Electrical safety in mines

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This guidance replaces L128 – *The use of electricity in mines: Electricity at Work Regulations 1989. Approved Code of Practice.*

It is primarily aimed at mine operators, engineers and technicians but will also be useful to others within the mining industry such as mine managers, safety representatives and representatives of employee safety, any employer with employees who work below ground at mines and self-employed contractors working below ground at mines.

Contents

Introduction

1 This guidance is intended to help mine operators, engineers and technicians comply with their duties with regards to controlling the major hazards associated with the use of electricity in mines.

2 Not all of this guidance will be relevant to every category of mine. The guidance for the control of specific hazards only applies where those hazards are present so, for example, in a mine where there is no likelihood of flammable gases, the mine operator will not need to take any specific action. Unless otherwise specified all voltages are alternating current (ac).

Relevant legislation and guidance

3 Relevant legislation includes:

- The Mines Regulations 2014[1]
- The Electricity at Work Regulations 1989[2]
- The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR)[3] (which implement Directive 99/92/EC – the ATEX Workplace Directive)[4]
- The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996 (EPS)[5] (which implement Directive 94/9/EC – the ATEX Equipment Directive)[4]
- The Provision and Use of Work Equipment Regulations 1998[6]

4 Mine operators should also consider other HSE guidance including:

- *Electricity at work: Safe working practices*[7]
- *Keeping electrical switchgear safe*[8]
- *Electrical switchgear safety*[9]
- *Avoidance of danger from overhead electric lines*[10]
- *Avoidance of danger from buried electric cables*[11]
- *Electrical test equipment for use by electricians*[12]
- *Guidance on the design and construction of safety critical electrical systems at mines*[13]
- *Guidance on the repair and overhaul of apparatus intended for use in coal mines susceptible to firedamp*[14]
- *The prevention and control of fire and explosion in mines*[15]

5 Mine operators must ensure that all electrical engineering activities at a mine are planned and carried out in such a way as to control risk. Safe systems of work should be developed. Mine operators must ensure that only competent people carry out electrical engineering work.

Planning the installation of electrical equipment

6 Mine operators should assess the inherent environmental conditions in each mine and plan the installation and operation of electrical systems to control risk.

7 This is particularly important where the potential for a flammable atmosphere exists.

8 Mine operators should consider arrangements for isolation or making safe and subsequent restoration to normal conditions when positioning equipment.

9 Schematic diagrams of electrical equipment installations should be made, kept up to date and retained to enable effective planning and to facilitate safe operation. The diagrams should include any interlocking arrangements.

10 Schematic diagrams of the distribution system should be clear. They should show all electrical equipment including cables operating at a voltage exceeding 250 V. Additionally, the diagram should show the planned settings of any electrical circuit protection devices which are designed to be adjustable.

11 Isolation arrangements should also be carefully considered, eg to avoid isolation points being positioned on the return side of a fire source.

12 Copies of the diagrams should be kept at the surface of the mine, and posted at substations or at any point where isolation is complex, eg ring main circuits or parallel feeds.

13 Schematic diagrams and plans should be updated periodically or after any major change.

14 In addition to schematic diagrams mine plans should show the position of major assets and cable routes, and when planning these routes and positions major hazards should be taken into consideration.

15 Consultation and exchange of information between electrical engineering staff, and those people responsible for ventilation should take place to ensure safety. Agreed plans should be endorsed (signed-off) by all parties.

Electrical system construction

16 Construction of an electrical system includes individual items of equipment and how they are assembled and connected. Equipment constructed to appropriate British Standards or equivalent international specifications should be used (eg Ingress Protection (IP) rating chart in Appendix 1).

17 When planning and constructing a system the mine operator should:

- ensure the system is planned, installed, protected, commissioned, tested and maintained to control risk;
- select suitable equipment to ensure compatibility, eg connecting ATEX-certified to non-certified or pre-ATEX-certified equipment;
- where necessary to control risks, ensure the supply can be automatically cut off or made safe.

18 A secure power supply must be provided where electrical plant is an essential part of major hazard control. This may include environmental monitoring equipment, control rooms, winding apparatus and ventilation fans. Systems should be constructed to minimise the risk of, or arising from, total power loss for any significant period of time.

19 The mine operator should consider the overall characteristics of an electrical system before undertaking any modifications to the system, or part of the system. Examples include changes in fault levels, fault paths, fault clearing capabilities and switching arrangements.

20 The demarcation of responsibilities between the electrical power supply provider and the mine operator should be determined and agreed.

