems. It is recommended that ABS be consulted for an opinion as to whether an alarm or a visual warning is more appropriate for a particular monitoring function.

5 Power Interruption *(1 July 2020)*

The hull condition monitoring system is to shut down after a loss of power in a structured manner and restart itself with the minimum achievable disruption to its function. The software and data are to be protected from corruption caused by loss of power.

6 Operating Manual

An Operations Manual written in English and in a language appropriate to the vessel's operating personnel, is to be placed onboard. The Operations Manual is to include the following.

- Instructions on Operating the System
- How to Interpret the Results
- Instructions for Maintenance
- Instructions for Fault Finding and Repair
- Sensor Set-up Procedure
- Sensor Calibration Procedure
- Verification Procedure (see Subsection 3/7)
- List of Spares

7 Verification Procedure *(1 July 2020)*

A Verification Procedure, covering initial set up and necessary calibration, is to be submitted for review. The procedure is to detail how to verify that sensors are both operational and in adjustment or within calibration limits, as needed. It is also to verify and detail how such confirmation will be needed for continued satisfactory operations in order to verify that the data collection, analysis, and display functions are still within function and calibration limits.

The Verification Procedure is to be included in the Operations Manual with a check sheet.

SECTION 4
Installation

1 Electrical and Mechanical Systems *(1 July 2020)*

All electrical and mechanical systems and components and electrical installations in hazardous areas are to comply with the ABS *Rules for Building and Classing Marine Vessels* or the ABS *Rules for Building and Classing Mobile Offshore Units*, where appropriate.

2 Power Supply *(1 July 2020)*

Consideration is to be given to both the quality of power supply and the possibility of a power outage. If considered necessary, an uninterruptable power supply is to be fitted, or the system connected to an emergency power circuit. The importance of the system to the safe operation of the vessel is to be considered in making the decision. Means of protecting against power surges are to be provided where surges could cause problems with the electronic equipment.

3 Sensors

3.1 Physical Protection

As far as possible, gauges are to be sited in locations protected from green seas, cargo operations, dropped container securing appliances, etc. In general, gauges situated at or near the side of a vessel and gauges fitted on the decks of tankers are to be protected.

3.1.1 Protection from Green Seas

Deck-mounted strain gauges are to be protected from green seas on deck by appropriate siting or by using substantially constructed breakwaters or similar means. Attention is to be paid to the possibility of green water damage to other gauges, junction boxes, cable conduits, etc.

3.1.2 Protection from Weather

An appropriate level of watertightness and protection to a recognized standard is to be arranged for all external fittings. Sensors fitted in exposed locations are to be hose tested.

3.1.3 Protection from Vibration *(15 December 2015)*

Sensors to measure motions are to be placed in positions where their functions will not be affected by vibrations. Accelerometers and motion monitoring devices are to be mounted on a hard structural point where local structural vibration will be minimal. If resilient mounts are used, it is to be demonstrated that they have frequency characteristics that do not affect the signal in the frequency range of interest.

3.2 Fitting

3.2.1 Welded Attachment

When gauges are welded to the hull, welding procedures are to comply with Section 2-4-1 of the ABS *Rules for Materials and Welding – Part 2*. Consideration is to be given to the damage and repair of coatings.

3.2.2 Through Hull Fittings *(1 July 2020)*

Pressure gauges, where fitted through the hull, are to be arranged so that the pressure diaphragm is flush with the outside of the plating. The gauge is to be arranged so as to enable it to be removed and refitted with the vessel in the water at an operational draft. Any such penetration is to be in accordance with the Rules.

4 Display, Processing and Recording Equipment *(15 December 2015)*

The equipment is to be positively pressured with the cooling air being filtered before being blown in to avoid dust build-up in the equipment. It is to be located, to the extent practicable, in a vibration free area and is to be protected from the effects of direct sunlight.

SECTION 5

Setup and Calibration

1 Setup

The intended method of setup including the means used to assess the stress in the structure and the attitude of the vessel, is to be submitted prior to installation. The setup is to be carried out to the Surveyor's satisfaction.

