Guide for

Ice Loads Monitoring Systems

September 2021

GUIDE FOR

ICE LOADS MONITORING SYSTEMS

SEPTEMBER 2021

American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862

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Foreword *(1 September 2021)*

This Guide provides requirements for the installation of, and the information to be provided by, Ice Loads Monitoring Systems fitted on ice-classed ABS vessels. These systems are intended as an aid to the Master and navigating officers when a vessel is operating in ice infested waters so that appropriate action can be taken to minimize the likelihood of the vessel sustaining structural damage from interaction with the ice. The Ice Loads Monitoring Systems specified by this Guide extend from basic monitoring systems to sophisticated, integrated systems, the selection of which is left to the Owner. The information provided in the Guide is intended to assist the Owner in selecting the most appropriate system for a vessel based on the vessel's probable operating parameters.

The Guide describes the Ice Loads Monitoring process and the procedures for collecting, recording, processing, evaluating, and presenting the data in a manner that permits the Master and or navigating officer to better measure vessel performance in ice and determine if remedial action should be taken. The monitoring systems specified in the Guide can assist in identifying when the vessel is operating in ice in a manner that could lead to structural damage or failure by providing early warning to the navigator when the performance parameters relating to vessel strength are approaching the preset allowable levels.

It is emphasized that the scope of the ice loads monitoring system selected for a specific vessel, the nature of the display and the form and aims of data processing are decisions that should be made by the vessel's Owner in conjunction with the system supplier as appropriate. If requested, ABS is able to provide technical assistance to an Owner considering installing an ice loads monitoring system based upon the information contained in this Guide.

ABS considers that it would be of mutual benefit to ABS and the Owner of an ABS-classed vessel that is fitted with an ice loads monitoring system for the recorded in-service data to be made available to ABS for evaluation for the purpose of further refining these requirements and improving safety, in accordance with the ABS mission.

An ABS-classed vessel that is fitted with an ice loads monitoring system that complies with the requirements of this Guide may, at the request of the Owner, be assigned the appropriate notation for entry in the ABS *Record*.

The requirements of this Guide are applicable to all types and sizes of ice-class vessels. The requirements are applicable both to new construction and to the retrofitting of an approved ice loads monitoring system to existing vessels.

The September 2021 edition replaces the requirements for surveys after construction with references to Section 7-9-44 of the ABS *Rules for Survey After Construction (Part 7)*.

The effective date of this Guide is the first day of the month of publication.

ABS welcomes comments and suggestions for improvement of this Guide. *Comments or suggestions can be sent electronically to rsd@eagle.org*.

GUIDE FOR

ICE LOADS MONITORING SYSTEMS

CONTENTS

SECTION 1
General

1 Application

This Guide is applicable to new construction and existing ABS-classed vessels for which any of the ice load monitoring system notations indicated in 1/9 of this Guide have been requested by the applicant.

The ice loads monitoring system is intended to:

- Provide to the bridge near real-time information of the measured data while transiting in ice.
- Warn the vessel's personnel that the near real-time parameters specified in 1/5 are approaching permissible levels so that corrective actions may be taken.
- Warn the vessel's personnel that during the voyage the value(s) of these parameters could be equal to or higher than corresponding permissible level(s) in the near future based on recent impacts.

The permissible level of the selected parameter(s) should be derived from applicable recognized criteria. While the ice loads monitoring system is intended to aid in the operation of a vessel, it is not a substitute for the judgment and the responsibility of the Master to take appropriate corrective action when operating the vessel.

The Guide also recommends onboard prediction of the short-term extreme value(s) of parameters specified in 1/5.

The term "Guide" in this document denotes the ABS *Guide for Ice Loads Monitoring Systems*, and "Rules" denotes the ABS *Rules for Building and Classing Marine Vessels*, as applicable.

3 Scope

This Guide describes the general conditions and procedures for assessing, evaluating and recording structural conditions of a vessel navigating in ice by measuring and monitoring parameters related to the structural response of the vessel. This Guide addresses "active" monitoring which provides near real-time onboard operational support.

The type of monitoring system, the methods of recording and processing data and the derivation of warning signals are largely decisions that should be made by the vessel's Owner, in conjunction with the system's supplier as appropriate.

The general recommendations given in this Guide are intended to assist the Owner in selecting, installing and using the system for collecting, processing, and evaluating the necessary data for predicting vessel behavior in ice.