21 Materials used in the construction of electrical equipment should be selected to minimise danger. Items to be avoided include:

- some insulating materials (typically phenolic types) which decompose when subject to arcing and give off large volumes of potentially toxic or flammable fumes;
- equipment containing polychlorinated biphenyls (PCBs) and polychlorinated terphenyls (PCTs);
- exposed light metals and their alloys, eg aluminium and magnesium or titanium and zirconium where the electrical equipment is to be used in a potentially flammable atmosphere. Aluminium and magnesium can produce incendive sparking if subject to frictional contact with rusty iron or steel. Titanium and zirconium can produce incendive sparks under impact or friction against any hard material, even in the absence of rust.

22 Where the use of such light metals or their alloys cannot be avoided, they should be encased or covered with alternative material to minimise the risk.

23 Where low-current auxiliary circuits are connected to high fault level bus bars suitable protection, such as fuses, should be provided as near to the bus bars as practicable to protect the auxiliary circuit wiring. The electrically unprotected connections between the fuses and bus bars should be arranged to avoid faults by, for example:

- keeping the leads as short as possible;
- physical segregation;
- the use of reinforced insulation.

24 Electrical signalling, control and interlocking systems should be designed, constructed and installed, so far as is reasonably practicable, so that any electrical failure causes the equipment they are controlling to fail to a safe condition.

25 Where any vehicle or locomotive with a battery or alternator is to be operated in a potentially flammable atmosphere, or for carrying explosives, the chassis or frame should not be used as the current carrying path for any electrical circuit capable of igniting that atmosphere. This does not preclude the earthing or referencing of the chassis or frame to enable suitable electrical protective or monitoring devices to operate.

26 Where more than one plug or socket of the same type is used at the same place, and danger could arise if unrelated plugs and sockets were coupled together, then precautions such as keyway coding, padlocking or marking of switchgear and plugs and sockets should be taken to control risks.

27 Transformers should be constructed to ensure lower voltage conductors cannot become charged above their normal voltage.

28 Where a potentially dangerous defect is found it must be recorded (in accordance with regulation 15 of the Mines Regulations 2014) and action taken as swiftly as possible to control the risks. If repair is not undertaken immediately, safeguards must be implemented, eg by isolation of equipment and the application of padlocks. A system of appropriately colour-coded locks or departmental locks with identification tags should be used for defective plant.

29 The supply voltage for use underground should not normally exceed 11 000 V. In certain circumstances system voltages should be restricted to lower values; these include:

- 6600 V supplying equipment which is normally stationary but is moved at certain times with the power applied to it, eg a transformer which moves in fixed increments in relation to a working mineral face;
- 3300 V supplying motors or machines (excluding distribution transformers) which are designed to be moved while working and which are served by flexible (trailing) cable;
- systems supplying electric traction equipment by means of contact lines:
  - 650 V with rail returns;
  - 1200 V for other systems;
- lighting systems:
  - 125 V at or within 10 m of a coal face;
  - 250 V elsewhere.

30 Appropriate precautions should be taken to avoid damage to electrical equipment arising from other activities, eg contact with mobile plant, shotfiring or dinting operations. Control measures include shielding, isolating, or removing and reinstalling.

31 Mine operators should have arrangements in place, prior to any work on equipment, to ensure that all potentially dangerous sources of electrical energy have been isolated and discharged. Appropriate safety checks and tests should be carried out to identify and isolate cables correctly, before equipment is dismantled – or cables are removed from any system – and prior to restoration of power.

Oil-filled and dependent manually-operated (DMO) electrical switchgear

32 Electrical equipment using oil as a means of cooling, insulation or arc suppression poses a significant fire hazard. No new oil-filled equipment should be introduced below ground. Existing underground oil-filled equipment should be replaced with equipment that does not contain oil as soon as practically possible. Risks may be reduced by replacing the oil with synthetic fluids specifically manufactured for switchgear which have a much higher flash-point; checks should be made with the electrical equipment manufacturer regarding suitability.

33 DMO electrical switchgear poses significant risks to personnel during switching and existing equipment should be replaced. In the interim an assessment of the safe operation of DMO switchgear should be made in accordance with the guidance in *Keeping electrical switchgear safe*.

Zoning of areas of a mine relating to potentially explosive atmospheres

34 Mine operators should prepare and keep updated a suitable plan at every mine showing any zones below ground in which flammable gas or flammable dusts, whether or not normally present, are likely to occur in a quantity sufficient to indicate danger, ie zones classified under the requirements of DSEAR regulation 7(1). The mine operator must ensure that overall explosion safety is verified by a competent person.

