RULES FOR
CLASSIFICATION OF

SHIPS / HIGH SPEED, LIGHT CRAFT AND NAVAL SURFACE CRAFT

NEWBUILDINGS

SPECIAL EQUIPMENT AND SYSTEMS
ADDITIONAL CLASS

PART 6 CHAPTER 11

HULL MONITORING SYSTEMS

JANUARY 2005
This booklet includes the relevant amendments and corrections shown in the July 2009 version of Pt.0 Ch.1 Sec.3.

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CHANGES IN THE RULES

General

The present edition of the rules includes additions and amendments decided by the Board as of November 2004, and supersedes the January 2003 edition of the same chapter, including later amendments.

The rule changes come into force 1 July 2005.

This chapter is valid until superseded by a revised chapter. Supplements will not be issued except for an updated list of minor amendments and corrections presented in Pt.0 Ch.1 Sec.3. Pt.0 Ch.1 is normally revised in January and July each year.

Revised chapters will be forwarded to all subscribers to the rules. Buyers of reprints are advised to check the updated list of rule chapters printed in Pt.0 Ch.1 Sec.1 to ensure that the chapter is current.

Main changes

- **General**

— The main aim of this revision has been to make the hull monitoring system more useful as an operational tool, including being a data base for maintenance planning.
— Additional requirements for onboard data analyses and display of data have been introduced.
— New requirements for storing and exporting of data have been added. These features are intended to be useful in the maintenance planning, as well as to the Society with a view to future rule development.
— This booklet has been made common to the Rules for Classification of Ships and the Rules for Classification of High Speed, Light Craft and Naval Surface Craft.

Corrections and Clarifications

In addition to the above stated rule requirements, a number of corrections and clarifications have been made in the existing rule text.

Comments to the rules may be sent by e-mail to *rules@dnv.com*
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SECTION 1
GENERAL REQUIREMENTS

A. Classification

A 100 Rule application

101 These rules are applicable to ships where a system for monitoring of the hull response, sea state and operational parameters is arranged. The system shall give warning when stress levels and the frequency and magnitude of ship accelerations approach levels that require corrective action. Further, the information acquired by the system can be utilised in planning of the ship's maintenance.

Guidance note:

The monitoring system is intended as an aid to the Master's judgement and not as a substitute for it. Accordingly, any failure of the system does not detract from the Master's absolute responsibility to take correct action in operating the ship.

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102 The owner shall decide how the hull monitoring system should be configured, i.e. which features to be included and how the measured and processed data shall be used.

A 200 Class notations

201 A ship equipped with a hull monitoring system designed, manufactured and tested in compliance with the requirements in this chapter may be assigned the additional class notation **HMON ( )** where within the brackets there will be letters specifying what type of sensors and or features are included in the system and digits specifying the number of each type of the sensors and or features.

Letters specify the following type of sensors/features:

A Sensor monitoring acceleration along one axis
C Online link to loading computer that is continuously up-dating the loading condition
D Online data link between hull monitoring system onboard to office ashore. The link shall make it possible to operate the system from an onshore computer, perform maintenance and transfer data
E Sensor monitoring the propulsion shaft(s) output/rpm
G Sensor monitoring global hull strain
H Sensor monitoring the liquid motion pressures in tanks (sloshing)
L Sensor monitoring local hull strain
M Device for monitoring of hull rigid body motions (six degrees of freedom)
N Measured data to be stored in Nauticus
O Navigation sensors (GPS, speed log, gyro compass, rudder angle etc.)
P Sensor monitoring the sea pressure acting on the hull
S Device for monitoring the sea-state
T Sensor monitoring the temperature
W Wind sensor.

Guidance note:

A ship assigned the class notation **HMON (S1,G4,A1)** is equipped with one device for monitoring of the sea-state, four sensors for monitoring of the global hull strain and one sensor for monitoring acceleration.

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Guidance note:

The required and recommended minimum sensors configuration for the different ship types is given in Sec.3 Table F1.

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202 The types and number of sensors shall be selected on basis of owner requirements.

203 The class notation will be assigned on the basis of plan approval, certification of equipment, if required, and onboard survey and testing.

A 300 Qualification of components

301 Sensors shall be approved or type approved by the Society.

Guidance note:

A sensor that has a MED type approval by a notified body will generally be accepted based upon presentation of the certificate, however accuracy requirements may need special consideration beyond normal MED approval.

