The new Electrotechnical Assessment Specification (EAS) Qualifications Guide

By: **Ruth Devine, Chair of The Electrotechnical Skills Partnership**

The Electrotechnical Assessment Specification (EAS) has long been the authority on the requirements for an enterprise (for example, contractor) to be recognized by a certification or registration body as competent to undertake electrotechnical work, including the competence requirements for registered qualified supervisors and electrical inspectors.

Recognizing the need for accompanying guidance that would help electricians and electrical contractors understand how their qualifications align with these requirements, the EAS Management Committee decided to develop the *EAS Qualifications Guide*, first published in 2020. The latest version was published in August this year and was effective for all new applicants from Monday 18 September.

The Guide maps out the acceptable qualifications for each work category that falls under the EAS, so it can be used by scheme applicants, enterprises and certification/registration bodies to identify eligible qualifications. Importantly, it also provides guidance on where to get advice when the required qualifications are not held.

The latest version includes the newly-developed industry qualification routes, the domestic electrician apprenticeship and aligned domestic electrician experienced worker assessment, both with robust work-based evidence requirements and independent end point assessment of competence. Older qualifications have been reviewed and updated to add clarity on what is accepted as equivalent, including more legacy regionally-issued qualifications.

The Electrotechnical Skills Partnership (TESP) is honoured to be a member of the EAS Management Committee and, on behalf of the industry committee, prepared the new *EAS Qualifications Guide* for publication.

In addition to the Guide being published on the IET website, TESP has also made it available on the Electrical Careers website so employers, learners and training providers can access it and receive guidance where required.

Future updates

A really important area of work at present is around low-carbon technology installation and competence. Adequate understanding of electrical scientific theory and principles, and demonstrable occupational competence are critical for the safe installation of technologies such as solar photovoltaic panels, battery storage systems and electric vehicle charging points. The core competence of a qualified electrician is the foundation from which to upskill and train in these areas.

In recognition of this, TESP recently launched the ‘Electrician Plus’ model, which highlights how once someone reaches qualified electrician status, all that is needed is top-up CPD and qualifications in specific new technologies, to enable safe, compliant and competent installations. The Electrician Plus logo will be available to identify selected qualifications with valid technical content, assessment methodology and entry prerequisites.

Future development of the EAS is expected to include these relevant low-carbon technologies and the *EAS Qualifications Guide* will be updated to align with it, to ensure competence around these new technologies is fully integrated into industry guidance and requirements.

Electric vehicle charging point fire safety considerations

By: **Michael Peace CEng MIET**

The proliferation of electric vehicles (EVs) and the looming ban on the sale of new petrol and diesel cars in 2035 has created a need for tens of thousands of electric vehicle charging points (EVCPs) to be installed. This article looks at EV fire safety considerations for private and commercial use.

Some would argue that the installation of an EVCP is no different to installing any other type of socket-outlet. This article points out why this is not the case. Given the characteristics of the connected load, further consideration is required when determining a suitable location to charge an EV with respect to fire safety. It is quite easy for the installer to think that their job ends at the socket-outlet, but it would be remiss not to consider the implications for fire safety with respect to the EV.

What are the requirements in BS 7671:2018+A2:2022 regarding the location of EVCPs?

Section 722 of BS 7671:2018+A2:2022 provides requirements for EVs. The specific requirements in Section 722 of BS 7671:2018+A2:2022 relate to external influences such as the presence of water, solid foreign bodies and impact, but there are no specific requirements relating to fire safety.

It is important to remember that the Part 7 Sections of BS 7671 are used to modify or supplement the general requirements. For the installation of an EVCP, the general requirements of BS 7671 apply.

Chapter 42 of BS 7671:2018+A2:2022 provides requirements for protection against thermal effects. This includes locations with risks of fire due to the nature of processed or stored materials, combustible construction materials and fire propagating structures.

Appendix 5 of BS 7671:2018+A2:2022 provides a concise list of external influences. The classification CB 2 is for fire propagation.

However, EVs require further consideration when it comes to fire safety.

What are the fire safety risks for an EVCP?

The main concern regarding the risk of fire is the EV, not the EVCP. Thankfully, it doesn't happen very often but when an electric vehicle catches fire, the consequences can be catastrophic.

EVs are powered by lithium-ion batteries which have a large storage capacity, thus large amounts of stored energy. The main danger with lithium-ion batteries is, when they become faulty, damaged or exposed to extreme heat, thermal runaway can occur causing an exothermic reaction. This creates dense smoke and toxic vapours and gases, such as carbon monoxide and hydrogen cyanide which are deadly if breathed in.

EV fires present new challenges for fire and rescue services as extinguishing an EV fire requires large amounts of water and the fire can reignite hours or sometimes days later. Experts are divided on the best way to fight EV fires and new, innovative ideas are being developed.

How common are electric vehicle fires?

