ClassNK

Guidelines for Large-capacity Storage Batteries

January 2013

Nippon Kaiji Kyokai

Guidelines for Large-capacity Storage Batteries

Preface

Power sources using natural energy such as solar batteries, wind-power generators and the like are being used in ships in recent years. The power generating capacity of these power sources is affected by weather and sea conditions. To ensure stabilization of power supply from a natural energy source connected to the shipboard power supply and to supplement this power supply during peak power demand, it is effective to combine these power sources with storage batteries. If the storage batteries are of large capacity, and if they can be charged during voyages by solar cells or the like so that the power demand can be met when the ship is berthed or at anchor, carbon dioxide emissions can be reduced at the calling ports .

Storage batteries have been used since the past; and lead storage batteries used in cars and so on are well known. Generally, these storage batteries are used in ships as well.

The conventional lead storage battery (vent-type lead storage battery) emits hydrogen gas. It has the disadvantage that the electrolyte had to be replenished; therefore, care was required in its installation and handling. In recent years, however, sealed lead storage batteries are increasingly being used since the generation of hydrogen gas is inhibited, and replenishment of liquid is not necessary. Such batteries are now commonly being used in ships as well.

However, if we assume that a sealed lead storage battery with power capacity equivalent to that of one diesel generator is to be used, a battery with a fairly large volume and mass must be used. How to reduce this volume and mass, that is, how to enhance the energy per unit volume/mass (energy density) becomes an important point in the use of large-sized storage batteries.

Storage batteries, such as sealed nickel metal hydride and lithium ion storage batteries which are being used in all kinds of equipment but especially small electric and electronic equipment have high energy density, are smaller, and can produce larger power compared to the conventional lead and sealed lead storage batteries. On the other hand, these storage batteries possess considerable risk of fracture and explosion similar to the conventional lead storage batteries. The risks also depend on the type of storage battery, the material of electrodes, and the electrolyte used. Sometimes manufacturing defects may cause accidents depending on the kind of storage battery used.

The application of large-capacity storage batteries of these kinds to ships is under research and development as part of a project supported by the Ministry of Land, Infrastructure, Transport and Tourism. ClassNK has also joined this group and has studied mainly the safety aspects.

The guidelines given below include a summary of the precautions to be taken in the use of these storage batteries. The authors hope that these guidelines will be used for guidance on the use of large-capacity storage batteries on ships.

These precautions can also be used for small-capacity storage batteries, and it is hoped that these guidelines will be used as reference when using these batteries as well.

Table of Contents

Chapter 1 Characteristics of storage batteries

Standards, properties, and reaction equations of storage batteries are given in this chapter.

1 Types of storage batteries

(1) Sealed lead storage battery (1*)

(2) Lithium ion storage battery (*2)

(3) Sealed nickel metal hydride storage battery (*3)

(4) Sealed nickel cadmium storage battery (*4)

(5) Sodium sulfur storage battery (*5)

(*1) to (*5) : Refer to “2. Terminology,” in Chapter 4.

2 Characteristics of storage batteries

(1) Sealed lead storage battery

This battery is also called valve regulated lead storage battery or cathode absorbing sealed type lead acid battery.

Generally, hydrogen is emitted from the positive electrode and oxygen from the negative electrode due to the electrolytic decomposition of water included in the electrolyte in a vented lead acid battery. These gases are discharged outside the storage battery, and an explosive gaseous atmosphere is generated around the battery, while at the same time, the electrolyte quantity decreases. However, the shift of electrolyte is reduced by using glass mat containing electrolyte as a separator between the electrode plates. Moreover, the ordinary charge/discharge system is designed such that gas generation and electrolyte quantity do not decrease easily because the oxygen generated in the negative electrode is absorbed. General characteristics of this storage battery are given as below.

① Deterioration phenomenon

A disadvantage of the lead acid storage battery is the reduction in capacity due to deterioration of electrode. This deterioration phenomenon has been suppressed compared to the vented lead acid battery, but if the discharge is heavy, material is formed on the electrode due to sulfation, and this material accelerates deterioration of the electrode.

② Self discharge

Self discharge is suppressed compared to the vented lead acid battery, but if left as-is for a long period, the deterioration phenomenon mentioned above accelerates due to self discharge.

③ Risks

Although gas generation is suppressed compared to vented lead acid battery, a safety valve is provided in the battery since gas is generated during over discharge.

④ Corrosiveness

Corrosion of electrolyte within the battery need not be considered since replenished liquid is not needed and there is no leakage of electrolyte due to rolling and pitching because electrolyte is impregnated in the separator.

(2) Lithium ion storage battery

Electron transfer takes place with the movement of lithium ions. All kinds of materials of such as electrodes or electrolyte with quality that enable movement of lithium ions may be used to configure the storage battery. Lithium ion storage batteries of various kinds and configurations are available for this reason and their characteristics vary. The general properties are as given below.

① High voltage and high energy density
Non aqueous organic solvent is used in the electrolyte. For this reason, higher voltage that exceeds the voltage obtained from electrolysis of water can be obtained. Voltage (about 3V per cell) of about three times and energy density of 1.5 to 2 times per unit mass compared to that of sealed nickel cadmium storage battery can be obtained.

② Life of charge/discharge cycle
Generally, charge/discharge cycles are in the range of 300 to 500. However, this life cycle has steadily improved with rapid progress.

③ Risks
The electrolyte is an organic solvent, and when exposed to over-charging and high temperature, the storage battery itself is subject to thermal runaway because of short circuit within the battery. Fracture or explosion of the battery may occur, and in the worst case, this battery may involve other sound storage batteries in the vicinity causing fire in the entire battery compartment.
In principle, compared to other storage batteries, the electrode falls into extreme oxidation and reduction states; therefore, the electrode material is likely to become unstable. If the battery is overcharged, the positive plate generates heat because of oxidation and crystallization. Lithium may be formed at the negative plate, battery deterioration accelerates, and explosion may occur due to thermal runaway.
If short circuit occurs because of entry of a metal piece during manufacture or the like, thermal runaway may occur. (Refer to instances of accidents in Chapter 2).

Generally, cobalt-based material is used in the positive electrode in most cases. Since this material is a scarce resource, a material containing iron phosphate is now being used as its substitute. While cobalt-based material becomes unstable after oxidation is removed due to heat generation, iron phosphate-based material has strong affinity with oxygen, does not become unstable easily, and suppresses thermal runaway. On the other hand, the energy efficiency is inferior.

④ Safety measures
The factors that cause fire and fracture of container due to breakdown of lithium ion storage battery may be considered as “abnormal battery voltage due to overcharging,” “abnormal current due to short circuit of power converter panel,” “abnormality in control and monitoring system,” and “temperature rise due to breakdown of parts within battery.” The automatic cut-off of storage battery when any of the factors below occurs, is considered to be the most effective measures to prevent these abnormalities beforehand.
・Voltage is abnormal
・Current is abnormal
・Temperature of storage battery is abnormal
・Control and monitoring system is abnormal.

(3) Sealed nickel metal hydride storage battery
Similar to sealed nickel cadmium storage battery, this battery belongs to the alkaline storage battery group. However, this sealed nickel cadmium storage battery included a pollutant, namely cadmium, and the energy density also differed; so the conversion to this storage battery accelerated.

① High specific capacitance

The specific capacitance is high compared to that of the sealed nickel cadmium storage battery.

② Self discharge
There are some kinds with high self discharge and there are also some with the disadvantage that the battery's capacitance decreases when it is not charging. There are also some batteries in the market in which such self discharging is suppressed.

③ Low environmental load
Does not contain pollutants such as cadmium, which is used in sealed nickel cadmium storage batteries.