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302 Data processing units (signal conditioning units, amplifiers, computers, display units) including flow charts and formulae for calculations shall be certified according to Pt.4 Ch.9 Sec.1

A 400 Maintenance and instruction manuals

401 Instruction manuals shall be kept on board. The manuals shall contain necessary instructions on:

— operation
— calibration of sensors and system
— identification of faults
— repairs
— systematic maintenance and function testing
— interpretation of measuring results.

402 The plan for systematic maintenance and function testing shall show how components and systems shall be tested and what shall be observed during the tests.

403 A log for maintenance and calibration of the hull monitoring system shall be kept onboard.

404 The maintenance log and all relevant certificates shall be kept together with in the manuals.

B. Definitions

B 100 Terms

The terms described below are relevant in these rules.

101 *Course*. The horizontal direction of the vessel in which the vessel is sailing expressed as angular distance from the true north.

102 *Display*. Means by which a device presents visual information to the operator.

103 *Data Processing Unit(s)*. Device(s) designed to process data according to defined algorithms (e.g. signal conditioning units, amplifiers, computers, display units).

104 *Global Positioning System (GPS)*. A satellite system intended to provide highly accurate position and velocity information on a global basis.

105 *Speed log*. An instrument for measuring the speed and/or distance travelled by a vessel.

106 *Position*. The description of a place by its global co-ordinates i.e. latitude and longitude.

107 *Response*. The response is a general term that includes

all types of reactions (e. g. strain, motion, acceleration etc.) of the hull due to an applied load.

108 *RPM.* The revolutions per minute of the propulsor(s).

109 *Sensor*. A device which measures a physical quantity as strain, acceleration, pressure etc.

110 *Slamming*. The result of the interaction (relative velocity) between ship and waves leading to sudden impact on the ship structure.

111 *Sloshing*. The result of the interaction (relative velocity) between liquid in a tank and the tank structure leading to impact on the structure.

112 *Speed*. The distance per unit time covered by the movement of the vessel through the sea.

113 *Strain*. Relative dimensional elongation and/or shortening caused by an applied force.

114 *Stress*. It is assumed the stress is proportional to strain and conforms to Hooke's law.

115 *Torque*. The torsional moment on the rotating propulsion shaft(s).

116 *Wave condition*. A two-dimensional frequency spectrum of the sea-state. Statistical parameters such as wave height, wave period and dominant wave direction are derived from this frequency spectrum.

117 *Wind condition*. The velocity, i.e. average speed and dominant direction of the wind relative to the longitudinal ship axis.

C. Documentation

C 100 Plans and particulars

101 Documentation types shall be as required in Pt.4 Ch.9 Sec.1. The following documentation shall be submitted for approval:

— documentation on data processing units
— sensor data sheet, including accuracy data
— single line diagrams for equipment in hazardous areas
— location of sensors.

102 For installation in hazardous areas documentation according to Pt.4 Ch.8 Sec.11 shall be submitted for approval.

103 Details of any modification to the approved hull monitoring system shall be submitted for approval.

SECTION 2
COMPONENT REQUIREMENTS

A. Component Requirements

A 100 General

101 All components and systems shall be designed and installed in accordance with the requirements given in Pt.4 Ch.9 Sec.5.

102 All components shall be replaceable and designed for easy maintenance.

103 Electrical equipment and installation in hazardous areas shall be in accordance with Pt.4 Ch.8 and applicable class notation(s) for Special Service and Type.

104 All equipment located at the navigation bridge shall be type tested in accordance with Pt.4 Ch.9 for EMC, emission only. In addition all equipment shall fitted with dimmers and have displays which do not interfere undue with the night vision of the officer of the watch.

B. Sensors

B 100 General

101 The sensor shall be designed in such way that the influence of changes of quantities other than the quantity that it is intended to be measured is minimised, i. e. strain sensors shall be designed in such way that the measured value is not influenced by changes in temperature.

Guidance note:

Any strain signal measured by a sensor, which is mounted on a piece of the actual material with free-free boundary conditions, during temperature changes shall be considered a measurement error and should ideally be zero.

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102 The sensors shall be mounted in such way that they only measure the quantity intended, i.e. sensors for measuring global hull strain shall be mounted in such way that influence of local strain is minimised.