35 Electrical equipment intended for permanent installation and use in such zones must be of an appropriately certified type, unless the mine operator's risk assessment finds otherwise. New equipment must meet the certification requirements of the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996 (EPS). Equipment that

predates the EPS Regulations that was certified for use in potentially explosive atmospheres to earlier standards, can continue to be used providing it is correctly repaired and maintained. Where the use of equipment from outside the EU – or wider European Economic Area – is considered, then to ensure safety it must be certified by an ATEX-notified body.

36 Where the mine operator's risk assessment indicates that circumstances allow for the safe use of electrically-powered equipment not of the type described in paragraph 35 and not permanently installed in the mine, eg for monitoring, testing, recording, measurement or other special purposes, then suitable arrangements for its safe use should be set out. This could be in the form of a method of work which allows such equipment to be used safely.

37 Mine operators must ensure arrangements are in place so that where uncertified electrical equipment, or equipment which does not provide an equivalent level of safety to appropriately certified equipment is taken into such a zone it is not energised during the time it is in that zone.

38 Notices should be posted at the entrances to the zones to warn people that only suitable types of electrical equipment are to be used beyond that point.

39 The introduction, location and use of equipment in zones where flammable gas is likely to exceed 25% LEL (1.25% v/v for methane), should be carefully planned and controlled. Mine operators should have procedures for making all equipment safe in these circumstances.

40 Blind ends require additional features to reduce risks. The arrangements should include locating the controlling switchgear and power supply on the intake side of any blind end. In addition, a fan interlock should be included to ensure the electrical supply is removed in the event of the auxiliary fan stopping. This is to ensure that electrical equipment does not remain, or become, energised in an unventilated location. Where the potential for an explosive atmosphere exists, fan interlocking should be provided.

41 When the air to a working place has previously circulated through an area where a potentially explosive atmosphere may be present, then flammable gas monitoring should be provided to detect the approach of flammable gas. Interlocks should be provided to remove power to all rotating cutting elements at 25% LEL. This is to provide protection from any plug of flammable gas created in other areas passing over rotating cutting element where incendive sparks can occur.

Storage batteries

42 Traction batteries should only be changed at designated charging or transfer stations which should be of adequate size and suitably equipped for the purpose, eg provided with arrangements for lifting or handling batteries and adequate means to combat fire.

43 Underground charging apparatus should be on the intake side of the battery racks and air passing from the battery racks should not subsequently ventilate any working place.

44 Where the transfer of traction batteries requires the use of trailing cables, arrangements should be made to protect the cable from damage due to over-tension and particular care should be taken to maintain plugs and sockets in a clean and dry condition. Only traction batteries having a mid-point isolator should be stored below ground at places other than the designated charging stations.

45 During the transportation or storage of traction batteries all isolators provided on the battery container should be switched off. Batteries should be transported in a suitable purpose-designed carrying case or vehicle.

46 Charging apparatus for traction batteries should incorporate means of automatically cutting off the charging current if excessive leakage current between the battery under charge and its container is detected.

47 The permanent lighting provided in underground charging stations should be certified for use in potentially explosive atmospheres.

Use of safe voltages on hand-held equipment

48 To avoid electric shock from exposed, charged, conductive parts only low voltages, at or below 50 V ac or 120 V dc, should be used as a substitute for earthing or other precautions. Hand-held equipment used at greater voltages will require additional precautions, including double insulation or supply from an isolating transformer.

49 In highly conducting locations, or where the body may be damp and have a large area of contact with earthed or referenced conductors, consideration should be given to using dc hand-held equipment.

Adverse or hazardous environments

50 Equipment must be sited to obviate its exposure to conditions which might adversely affect its safe operation. Where this cannot readily be achieved equipment must be suitably protected from adverse conditions, including:

- impact, stress, strain, abrasion, vibration or crushing;
- liquids or vapour (see IP rating chart in Appendix 1);
- dirt or dust (see IP rating chart in Appendix 1).

51 Where equipment may be exposed to atmospheres containing combustible dust it should be constructed to avoid any external part achieving a surface temperature in excess of 33% of the ignition temperature of the dust in normal operation (150 °C for coal dust).

52 Where a potentially flammable or explosive atmosphere could occur at the surface of a mine, eg a flammable gas drainage plant or at places containing large quantities of explosive or flammable materials, electrical equipment should be selected, installed and maintained to minimise the ignition risk.

53 Lightning protection devices and anti-static materials or devices should be used where necessary.

Insulation, protection and placing of conductors

54 Where the conductors or insulation may be vulnerable, additional protection against physical, mechanical, chemical or other foreseeable damage should be provided by means of enclosure or armouring and sheathing.