As EVs are a new technology, when one catches fire it is likely to make headline news. However, it is important to keep things in perspective. According to the Bedfordshire Fire & Rescue Service website, in 2019 the London Fire Brigade (LFB) dealt with 54 EV fires compared with 1898 petrol and diesel fires.

Vehicle registrations from the Department for Transport (DfT) show that of the 4.63 million cars in London, 50,000 of these are plug-in cars. When compared with the data from LFB, this suggests an incident rate of 0.04 % for petrol and diesel car fires and 0.1 % for electric vehicles.

What are the fire safety risks for an EV?

For ease of installation and cable routes, it can be tempting to install an EVCP on an exterior wall of a building, but it may not be the best place with respect to fire safety. One important factor to consider is fire spread to an adjacent building. Given the ferocity of a lithium-ion battery fire, it wouldn't take long for an EV fire to spread to combustible materials or melt exterior PVC doors and windows in proximity. Another consideration is if an EV on charge was to catch fire, would it impede access and egress from the building?

The fire safety risk increases when EVs are charged in enclosed spaces, such as underground car parks. Where there are multiple EVCPs, the fire could spread from one EV to another in an adjacent parking space. Early detection by a fire alarm system and sprinklers provide the best form of active fire protection for enclosed car parks to contain the fire, however, the fire and rescue services are still required to extinguish the fire.

Other considerations include proximity to flammable materials, such as fuel storage tanks and low overhanging roofs where fire could spread to the building roof structure.

Where can I find information regarding fire safety considerations for the location of an EVCP?

Before starting any work, it is important to check that the client has spoken with their insurance company to establish if they have any requirements for the location of EVCPs. Regardless of whose responsibility it is, you won't be thanked if the client is subsequently advised by their insurance company that they are not covered as the EVCPs are installed on the exterior wall of the building.

The insurance company, Zurich, have produced a useful guidance document to highlight the fire safety risks for EVs. The guidance states that EV charging should take place at least 10 m from combustible walls or at least 7.5 m from unprotected/extensive glazing in non-combustible walls.

A guidance document produced by RISCAuthority RC59 provides recommendations for fire safety when charging EVs.

The IET *Code of Practice for Electric Vehicle Charging Equipment Installation*, 5th Edition has been published and provides guidance on fire safety considerations for the location of an EVCP.

What is the law for domestic premises?

The requirements of the Building Regulations apply to domestic and commercial installations.

Approved Document S of the Building Regulations provides requirements for infrastructure for the charging of electric vehicles. This Approved Document does not provide guidance on electrical or fire safety but does refer to Approved Document P and Approved Document B respectively.

What is the law for commercial and industrial premises?

The Health & Safety at Work Act 1974 outlines the general duties of employers, those who are self-employed, and employees. The specific details are provided in The Management of Health and Safety at Work Regulations 1999. Regulation 3 – Risk assessment requires:

> "every employer to make a suitable and sufficient risk assessment of-
> (a) the risks to the health and safety of his employees to which they are exposed whilst they are at work and;
> (b) the risks to the health and safety of persons not in his employment arising out of or in connection with the conduct by him or his undertaking."

The Regulatory Reform (Fire Safety) Order came into force in 2005 and sets out the requirements for fire safety in almost all buildings other than individual private homes. In particular, Regulation 9 – Risk assessment requires the responsible person to make a suitable and sufficient assessment of risks to which relevant persons are exposed for the purpose of identifying the general fire precautions. The Regulatory Reform (Fire Safety) Order 2005 also provides requirements for firefighting and fire detection.

The Construction (Design and Management) Regulations 2015 also apply to all construction work. The designer has a duty to eliminate foreseeable health and safety risks to anyone affected by the project and take steps to reduce or control any risks that cannot be eliminated. When a contractor works for a domestic client, it is no different to working for a commercial client, however, the client's responsibilities are taken on by the contractor.

What is the guidance for installing EVCPs at domestic installations?

Whilst some of the legislation mentioned above does not apply directly to the client in domestic premises, it would be sensible to take a similar approach to that given in the available guidance documents with respect to fire safety. For domestic installations, this can be challenging, especially for properties with a small curtilage. It is important any risks are discussed with the client to allow them to make an informed decision for a suitable location.

It may be that professional fire engineering advice is required and additional fire protection measures may be required to manage certain risks. Where there is uncertainty and fire engineering advice is required, it is important to consult a fire engineer. The Institution of Fire Engineers website features an online directory of qualified fire engineers with different areas of expertise.

Further reading

BS 7671:2018+A2:2022
The IET Code of Practice for Electric Vehicle Charging Equipment Installation, 5th Edition
RISCAuthority RC59 Recommendations for fire safety when charging electric vehicles
Zurich Risk Insight: Electric Vehicle Charging
The Health & Safety at Work Act 1974
The Management of Health and Safety at Work Regulations 1999
The Construction (Design and Management) Regulations 2015
The Regulatory Reform (Fire Safety) Order 2005
Approved Document B (Fire safety)
Approved Document P (Electrical safety)
Approved Document S (Infrastructure for the charging of electric vehicles)

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Surge Protective Devices (SPDs)

By: **Craig O’Neill**

Surge Protective Devices (SPDs) can be used to help protect an electrical installation and its connected equipment from the potentially harmful effect of transient overvoltages.