103 Sensors that are part of other systems, i.e. the bridge navigation system, loading computer and engine control system, can be utilised in the hull monitoring system. Connections to such sensors shall be made in such way that they do not influence performance of the other systems. Failure of the hull monitoring system shall not influence the performance of other systems.

104 Accelerations shall be measured over a range of -20 m/s^2 to +20 m/s^2. The measurement uncertainty of the acceleration shall be less than 2% of the measured value, or 0.10 m/s^2, whichever is the greater.

105 The rigid body ship motions shall be measured by a device with integrated sensors, giving the 6 degrees of freedom (3 translations and 3 rotations). The translations (accelerations) shall be measured over a range of -20 m/s^2 to +20 m/s^2. The angles shall be measured over a range of -90 degrees to +90 degrees, -45 degrees to +45 degrees and -180 degrees to +180 degrees, for the roll pitch and yaw motions respectively. The measurement uncertainty shall be less than 2% of the measured value, or 0.10 m/s^2 for translations and 0.5 degrees for angles, whichever the greater.

106 The sea pressure acting on the hull shall be measured over a range of 0. MPa (atmospheric pressure) – 2. MPa. The measurement uncertainty of the pressure shall be less than 2% of the measured value, or 0.01 MPa, whichever the greater.

107 The liquid motion pressures in tanks (sloshing) shall be measured over a range of 0. MPa (atmospheric pressure) – 4. MPa. The measurement uncertainty of the pressure shall be less than 4% of the measured value, or 0.02 MPa, whichever the greater.

108 The structural strain shall be measured in a range related to the yielding strain of the material. The measurement uncertainty shall be less than 3% of the measured value or 20 micro strain, whichever is the greater. For ships made of steel or aluminium, a range from -2 000 micro strain to +2 000 micro strain can be assumed. For ships constructed using special material qualities or different types of materials, i.e. composite materials, the strain range shall be approved by the class case by case.

109 The sensors installations designed for low frequency responses, i. e. motions and wave loading shall record the physical quantities within the specified uncertainties within the frequency range 0.01 – 3 Hz. Installations designed to measure slamming responses shall record the physical quantity within the specified uncertainties in the frequency range 5 – 100 Hz. Installations designed to measure sloshing responses shall record the physical quantity within the specified uncertainties in the frequency range 30 – 1 200 Hz.

110 The data processing unit shall be capable of handling information supplied by all sensors including navigational instruments at the actual transfer rate.

Guidance note:

Navigation system (or dedicated units) commonly uses NMEA format for information transfer.

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111 The information from the sea-state parameters shall at least be up-dated and submitted every 10 minutes.

C. Signal Conditioning Units

C 100 General

101 The signal conditioning units shall be matched to the connected sensor.

102 The signals from analogue sensors shall be low-pass filtered prior to digitising to avoid signal noise. The filters shall be matched to the frequency range for the different sensors. See Sec.2 B109.

103 The sensors installations designed for low frequency responses, i. e. motions and wave loading shall be digitised with at least 20 Hz. Installations designed to measure slamming responses shall be digitised with at least 500 Hz. Installations designed to measure sloshing responses in tanks shall be digitised with at least 3kHz.

SECTION 3
SYSTEM DESIGN

A. System Requirements

A 100 General

101 The mandatory and the recommended minimum of parameters to be measured for the different ship types are given in Table F1.

102 In the case when signals from two or more sensors are transmitted through the same conductor(s), the measuring signal from each individual sensor shall be separated in such way that each sensor can utilise the full measuring range without interfering with the signals from other sensors.

103 All electrical components that are exclusively used in the hull monitoring system, i.e. not sensors included in the navigation system, shall be powered through an UPS (un-interruptible power supply). In case of mains power failure, the UPS shall have sufficient capacity to maintain normal operation of the hull monitoring system for at least 10 minutes. The hull monitoring system shall automatically shut down in a controlled manner within the UPS power reserve time.

104 The hull monitoring system shall automatically re-start at return of mains power. The default display shall appear.

105 The hull monitoring system shall be designed in such way that possible influence of settling time of the hardware and the software (e.g. software filters) on the measured data shall be within the tolerance limits.

106 The system shall include a computer with sufficient capacity to perform the tasks required, e.g. process the sensor signals, display the information required on a screen, give audio alarms and store the data.

