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CONSULTANCY SERVICES

EN 60204-1

FOR MACHINE AND PANEL BUILDERS

A GUIDE TO AVOIDING COMMON ERRORS



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introduction:

This white paper discusses some common errors machine and panel builders make concerning EN 60204-1 'Safety of machinery. Electrical equipment of machines. General requirements'. It is not a training course, exhaustive guide or explanation of the changes in the latest edition.

EN 60204-1 (abbreviated to 60204) is the European harmonised implementation of IEC 60204-1 and BS EN 60204-1 is the designated British standard equivalent.

Complying with harmonised/designated standards is not mandatory, but doing so can provide a presumption of conformity with specific Essential Health and Safety Requirements (EHSRs). These EHSRs are stated in the European Machinery Directive (MD) and the UK Supply of Machinery (Safety) Regulations 2008, as amended (SMSR).

Currently, the technical requirements of the MD for the European market and the SMSR for Great Britain are identical. Compliant machinery must be CE marked for the EU market, and UKCA marked for the GB market.

The white paper uses the same headings as those in the standard for ease of use. Note that clause numbers relate to EN 60204-1:2018 and may differ in other editions.

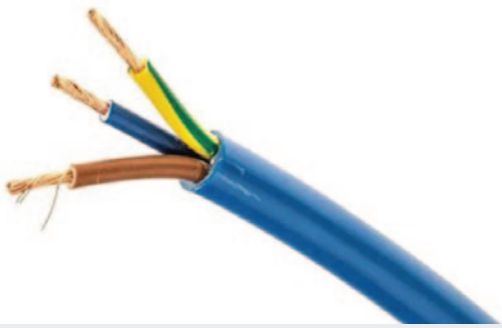
1. Scope:

60204 covers electrical equipment of machinery that is not hand portable while in use. It also covers machines that are linked or working together and the links between them.

Most importantly, 60204 should be used for machinery, not BS 7671 'Requirements for Electrical Installations. IET Wiring Regulations'. The incorrect application of BS 7671 to machinery is commonplace. The EN 61439 series are also not intended for use for machinery control.

2. Normative References:

60204 is referenced in legislation through its harmonised/designated status. 60204 also requires compliance with standards termed normative references. Conversely, other standards require compliance with 60204. Often the standards listed as normative references have not been followed.



3. Terms, Definitions and Abbreviated Terms:

Confusion over terms is common, as shown by the examples below.

Earthing and bonding:
Earthing (defined in 60204) is used to implement Automatic Disconnection of Supply (ADS) in the event of a fault. A good earth path from the fault to the origin (i.e. a low earth fault loop impedance) ensures fast disconnection of the protective device and minimises the ability of the fault to cause harm.

Bonding (not defined in 60204) ensures any extraneous-conductive-parts (e-c-p) introducing a potential (generally an earth potential) are connected to the machine's protective conductor network. Bonding reduces hazardous voltages between exposed-conductive-parts or extraneous-conductive-parts to a level that should not cause harm.

Note: the terms exposed-conductive-part (ex-c-p) and extraneous-conductive-parts (e-c-p) are often misunderstood. They are used in BS 7671.

An ex-c-p forms part of the electrical installation that may become live under fault conditions. An e-c-p is not part of the machine electrical installation; it is not an ex-c-p but is likely to introduce a potential, generally earth potential, into the machine's proximity. Examples include metallic compressed air pipes, perimeter guarding or handrails fixed to the floor, machine frames and the factory structure. These must all be bonded to the electrical supply installation of the building to comply with BS 7671.

The protective device for a machine fault is within the machine. The potential of ex-c-p and e-c-p could differ between the machine and building, resulting in a hazardous voltage between the two.

Emergency switching off device:
An emergency switching off device is red and yellow. It is not the same as an isolator. The only time an isolator should be coloured red and yellow is if specifically designed to implement emergency isolation of the equipment or parts from electrical hazards.

An isolator (not defined in 60204) is for routine disconnection of the electrical energy from the machine or parts thereof and should be black or grey.

Neutral conductor (N):
A neutral conductor in the incoming supply is a live conductor and must be treated as such. In a single-phase machine, it carries equal current to the line (phase) conductor. (Beware harmonic currents, another topic not covered in this paper.)