5 Terminology

Performance. Performance defined by the measurement, calculation or both of one or more parameters which provide information about the vessel's structural condition and/or response when in ice.

Parameters. Conditions and properties that could indicate that a structural defect(s) and/or abnormal vessel behavior may occur and that corrective actions are advisable. The most important parameters for ice loads are local stresses in the icebelt structure.

Monitoring System. The system that monitors parameters and compares them with permissible levels that were established using recognized applicable criteria.

7 Modifications and Alternatives

ABS may consider ice loads monitoring system arrangements which do not fully comply with the requirements of this Guide provided they can be shown to be equally effective in meeting the overall standards of this Guide. Such alternative systems may be considered provided that details of any modifications, additions and alternatives to the system are submitted to ABS for satisfactory review.

Any modification, addition or alternative to the approved systems is to be carried out under survey.

9 Notations

At the request of the vessel's Owner or the shipyard, when a vessel is fitted with an ice loads monitoring system that complies with requirements of this Guide, it may be eligible to be assigned the **ILM** notation and the applicable optional extensions.

9.1 Basic Ice loads Monitoring System, ILM

The notation **ILM** may be assigned when the vessel has been provided with the basic ice loads monitoring system to monitor the local icebelt stresses in compliance with Section 2 of this Guide. The system warns the vessel's navigators when these stresses are approaching the permissible levels and a corrective action is advisable.

9.3 Optional Ice Loads Monitoring Systems

When requested, any or all of the following optional extension(s), specified in Section 3, may be added to the notation **ILM** (e.g., **ILM (n) + optional extension(s)**), when the approved ice loads monitoring system has been provided with the appropriate equipment:

(n)	Number of additional strain gauge locations
T	Turning ice loads monitoring for quarter
G	Global ice loads monitoring
L	Local ice loads recording
P	Local pressure recording

9.5 Table of Notations

Notation	*Definition*	*Description*
ILM	Basic Ice loads Monitoring System	This notation is assigned to a vessel having the basic system that monitors the hull girder bending stress
Additional Optional Notations		

Notation	*Definition*	*Description*
(n)	Number of additional strain gauge locations (e.g., 2, 4 etc.)	This notation is assigned to a vessel having strain gauge locations in addition to those required for the basic ice loads monitoring system. **(n)** denotes the additional number of additional strain gauge locations
+T (Turning Ice Loads)	Turning ice loads monitoring on the quarter	This optional notation, in addition to **ILM**, may be assigned to a vessel having ice loads monitoring systems with the additional purpose of monitoring the ice loads induced at the quarters of the vessel due to turning in ice.
+G (Hull Girder Loads due to Ice Impact)	Global ice loads monitoring	This optional notation, in addition to **ILM**, may be assigned to a vessel having ice loads monitoring systems for hull girder bending and shear monitoring due to operation in ice, typically ramming loads.
+L (Recording)	Local ice loads recording	This optional notation, in addition to **ILM** may be assigned to a vessel having ice loads monitoring systems with the additional purpose of recording the stresses for analysis of ice loads.
+P (Pressure Measurement and Recording)	Local ice pressure monitoring and recording	This optional notation, in addition to **ILM** may be assigned to a vessel having ice loads monitoring systems with the additional purpose of measuring and recording local impact pressures.

11 Information to be Submitted

The following plans and documents are to be submitted to ABS for review:

i) General arrangement showing the positions of the strain gauges, and of the accelerometer(s), pressure transducer(s) and motion sensor(s), if fitted

ii) Hull structural drawings in way of strain gauges

iii) Block diagram and description, illustrating the operation of the system

iv) Description of accuracy, range and frequency response of strain gauges

v) Procedures for installation, set-up and calibration of the strain gauges

vi) Procedures for system testing and operational verification

vii) Description of the methods used to process the data for display

viii) Description of the selection of the warning criteria

ix) Description of the output display method

x) Description of the method and capability of the data recording system and facilities for examination of the recorded data

xi) Operating Manual for the system:

An Operating Manual written in English and in a language appropriate to the vessel's operating personnel is to be placed onboard.

The Operating Manual is to include instructions on operating the system, instructions for interpretation of results, maintenance and repair including procedures for set-up, calibration and verification of sensors.

Plans should generally be submitted electronically to ABS. However, hard copies will also be accepted. In some cases, ABS may request the submission of additional information when it is considered necessary to review particular features of an ice loads monitoring system.