107 In the case that the ship is equipped with a loading computer, the still water forces and moments shall be transferred to the hull monitoring system. These data can be entered manually through the computer keyboard, read from a disk or transferred through an electronic link. The system shall use this information to calculate the bending stress at the global strain positions.

Guidance note:

It is recommended to design the loading computer software to calculate the bending moment at the positions where the global strain sensors are located. If this is not the case, linear interpolation of the moment can be used to estimate the moment at the sensor position.

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108 The system shall be designed to give visual and audible alarm for at least the following incidents:

— power failure
— unreasonable values indicating sensor failure
— signal from a sensor exceeding the alarm threshold value.

109 The programs and data held in the data recording system shall be protected from corruption by loss of power.

110 The user interface (display, keyboard and audible alarms) shall be installed on the bridge at a position close to, or integrated in the bridge navigation system.

111 A data storage device suitable for saving time series and statistical information shall be used.

112 The system shall have minimum data storage capacity and functionality as specified in Sec. 3 E.

113 The hull monitoring system shall be configurable. The configuration shall include all settings that are relevant for a specific installation. Such settings will typically be calibration factors, sensors threshold values, filter cut-off frequencies, statistical calculations that are selected for the different sensors etc. The configuration shall be included in the manual.

B. Primary Elements

B 100 General

101 Sensors shall be protected against mechanical damage, humidity (water), exposure to excessive high or low temperatures and damage from local vibration sources.

102 In the case that the ship already has installed a sensor for monitoring of a certain parameter, it is not required to install a separate sensor for the hull monitoring system.

Guidance note:

If the ship has installed navigation EPFS (Electronic Position Fixing System), the HMON system may be connected to the navigation EPFS. When navigational sensors are used, the listener port on the hull monitoring system shall be in accordance with IEC 61162 in order to protect the talker (EPFS) from failure in the hull monitoring system.

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103 The system shall have output port for providing Voyage Data Recorder with all IMO mandatory information (IMO Res. A.861(20)) from the system. The port should be compliant with IEC 61162.

B 200 Strain gauges

201 The position of the strain gauges shall take account of the structural configuration of the ship and its mode of operation.

Guidance note:

The strain gauges for measuring vertical hull girder bending should be located in such a way that the system monitors global strain (port + starboard) in the deck structure as near as practicable to amidships and in addition at the quarterly lengths (± L/4 from mid ship for vessels with L > 180 metres). See Table F1.

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B 300 Accelerometers

301 Dynamical amplification, in the frequency range of interest, of the mounting fixture shall be minimized.

B 400 Position indicator

401 A global positioning system shall be installed.

Guidance note:

If the ship has navigation GPS, the position may be taken from the navigation GPS.

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B 500 Wave sensors

501 An arrangement to monitor the wave condition shall be installed. The system shall produce a two-dimensional spectrum (wave frequency and relative direction between wave and ship heading). Based on the spectrum, significant wave height, main wave direction and main wave period shall be derived.

Guidance note:

Systems that use the hull motions to derive the wave data will not

be accepted. Systems that use the signal from the navigation radar shall have a sign that instruct the navigator to put the radar into correct mode for wave monitoring when the radar is not in use for navigation purposes.

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B 600 Wind sensors

601 An anemometer giving speed and dominant direction of the wind shall be used.

Guidance note:

An instrument that corrects the displayed values with respect to ship speed and heading is recommended.

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B 700 Speed monitoring

701 The speed of the vessel may be taken from the GPS system or the speed log.

B 800 Course monitoring

801 The course of the vessel may be taken from the GPS system or the gyro compass.

B 900 Hull rigid body motions

901 The rigid body motions shall be referred to a position close to the centre of gravity in loaded condition.

Guidance note:

In the case that it is inconvenient to install the motion sensor close to the centre of gravity, the sensor may be mounted as close as possible to the centre of gravity and the motions in the reference position may be computed by software based on the motions measured and the distance from sensor position to the reference position.

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B 1000 Loads due to transient sea pressure (slamming)

1001 Loads due to transient sea pressure (slamming) are preferably to be measured in terms of normal stress (strain) at the structure on which the pressure is acting, e.g. the pressure loads shall be measured as normal stress on longitudinal(s) or plating.

1002 The loads may alternative be measured in terms of sea pressure using pressure transducer(s) mounted through the hull.

Guidance note:

A pressure transducer mounted through the hull bottom plating in the bow area can given information about the distance from the water surface down to the ship bottom. Hence, a pressure transducer in this position may give an early warning on the possibility of bottom slamming.