④ Discharge characteristics
Discharge characteristics during high power and high current are excellent.

⑤ Risks
There is a risk of emission of hydrogen which is an explosive gas, when overcharged. However, in normal conditions, safety is comparatively high.

(4) Sealed nickel cadmium storage battery
This battery has deficiencies in characteristics given in ① and ② below; therefore, conversion to nickel metal hydride storage battery has progressed, and opportunities to use this battery presently are hard to come by.

① High environmental load
Contains cadmium, a pollutant.

② Memory effect
Memory effect refers to the phenomenon wherein the battery gradually loses its maximum energy capacity if it is repeatedly recharged after being only partially discharged, and appears to "remember" the smaller capacity. The net result is that the battery capacity decreases (it holds less charge). This memory effect is noticeable in sealed nickel cadmium storage batteries.

③ Recovery after excessive discharge
Recovers initial energy capacity when it is charged even after over-charging.

④ Large current discharge
Large current discharge is possible since internal resistance is low.

(5) Sodium sulfur storage battery

Sodium sulfur storage battery is commonly known as NaS (Na – sodium; S – sulfur) battery. This is a storage battery in which sodium and sulfur are used as active materials. The energy density per unit mass is about three times compared to that of the lead acid battery, self discharge is small, charge-discharge efficiency is high, and installation cost is moderate compared to other storage batteries. In view of these advantages, this battery is frequently used in large scale power storage facilities on shore.

① Shore standards
Comprehensive requirements are stipulated in the Electric Utility Law of Japan and accompanying technical standards since instances of use of this battery on shore are numerous.

② Application to ships
Since the operating temperature is as high as 300ºC, heating equipment is required for start up of operation. Also, discharge operation is required for maintaining the

operating temperature. On account of these reasons, it is difficult to use this battery on ships.

③ Risks
Ignition occurs when sodium and sulfur come in direct contact; therefore, the construction and, strength of the separator and the container have a large impact on safety. Furthermore, fire extinguishing media for general electric equipment (gas-based fire extinguishing media for shutting off oxygen, water-based fire extinguishing media) are not effective or such media cannot be used because those media will promote fire due to reaction with sodium.

3 Standards related to storage batteries

(1) Sealed lead storage battery
Applicable standards include: JIS C 8704-2-1 “Stationary lead-acid batteries -- Part 2-1: Valve regulated types -- Methods of test,” JIS C 8704-2-2 “Stationary lead-acid batteries -- Part 2-2: Valve regulated types – Requirements,” IEC60896-21 “Stationary lead-acid batteries - Part 21:Valve regulated types – Methods of test” and IEC60896-22 “Stationary lead-acid batteries-Part 22:Valve regulated types-Requirements.”

(2) Lithium ion storage battery
Standards for small storage batteries include JIS C 8712 “Safety Requirements for Portable Sealed Secondary Cells and Batteries for Use in Portable Applications” and JIS C 8714 “Safety Tests for Portable Lithium-ion Secondary Cells and. Batteries for Use in Portable Electric Applications.” Standards for comparatively large lithium ion storage batteries include: JIS C 8715-2 “Secondary Lithium Cells And Batteries For Use In Industrial Applications - Part 2: Tests And Requirements Of Safety, “ Standards of the Battery Association of Japan SBA S 1101 “Safety Tests of Secondary Lithium Cells And Batteries For Use In Industrial Applications（single cell and battery systems）” and the like.

(3) Sealed nickel metal hydride storage battery (Ni-MH battery)
Standards for comparatively small-sized Ni-MH battery include JIS C 8708 “Sealed nickel-metal hydride rechargeable single cells, JIS C 8712 “Safety Requirements for Portable Sealed Secondary Cells and Batteries for Use in Portable Applications,” IEC 61951-2 Ed. 2 “Secondary cells and batteries containing alkaline or other non-acid electrolytes – Portable sealed rechargeable single cells – Part 2:Nickel-metal hydride” and so on.

(4) Sealed nickel cadmium storage battery (Ni-Cd battery)

Standards include JIS C 8709 “Sealed nickel-cadmium rechargeable single cells,” JIS C 8712 “Safety Requirements for Portable Sealed Secondary Cells and Batteries for Use in Portable Applications,” IEC 60622 “Secondary cells and batteries containing alkaline or other non-acid electrolytes – Sealed nickel-cadmium prismatic rechargeable single cells.”.

(5) Sodium sulfur storage battery
Comparatively large-capacity sodium sulfur storage batteries have been realized because this battery comes with heating equipment and is different from the kinds of batteries mentioned above.. For this reason, this battery has not been covered in standards such as JIS, and there are many instances where its safety evaluation has been carried out as a part of the plant equipment. Japan Electrical Association Standards for land-use storage batteries（JEAC 5006-2010）have been issued.

4 Battery reactions

(1) Sealed lead storage battery

Reaction at the positive electrode $PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \leftrightarrow PbSO_4 + 2H_2O$

Reaction at the negative electrode $Pb + SO_4^{2-} \leftrightarrow PbSO_4 + 2e^-$

(2) Lithium ion storage battery
Reaction also changes depending on the materials used in the electrode. The reactions with cobalt included in the electrode material are as given below.

Reaction at the positive electrode $LiCoO_2 \leftrightarrow Li_{1-x}CoO_2 + xLi + xe^-$

Reaction at the negative electrode $xLi^+ + xe^- + 6C \leftrightarrow Li_xC6$

(3) Sealed nickel metal hydride storage battery

Reaction at the positive electrode $NiOOH + H_2O + e^- \leftrightarrow Ni(OH)_2 + OH^-$

Reaction at the negative electrode $MH + OH^- \leftrightarrow M + H_2O + e^-$

(4) Sealed nickel cadmium storage battery

Reaction at the positive electrode $NiOOH + H_2O + e^- \leftrightarrow Ni(HH)_2 + OH^-$

Reaction at the negative electrode $Cd + 2OH^- \leftrightarrow Cd(OH)_2 + 2e^-$

(5) Sodium sulfur storage battery
Electrolyte is β-alumina. Positive electrode is sulfur. The molten sodium in the negative electrode is ionized to Na+ at the interface with the β-alumina, passes through the electrolyte and moves to the positive electrode. The Na+ ions get reduced at the positive electrode by the sulfur and become sodium pentasulfide. (Na_2S_5). Battery reactions (discharge reactions) are as follows:

Reaction at the positive electrode $5S + 2Na^+ + 2e^- \leftrightarrow Na_2S_5$

Reaction at the negative electrode $2Na \leftrightarrow 2Na^+ + 2e^-$

Overall reaction $2Na + 5S \leftrightarrow Na_2S_5$

Chapter 2 Instances of accidents to storage batteries

Typical instances of accidents to batteries are described in this chapter.

1 Sealed lead storage battery

– Explosion in the battery room of an intelligent building –

This is an instance of an accident pointed out by the International Association of Classification Societies at a meeting to debate whether closing appliances were needed for ventilation equipment in the battery room.

Sealed lead storage batteries were installed as backup power supply (UPS) for computers and related equipment in the building, and the quantity of flammable gases generated from sealed lead storage batteries was suppressed compared to general lead storage batteries. Ventilation system had been provided in the battery room. Hydrogen gas monitoring system was also provided, but hydrogen gas alarm could be extended only at the local panel; it could not be warned at the fire control room. The ventilation system was not an exhaust type specifically for the battery room. The ventilation system was a supply ventilation system common to other compartments in the building, and it was not intended to be operated all the time. In view of these factors, the hydrogen gas generated from the sealed lead storage battery gradually accumulated near the upper part of the battery room, and it was presumably ignited by non-explosion-proof electric equipment (assumed to be illuminating equipment), resulting in an explosion. （http://www.cholarisk.com）

This is an instance of an accident that makes us recognize anew the importance of safety devices such as gas detection alarms and adequate ventilation.