The effects of a surge can result in either instant failure or damage to the equipment, only evident over a longer period of time. SPDs are usually installed within a consumer unit or a distribution board to protect an electrical installation and connected equipment but can also be installed locally to protect an individual item of equipment. A surge can be transmitted via other incoming services such as telephone lines, some cable TV networks etc., so it is important to remember to consider all routes a surge can enter the property. For information regarding overvoltages transmitted by information and communication technologies, see BS EN 50174, BS EN 62305-4, PD CLC/TS 61643-22 and, for telecoms systems in general, see BS 6701.

There are three common types of SPD:

1. Type 1 SPD installed at the origin, for example, main distribution board.
2. Type 2 SPD installed at sub-distribution boards.
   (Combined Type 1 and 2 SPDs are available and are usually installed in consumer units.)
3. Type 3 SPD installed close to the protected load. These must only be installed as a supplement to a Type 2 SPD.

Where multiple SPD devices are required for protection throughout the installation, they must be coordinated in accordance with Regulation 534.4.4.5 to ensure correct operation. SPDs supplied by different manufacturers should be confirmed for suitability as required by Regulation 536.4.203.

Figure 1 Surge protector (Image credit: Electrium)

What are transient overvoltages?

Transient overvoltages can be defined as short duration, high magnitude voltage peaks with fast rising edges, commonly referred to as 'surges', which can range from a few volts to many thousands of volts on a low-voltage consumer network, for no more than millisecond duration.

These surges occur due to the sudden release of energy previously stored or induced by other means. This energy can then find its way into electrical installations, naturally occurring either indirectly from lightning strokes or directly from lightning strikes, or created by the switching and operation of certain equipment within an installation.

How do transient overvoltages occur?

Transient overvoltages occur when equipment likely to produce switching overvoltages or disturbances exceeding the applicable rated impulse voltage of equipment according to Table 443.2 of BS 7671, are installed locally. Equipment such as large inductive or capacitive equipment, motors, transformers, capacitor banks, storage units or high current loads.

Historically, this has not been an issue within domestic installations but, more recently, installations are changing with the advent of recent technologies such as electric vehicle charging, air/ground source heat pumps and speed-controlled washing machines. These technologies have made transients more likely to occur within domestic installations at some level.

Transient overvoltages due to atmospheric origin can occur if either the property itself or nearby electrical transmission infrastructure suffers a hit by lightning strokes. These types of transient overvoltages are most likely to happen when a direct lightning stroke on an adjacent overhead power or telephone line causes the transient overvoltage to conduct along the lines into nearby properties, which can cause considerable damage to the electrical installation and associated equipment. BS EN 62305-2 contains information required for risk management for protection against transient overvoltages due to direct or nearby lightning strokes on the structure.

Where are SPDs required?

The current edition of the IET *Wiring Regulations*, BS 7671:2018+A2:2022, states in Regulation 443.4.1:

"Protection against transient overvoltages shall be provided where the consequence caused by overvoltage could result in:

(i) serious injury to, or loss of, human life
~~(ii) failure of a safety service, as defined in Part 2~~
(This has been deleted by BS 7671:2018+A2:2022 - Corrigendum (May 2023))
(iii) significant financial or data loss.

For all other cases, protection against transient overvoltages shall be provided unless the owner of the installation declares it is not required due to any loss or damage being tolerable and they accept the risk of damage to equipment and any consequential loss."

Regulation 443.4.2 goes on to state that protection against overvoltages shall be considered due to equipment likely to produce switching overvoltages or disturbances exceeding the applicable rated impulse voltage of equipment according to Table 443.2. It is therefore important to check with the manufacturer of any installed equipment and confirm the rated impulse voltage level of the equipment to be installed, to make an informed choice regarding the decision.

It is important to remember that in the introduction to BS 7671:2018+A2:2022 it states:
"Existing installations that have been installed in accordance with earlier editions of the Regulations may not comply with this edition in every respect. This does not necessarily mean they are unsafe for continued use or require upgrading."

Regulation132.16 also states:

"No addition or alteration, temporary or permanent, shall be made to an existing installation, unless it has been ascertained that the rating and the condition of any existing equipment, including that of the distributor, will be adequate for the altered circumstances. Furthermore, the earthing and bonding arrangements, if necessary for the protective measure applied for the safety of the addition or alteration, shall be adequate."

In summary, unless required by one of the indents in Regulation 443.4.1 or if a lightning protection system (LPS) is installed, the decision on whether to install SPDs is in the hands of the owner of the installation, but they should be provided with enough information to make an informed decision on whether they wish to omit SPDs. A decision should be made based on any existing risk factors and following a cost evaluation of SPDs, which may cost less than it would to replace equipment that may be damaged from the effects of an overvoltage.