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1003 An accelerometer in the bow area may also be used as an indicator of slamming incidents.

B 1100 Loads due to liquid motions in tanks (sloshing)

1101 Loads due to liquid motions in tanks (sloshing) are preferably to be measured in terms of stress (strain) in the structure on which the loads are acting.

1102 The loads may alternatively be measured in terms of pressure using a pressure transducers mounted through the tank wall.

1103 In tanks with insulation system and inner gas tight membrane (LNG tanks), the loads may alternatively be measured by a load cell mounted behind the membrane.

B 1200 Structural temperature

Temperature sensors installed on the supporting structure of cargo tanks containing cooled or heated cargo, shall at least have an operational range that covers the temperature of the cargo and the temperature in the structure when the cargo hold is empty.

C. Data Processing

C 100 General

101 The parameters given in Table F1 shall be processed and made available for the hull monitoring display.

102 The measured signals shall be split into given time intervals for data processing. The results from the data processing for each time interval shall be stored. The time interval selected shall be set during the initial configuration of the software.

Guidance note:

The data on the screen should be updated at intervals not longer than 5 minutes. In cases when an averaging period longer than 5 minutes is selected, the data processing should be performed at least every 5^{th} minute on the latest data sequence corresponding the selected processing period. Time intervals of 30 minutes and 10 minutes are suitable for conventional ships and for high speed light crafts, respectively.

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103 The type of processing each individual sensor signal is subjected to shall be defined during the initial configuration of the system. The configuration shall be included in the documentation.

Guidance note:

The different types of processing may not be relevant for all types of sensors (i.e. Rainflow counting may not be useful on an accelerometer signal). Hence, this aspect should be carefully considered during the configuration.

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C 200 Data filtering

201 The software shall include high-pass, low-pass and band-pass time domain digital filters. The cut-off frequency of the filters shall be configurable through the software.

Guidance note:

It should be noted that filtering may not be relevant for all types of sensors or phenomena to be measured. Only in cases when relevant, filtering should be considered.

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202 The filters shall be designed to have a stop-band attenuation of at least 40 dB.

203 The filters shall be initiated at the start-up of the hull monitoring software, and be continuously active as long as the software is running during normal operation. The part of the filtered signal that is corrupted by the settling of the filter during start-up shall not be used in the subsequent data analyses.

204 The system shall have the capability to simultaneously perform filtering on all the measured time series of hull responses. The time series subjected to filtering shall be configurable through the software.

205 The system shall be able to put the time signal from all sensors measuring the ship responses through the following filtering processes, giving four different time series:

— no filtering (static value and both wave and vibrations responses are maintained)
— high-pass filtering (static value and low cycle temperature fluctuation are removed, the wave response and vibration responses of the signal are maintained)
— low-pass filtering (static value and the wave response is maintained)

— high-pass filtering (only the vibration response is maintained).

Guidance note:

The following filter characteristics may be assumed for all sensors, except sensors dedicated for sloshing and slamming responses:

- the high-pass filter removing static value and low cycle fluctuations shall maintain the energy above 0.01 Hz
- the low-pass filter shall maintain the energy for frequencies below 0.3 Hz, and remove the energy for frequencies above 0.45 Hz
- the high-pass filter shall remove the energy for frequencies below 0.3 Hz, and maintain the energy for frequencies above 0.45 Hz.

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Guidance note:

For sensors dedicated to slamming measurements, the low frequency boundary is suggested to 5 Hz. For sensors dedicated to sloshing measurements, the low frequency boundary is suggested to 30 Hz.

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206 The software shall be able to display each of the four different time series described in 205.

207 The software shall be able to perform the data analyses described in 300 through 600 on each of the four different time series described in 205.

208 The software shall be able to utilise both the non-filtered signal and the signal where the static value and the low cycle fluctuations are removed (see 205) in connection with Global Hull Stresses (see 600) and Threshold Values and Alarms (see 700). The choice shall be configurable through the software.

C 300 Statistical calculations

301 The software shall be able to perform the statistical calculations on the time series described in 102 and 205. The sensors selected for statistical calculations and statistical operation to be performed shall be configurable in the initial set-up of the software.

302 The following statistical parameters shall be calculated for each of the selected ship response parameters:

— maximum value
— minimum value
— mean value
— standard deviation
— skewness
— kurtosis
— mean zero crossing period.

