Guidance on the design and construction of safety critical electrical systems at mines

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This guidance is primarily for managers, electrical engineers and electrical engineering supervisors, but it may also be of interest to other electrical engineering staff and to mine owners. It deals with the design, construction, alteration and adaptation of power supplies to safety critical plant and equipment at mines.

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This guidance is issued by the Health and Safety Executive. Following the guidance is not compulsory and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law. Health and safety inspectors seek to secure compliance with the law and may refer to this guidance as illustrating good practice.

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Introduction

1 This guidance is primarily for managers, electrical engineers and electrical engineering supervisors, but it may also be of interest to other electrical engineering staff and to mine owners. It deals with the design, construction, alteration and adaptation of power supplies to safety critical plant and equipment at mines.

2 It does not cover:

- electrical systems supplying plant and equipment which are not safety critical - other than where they could have a bearing on the reliability of safety critical plant or equipment;
- the prevention of shocks and/or burns; or
- the selection, maintenance or repair of mineral production equipment.

Although these matters are outside the scope of this document, engineers may wish to take account of the principles set out in this guidance when assessing what is required and designing, selecting and using suitable equipment.

Definitions

3 The following definitions apply throughout this guidance:

Dedicated feeder system means an electrical system fed by a single feeder cable originating from a supply point (usually via an outgoing switch), which is dedicated to a specific purpose and not liable to be affected by faults on other unrelated equipment.

Duplicate feeder system means an electrical system fed by two feeder cables supplying a common busbar. The system may include an interlock so that only one feeder can be in service at any given time.

Hospital supply means an alternative limited capacity supply, which may be made available by the Regional Electricity Company (REC) in the event of total loss of normal supplies.

Overcurrent (O/C) means protection against excessive current which can, when graded, provide an amount of discrimination. It is directed entirely to the clearance of electrical faults, although with the settings usually adopted some measure of overload protection may also be obtained.

Overload (O/L) means protection which normally employs relays operating in a time-related manner to try to simulate the thermal capability of the plant to be protected.

Parallel feeder system means two or more feeder cables originating from a common busbar which can be switched to form a ring main. It is the simplest form of a ring main when the bus section is closed.

Radial feeder system means a part of an electrical system in which a single feeder cable feeds a single specified location only.

Ring main feeder system means two or more feeder cables in the form of a ring where power may be supplied to or taken from a number of points.

Standby supply means a supply which is an alternative to the normal supply and is readily available for use as an alternative to it.

Supervised/monitored equipment means equipment so arranged that it is either attended or monitored in such a way that a person (who may be local or remote) is immediately aware of malfunctions.

What are safety critical electrical systems?

4 Safety critical electrical systems are those systems which supply safety critical plant or equipment. Safety critical plant and equipment fall into two categories:

- those whose failure could lead to immediate risk to the safety or health of any person; and
- those whose failure might prejudice the recovery of an emergency situation or the conduct of rescue operations.

5 Systems affecting the safety or health of persons include:

- winding apparatus and transport systems in long, steep surface drifts on which persons are carried or may need to be carried;
- ventilation equipment where the interruption of ventilation would lead to a rapid build-up of gases to hazardous concentrations;
- firedamp drainage equipment where failure could lead to the rapid build-up of flammable gases; and
- pumping equipment where failure may lead to flooding which prejudices the safe exit of persons from the mine.

6 Systems affecting emergency situations or rescue operations include:

- communications systems necessary to facilitate:
  - the safe evacuation of a mine, or parts of it;
  - the recovery of an emergency situation;
  - the control of rescue operations; and
  - environmental monitoring systems which supply information on the state of the mine atmosphere or equipment.

7 Not all mines will have the full range of safety critical plant and equipment. Some mines will have very little, and some none at all. What is safety critical at a particular mine depends on the hazards present and the risks to persons that they pose. For example, an auxiliary ventilation system would only be regarded as safety critical if it was essential to prevent the rapid build-up of dangerous concentrations of flammable gases.

Identifying hazards and assessing risks

8 The electrical systems needed to maintain safety critical services at mines will depend on the hazards present and the risks that arise in the event of any failure of the power supply system to or within the mine. A number of potential mining hazards can pose risks to the electrical power supply at a mine. These include:

- falls of ground;
- inrushes;
- outbursts of toxic and flammable gases;
- fires; and
- the ignition or explosion of flammable gases and/or combustible dust.

9 Not all of these hazards are present at all mines, and those that are present are mostly well known and well understood. At mines where there are only a few hazards, the process of identifying them will be relatively straightforward and should not take very long.

10 In assessing the situation, consider the potential impact on the electrical distribution system if a hazard occurs. A systematic approach will help, as follows:

- **look for significant hazards;**
- **analyse the consequences of a hazard occurring** - decide who might be harmed and how. For example, a fall of ground may not injure anyone directly but people may be put at risk if power is lost to the mine or part of it;
- **evaluate the risks arising from the hazards** - decide if existing precautions are adequate to protect persons, or what action is necessary if they need improving;
- **record only the significant findings** - those which need to be taken into account when designing the electrical system or part of it;
- **review the assessment** from time to time and revise, or improve, the precautions when necessary.

11 Take into account local circumstances when deciding whether existing precautions are adequate. For example, at relatively gassy mines the loss of electrical power to ventilating equipment could give rise to significant risks. At mines where there are no significant quantities of flammable or noxious gases, natural ventilation might be sufficient to keep the workings safe provided normal working is halted.

12 Consider also the likely consequences from a loss of power to associated ancillary equipment or services. For example:

- shaft side equipment and shaft signals needed for mine winders to operate;
- transducers providing signals to safety critical equipment;
- data communications systems used to monitor safety critical equipment or the underground environment;
- firefighting pumps;
- medical equipment in medical centres;
- communications centres, lamp rooms, and emergency organisation rooms or other areas identified by the manager's emergency organisation rules.

13 The assessment will also need to take account of any measures necessary to prevent one item of faulty equipment causing damage to other safety critical equipment. Such measures might include:

- 'blastwalls' between sections of switchgear to prevent a chain reaction of failures if one item of plant suffers a catastrophic failure (Figure 1);
- suitable fire resistant walls, doors and cable routes to prevent fire spreading and damaging safety critical equipment;
- firefighting equipment and arrangements to tackle electrical fires;
- reducing the fire-loading by minimising the use of apparatus filled with large quantities of flammable oil, in places where there is a lot of safety critical equipment (such as winding engine houses and main ventilating fan houses).