13 Sensors

The sensors used in ice loads monitoring systems are to be suitable for use in the marine environment. It is recommended that ABS Type Approved sensors be used wherever possible.

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

SECTION 2

Basic Ice Condition Monitoring System (ILM)

1 Application

Where requested, the notation **ILM** may be assigned to a vessel having a basic ice condition monitoring system to monitor local hull stresses caused by ice loads in compliance with this Section. The basic ice condition monitoring system is to display local stresses from strain gauges and to warn the vessel's personnel that stresses are approaching levels at which corrective action is advisable.

3 Local Hull Stress Monitoring due to Ice Loads

3.1 Stresses during Transit in Ice

A display of the local critical stresses associated with typical icebelt structure is to be available on the bridge to monitor these stresses during operations in ice to minimize the possibility of vessel overloading and the overstressing and buckling of hull structures. An alarm is to be provided to indicate when the critical stresses exceed 80% of the material yield stress.

Critical stresses are defined as stresses in areas of the icebelt structure that will have the highest stresses during ice impact loading. Depending upon the impact location, the magnitude and extent of the load, and the loading condition of the vessel, critical stresses may occur in different parts of the structure. To provide adequate warning, multiple stress locations must be monitored in a local area of the icebelt structure to determine the most critical stress for a given ice impact. This most critical stress is used in the bridge display and displays as a percentage of the material yield stress.

3.3 Prediction of Near Term Extreme Events

Information is to be collected and presented so that the maximum measured ice-induced stress does not exceed the material yield stress.

It is often desirable to predict onboard the extreme value of the vessel's response using obtained onboard statistical parameters. For evaluation of the most likely extreme value of local ice-induced stress, a linear curve-fit of the extreme value distribution of the last 100 events should be maintained continuously within the system and a prediction for the next 100 events should be made and displayed on the bridge in a format of the percentage of the material yield stress.

When the monitor shows that the total measured and/or onboard-predicted stress is approaching the yield stress level, timely corrective action is to be taken by reducing the vessel's speed or altering the vessel's heading. The monitor should also show the effect of these changes on the ice-induced stresses within a short time of the change in speed, heading, etc.

3.5 Strain Gauges

3.5.1 General

Measurements of ice-induced local stresses generally are to be performed using normal strain gauges with base length short enough to measure local stresses at the identified critical locations in the structure. The strain gauges are to be located as close as possible to the positions where the critical stresses are expected to be most significant. Critical stresses may be bending or shear stresses, so both tension-compression and shear measurement gauge types should be considered. Where the strain gauges cannot be sited at these locations, the measured stress is to be adjusted to indicate the stress at the appropriate location. The method of stress adjustment is to be approved by ABS and included in the operating manual for the systems.

The effects of temperature variations on the measured stresses are to be considered for adjustment of the stress.

3.5.2 Number and Locations of Sensors

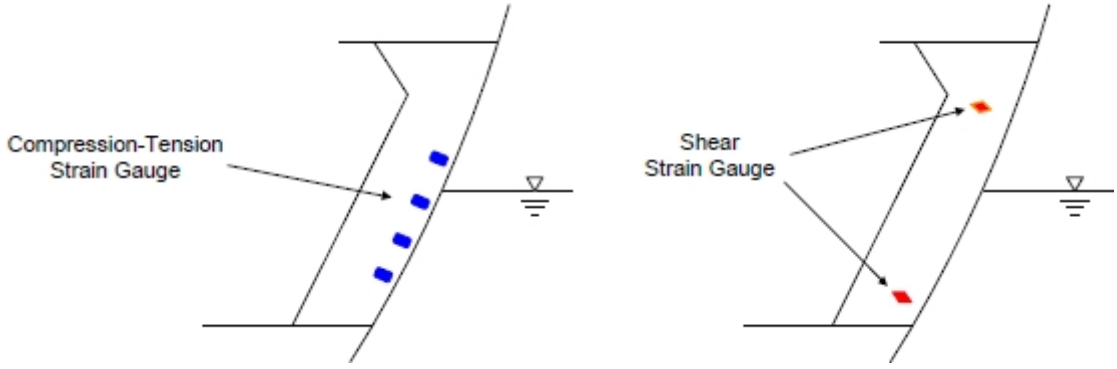
When the notation **ILM** is requested, the required number and approximate position of the strain gauges are as follows:

3.5.2(a) For Transversely-framed Vessels

i) Two (2) frames spanning the load waterline, one to port and one to starboard at the bow. The selected frames should be typically near the quarter beam in the icebreaking or ice impact portion of the bow.

ii) Tension-compression type strain gauges should be placed at the ends and midpoint of the frames close to the shell plating on the web and the shear gauges should be placed at the neutral axis of the frame near the ends. Finite element analysis of the frames can be used with the appropriate design loads from the Rules for the frame to determine if other locations are more appropriate. Strain gauge locations are subject to ABS review and approval.