2 Lithium ion storage battery

(1) Abnormal heat generation and ignition accident of lithium ion storage battery for notebook computer
The recall of 5 million lithium ion batteries by Company S is fresh in memory as an instance that heightens awareness of the risk of lithium ion storage batteries. A metal piece entered the battery during its manufacture. Since abnormal heat generation and ignition may occur because of internal short circuit, the products were recalled.

(2) Explosion in the Huis Ten Bosch pleasure boat
The lithium ion storage battery installed on the deck of a pleasure boat at berth exploded, and a part of the deck and the hull was damaged. Both the lithium ion battery and the

charger were made overseas, but the BMU of the storage battery (see “2. Terminology” in Chapter 4) and the cases were made in Japan.

(Estimated causes of the accident and history)
The battery cell(s) in the battery pack caught fire caused by uncertain effect. Thermal runaway occurred in the battery cells due to the heat, and the entire pack burned out while discharging flammable gas. Thermal runaway began in other packs as well because of this heat; however, because of the lack of oxygen in the engine room due to the combustion, the fire died out. The storage battery however, continued to discharge flammable gas because of the excess heat. This flammable gas filled the engine room, and an explosion occurred probably because of ignition due to entry of air containing oxygen from the outside or due to some other reason.

3 Sealed nickel metal hydride storage battery

There are many instances of explosion due to mis-matching of charger and battery. In principle, over-charging condition continues when a charger not matching the storage battery is used. In most of the cases, hydrogen gas filled up the space within the storage battery and explosion occurred. However, there are also several instances of explosion that occurred during transportation of container loaded with several dry type nickel metal hydride storage batteries. So it cannot be said with certainty that risk is present only during battery charging. Even when the battery is overheated, an explosion may occur.

4 Sodium sulfur storage battery

Several instances of fire have been recorded. In all these cases, short circuit within a battery pack caused the fire to spread to all the battery packs The general fire extinguishing media were not effective (See Sec. 4 of Chapter 3), therefore, in some instances, a large quantity of sand was thrown on the fire to extinguish it.

Chapter 3 Study on the requirements for storage battery systems

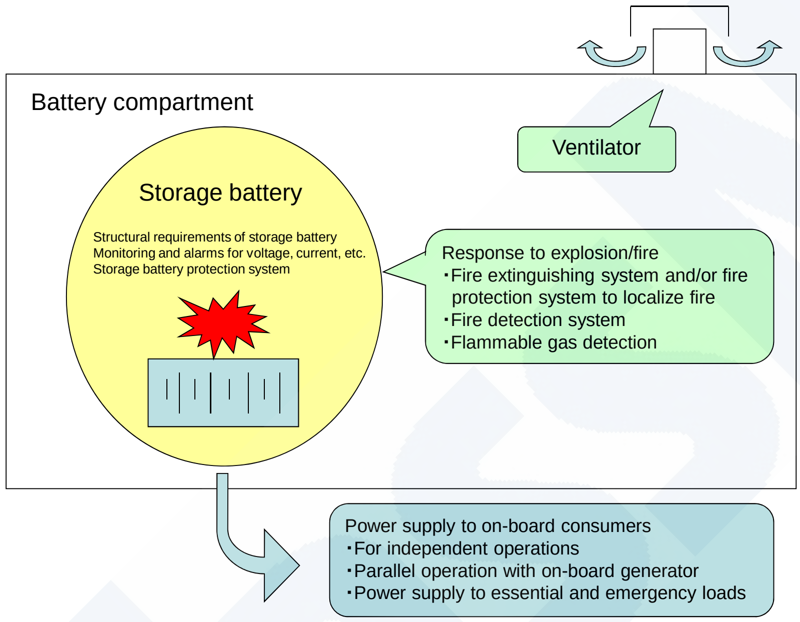
Comprehensive requirements for storage batteries should be established based on the properties and instances of accidents to storage batteries mentioned until now corresponding to the items shown below as an outline . Comprehensive requirements based on these studies are given in the next chapter.

1 Storage battery

Structural requirements of storage battery, monitoring and alarm systems of storage battery, protective devices of storage battery, and so on

2 Response to explosion and fires

Flammable gas detector, fire detecting system, fire extinguishing system, fire protection equipment, etc.



3 Ventilation system

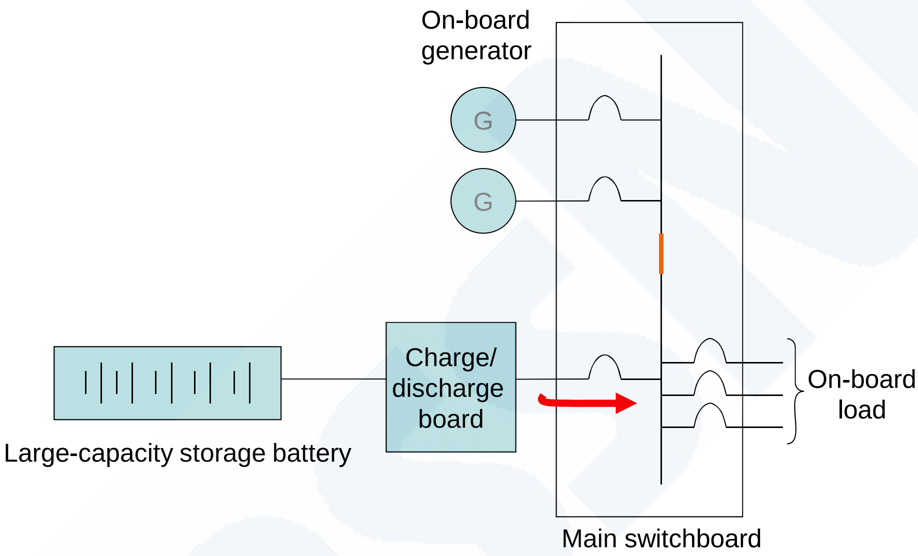
Even if a storage battery does not discharge explosive gas, flammable vapors, etc., during normal charging and discharging, comprehensive ventilation at all times needs to be considered during abnormal conditions such as overcharging and so on, if the storage battery has the risk of discharging these gases or vapors.

However, adverse ventilation conditions can be mitigated by providing equipment that prevents explosion and fire (automatic stop device when voltage, temperature, etc., is abnormal, flammable gas detector, and so on).

Apart from this, the storage battery generates heat during charging/discharging; therefore ventilation that takes into account the operating temperature of the battery and the ambient temperature on the ship is necessary.