55 Circuit conductors must be suitably placed or otherwise safeguarded to prevent risks through unintentional contact or should be covered with insulating material of suitable quality and thickness. Additionally:

- conductors used at a voltage exceeding 125 V, where necessary, should be further protected by metallic screen, armour, or conduit. Semi-conductive materials may also be used where they afford a similar level of protection;
- conductors used below ground where flammable gas or dust may occur should be provided with a metallic covering, screens or armour so arranged to minimise the ignition of flammable gas or dust. This is not required where conductors are connected to intrinsically safe circuits incapable of producing incendive sparks or arcing.

56 Steps must be taken to ensure that exposed conductive parts either do not become charged or, if they do, the values of voltage and current and their duration are such that danger will not arise. These include:

- referencing, and equipotential bonding or earthing;
- use of safe voltages;
- current limitation.

57 The outermost protective covering provided for any conductor in cables should not readily propagate flame.

58 All terminations of cable coverings, armourings or conducting screens should be securely attached to the apparatus and adequately sealed, where necessary, to prevent the ingress of substances likely to affect the integrity of the insulation or circuit conductors.

59 The conducting coverings, armourings or screens provided in any cables should be connected to the frame or case of the associated equipment to ensure adequate mechanical strength for the duty and to provide a low-resistance path. Armourings should be protected, as necessary, against corrosion and enclose all the conductors in the cable.

60 For fixed cables operating above 650 V, the metallic screens should be of steel wire armour or other suitable hard metallic sheath. Where necessary to increase conductivity, steel armourings may be supplemented by copper strands.

61 Permanently or semi-permanently installed cables should be positioned or properly supported at suitable intervals throughout their length, to minimise the risk of damage.

62 Where the route of a cable is not obvious, eg a cable in a trench, it should be marked by marker tape or ‘danger’ tiles buried with the cable and its position kept on a plan at the mine office.

63 For flexible cables which are designed to move while energised, the metallic covering may be:

- steel wire armourings which are suitably flexible and enclose all of the conductors in the cable and are protected, as necessary, against corrosion; or
- conducting screens which are suitably flexible and protect each circuit conductor individually; or
- a suitable flexible conducting screen protecting the circuit conductors collectively, containing an independent earth or reference conductor of at least the same cross-sectional area as the largest circuit conductor; or
- a combination of the above.

64 Unarmoured and unscreened flexible cables, where used in adverse conditions, should be positioned within shielding and protected to avoid inadvertent contact or damage whilst energised.

65 Mains-powered (230 V and above) flexible cables used at places where they are vulnerable to damage, except those forming parts of intrinsically safe circuits, should be:

- operated in a system which is earthed or referenced;
- of a type in which the circuit conductors are individually enclosed by metallic or conducting elastomeric screens electrically connected to earth or the reference;
- provided with suitable leakage protection arranged to cut off the supply in the event of the screens becoming connected to a live conductor.

66 Where flexible trailing cables do not need to be moved, they should be effectively supported and protected against physical damage.

67 Wherever trailing cables supply 3300 V to mobile machinery they should, where necessary, be safeguarded by an appropriate cable handling system.

68 Where trailing cables are used to supply mobile plant in multi-entry systems, arrangements should ensure that the risks of cable damage are minimised. These may include ramps to allow vehicles to cross over cables and cables being positioned away from moving machinery.

69 Manual handling of flexible cables should be minimised by the use of appropriate cable reeling or handling devices.

70 Exposed conductors should be placed so that they are not normally accessible.

71 Where the placing or safeguarding of conductors is insufficient to prevent exposure to risk other precautions should be taken, eg padlocked rooms with controlled access.

72 Notices should be attached to enclosure covers to warn if live conductors are enclosed. Access should only be permitted by the use of keys or tools by a competent person.

73 The risk of incendive sparking or shock from conductors which have become charged from high-voltage sources should be minimised by placing, or otherwise protecting, conductors to avoid induction or leakage of current.

74 Intrinsically safe circuits and other low-voltage cables are vulnerable to induction from high-voltage sources and should be segregated and protected to minimise these effects.

Earthing

75 Steps should be taken to ensure referenced conductors that carry electric current in normal conditions, eg combined neutral and earth, are prevented from reaching significant potentials above the reference level. Where potentially explosive atmospheres may occur, combined neutral and protective conductors should not be used.

76 Open circuit or high impedance in a combined neutral and protective conductor can result in the exposed conductors, connected to the protective conductor, becoming charged at a significant potential leading to an increased risk of electric shock or burn.

77 Engineered joints or bolted links or bus bar primaries of current transformers may be installed in a referenced conductor provided the integrity of the conductor is maintained.

78 If removable links or manually-operated knife switches are inserted in a referenced conductor suitable arrangements should be made to maintain the reference point.