Safeguard and safeguarding:
Together, these are the first line of defence to prevent access to hazardous machine parts. For example, machine guards and light guards.

Emergency stop devices (defined in 60204) are not safeguarding. They should be considered a means of protecting machinery, not people.

Safety function:
A safety function (defined in 60204) is not just a switch. A safety function comprises, for example, an actuating device (e.g. switch), a means of processing the signal, and a relay or safety relay with an output function to make something safe.

4. General Requirements:

60204 requires all risks associated with hazards relevant to the electrical equipment to be assessed as part of the machine's overall risk assessment. Furthermore, materials and equipment should meet the relevant harmonised/designated standards and be CE/UKCA marked.

On many occasions, non-CE/UKCA marked equipment and materials are used, including wiring and cables that do not meet IEC standards. The issues here tend to be the current rating, potential flexibility of the wire due to different conductor strand make-up, different insulation thickness and interference with terminals, and insulation performance. (4.2.1)

Note that machinery panels seldom need to comply with the IEC 61439 series of standards (61439) for low-voltage switchgear and controlgear assemblies, as these are not harmonised/designated to the MD/SMSR. However, there are a few places that 61439 is referenced, such as 4.2.2 (Switchgear).

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5. Incoming Supply Conductor Terminations and Devices for Disconnecting and Switching Off:

There is often no specific terminal for connecting the external protective conductor provided at the machine. Where there is, it is not suitably identifiable. It should have a PE label and should be the only conductor identified as PE. (5.2)

A common error on machines are feeds for equipment taken from the live side of the incoming isolator and the incoming mains supply being run through the machine panel wiring containment to the main isolator. This technique results in the wiring being live when the machine isolator is open, putting anyone working on the panel at risk. (5.3.5)

If the machine isolator is fitted to the panel door, which moves, and the incoming electrical supply is taken directly to this isolator, these cables run through the panel, they would be live with the panel isolated, and they are vulnerable because they flex every time the panel door moves. If there is no option to mount elsewhere, the cables must be double insulated, insulated and sheathed or have reinforced insulation, not "Spirowrap" or similar. (5.3.5)

Under 60204, it is acceptable to take feeds for panel lighting and socket outlets for programming devices. However, they require special measures such as the wiring being orange, suitably identified and protected, and running in a specific manner. (5.3.5)

Another example of wiring being live with the main isolator open would be interlock signals on linked machines. These could be process or safety interlocks with low or extra-low voltage signals, but they must be treated similarly. (5.3.5)

6. Protection Against Electric Shock:

Often there is no consideration of wire sizes or current-carrying capacity to enable adequate fault current to be carried before the circuit protection operates.

MD/SMSR EHSR 1.5.6 requires the prevention of fire. Automatic Disconnection of Supply (ADS) is an acknowledged method of prevention of overheating of wiring and fire, even if it is not required for shock prevention.

Shaped locks are commonly encountered on machine control panel doors, but the central pin is often broken. This situation allows the lock to be operated with a coin or other improvised tool, so access is not restricted to skilled or instructed persons. (6.2.2)

Neutral terminals are live parts and often not protected against unintentional contact.

7. Protection of Equipment:

Where equipment utilises extra-low voltage to prevent electric shock, it is still necessary to protect conductors against overload. However, circuit breakers often cannot achieve this because the current carrying capacity of wiring is inadequate, and it would burn out before the breaker tripped. (7.2)

8. Equipotential Bonding:

A lack of bonding is a common error. The 2018 version of 60204 requires a greater level of bonding than previous editions. However, even earlier editions required bonding to be given more consideration than BS 7671 does. (8.1)

In addition, multiple protective conductors are often connected, erroneously, to a single terminal. 60204 requires 'one screw, one wire' unless specialised bonding terminals are used, enabling a single fastener and multiple wires connected via 'Faston' connectors.

Note that the protective conductor network should be tested upon completion and each time after being disturbed. If there is more than one protective conductor per connection, multiple circuits would require testing upon completion and after being disturbed.

9. Control Circuits and Control Functions:

There are often misunderstandings relating to stopping. For instance, initiating an emergency stop does NOT mean everything must stop immediately.