FIGURE 1
Strain Gauge Locations for Transverse Frames

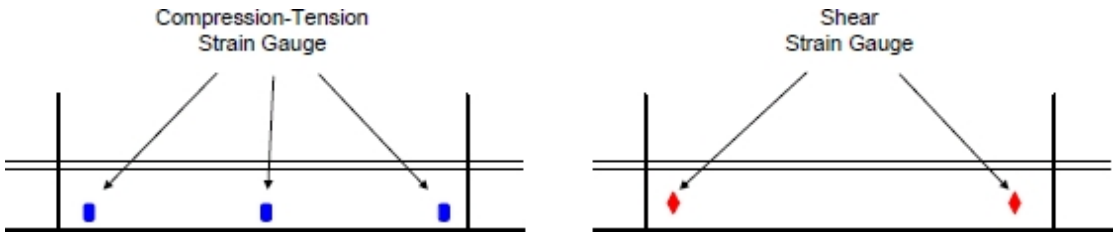


3.5.2(b) For Longitudinally-framed Vessels

i) Two (2) longitudinals just below the load waterline, port and starboard at the bow. The selected longitudinals should be typically near the quarter beam in the icebreaking or ice impact portion of the bow.

ii) Tension-compression type strain gauges should be placed at the ends and midpoint of the longitudinals close to the shell plating on the web and the shear gauges should be placed at the neutral axis of the longitudinal near the ends. Finite element analysis of the longitudinals can be used with the appropriate design loads for the longitudinal to determine if other locations are more appropriate. Strain gauge locations are subject to ABS review and approval.

FIGURE 2
Strain Gauge Locations for Longitudinal Frames



3.5.3 Requirements

Strain gauges are to have a constant response over the range of 0 to 150 Hz. The accuracy of measurements of the strain is to be at least one micro-strain. The measurement range of the strain gauge must cover the full range strain to beyond the yield of the material, both positive and negative.

Installation, testing, set up, and calibration of strain gauges is to be performed in accordance with Section 4 of this Guide.

5 Data Sampling

Data sampling rates are to be suitable for the frequency response of the sensors and the use of the signal. In general, the sampling rate is not to be less than 150 Hz. Continuous sampling of the signals is required, but peak detection algorithms should be employed to identify impacts above a given threshold. The threshold can be adjusted based on experience with the system to display a reasonable number of impacts. Too few impacts give the operator insufficient information and too many impacts may overload the system. A proper balance can be achieved by tuning the system in use.

Care must be taken to route cables away from power distribution cables to avoid interference. Power frequencies are within the range of frequencies for ice loads and can trigger the system with false readings.

7 System Display

A visual display unit is to be placed on the bridge. Each location frame or longitudinal should be displayed individually, such as bar chart style graph of the last approximately ten events from oldest to newest. When ice impacts a location and a new event is measured, the new result is displayed as a bar on the right of the graph and the oldest previous event is removed from the left. It is best to fit all locations on a single display so all data can be viewed without changing screens. The displays are updated whenever a new impact occurs at the location for the display.

7.1 Parameters

The parameter to be displayed for each location is the maximum stress relative to the material yield stress shown as a percentage. If there are several stresses measured on a frame or longitudinal, the maximum of these when compared to its corresponding allowable stress is the value to be displayed.

The events are triggered by having any strain gauge channel exceed a threshold and then ended by having all channels return below the threshold. The maximum stress at each location is to be computed from the maximum strain measured during the time the system is “triggered”. The maximum stress at each strain gauge location is divided by the allowable stress at that location to determine the percentage of the allowable stress, and the highest of these ratios for the strain gauges on one frame or longitudinal (one location) is to be displayed.

It is recommended that the measurement system maintain a database of the last 100 events from any location and be able to predict the value of the highest value in the next 100 events by fitting a Gumbel extreme-value distribution to the data.