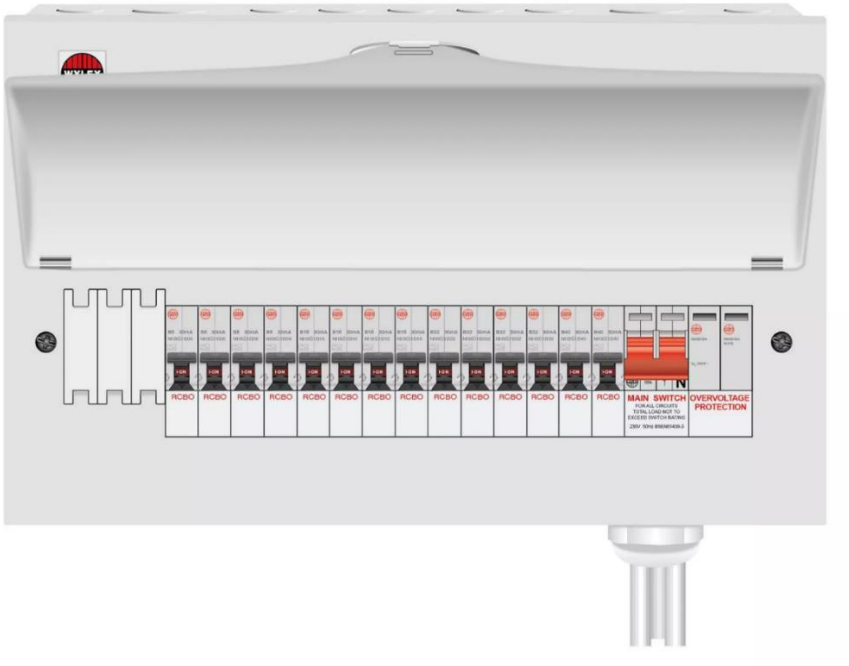
An approved electrician can help assess the need for SPDs and any risk factors that may exist, and manufacturers of surge protective devices can help advise on required protection levels and coordination of devices.

Overvoltage protection could be installed in an existing consumer unit where appropriate physical space is available. Alternatively, where insufficient space is available, overvoltage protection could be installed in an external enclosure adjacent to the existing consumer unit.

Many home insurance providers cover lightning strokes but surges caused by equipment or faults can vary depending on the cause of the surge, so, it is important to check your home insurance policy.

For requirements when selecting and installing SPDs for an electrical installation, where required, see Section 534 and Appendix 16 of BS 7671:2018+A2:2022.

Figure 2 Surge protected consumer unit (Image credit: Electrium)



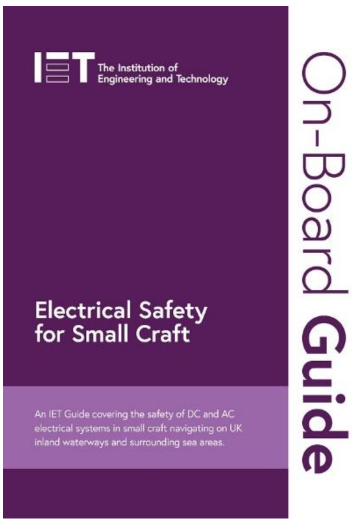
Boat wiring - why BS 7671 doesn't address all the issues…

By: **Graham Freeman BSc IEng**

Introduction

This article has two objectives, firstly, to develop a better understanding of why a percentage of the requirements for small craft electrical wiring systems differ from those in the BS 7671-controlled domain, and secondly, to announce the publication of the IET's ***On-Board Guide: Electrical Safety for Small Craft.***

Figure 1 The IET On-Board Guide: Electrical Safety for Small Craft



Whilst BS 7671 sets the scene, this article aims to identify those elements of boat electrical wiring systems that require a different approach - particularly from the traditional 'selection and erection' perspective. In the small craft world, these differences highlight the need for more focussed installation practices that are driven by the presence of vibration, movement of the craft due to the operating environment and sea states, external heat sources and of course, the presence of water.

The information provided in this article is presented in the form of wiring system design considerations sourced from the following standards/guides:

- **BS EN ISO 13297:2020+A1:2002** ***Small craft – Electrical systems – Alternating and direct current installations***.
  (Applies to DC installations which operate at a nominal voltage not exceeding 50 V DC and single-phase AC installations which operate at a nominal voltage not exceeding 250 V AC.)

- **IEC 60092-507:2015 –** ***Electrical installations in ships***.
  (Captures ISO 13297 and AC three-phase systems not exceeding 500 V AC.)

- **BS EN ISO 16315:2016 – Small craft – *Electrical propulsion system.***

- **IET *On-Board Guide: Electrical Safety in Small Craft*.**

To underpin the necessary design considerations, examples of best practice are also included.