79 Where a protective conductor is combined with a neutral conductor, precautions should be taken to prevent persons from simultaneously contacting the protective conductor and earth. All metalwork which may reasonably become charged should be bonded together and connected to the protective conductor.

Referencing and equipotential bonding or earthing

80 The electrical system should be connected to a reference point such as the general mass of earth or the metallic framework of an installation to facilitate correct operation of the system to:

- enable fault protection or insulation monitoring systems to function, eg earth fault protection;
- stabilise the potential between circuit conductors and the reference point;
- reduce the prospective shock voltage between circuit conductors and the reference point.

81 Equipotential bonding or earthing reduces hazards arising from:

- potential differences between exposed conductive parts;
- the passage of stray fault currents through fortuitous paths, eg people.

82 Where single-phase systems are earthed or connected to a reference point the connection should be at the mid-voltage point. This does not normally apply to 110 V contactor control circuits.

83 In the case of polyphase systems the neutral point should be earthed or referenced at the source of supply.

84 Where the mid-point or neutral point is artificially created by the use of balanced impedances or resistances, protection should be no less effective than earthing or referencing at the source.

85 Mine operators should be aware that earthing practices for electric arc welding in mines differ from industrial practices and these are outlined in *Electrical earthing in coal mines*.

86 A conductor used to connect a system to earth or a reference point should not incorporate any switch, fuse or other device that results in loss of reference. This does not preclude the use of current limiting devices or suitable arrangements to transfer the reference from one point to another, nor the use of switches designed to open all the circuit conductors (including the neutral) simultaneously to prevent danger.

87 Where the continuity of earth or reference conductors is interrupted by disconnection of restrained and interlocked plugs and sockets, the earth or reference circuit should be the first to make on connection and the last to break on disconnection.

88 Where referencing and equipotential bonding or earthing is adopted, any exposed conductive parts should be efficiently connected together and to the reference point.

89 All electrical network reference points should be connected together and connected to the general mass of earth by means of suitable earth electrodes.

90 The resistance between the earth electrodes and the general mass of earth should be low enough to allow the electrical protection equipment to operate in the event of a fault occurring. This resistance should not exceed 2 Ω.

91 Where 'earth-free' referencing is used a specific reference point should be created (eg the metal framework of a vehicle) and all exposed conductive parts of equipment bonded to this part by suitable conductors.

92 The design and construction of an earthing or referencing conductor should be suitable for the maximum current it may carry under fault conditions.

93 Consideration should be given to the selection of cables where the earth conductor is a screen enclosing a circuit conductor. This is to ensure cables are capable of carrying the maximum earth fault current that can occur, and for the duration that the fault may be sustained, before the protection operates.

94 Earthing or referencing conductors, including joints and connections, in fixed equipment or cables should have a combined conductivity of not less than 50% of that of the largest associated circuit conductor. In the case of cables having metallic coverings, not less than half of the minimum 50% conductivity should be provided by the metallic covering.

95 A lower level of conductivity may be used for fixed cables operating on power systems at the surface of mines where the maximum earth fault current is restricted and automatic leakage fault trip devices are provided. The protection should be no less than that on an equivalent unrestricted system.

96 Earthing or referencing conductors in flexible cables should have a combined conductivity, including any joints or connections, of not less than that of the largest conductor in the cable.

97 In systems containing flexible cables where the maximum earth fault current is restricted, a lower level of conductivity may be used but the combined conductivity of the earthing or referencing conductors should not be less than half of that of the largest conductor in the cable.

98 Unscreened flexible cables, including pliable wire armoured, should incorporate an earth conductor or conductors in addition to any armouring provided for mechanical protection.

Connections

99 Connections should:

- incorporate adequate insulation to prevent electric shock;
- be made to avoid high resistances which can lead to overheating, arcing and incendive sparking, particularly where a flammable atmosphere may be present, to avoid fire or ignition.

100 Circuit conductors with differing current carrying capacities should not be connected together, unless the circuit electrical protection is arranged to protect the circuit conductor having the lowest current carrying capacity.

101 Cable glands, couplers, plugs and sockets, and cable entries of junction and sealing boxes, should be constructed to maintain effective electrical continuity and be sealed to prevent ingress of contaminants.

102 To avoid any potentially dangerous arcing while any plug is being inserted or removed from any socket, interlock circuit pins must be shorter than power circuit pins.

103 Plugs and sockets used below ground should be of the restrained or bolted and interlocked type. To restrict interference by unauthorised personnel, plugs and sockets should be of a bolted type where they are used on equipment served by flexible cable and operating at above 1100 V.