Another misconception is the requirement to remove energy from actuators; this includes all energy, not just electrical if it poses a risk to those interacting with the machine. It is necessary to remove pneumatic and hydraulic pressure electrical and kinetic energy from actuators. This removal can be accomplished by several means but all form part of a safety function or a safety-related part of the control system (SRPCS).

ISO 13849-1 and -2 (13849) require electrical systems to be designed to meet the relevant required Performance Level (PLr). However, this cannot be done without compliance with 60204. It is often the case, especially with higher PLr levels, that Common Cause Failures are not considered, and the primary circuit designs are inadequate.

Challenges to the current limits are common, especially under fault conditions for control devices, even if protected by circuit breakers or fuses when fed from the incoming mains supply. In addition, control systems are often wired with multiple devices directly from the incoming electrical supply. This wiring method increases the risk of electric shock at the machine. 60204 precludes this for all but simple machine controls. (9.1.1)

Effectively this precludes 400V control for anything other than simple machines. (9.1.2)

Stop and Emergency Stop functions must override any start functions. Generally, the stop or emergency stop actuators are at the start of the control circuit device chain in hard-wired control circuits to meet this requirement, e.g. emergency stop > stop > start > contactor.

In older machines, it is common to see control devices in both sides of the wiring to a contactor coil, but this is no longer acceptable. The voltage to retain a contactor coil is much lower than that to energise it. Faults in one side of the coil wiring can therefore allow a contactor to remain energised when it should not be. (9.4.3)

10. Operator Interface and Machine-Mounted Control Devices:

Many of the issues in this area relate to colour coding for actuators. In particular, red is often used for STOP/OFF. Although 60204 permits this, it should not be used near an emergency operation device. The preferred colour for STOP/OFF is black. (10.2.1)

Likewise, the preferred colour for START/ON is white, though grey, black and green are permitted.

If the client demands green and red for start and stop buttons, this should be documented and included in the machine Technical File.

Since 2015, it has no longer been acceptable to use emergency stop actuator heads with white arrows indicating the direction the mushroom head should be turned to release the actuator. Today, if the button head of emergency stop actuators has direction indications, these must be the same or substantially the same colour as the actuator. (ISO 13850)

Similarly, the background for an emergency stop button must be yellow, and it should not have any text or symbol apart from the IEC symbol for emergency stop (e.g. the background must not state 'Emergency Stop'). (ISO 13850, IEC 60417-5638)

60204 is clear that the preferred way to prevent inadvertent operation is through the mounting location, not shrouds. ISO 13850 requires that an emergency stop shall be able to be operated with the palm of a hand, which is rarely possible with a shroud. Nevertheless, shrouds are still misused.

Note that other standards not linked to the MD/SMSR, such as the SEMI standards, may require recessed or shrouded emergency stop actuators. Care must be exercised in these applications.

11. Controlgear: Location, Mounting and Enclosures:

Electrical panels and enclosures are frequently mounted at a high level. 60204 requires that all equipment is accessible, and the MD/SMSR EHSRs require consideration to be given to work at height. Permanent means of access must be provided for any foreseeable maintenance work at height. (11.2.1, EHSRs, ISO 14122)

The separation of terminals is often unclear, even though they should be grouped – e.g. power, control, interlocks. Another standard error is hydraulic, lubricating, or coolant equipment located in the same enclosure as electrical equipment – or separate enclosures but open to the electrical enclosure. (11.2.2, 11.4)

Access to electrical panels for work is often poor, with panels on the rear or sides of the machine close to building walls. This design often constrains access to the electrical enclosure and can create a confined space when the doors are opened. (11.5, EHSRs, IEC 60364-7-729)

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12. Conductors and Cables:

Conductors are often undersized. 60204 Table 5 stipulates minimum conductor sizes, and it also requires consideration of external influences such as temperature, vibration, movement and contaminants.

Conductors are often undersized because the current carrying capacity of conductors for compliance with 60204 is different from those in BS 7671. Furthermore, 60204 lays down requirements relating to installation methods that can influence the rating of cables and wiring.