14 Managers should ensure that the assessment is reviewed and revised if it appears that there has been, or is likely to be, a significant change in the matters to which it relates, for example, whenever major alterations are made to the mine layout. In any event, it is recommended that the risk assessment be reviewed annually during the life of the mine to ensure that the preventive and protective measures are still appropriate.

Figure 1 Blastwall

Continuity of the electrical supply to the mine

Integrity, reliability and security of the supply to the mine

15 At mines where the total failure of the incoming power supply would not immediately give rise to significant risks, one incoming supply should be sufficient.

16 At least two independent reliable supplies are recommended at mines:

- where ingress and egress is only possible through shafts; and
- with safety critical ventilation systems.

17 Where there are two independent supplies, each supply should be secure and capable of maintaining power to:

- the winding engines;
- the main fan(s); and
- other safety critical plant or equipment.

A schematic diagram of a typical colliery network for a mine having an 11kV and 6.6kV electrical systems is shown at Figure 2.

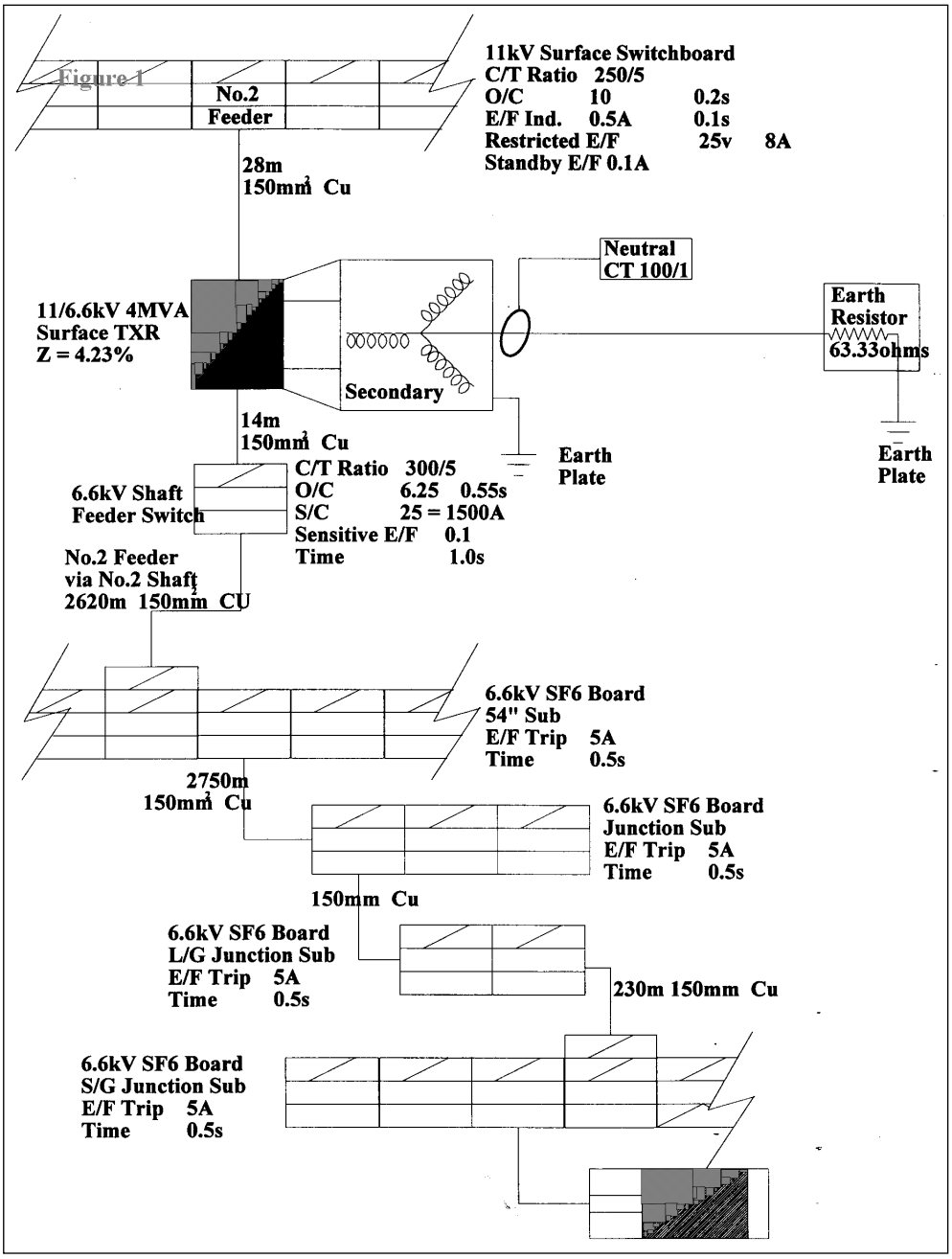

Figure 2 Electrical diagram (see paragraph 17)

18 To determine the security of supply ask:

- what can the electricity supplier provide?
- is a 'hospital supply' needed to allow for evacuation of a mine? If so, what would its capacity need to be?
- is an emergency generator needed to maintain some services in the event of total loss of mains power?
- where a single feeder is used, can it be fitted with 'unit protection' and made into a dedicated feed to avoid its being affected by faults on non-safety critical systems? (**Note - unit protection** means a fault protection system able to detect abnormal conditions in an electrical system, or part of an electrical system, by comparing input and output parameters. An example of such protection is would be a system which monitors the current between two fixed points. It cuts-off (trips) power if there has been unacceptable leakage or loss of current between these points. Such protection is often used to protect

specific items of generating, transforming, or distribution plant, as a back-up to the conventional (overcurrent, earth fault and short circuit) protection. It does not normally include facilities to allow the user to select time delay discrimination between it and other protective systems.

- where duplicate feeders are used:

  – can they be arranged so as to reduce the risk of failure due to common electrical faults or causes? - for example, by the use of 'directional' protection devices (a device usually arranged to cut-off the system supply due to excessive current flowing in one direction only);
  – can they be routed separately to reduce the likelihood of total supply failure due to mechanical or physical damage to both feeders at the same time, such as damage by vehicles or digging machines?

- is the electrical network arranged so that main distribution switchgear can be switched on and off without causing supply interruption (for example, by ensuring that the phase rotation and instantaneous voltage on all incoming cables to a common distribution centre are compatible). This will allow parallel connections to be made before one or more is taken out of service.

Arrangements with the Regional Electricity Company

Operating the REC's switchgear

19 Where an REC owns circuit breakers on mine premises, the mine owner will need to make arrangements with the REC to enable mine personnel to operate the circuit breakers when necessary. Usually an agreement will include a condition that mine personnel only operate the REC's switchgear under instruction from the REC's control engineer.