7.3 Display Requirements

i) The displays of frame or longitudinal stresses are to be visually compared with user-selectable criteria and with criteria based on the material yield stress. Audible and visual alarms are to be provided when stresses exceed permissible levels as described in 2/3.1.

ii) The visual display should be easily read under all operating lighting conditions. A nighttime display with reduced light intensity is required. Colors that will not affect night vision are to be used. Manual adjustment of brightness for the visual display unit will be provided

iii) Displays and supporting documentation are to be in English and in a language appropriate for the vessel's operating personnel.

iv) The ice loads monitoring system is to be provided with a storage device to record the displayed parameters for a period of at least 30 minutes for verification purposes.

SECTION 3

Optional Ice Loads Monitoring Systems

1 Application

Vessels which have been provided with an ice load monitoring system **ILM** which complies with the additional optional criteria specified in this Section, will be assigned, where applicable, the optional extension(s) **(*n*)**, **+T**, **+G**, **+L**, **+P**, for example: **ILM(4)+T+G+P**.

3 Optional Extension "(*n*)" for "System with an Additional Number of Strain Gauge Locations"

The optional extension **(*n*)** will be added to the notation **ILM** when the basic ice load monitoring system has been provided with additional strain gauge locations. The extension **(*n*)** is the number of additional strain gauge locations (frames or longitudinals) to those specified in 2/3.5.2 of this Guide.

The following additional strain gauges may be provided:

3.1 Transversely-framed Vessels

The additional strain gauges may be installed on additional frames at the bow to measure other areas of the bow ice impact area. Typically these would not be adjacent frames but spread over the bow area. Sometimes a panel (a number of adjacent frames) may have gauges installed to measure both the load and the extent of the load. Each frame is considered a new location for the purposes of this option and thus increases the extension **(*n*)** by 1.

3.3 Longitudinally-framed Vessels

The additional strain gauges may be installed on additional longitudinals at the bow to measure other areas of the bow ice impact area. Typically these would not be adjacent longitudinals but spread over the bow area. Sometimes a panel (a number of adjacent longitudinals) may have gauges installed to measure both the load and the extent of the load. Each longitudinal is considered a new location for the purposes of this option and thus increases the extension **(*n*)** by 1.

5 Optional Extension "+T" for "Turning Ice Loads Monitoring on Quarter"

5.1 Application

When requested, the optional extension **+T** may be assigned to a vessel having an approved ice loads monitoring system with the additional capability of monitoring ice loads at the stern shoulder area.

A quarter monitoring system is positioned as far aft as possible on the flat of a wall-sided vessel and is intended to measure ice impact loads in the area of highest rotation speed when the vessel makes a turn. Experience has shown that these ice loads can increase significantly in cases where the vessel is highly

maneuverable, such as shorter wall-sided icebreakers with high-lift rudders and vessels with azimuthing propulsion systems.

A motion monitoring system is to be identified by its main function or purpose and it is this that will form the descriptive part of the notation awarded, as indicated in the following paragraphs.

5.3 Ice Loads Due to Turning Monitoring

5.3.1 Application

The optional extension **+T** will be added to the notation **ILM** to denote Turning Ice Loads Monitoring on Quarter when the basic ice loads monitoring system has been provided with sensor locations on the sides near the stern of the vessel. Measurements of these ice loads are to be done with the same type of strain gauge sensors placed in the same configurations as the basic system at the bow (2/3.5.2). Finite element analysis can also aid in determining or validating the best location of the strain gauges within a measurement location.

5.3.2 Number and Locations of Sensors

At least one strain gauge location is identified on each side of the vessel as close as is practical to the transition from the vessel's side to the after-body or the most vulnerable area of the after-body when turning.

5.3.3 Data Sampling

The data sampling requirements are the same as the requirements for the basic system (2/5). Sampling rates are the same. Triggering is done in a similar manner. In general, it is sufficient to have a common trigger level for all locations unless there is a drastic difference in load carrying capacity between locations.

5.3.4 Data Display

The system should display the data from the additional monitoring locations in the same manner as the base system (2/7). These new locations become similar types of displays on the main screen. If additional locations have been added to the base system, it may be necessary to add additional screens to view each location.

7 Optional Extension "+G" for "Global Ice Loads Monitoring"

7.1 Application

The optional extension **+G** will be added to the notation **ILM** to denote Global Ice Loads Monitoring when the ice loads monitoring system has been provided with the appropriate additional measurements as detailed in this Subsection.