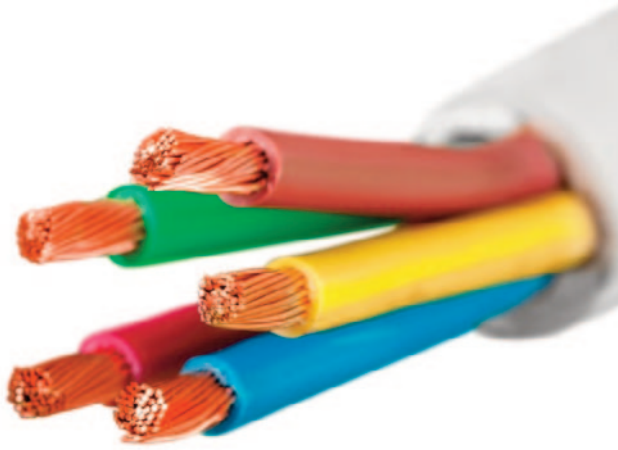
Voltage drop needs to be considered and often it is not.

13. Wiring Practices:

One of the most common mistakes is using colour codes from BS 7671 when wiring machinery covered by the MD/SMSR. These regulations have a broad scope, including ventilation, refrigeration and air-conditioning units, machine tools and manufacturing equipment. BS 7671 clause 110.2, xi refers.

60204 has different colour codes, and these should be used on machinery. End users who demand the BS 7671 colours should indemnify their suppliers in writing for breaching standards that would otherwise provide a presumption of conformity. The machine or panel builder should record this deviation in the TF.

Multiple protective conductor connections are often made to a single point, but this is unacceptable. This wiring method poses a safety hazard during maintenance and repairs, as circuit protective conductor continuity is compromised by disconnection of other circuits and/or connections not being remade and retested. (13.1.1)



Another error is to have cables entering the top of enclosures. Although 60204 is not explicit, it says flexible conduits and cables must allow liquids to drain away from the fittings. Liquid can't drain away from a fitting when cables or conduits enter the top of an enclosure or terminal box. (13.1.1)

Most wiring on machinery utilises finely stranded class 5 or 6 conductors. Unless the terminals are specially designed to accept such wires directly, a means of retaining the conductor strands is required when using screwed connections, such as bootlace ferrules. (13.1.1)

Soldering is not permitted unless the terminals are specifically designed for it. (13.1.1)

Sometimes panels have trunking above a terminal rail and connections made to the bottom of a terminal, which is not permitted because wiring should not cross over terminal blocks. (13.1.1)

Another common problem is unsupported connections, such as strip connectors hanging freely. (13.1.2)

Conductor identifications are often inadequate or omitted. Lack of identification is a safety issue and can increase downtime, making fault-finding more complicated. Identification is required on both the wiring and the terminal, and it must be as per the technical documents (drawings). (13.2.1)

Wiring within panels needs to be adequately supported, typically with trunking. It is common to see wiring no longer supported after the panel has been accessed for maintenance. A lack of support can allow damage to occur, potentially leading to overheating, fire and risk of injury, as well as reliability issues. (13.3)

14. Electric Motors and Associated Equipment:

The most common errors concerning motors relate to mounting and maintenance. For example, terminal boxes are inaccessible, and motors cannot be safely manipulated on and off the machine for maintenance. (14.4 EHSRs)

15. Socket-Outlets and Lighting:

Socket-outlets are often rated at < 20A and have no RCD protection.

Furthermore, UK machines are sometimes equipped with RCD BS 1363 socket outlets (to BS 7288). BS 7288 devices do not afford additional protection as described in BS 7671, IEC 60364 and IEC 61140. (15.1) This means additional RCDs are required upstream of RCD sockets. (BS 1363 and BS 7288 refer, and, whilst not applicable, BS 7671 requires all socket-outlets < 20 A to have RCD protection; thus, it isn't easy to justify not fitting this to machinery), 60204 clause 15.1 indent 6 also refers.

16. Marking, Warning Signs and Reference Designations:

Enclosures should be clearly marked, often they are not – for example, those containing electrical equipment are visually identical to those containing pneumatic controls. Unless it is self-evident that an enclosure contains electrical equipment, it needs to be identified as such. (16.2.1)

Another issue is the lack of identification of enclosures, assemblies, control devices and components, and mismatches between identification on the machine and the technical documentation.

