3

Electrical installations

For more technical information

The requirements in this chapter have been informed by, and may refer to, the following technical references, codes and regulations. If you are building, fitting-out or making substantial changes to a vessel, we strongly recommend you refer to, and take account of, the codes and standards below:

- **BS 4343:1968 'Specification for industrial plugs, socket-outlets and couplers for a.c. and d.c. supplies' (superseded, withdrawn)**
- **BS EN ISO 10133:2001 'Small craft. Electrical systems. Extra-low-voltage d.c. installations'**
- **BS EN ISO 13297:2001 'Small craft. Electrical systems. Alternating current installations'**
- **BS EN 60309-1:1999 'Plugs, socket-outlets and couplers for industrial purposes. General requirements'**
- **IP67 an immersion protection standard for circuits subject to intermittent immersion. Details in BS EN 60529:1992 'Degrees of protection provided by enclosures (IP code)'**
- **British Marine Electronics Association (BMEA) 'Code of Practice for Electrical & Electronic Installations in Small Craft' is available from British Marine Federation Technical Department: tel: 01784 223634 or email: technical@britishmarine.co.uk**

Faulty, or poorly installed electrical systems are a hazard and could place you and others at risk. This chapter covers the need to minimise the risks from short circuits and overheating cables, both of which are a common cause of boat fires. It also addresses the potential risks linked to hydrogen, a highly flammable gas that is a by-product of charging your batteries, which is easily ignited by low energy sparks.

You can reduce these risks by making sure that batteries are stowed in a ventilated area, that batteries and cables cannot move around, that your fuses and circuit-breakers are correctly installed and rated for the circuits they protect and that wear and tear has not left your system vulnerable to failure.

Best industry practices and competent installation reduces the risk of personal injury caused by electric shocks. Further information on present industry practice is available through the British Marine Electronics Association's Code of Practice or from the small craft electrical standards (see technical information section on previous page).

Boats obliged to meet BSS electrical requirements must comply with the following:

8 All electrical systems must be designed, installed and maintained in a way that minimises the risks of explosion or of fire starting and spreading.

9 All electrical systems must be capable of being safely and quickly disconnected from their power source(s) in an emergency.

10 Control and emergency devices, or their means of operation, must be marked when not in clear view or when their function is not clear.

11 All battery compartments containing unsealed or open-vented batteries must be adequately ventilated to prevent a build-up of a flammable mix of gases.

3.1 Battery storage

Most batteries produce hydrogen gas when being charged. If this gas builds up, it can be easily ignited and explode.

3.1.1/R REQUIREMENT

Are all unsealed or open-vented batteries ventilated to prevent risk of explosion through hydrogen accumulation?

Identify the location of all batteries.

If batteries are stored within an engine, accommodation or other non-dedicated battery space, check that the space is ventilated.

If batteries are stored within a dedicated battery space or box:
- check if the space or box has any ventilation; **and**,
- check the height of the ventilation provision and the route of any ducted ventilation.

Check the ventilation pathway from all battery storage locations leads to the outside of the hull or superstructure.

All unsealed or open-vented batteries must be stored within a ventilated space.

Dedicated battery spaces or boxes for unsealed or open-vented batteries must be ventilated at the top or the highest point of the sides of the space or box and any ductwork used must run horizontally or upwards.

The ventilation pathway from all battery storage locations must lead to the outside of the hull or superstructure.

Notes – Battery manufacturer's recommendations must support storage in unventilated spaces where 'sealed'-type batteries are stored in a **non-ventilated space**. You must have documentation from the manufacturer indicating compliance, available for inspection.

Ventilation pathways into accommodation spaces having fixed high-level ventilation or into canopied areas are acceptable.

Battery covers must not allow the accumulation of hydrogen gas.

Where there is no ventilation provision, further information is available on www.boatsafetyscheme.com or by post or email from the BSS Office.

If batteries are able to move around there is potential for damage to the cables and for them to short-circuit, which could lead to fire. There is also a potential for the connections to short against the superstructure or sparks to be created by metal objects such as tools coming into contact with the terminals. If a battery can tip over, in addition to these hazards, the boat may also suffer from the effects of any acid spill leaking from the filling/ventilation points or from a cracked or damaged case.

3.1.2/R REQUIREMENT

Are batteries secure against excessive movement in any direction?

Check the extent all batteries and battery boxes can move.

Apply light manual force to verify the extent of movement.