REC's employees working on mine premises

20 Regulation 11(3) of the Management and Administration of Safety and Health at Mines Regulations 1993 requires managers to ensure the appointment of suitably qualified and competent persons to manage, supervise or undertake any work on plant and equipment at mines. This duty extends to any REC employee carrying out work to the supplier's switchgear at the mine. They too must be appointed in writing by the mine manager before carrying out any work.

Joint permits-to-work

21 Before carrying out work in a substation which contains electrical equipment belonging to both the REC and the mine owner, the mine manager should take steps to ensure that safety precautions are put in place, such as a suitable 'permit-to-work' procedure, which are acceptable to both the manager and the REC. If work is to be carried out on equipment which can only be isolated or made dead by joint action of the mine and the REC, the safety precautions will need to include a procedure in which the permit(s)-to-work are signed by both parties before the work commences.

22 The manager should ensure that mine electrical engineers and electricians and the REC's engineers and electricians know the correct settings of protection devices on each other's switchgear. The protection levels and tripping discriminations need to be compatible to secure the reliability of the network.

23 On the switchgear, or in a prominent place in the substation, display a notice showing the settings. Make arrangements to ensure that if one party changes the settings, the other is immediately notified so that they can take any necessary action.

24 Ensure that there is effective communication between the mine's main incoming supply substation and the REC's control room.

Mines at significant risk as a result of power supply failure

25 At mines where a total power failure could give rise to significant risks, mine owners should enter into a contract with an REC. The contract should detail what services the REC will provide. It should include arrangements for both normal working and foreseeable abnormal circumstances, such as loss of the normal electricity supply. In particular it should include the maximum time before a lost supply is restored, and the minimum power demand.

26 The electrical engineer or electrician-in-charge should meet the REC at least annually to check that the security of the supply is still at an acceptable level, and to review;

- the provisions made in the assessment;
- any changes made to supply systems; and
- methods used to notify the mine of temporary changes made to supply systems.

Surface sub-stations and distribution equipment

27 To prevent unnecessary loss of power at main surface electrical sub-stations and other places where main electrical distribution equipment is housed, check that:

- equipment is of suitable design for the environment in which it is located;
- equipment is adequately protected from the weather;
- there is more than one way out to allow escape in an emergency;
- suitable fire fighting apparatus is provided;
- cable ducts are properly sealed to prevent the spread of fire or flow of burning liquids (such as insulating mineral oil);
- blastwalls are provided where necessary to sectionalise and contain explosion damage, and to limit its effect on other adjacent equipment;
- where shunt tripping is used, the tripping batteries and supply availability at the tripping relay are monitored and a warning given of failure;
- the place is suitably fireproofed;
- there is access to all technical information which may be required;
- suitable notices and diagrams are posted, such as:
  - electric shock/resuscitation notices;
  - schematic diagrams of the distribution network /isolation points;
  - protection level and trip level settings notices;
  - 'NO SMOKING' signs;
  - REC control-room telephone number; and
- where necessary, provide and maintain:
  - any soak-aways, or similar provision, needed to contain any liquids which might escape the equipment if it is damaged;
  - suitable vermin proofing; and
  - suitable lightning protection equipment.

Planning for routine maintenance

28 Plan routine maintenance to ensure that interruptions to the main power supply to the mine are kept to a minimum.

29 Where there is more than one power supply to a mine, arrange the means of isolation so that one supply can be tested and maintained while the other is being used as the main power supply to the mine.

Restoring main supplies following disruption or equipment failure

30 Electrical supply systems should be designed so that power can be restored quickly after a temporary loss. At some mines there may be difficulty in responding quickly to a loss of supply, for example, due to the travelling distances involved. Consider using remotely operated, automatically reclosing switchgear, or switchgear specifically designed to prevent unnecessary opening of the contactor.

31 Check the standby capacity of transformers and cables to ensure that safety critical services can be maintained in event of a single equipment failure. Switchgear fault rating and protection settings will need to be compatible with the alternative supply arrangements.

Prevention of vandalism and tampering

32 Where there is a risk of vandalism or tampering, take appropriate steps to prevent disruption of supplies by using attendants at main sub-stations and distribution points, or by providing surveillance systems. Doors and gates should be locked when main sub-stations and distribution points are not attended. Notices warning that operation of switchgear may cause a dangerous situation to develop may be necessary on certain switches.

33 All electrical equipment which could present a danger from electric shock should be protected to prevent inadvertent contact with live conductors. All enclosed electrical equipment should be designed and maintained to IP20 or better.

Severe weather conditions

34 Take precautionary measures when severe weather conditions are likely to cause disruption of the main power supplies to the mine. Where provided, check that:

- the mine's standby feed and hospital feed are available; and
- mobile generators have sufficient fuel.

35 Inform key personnel, including appropriate underground officials, that there is an increased likelihood of power supply disruption. This will enable them to make arrangements to restore power after any loss.

36 Consider deploying competent persons to the fan house and the sub-station. This could prevent unnecessarily long delays in restoring power.

37 Keep the situation under review throughout the period of any loss of power supply to the mine. Take steps to ensure that an unexpected hazard does not develop during a period of disruption.

Continuity of supply to the underground workings

Design of networks an selection and maintenance of equipment

Distribution network design

38 Distribution networks used to supply safety critical plant or equipment should be designed to minimise disruption of the electrical system during testing, examination, inspection, maintenance or alteration.

39 When selecting equipment to supply or monitor safety critical plant or equipment, avoid that which is known to be susceptibile to failure.

40 Try to ensure that all safety critical plant can be supplied and operated at full capacity in the event of a single line component failure.

41 Where possible, main underground substations should be supplied from the surface by at least two cables which form a ring, duplicate, or parallel feed system. As far as possible, route each cable through different shafts, or drifts, and roadways to minimise the possibility of a single hazard (eg roof fall) affecting both cables.

42 Ring main systems are not usually appropriate for supplying electical power to safety critical plant or equipment. It is difficult to set protection, and the whole ring can be tripped by a single fault on the system.

43 Where distribution is by parallel feeders, arrange the system so that:

- each feeder is operated as an independent system whenever possible;
- directional protection is provided;
- each feeder is designed with sufficient capacity to supply all safety critical plant;
- the system is designed to allow switching between feeders to be carried out without interrupting the supply to the mine; and
- the phase rotation and instantaneous voltage are correct.

44 For duplicate feeders operated from a common supply point, directional relay protection should be provided.

Protecting circuits

45 It is recommended that circuits supplying safety critical plant or equipment are segregated to avoid sympathetic tripping due to non-related faults on the system. Circuit protection will need to be arranged to discriminate between real and non-related faults.

