Sjøfartsdirektoratet
Norwegian Maritime Authority

**Circular - Series V**

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| **No.:** | **RSV 12-2016** |
| **Date:** | 18/07/2016 |
| **Journal No.:** | 2016/8065 |
| **Applicable until:** | Maximum 31 Dec + 5 years |
| **Supersedes:** | Previous circular series V |
| **Reference to:** | Excerpts from ............., year and page No. |


# Guidelines for chemical energy storage - maritime battery systems

The maritime industry in Norway is currently at the forefront of the development and use of maritime battery systems. In cooperation with the industry, the Norwegian Maritime Authority (NMA) wishes to contribute to using this advantage and to further develop the technology in a safe manner.

Batteries can, depending on chemistry and design, generate significant volumes of flammable gases, with the risk of both explosion and fire. Internal faults in the battery cells may occur despite the battery system's safety systems.

The background for this Circular is to facilitate that ships with installed battery systems maintain the same level of safety as ships with conventional operation.

The Circular is issued pursuant to the Act of 16 February 2009 No. 9 relating to ship safety and security, in particular sections 6, 9, 11, 43 and 45, and the Regulations of 1 January 2005 No. 8 on the working environment, health and safety of persons working on board ship.

## 1. Scope of application

The Circular applies to all Norwegian-registered vessels with installed battery systems based on Li-ion or similar technology. The Circular does not apply to Norwegian-registered vessels of less than 24 metres in overall length not used for commercial purposes.

For battery installations of less than 20 kWh, please refer to section 8 of this Circular.

## 2. General

If the company wishes to satisfy the provisions of the Ship Safety and Security Act in other ways than described in this Circular, the NMA will follow this closely. In such cases, the NMA presupposes that for new and alternative technology, a technical analysis is carried out based on MSC.1/Circ.1455 Guidelines for the Approval of Alternatives and Equivalents as Provided for in Various IMO Instruments.

As an alternative, rules on battery systems from a recognised classification society may be used in combination with this Circular. In such cases, the rules must be accepted by the NMA.

Battery systems should in any case be certified or approved by a recognised classification society.

The company should describe their philosophy with regard to design and location of battery spaces, solutions for explosion relief, ventilation and fire-extinguishing based on their selected specific battery solution. The battery solution should be tested in accordance with this Circular.

Air extraction from ventilation, if any, of modules or battery spaces should be carried to areas where it can do no harm.

Only equipment associated with the battery system should be placed in the battery room.

# 3. Tests

In order to identify the damage potential of a possible thermal runaway event in a specific battery system, testing should be carried out on both cellular, modular and system level. The results from the tests satisfying the acceptance criteria will determine the design of battery spaces with associated systems for fire extinguishing, explosion relief, ventilation, etc and may be used as basis for using this type of battery systems on ships.

## 3.1. Propagation test 1

If the battery system design indicates that the below test set-up is not relevant, this should be clarified in advance with the NMA.

A propagation test as described below should be carried out. Auxiliary systems which are integrated in the battery pack in order to prevent propagation and which are operative when the battery is in use, may also be used during the propagation test. Loss of these auxiliary systems should lead to shutdown of the battery system.

### 3.1.1. Test set-up

a. The test should be carried out in an enclosed space, as similar as possible to the manufacturer's recommendation for battery spaces. The temperature of the space should be equivalent to the maximum operating temperature (+/-5°C) for the battery system.
b. The tested module should be surrounded by other modules and be installed in a rack system similar to the one used on board ships. The modules in the least favourable positions with regard to fire propagation from the tested module should be operative modules. The internal structure of the modules should not be changed. The remaining may be dummy modules as long as they have the same heat capacity, heat reflective properties and conductivity as the actual modules.
c. All operative modules in the test should have a 100% State of Charge at the start of the test.
d. The module being tested should be randomly selected from a production batch, and should not be altered apart from instrumentation. Any alterations made to cells in order to initiate the thermal event, should be clarified with the NMA in each case.
e. The cell or cell pair to be overloaded should have the least favourable position in the module with regard to propagation.
f. The safety functions of the battery management system (BMS) should be deactivated during testing.
g. The test should be instrumented to continuously record relevant data. Voltage and temperatures of the tested module and the other operative modules should be logged as a function of time. The temperature of the dummy modules should be logged in the same way. The temperature sensors should be placed on the surface closest to the module where the thermal event is initiated.

h. Modules in the test set-up should be continuously monitored and the result registered until the temperature is back to ambient temperature, and as a minimum for 24 hours after the thermal event occurred.
i. The test should be conducted without use of active external safety functions such as fire extinguishing system, ventilation, etc. in the test space.