Wiring system design principles

Electrical system designers should first seek to understand the small craft's layout, construction and intended use, together with the anticipated operational environment and any operational hazards and risks. This activity should include:

- Identifying load characteristics for all items of DC and AC equipment to be installed. For each equipment type, manufacturer's data should be obtained, including full load current and equipment terminal voltage limits for correct operation under load, and also under transient conditions created by the operation of autonomous power sources.

- Designing the distribution systems from power sources for the DC and AC systems by scheduling each final circuit for both DC and AC installations.

- For DC circuits, establishing:

  - Continuous service and maximum currents required in each circuit (I_b), and minimum equipment terminal voltage requirements.
  - The length of each cable route and any associated cable environment issues (C_x) when selecting cable cross-sectional areas (csa) and insulation temperature rating of each cable.
  - The voltage drop in each circuit and checking that minimum equipment terminal voltage under full load conditions is maintained under design minimum battery terminal voltage conditions. (Typically, 90 % nominal voltage.)

- For AC circuits, establishing:

  - Continuous service and maximum currents required in each circuit (I_b), and minimum equipment terminal voltage requirements.
  - The length of each cable route and any associated cable environment issues (C_x) when selecting cable csa and insulation temperature rating of each cable.
  - The ($R_1 + R_2$) for each circuit from its associated circuit protective device.

NOTE : The Z_e component of the overall earth fault loop impedance from the TN-S shore transformer to a 16 A rated shore-supply socket outlet on-board a craft is likely to be both variable (depending on the location of a craft in a marina or similar location) and indeterminate (except by direct measurement in a particular craft location). The Z_e component must therefore be assumed to be less than $Z_s = 2.73\ \Omega$ (where: $Z_s = Z_e + (R_1 + R_2)_{shore}$) up to the shore-supply socket-outlet.

- Establishing each final circuit sheath/insulation type of each DC and AC cable relative to calculated maximum current to be carried and conductor csa considering:

- The ambient temperatures and any sections of cable routes passing through insulating material.
- When cables passing through compartments may be covered/carried in conduits and enclosures.
- Cables being potentially bunched/in contact with other cables particularly with different maximum insulation temperature limits (for example, thermoplastic, thermosetting).

Sizing of conductor csa

The approach adopted by the IET's *On-Board Guide* is similar to that adopted in BS 7671. Overcurrent protective devices provide both fault current and overload current protection. The design current (I_b) of the circuit must first be established and the overcurrent device rating (I_n) is then selected so that I_n is greater than or equal to I_b. The tabulated current-carrying capacity of the selected cable (I_t) is then given by the following formula for simultaneously occurring factors C**:**

$$I_t \geq \frac{I_n}{C_a C_g C_i C_f}$$

The various rating factors are identified as follows:

- C_a for ambient temperature which may increase the current carrying capacity for conductors under 45 °C or reduce if greater (see Table 10.2 in the IET's *On-Board Guide*).
- C_g for grouping.

The following multiplying factors (C_g) are to be applied to the tabulated Table 13.2 of the IET's *On-Board Guide* when considering single multicore cables:

- 0.85 for two-core cables.
- 0.70 for three- and four-core cables.

Where bunching of a number of circuits or cables together is required, Table 10.4 of the IET's *On-Board Guide* provides C_g multiplying factors for increasing groups of cables individually or multicore.

C_i for thermal insulation

For a single cable likely to be totally surrounded by thermally insulating material over a length of more than 0.5 m, the current-carrying capacity should be taken (in the absence of more precise information) as 0.5 times the current-carrying capacity for that cable installed in ventilated conditions.

Where a cable is totally surrounded by thermal insulation for less than 0.5 m, the current-carrying capacity of the cable should be reduced appropriately depending on the size of cable, the length in insulation and the thermal properties of the insulation. The derating factors in Table 10.3 of the IET's *On-Board Guide* are appropriate to conductor sizes up to 10 mm^2 in thermal insulation with a thermal conductivity λ greater than 0.04 $Wm^{-1}K^{-1}$.

NOTE: Lighting cables are frequently installed behind insulated deckhead cladding, but, where LED type luminaires are fitted, then cables may not need to be derated due to low service currents.

The C_f for the type of protective device and for most installations using circuit-breakers or totally enclosed fuses on-board small craft will be 1.0.

Estimation of voltage drop in pairs of live conductors and value of (R_1 + R_2) for AC circuits

The terminal voltage measured at an item of equipment under its full load conditions is determined by:

- The voltage drop in the complete circuit between source and equipment.
- The terminal voltage of the source, for example, battery/DC generator for DC systems, on-board generator or shore-supply for AC which may reduce/droop under varying load conditions.

Typical resistance per metre run of single core cable with tinned annealed stranded copper conductors at 20 °C can be found at Table 13.3 of the IET's *On-Board Guide*.