46 Shaft-feeder short-circuit protection should be arranged to trip instantaneously. For other circuits the most effective form of protection is usually one based on a combination of both ‘time delay’ and ‘fault current magnitude’ trips. Protection based on time delay alone can lead to outbye switchgear needing such a large time delay setting that the equipment could be damaged while the fault persists. Protection based purely on the fault current magnitude may have difficulty responding to the reduced fault current available at the remote end of circuits which include several miles of cable.

47 Set electrical circuit protection to operate at a level that safeguards the lowest current carrying capacity of the installed plant. Take extra care where there is a

change in the cross-sectional area of a conductor in a cable, terminal box or connection - eg where 200A to 300A 'stepped pins' are used to connect old to new style cable couplers.

48 Display notices and electrical schematic diagrams at each circuit breaker and remote shaft feeder trip to identify critical supplies which will be affected if a circuit-breaker opens.

Computer-based network analysis

49 For mines with extensive electrical distribution systems, computer-based network analysis can be extremely helpful in:

- calculating maximum potential short circuit fault currents; and
- deciding if the fault rating of existing switchgear is suitable to disconnect the supply to the electrical network whilst a short circuit current is flowing.

A number of network analysis software packages are available.

Changing the electrical network

50 Before changes are made to distribution networks, check that they will not adversely affect the supply to safety critical plant or equipment.

Sustaining colliery network supplies in the event of disruption

51 When assessing the protection necessary to guard against the unintended loss of power supplies to safety critical services, and what measures are required to ensure that power can be quickly restored after an interruption, consider:

- whether the risk of unintentional tripping by using tripping mechanisms with a low susceptibility to system disturbances can be minimised;
- whether the likelihood of spurious tripping by removal of unnecessary protection circuits can be reduced;
- the use of shunt, tripping since it is better than undervoltage tripping where no hazard could arise from unintended operation of equipment; and
- the use of circuit breakers which can be reclosed:

  – automatically; or
  – from a remote position, eg from the mine control room, to minimise the length of power supply interruptions.

Automatic and remote reclosure equipment

52 Automatic or remote reclosure of high voltage (HV) and medium voltage (MV) distribution network equipment can help in restoring supply to safety critical systems quickly following short duration disturbances or nuisance tripping.

53 Automatic reclose facilities should not be fitted to circuit breakers supplying equipment sited within auxiliary ventilated headings because of the possibility of flammable gas accumulating if power supply is lost to the auxiliary fan.

Where automatic or remote reclosure equipment is used

54 The mine manager should specify the maximum number of reclosure attempts and the permitted time period between them.

55 The closing of distribution switchgear should be inhibited by a latching arrangement (preferably locally at the switch itself) if the reason for it opening/ tripping is because of either:

- an overload, earth or short-circuit fault; or
- adverse environmental conditions.

56 In either case the inhibit latch will need to be reset locally and the switch reclosed only after a competent person has determined that it is safe to restore the power. The competent person might be:

- an electrician, where the latch has been caused by an electrical fault; or
- a mine official, where the latch has been caused by adverse environmental conditions.

However, power may be restored automatically following an overload trip where the circuit breaker does not provide the main overload protection for safety critical plant or equipment.

57 Fix notices on or near circuit breakers, or on their associated transformers, indicating that they may close automatically.

Shunt tripping

58 An alternative to automatic/remote reclosure of distribution equipment is to fit 'shunt tripping' to the circuit breakers. With this arrangement there is a risk of the switch failing to trip when required when compared with an 'under-voltage tripping' arrangement. For this reason periodically check to ensure that the shunt tripping arrangement is operating within its design limits.

59 The 'shunt tripping supply' and the electrical continuity of the 'shunt tripping coil' needs to be monitored continuously to provide a warning of loss or malfunction.

Siting of equipment

60 Take into account the following points when deciding what accommodation should be provided for electrical equipment in mines:

- avoiding the accumulation of excessive dust and other contaminants (for example, avoid siting switchgear or transformers under conveyors);
- the suitability of equipment for the site environment (for example, switchgear having waterproofing seals and an appropriate ingress protection (IP) rating will need to be used where dripping mine water cannot be avoided);
- the adequacy of access to the equipment (there should be sufficient space for persons to operate and maintain the installed equipment in comfort);
- avoidance of oil-filled equipment. Regulation 23 of the Electricity at Work Regulations 1989 prohibits the introduction of new oil-filled equipment below ground at a mine. Existing oil-filled equipment should be phased out when the opportunity arises. Where such equipment remains, suitable oil soakaway pits and automatic firefighting systems need to be provided;
- the removal of any redundant equipment to avoid confusion and clutter;
- the provision of up-to-date diagrams, schematics and other necessary information;
- the provision of physical barriers where they are needed to protect electrical equipment against damage by moving vehicles;
- the provision of notices and/or fencing to deter unauthorised tampering with the equipment;

- the provision of suitable foundations or mounting structures to ensure that the equipment is stable; and
- prevention of the storage of flammable materials close to electrical switchgear.

Cable, cable couplers and joints

61 To prevent mechanical damage, all medium or high tension cables supplying safety critical equipment should be of the steel wire armoured type.

62 Where there is a foreseeable risk of mechanical damage, cables for telephones and intrinsically safe circuits to and from underground workings should also be of the steel wire armoured type.

63 All cables should be:

- routed to minimise the chance of damage;
- properly terminated; and
- properly supported off the floor (Figure 3).

64 To reduce the number of potential failure points, try to reduce the number of cable couplers using 'pin and socket' type connections.

65 Where cable couplers cannot be replaced by permanent resin-filled 'through-joints' (where, for example, the installation is temporary or continually extending/reducing in length), use only pin and socket connectors which are in good condition.

Figure 3 Cables supported in a mine roadway used by free steered vehicles

66 Make regular checks to ensure that cables provide a good electrical connection and are not overheating in use. Heat-sensing stickers and thermal monitoring instruments are particularly useful to help diagnose impending problems at joints and connections.

67 Where possible, avoid using bitumen-filled cable joints, as these fail frequently in service due to the formation of voids in the filling medium. In particular, avoid using bitumen-filled cable joints for new installations and in systems supplying safety critical plant.

68 It is recommended that cable couplers using cold pouring type bitumen are removed from all underground distribution networks.

Continuity of Safety critical, electrically powered ventilation equipment

Provision of ventilation equipment

69 Where a mine cannot be adequately ventilated by the natural flow of air, a main fan will be needed. A main fan will normally be on the surface. It should be of sufficient size to ensure that all working places are adequately ventilated and that noxious or flammable gases are diluted.