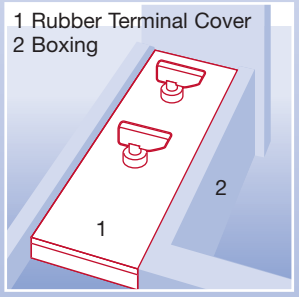
All batteries must be incapable of movement in excess of 10 mm (⅜ in) any direction.

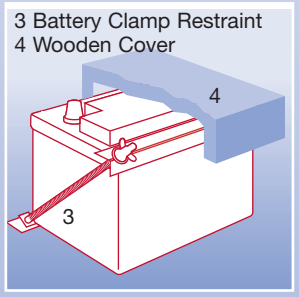
Note – restraint against vertical movement is generally required. However, batteries may be secured by means of a cradle or framework sufficient to ensure batteries remain secure under any condition up to 45° to the horizontal. Recesses, cradles or frameworks extending to half the height of the battery meet this allowance.

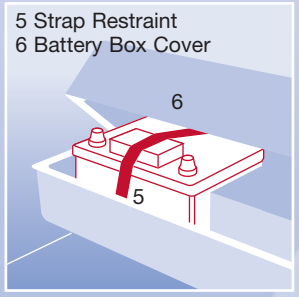
Best practice

If any batteries are connected to an alternator, or alternative battery-charging source, having a maximum charge rate in excess of 2kW (approx. 150 A at 13.8 V) it is strongly recommended to install a fan-assisted ducted ventilation system. The fan motor is best placed externally to the duct and battery space to avoid any potential for spark ignition. The fan should operate automatically during charging and the safe operation of the facility should be checked by a competent person on a routine basis.

b







3.1.3/R REQUIREMENT

Are battery terminals correctly insulated or protected?

Check for the presence of a battery cover or terminal covers.

Check material and condition of any battery cover or terminal covers.

All metal parts of battery terminals or connections must be insulated or protected by battery covers or terminal covers.

All battery covers or terminal covers:

- must be made of insulating material; **and**,
- must not allow any metal part of the terminal or connection to be exposed; **and**,
- must be free of signs of damage.

Note – deck boards, locker lids, etc made from or lined with insulating material may only be considered as battery covers where they will not be removed for any purpose other than gaining access to the batteries.

Best practice

Because of the potential risk of a gas explosion under fault conditions, we recommend locating batteries outside of accommodation areas or in sealed boxes ventilated directly to the outside. Batteries are best located away from heat sources.

b

3.1.4/R REQUIREMENT

Are batteries installed away from metallic petrol and LPG system components?

Measure the distance between batteries not in a box and any metallic petrol or LPG system components installed directly above them.

Where batteries are installed within 300 mm (12 in) directly under metallic petrol or LPG system components, check the components for the presence of a conduit, shield or enclosure made of insulating material.

All batteries must be at least 300 mm (12 in) away from all metallic petrol and LPG system components installed directly above them, or the components must be contained within a conduit, shield or enclosure made of insulating material.

Note – all metallic petrol and LPG system components are covered by this check including tanks, cylinders, pipes, valves, filters, connectors, etc.

3.2 Cable specifications and condition

Exposed wiring could allow short-circuits, sparks and thus potentially cause fires. Exposed 230/240 V wiring can also give people on your boat an electric shock.

3.2.1/R REQUIREMENT

Are all electrical cables insulated?

Check all electrical cables which can be seen for the presence of outer insulation.

All electrical cables must be insulated.

Note – this check applies to both a.c. and d.c. cables.

Cables can overheat if they are not adequately sized or rated to carry the current required by the installation. Battery cables are subject to high currents, so it is crucial for the prevention of fire that these are suitable for their purpose.

3.2.2/R REQUIREMENT

Are battery cables of a sufficient current-carrying capacity?

Check the size of the following cables.

- battery to master switch;
- battery or master switch to starter solenoid;
- battery to battery;
- engine return to battery or master switch;
- battery to bow-thruster motor;
- battery to anchor winch motor;
- battery to inverter system (over 1000w size).

The battery cables prescribed in the check must be approximately 25mm^2.

Notes – Outboard engines having the engine manufacturer's original loom are not required to meet these dimensions.

The actual layout of cable runs may vary depending whether master switches are installed in the positive or the negative cables.

Best practice
The above are minimum recommendations. Systems may call for larger cable sizes, depending upon the loads encountered. To minimise this risk, ask advice of a suitably competent person whether your boat's wiring is of the right construction and grade and capable of carrying the required current safely.