1.1 Initial Settings

1.1.1 Strain Gauges

1.1.1(a) Hull Girder Stress. (1 July 2020)

Strain gauges only affected by longitudinal global hull girder loads (e.g., deck gauges in a tanker) are to be set to the stress levels resulting from the loads indicated by the vessel's loading instrument and the actual vessel scantlings for the condition it is in, or by the use of other appropriate stress analysis methods. The setup is to be undertaken, to the extent practicable, in a condition when the vessel's loading is not changing, the difference between the air and sea temperatures is low and when the vessel is in a medium or heavy ballast condition.

1.1.1(b) Local Stress.

Where a strain gauge is fitted to a structure that has other significant components of stress in addition to global hull girder loading stress, a detailed analysis of the stress to which it is to be set is to be undertaken and submitted for review.

1.1.2 Motion Monitoring Sensors

The setup of motion monitoring sensors is to take account of the attitude of the vessel at the time of setup.

1.2 Setup Check *(1 July 2020)*

The setup of the gauges is to be assessed between three months and six months after the initial setup. The vessel's operating personnel are to take the relevant values from the loading instrument and the hull condition monitor in accordance with the Verification Procedure, and submit them to ABS. If the variation is too great, the setup procedure will need to be repeated.

2 Calibration

Sensors are to be recalibrated by suitably qualified personnel in accordance with the manufacturer's recommendations at least annually. Calibration records are to be kept on the vessel with the Operating Manual and will be inspected by the ABS Surveyor, in accordance with Section 6.

3 Thermal Stresses

The method of allowing for temperature effects in both setup and calibration is to be submitted for review. The effects to be dealt with are given in 5/3.1 and 5/3.2, below.

3.1 Sensors

In general, sensors are to be temperature-compensated when the steady state or slowly varying part of the signal forms part of the data of interest.

3.2 Structure *(1 July 2020)*

Thermal stresses in structure are to be considered, including the variation caused by the day/night cycle.

SECTION 6

Survey Requirements *(2001)*

The surveys after construction for Hull Condition Monitoring Systems are to be in accordance with the applicable requirements as contained in the ABS *Rules for Surveys After Construction – Part 7*.

APPENDIX 1

Guidance on Selection of Hull Monitoring Systems

1 Motion Monitoring *(1 July 2020)*

In addition to the pure motions of roll, pitch, sway, heave, surge or yaw, also of interest is the resulting effect or load on the whole vessel, local structure or cargo due to those motions.

2 Slam Warning *(15 December 2015)*

The most common wave impacts are bottom slamming and flare impacts or flare slamming.

The slam warning levels are dependent on vessel size, speed and hull shape.

As slam wave impacts shown on the monitor increase towards the warning levels with deteriorating weather, timely corrective action can be taken to reduce slam impacts by increasing ballast or changing speed and/or heading.

3 Green Seas Warning *(1 July 2020)*

The shipping of green seas is a function of sea conditions, vessel speed and vessel form, particularly at the fore end of the vessel.

As the monitor shows on-deck green seas to increase towards limiting levels, timely corrective action can be taken to reduce the shipping of green seas.

4 Ship Motion *(1 July 2020)*

Ship motions themselves are not often a problem for vessel integrity, but are often the reason that a Master reacts to deteriorating environmental conditions. Roll, pitch and heave are the principal motions whose limitations bring benefits.

The levels will usually be dependent upon the frequency of the motion as well as its magnitude. The situations for which the motion indication warning levels may be set include:

i) *Cargo Securing*. Trailers on RO/RO vessels and containers on deck are two examples of cargo that can be lost or damaged in bad weather. The criteria should be set taking into account the ABS approval criteria in the relevant Rules and Guides and the design values.

ii) *Passenger Comfort.* A combination of motion amplitude and frequency induces nausea in passengers. Criteria should be set in accordance with a recognized standard and the origin of the criteria clearly stated.

iii) *Sea Loads*. Wave impacts on the wet decks of SWATHs and catamarans are a function of pitching amplitude and criteria should be set to provide guidance on these critical motions to avoid wet deck overloading.

As the likelihood increases, timely action can be taken.