70 It is essential that main and standby electricity supplies are sufficiently secure to give a high degree of assurance that the main fan will run continuously. What is provided to secure supplies will depend on the hazards present and the risks they pose if power to the main fan is lost.

72 The hazards that might result from a main fan stoppage include:

- flammable gases in dangerous concentrations, including the risks posed by degassing operations;
- high concentrations of toxic or suffocating gases;
- lack of oxygen; and
- excessive temperatures/humidity.

73 The greater the hazards and risks, the more secure power supplies should be.

74 The following paragraphs give guidance on electrically driven surface fans, booster fans and auxiliary fans and will apply depending on the circumstances at a particular mine.

Surface fans

75 If a continuously running surface fan is needed to maintain a safe mine atmosphere, a standby fan is strongly recommended. A standby fan will ensure the continuity of ventilation, and normal working, if the main fan breaks down.

76 Where there are both main and standby fans there should, if possible, be a separate power supply to each of them. This will greatly reduce the chance of a total loss of supply due to a single cause and therefore increase the likelihood that one fan can be run.

77 There are a number of ways of providing separate supplies to the main and standby fans. These include:

- using different distribution boards and separate buildings for housing the equipment;
- splitting a single distribution into two with a bus section switch between them; and
- providing another power supply source, eg diesel generator.

78 Ideally the standby fan should have the same capacity as the main fan. Both the main fan and the standby fan need to be used as the duty fan at suitable intervals to ensure the reliability of both.

79 Where a fan is sited in a remote location and is unattended, consider providing automatic or remote restarting, particularly if conditions in the mine could rapidly deteriorate in event of a stoppage.

80 Where fan monitoring circuits are provided (eg for vibration or temperature), they should be set to give warning rather than to trip the fan. Arrange to provide the warning to a person who can take or initiate corrective action.
The fan should only trip when the monitoring indicates that there is a risk of severe damage to the fan or some other danger, eg causing a fire in the roadway.

81 To reduce the potential for serious damage, set up main circuit-breaker electrical-protection circuits to remove power as quickly as possible under electrical power fault conditions. At the same time take care that electrical protection circuits do not spuriously trip surface fans in the event of transient supply disturbances.

82 'Fan-running' and 'fan-stopped' indicators may provide additional safety and efficiency benefits. If they are provided, site them at places where they can be seen by persons who can take action or initiate remedial action.

Booster fans

83 Underground booster fans are provided to boost, and sometimes to redirect, the quantity of air drawn into the mine by the main fan.

Prevention of recirculation
84 Where booster fans are provided, a system of management control, or some form of electrical interlocking, will need to be put in place to ensure that no recirculation occurs if the main fan stops.

Provision of a dedicated feeder system
85 The reliability of underground booster fans can be greatly improved by providing a dedicated feeder system, as this reduces the risk of power loss due to faults on other non-safety critical equipment. It is better for the dedicated supply to start at the mine surface and include its own dedicated shaft or drift feeder. If circumstances make this impractical, the dedicated supply will need to start from a main pit bottom substation. Providing the means to connect onto a standby supply may also prove useful in the event of a major failure in the normal dedicated booster fan supply.

86 Some booster fans operate under a notice of approval served on the manager by an inspector under regulation 19(1)(a) of the Coal and Other Mines (Ventilation) Regulations 1956. Such an approval allows the interval between fan examinations and water gauge readings to be extended beyond 30 minutes. A key condition of such approvals is that fans are equipped to be continually

monitored at some remote location, usually the surface control room. In these circumstances, it is better to arrange all safety critical protective trips and interlocks to operate locally at the fan site. This will avoid a fan stopping or tripping if monitoring information is temporarily lost. If fan monitoring information is lost for 30 minutes or more at safety lamp mines, a condition of the approval cannot be met and managers must put into place arrangements to ensure that the person in charge of machinery driving such a fan examines it at least half-hourly and reads the water gauge.

Surface restarting and automatic restarting of booster fans

87 Restarting booster fans automatically or from the surface can significantly improve the reliability of a mine's ventilation system. Such facilities make it possible to re-establish ventilation quickly once power is restored.

Manager's rules

88 Where surface or automatic restarting facilities are provided, the manager should make rules appropriate to each installation.

Provision of equipment

89 Providing a surface restarting facility is straightforward for booster fans which are already fully monitored and supervised.

90 Where booster fans are not remotely supervised and do not incorporate full monitoring, providing an automatic restarting facility is less complicated than providing a surface restarting facility.

91 Suppliers can advise on the electrical equipment needed to provide either surface or automatic restarting facilities.

Monitoring and control

92 In either case, arrange the control equipment to prevent any fan restarting if:

- the firedamp concentrations in the general body of air at the fan installation exceeds 1.25% by volume limit prescribed by law;
- any of the electrical equipment has tripped because of electrical power fault conditions such as short circuit, earth fault, or overload; or
- any other main ventilating machinery needs restarting beforehand.

93 Arrange other protective equipment, such as:

- vibration monitoring;
- water curtain; and
- emergency stop switches

to minimise the chance of them leading to an unnecessary fan stoppage.

Other equipment for automatic restarting

94 Fans with an automatic restart facility also need:

- an interlock to prevent them restarting automatically after a predetermined time period has elapsed. The manager should determine a time period for each booster fan site; and
- their automatic mode/non-automatic mode selector positioning to prevent unauthorised interference or tampering.

95 Where booster fans with an automatic restarting facility are monitored to a control station, arrange the automatic restarting facility to operate through local circuitry. It should not depend on a data link to the control station.

Other equipment for surface restarting

96 Where booster fans have a surface restarting facility, the control equipment needs to include a surface/local start selector, suitably protected against unauthorised interference or tampering.

Notices and diagrams

97 Readily available, simple and easy-to-follow diagrams should identify safety critical parts of the control equipment, such as interlocks, and indicate how they should operate in normal circumstances.

Auxiliary ventilation

98 Auxiliary fans are usually provided to ventilate single entry workings to avoid the build-up of hazardous concentrations of gases or dust.

99 Where mechanical failure of an auxiliary ventilation fan could result in a danger from fire, then the fan should be designed to a suitable standard to use non-sparking mechanical components.

Interlocking in blind ends

100 The mine owner's operating rules for the ventilation of blind ends (which must be made under regulations 3 and 4 of the Coal Mines (Owner's Operating Rules) Regulations 1993) will require that when an auxiliary ventilating system is installed it must remain operational as far as practical. The rules will also require that planned changes are organised to achieve this and that inspection and maintenance must be arranged with minimum interruption to the system (paragraph 11(e) of Model Rules on the ventilation of blind ends). Compliance with this rule will minimise the nedd for degassing operations.