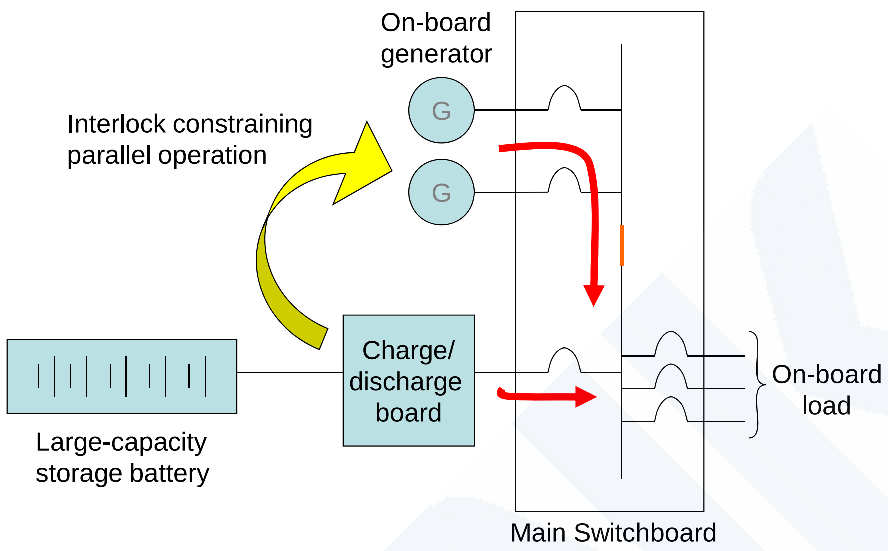
4 Battery systems by power supply method

(1) Requirement for storage battery intended to independent power supply for on-board loads
In case the storage battery is to supply power independently for on-board loads without using the on-board generator, and if a short circuit occurs on the load side, capability to supply short circuit current is required to operate the nearest protective device (MCCB or the like) for isolating the accident point from the supply circuit.
The generator is required to supply sustaining short circuit current of 300% of the rated current for duration of 2 seconds. The same performance is required of a storage battery system performing independent operation.
Since it is important to isolate the accident point in the distribution system the required short circuit current and duration could be reduced, if a selective trip can be initiated at a lower current value.



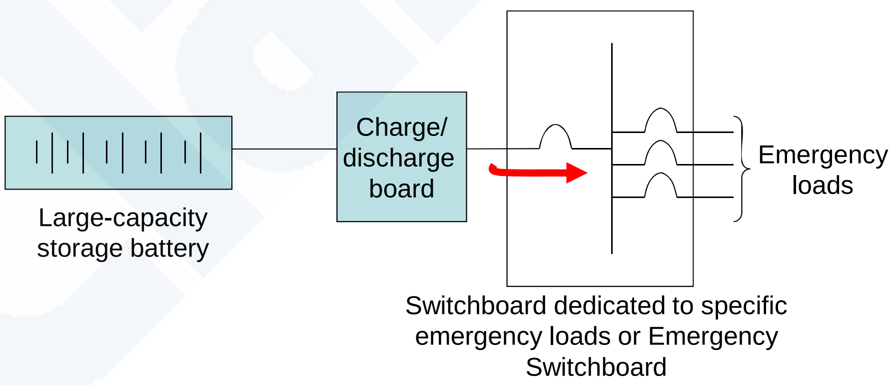
Example of system diagram for independent operation of storage battery (no interlock with parallel operation condition provided)

(2) Requirement for storage battery system intended for parallel operation with on-board generators
If the storage battery does not independent supply power to on-board load, then the performance requirement of supplying short circuit current during an accident in (1) does not apply. However, an interlock should be provided between the on-board generator and the storage battery system so that the storage battery system stops if all the on-board generators stop (when on-board generators in parallel operation stop).



Example of storage battery system intended for
parallel operation with on-board generators

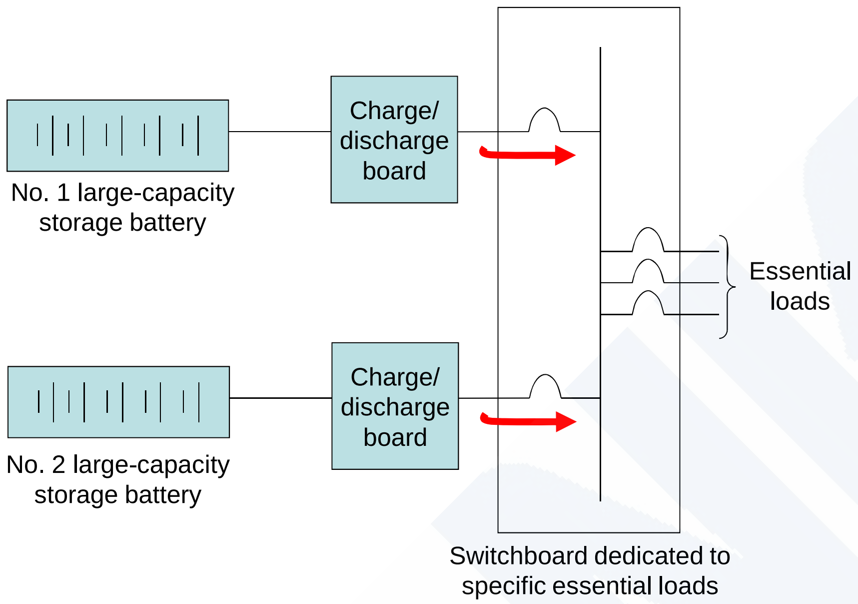
(3) Requirement for storage battery system intended to supply power to emergency loads
In case storage battery system is intended to supply emergency consumers required by the SOLAS Convention instead of the emergency power supply (emergency generator and the like), etc., the storage battery system should satisfy all the requirements for emergency power supply including the requirement of independent operation.



Example of storage battery system intended to
supply power to emergency loads

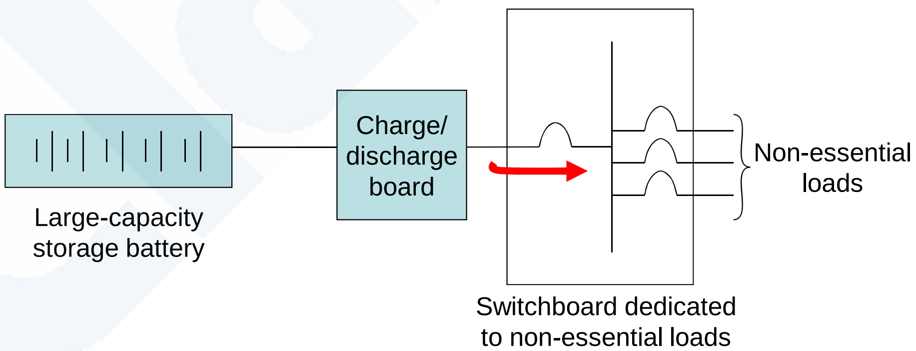
(4) Requirement for storage battery system intended to supply power to specific essential loads
In case storage battery system is intended to supply power to essential loads on-board without

application of the on-board generator, redundancy of the power supply system of a level equivalent to that of the on-board generator system should be considered for the storage battery system.



Example of storage battery system intended to supply power to specific essential loads

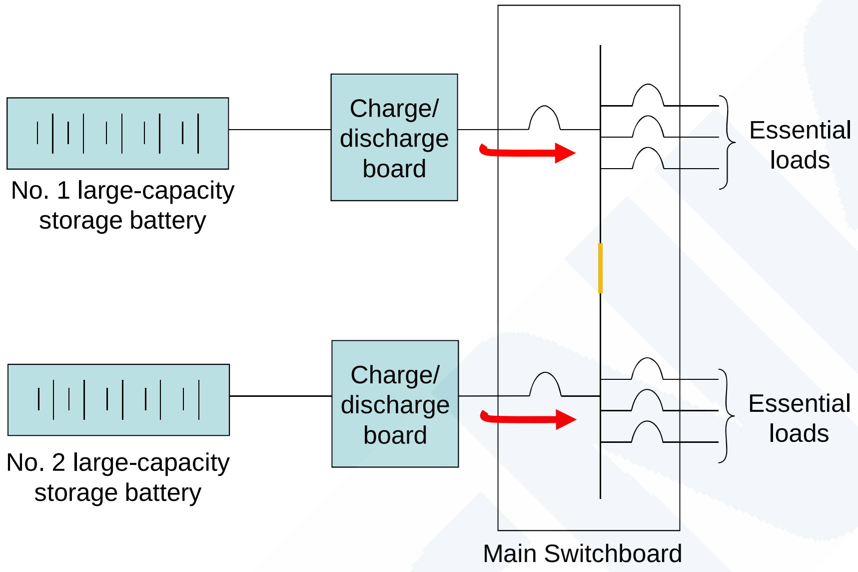
(5) Requirement for storage battery system intended to supply power to non-essential loads
In case storage battery system is intended to supply power only to non-essential loads, the redundancy of power supply system indicated in (4) above need not be considered. Also, voltage supplied from the charge/discharge system, and frequency also that exceeds the permissible range required in the rules may be permitted, if they are in the range that does not have any effect on the equipment.