303 For each of the ship responses, a histogram of all the peaks in the time history shall be established. The amplitude for each response shall be divided into pre-set intervals, and the number of peaks within each interval shall be counted. Hence, the histogram will contain the number of peak occurrences within each interval. The intervals shall be set during configuration of the software.

Guidance note:

The following intervals are suitable for the different types of ship responses:

- stress for steel ships 5 Mpa
- stress for aluminium ships 2.5 MPa
- acceleration 0.1 m/s^2
- pressure 0.05 MPa
- roll angle 2 degrees
- pitch angle 0.5 degrees
- heave translation 0.25 m.

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304 Similar histograms of the ship responses as described for the peaks in 303 shall also be established for the troughs.

305 For transient phenomena, such as liquid impacts (slamming and sloshing), the integrated energy of each impact shall be calculated.

306 For transient phenomena, such as liquid impacts (slamming and sloshing), the rise time of each impact shall be calculated. The limits for the calculation shall be configurable.

Guidance note:

The rise time may be defined as the time it takes the impact to reach from 20% of peak value to 90% of peak value on the rising flank.

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307 Based on assumptions of statistical distribution of the parameters derived in 302 to 305, a curve for the probability of exceeding a certain value within a given time period shall be estimated. The time period shall be configurable through the software.

308 Based on the probability curve (see 307) the probability of exceeding a predefined threshold value shall be found. The threshold value shall be configurable through the software.

C 400 Fatigue life estimation

401 The fatigue life of the structural elements equipped with strain sensors shall be estimated based on the measured time history.

Guidance note:

The method described in Classification Notes No. 30.7 Fatigue Assessment of Ship Structures may be used.

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402 The stress response histograms shall be established for each strain sensor using a type of cycle count method.

Guidance note:

The Rainflow Cycle Counting method (ASTM Standard E-1049) is recommended for establishing the stress response histograms. The following intervals are suitable for the different types of ship:

- stress for steel ships 5 MPa
- stress for aluminium ships 2.5 MPa
- stress interval for other materials should be approved by the Society.

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403 The damage rate shall be estimated based on the stress response histogram, a relevant stress concentration factor (K-factor) and a S-N curve. The Society shall specify the K-factor and S-N curve to be applied for each sensor.

404 The damage rate for each time interval shall be added together, resulting in accumulated damage rate for each strain sensor.

C 500 Loads due to transient sea pressure (slamming)

501 The number of transient peaks recorded by the sensor installed for the recording of slamming incidents exceeding the threshold level, shall be counted. The number count for a predefined time period shall be made available for the display. The treshhold value and the time period shall be configurable through the software.

C 600 Hull stress

601 The hull girder strain (stress) may often be influenced by strain induced by temperature differences in the hull structure. This strain may be caused by temperature differences between the cargo and the environments or by partial heating of the hull structure due to sunshine. These effects may be reflected as low cycle variations of the measured strain. The strain due to these temperature differences is normally not to be included in the analyses performed by the hull monitoring system. The

hull monitoring system shall have the capability to optionally remove the strain due to temperature differences in the hull girder (See 204 and 205).

Guidance note:

It should be noted that in the cases that the strain due to temperature differences in the hull structure is removed, both the static value and the slow variations in the loading condition may also be influenced. Hence, variations due to shifting of ballast or water ingress in a cargo hold may also be influenced.

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602 The hull monitoring system shall have the capability to read the still water bending/torsion moments calculated by the loading computer (if applicable). This information could either be typed manually into the hull monitoring system through a keyboard or be transferred electronically by disk or data link. Based on this information, the hull monitoring system shall be capable of computing the strain (stress) due to the still water moments at each position where a sensor measuring global hull strain (stress) is positioned. In the case when the sensor position do not correspond to a section for where the still water moments is computed, a linear interpolation between the moments on each side of the sensor position may be applied.

Guidance note:

The information needed to convert the still water bending moments into strain (stress) will be supplied by the Society.

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603 The hull monitoring system shall have the following three options for each individual strain sensor, to be selected independently, for input to the statistical analyses and the alarm handler (see 300, 400, 500 and 700). The option should be selected during the initial installation of the hull monitoring system.

