BS 8519:2010

BSI Standards Publication

Selection and installation of fire-resistant power and control cable systems for life safety and fire-fighting applications – Code of practice

Publishing and copyright information

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ISBN 978 0 580 64469 6

ICS 13.220.20, 29.060.01

The following BSI references relate to the work on this standard:
Committee reference FSH/1
Draft for comment 09/30189450 DC

Publication history

First published as BS 7346-6, March 2005
First published as BS 8519 (present edition), February 2010

Amendments issued since publication

Date	Text affected

Contents

Summary of pages
This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 26, an inside back cover and a back cover.

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Foreword

Publishing information

This British Standard is published by BSI and came into affect on 28 February 2010. It was prepared by Technical Committee FSH/1, *Fire safety cables*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 7346-6:2005, which is withdrawn.

Information about this document

This is a full revision of BS 7346-6, and introduces the following principal changes:

- change of identifier;
- change of scope;
- change from a specification to a code of practice;
- removal of Annex B (now published separately as BS 8491);
- expansion of content to include all life safety/fire-fighting systems (not only smoke venting and fire-fighting cores as in the previous edition);
- inclusion of new and revised technical guidance relating to the selection and installation of fire-resistant cables and systems for life safety and fire-fighting applications.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

The word "should" is used to express recommendations of this standard. The word "may" is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the clause. The word "can" is used to express possibility, e.g. a consequence of an action or an event.

Notes and commentaries are provided throughout the text of this standard. Notes give references and additional information that are important but do not form part of the recommendations. Commentaries give background information.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Introduction

High rise and complex buildings have developed in terms of increased size, height and complexity of active fire protection. This has allowed fire engineered solutions to be developed which require a high level of performance from the components of the building services, including the electrical supplies. This British Standard is primarily intended for designers, contractors, fire engineers, regulators and enforcers including building control bodies, fire authorities and health and safety inspectors.

This British Standard does not cover cables for property protection and business continuity, but its provisions might be of use when planning property protection and business continuity systems.

This British Standard identifies those electrical loads defined as life safety and fire-fighting loads. It lists the factors to be considered by the engineer when selecting and specifying the performance requirements of the electrical distribution system needed to maintain integrity under defined fire conditions for a specified period, referred to as the fire survival time.

It makes reference to the recommendations identified in BS 9999, with regard to the design and installation of the electrical distribution systems for life safety and fire-fighting equipment.

It also makes reference to three categories of circuits required to maintain their circuit integrity under defined fire conditions for varying fire survival times of 30 min, 60 min and 120 min. Appropriate cable tests are identified for each category derived from applicable British Standards that assess cable performance under conditions of fire as might be expected in an actual fire incident.

This British Standard aims to ensure that the level of circuit integrity is not compromised by other components of the whole electrical distribution system, including cable glands, terminations, joints and cable support systems.

It covers:

- the source of supply;
- the distribution voltage [high voltage (HV) or low voltage (LV)];
- the appropriate location of the main intake enclosures, HV switchrooms, LV switchrooms, transformer rooms, generator rooms, risers, fire life safety plant rooms and fire-fighting/evacuation lift motor rooms/shafts.

It also identifies the need for dual redundant electrical supplies run via diverse cable routes, installed within separate fire compartments, and the need to incorporate automatic changeover devices, located within the same fire compartment as the life safety and fire-fighting equipment.

1 Scope

This British Standard gives guidance and recommendations on the selection and installation of power and control cable systems which are required to maintain their circuit integrity for life safety and fire-fighting applications. It also gives specific recommendations for electrical system design for such applications, and recommended limits for survival times.

This British Standard does not give recommendations for those installations covered in BS 5839-1, BS 5839-8, BS 5839-9 and BS 5266-1, but makes reference to these standards in an informative capacity.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 7671, *Requirements for electrical installations – IEE Wiring Regulations – Seventeenth edition*

BS 8434-2:2003+A2:2009, *Methods of test for assessment of the fire integrity of electric cables – Part 2: Test for unprotected small cables for use in emergency circuits – BS EN 50200 with 930° flame and with water spray*

BS 8491, *Method for assessment of fire integrity of large diameter power cables for use as components for smoke and heat control systems and certain other active fire safety systems*

BS EN 1366-5:2003, *Fire resistance tests for service installations – Part 5: Service ducts and shafts*

BS EN 13501-2:2007+A1:2009, *Fire classification of construction products and building elements – Part 2: Classification using data from fire resistance tests, excluding ventilation services*

BS EN 50200:2006, *Method of test for resistance to fire of unprotected small cables for use in emergency circuits*

BS EN 60529:1992, *Specification for degrees of protection provided by enclosures (IP code)*

BS EN 60947 (all parts), *Low-voltage switchgear and controlgear*

3 Terms and definitions

For the purposes of this British Standard, the following terms and definitions apply.

3.1 fire-resistant cable
cable able to maintain circuit integrity for a stated period of time and under conditions as defined in a standard test

3.2 substation
subsidiary station of an electricity generation, transmission and distribution system where voltage is transformed from high to low or the reverse using transformers

4 General

The electrical distribution system should be designed and installed by a competent person as defined in BS 7671.

The electrical arrangements should conform to BS 7671 and the appropriate parts of BS EN 60947.

The type of electrical distribution system selected during the design phase should be derived from a detailed process of consultation with the relevant authorities having jurisdiction over the project in question. The design should be agreed at an early stage.

5 Fire survival times

The type of electrical distribution system used to supply life safety and fire-fighting systems should meet the following criteria.

a) For life safety systems, the system should be capable of remaining operational to allow the building occupants to be alerted, evacuated and protected in their escape from the building for:
   - 60 min for large and/or complex buildings;
   - 30 min for other buildings.

b) For fire-fighting systems, the system should be capable of maintaining functionality to serve active systems for protecting and assisting fire-fighters in their role for 60 min or 120 min, depending on the specific fire-fighting application. The system would typically include pressure differential systems for fire-fighting, smoke and heat exhaust ventilation, sprinklers, fire-fighting lifts and wet fire main systems.

*NOTE See also Clause **11**.*

6 Power supplies

Where electrical services in the building are essential to maintain the operation of the life safety and fire-fighting systems, a secondary power supply, e.g. an automatically started standby generator (see Figure 1) or an alternative utility supply (see Figure 2) from another external substation, should be provided which will, independently of the primary supply:

a) be of sufficient capacity to maintain any system in operation for at least the fire survival time identified in Clause **5** for the appropriate system and type of building; and

b) be capable of operating safely in fire conditions for the appropriate period of time.