17. Technical Documentation:

The technical documentation is often not in the destination country's language (English in the UK). (EHSRs)

There is often a poor correlation between the drawings and other technical documentation, wire numbering, device identification, etc. Sometimes fluid power schematics utilise different reference identifiers to the electrical drawings for the same devices.

BS 7671 certifications for new electrical supplies are often lacking, resulting in any potential issues with ADS not being identified. This verification is necessary because the machine wiring requires a reliable and robust earth path.

60204 requires specific inspection and test documentation, but this seldom exists. It is either ignored by builders or not passed to end-users. When machinery is modified, moved or repaired, the inspections and tests are seldom repeated, so it is impossible to verify that it is safe to operate. (17.2)

Often, the terminology used is not familiar in the end user's language. For example, US and UK terms for the same electrical equipment can vary, resulting in confusion that could be hazardous.

60204 also requires the ISO 13849-2 validation to form part of the machinery documentation. This validation is rarely provided, and, when requested, most suppliers have not undertaken an ISO 13849-2 validation. Therefore, it is impossible to claim a presumption of conformity by compliance with that standard, 60204 or the EHSRs. (17.2)

18. Verification:

60204 requires inspection and testing of the electrical systems. These are similar to those required by BS 7671 but not identical, so BS 7671 inspections and tests do not prove the machine fulfils the EHSRs. Without 60204 inspections and tests, a machine may still pose a risk of electric shock, overheating and fire.

Cooling systems are often installed to extract warm air

Annexes:

Annex A, 'Fault protection by automatic disconnection of supply' is normative, and therefore compliance is required if 60204 is being used to claim a presumption of conformity.

Annex H is about EMC. Electromagnetic compatibility is frequently ignored by electricians and panel builders. It is a legal requirement to comply with the EMC Directive or UK Regulations.

A typical failure is the installation of variable frequency drives and not following the manufacturers guidelines. if a drive is installed to the instructions there is still a chance it would fail EMC testing. If it is not installed to the instructions it will fail testing.

The remaining annexes are only informative, so compliance is optional. However, they contain a wealth of valuable and helpful information; unfortunately,many machine and panel builders appear to ignore them or fail to comply with so many of them.

This white paper focuses on 60204, but the standard is just one of many that can be used together to achieve apresumption of conformity when CE/UKCA marking machinery. The most apparent related standard is ISO 13849 parts 1 and 2 but there are many others.

Related Issues

Cooling systems are often installed to remove warm air from control cabinets. If these are reduced in their effectiveness due to an accumulation of dirt or are not repaired when they fail, electrical equipment can overheat. This overheating gives rise to the risk of fire.

Furthermore, electrical equipment can fail prematurely if it is too warm, resulting in downtime and the cost of replacement parts.

It is common to find electrical panels and enclosures not latched closed. This practice allows access to hazardous equipment and also the ingress of contaminants.

who we are:

Safe Machine Ltd:

Derek Coulson founded Safe Machine Ltd in 2012 to offer a range of machinery safety services. These include CE marking, CE audits, UKCA marking, UKCA audits, PUWER inspections and training. Derek Coulson is a machinery safety specialist with over 25 years of experience.

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COMPLIANCE Risk Software:

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Hold Tech Files Ltd:

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To this end, Hold Tech Files has created a web-based service for manufacturers of machines, partly completed machines and safety components covered by the European Machinery Directive. After signing a mandate and paying a fee, the customer can upload relevant files to a secure server. Payment of a one-off fee entitles the manufacturer to name Hold Tech Files on the DoC or DoI for a period of ten years. In addition, Hold Tech Files can be named on the DoC or DoI as the person responsible for compiling the technical file in compliance with the Machinery Directive.

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Paul Skyrme:

Paul Skyrme had a wealth of machinery safety experience in advisory and implementation roles. He was the Director and Principal Consulting Engineer at Abertawe Engineering Services and a Technical Advisor (Associate) with Safe Machine Ltd.
Paul sadly passed away in 2023 and is greatly missed.

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