Protection from excess current

104 Systems should incorporate some form of excess current protection. Where excess current protection is not provided, the size, strength and capability of the equipment in the system must be adequate for the most onerous thermal, magnetic, electrical and mechanical stresses to which it may be subjected.

105 The excess current protection must match the characteristics of the system and be supplemented, if necessary, by other devices, eg thermal protection against overheating. It should be set to operate at as low a value of time and current as possible. The settings should be arranged to give the necessary discrimination to permit the effective operation of equipment.

106 Circuit breakers should be capable of making and breaking the most onerous short-circuit current without danger. Equipment not required to make or break a short circuit should be capable of carrying such a short-circuit current either indefinitely or until such time (normally less than five seconds) as the system fault can be cleared.

Earth leakage current

107 The danger from earth leakage can be minimised by limiting the prospective fault current in the system and consequent selection of appropriate protection devices. In assessing the risk the mine operator should consider the characteristics of the system and the maximum energy available.

108 If the leakage fault currents are limited by high-integrity resistors or reactors, the risk of electric shock from exposed conductive parts, eg the framework of machines, is correspondingly reduced. This technique should be used for equipment that is moved while energised.

109 Power systems which are referenced to earth (excluding those using an earth return) should have protection provided to cut off the supply automatically in the event of excess leakage to earth, or reference as follows:

- above 650 V for systems comprising equipment designed not to move while energised;
- above 125 V for systems comprising equipment that is intended to move while energised.

110 For power systems with their reference connected solidly to earth the fault current and its duration should be limited to as low a value as reasonably practicable. The maximum value of trip settings should not exceed 5 A, or 15% of the rated load current, whichever is the greater.

111 Where cables containing conducting elastomeric (semi-conducting, non-metallic material) screens are used, the trip setting should take account of the low screen conductivity and should be less than 1 A.

112 In power systems the following values of earth fault current limits should be adopted:

- 1 A for mains lighting at or within 10 m of a production face;
- 2 A where more than one neutral point is connected to earth;
- 2 A on every system below ground operating at voltages between 650 and 1200 V;
- 2 A on every system supplying equipment designed to be moved while working, and which is served by flexible (trailing) cable, up to 3300 V;
- 16 A on every other system below ground operating at voltages between 250 and 650 V, and supplying electrical equipment installed in potentially explosive atmospheres.

113 No system that operates above 1200 V and has a maximum prospective earth fault current exceeding 150 A should be installed below ground in a mine.

114 To ensure effective operation, the settings of earth leakage fault protective devices should have a ratio between the maximum prospective earth fault current and that required to operate the tripping mechanism of at least 3:1 and preferably 5:1.

Cutting off the supply to underground

115 Surface switchgear should be provided for all underground electrical systems supplied from the surface, except communication systems, to allow the power supply to be cut off and isolated.

116 Competent people should be available at the surface to operate the switchgear and be contactable whenever people are below ground. Operation may be manual or remote. Any remote tripping circuit should be monitored and reliable.

117 The supply may be cut off automatically or manually and the switchgear should be:

- capable of cutting off the supply under all foreseeable normal and abnormal conditions;
- located in a suitable and convenient place;
- arranged for the continuity of electrical power to equipment essential for the safety of people, such as ventilating fans, winding apparatus and water pumps;
- clearly marked to indicate the equipment which it controls.

Isolation and actions where flammable gas is detected

118 Mine operators should have arrangements in place to ensure that when any person or system at a mine detects flammable gas in a concentration exceeding 25% LEL in the general body of the air, either below ground or at any place on the surface:

- the supply of electricity is immediately cut off to any electrical equipment, other than electrical equipment certified to remain energised, situated at the place where the flammable gas concentration is detected;
- where this is not possible, take all reasonably practicable steps to make such equipment safe;
- if unable to make safe for any reason, then this should be reported immediately to the most senior person on duty.

119 Where action has been taken details of the time, duration and location should be recorded.

120 If the supply of electricity to electrical equipment is cut off, or the equipment made safe, it should remain in that condition until the senior person on duty at the mine, having determined that it is safe to do so, directs that the supply can be re-established.

121 Where equipment derives power from an internal source, eg a battery, then additional precautions may be needed in addition to cutting off the supply to make that equipment safe. Such precautions may include removal to a non-hazardous area and re-introduction following permission from the senior person on duty at the mine.

122 When equipment has been exposed to flammable gas exceeding 40% LEL some flammable gas may remain within equipment. Enclosures which include devices that arc or produce sparks in normal operation should be purged to remove flammable gas before power is restored.

Isolation of plant

123 A switch to cut off the power supply between a flexible cable and a fixed cable should be provided at the interconnection. Where this is not the case, protection should be provided to trip and cut off the supply in the event of movement of the joint.