5 Sloshing Monitoring *(1 July 2020)*

Sloshing due to the motion of liquid cargo inside a moving tank may exert undesired impact loads on the inner surface of the tank and cause structural failures.

For tanks which are not suitable for instrumenting strain gauges and/or pressure transducers, other indirect means to achieve the same functionality may be alternatively considered.

6 Structural Response Monitoring *(1 July 2020)*

Stresses are usually deduced from measurements of strain. Strain is commonly measured using short gauge length electrical resistance strain gauges, long base strain gauges incorporating linear variable differential transformers or linear potentiometers, or fiber-optic strain gauges (such as Fiber Bragg Grating (FBG) strain gauges). The use of other devices will be accepted by ABS if their equivalent performances can be demonstrated.

The number, type and location of these gauges depends upon the type of system being fitted and the type of vessel.

6.1 Hull Girder Stress *(1 July 2020)*

The major hull girder design loads, depending on vessel type, are a combination of vertical bending, horizontal bending, torsion, vertical shear and horizontal shear. All of these loads, except horizontal bending, can be considered to have a static part caused by the distribution of weight and buoyancy and a dynamic part caused principally by waves.

The static (or still-water) loads are calculated using the loading manual or loading instrument and generally account for about 40% to 55% of the total with the dynamic (or wave) loads accounting for the rest. The calculation of the still-water loads is relatively accurate, while the calculation of wave loads are less so. Conversely, the measurement of wave loads may be generally more accurate than the measurement of still-water loads, mainly due to the influence of day/night thermal changes.

Hull Girder Stress may be collected and presented in the following ways:

i) *Still Water Loads (1 July 2020)*. Prevention of overloading, buckling and collapse of the hull during cargo and ballast operations and confirming that required strength for wave loading remains in the hull girder when the vessel puts to sea. An interface with the loading instrument as a check between calculated and actual SWBMs can provide the vessel's operating personnel with a warning of a departure from the loading plan and it should be verified if this is due solely to day/night thermal changes. A display for the still-water loads should be available in the area where cargo operations are controlled. Still-water hull girder stress warning levels should reflect both 'At Sea' and 'In Harbor' criteria as well as any others that may be appropriate.

ii) *Wave Loads*. Provision of information enabling the Master to avoid damage to the hull due to wave loads. Where the monitor shows an increase in wave loads approaching the limiting values, timely corrective action can be taken by changing speed and/or heading. The monitor must also show the effects of these changes on the wave loads within a short time of the change in speed, heading etc.

Motion monitors for other purposes are possible.

6.2 Local Load Monitoring *(1 July 2020)*

Examples might include:

i) *Ice Loading*. Monitoring shell deflections when operating in ice to give guidance on speed reduction. Refer to the ABS *Guide for Ice Loads Monitoring Systems*.

ii) *Bulk Carrier Loading*. Monitoring inner bottom structure during loading of bulk carriers to give guidance on loading rates.

iii) *High Speed Craft Impact Loading*. Monitoring of bottom panels to prevent bottom damage.

iv) *Sloshing Response of Liquid in Tanks:* Monitoring the sloshing in liquid carrying tanks susceptible to potential sloshing-induced damage.

6.3 Fatigue Monitor *(1 July 2020)*

The Fatigue Monitor usually uses sensors to conduct local stress monitoring of a fatigue prone area directly.

The Fatigue Monitor is used to show the vessel operators the extent of remaining design fatigue life. There are a number of different loading mechanisms that cause fatigue damage in vessels, and it is necessary to monitor the fatigue at locations that will give results typical of each mechanism and combination of mechanisms.

Information on the utilization of the design fatigue life is invaluable for the planning of surveys and dockings as it indicates areas more likely to experience fatigue cracking. ABS will advise on the interpretation of data, when requested.

Typical locations at which fatigue monitoring is useful are:

i) Deck longitudinals to provide information on hull girder loading's possible fatigue damage to welded connections.

ii) Side shell longitudinals or frames to provide information on possible fatigue damage due to wave pressure loading.

iii) Bottom longitudinal to provide information on possible fatigue damage due to combination of wave pressure and hull girder loading.

iv) Inner bottom longitudinals to provide information on possible fatigue damage due to combination of dynamic cargo loading and hull girder loading.