Example of storage battery system intended to supply power to non-essential loads

(6) Requirement for storage battery system as an alternative to the two main power supply systems

Even if a storage battery system of large capacity is provided on a ship, it is difficult for this battery system to cover the amount required for ocean voyages. For this reason, it is difficult to install a storage battery as an alternative to the main power supply system on board ships except in ships to which international conventions such as the SOLAS Convention do not apply (hereafter referred to as "coastal ships or the like"). Even if a ship is a coastal ship or the like, in addition to restrictions on the route and the duration of cruise, requirements for safety when installing large capacity batteries are applicable.



Example of storage battery system as an alternative to the two main power supply systems

5 Protective devices for storage batteries

Fuses are generally provided as protective devices in storage batteries. However, if a short circuit occurs in the line between the storage battery and the fuse, the battery becomes short circuited, and ignition and fire may occur depending on the kind of battery used.
In lithium ion storage batteries especially, there is concern of ignition because of thermal runaway; therefore, fuse is provided close to the battery (in the battery pack). However, resistance to ignition against short circuit is required.
Signal wires for measurement of voltage and temperature in cell units are often connected to the battery. In such cases also, ignition of signal wire or thermal runaway of storage battery may be caused by short circuiting of the signal wire. Thus, protection by fuses, provision of flame retardant signal wires and connection terminals, and separated signal wires should be considered. For realizing high capacity, it is necessary to combine and modularize multiple battery cells including these protective devices and signal wire circuits.

6 Fire extinguishing system

The flammable gas that may be generated in lead acid storage battery, sealed nickel storage battery and nickel metal hydride storage battery is hydrogen gas. Presumable firing is a spreading fire to various equipment in the vicinity after a hydrogen gas explosion. To inhibit such equipment from spreading fire, any general fire extinguishing system for electric equipment (dry powder, foam, gas based systems, etc.) is considered to be effective.

On the other hand, the electrolyte used in the lithium ion battery is organic solvent. Oxygen may be released from the electrode material during a fire; therefore, extinguishing the fire after the storage battery ignites is considerably difficult. For this reason, it is preferable to perform cooling and oxygen cut-off simultaneously as a means of extinguishing the fire. However, the storage battery may emit hydrogen, a flammable gas, after electrically disassociating water, and so fire extinguishing systems for injecting and spraying water are not generally used. Fire-smothering gases such as nitrogen and carbon dioxide gases are generally used in the fire extinguishing systems.

There is no effective fire extinguishing system presently for sodium sulfur batteries (NAS batteries) as mentioned in 2(5)③ of Chapter 1. A breakthrough in fire extinguishing systems is anticipated for installing this kind of battery on board ships.

The merits and demerits of the fire extinguishing methods for each kind of battery are as below.

(1) Lead acid storage battery, sealed storage battery and nickel metal hydride storage battery
Any general fire extinguishing system (dry powder, foam, gas-based systems) is considered to be effective.

(2) Lithium ion storage battery

(a) Fixed gas fire extinguishing system
This system is effective in extinguishing fires, but to suppress thermal runaway in the lithium ion storage battery, it is preferable to cool it simultaneously. Presently, there is no fire extinguishing method that can work effectively while cooling simultaneously; therefore, nitrogen or carbon dioxide gas-based fire extinguishing systems are mostly used. The precautions below need to be taken if gas fire extinguishing system is used on lithium ion storage battery.

① Gas quantity required for extinguishing fire
Quantity greater than normal demand should be required because oxygen may be released from the electrode material. The extent of release of oxygen varies depending on the materials that make up the electrodes of the lithium ion storage battery.
This kind of phenomenon does not occur in other kinds of batters (lead acid, sealed type, nickel metal hydride, etc.)

② Preventing the formation of explosive gas atmosphere after fire extinction
When a lithium ion storage battery is exposed to the high temperature state (130 ºC and above), the internal electrolyte vaporizes and is released outside through the safety valve of the storage battery. This gas may cause a fire or an explosion. Burning can be suppressed by smothering gas, but there is a high probability that flammable gas will be emitted even after fire extinction, and may form an explosive gaseous atmosphere. Accordingly, if a person enters a compartment after the fire has been extinguished without adequate preparations, or opens the door of the compartment, there is a risk of fire or explosion due to entry of air.
For this reason, procedures should be established for ensuring adequate cooling time after release of smothering gas, subsequent dispersion and avoiding entry of unwanted air.
This kind of phenomenon does not occur in other kinds of batteries (lead acid, sealed type, nickel metal hydride, etc.)

(b) Other fire extinguishing systems
Presently, effective fire extinguishing systems other than mentioned in (a) above have not been considered.

(3) Sodium sulfur storage battery (NAS battery)
Furthermore, general purpose fire extinguishing media (gas-based fire extinguishing media for shutting off oxygen, water-based fire extinguishing media) are of no use, or they promote fire due to reaction with sodium, so such media cannot be used. At this point of time, effective fire extinguishing media do

not exist; to use this battery in ships, fires should be localized, and other methods/isolations to prevent the battery from catching fire should be established.

Chapter 4 Requirements for storage battery systems

According to 2.22.1-2, Part H of the Rules for the Survey and Construction of Steel Ships, states that storage batteries other than vented type may be accepted if deemed appropriate by the Society. The requirements given here should be satisfied based on this rule. However, in case that the same level of safety and redundancy can be obtained, flexible treatment may be adopted notwithstanding these requirements.

1 Scope

The requirements in this chapter apply to storage batteries given below from among secondary batteries other than the vented type stipulated in 2.11.1-2, Part H of the Rules for the Survey and Construction of Steel Ships, and to charging and discharging equipment connected to these batteries. For details of vented type storage batteries, such as general lead acid storage batteries and alkali storage batteries, refer to the regulations of 2.11, Part H of the Rules for the Survey and Construction of Steel Ships.

(1) Sealed lead storage battery

(2) Lithium ion storage battery

(3) Sealed nickel metal hydride storage battery

(4) Sealed nickel cadmium storage battery

(5) Sodium sulfur storage battery

2 Terminology

(1) Storage battery
Secondary battery consisting of cells and battery packs; this is a battery that does not include charger and other associated equipment.

(2) Secondary battery
Battery that stores electricity through charging, and which can be repeatedly used. In contrast, a battery that cannot be charged is called a primary battery.

(3) Charge/discharge system
Charge/discharge system refers to the charge/discharge equipment consisting of charger, converter, inverter, and so on, but does not include the storage battery. In fields other than the marine field, it refers to equipment called power conditioner, interconnected system and so on.

(4) Battery pack
This is a system assembled with more than one cells or packs. It has a battery management unit (BMU) that monitors and controls cells such that they remain in the usage range.

(5) Battery Management Unit (BMU)
This is a unit that monitors and controls cells and battery packs such that the cells remain in the usage range. It may consist of battery unit controllers for small battery units (battery modules, etc.) and a Battery System Controller (BMS) which totally controls battery unit controllers.

(6) Storage battery system
Overall name of the system that consists of storage battery, battery management unit, and charge/discharge system.

(7) Sealed lead storage battery
This is a secondary battery also called valve regulated lead acid storage battery or cathode absorbing seal type lead acid battery. Under normal conditions it is in the sealed condition, however if the internal pressure exceeds the regulation value, gas will be emitted. Furthermore, the electrolyte cannot be replenished.