Figure 1 **Example of dual supply – Mains with standby LV generation**

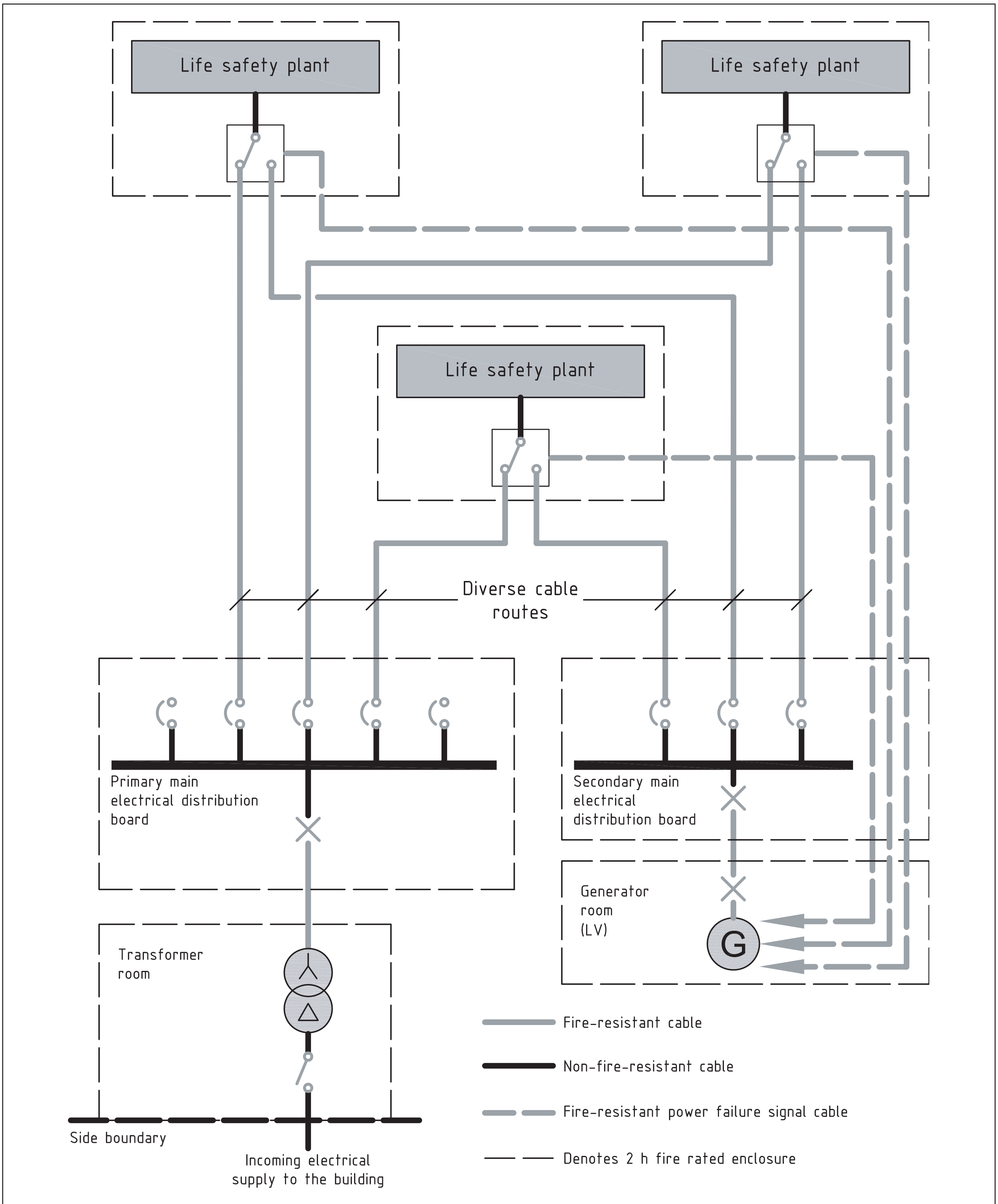
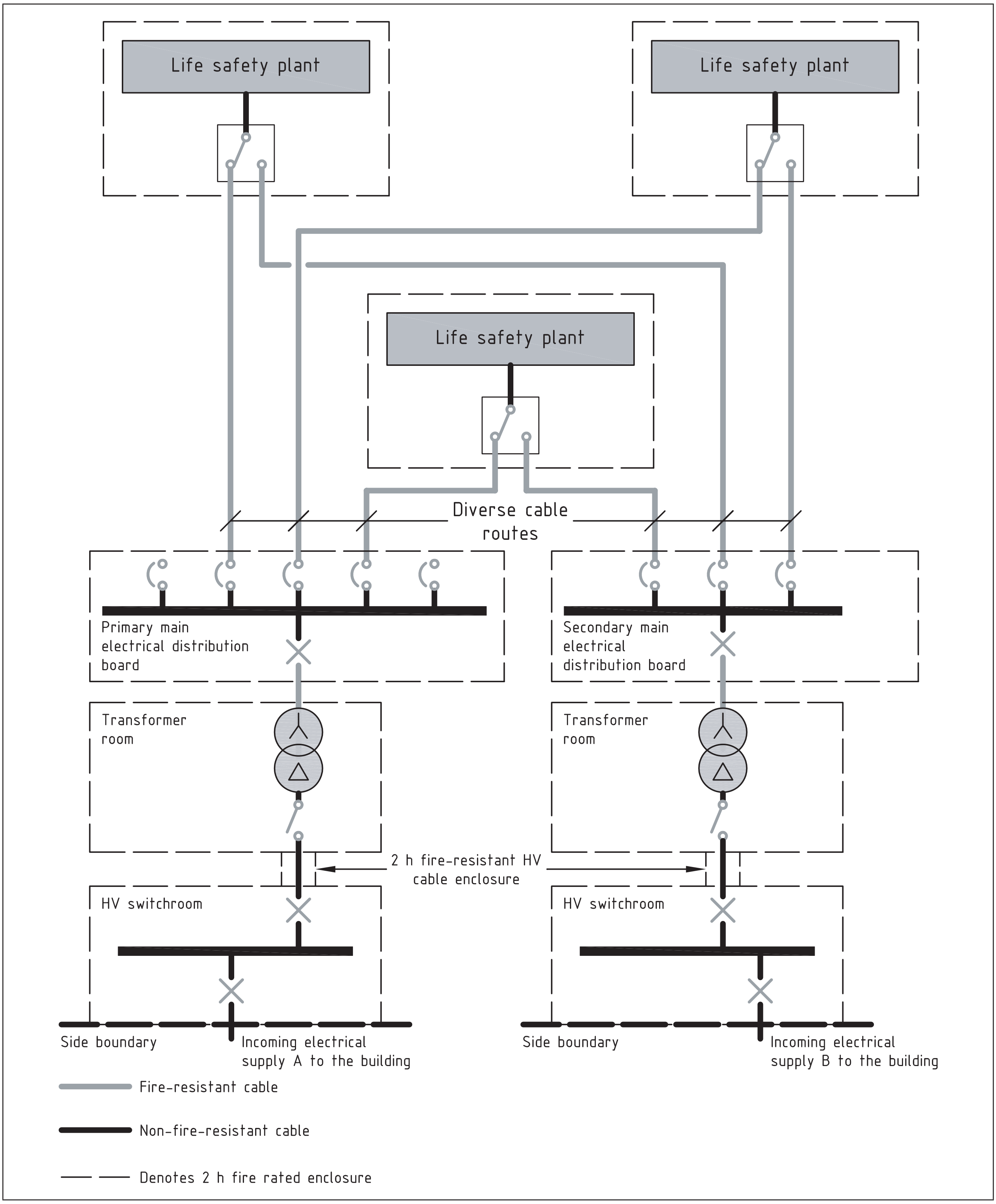


Figure 2 **Example of dual supply – Mains with standby primary utility supply**



Each connection to the power supply should be via an isolating protective device reserved solely for the life safety and fire protection equipment and independent of any other main or sub-main circuit. Such isolating protective devices should be clearly labelled and identified as to their purpose and should be secured against unauthorized operation.