6.4 Structural Temperature Monitoring *(1 July 2020)*

Structural temperature monitoring is used to monitor the components of the vessel's structure that are being subjected to unwanted temperature variation and to support the further evaluation of the severity of such unwanted temperature variation. If necessary, local stress monitoring at these areas can be installed to verify the thermal stress contribution to the local stress. Refer to the ABS *Guidance Notes on Thermal Analysis of Vessels with Tanks for Liquefied Gas* for the thermal stress analysis, when applicable.

Typical scenarios for which structural temperature monitoring is useful are:

i) Tank supporting structures of vessels equipped with Type C tanks (e.g., bunkering vessels, gas fueled vessels, LNG carriers)

ii) Aluminum hull structures of high-speed craft

7 Voyage Data Recording *(1 July 2020)*

The recorded data is usually gathered for specific vessel management purposes or to determine the causes of accidents and other incidents.

8 Derivation of Output *(1 July 2020)*

Separation of high and low frequency components of wave-induced signals requires a knowledge of the frequency of the vibration modes of the hull. These can be calculated with acceptable uncertainty to define the necessary filters.

Refer to Appendix 2, Table 1 for recommended sensor signal processing settings (e.g., sampling rate f_s, time interval for statistical calculation T_i) when processing sensor data to have insights into physical quantities of concern.

Refer to the ABS *Advisory on Structural Health Monitoring: The Application of Sensor-Based Approaches* for commentary on coupling sensor data with analysis and analytics models.

9 Sensors *(1 July 2020)*

Consideration should be given to designing redundancy into the system and to making it possible to change gauges simply. This is especially important when fitting strain gauges in inaccessible locations. Consideration should be given to reliability and longevity when selecting strain gauges to measure local loads, and also to the carriage of spares.

Refer to the ABS *Advisory on Structural Health Monitoring: The Application of Sensor-Based Approaches* for the details of recommended structural sensor packages for common commercial vessel types.

Refer to Appendix 2, Table 1 for recommended sensor specifications (e.g., range, uncertainty, bandwidth) in terms of the physical quantities of concern.

10 Displays *(1 July 2020)*

Ease of use and understanding by non-technical specialists is important. The language complexity and jargon used on the displays and in supporting documentation should be at the level of the vessel's operating personnel and not overly complex and technical.

Careful consideration should be given to the rate at which the data being displayed is updated. Statistical data being displayed for too long a period between updates will reduce its usefulness to the vessel's operating personnel, while too short a period will impair the value and proper use of the data. Rolling statistical analysis can help overcome some of these problems.

11 Recording *(1 July 2020)*

Manual input may be the most effective method of recording some data.

Recordings should be sent for analysis on a regular basis. The recording period should take into account the ability of the system to display system failures to the vessel's operating personnel for rectification. A long recording can result in problems going undetected for long periods.

12 Training *(15 December 2015)*

Although not a requirement in order to obtain the class notation, it is very strongly recommended that the vessel's personnel operating the system are formally trained in its use.

13 Fitting of Sensors *(1 July 2020)*

Motion sensors should be placed in positions where they will not be affected local structural by vibrations. For example, it may be worth considering the mode shapes of the hull girder. Accelerometers and motion monitoring devices should be mounted on a stiff structural point where local structural vibration is minimal.

APPENDIX **2**

Recommended Sensor Specification and Signal Processing *(1 July 2020)*

For the physical quantities of concern, Appendix 2, Table 1 lists guidance on measurement range, uncertainty, bandwidth, sampling rate, and digital resolution for a measuring chain (including component sensors and all associated data acquisition devices). Furthermore, Appendix 2, Table 1 also provides guidance on onboard statistical calculation and fatigue calculation using time series.

Note that the minimum sampling rate for data storage should be lower than the value recommended in Appendix 2, Table 1, but it should be good enough to reconstruct the corresponding time series of the physical quantity without loss of accuracy.

Thus, these values are a reference for typical steel ships only. For non-steel ships, values should be submitted to ABS and considered on a case-by-case basis.