(8) Lithium ion storage battery
This is a secondary battery performing charge/discharge by movement of lithium ions. Under normal

conditions it is in the sealed condition, however if the internal pressure exceeds the regulation value, gas is emitted. The electrolyte cannot be replenished.

(9) Sealed nickel metal hydride storage battery
It uses nickel oxide in the positive electrode, metal hydride alloy in the negative electrode, and an alkaline solution such as sodium hydroxide in the electrolyte. It is a sealed secondary battery wherein the two positive electrodes are isolated by separator, and under normal conditions, it is in the sealed state; however if the internal pressure exceeds the regulation value, gas will be emitted. In the normal condition, the electrolyte cannot be replenished.

(10) Sealed nickel cadmium storage battery
It uses nickel oxide in the positive electrode, cadmium in the negative electrode, and an alkaline solution such as potassium hydroxide in the electrolyte. Under normal conditions it is in the sealed state, however if the internal pressure exceeds the regulation value, gas will be emitted. In the normal condition, the electrolyte cannot be replenished.

(11) Sodium sulfur storage battery
This is a secondary battery in which sodium and sulfur are used as active materials.

3 Drawings and data to be submitted

Except when the storage battery system is of small capacity (storage battery system connected to charging equipment having output of less than 5 kW), the following drawings should be submitted for approval:

(1) Storage battery specifications

(2) Cable run system drawing (including rated and adjusted values of protective devices, type of cable and size of conductor)

(3) Short circuit current calculations (when storage battery system is operated independently)

(4) Voltage drop calculations

(5) Charge/discharge system assembly drawing (including specifications of protective devices, instrumentation, cables) and connection drawing

(6) Layout drawing of electric equipment in the storage battery system

(7) Risk assessment table (if required in Section 9)

(8) Other items deemed necessary by the Society.

4 Precautions for the storage battery system intended to use as the main generator

If the storage battery system is installed as the main generator, the requirements below should be complied with.

(1) Service route and duration of cruise should be determined in advance. Voyage time and charging time when ship is anchored/berthed should be fixed

(2) Storage battery should have adequate capacity considering deterioration with ageing and ship's voyage time.

(3) The storage battery system should comply with the requirements of main generator specified in Chapter 3, Part H of the Rules for the Survey and Construction of Steel Ships. In this case, relaxed regulations for main generator specified in Chapter 6 of the same rules may be compiled with depending on the ship's tonnage, range of service, etc.

(4) Wherever possible, the regulations related to generator in Part H of the Rules for the Survey and Construction of Steel Ships should be satisfied.

5 Requirements for storage battery systems

(1) Storage battery system intended to independent power supply to ship’s loads
A storage battery system that supplies power to ship’s loads by parallel operation and independent operation should comply with the requirements below, treating the storage battery system as a generator. The speed fluctuation in this case should comply with the requirements reading the speed fluctuation as frequency fluctuation of the storage battery system.

(a) Total harmonic distortion (THD) specified in 2.1.2-4 of Part H of the Rules for the Survey and Construction of Steel Ships

(b) General requirements related to protection coordination of power supply system specified in 2.3.1 of Part H, Rules for the Survey and Construction of Steel Ships.

(c) Reverse power protection of generator specified in 2.3.5-3, Part H of the Rules for the Survey and Construction of Steel Ships (except when shared with charging circuit)

(d) Governing characteristics of generator specified in 2.4.2-1 and -3 of the same section of Part H of the Rules for the Survey and Construction of Steel Ships

(e) Short circuit withstand capability specified in 2.4.6 of Part H of the Rules for the Survey and Construction of Steel Ships

(f) Requirements for AC generator specified in 2.4.14, Part H of the Rules for the Survey and Construction of Steel Ships

(g) Requirements for generator specified in 18.5, Part D of the Rules for the Survey and Construction of Steel Ships (excluding requirements for prime mover). However, if one storage battery system is installed as one set out of two sets of generators required, then it will be treated as auxiliary (if relevant) related to power generating equipment specified in 18.1.1(4) and (5) of the same Rules, and the requirement of Chapter 18 of the same Part will apply. In this case, the storage battery system will be categorized as system belonging to Category II of Table D18.1 in the scope of Sec. 18.2.7.

(2) Storage battery system intended for parallel operation with generators to supply on-board loads
A storage battery system that supplies power to ship’s loads by parallel operation with generator should comply with the requirements below, treating the storage battery system as a generator. The speed fluctuation in this case should comply with the requirements reading the speed fluctuation as frequency fluctuation of the storage battery system.

(a) Total harmonic distortion (THD) specified in 2.1.2-4 of Part H of the Rules for the Survey and Construction of Steel Ships

(b) Reverse power protection of generator specified in 2.3.5-3, Part H of the Rules for the Survey and Construction of Steel Ships (except when shared with charging circuit)

(c) Governing characteristics of generator specified in 2.4.2-1 and -3 of the same section of Part H of the Rules for the Survey and Construction of Steel Ships

(d) Requirements for AC generator specified in 2.4.14, Part H of the Rules for the Survey and Construction of Steel Ships

(e) Requirements for generator specified in 18.5, Part D of the Rules for the Survey and Construction of Steel Ships (excluding requirements for prime mover).

(f) A device for automatically cutting out the storage battery system from the power supply circuit should be provided in case a generator or generators under parallel operation stops due to an abnormality. (Measure to prevent independent operation)

(3) Storage battery system intended to supply only to specific loads
A storage battery system that supplies power only to specific loads and which is separate from the on-board power supply system should be as given below.

(a) Storage battery system intended to supply emergency load
Storage battery system supplying power to lamps emergency lighting fixtures, storage battery

charging for lifeboat, liferaft lamp and so on which is required to supply from an emergency power source, should be according to the following:

① Charge/discharge system should satisfy the requirements for duration of power supply, voltage fluctuation, etc., specified in 3.3, Part H of the Rules for the Survey and Construction of Steel Ships.

② In case the storage battery system is intended to act as an emergency power source, the requirements for arrangement specified in 3.3, Part H of the Rules for the Survey and Construction of Steel Ships should be satisfied.

③ The charge/discharge board (including power conversion board) is considered as emergency switchboard, and it should satisfy the requirements of arrangements specified in 3.3, Part H of the Rules for the Survey and Construction of Steel Ships.

(b) Storage battery system intended to supply essential services

For supply of power to loads of important applications, breakdown of storage battery system, reduction in capacity, deterioration with aging and so on, should be considered, and approval given only when supply of power for predetermined routes and voyage periods, etc. is deemed appropriate.

(c) Storage battery system intended to supply non-essential services (except emergency loads)

① Regardless of the requirements of the Rules for the Survey and Construction of Steel Ships, voltages, frequencies, etc., derived from the charge/discharge system may be allowed to fluctuate beyond the required limit if there is no problem when they are used in loads.

② The storage battery may be of a type deemed appropriate by the Society, regardless of the requirement of 6.

6 Requirements for storage battery

(1) General requirements
The storage battery should satisfy the requirements below.

(a) Should have adequate manufacturing track record. A battery with inadequate track record may be required to be tested at the storage battery manufacturer.

(b) The storage battery should operate without hindrance under the ambient temperatures, angles of inclination and vibration conditions specified in 1.1.7, Part H of the Rules for the Survey and Construction of Steel Ships.

(c) Even if the positive and negative electrodes are short circuited, the electrodes should not ignite and catch fire, or fracture.

(d) Even if the storage battery falls from its estimated stowed position, it should not ignite, catch fire or fracture.

(e) Even at high temperatures of about 130 ºC, the battery should not ignite, catch fire or fracture.