The primary and secondary power sources, electrical distribution board, cables and control equipment supplying power to the life safety and fire-fighting equipment (see Figures 1 and 2) should be protected against fire and water damage for a period of at least the fire survival time identified in Clause **5** for the appropriate system and type of building. Any structural enclosure for the equipment should have a minimum fire resistance of 2 h (see BS 9999).

The primary and secondary supplies should be separated from each other so that a failure in a cable or equipment, either by mechanical breakdown or damage by fire, in either supply does not affect the other supply.

The electrical distribution system supplying the life safety and fire-fighting equipment should be designed in such a way as to ensure that power is available at all times. In order to achieve this, dual supplies should be provided, to each of the critical systems, via an automatic changeover device, installed within the protective enclosure of the critical equipment.

NOTE 1 The primary supply is generally derived from the mains or utility supply, whilst the secondary supply is derived from either a standby generator or an independent secondary mains supply.

Where there is a need to install two independent incoming mains supplies, with one operating as a standby to the other, the arrangement should be configured to ensure that a single external incident, such as a cable fault, does not result in the loss of both supplies. For instance, the two supplies should not be connected to a single external supply cable running adjacent to the site at opposite ends of the site, as a single cable fault would result in the loss of supply to the critical load.

The standby generator should start automatically and be adequately sized to maintain in operation the maximum life safety and fire-fighting load for at least 3 h without the need to replenish the fuel. The generator starting electrical supply should also be independent of the primary source of supply (i.e. it should incorporate a battery backup).

The standby generator should be capable of providing the supply to the critical life safety and fire-fighting load within 15 s of the failure of the primary supply.

Where the secondary electrical supply is to be derived from an independent utility supply from that supplying the primary electrical supply, the following criteria should be met.

1) The electrical supplies should be taken from two separate high-voltage supplies, and not originate from the same source of supply.
2) The failure of one source of supply should not lead to the failure of the other.
3) The two independent sources should be adequately separated. Where the supply intake rooms are located within the building they serve, the following criteria should be met.

i) Each intake room should be enclosed within a fire-resisting structure having a minimum of 2 h fire resistance.

ii) The two intake rooms should be located in two separate parts of the building.

4) Supply cables should where practicable enter directly the high voltage/low voltage switchrooms and not pass through the building. Where high voltage supply cables have to be routed through the building, the high voltage cable routes should be fire protected for the period recommended in Clause **5** for the appropriate system and type of building. This may be achieved in one of the following ways:

   i) enclosed for their entire length by passive fire protection material giving 2 h fire resistance (see Clause **12**);

   ii) routed within a dedicated shaft or void of the appropriate fire rating;

   iii) installed within a concrete trench with concrete cover.

   Due account should be taken of the reduction in the current rating of cables which occurs when they are enclosed. If necessary, the cable manufacturer should be consulted. For cables installed within an enclosure of passive fire protection material, no ratings have been published but a derating factor of 50% is generally considered appropriate and should be used unless the manufacturer of the protective system is able to verify a different figure for their particular system.

   NOTE 2 For cables installed within a concrete trench, derating factors were published in BS 7671:2001, which has now been withdrawn.

   An example of a cable size calculation is given in Annex A.

5) The two supply cable routes should be adequately separated from each other to avoid a single fault affecting both supplies.

Whichever secondary power source is provided, the distribution should be organized such that the secondary supply remains live when the remainder of the supplies in the building are isolated in an emergency.

7 Dual circuits/diverse routes

A fundamental principle of this British Standard is that both the primary and the secondary supplies should be protected against fire and water damage (see Clause **6**) and separated from each other by adopting diverse cable routes.

The diverse cable routes for the power supplies should be separate from any non-life safety/fire-fighting system circuits that could be detrimental to the operation of the life safety and fire-fighting system circuits.

Where the HV supply cables from the intake rooms have to be routed through the building to HV switchrooms and transformer rooms, both the primary and secondary supply cables should be protected against the risk of damage by exposure to fire and water.

When designing diverse cable routes, account should be taken of any fire risks located within the area of the cable route. Where the diverse routes come together in the same area, they should be separated from each other by a partition with a fire resistance period of at least the fire survival time identified in Clause **5** for the appropriate system and type of building.

In the case of two low voltage cables (i.e. 400 V 3-phase), the cables should be selected for the appropriate fire survival time (see Clause **11** for cable selection and Clause **5** for fire survival times).

8 Fire protective enclosures for equipment

Any electrical substation or enclosures containing any of the following equipment should be separated from the building by construction protected against fire and water damage for a period of at least 2 h:

- distribution boards;
- motor control panels;
- smoke control plant;
- pressurization plant;
- communication equipment;
- automatic changeover devices, with their associated switchgear;
- any other equipment associated with life safety and fire-fighting systems.

9 Automatic changeover devices

The primary and secondary power supply cables should be terminated via a changeover device (automatic transfer switch or similar) located within the plant room(s) housing the life safety and fire-fighting equipment, or in the case of a fire-fighting lift, within the fire-fighting shaft.

The changeover device should automatically effect the transition from the primary to the secondary power supply in the event of the loss of the primary supply to the plant.

Changeover devices should conform to BS EN 60947-6.

Where the availability of the life safety and fire-fighting equipment is conditional to the occupation of the building, a bypass arrangement should be incorporated to enable the changeover device to be maintained without loss of service from the critical plant.

10 Motor control panels

Control panels serving the appropriate life safety and fire-fighting circuits should be protected to IP54 classification as specified in BS EN 60529:1992.

If a fire control room is provided, it should contain monitoring facilities to show, as far as is reasonably practicable, that power is available up to the final control point, e.g. motor control panel.

NOTE The regulatory authorities will usually require exact details of all switchboard, automatic transfer switches and standby generator enclosures (including oil storage) associated with life safety systems to be submitted for approval, including location, ratings, operation, fire rating proposals and protection afforded.

11 Cable selection

The cables selected for life safety and fire-fighting systems should be either:

a) fire-resistant cables meeting the minimum fire survival time categories for the appropriate application as shown in Table 1; or

b) non-fire-resistant HV cables, having protection as described in Clause **12**.