124 Where a flexible cable feeds a pantechnicon from a fixed cable a means to trip the supplying switch and cut off the power should be provided at the pantechnicon.

125 A switch should also be provided on or near mobile machines to cut off the power in an emergency. Where switchgear cannot be sited near the operator, remote tripping devices should be used and be arranged to fail to safety.

126 Any isolation switch on a mobile machine should be suitable for immobilisation purposes and form part of the machine itself.

127 Isolation arrangements should be accessible and procedures should be simple to prevent mistaken operation.

128 Batteries cannot be totally de-energised and should, if possible, be removed from any zones where conditions indicate an increased risk of fire or explosion.

129 Where equipment, other than batteries, may store energy, eg capacitors, provision should be made for the energy to be discharged as part of the isolation procedure.

Work on equipment made dead

130 Isolation should only be carried out by competent and authorised people.

131 Precautions must be taken to ensure that the equipment remains isolated during the time people are working on it or for as long as is necessary.

132 To avoid any unplanned restoration of power while work is being carried out, facilities for padlocking or removable isolator handles should be provided.

133 If the continued control of isolation of equipment cannot be guaranteed additional precautions such as earthing must be taken.

134 Equipment may become live as a result of induction, backfeeds or leakage. Low voltages from other circuits inadvertently impressed on the secondary side of the transformer may cause a hazard when transformed up and this should be considered when working on the primary side. It may be necessary to apply the earth to the circuit through a circuit breaker capable of making and breaking fault current safely. If necessary, additional earthing may be applied in accordance with a safe method of work.

135 Safe methods of work include, as appropriate, locks, control of keys and control of withdrawn fuses or links. Arrangements should include a formal system for the control and issue of unique padlocks to nominated people and each of the padlocks should be clearly marked to identify the person to whom it was issued.

136 Permit-to-work systems, as required by regulation 13 of the Mines Regulations 2014, should typically form part of the isolation and check procedures for circuits above 250 V but may not be necessary where isolation can be assured in an alternative way.

137 If those planning the work and carrying it out and isolating the equipment are not the same person, the person in charge should be clearly identified, issue clear instructions detailing the work to be done and the methods and places of isolation and subsequent restoration of the supply.

138 Where complex isolations or significant circuit changes are required, a structured method of work using diagrams of the existing circuitry and proposed changes should be used as part of a safe system of work.

139 It is imperative that a final check is made before touching any exposed conductors. In mines where flammable or explosive atmospheres can occur, an appropriately certified non-contact instrument such as a ‘dead line checker’ should be used; elsewhere the use of contact type devices is permissible provided that they are suitable for the voltage range and the environmental conditions are dry.

140 When lamps in lighting circuits are to be changed the precautions taken do not necessarily need to include isolation and padlocking of the circuit, provided that the lighting circuit is switched off, either by a member of the electrical engineering staff or by another competent authorised person.

Work on or near live conductors

141 Work on live conductors should only be considered on those systems where it is impracticable to make them dead before the work is carried out, eg work on storage battery terminals, or the carrying out of certain electrical tests.

142 To reduce risks associated with live working, mine operators should consider the provision of alternative power supplies, properly laid out distribution systems and engineered equipment housings with inbuilt test facilities at the design stage of an installation.

143 Mine operators must ensure that no person attempts to work on, or near, any live conductor unless all the associated risks have been competently assessed.

144 Where it is not practicable to make the conductors dead, and it is reasonable in all the circumstances for the work to be performed live, the assessment should take into account:

- electric shock. In wet situations or conductive locations live work should not take place above 25 V ac or 60 V dc;
- arc burn and fire;
- ignition of flammable gases.

145 Following assessment the procedures for safe working should include:

- adequate information about the electrical system and its risks;
- the use of suitable insulated barriers or screens;
- the use of suitable equipment, instruments and test probes. Testing to establish whether electrical conductors are live or dead should always be done on the assumption they may be live;
- effective control of the access to live conductors. Unauthorised people should be prevented from entering the area by the provision of barriers or lockable enclosures and warning notices;
- the use of personal protective equipment and clothing;
- the presence of an additional person, suitably trained to recognise danger, render first aid and call for assistance in an emergency.

146 Intrinsically safe circuits should, where practicable, be made dead prior to any work taking place.

147 Incendive sparking can occur as a result of interconnecting, multiple intrinsically safe circuits. To minimise this risk only one live circuit should be worked on at a time.

Electric arc welding

148 Electric arc welding is a special case of work near live conductors. The precautions should include insulated electrode holders and provision of suitable protective clothing. In addition, the article being welded and any associated metalwork should be earth bonded to any surrounding metalwork or framework which the operator is in contact with.