To calculate the voltage drop in the pair of conductors supplying an item of equipment in millivolts (mV), the resistance per metre (mΩ/m) of the particular conductor csa (see Table 13.5 in the IET's *On-Board Guide*) is multiplied by the design current of the circuit I_b and the length of run in metres L:

$$\text{Volt drop (mV)} = \text{resistance per metre (m}\Omega\text{/m)} \times I_b \times L$$

Value of (R_1 + R_2) for AC circuits

For the purpose of estimating (R_1 + R_2) in circuits up to 16 mm^2 csa, the resistance value (R_1 + R_2) will be the same as used for the circuit volt drop since the cross-sectional area of the circuit protective conductor will be the same as for the live conductors as required in marine practice. However, where there are cables or circuits with live conductors greater than 16 mm^2 nominal conductor size, the csa of the circuit protective conductor (cpc) may be reduced and the value of (R_1 + R_2) will correspondingly vary as shown in Table 13.4 of the IET's *On-Board Guide*.

Correction factors for resistance values of pairs of conductors or (R_1 + R_2) temperature at times of test (ambient) or conductor service temperature

The resistance per metre values (mΩ) tabulated at a temperature of 20 °C (R_0) in Table 13.5 of the IET's *On-Board Guide* should be adjusted as required by multiplication by the following factors to estimate resistance per metre (R) for various anticipated conductor temperatures in accordance with the following equation:

$$R = R_0 [1 + 0.00373 (t - 20)]$$

For convenience, Table 13.5 in the IET's *On-Board Guide* provides calculated multipliers for correcting resistance values (mΩ) for ambient or service temperatures.

Conductor identification (DC systems)

DC negative conductors should be identified by black or yellow insulation (see Figure 2). Where craft are equipped with both DC and AC electrical systems, the AC system uses black insulation for live conductors.

Figure 2 DC switch/panel-board wiring

Means of identification other than insulation colour may be used to identify DC positive conductors if properly identified on the craft's electrical system wiring diagram(s).

Where craft are equipped with both DC and AC electrical systems, insulation coloured brown, white or light blue should not be used in the DC system (unless such conductors are clearly separated from any AC conductors and are specifically identified as DC).

All equipotential bonding conductors should be identified by insulation coloured green, or green with a yellow stripe. Alternatively, such conductors may be in the form of uninsulated strip or braid. Conductors with green or green/yellow insulation must not be used as current-carrying conductors.

NOTE: A coloured stripe may be added to conductor insulation for identification purposes.

Conductor identification (AC systems)

Black or brown coloured insulation should be used for the active (phase) conductor of single-phase AC electrical systems.

Neutral conductors of single-phase AC electrical systems are to have insulation coloured white or light blue.

All protective conductors are to be identified by insulation coloured green, or green with a yellow stripe.

Separation of AC and DC systems

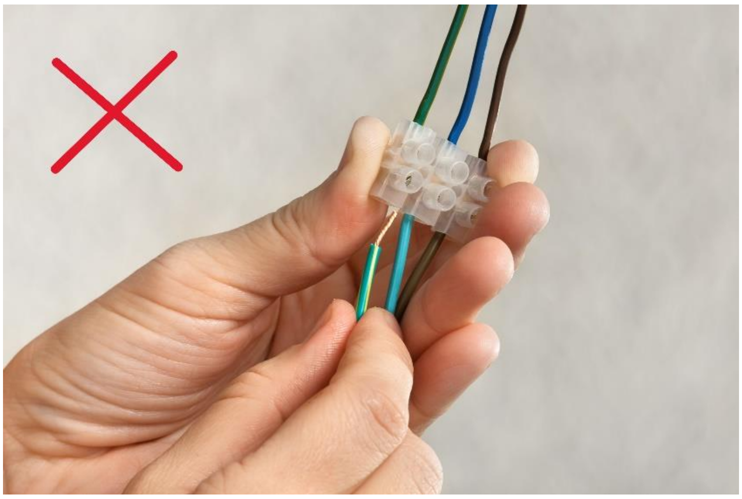
DC circuit conductors should not be contained in the same wiring system as AC circuit conductors unless one of the following methods of separation is used:

- Housed within separate conduit, trunking or sheathing.
- Fixed directly to a surface and separated by at least 100 mm.
- Insulated for their system voltage and installed in a separate compartment of a conduit or trunking system.
- For multi-core cables/cords, the cores of the DC circuit(s) need to be separated from the cores of the AC circuit(s) by a grounded/earthed metal screen of equivalent current-carrying capacity to that of the largest csa core in either circuit.

Cable termination

All conductors should have suitable terminals fitted. To eliminate vibration-induced fretting of individual conductor strands, there are to be no terminations in the form of bare wires to any screw or stud type terminal (see Figure 3).

Figure 3 No suitable terminal fitted



Solderless crimp-on terminals/lugs are to be attached by a crimping tool that is compatible with the terminal/lug size and type.