NOTE 1 The authorities having jurisdiction in the area of construction might specify a particular category to satisfy the requirements of the structure in its location.

The categories given in Table 1 are defined as follows, based on the fire survival time required of the cable (i.e. 30 min, 60 min or 120 min).

1) **Category 1: means of escape (30 min fire survival time)**. Category 1 cables should be one of the following:

   - power cables of 20 mm overall diameter and above meeting the 30 min survival time when tested in accordance with BS 8491 (see Note 2 for smaller cables); or
   - control cables meeting the PH30 classification when tested in accordance with BS EN 50200:2006, and the 30 min survival time when tested in accordance with Annex E of that standard (core sizes up to and including 4 mm^2 cross-sectional area).

2) **Category 2: means of escape (60 min fire survival time)**. Category 2 cables should be one of the following:

   - power cables of 20 mm overall diameter and above meeting the 60 min survival time when tested in accordance with BS 8491 (see Note 2 for smaller cables); or
   - control cables meeting the PH60 classification when tested in accordance with BS EN 50200:2006, and the 120 min survival time when tested in accordance with BS 8434-2:2003+A2:2009 (core sizes up to and including 4 mm^2 cross-sectional area), excluding 3-phase power circuits.

3) **Category 3: fire-fighting (120 min fire survival time)**. Category 3 cables should be one of the following:

   - power cables of 20 mm overall diameter and above meeting the 120 min survival time when tested in accordance with BS 8491 (see Note 2 for smaller cables); or
   - control cables meeting the PH120 classification when tested in accordance with BS EN 50200:2006, and the 120 min survival time when tested in accordance with Annex B (core sizes up to and including 4 mm^2 cross-sectional area), excluding 3-phase power circuits.

NOTE 2 Power cables of overall diameter less than 20 mm may be used if they can be demonstrated to give the same level of fire resistance as in BS 8491.

An application list is provided in the third column of Table 1, allowing the appropriate cable category for each application to be determined by the system designer/installer. Where a relevant application document exists, it is noted in the second column for reference.

Table 1 **Minimum fire survival time categories**

System	Related standards A)	Application	Minimum category
Fire alarms	BS 5839-1	Standard	(1) B)
	BS 5839-1	Enhanced	(3) B)
Communications	BS 5839-9	Disabled evacuation alarms (refuges)	(3) B)
	BS 5839-9	Emergency voice communication systems	(3) B)
	—	Closed-circuit television (CCTV)	2
	BS 5839-8	Voice alarm systems – standard	(1) B)
	BS 5839-8	Voice alarm systems – enhanced	(3) B)
Emergency lighting	BS 5266-1	Emergency escape lighting	(2) B)
	BS 5266-1	Escape route lighting	(2) B)
	BS 5266-1	Central battery and distribution	(2) B)
Sub-main power distribution (see Figure 1)	—	Fire-fighting applications	2
	—	Means of escape applications	1
Smoke and heat control:	BS 7346-7	Car park smoke control	3 C)
Fire-fighting	—	Wiring in other areas of special fire risk	3 C)
	prEN 12101-8 D)	Motorized fire and smoke dampers (MFSDs) – supply and control	3
	BS EN 12101-1	Smoke barriers – supply and control	3
	BS 8524 D)	Fire barriers – supply and control	3
	BS EN 12101-2	Natural smoke and heat exhaust ventilation systems (SHEVS) – supply and control	2
	BS EN 12101-3	Powered SHEVS – supply and control	2 or 3 E)
	BS EN 12101-1	Smoke curtains – supply and control	3
	BS EN 12101-3	Smoke fans	3
	—	Smoke shafts – controlled MFSDs	2
	—	Powered smoke shafts and controlled MFSDs	3
	BS EN 12101-6	Pressurization	3
	—	Fire-fighting systems activation and monitoring	2 or 3 F)
Means of escape	BS 7346-7	Car park smoke control	2
	—	Wiring in other areas of special fire risk	3 C)
	prEN 12101-8 D)	Smoke control dampers – supply and control	2
	BS EN 12101-1	Smoke barriers – supply and control	2
	—	Fire barriers – supply and control	2
	BS EN 12101-2	Natural SHEVS – supply and control	2
	BS EN 12101-3	Powered SHEVS – supply and control	2
	BS EN 12101-1	Smoke curtains – supply and control	2
	BS EN 12101-3	Smoke fans	3
	—	Smoke shafts – controlled MFSDs	2
	—	Powered smoke shafts and controlled MFSDs	2
	BS EN 12101-6	Pressurization	2
	BS 7273-4	Powered sliding doors	2
	—	Means of escape systems activation and monitoring	1 or 2 G)
Fire-fighting shafts	BS EN 12101-6	Pressurization	3
	—	Chimneys – controlled [MFSD] dampers	3
	—	Powered chimneys and controlled MFSDs	3
	BS 9999	Fire-fighting shaft emergency lighting	3
	BS 9999	Fire-fighting shaft system monitoring	3

Table 1 **Minimum fire survival time categories** *(continued)*

System	Related standards A)	Application		Minimum category
Lifts	BS 9999	Fire-fighting	Lift supplies	3
	BS EN 81-72		Communications	3
	BS 9999	Evacuation	Lift supplies	2
	—		Communications	2
Fire suppression	BS EN 12094	Gaseous extinguishing systems		2
	BS ISO 14520	Gaseous extinguishing systems		2
	DD 8489 D)	Watermist		3
	BS EN 12416	Powder systems		2
	BS EN 12845	Sprinkler pumps		3
	BS EN 13565	Automatic foam systems		2
	BS 5306-1	Hose reel systems		3
	DD CEN/TS 14816	Water spray systems		3
	—	Suppression system monitoring		2
Fire mains	BS 9990	Wet riser pumps		3
	—	Valve and equipment monitoring		3

NOTE Further guidance on power supplies is given in BS EN 12101-10.

A) Refer to these standards for further information on the relevant system or application.

B) The categories given in parentheses are approximately equivalent to the cable performance recommendations given in the related standards, and are included here for information. The actual cable performance recommendations for these applications are given in the related standards.

C) See Clause **20** for information on areas of special fire risk.

D) These publications are in preparation at the publication of BS 8519.

E) Use minimum Category 2 or 3 depending on the type of system (1 h or 2 h).

F) Use minimum Category 2 for automatic system activation, or Category 3 for manual override.

G) Use minimum Category 1 for automatic system activation, or Category 2 for manual override.

12 Fire protective enclosures for cables

Fire protective enclosures (ducts or shafts) may be used as a means of protecting non-fire-resistant high voltage cables (see Clause **6**). In such cases, the enclosure should fully surround the cable(s) and enable them to operate for the required 120 min duration. The enclosure should contain nothing other than the cable(s) that it is designed to protect.