(f) Even after long-term charging, the battery should not ignite, catch fire or fracture.

(g) Even if a cell is connected reverse to the charger by mistake, the battery should not ignite, catch fire or fracture.

(h) Even if excessive current flows to the cell because of breakdown of charger, the battery should not ignite, catch fire, or fracture.

(2) Sealed lead storage battery
Should comply with: JIS C 8704-2-1 “Stationary lead-acid batteries -- Part 2-1: Valve regulated types -- Methods of test,” JIS C 8704-2-2 “Stationary lead-acid batteries -- Part 2-2: Valve regulated types – Requirements,” IEC60896-21 “Stationary lead-acid batteries - Part 21:Valve regulated types – Methods of test” and IEC60896-22 “Stationary lead-acid batteries-Part 22:Valve regulated types-Requirements”

or equivalent standards.

(3) Lithium ion storage battery
Large lithium ion storage battery should comply with JIS C 8715-2 “Secondary Lithium Cells And Batteries For Use In Industrial Applications - Part 2: Tests And Requirements Of Safety, “ Standards of the Battery Association of Japan SBA S 1101 “Safety Tests of Secondary Lithium Cells And Batteries For Use In Industrial Applications（single cell and battery systems）” or equivalent standards.

(4) Sealed nickel metal hydride storage battery
Sealed Ni-MH battery should comply with JIS C 8708 “Sealed nickel-metal hydride rechargeable single cells, JIS C 8712 “Safety Requirements for Portable Sealed Secondary Cells and Batteries for Use in Portable Applications,” IEC 61951-2 Ed. 2 “Secondary cells and batteries containing alkaline or other non-acid electrolytes – Portable sealed rechargeable single cells – Part 2:Nickel-metal hydride” or equivalent standards.

(5) Sealed nickel cadmium storage battery
Sealed nickel cadmium storage battery should comply with JIS C 8709 “Sealed nickel-cadmium rechargeable single cells,” IEC 60622 “Secondary cells and batteries containing alkaline or other non-acid electrolytes – Sealed nickel-cadmium prismatic rechargeable single cells” or equivalent standards.

(6) Sodium sulfur storage battery
In principle, sodium sulfur storage batteries should not be used because of the risks. However, this restriction does not apply to sodium sulfur storage battery complying with safety measures (including fire extinguishing system) deemed appropriate by the Society.

7 Requirements for equipment other than storage batteries

(1) Battery charger

(a) Battery charger should be designed according to the specifications of the storage battery manufacturer.

(b) The battery charger should be capable of maintaining the appropriate charging voltage to suit the characteristics of the storage battery.

(c) For changing setting values (charge-end voltage, battery temperature, etc.) that may lead to a critical condition of the battery, protective measures such as a password, etc., should be necessary so that the values cannot be changed easily.

(2) Battery Management Unit (BMU)

(a) Battery management unit used in lithium ion storage battery should comply with JIS C 8715-2 “Secondary Lithium Cells And Batteries For Use In Industrial Applications - Part 2: Tests And Requirements Of Safety, “ Standards of the Battery Association of Japan SBA S 1101 “Safety Tests of Secondary Lithium Cells And Batteries For Use In Industrial Applications（single cell and battery systems）” or equivalent standards.

(b) The BMU should operate without hindrance under ambient conditions specified in 1.1.7, Part H of the Rules for the Survey and Construction of Steel Ships.

(c) The BMU should satisfy requirements related to construction, materials, installation, etc., of the electric equipment specified in 2.1.3, Part H of the Rules for the Survey and Construction of Steel Ships.

(d) The insulating materials, wiring materials and so on within the unit should be flame retardant.

(3) Equipment connected to on-board power supply system

If power conversion equipment (converter, inverter, etc.) are to be used for the connection to on-board power supply system, the requirements of 2.12, Part H of the Rules for the Survey and Construction of

Steel Ships should be satisfied.

(4) Other electrical equipment

The relevant regulations of Part H of the Rules for the Survey and Construction of Steel Ships should be complied with, as necessary.

8 Alarms and safety devices

Storage battery systems that are connected to a charging system having an output exceeding 5 kW should be provided with the alarms and safety devices mentioned below. However, those requirements are not applicable for a storage battery system of which the safety has been confirmed based on risk assessment specified in 9, or a storage battery system that satisfies the requirements of vented lead acid storage battery specified in 2.11, Part H of the Rules for the Survey and Construction of Steel Ships, a sealed lead acid storage battery, sealed nickel metal hydride storage battery or sealed nickel cadmium storage battery.

(1) Equipment to monitor temperature, voltage, and current of the storage battery should be installed, and alarm that issues a warning when the storage battery is overcharged or its temperature is abnormal should be installed where persons are normally present such as at the bridge, engine control room, and so on. The alarm in this case may be a common alarm. This alarm should be interlocked with a device installed to stop the charging/discharging of battery automatically.

(2) In addition to (1) above, the alarm system indicating an abnormal condition of the storage battery according to the characteristics of the storage battery should be provided.

(3) If a storage battery is formed by assembling multiple cells, a device or mechanism that automatically corrects the charge imbalance between the cells in battery pack or cell group units should be provided as far as possible.

9 Risk assessment

Risk assessment consisting of at least the following items should be performed for storage battery systems using lithium ion storage battery or sodium sulfur storage battery except those of small capacity (storage battery system connected to charging system having an output of 5 kW or smaller):

(1) All factors that lead to ignition of the storage battery and charge/discharge system
The factors to be considered are charging after excessive discharge, electromagnetic interference, electric shock, vibration, oscillation, flooding, external short circuit, internal short circuit, over-charging, over-heating, drop, collapse, leakage, ignition of exhaust gas, fire, etc.

(2) Condition monitoring, control, abnormality detection, circuit cut-off, all parts contributing to risk reduction, construction, mechanism, etc.

(3) Description of validation tests and results

(4) Fire extinguishing system (or mechanism leading to extinguishing fires, fire protection equipment, etc.)

10 Shop tests

Storage batteries with small track record including usage on shore, storage batteries connected to charging system with output exceeding 5 kW and associated storage battery systems may require the shop tests indicated below as part of safety assessment:

(1) Storage battery

Details of tests are to be in accordance with JIS C 8712, JIS C 8715-2, SBA S1101 or equivalent standards.

(a) Improper connection test

Applies to sealed nickel cadmium storage batteries or sealed nickel metal hydride storage batteries, and cells likely to be replaced by crew member during voyage or battery packs.
Confirm that ignition or fracture does not occur even if the polarity is reversed.

(b) External short circuit test

Confirm that even if the positive and negative electrodes are short circuited, battery does not ignite or fracture.

(c) Drop test

Applies to a storage battery foreseen to drop from a designated location during its replacement, storage, or installation. The battery should be dropped three times from the designated height confirming that it does not ignite or fracture.

(d) Heating test

Raise the temperature of the storage battery to 130 ºC using a hot bath and confirm that battery does not ignite or fracture.

(e) Over-charging test

Confirm that even after charging for a long period, the battery does not ignite or fracture.

(f) Forced discharge test

Applies to cells that may be subject to reverse charging because of polarity reversal of the cells by mistake. Reverse charge the discharged storage battery and confirm that the battery does not ignite or fracture.

(2) Battery Management Unit (BMU)
Details of battery tests including BMU are to be in accordance with JIS C 8715-2, SBA S1101 or equivalent standards.

① Overcharge voltage control confirmation test

② Overcharge current control confirmation test

③ Overheat control confirmation test

④ Thermal runaway test (select one from below)

i) Internal short circuit withstand test

ii) Flame spread resistance test

(3) Battery charger
Tests specified by battery charger manufacturer should be carried out. In this case, surveyor may not witness the tests, however in case the Society deems necessary, submission of the test results may be requested.