101 The owner's operating rules on the ventilation of blind ends will also require that where blind ends are ventilated by electrically driven auxiliary fans the electrical power supply to the blind end must be interlocked with the power supply to the auxiliary fan(s) (paragraph 18(1)(a) of the Model Rules). Under the rules, interlock arrangements must be such that the power supply to the blind end is automatically isolated if the contactor(s) controlling the supply of electricity to the auxiliary fan(s) ventilating the blind end is/are open.

102 Where auxiliary ventilation is by means other than auxiliary fans, for example by pressure differential between intake and return, control equipment must be arranged to automatically isolate the power supply to the blind end if the quantity delivered to the face of the blind end is less than the minimum specified in the Manager's Auxiliary Ventilation Rules.

103 The power supply to any electrically powered auxiliary ventilation system should also be capable of being maintained while the power supply to all, or any of, the other plant installed in the blind end is isolated.

Firedamp, airflow and air pressure monitors

104 Environmental monitors, such as firedamp, airflow or air pressure transducers, can enhance the safety of persons working in blind ends.

105 To achieve this, configure the monitoring system to provide a suitable alarm to a person who will then be able to respond if the air flow falls below the minimum

specified by the manager. For example, an alarm might be generated in a surface control room, or at some manned point below ground.

Integrity of HV supply to the fan site

106 If possible, connect the transformers used to supply auxiliary ventilation equipment to a dedicated feed derived from an HV distribution point supplied by more than one feeder. If this is not possible, minimise the number of intermediate switching points between the HV distribution point and the transformer.

General electrical principles

107 It is recommended that the supply to auxiliary fans is derived from a dedicated transformer different to those feeding production equipment.

108 Where the auxiliary ventilating fan and blind heading equipment are supplied via the same transformer, take additional measures necessary to minimise disruption of the auxiliary ventilation due to faults elsewhere. Such measures could include:

- dual outlet transformers with two circuit breakers, one supplying the heading and the other the fan circuits;
- the use of 'single point earthed' sensitive core balance earth leakage protection systems rather than the 'multi-point earthed' systems which are more prone to sympathetic tripping;
- time discrimination on the earth leakage circuits of the auxiliary fan switchgear where 'multipoint earthed systems' have to be used;
- an automatic restarting facility to operate in the event of non-related spurious trips; and
- connecting only low voltage circuits to the common busbars (for example, only signalling and lighting circuits which are unlikely to reflect any earth faults back to the main transformer circuits).

Automatic or remote restarting of auxiliary fans

109 Automatic or remote restarting of auxiliary fans can significantly reduce the time taken to restore ventilation to blind ends following a power loss. This will reduce the chance of flammable gas building to dangerous concentrations. Automatic restarting is preferred to remote restarting as the latter depends on data/control links to the remote station and is therefore less reliable.

General requirements

110 Arrange the interlocks and control arrangements to facilitate any degassing operations that may be necessary.

111 The control switchgear should permit the gradual pressurisation of forcing auxiliary ventilation systems, to minimise the chance of flat-lay ventilation ducting blowing apart as it is repressurised.

112 It is good practice to use bolted-type cable entries on fan circuits. If using restrained plug and socket assemblies, lock them into place to prevent unauthorised swapping of cables or changes to the ventilating system interlocking arrangements.

Further provisions for automatic restarting

113 Automatic restart will need to be inhibited where more than 1.25% by volume of firedamp, or potentially hazardous concentrations of other flammable gases, may be drawn through the fan. Automatic restart may be inibited at lower concentrations of gases specified by the manager.

114 The manager will need to:

- ensure that appropriate interlocks and monitors are provided at each site; and
- specify warning, alarm and, where appropriate, trip levels taking into account conditions pertaining to that particular site.

115 Automatically restarting exhausting fans presents a higher risk than automatically restarting forcing fans. Make sure that control measures are in place to prevent unacceptable concentrations of flammable gases from being passed over the fan blades when exhausting fans are equipped with an automatic restart facility. In most cases this will involve the use of a flammable gas monitor sited inside the ventilation duct close to the inbye end.

116 To further reduce the possibility of high flammable gas concentrations passing over the fan blades, the protective measures should also include an interlock to prevent automatic restarting after a fan has not run for a period of time determined by the manager.

117 Provide a system of control to prevent an auxiliary fan automatically restarting where recirculation might occur if the main or booster fans are not operating.

118 Fans equipped to restart automatically will need to be protected by latching-type overload protection.

119 Control switches or links used to select automatic or manual operation should be protected against unauthorised interference.

120 Wherever possible provide the automatic restart facility, including all interlocks, through local switchgear so that it does not depend on data transmission links to the surface.

121 Where an automatic restart facility is provided there should at least be an indication at the mine surface that the fan is ‘Operating’ or ‘Stopped’.

122 A notice will need to be displayed at the fan site to warn that the fan may restart automatically.

Further provision for remote restarting
123 Where remote starting is provided, provide a switch on site to enable an authorised person or official to select local start mode of operation.

Maintaining reliability of auxiliary fans and small booster fans (up to 112kW)
Installation and maintenance

124 To comply with the requirements of regulation 11(1) of the Management and Administration of Safety and Health at Mines Regulations 1993, managers must ensure that all plant and equipment, including fans, are properly installed and commissioned by suitably qualified and competent persons before being brought into service. They must also be periodically inspected, examined, tested and maintained thereafter. The sorts of fan tests recommended include:

- vibration spectrum analysis after installation or re-siting underground and at intervals not exceeding 6 months; and
- fan blade clearance checks, after each installation or re-siting underground, or in any case at intervals not exceeding one year.

125 If the tests show deterioration or impending failure, the fan will need to be withdrawn from service.

Full continuous monitoring

126 The best way of protecting both the fans and the health and safety of persons in the mine is to provide comprehensive continuous monitoring, preferably indicating to a permanently staffed place on the surface. The coverage of such monitoring might include:

- a 'running/stopped' indicator which alarms whenever a fan stops;
- excessive vibration capable of detecting imbalance in the rotating parts and monitoring the running condition of bearings;
- bearing surface temperature set to alarm in the event of a rise of 10ºC above normal running temperature occurring and set to trip the fan at 90ºC. The most appropriate sensors are those which monitor the temperature as close as possible to the bearing surface;
- firedamp concentration and air flow; and
- smoke/fire detectors in the centre of the airstream in the vicinity of the fan.

Partial monitoring

127 Where an auxiliary fan is fitted with continuous vibration monitoring, but no other devices, the intervals between fan blade clearance checks can be extended but should not exceed 12 months. The interval between major overhauls can also be extended but should not exceed three years.