The performance of the enclosure should be assessed in accordance with BS EN 1366-5:2003 for integrity and thermal insulation under furnace exposure conditions for fire outside duct. The protective enclosure (duct or shaft) should met the performance criteria given in BS EN 1366-5:2003 after 120 min. Additionally, the protective enclosure should be capable of withstanding the effects of a water jet at the conclusion of the test.

In addition, for a judgement to be made on the potential adverse effects of combustible cables enclosed within the duct or shaft, the surface thermocouples located inside the duct (T3) should not exceed 180 °C above the initial mean temperature as required for classification in BS EN 13501-2:2007+A1:2009.

Also, load-bearing capacity (stability) should be assessed as the ability of the enclosure within the furnace to fulfil its intended function for the specified time. Failure of the stability criteria should be deemed to have occurred when the suspension or fixing devices can no longer retain the duct or shaft in its intended position, when sections of the duct or shaft collapse or when cracks, holes or other openings through which flames pass are evident.

13 Effects of fire temperature on cable size

*COMMENTARY ON CLAUSE **13***
When a cable is involved in a fire, the conductor temperature will rise above the maximum conductor temperature upon which tabulated current rating and voltage drop data is based.

In carrying a set current, a cable with its conductor temperature at 840 °C will experience a greater temperature rise due to current loading than a cable with its conductor temperature at 90 °C. However, the additional temperature rise due to this factor will be less than 50 °C and is not significant in relation to the temperature rise caused by the fire.

The voltage drop at typical fire temperatures will be higher than at 90 °C and this can be significant for certain types of load. Assuming a worst case of the total length of cable run in the fire, it would be necessary to increase the conductor size by approximately two sizes.

It is possible to calculate the voltage drop for cables involved in a fire by assuming the cable temperature in a fire and cable length affected. Examples of the calculation are given in Annex C.

Information on the effects of fault currents on cables operating under fire conditions is given in Annex D.

The process of cable sizing and selection for fire-resistant cable should take into account the effects on the cable performance resulting from the increased operating temperature above its normal maximum ambient temperature likely to be experienced under fire conditions (e.g. 840 °C).

The voltage drop and impedance of the cable increase with temperature, and therefore the advice of the cable manufacturer should be sought to select the appropriate cable for the load being fed.

14 Use of circuit protective conductors (CPCs)

When sizing cables, it is important to take into account the earth fault loop impedance of the appropriate circuit from source to final load, and in particular the impedance contribution of the cable being sized. The total earth fault impedance should be sufficiently low to ensure that the earth fault current is high enough to trip the circuit protective device in the required time. Where the impedance of the circuit is too high to achieve this, there is an accepted practice of supplementing the cable armouring with an additional separate external supplementary CPC.

If an external CPC is used, it should be not less than a quarter of the cross-sectional area of the line conductor.

15 Cable installation practice

When installing cables that are required to maintain circuit integrity under fire conditions, the resistance to fire of the cable fixings, cable containment system and any joints should be at least equivalent to the survival time required for the cable.

Cables should be installed in accordance with the following recommendations.

a) Where fire-resistant cables have by their method of construction adequate mechanical protection (e.g. cables conforming to BS 8491), they should either be fixed directly to the building structure, or be installed such that they are enclosed in or carried upon cable management or containment systems [see item b)]. If the cables are fixed directly to the building, the fixings should provide adequate support in the presence of the potential hazards (see Introduction).

b) Where fire-resistant cables require additional mechanical protection, they should be enclosed in or carried upon cable management or containment systems. Such systems should provide adequate support and maintain necessary mechanical protection in the presence of the potential hazards. The supports should be oversized to cater for the reduction in the tensile strength of steel when exposed to the effects of fire.

c) Cable management or containment systems that are not used as a primary means of support or to provide necessary mechanical protection should not compromise the defined performance of the cables in the presence of the potential hazards.

d) Any glands used in the termination of fire-resistant cables into equipment should not compromise the defined performance of the cables in the presence of the potential hazards.

e) Joints should be avoided where possible and minimized in their use. Where conditions require that a joint has to be used, it should be of a type that has the same performance as the cable in the presence of the potential hazards.

f) Where practicable, the fire-resistant route should be arranged to be one of the upper tiers of the coordinated high level services.

   NOTE 1 When coordinating the route for the fire-resistant cables, it needs to be recognized that some of the other services, such as pipes ducts, busbars and other cable routes, are likely not to be designed to maintain their integrity under fire conditions and could collapse during a fire. The result of the collapse could be the overloading of the fire-resistant cable containment system, which itself could then fail.

g) In order to maximize the integrity of the fire-resistant cable system, fire-resistant and non-fire-resistant cable routes should be segregated.

   *NOTE 2 Such practice could be advantageous when considering the oversizing of the support systems (see Clause **16**).*

h) The cable fixing should be in accordance with the cable manufacturer's recommendations. For example, plastic, nylon, and aluminium cable cleats would not normally be deemed suitable.

i) The cable fixing centres should be within the cable manufacturer's recommended maximum spacings for both the vertical and horizontal runs.

j) Cables should wherever practicable be installed upon the cable support system. Where this is impractical due to the nature of the installation, the cable may be installed to the underside of the support system, provided the cable fixings are of the equivalent fire rating.

16 Cable support systems

The support system should have a fire survival time equal to that of the cables it supports and for the same defined fire conditions.

When sizing the support brackets for containment routes, which are intended to support fire-resistant cables in a fire condition and where the circuits are to maintain their integrity for a pre-determined period, the drop rods and hangers should be sized to take into account the fact that the tensile strength of steel will be significantly reduced in a fire situation.

NOTE Failure to observe the design criteria will result in premature collapse of the cable containment system and the circuit failure of the cables being supported.

The cross-sectional area of the drop rods should be determined in accordance with Annex E.

17 Inverters

Power supplies for life safety systems, such as pressurization and smoke extract fans, derived from frequency inverters in order to vary the speed of the motor, should be equipped with a fail-safe fire mode. The fire mode should enable, if necessary, the inverter/motor to run to destruction. The fire mode is commonly initiated by a series of input/output modules residing on the addressable fire detection loop, and controlled by the fire alarm system cause-and-effect programmable software. Once the fire mode has been initiated, the drive should operate at a fixed predetermined speed initiated from the hard-wired control interface from the fire alarm system.

If the life safety ventilation system is required to have multiple speeds in fire mode, in order to perform the required duty, each speed should be separately hard-wired and initiated from the individual fire alarm interface modules.

On initiation of a fire mode, the inverter should effectively disable the motor protection functions to enable the drive, if necessary, to run to destruction.

When necessary to maintain the operation of the critical life safety equipment, the inverter should be equipped with a bypass.

18 Multi-zoned smoke ventilation systems

The components for multi-zoned smoke ventilation systems using smoke detector operated smoke/fire dampers should be protected against fire throughout the system.

NOTE The installation of multi-zoned smoke ventilation systems introduces specific problems. Guidance is provided in Annex F.