149 Certain types of plasma arc cutters have high open-circuit strike voltages, significantly greater than those of welding equipment. Where these devices are used additional controls will be required to minimise the risk of electric shock, eg restricting their use to dry clean workshops.

Electric shock notices

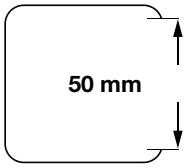
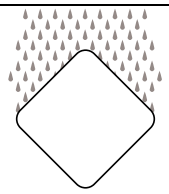
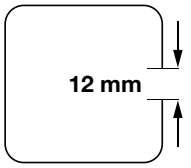
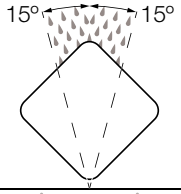
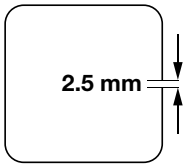
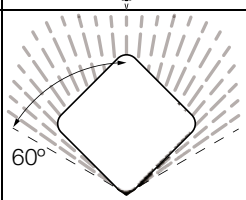
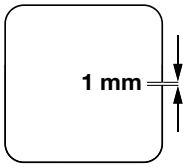
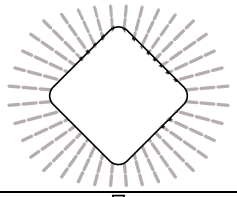
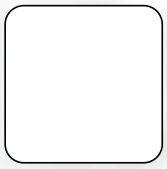
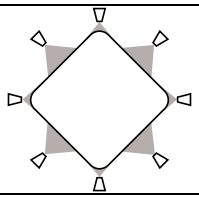
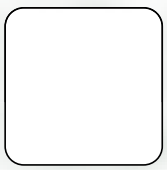
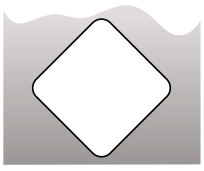
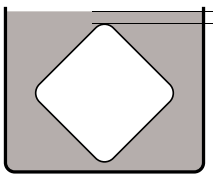
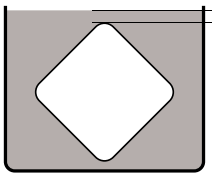
150 Access to first aid or emergency treatment following electric shock may involve lengthy delay at large mines and those located in remote areas. To provide

instruction for non-first aid trained personnel, notices should be displayed in a form which can be easily read and understood and contain information on the appropriate first-aid treatment for electric shock and emergency action.

151 These notices should be posted in sub-stations, control and switch rooms, engine houses and in reasonable proximity to other places where switchgear and motors are installed or where electric arc welding is taking place. Also at places where electrical energy is being generated, transformed or used at a nominal voltage in excess of 125 V ac or 250 V dc.

152 The notices should also include a prohibition on unauthorised people tampering with electrical equipment and directions on action to be taken in the event of fire or explosion.

Appendix 1 IP rating chart

IP65 = IP Letter code: IP (1st: 6 - 2nd: 5)			
1st Digit	Protection from solid objects	2nd Digit	Protection from moisture
0	Not protected	0	Not protected
1	 Protected against solid objects greater than **50 mm**	1	 Protected against dripping water
2	 Protected against solid objects greater than **12 mm**	2	 Protected against dripping water when tilted up to **15°**
3	 Protected against solid objects greater than **2.5 mm ø**	3	 Protected against spraying water 
4	 Protected against solid objects greater than **1 mm ø**	4	 Protected against splashing water 
5	 Dust protected 	5	 Protected against water jets 
6	 Dust tight 	6	 Protected against heavy seas 
Note: BS EN60529 does not specify sealing effectiveness against the following: Mechanical damage of equipment, The risk of explosions, certain types of moisture conditions eg those that are produced by condensation, corrosive vapours, fungus and vermin		7	 **0.15 m - 1 m** Protected against the effects of immersion 
		8	 **Over 1 m** Protected against submersion (see note) 

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7 *Electricity at work: Safe working practices* HSG85 (Third edition) HSE Books 2013 ISBN 978 0 7176 6581 5 www.hse.gov.uk/pubns/books/hsg85.htm

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14 *Guidance on the repair and overhaul of apparatus intended for use in coal mines susceptible to firedamp* ISBN 0 7176 1249 X www.hse.gov.uk/mining/repair-overhaul-apparatus-susceptible-firedamp.pdf

15 *The prevention and control of fire and explosion in mines* HSE Books with Deep Mined Coal Industry Advisory Committee and The Mining Association of the United Kingdom www.hse.gov.uk/mining/feguidance.pdf

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