No monitoring

128 Where an auxiliary fan is not monitored, it should:

- have a vibration spectrum analysis made and fan blade clearance check on initial installation, or following reinstallation, and subsequently every three months;
- be attended when it is running; and
- have a major overhaul for every two years' service.

Standby ventilation

129 It is good practice to provide standby ventilation equipment, such as air movers or compressed air fans, or to arrange an auxiliary ventilation system such that a proportion of main fan pressure is available. Where such facilities are not provided, draw up contingency plans for re-establishing, without undue delay, the power supply to the fan in the event of failure of any single line supply components.

Winding equipment

Requirements for the availability of exits from the mine

130 Regulation 3(2) of the Mines (Safety of Exit) Regulations 1988 requires mine managers to ensure so far as practicable that there is available at least one exit from the mine, and, so far as is reasonably practicable, two separate exits. The power supplies to each winding apparatus will therefore need to be as secure as is practicable to make them.

131 Where possible, provide a separate power supply to each winding apparatus. This will reduce the risk of both engines failing due to one cause. Where there are only two means of escape there is probably a need to duplicate the power supplies, and to segregate each supply to a different distribution board and/or use separate buildings for housing the equipment, so that no single failure will adversely affect the operation of both engines.

132 Alternatively another supply source, eg from a standby generator, may provide the required security.

133 There will also be a need to ensure that certain 'associated parts' of the winder and shaft side equipment can be operated if the main power supply to the mine is lost (for example shaft side interlocks, shaft signals, and communications).

134 Where safety-related winding functions rely on a compressed air supply there will also be a need to have ready an alternative supply of compressed air, for example from an emergency air compressor.

135 When for some reason a wind has not been completed and people are held in the shaft for prolonged periods, in-cage communication systems can reduce stress and assist their safe recovery. Power supply to such equipment will also need to be kept in serviceable condition.

Facilities to cater for breakdown of apparatus

136 Regulation 4(1) of the Mines (Safety of Exit) Regulations 1988 requires mine owners to provide suitable and effective auxiliary apparatus and equipment to enable persons to gain exit to the surface safely in the event of a breakdown of the normal winding apparatus.

137 Foreseeable circumstances when the normal winding apparatus might not be available include:

- a widespread power failure to such an extent that it becomes necessary to evacuate persons from the workings;
- a breakdown of the winding apparatus which makes it necessary to complete the wind using an alternative means to the main winding apparatus;
- a hold-fast or immobilisation of a conveyance in the shaft; and
- the need for persons working or travelling in the mine shaft to leave in an emergency.

138 Some of the recognised methods of providing the required auxiliary facilities are:

- gravity winding apparatus;
- an independent 'pony motor/engine' driving the main drum;
- mobile emergency winder; and
- any standby power supply necessary to operate equipment such as shaft signals and shaftside interlocking systems.

Auxiliary 'pony' drive

139 In the case of auxiliary 'pony' drives, the mine owner will need to ensure that:

- its source of power is independent of the power source to the winding engine; and
- it is capable of driving the main drum or rope sheave in the worst case out-of-balance condition.

Gravity winding

140 Gravity winding usually involves placing water tanks on the uppermost conveyance to increase its weight. The out-of-balance load is used to raise the lower conveyance in controlled manner. Even though the winder requires no electrical power to move, a power supply may still be needed for:

- the winder's hydraulic or pneumatic brakes;
- certain winder controls including safety circuits;
- water pumps to get water to the gravity winding tanks;
- communications; and
- shaft signals.

Testing of auxiliary pony drive and gravity winding systems

141 Both the gravity winding and pony-drive facilities need periodic checking and frequent operation to ensure that they are available and ready for use when needed. Ideally, there should be a full mock test at least every 12 months.

142 Such tests present an opportunity for training new staff and re-training existing staff of the procedures required by manager's rules made under Regulation 4(2) of the Mines (Safety of Exit) Regulations 1988.

Diesel-driven emergency generators

143 A diesel-driven emergency generator can provide a power source which can be connected onto the appropriate distribution board(s) (Figure 4).

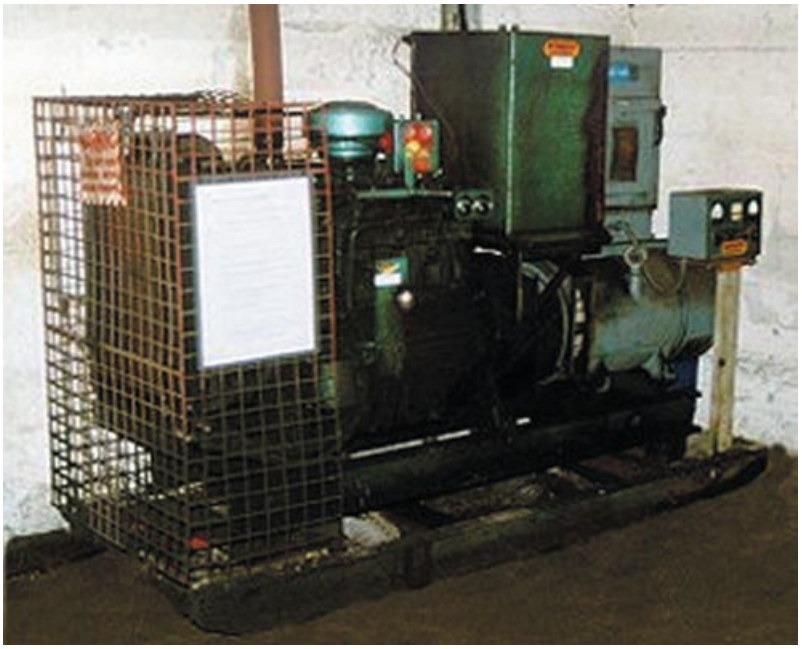

Figure 4 An emergency generator used to release the winding engine's brakes during gravity winding

144 At mines with a.c. winders and dynamic braking, select a higher-power emergency generator which is capable of operating the winder's dynamic braking circuit. This will give better speed control of the conveyances during gravity winding and removes the need to depend totally on the winding engine's mechanical brakes. Where the generator does not have sufficient power to enable dynamic braking, consider the need to provide additional cooling for the brake paths.

Mobile emergency winders

145 A mobile emergency winder can usually be made available within approximately two hours of a request. To fully meet their responsibilities under regulation 4(1) of the Mines (Safety of Exit) Regulations 1988 to ensure that auxiliary apparatus is effective, mine owners must ensure that adequate preparations are made so that a mobile emergency winder can be put to immediate use on arrival.