19 Junction boxes

Joints in cables, other than those contained within the enclosures of equipment, should be avoided wherever practicable.

Where life safety and fire-fighting circuits require the use of junction boxes to house terminations and critical system components, such as those described in Annex F, they should be capable of maintaining their integrity when tested using the general test protocol and principles given in BS EN 1366-5.

The maximum permitted internal operating temperature and the temperature rise above ambient should be subject to the equipment to be accommodated within the junction box and should be as defined by the equipment manufacturer.

20 Areas of special fire risk

*COMMENTARY ON CLAUSE **20***
Research has confirmed that where there are ventilation limitations and/or very large fire sizes (e.g. in underground car parks and loading bays), temperatures can reach as high as 1 200 °C. Such areas therefore need special consideration.

Areas that can be classified as areas of special fire risk include:

- *high bay warehouses;*
- *loading bays;*
- *underground car parks;*
- *large basement storage;*
- *hydro carbons fuel storage;*
- *self-storage buildings/units.*

Further information regarding areas that could be classified as areas of special fire risk is given in BS EN 12485.

As a general principle, cables for life safety and fire-fighting systems should not be installed within areas of special fire risk. However, there will be occasions where this cannot be avoided. In these situations, the cables used should be Category 3 cables as defined in Clause **11**, and should additionally be protected by a fire-resisting enclosure that has been shown to be suitable for the anticipated maximum temperatures, with a survival time at least equal to that of the cable. Any fixings should have suitable protection, e.g. intumescent coverings, appropriate for the anticipated maximum temperatures.

Annex A (informative) Typical medium voltage circuit in a building

The example shown in this annex is for a circuit with the following characteristics: 11 kV a.c. 3 phase, 1 000 kVA and a 1 s fault of 14 kA using a 3-core copper conductor, XLPE insulation, copper tape screened, PVC bedding, galvanized steel single wire armour and PVC sheathed overall conforming to BS 6622 laid in a fire and thermally resistant boxed trunking system.

Amperes per phase can be determined using the parameters taken from the example [kVA = 1 000, V = 11 000 (phase to phase voltage)] using the following equation.

$$\text{kVA} = \frac{1\,x\ \text{V}\ x\,\sqrt{3}}{1000} \quad \text{(A.1)}$$

$$\frac{\text{kVA} \times 1000}{\text{V} \times \sqrt{3}} = I \quad \text{(A.2)}$$

$$\frac{1000 \times 1000}{11000 \times \sqrt{3}} = 52.5\ \text{A} \quad \text{(A.3)}$$

Frequently, when medium voltage circuits have a relatively low current requirement, sizing of the cable is determined by the short circuit limits.

The minimum conductor size that can safely carry a 14 kA fault for 1 s is 120 mm^2, which has a fault rating of 17.2 kA for 1 s.

A 120 mm^2 conductor has a sustained current rating, at 25 °C ambient temperature, of 390 A when installed in free air. When installed in a thermally rated fire trunking system, the in free air rating is corrected by 0.5, therefore its rating is 390 × 0.5 = 195 A. This is more than adequate for the circuit.

Dependant on the earthing arrangements, the armour might also be required to carry a 14 kA fault for 1 s. The minimum size cable that has sufficient armour to carry the fault current is a 3-core 185 mm^2 cable that can carry 14.2 kA for 1 s. The rating of this cable when installed in a thermally rated fire trunking system is 505 × 0.5 = 252 A, which again is more than adequate for this circuit.

The sizing of the cable for any circuit is determined by several factors; current rating is only one of them and, as in the example given, not the determining one.

Current rating of cables in air and 1 s fault ratings can be found in cable manufacturers' data sheets.

Annex B (normative) Testing of Category 3 cables of core sizes up to and including 4 mm² cross-sectional area

NOTE This annex recommends a method of test to be used for small cables where the requirements of BS EN 50200 are modified to use a flame temperature of (930^{+40}_{0})*°C and the application of water spray.*

B.1 Duration of survival

B.1.1 Time

The duration of the test should be 120 min (115 min for the initial fire and impact phase followed by an additional 5 min for the fire, impact and water phase), during which the cable should not reach the point of failure.

B.1.2 Point of failure

The point of failure should be in accordance with BS EN 50200.

B.2 Test environment

The test environment should be in accordance with BS EN 50200.

B.3 Test apparatus

The test apparatus should be in accordance with BS 8434-2:2003+A2:2009, Clause **6**.

B.4 Verification procedure for source of heat

The verification procedure should be in accordance with BS 8434-2:2003+A2:2009, Clause **7**.

B.5 Test sample

The test sample should be in accordance with BS EN 50200.

B.6 Cable test procedure

B.6.1 General

The general test procedure should be in accordance with BS EN 50200.

B.6.2 Procedure for different cable types

The procedure for different cable types should be in accordance with BS EN 50200.

B.6.3 Ignition and shock production

Ignition and shock production should be in accordance with BS EN 50200.

B.6.4 Electrification or optical monitoring

Electrification or optical monitoring should be in accordance with BS EN 50200.

B.6.5 Application of water spray

After 115 min exposure in accordance with **B.6.3**, with the flame and shock still being applied, start the water spray in accordance with the method described in BS EN 50200:2006, Annex E.

Continue applying the water until the end point of the test.

> **WARNING.** If the application of the water extinguishes the flame then, for safety reasons, turn the gas supply off and consider the test invalid.

The point of failure should be as defined in **B.1.2**.

B.7 End-point

The test should be continued either:

a) until 115 min of fire and impact alone, followed by 5 min of fire, impact and water (total 120 min) has been completed; or

b) to the point of failure.

The point of failure should be as defined in **B.1.2**.

B.8 Test report

The test report should be in accordance with BS 8434-2:2003+A2:2009, Clause **10**.

Annex C (informative) Voltage drop calculations for cables in a fire

In order to calculate the voltage drop of a cable in a fire, the following factors need to be known or assumed:

- total cable length;
- current to be carried;
- voltage drop per amp per metre of cable at 90 °C;
- correction factor for voltage drop from 90 °C to cable temperature in the fire;
- temperature of that part of the cable that is in the fire;
- length of that part of the cable that is in the fire.

The following correction factors are based on a copper conductor with a temperature coefficient of 0.003 93 °C:

- 90 °C to 650 °C = 2.726 0;
- 90 °C to 750 °C = 3.034 2;
- 90 °C to 850 °C = 3.342 4;
- 90 °C to 950 °C = 3.650 6.

For example, the first factor is calculated by:

$$\frac{1 + 0.003\,93(650 - 20)}{1 + 0.003\,93(90 - 20)} = 2.726\,0$$

The process of calculating the voltage drop of a cable under given operating conditions is normally straightforward. The manufacturer's tabulated values of voltage drop per amp per metre are multiplied by the length of run and current to be carried, to give the expected voltage drop.

The manufacturer's tabulated values assume that the cable conductor temperature is at its maximum permitted operating temperature.