Tensile (pull-off) testing

To ensure that all conductor-to-connector and conductor-to-terminal connections are adequately made, they need to be subjected to a tensile force of at least the values detailed in Table 1 below.

Table 1 Tensile (pull-off) force

csa	Tensile force		csa	Tensile force		csa	Tensile force	
mm^2	N	kgf	mm^2	N	kgf	mm^2	N	kgf
0.75	40	4	6	200	20.4	50	400	40.8
1	60	6.1	10	220	22.4	70	440	44.9
1.5	130	13.3	16	260	26.5	95	550	56.1
2.5	150	15.3	25	310	31.6	120	660	67.3
4	170	17.3	35	350	35.7	150	770	78.5

NOTE: Where multiple conductors of differing csa are terminated in a single connector/terminal, the smaller csa conductor has to withstand the applied tensile force without separating from the connector/terminal.

Protection of exposed terminal shanks

With the exception of circuit protective conductors and bonding conductors (see Figure 4), the shanks of all exposed terminals/lugs need to be protected from short-circuit hazards by the use of insulation barriers or sleeves (see Figure 5).

Figure 4 Compliant bonding conductor exposed terminal lug shank

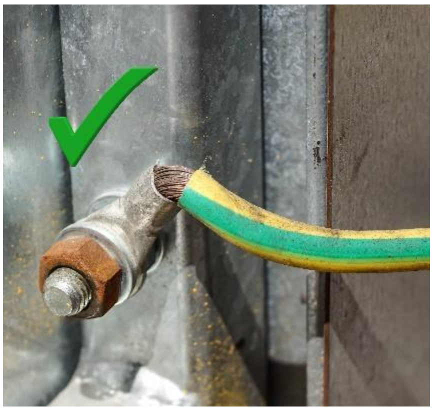
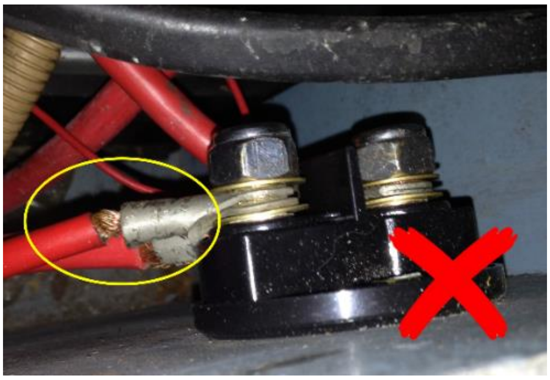


Figure 5 Non-compliant exposed terminal lug shank on a +12 V connection to a battery isolation switch



Terminal blocks (and associated terminations)

To avoid vibration induced failures, ferrule bootlace crimps (see Figure 6) must be used with screw type terminal blocks. This will reduce individual strands separating from the connection.

Figure 6 Ferrule terminal

Figure 7 Effect of vibration-induced fretting

Alternatives to the ubiquitous 'choc-block' come in the form of the screw-clamp (see Figure 8) or the increasingly popular, lever-arm locking-type screwless terminal block (see Figure 9). These devices compliantly accommodate bare conductor strands because the mechanical action of their conductor clamping devices ensure physical retention and electrical contact without damaging the conductor strands.

Figure 8 Screw clamp terminal block

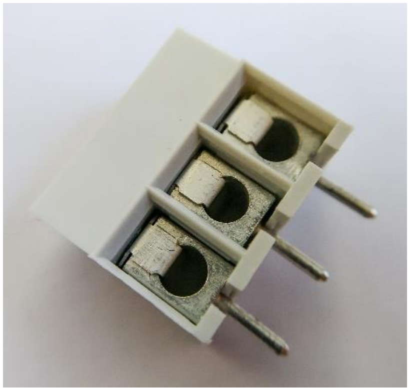
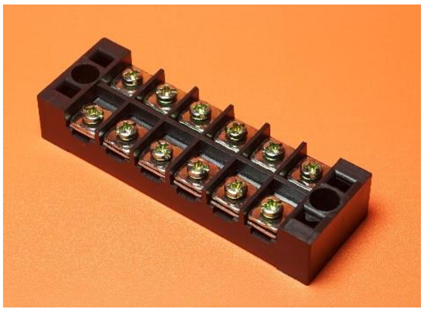


Figure 9 Screwless lever arm locking terminal block

When considering a simple screw or nut terminal block of the types illustrated in Figures 10 and 11, many would assume that simple ring or spade terminals could be used in conjunction with these types of terminal blocks and, for the domestic environment, they may well be correct.