— measured strain as recorded (including possible effects due to temperature differences in the hull structure)
— measured strain high-passed filtered in order to remove low cycle temperature effects
— measured strain high-passed filtered in order to remove low cycle temperature effects, and then have a strain offset added to the filtered strain signal, corresponding to the strain calculated by the loading computer at each sensor position.

604 All the stress measurements shall be put through the data analysed described in 300 and C400.

C 700 Threshold values and alarms

701 The hull monitoring software shall be designed to allow input of a minimum and a maximum threshold value for each sensor.

Guidance note:

For sensors that measure more than one quantity, the software shall be designed to allow threshold values for each quantity.

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702 The measured values shall be compared to the given threshold values for each sensor. In the case that the computed value exceeds 80% of a threshold value, an audible alarm shall be given. The cause of the alarm shall automatically appear at the hull monitoring screen.

Guidance note:

In the case that the mean value of the measured strain (stress) signal is replaced by the value based on the still water bending moment, the sum of the measured dynamic strain (stress) and the still water strain (stress) shall be compared to the threshold values (see 204 and 205).

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703 The cause of the alarm shall automatically be written to an alarm log that shall be stored on an electronic device. This alarm log shall be maintained for inspection on the hull monitoring display.

C 800 Trend predictions

801 The results from the calculations for each time interval as described in 300 through 500 shall be arranged in such way that a sequence of the latest data from each individual sensor can be displayed as a trend. The sequence shall at least include data from the last 4 hours and 30 minutes for displacement ships and HSLC, respectively.

802 A 4 hour data sequence from each individual sensors shall form the basis for a forecast trend prediction of the expected response from each individual sensor for at least the next hour. The measured and the predicted data shall be made available for the display.

803 When the signal from an individual sensor exceeds 80 % of the specified threshold value for that sensor, the expected time to reach the threshold value shall be predicted based on trend analyses. The measured and the predicted data shall be made available for the display.

D. User Interfaces

D 100 Display

101 The hull monitoring system shall have a display suitable for presentation of screen images that comply with Pt.4 Ch.9 Sec.6.

102 The system shall have screen images that clearly display all relevant information with respect to sensor positions, time series and processed data.

103 The system shall have at least screens that display the following information:

— clearly visualise the position of each individual sensor
— the status of each individual sensor, i.e. whether the sensor is operational or faulty
— real time information of the measured time series of each individual sensor
— signal level from each individual sensor compared to the threshold values
— current damage rate for each individual strain sensor
— trends of the statistical parameters for each individual sensor, including forecast predictions
— alarm status.

D 200 Audible alarm signal

201 The system shall have audible alarm signal that comply with Pt.4 Ch.9 Sec.3.

D 300 Keyboard

301 The system shall have a keyboard for manual input.

Guidance note:

Keyboard may be replaced by a touch screen.

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E. Data Storage

E 100 General

101 The system shall have capacity to store at least one year of statistical data and 24 hours of time series from all sensors. For sensors dedicated to slamming and sloshing measurements, it is sufficient to store the time sequences where the transients are exceeding a given threshold value.

102 The system shall have the capability to back-up the recorded data on a medium suitable to be read on a personal computer (PC).

103 The data back-up file(s) shall include all the recorded data presented on a suitable text format. The file(s) shall include sufficient information to clearly describe the content of the file(s).

104 For each time interval (see C102), the system shall store the results from all the calculations for all the individual parameters recorded. The data shall be labelled with a time stamp (date and time) corresponding to the beginning of the time interval.

105 The system shall automatically store time series for all the measured parameters for a number of time intervals corresponding to at least a period of the last 4 hours of recording. Time series older than this period shall automatically be deleted from the storage device.

Guidance note:

This feature may be utilised as a simple voyage recorder.

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106 The system shall have the functionality, on request from the operator, to permanently store the data specified in 105. The system shall have the storage capacity to permanently store at least 12 such periods.

107 The system shall have output port for providing Voyage Data Recorder with all IMO mandatory information from the system. The port should be compliant with IEC 61162.