Monitoring of global ice loads is to be accomplished by sensors that measure long-based strain in the deck and at a location where major hull girder structure is located low in the vessel. The longitudinal location of these measurements should be at 25% of the waterline length from the forward end of the waterline aft. Shear forces may also be measured in continuous longitudinal bulkheads at various points longitudinally through the forebody. The objective of these measurements is to measure the hull girder bending loads and response due to the vessel's bow hitting ice, especially when the vessel must ram large ice features to make progress.

7.3 Warning Signals

The global ice loads monitoring is to warn the operating personnel that the operating conditions during ramming type impacts are approaching stress levels that could lead to damage of the vessel's structure.

When the monitor shows that hull girder stresses or bending moments are approaching the limiting level, timely corrective action is advised to reduce ramming speed in the prevailing ice conditions.

Warning displays and alarm levels are to be set, taking into account the approved scantlings. Criteria to judge whether the levels of moment or stress are approaching those that could cause damage to the vessel are to be derived from calculations and are to be submitted for review.

9 Optional Extension "+L" for "Local Ice Loads Recording"

9.1 Application

When requested, the optional extension +**L** may be assigned to a vessel having an approved ice loads monitoring system (**ILM**), with the capability for storing all stress time histories associated with ice load impact events. These time histories are typically three to ten seconds in duration and occur, depending on the threshold setting, in the tens to hundreds per hour. Proper selection and adjustment of the threshold provides adequate data for monitoring alarms but limits the total amount of data to reasonable levels for storage.

9.3 Storage Data

The electronic data storage/recording device should be suitable for recording the following measured data, where applicable, at the data rates described above:

i) All strains at the strain gauge locations when a triggered recording occurs for the duration of the recording (until the threshold is no longer exceeded).

ii) Navigation data on ship speed, position, heading, propeller RPM, and time at a rate of at least once per second. Strain data should be time-stamped with times based on Global Positioning System (GPS) time.

9.5 Recording and Storage Devices

The recording device should have the capability to record the stresses for each sensor. The data storage/recording device should be automatic with a 30-minute constant power supply.

The data storage device should have the capability to store the data for a period of 30 days or the typical voyage duration, whichever is longer, and should have a removable storage medium for storing the required data.

11 Optional Extension "+P" for "Local Ice Pressures Recording"

11.1 Application

When requested, the optional extension +**P** may be assigned to a vessel having an approved ice loads monitoring system (**ILM**), with the capability for storing ice impact pressure time histories associated with ice load impact events.

Pressure measurements are obtained by strain gauging the structure in a manner that permits the measurement of the local impact pressure. Two techniques are commonly used. The first uses compression type strain gauges placed near the mid-depth of the frame, and at regular and close spacing along the frame, measuring perpendicular to the shell plating. The second has similar spacing at mid-depth of the frame but uses shear type strain gauges. In the latter case, the pressure on the shell plating between two adjacent gauges is related to the shear difference between the two gauges. In the former, the pressure over a gauge spacing centered on the gauge location is related to compressive strain at the gauge.

The time histories are typically three to ten seconds in duration and occur, depending on the threshold setting, in the tens to hundreds per hour. Proper selection and adjustment of the threshold provides adequate data for monitoring alarms but limits the total amount of data to reasonable levels for storage. For pressure measurements, the strain gauges are typically arranged on multiple adjacent frames in an attempt to capture as much of the contact area of an ice impact as is reasonably practical.

11.3 Storage Data

The electronic data storage/recording device should be suitable for recording the following measured data, where applicable, at the data rates described above:

i) All strains at the strain gauge locations when a triggered recording occurs for the duration of the recording (until the threshold is no longer exceeded).

ii) Navigation data on ship speed, position, heading, propeller RPM, and time at a rate of at least once per second. Strain data should be time-stamped with times based on (GPS) time.

11.5 Recording and Storage Devices

The recording device should have the capability to record the stresses for each sensor. The data storage/recording device should be automatic with a 30-minute constant power supply.

The data storage device should have the capability to store the data for a period of 30 days or the typical voyage duration, whichever is longer, and should have a removable storage medium for storing the required data.

SECTION 4

Installation, Testing, Setup, and Calibration

1 General

The procedure for installation, setup, and calibration of strain gauges and the procedure for testing and operational verification of the ice loads monitoring system are to be submitted to ABS for approval, and copies of the approved procedures are to be kept onboard the vessel.

3 Electrical and Mechanical Systems

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*.