Figure 10 Terminal block (screw fixings) **Figure 11** Terminal block (nut fixings)



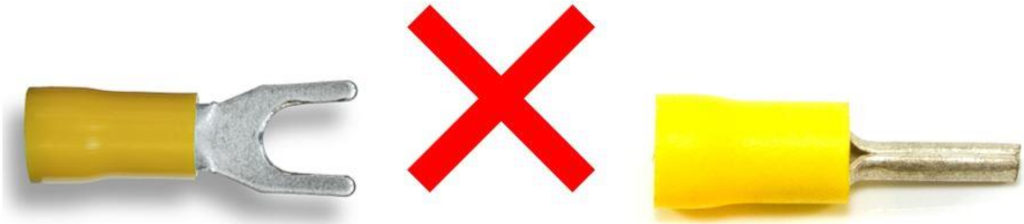
However, due to the presence of vibration on small craft, ISO 13297 mandates that all terminals/lugs shall be of the ring or captive hook type because they are not dependent on screw/nut tightness alone for their retention (see Figure 12).

Figure 12 Suitable for terminal blocks with screw/nut fixings

(retained under vibration)

When used with the type of terminal blocks illustrated in Figures 10 and 11, open-ended spade or 'pin' type terminals/lugs (see Figure 13) are unsuitable for such use as they are not positively retained under vibration conditions.

Figure 13 Unsuitable for terminal blocks with screw/nut fixings

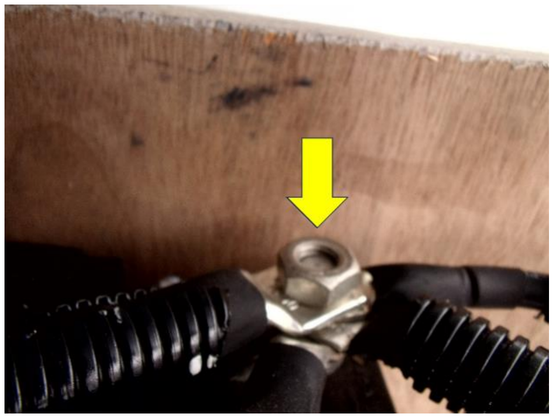


(not positively retained under vibration)

Twist-on 'wire nut' connectors (see Figure 14) are also prohibited due to their ability to loosen when subjected to vibration.

Figure 14 Unsuitable for in-line conductor joining

Figure 15 Inadequate battery cable retention



Where multiple connections are made to stud terminals (for example, battery terminals), the number of connections should not exceed four. This requirement is driven by two factors. Firstly, terminals/lugs by their very shape prohibit axial alignment which in turn results in radial dispersion around the securing stud; secondly, and driven by the vibration element, there is a need to ensure that the long-understood engineering 'rule of thumb' that requires a minimum of 2.5 thread studs to be visible beyond the upper face of the securing nut is implemented.

It should also be noted that a terminal stud needs to accommodate not only the terminals themselves, but room is also needed for placement of locking devices such as locking/spring washers. Figure 15 is an example where 4 thick-section battery terminal lugs are precariously secured by nothing more than a plain nut. Note, not only the absence of any locking device but also the fact that only 50 % of the plain nut threads are actually engaged! (See Figure 15 arrowed.)

Termination and fixings – material requirements

While terminal studs, securing nuts and associated washers need to be corrosion-resistant (for obvious reasons), it is important to remember that these items also need to be galvanically compatible with each other as well as the conductor and associated terminal material. Un-plated steel and aluminium should not be used for terminal stud securing nuts or washers.

NOTE: The practice of solder-tinning stranded conductors is effectively prohibited as such action creates a solid conductor which is then susceptible to vibration-induced fracture risk.

Cable routing and support

All small craft cable and conductors need to be supported throughout their length in conduits, trunking, cable trays or individually supported at a maximum of 450 mm intervals (unlike the standard of wiring found on a high percentage of UK inland craft (see Figure 16)).

Figure 16 Poor cable routing and support

Conductors which may be susceptible to physical damage should be protected by trunking, conduit or other equivalent means. Note that several of the cables illustrated in Figure 16 pass through drilled holes in the steel bulkhead with no additional protection (for example, sleeving or a cable grommet).

Conductor connections need to be in locations protected from the effects of weather or contained within enclosures in accordance with IEC 60596:1989 and rated IP 55 minimum. All above-deck connections that are exposed to intermittent immersion are to be contained within enclosures in accordance with IEC 60596:1989 rated IP 67 minimum.

To avoid damage to insulation, all cables are to be routed away from engine exhaust systems and other on-board heat sources. Cables should be located no closer than 250 mm from dry exhaust systems and 50 mm from water-cooled exhausts.

Current-carrying conductors need to be located above areas where water can accumulate (for example, bilges) and at least 25 mm above the level at which any automatic bilge pump activates.

In circumstances where conductors need to be routed below the anticipated bilge water level, all wiring and associated terminations need to be located in enclosures in accordance with IEC 60596:1989 and rated IP 67 minimum. Connections below the foreseeable water level are not permitted.

If you wish to dig deeper into the vagaries of small craft wiring systems, visit the IET bookshop to order a copy of the IET's *On-Board Guide: Electrical Safety for Small Craft* today!