### 3.1.2.

A cell or cell pair in the test module should be overcharged with a voltage of at least 150% of the maximum charging voltage over time until a thermal event occurs. The charging current should be maximum of what the cell is designed for.

### 3.1.3.

If a thermal event has not occurred after 4 hours, additional heat may be applied by using fitted heating elements.

### 3.1.4.

For battery cells fitted with an internal circuit interrupt device (CID), where it is documented that this is functioning, the thermal event may be initiated by using heat.

### 3.1.5. Acceptance criteria

Three witnessed tests should be carried out. The acceptance criterion is that no propagation occurs between modules.

If the test fails, the test should be aborted, and the criterion of propagation test 1 has not been satisfied.

## 3.2. Propagation test 2

If propagation test 1 fails, the arrangement may be tested with active external safety systems upon acceptance from the NMA. The test set-up for propagation test 2 is the same as for propagation test 1, with the exception of item 3.1.1i which should be disregarded.

As for propagation test 1, three witnessed tests should be carried out. The acceptance criterion is the same: no propagation between modules. All tests should be successful.

When the battery system is fitted on board, active external safety systems should be installed, which should be equivalent to the test arrangement with regard to capacity and details. These systems should be available in all relevant emergency situations. If a gas fire extinguishing system is used to inhibit propagation, it should have capacity for at least two subsequent releases.

# 4. Witnessing of tests

Propagation tests should be notified to the NMA in reasonable time before the tests, and the NMA reserves the right to have an NMA inspector or someone designated by the NMA present to witness the tests.

# 5. Explosion analysis

The explosion analysis should be prepared for a ship-specific selected battery space, based on the results from the gas analysis in section 6 with off-gas from all cells in an entire battery module.

If the module has passed propagation test 1 described in section 3.1 and is designed so that a thermal runaway event in a cell or cell pair will not spread to all cells in the module, the analysis may be prepared based on the gas generation from the affected cells only. The limitation must be documented and explained in the module design.

The analysis should include the estimated course of an explosion and the management of explosion pressure.

If it can be documented that an explosive atmosphere will not occur, the explosion analysis may be omitted.

# 6. Gas analysis

The gas analysis should be carried out for the cell type that has passed one of the propagation tests in section 3.

The test should be conducted in an inert atmosphere by controlled heating of a single cell until the cell vents. The cell should be randomly selected, and should have a 100% State of Charge at the start of the test.

The resulting atmosphere should be analysed in order to identify maximum gas generation and gas composition.

# 7. Lists of documentation

The following documentation should be submitted and processed before the battery system is put into operation.

## 7.1. Battery-specific documentation:

1. Safety description from battery supplier
2. Data sheet for battery cells
3. Test procedure
4. Gas analysis procedure
5. Gas analysis report
6. Propagation test report. The test report should include information regarding propagation between cells.
7. Confirmation of certification or approval of the battery system from a recognised classification society

## 7.2. Vessel-specific documentation:

1. Arrangement drawing of battery space with description of components
2. Risk analyses for the battery installation
3. Documentation of selected fire extinguishing system
4. Ventilation arrangement
5. Explosion analysis
6. Confirmation of fulfilled classification society rules, if applicable

# 8. Battery systems below 20kWh

For Norwegian-registered vessels with battery systems of less than 20kWh, a risk analysis should be carried out and documented based on the risk of gas formation, explosion and fire, cf. Regulations of 1 January 2005 No. 8 on working environment, health and safety for persons working on board ships, section 2-2.

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# 9. Alterations

In the event of alterations of arrangements, this should be reported to the NMA.

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