TABLE 1
Guidance on Measurement and Onboard Calculation of Motions and Hull Responses (Excluding Ice Load) *(1 July 2020)*

Physical Quantity/ Measurand [Component sensor]	*Characteristics*	*Recommendation*
Measurement		
Strain [Long Base Strain Gauge, Strain Gauge]	Range	$\geq \varepsilon_{still-water} + \varepsilon_{dynamic}$ ± 2000 με for steel
	Uncertainty (min req.)	max (3% of the measured value, 20 με
	Bandwidth (Hz) – motions and wave loadings	0 to 5
	f_s (Hz) - motions and wave loadings	3 times of required frequency (general req.); 20 (recommended)
	Bandwidth (Hz) – slamming	5 to 100
	f_s (Hz) – slamming	3 times of required frequency (general req.); 300 (recommended)
	Bandwidth (Hz) – sloshing	30 to 1200
	f_s (Hz) – sloshing	3 times of required frequency (general req.); 2000 (recommended)
	Resolution (digital)	5 με

Physical Quantity/ Measurand [Component sensor]	*Characteristics*	*Recommendation*
Rigid body Motion – translation acceleration [MRU]	Range	± 2 g
	Uncertainty	0.01 g
	Bandwidth	0 to 5
	f_s (Hz)	20
	Resolution (digital)	≤ 0.01 g
Rigid body Motion – roll angle [MRU]	Range	± 90°
	Uncertainty	max (2% of the measured value, 0.50°)
	Bandwidth	0 to 5
	f_s (Hz)	20
	Resolution (digital)	≤ 0.50°
Rigid body Motion – pitch angle [MRU]	Range	± 45°
	Uncertainty	max (2% of the measured value, 0.50°)
	Bandwidth	0 to 5
	f_s (Hz)	20
	Resolution (digital)	≤ 0.50°
Rigid body Motion – yaw angle [MRU]	Range	± 180°
	Uncertainty	max (2% of the measured value, 0.50°)
	Bandwidth	0 to 5
	f_s (Hz)	20
	Resolution (digital)	≤ 0.50°
Acceleration [Accelerometer]	Range	± 2 g
	Uncertainty	0.01 g
	Bandwidth – motions and wave loadings	0 to 5
	f_s (Hz) – motions and wave loadings	3 times of required frequency (general req.); 20 (recommended)
	Bandwidth (Hz) – slamming	5 to 100
	f_s (Hz) – slamming	3 times of required frequency (general req.); 300 (recommended)
	Bandwidth (Hz) - sloshing	30 to 1200
	f_s (Hz) - sloshing	3 times of required frequency (general req.); 2000 (recommended)
	Resolution (digital)	≤ 0.01 g

Physical Quantity/ Measurand [Component sensor]	*Characteristics*	*Recommendation*
Slamming pressure (Sea Pressure on hull) [Strain Gauge, Pressure Transducer]	Range	0 MPa (atmospheric pressure) to 2 MPa
	Uncertainty	max (2% of the measured value, 0.01 MPa)
	Bandwidth	5 to 100
	f_s (Hz)	3 times of required frequency (general req.);
	Resolution (digital)	≤ 0.05 MPa
Sloshing pressure in tanks [Strain Gauge, Pressure Transducer]	Range	0 MPa (atmospheric pressure) to 4 MPa
	Uncertainty	max (4% of the measured value, 0.02 MPa)
	Bandwidth	30 to 1200
	f_s (Hz)	3 times of required frequency (general req.); 2000 (recommended)
	Resolution (digital)	≤ 0.05 MPa
Statistical Calculation		
Time interval, T_i	Time interval for statistical calculation T_i (min)	20 to 30
Stress, σ	Bin size for histogram	approximately 10 MPa (i.e., 50 με per ABS (2016)' req.) for steel
Acceleration	Bin size for histogram	0.01 g
Pressure	Bin size for histogram	0.05 MPa
Roll angle	Bin size for histogram	2°
Pitch angle	Bin size for histogram	0.5°
Fatigue Calculation		
Stress range, $\Delta\sigma$	Bin size for fatigue	approximately 10 MPa (i.e., 50 με) for steel