If the cable is involved in a fire, the conductor temperature and hence the resistance would be higher, therefore the voltage drop would be higher.

The problem in determining the voltage drop for a run of cable in a fire is to know the conductor temperature at each point along its length. Therefore assumptions have to be made in calculating what the voltage drop would be.

To illustrate the effect of assuming different lengths of cable being involved in a fire, two sets of examples are given, one based on 5 A and the other based on 200 A load.

a) **Example 1.0**

Assume a 2-core 2.5 mm^2 cable conforming to BS 7846, carrying 5 A over 50 m.

In normal operation the voltage drop would be:
19 × 0.001 × 5 × 50 = 4.75 V.

The voltage drop per amp per metre for this cable is 19.

b) **Example 1.1**

Assume a 2-core 2.5 mm^2 cable conforming to BS 7846, carrying 5 A over 50 m. Assume 2 m are at 750 °C and the rest of the cable is at 90 °C.

The voltage drop would be:
(19 × 0.001 × 5 × 48) + (19 × 0.001 × 3.034 2 × 5 × 2) = 5.14 V.

The voltage drop per amp per metre for this cable is 19.

The correction factor from 90 °C to 750 °C for copper (Cu) is 3.034 2.

c) **Example 1.2**

Assume a 2-core 2.5 mm^2 cable conforming to BS 7846, carrying 5 A over 50 m. Assume all 50 m are at 750 °C.

The voltage drop would be: 19 × 0.001 × 3.034 2 × 5 × 50 = 14.41 V.

The voltage drop per amp per metre for this cable is 19.

The correction factor from 90 °C to 750 °C for copper (Cu) is 3.034 2.

d) **Example 2.0**

Assume a 2-core 120 mm^2 cable conforming to BS 7846, carrying 200 A over 50 m.

In normal operation the voltage drop would be:
0.42 × 0.001 × 200 × 50 = 4.2 V.

The voltage drop per amp per metre for this cable is 0.42.

e) **Example 2.1**

Assume a 2-core 120 mm^2 cable conforming to BS 7846, carrying 200 amps over 50 m. Assume 2 m are at 750 °C and the rest of the cable is at 90 °C.

The voltage drop would be:
(0.42 × 0.001 × 200 × 48) + (0.42 × 0.001 × 3.034 2 × 200 × 2) = 4.54 V.

The voltage drop per amp per metre for this cable is 0.42.

The correction factor from 90 °C to 750 °C for copper (Cu) is 3.034 2.

f) **Example 2.2**

Assume a 2-core 120 mm^2 cable conforming to BS 7846, carrying 200 A over 50 m. Assume all 50 m are at 750 °C.

The voltage drop would be:
0.42 × 0.001 × 3.034 2 × 200 × 5 = 12.74 V.

The voltage drop per amp per metre for this cable is 0.42.

The correction factor from 90 °C to 750 °C for copper (Cu) is 3.034 2.

As can be seen from these examples, although the voltage drop has increased from normal operation, with part of a cable or all the cable in a fire, the percentage drop from a 240 V single phase supply does not increase significantly.

That is to say: Example 1 would give 1.98%, 2.14% and 6% respectively.
Example 2 would give 1.75%, 1.9% and 5.3% respectively.

From these percentage volt drop values, it would seem unlikely that a fire would have a significant effect on most equipment being supplied by the cable, even in the example of the worst case given above.

However, if it is required to limit the volt drop to 4% for the example when the whole length of cable is in a fire, e.g. motors running, fire-fighting water pumps etc., then the cable sizes in Examples 1.2 and 2.2 would have to be increased from 2.5 mm^2 to 4.0 mm^2 and 120 mm^2 to 185 mm^2 respectively.

g) **Rework of Example 1.2 but with a 4.0 mm^2 cable**

The voltage drop would be: 12 × 0.001 × 3.034 2 × 5 × 50 = 9.1 V.

The voltage drop per amp per metre for this cable is 12.

The correction factor from 90 °C to 750 °C for copper (Cu) is 3.034 2.

On a 240 V circuit, the voltage drop would be 3.8%.

h) **Rework of Example 2.2 but with a 185 mm^2 cable**

The voltage drop would be: 0.29 × 0.001 × 3.034 2 × 200 × 50 = 8.8 V.

The voltage drop per amp per metre for this cable is 0.29.

The correction factor from 90 °C to 750 °C for copper (Cu) is 3.034 2.

On a 240 V circuit, the voltage drop would be 3.7%.

From the above it is possible to calculate the voltage drop for cables involved in a fire by assuming the cable temperature in a fire and cable length affected, following the examples previously given.

In most cases it is unrealistic to assume that all of the cable length is involved in a fire. If a cable size was selected for a maximum of 2% voltage drop in normal operation, the voltage drop of this cable would be a maximum of 4%, even assuming 950 °C.

Annex D (informative) Fire-resistant cables under fire and fault conditions

The melt temperature of copper is 1 083 °C. Therefore if a copper conductor in any cable reaches 1 083 °C, it will melt and no longer function.

As an example, cables conforming to BS 7846 operating under normal conditions are designed to have a maximum continuous conductor temperature of 90 °C, which is the combination of ambient temperature and temperature rise due to carrying current. These cables are suitable for a normal overload temperature of 250 °C based on their re-use and the fact that they have thermosetting insulation (e.g. XLPE). The temperature rise of 160 °C (90 °C to 250 °C) is based on the conductor carrying 143 A/mm^2 for 1 s. This current is based on the standard ohms law:

$$I_f = \frac{V}{Z_e + R_1 + R_2}$$

where:

- I_f is the fault current, in amps (A);
- Z_e is the input impedance of the system, in ohms (Ω);
- R_1 is the resistance of the line conductor at average fault temperature, in ohms (Ω);
- R_2 is the resistance of the earth fault path at average fault temperature, in ohms (Ω).

During a fire, the fault current obtained is lower than under normal operating conditions, as both R_1 and R_2 are greatly increased due to their resistance being based on a much higher temperature. Temperature correction factors for copper are shown in Table D.1.

Table D.1 **Temperature correction factor for copper**

Temperature °C	Factor
20	1.0
90	1.275
170	1.590
250	1.904
650	3.476
750	3.869
800	4.065
850	4.262
900	4.458

It is extremely difficult to calculate the potential fault current of a cable when it is in a fire, because much of the information required is not known exactly, such as the temperature of the cable at the fire, the length of cable involved in the fire, and the temperature of the cable not involved in the fire. However, the temperature rise due to a fault, because R_1 and R_2 are higher than normal, will not be more than 160 °C and quite possibly significantly lower.

Therefore, taking into account the melt temperature of copper of 1 083 °C, and assuming a maximum rise due to a fault of 160 °C, providing the temperature of the copper conductor before fault is less than about 900 °C, the copper conductor is not expected to be at its melt temperature.