Best practice
We highly recommend that new electrical installations be made with multi-stranded conductors as single solid-wire cables are vulnerable to breakage where there is high vibration or repeated flexing.

Cables showing signs of damage or deterioration indicate that shorting or sparking is possible. Indeed, it may indicate that the cable or insulation is already subject to high temperature or even close to fire.

3.2.3/R REQUIREMENT

Are all cables free of damage or deterioration?

Check the condition of all cables, which can be seen.

Check the condition of insulation and sheathing that can be seen.

All cables must be free of:
- signs of overheating; **and**,
- signs of damage or deterioration, such as broken cable strands, chafing, or heat damage.

Insulation and sheathing must show no signs of damage or deterioration caused by a reaction with water or fuel.

Note – This check applies to both a.c. and d.c cables.

Best practice
We recommend checking the condition of all of your boat's wiring during routine maintenance and inspection, to provide an assurance that all wiring including the cables, conduits, cable trays and connections remain effective and free of damage or deterioration.

3.3 Cable location

This may cause the hazard of shorting or sparking which can then lead to fire or explosion.

3.3.1/R REQUIREMENT

Are all electrical cables supported in a safe position?

Check the run of all cables which can be seen and identify any structure or item of equipment likely to cause impact or abrasion damage.

Identify any cables subject to the possibility of impact or abrasion damage and check for means of protection or support.

Check arrangements where cables can be seen passing through bulkheads or structural members.

Check the condition of all cable conduit or trays that can be seen.

All electrical cables must be:

- supported away from equipment likely to cause impact or abrasion damage; or,
- contained in a conduit or cable tray supported away from it.

Cables passing through bulkheads or structural members must be protected against chafing damage by the use of grommets, sleeves or sealant used effectively.

Cable conduit or cable trays must be free of signs of overheating or damage.

Notes – This check applies to both a.c. and d.c. cables.

For cables verified as double-insulated cables, where such cables pass through bulkheads and other structural members, the outer insulation (sheathing) should be considered as adequate protection, providing the insulation is in good condition.

Information

Bilge water level can usually be determined by the presence of a 'tidemark', the position of the bilge pump or its inlet, or the level at which the float switch is set.

There is a risk of sparks from damaged cables igniting fuels carried in adjacent fuel and gas pipes.

3.3.2/R REQUIREMENT

Are all cables clear of LPG and fuel supply lines?

Check the clearance of all electrical cables that can be seen from LPG or fuel supply lines.

Check any conduit is of a non-conducting material.

Electrical cables must be installed clear of LPG and fuel supply lines unless they are in a conduit made of non-conducting material.

Notes – This check applies to both a.c. and d.c. cables.

Cables verified as double-insulated (sheathed) cables are not subject to this check.

There is a risk of bilge water causing low-lying cable connections to short leading to a risk of overheating and fire.

3.3.3/R REQUIREMENT

Are all electrical cable connections above bilge water level or suitably protected?

Check the position of all cable connections that can be seen.

Where cable connections are below bilge water level, check for the presence of watertight enclosures marked as compliant with IP 67.

All electrical cables connections either must be above bilge water level, or, protected by a watertight enclosure meeting the IP 67 standard.

Notes – This check applies to both a.c. and d.c. cables.

The final cable connections to submersible bilge pumps, transducers or any other equipment intended for operation below bilge water are presumed to comply.

3.3.4/R REQUIREMENT

Are spark plug leads free of damage or deterioration and properly supported?

Check the support and condition of spark plug leads.

Spark plug leads must be:
- free of signs of damage or deterioration; **and**,
- properly supported away from the engine block or cylinder head.

Best practice
To keep cables in sound condition, we recommend keeping cable runs away from potential sources of heat or impact damage e.g. close to flues, where it could be kicked, etc. More guidance is available in ISO 10133 [DC] or ISO 13297 [AC].

3.4 Cable connections

Loose or ineffective cable connections can lead to sparking or increased resistance and overheating of the cable. As a result, the risk of fire or explosion is increased.

3.4.1/R REQUIREMENT

Are all battery cable connections effective and in good condition?

Check the type and condition of connectors to the cables listed at Checklist Item 3.2.2.

All battery cables listed at Checklist Item 3.2.2 must be fitted with soldered or crimped lug connectors or other pre-made connections of suitable proprietary manufacture.