F. Extent of Monitoring

F 100 General

101 The required minimum and the recommended minimum of sensors are shown in Table F1.

Guidance note:

IMO Recommendations for the Fitting of Hull Stress Monitoring Systems. (MSC/Circ.646)

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Table F1 - Parameters to be monitored for the various types of vessels

A: Oil Carriers, Chemical Carriers, Liquefied Gas Carriers and Oil Production and Storage Vessels
B: Bulk Carriers and Ore Carriers
C: Container Vessels
D: General Cargo Ships, Ro-Ro Vessels, Passenger Vessels and other Vessels
E: High Speed Light Craft

Parameter	*Required*	*Recommended*	*Remarks*
Vertical accelerations at forward perpendicular (0.01L) at centre line		A, B, C, D	
Vertical, transverse and longitudinal acceleration at the centre line of each hull in the fore body (fore of forward perpendicular)	E		
Transverse acceleration in the 0.4L mid ship area		B, C, D	To monitor inertia loading on sensitive cargo. Sudden change in response may indicate irregular situations such as ingress of water in holds or at vehicle decks.
Vertical, transverse and longitudinal acceleration at the longitudinal centre of gravity (LCG)	E		
Vertical, transverse and longitudinal acceleration at the centre line of each hull aft body (aft of aft perpendicular)	E		
Global longitudinal stress amidships (port and starboard)	A, B, C, D[1]	E[2]	[1] For vessels with hull girder sectional modulus $< 1.5\ Z_{rule}$. [2] For vessels with length L> 50 m.
Global longitudinal stress at the quarter length L/4 from mid ship (port or starboard side)		A[3], B[3], C[3], D[4]	[3] For vessels with length L>180 m. [4] For vessels with hull girder sectional modulus $< 1.5\ Z_{rule}$ and with length L>180 m.
Longitudinal stress close to bottom (L/2) amidships (port and starboard)		B[5], C[6]	[5] Longitudinal stresses (L/2) amidships below the neutral axis, e.g. at bilge area. Only for ships with large openings in deck, for example open hatch carriers. [6] Longitudinal stresses (L/2) amidships below neutral axis, e.g. at bilge area.
Double bottom bending		B[7]	[7] For Bulk Carriers with class notation **BC-B**, **BC-A** or **BC-B***, one strain sensor in inner bottom of each hold.
Bending/shear stress in pillar bulkheads		C[8]	[8] For vessels with operational limits with respect to draught with empty holds.
Global transverse stress in wet deck in centre between each hull		E[9]	[9] For multi-hull vessels with length L>50 m
Lateral loads at bottom near forward perpendicular		A, B, C, D,E[10]	[10] If slamming in the fore body may occur (ballast).
Lateral loads at side		A, B, C, D	
Lateral loads at the bow door		D[11]	[11] For Ro-Ro Vessels only. Measuring of relevant parameters, i.e. stresses or pressures.
Loading computer system	A, B, C, D		
Position, speed/course	E	A[12], B, C, D	[12] Not relevant for Oil Production and Storage Vessels.
Power output and revolutions of propulsor (s)	E	A, B, C, D	
Wave condition	E	A, B, C, D	
Wind condition	E	A, B, C, D	

SECTION 4
INSTALLATION AND TESTING

A. General

A 100 Certificates

101 All relevant certificates on the equipment included in the hull monitoring system shall be delivered.

A 200 Operations manual

201 An operations manual written in English and in a language appropriate for the ship's crew shall be on board.

A 300 Monitoring system

301 Information on how to interpolate the vertical hull girder bending moment values from the loading computer to the strain gauge positions shall be included in the computer programme of the system so that the loading instrument readings can be used for setting and checking the system.

302 Each strain gauge is initially to be set to a stress calculated in an agreed loading condition. This calculated stress shall be compatible with the output of the loading instrument and calculations made using the loading manual. The set-up shall not be carried out when dynamic stresses are present and shall be made when temperature effects are minimised and in absence of large gradients.

303 The initial readout of the sensor shall be checked against an agreed loading condition in calm water, with the attendance of a surveyor from the Society. In the event that the difference is greater than 5% of the approved value or 10 N/mm^2 occurs, whichever is the greater, the setup and subsequent checking shall be repeated.

304 The calibration shall be verified by a surveyor from the Society. Recommendations and certificates of calibration, signed by an authorised person shall be kept on board the ship.

B. Approval and Testing Procedure

B 100 General

101 The operation of the hull monitoring system shall be verified upon installation by a surveyor from the Society:

— witness that the relevant procedures for testing the system are carried out
— ensure that the recorded data is according to the requirement
— verify that the maintenance and calibration log is complying with the relevant procedures.

Guidance note:

All relevant procedures shall be kept together with the manuals as stated in Sec.1 A400.

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