Consideration is to be given to both the quality of the power supply and the possibility of a power outage. Where specified in Section 3, an uninterruptible power supply should be fitted or, where deemed appropriate, the system should be connected to an emergency power circuit. The decision as to availability of power is to consider the importance of the system relative to the safe operation of the vessel. Means of protecting against power surges are to be provided where surges could cause with a malfunction of the electronic equipment. Local distribution panels are to be provided for all items of electrically-operated components of the ice loads monitoring system. These panels are to be supplied by main and emergency sources of electrical power.

5 Physical Protection of Sensors

The main body of strain gauges required for ice loads monitoring will be located on the side shell near the waterline. As far as possible, they should be protected from mechanical damage from operations or cargo within the space in which they are placed. Strain gauges should generally be made watertight and those placed in tanks watertight to the maximum head for which the tank has been designed.

As far as possible, these and other gauges (such as for hull girder bending), are to be situated in locations protected from green seas, cargo operations, dropped objects, mechanical damage, etc. Attention is to be paid to the possibility of such damage affecting system components such as junction boxes, cable conduits, etc.

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

7 Mounting

When gauges are to be welded to the hull, the welding procedures are to be submitted to the ABS Engineering office for approval. Consideration is to be given to the damage and repair of coatings.

9 Display, Processing and Recording Equipment

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, as far as possible, in a vibration-free area (or fitted with isolation mounts) and is to be protected from the effects of direct sunlight.

11 Initial Settings

The strain gauges should be set up to have an adequate linear range to cover the full range of expected quasi-static and dynamic stresses.

Strain gauges only affected by longitudinal global hull girder loads, (e.g., deck gauges in a vessel), are to be set to the stress levels resulting from the loads indicated by the vessel's loading instrument and loading manual 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, as far as possible, 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, preferably in sheltered waters with the wave conditions not exceeding sea state one.

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

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 resistance-type strain gauges in inaccessible locations. Consideration should be given to reliability and longevity when selecting strain gauges to measure local stress, and to the carriage of spares.

13 Calibration

Local strain gauges are normally provided with a calibration certificate from the manufacturer, but the calibration of stress, load, and pressure from strain should be obtained through finite element analysis.

Other sensors such as long-based strain gauges may require calibration, and if so, are to be recalibrated by suitably qualified personnel in accordance with the manufacturer's recommendations, but at least annually. Calibration records are to be kept onboard the vessel with the Operating Manual and will be inspected by the ABS Surveyor in accordance with Section 5 of this Guide.

15 Thermal Stresses

The method of allowing for temperature effects in both setup and calibration is to be submitted to ABS for review. The effects to be dealt with are given below:

i) 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.

ii) Thermal stresses in structure are to be considered, including the effects of diurnal variation caused by the day/night cycle

17 Training

Although not a requirement in order to obtain the notation applied for in this Guide, it is recommended that the vessel's personnel operating the monitoring systems be formally trained in their use.

SECTION 5

Survey Requirements

1 General

In addition to the survey requirements of the Rules applicable to the vessel receiving an ice loads monitoring notation, surveys are to be carried out on ice loads monitoring systems as required for electrical, mechanical, and hazardous area equipment. The scope of the survey includes the items comprising the ice loads monitoring system itself and also the other items for which the additional notations, if any, have been granted.

The systems are to be subjected to the following surveys:

i) Survey of the initial installation of the system

ii) Annual Surveys

iii) Surveys due to damage, repair, or modification of the monitoring system

3 Survey of the Initial Installation of the System

The installation, initial set-up, and performance of the systems are to be examined at the survey for the initial installation of the system for conformance with the requirements of this Guide.

The location of sensors and the operation of the system are to be verified in accordance with the approved verification procedure.

Sensors fitted in exposed locations are to be hose tested in accordance with 4/5 of this Guide.

5 Simulation Test

Functions of the system are to be tested in the presence of the Surveyor.

The simulation test is to be performed in accordance with the simulation test procedure submitted prior to the test.

7 Annual Surveys *(1 September 2021)*

See 7-9-44/3 of the ABS *Rules for Survey After Construction (Part 7)*.

9 Special Periodic Surveys *(1 September 2021)*

See 7-9-44/5 of the ABS *Rules for Survey After Construction (Part 7)*.

11 Surveys due to Damage, Repair, or Modification of the System *(1 September 2021)*

See 7-9-44/7 of the ABS *Rules for Survey After Construction (Part 7)*.