146 Measures to be in place for each shaft will include:

- a detailed set-up procedure. This should be readily available at the mine at all times. The manager should ensure that everyone who might play a role in setting up an emergency mobile winder understands the procedure;
- a concrete pad or hard-standing with suitable anchor points for any mobile emergency winder that may arrive;
- electrical earthing facilities for the mobile generator;
- power supply for the signalling systems;
- trained persons who are competent to set up and commission the mobile emergency winder;
- trained persons who are competent to drive the winder and to take charge of use of the kibble; and
- a suitable mains power supply.

147 A full emergency mobile winder test should ideally be undertaken at each shaft at least every five years.

Power supplies to de-watering and firedamp drainage plant and equipment

148 Where there is a risk of water or firedamp entering the mine, and drainage systems have been provided as part of the control measures, steps similar to those described for ventilating fans and winding engines may be needed to ensure continuity of the power supply to the drainage equipment and its associated instrumentation and monitoring.

Monitoring and control systems

General

149 Environmental monitoring can provide valuable quality information, warnings, alarms and controls. It can improve the protection of the health and safety of workers below ground by giving early warning of when things are going wrong. It is also useful in providing information on the underground environment at times when no-one is below ground.

150 It is preferable that the computers and data highways forming part of the environmental monitoring system are independent of other systems. The best arrangement is one which provides for separate hardware, separate data transmission cables and separate out-stations.

151 A back-up power supply will be needed to maintain the operation of transducers and associated data transmission systems for as long as possible after interruption of the mains supply to the mine. For this purpose standby batteries may be necessary. Where standby batteries are provided below ground in places where firedamp levels can exceed 1.25% by volume in the general body of air, they should be certified as being intrinsically safe to category ‘ia’ (ie safe with more than one fault on the circuit) and approved by HSE.

152 To ensure that environmental monitoring systems are properly designed, installed and operated, managers need to draw up rules including coverage, as appropriate, of:

- the levels at which any warnings, alarms or trips should occur;
- persons responsible for ensuring that the settings are maintained at those levels;
- persons responsible for siting, setting, inspecting, examining, testing and maintaining transducers, and
- the means to maintain the operation of transducers and the data transmission system for as long as possible after interruption of the mains supply to the mine.

153 System cabling and configurations will need to be in accordance with any certification requirements and in particular any special conditions included in the certification. Certificates having special conditions attached have an 'X' mark after the certificate number. In such circumstances, users will need to establish from the manufacturer what the special conditions of use are.

154 Electrical systems feeding transducers sited in auxiliary ventilated headings are best supplied from an intake airway. It is preferable to obtain this supply from a highly reliable source outbye of that feeding the associated heading ventilation equipment.

Maintenance

155 Maintenance checks will need to include testing the operation of battery changeover arrangements and the battery condition.

156 Back-up power supply batteries are normally continuously trickle-charged and checks need to be made to determine a back-up battery's ability to store its charge, by disconnecting the charging supply. Replace batteries when they can no longer store sufficient charge to maintain the supply for a specified period.

157 Arrangements to prevent tripping of fans or electrical systems during testing will need to be protected against unauthorised operation and designed to prevent them being left in the override position.

158 Where the heading power supply is interlocked to the environmental monitoring systems, an indication of the reason for automatic cut-off of the supply will need to be provided at the location of the associated switchgear.

Auditing

159 Mine managers will need to ensure that the whole underground environmental monitoring system at the colliery is audited on at least an annual basis. Audit arrangements should include:

- identifying or confirming which transducers are safety critical;
- considering whether they are correctly sited;
- assessing whether the trip or alarm settings are appropriate for the circumstances; and
- checking that power supply arrangements are secure.

Communications systems

Main underground telephone system

160 When making an assessment of what is required, take account of those circumstances which could interfere with the mine's emergency procedures, such as disruption of the mine's main telephone system.

161 The main causes of telephone system disruption include direct loss of electrical power and/or overloading of the system, eg when many persons attempt to contact a particular location or gain information about an occurrence simultaneously.

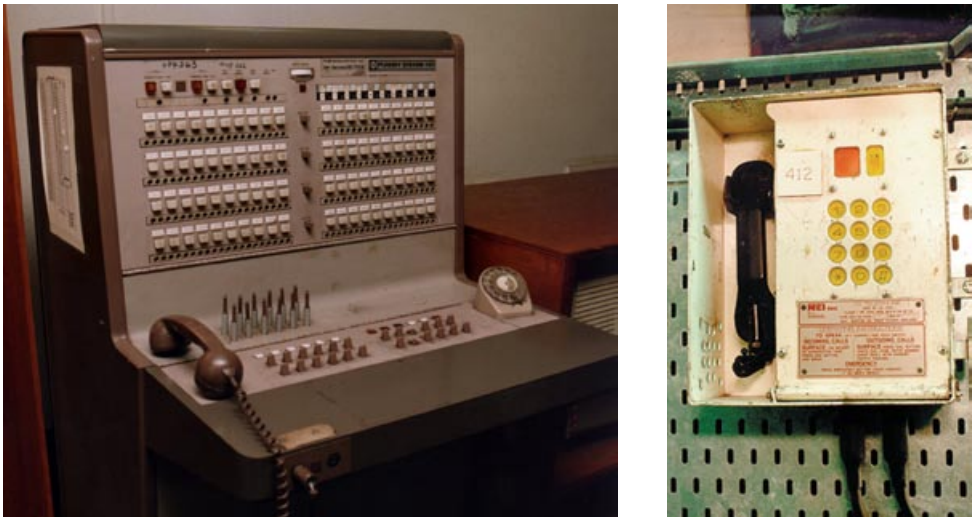

Figure 5 A typical 'telephone emergency desk' installed in an incident control room and intrinsically safe telephone installed underground

162 For mines with complex underground workings inter-connected by automatic telephones, consideration should be given to installing a 'telephone emergency desk'. Such a desk will need to:

- be able to be manned in an emergency;
- have routed though it all of the important telephone lines;
- have a facility to override an existing conversation on an engaged automatic line; and
- prevent unwanted calls to a specific telephone(s), usually at the incident site.

163 An assessment will also be needed as to the ease and availability of contact with outside emergency services, such as the fire authority, ambulance service and police. In many cases, the provision of at least one continuously available mobile telephone or radio telephone can provide the necessary back-up to the mine's normal telephone system.

Further information

For information about health and safety ring HSE's Infoline Tel: 0845 345 0055 Fax: 0845 408 9566 Textphone: 0845 408 9577 e-mail: hse.infoline@natbrit.com or write to HSE Information Services, Caerphilly Business Park, Caerphilly CF83 3GG.

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