Annex E (normative) Methodology for determining the cross-sectional area of drop rods

COMMENTARY ON ANNEX E
This methodology is based on the guidance outlined in BS 476-24 (ISO 6944). The purpose of these standards is to measure the ability of ductwork systems to resist the spread of fire from one fire compartment to another without the aid of dampers. The standards refer to a complete ductwork installation and therefore include joints, supports and the fire stopping through the furnace wall.

The support elements for ductwork systems are similar to those used to support cable containment systems, i.e. anchors, drop rods, horizontal channel bearers, nuts and washers, and have therefore been used as a basis for the methodology given in this annex.

The cross-sectional area of the drop rods should be calculated using the following formula:

$$A = \frac{(W \times L_h + W_T \times L_h + W_b \times L_b + W_r \times h) \times 9.81}{2 \times \varsigma_{max}}$$

where:

- A = cross-sectional area of a drop rod, in square millimetres (mm^2);
- h = height of drop rod, in metres (m);
- L_b = length of bearer, in metres (m);
- L_h = distance between hangar supports, in metres (m);
- W = weight of cables per metre, in kilograms per metre (kg/m);
- W_b = weight of bearers per metre, in kilograms per metre (kg/m);
- W_r = weight of drop rods per metre, in kilograms per metre (kg/m);
- W_T = weight of tray or ladder rack per metre, in kilograms per metre (kg/m);
- ς_{max} = maximum allowable tensile stress, in newtons per square millimetre (N/mm^2).

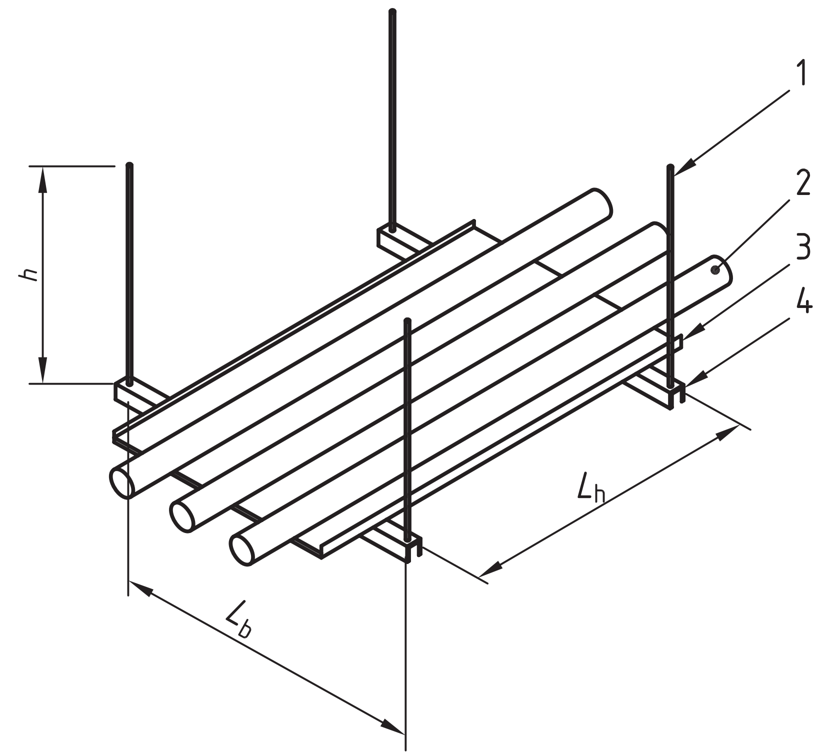
The elements of the cable support system are shown in Figure E.1.

From information published by manufacturers of fire-rated ductwork, unprotected drop rods and bearers made of steel should be sized such that the calculated stresses do not exceed the valves given in Table E.1.

Table E.1 **Maximum allowable tensile stress of steel drop rods in fire conditions**

Fire duration	**Maximum allowable tensile stress** (ς_{max})
h	N/mm^2
0.5	30
1	15
2	10

Figure E.1 **Elements of the cable support system**



Key

1	Drop rod	3	Cable tray or ladder
2	Cable	4	Bearer

Annex F (informative) Multi-zoned smoke ventilation systems

F.1 General

The components for multi-zoned smoke ventilation systems usually comprise:

- smoke/fire damper (**F.2**);
- actuator (**F.3**);
- control box (**F.4**);
- power supply (**F.5**);
- fire alarm detection loop (**F.6**).

F.2 Smoke/fire damper

Located within ventilation ductwork in order to maintain the fire compartmentation, the smoke/fire damper is operated by a smoke detector on detecting smoke in the appropriate zone. The dampers are certified in terms of their fire rating, either 1 h or 2 h, and are either two-position open/closed or three-position open/closed/normal.

The two-position dampers are usually powered open and use a spring mechanism to close the damper in the event of fire as a fail safe condition on removal of the open signal. They generally require two input/output (I/O) modules from the fire alarm system, one to give the open signal and the other to provide the monitoring of the damper position (closed).

The three-position dampers are more sophisticated, having an open and a closed position for their fire operation, and a mid-position controlled by a building management system (BMS) to give normal modulating operation. This type of damper generally requires four I/O modules from the fire alarm system, two to provide the open and closed control signals and two further modules to provide the confirmation of the damper position, opened/closed. These dampers do not have a spring mechanism, as there is no single position for the fire mode. As an example, in the event of a fire, initially all the dampers close, and then those dampers that are associated with the floor or zone of fire origin open to extract the smoke from that area only.

F.3 Actuator

An actuator might have to be installed within a fire-rated enclosure, if it is to be located within the area served by the ductwork system.

It is important that the damper/actuator assembly is tested and certified to operate correctly for the required period under defined fire conditions.

F.4 Control box

A control box is likely to be required adjacent to each of the damper actuators, which is used to house the 240/24 V transformer to power the actuator and the fire alarm interface modules to provide the control interface. When the damper requires a BMS interface for the normal modulating ventilation mode, the control box also needs to accommodate the terminals for the BMS cable.

Where the damper is required to be housed within a fire-rated enclosure, this also needs to accommodate the control box.

F.5 Power supply

The mains power supply to the actuator is vitally important to the integrity of the smoke ventilation strategy. The distribution boards need to be housed within fire-rated enclosures of the appropriate rating and the circuits wired using cables conforming to this standard and BS 8491. A means of local isolation needs to be provided adjacent to the actuator, however it is important that this does not compromise the operation of the actuator when exposed to a fire. A means of isolation needs to be housed within a fire-rated enclosure, if extended fire operation is required.

F.6 Fire alarm detection loop

It is common practice for the fire mode control interface with the damper actuator to be via fire alarm system addressable I/O modules installed on the addressable detection loops. These circuits may be wired in either standard or enhanced grade cable in accordance with BS 5839-1. Where extended fire operation is required from the fire dampers, or where a fire-fighter's override facility is to be provided, the detection circuits need to be wired only in enhanced cable in accordance with BS 5839-1.

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