All battery cable connections on cables listed at Checklist Item 3.2.2 must be free of:
- missing components or loose or poorly made connections; **and**,
- signs of damage or deterioration;
- excessively exposed or damaged cable strands.

Note – Battery terminals fitted with screw clamps are acceptable if the cable strands are protected by the use of spreader plates or tinned cable ends in the terminal.

3.4.2/R REQUIREMENT

Are all electrical circuit cable connections effective and in good condition?

Check the type and condition of all electrical circuit cable connections that can be seen.

All electrical circuit cable connections must be free of:

- missing components or loose or poorly made connections e.g. applying compression crimp terminals without using the appropriate tool; **and**,
- signs of damage or deterioration; **and**,
- excessively exposed and/or damaged cable strands.

Note – this check applies to both a.c. and d.c. cables.

For your own safety, we strongly urge you to check that the correct arrangements for shore-to-boat connections are used.

3.4.3/A ADVICE

Are shore power and battery charging lead connections splash-proof to BS EN 60309?

Check the type of shore power or battery charging appliance inlet connections fitted in any location likely to be subject to the weather or splashing.

Check the markings on the appliance inlet connection.

Shore power and battery charging lead connections that are exposed to weather or splashing, are recommended to be of a weatherproof type to BS EN 60309 Part 2 or equivalent.

Notes – If the appliance inlet connection for shore power or a battery charging lead is the 'female type', then the plug on the connecting lead will have exposed pins, see best practice box and photograph in Ch4 Pg6. There is a risk of electrocution from the exposed pins on the lead. An examiner or navigation officer finding such an arrangement may issue a BSS Warning Notice.

Existing connections marked to BS 4343 are equally as acceptable.

Best practice

We would like to draw your attention to the best practice information regarding sockets for shore supply on page 6 of Chapter 4.

3.5 Fuses and circuit-breakers

To be effective, the fuse or circuit-breaker must have a rating that is lower than the current that would cause damage to the circuit.

The safe operation of these devices must not be compromised.

3.5.1/R REQUIREMENT

Are fuses and circuit-breakers appropriately rated, complete and in good condition?

Check the rating, completeness and condition of all miniature circuit-breakers and fuses which can be seen.

Fuses and circuit-breakers must be:

- rated not greater than the rating specified on the fuse holder or the body of the circuit-breaker; **and**,
- rated less than the current-carrying capacity of the cable protected; **and**
- complete and free of signs of heat damage or deterioration; **and**,
- fitted securely.

Fuse holders must contain appropriate 'fuse wire' and not nails, silver paper, etc.

Circuit-breakers must not be held closed by the use of tape or other devices.

Notes – This check applies to both a.c. and d.c. systems.

The lack of a fuse or circuit-breaker is not a fail point.

Important information

When booking the boat's BSS examination, it is crucial that in making the arrangements with the examiner, you inform him or her of the exact locations of fuses, distribution boards and circuit-breakers, as necessary.

There is a potential risk of fire because of a reduced current carrying capacity or shorting if any fuse panels, boxes or holders in poor condition or are incomplete.

3.5.2/R REQUIREMENT

Are all fuse panels, boxes and holders and distribution boxes complete and in good condition?

Check all fuse panels; boxes and holders; and distribution boxes that can be seen for the presence of lids or covers covering exposed terminals, when designed to have one.

Check the condition of all fuse panels; boxes and holders; and distribution boxes that can be seen.

All fuse panels, boxes and holders and distribution boxes designed to have a cover must:

- have lids or covers covering exposed terminals; **and**,
- be free of signs of damage or deterioration.

Note – This check applies to both a.c. and d.c. supplies.

Best practice

If your boat has a 230/240V supply, we strongly recommend having a residual current device (RCD) to disconnect the supply automatically in the event of a fault, which may help protect someone from an electric shock.

b

3.6 Battery isolators

It is important that all power to the electrical system can be cut off in the event of an electrical fault or when leaving the boat, as well as when carrying out maintenance works.

Damage, overheating and fire may result if isolation switches cannot carry the maximum current, especially the engine starter motor circuit.

3.6.1/R REQUIREMENT

Are battery isolators fitted and are they as close as practicable to the battery?

Check for the presence of a battery isolator at each battery or bank of batteries.

Check the distance of battery isolators from batteries.

Battery isolators must be fitted to each battery or bank of batteries.

Battery isolators must be located as close as practicable to the batteries.

Notes – Accessibility takes precedence over proximity to the batteries.