(4) Power conversion board (DC-DC converter, inverter, power conditioner, etc.)
The following shop tests of power conversion board used in the supply of power to on-board loads should be carried out:

(a) Tests for a power converter
The “shop tests” specified in 2.12.4, Part H of the Rules for the Survey and Construction of Steel Ships should be carried out.

(b) Short circuit withstand test
For a power conversion board intended to supply power independently, the short circuit withstand test specified in 2.4.15.6, Part H of the Rules for the Survey and Construction of Steel Ships should be carried out. In this case, the power supply used during short circuit test may not be the storage battery. Also, depending on the distribution system on the ship, the test conditions specified in 2.4.15-6, Part H of the Rules for the Survey and Construction of Steel Ships may be relaxed if there is no effect on selective trip operation of the protective devices. In this case, the documents listed below should be submitted to the Society and approval received beforehand.

① Short circuit current calculations when storage battery operates independently

② List of circuit breakers used (including breaking capacity, operation setting values, etc.)

③ Proposal for short circuit withstand test

④ Declaration stating that the present selective coordination of trips is effective during short circuit condition

(5) Other electrical equipment

Shop tests should be carried out following the relevant regulations in Part H of the Rules for the Survey and Construction of Steel Ships.

11 Storage battery compartment

Locations for installing the storage battery are as follows:

(1) Ambient conditions of installation location should be according to 1.1.7, Part H of the Rules for the Survey and Construction of Steel Ships.

(2) Except storage batteries of small capacity used in UPS and the like, storage batteries should not be installed within accommodation compartments.

(3) Storage batteries of total capacity greater than 100 kWh should installed in special compartments. In this case, storage battery related equipment such as charge/discharge equipment may sometimes be permitted to be installed within the compartment where the storage battery is installed based on risk assessment and so on.

(4) Compartment dedicated to storage batteries may be treated as control location considering fireproof construction, and relevant regulations in Part R of the Rules for the Survey and Construction of Steel Ships may be applied.

(5) Sodium sulfur storage battery (NAS battery) should be installed only at locations deemed appropriate by the Society.

12 Securing the storage battery

(1) The storage battery should be firmly secured to the ship by a method specified by the storage battery manufacturer so that it does not become unusable because of vibration or oscillation of the ship.

(2) Except when a forced cooling system is installed, and if storage batteries are arranged in two or more stages, the front and rear parts of the shelf should have gaps greater than 50 mm for ventilation, in principle.

13 Ventilation of storage battery compartment

Ventilation equipment for storage battery compartment should be as given below. However, requirements for sodium sulfur storage battery should be as deemed appropriate by the Society, notwithstanding the provisions below.

(1) Except in case of (4), the storage battery compartment should be effectively ventilated by independent ventilation system.

(2) The performance of ventilation system for storage battery compartment should be greater than the value estimated below. The ventilation system for lithium ion storage battery compartment may be as deemed appropriate by the Society, regardless of the provision above.

Exhaust volume $Q = 2 \times kWh (m^3 / h)$

kWh : Total capacity of storage battery (kWh)

(3) The ventilation system in a compartment where storage battery is connected to charging system having output exceeding 5 kW should be a mechanical ventilation system. It should be provided with an alarm that issues a warning when ventilation has failed and this alarm should be installed at a location where persons are normally present.

(4) Notwithstanding the requirements of (1) to (3) above, if the requirements in (a) and (b) are satisfied, the

installation of ventilation system may be omitted. In such a case, means to discharge smoke required in (5) should be separately installed.

(a) In case of sealed lead acid storage battery, sealed nickel cadmium storage battery or sealed nickel metal hydride storage battery, flammable gas detector and alarm mentioned below should be installed.

① A flammable gas detector having fault alarm function should be installed in the storage battery. A device should be installed that interlocks with this detector and cut out the operations of all electrical equipment (excluding explosive-proof electric equipment) in the battery storage compartment.

② The flammable gas detector should issue an alarm at a location where persons are normally present.

③ Fault alarm should at least detect disconnection of wire, short circuit and failure of power supply to detectors, and issue an alarm when such an event occurs.

(b) If ventilation is not necessary during normal operation of lithium ion storage battery, the installation of ventilation system may be omitted.

(5) In a compartment where storage battery connected to a charging system having output exceeding 5 kW is installed, means to discharge smoke (also serving as means to discharge flammable gas in case the storage battery discharges flammable gas) after initial extinguishing of fire should be installed. These means should include ventilation system for storage battery compartment, and may be shared, but power supply to the ventilation system should be fed from a power source outside the battery compartment. This ventilation system may be natural exhaust from openings in the same compartment; However, if a mechanical system is used, and if the battery is such that there is a possibility of discharge of flammable gas after fire is extinguished (lithium ion storage battery), then the motor should be externally mounted or explosion-proof type, and the ventilator should be of non- sparking construction.

14 Explosion-proof requirements of storage battery compartment

Except when specially required by the Society, the storage battery compartment satisfying the requirements of this chapter may not be installed with explosion-proof electrical equipment.

15 Fire protection/extinguishing system

(1) Excepting when a small capacity storage battery used in UPS and the like is installed, and the IC or IIC system specified in 7.5.1, Part R of the Rules for the Survey and Construction of Steel Ships is used, fire detector complying with Chapter 29, Part R of the same Rules should be provided in the storage battery compartment. The fire detector used should be of a type (smoke type, heat type, photoelectric type, etc.) capable of quickly detecting a fire and should suit the characteristics of the storage battery.

(2) Effective fire extinguishing system that suits the characteristics of the storage battery should be installed in the storage battery compartment.
A fixed fire extinguishing system should be installed in compartments where a storage battery of total capacity exceeding 200 kWh (exceeding 100 kWh in case of lithium ion battery) is installed.

(3) In case of lithium ion storage battery and sodium sulfur storage battery, if the fire extinguishing system provided in accordance with (2) above is judged to be not adequately effective in suppressing fires, then measures to localize storage battery fire may be required (enclosing battery in flame retardant, fire-resisting containers, and so on).

16 On-board tests

The confirmatory tests listed below should be implemented for storage battery systems of total capacity exceeding 100 kWh after installation on board.

(1) The following tests should be implemented for a storage battery system performing independent operation:

(a) Voltage regulation test

Load tests from no load to rated load should be conducted on storage battery supplying power to on-board loads including systems connected to on-board power supply. In this case, the voltage fluctuation of the supplied power should be within ± 2.5% of the rated voltage.

(b) Frequency variation characteristics test (governing characteristics test)

For the charge/discharge system linked to on-board power supply, the storage battery system should be treated as the main generator specified in 2.4.2-1, Part H of the Rules for the Survey and Construction of Steel Ships, and the governing characteristics test required in the same rule should be conducted. In this case, the permissible variation value should be taken reading the speed variation specified in the said rules as the frequency variation and applied to the storage battery system.

(c) Validation tests of safety devices and alarms

The existing operations of detectors, alarms and automatic stop devices for over-charging, abnormal voltage, abnormal temperature and flammable gas for charge/discharge systems should be validated. In this case, tests may be conducted using simulation signals.

(2) For storage battery system intended to operate in parallel with on-board power supply, the interlocking operation with the condition of parallel operation should be confirmed in addition to the tests specified in (1) above.

For questions related to the content of this chapter, please contact:

Machinery Department, Nippon Kaiji Kyokai
4-7 Kiooi-cho, Chiyoda-ku, Tokyo-102-8567
Tel: 03-5226-2022 (General)
FAX： 03-5226-2024
e-mail：mcd@classnk.or.jp

ClassNK

Nippon Kaiji Kyokai