If there are separate circuits connected to separate batteries, each of them must have a battery isolation switch. A combined-switch can be used, for example in a two-battery system, where one battery is used for starting the boat's engine and the other is used for domestic services.

Best practice

We recommend that battery isolators or their means of operation are located in an 'easy to reach location', where they can be quickly operated in the event of an emergency.

b

Certain circuits supplying power to equipment that requires a continuous supply, e.g. bilge pump, may bypass the battery isolation switch. However, the risks associated with a short circuit or overload fault must be minimised particularly when the boat is left unattended.

3.6.2/R REQUIREMENT

Do all electrical circuits pass through a battery isolator, or are those requiring a continuous supply otherwise protected?

Identify any electrical circuits bypassing the battery isolator.

Check that any electrical circuits bypassing the battery isolator supply the following equipment:

- automatic bilge pumps;
- security alarms (including marine radios);
- fire pumps;
- electronic navigation equipment with memories;
- any other equipment where the manufacturer's instructions indicate or specifically require direct connection to a battery, such as diesel-fired central heating boilers;
- battery charger outputs;
- inverters or combination inverter/chargers.

Check electrical circuits supplying any equipment on the specified list and which bypass a battery isolator, for the presence of a fuse or circuit-breaker, where the circuit can be seen.

All electrical circuits must pass through a battery isolator, except those that feed equipment requiring a continuous supply, which must be protected by a suitable fuse or circuit-breaker.

Notes – In cases where circuits directly connected to the battery do not appear in the specified list, compliance must verified on request by supportive paperwork from the manufacturer or supplier.

The fuse or circuit-breaker protecting specified equipment bypassing a battery isolator must be installed where the circuit can be seen at examination or otherwise required. If not, it will be considered as not meeting the requirement, because the fuse or circuit-breaker is very unlikely to be located either where the circuit is hidden or be more than a short distance from the battery.

In the event of an emergency, shutting down electrical circuits may help prevent a fire starting or spreading. The ability to do so quickly can be vital.

3.6.3/R REQUIREMENT

Are battery isolators, or the means to operate them, in readily accessible positions?

Check the accessibility of battery isolators, or the means to operate them.

Battery isolators, or their means of operation, must be installed in readily accessible positions.

Any battery isolation switches or connections not in good working order or in poor condition may lead to overheating and fire if the current-carrying capacity is reduced.

3.6.4/R REQUIREMENT

Are battery isolators and connections complete and in good condition?

Check the completeness and condition of all battery isolators and connections.

Battery isolators and connections must be:

- free of missing fixings; **and**,
- free from signs of heat damage indicating an inability to carry the maximum current of the circuit; **and**,
- free from other signs of damage or deterioration.

In the event of an emergency, shutting down electrical circuits may help prevent a fire starting or spreading. The ability for anyone aboard the vessel to locate the isolator switch or means to operate it and do this quickly can be vital.

3.6.5/R REQUIREMENT

Is the location of all battery isolators, or the means to operate them, in open view, or their location clearly marked?

Check that all battery isolators, or their means of operation, are in open view with all removable lids, deck boards, curtains, doors, etc in place.

If not in open view, check their location is clearly marked in open view.

Battery isolators, or the means to operate them, must:

- be in open view with all removable lids, deck boards, doors, etc in place; or,
- have their location clearly marked in open view.

Best Practice

We recommend labelling the battery isolators to indicate the circuits they protect for example, 'STARTER' and 'SERVICES'.

3.7 Two-wire systems

For reasons of personal safety, we recommend that no part of the hull of the boat is used as part of the return circuit because of the risk of personal injury. A further disadvantage is that hull corrosion may be advanced as a result of electrolytic action.

3.7.1/A ADVICE

Is the electrical system insulated from the hull?

Check any wiring that can be seen to a suitable device such as a horn, headlamp, or navigation light for the presence of a two-wire insulated cable.

It is not recommended to use the hull as a conductor in an electrical system.

Note – An electrical fitment attached to a metal hull or superstructure and having only a single wire connected indicates the use of the hull as a conductor.

Unsuitable return cables in single wire installations may not be able to carry the starter current leading to possible overheating, damage and fire.

3.7.2/R REQUIREMENT

Is a low-resistance return cable provided from the engine or starter motor to the battery?

Identify the low-resistance return cable from the engine or starter motor to the battery (or battery master switch in systems having negative switching).

Apply the cable sizing checks at 3.2.2.

A low-resistance return cable from the engine or starter motor to the battery must be provided on all installations.