

# **Health and Safety Executive OC 501/11 (REV)**

Field Operations Division...

To

Factory Inspectors

FCG Specialist Inspectors (Electrical)...

## **ELECTRICAL SAFETY AT LASERS, MAGNETRONS, ACCELERATORS, RADIO FREQUENCY EQUIPMENT AND THE LIKE...**

This OC and attached information document revises and replaces OC 501/11. The attached information document outlines the electrical protective measures that may be employed to protect against electric shock, burn, fire and explosion at the above type of equipment...

1 The information will be useful in discussion with designers, manufacturers and suppliers. The information document may be copied and given to interested persons outside HSE. ...

2 The information document was produced at the request of the Radiation Equipment Safe Working Group at TD headquarters and was originally issued in a slightly different form as an appendix to TD Minute TD1B/T/4/1989. ...

3 TD 1B have emphasised that the information is for general guidance. Detailed consideration of problems should be referred to the appropriate FCG specialist inspector. ...

### **Cancellation of instructions...**

4 OC 501/11 - cancel and destroy. ...

27 June 1991

(1349/FI/1989)

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## **ASI headings**\_\_\_

Electric(ity): electrical equipment (excluding hand tools): lasers: radio: radio frequency:

# **Health and Safety Executive Information Document**

**HSE 501/11 (REV) \_\_\_**

This document, which revises and replaces information document HSE 501/11 contains internal guidance which has been made available to the public. The information may not be directly applicable in all circumstances and any queries should be directed to the appropriate enforcing authority. \_\_\_

## **METHODS OF PROTECTION AGAINST ELECTRICAL HAZARDS AT LASERS, MAGNETRONS,**

## **ACCELERATORS, RADIO FREQUENCY EQUIPMENT AND THE LIKE**\_\_\_

INTRODUCTION \_\_\_

1 This paper sets out the electrical hazards presented by the above type of equipment and the protective measures that can be adopted to guard against those hazards. It also includes advice concerning relevant equipment standards and systems of work necessary to ensure the safety of workers and others in relation to these electrical hazards. The Electricity at Work Regulations 1989, which extend in general terms to all people at work, came into force on 1 April 1990 and replace the Electricity (Factories Act) Special Regulations 1908 and 1944 (referred to as the "1908 Regulations"). \_\_\_

THE HAZARDS \_\_\_

2 The electrical hazards may be summarised as follows:\_\_\_

(1) Electric shock \_\_\_

This may be fatal (ie electrocution) and can arise from:\_\_\_

(a) contact by persons with exposed, bare, live or energised conductors, (this is known as direct contact), or \_\_\_

(b) contact by persons with metalwork made live, due to insulation failures, from live or energised conductors (this is known as indirect contact).\_\_\_

(2) Electrical burns\_\_\_

These can arise from:\_\_\_

(a) contact by persons with exposed, bare, live or energised conductors, or\_\_\_

(b) persons being in close proximity to conductors carrying radio-frequency currents, or\_\_\_

(c) persons being in proximity to arcs created by short-circuits due to faults such as insulation failures.

(3) Fires caused by electricity:\_\_\_

These can arise from:\_\_\_

(a) sparking at faulty connections or joints causing ignition of insulating materials;\_

(b) overloaded conductors and terminals, resulting in temperature increases so causing ignition of insulating or other combustible materials; and/or\_\_\_

(c) electrical sparking such as results from relay contacts operating causing ignition of flammable atmospheres. \_\_\_

#### VALUES OF VOLTAGE \_\_\_

3 It is important to appreciate the definitions of voltage used in the standards for this type of equipment. They may be summarised as follows:\_\_\_

(1) Extra low voltage: below 50 volts ac or 120 volts dc (ripple free) ie where the ripple current of the direct current (peak to peak) is less than 10% of the pure dc level. \_\_\_

(2) Low voltage: above 50 volts ac or 120 volts dc and below 1000 volts ac or 1500 volts dc. \_\_\_

(3) High voltage: above 1000 volts ac or 1500 volts dc. \_\_\_

4 In normal, open, dry surroundings values of voltage not exceeding extra low voltage are regarded as safe even when direct contact is made with live bare exposed conductors at these voltage levels. However in confined, conductive surroundings or wet surroundings even these levels may prove dangerous and much lower values are necessary for safety if access to live bare conductors is possible. \_\_\_

#### PROTECTIVE MEASURES \_\_\_

5 The protective measures against electric shock are based upon the criteria set out in the International Electrotechnical Commission Publication 364-4-41. Some of these measures will also provide protection against electrical burns. They are applicable for normal, open, dry, spacious surroundings. \_\_\_

6 Protection against both direct and indirect contact as set out in 2(1)(a) and 2(1)(b) can be achieved in the following ways: \_\_\_

- (1) use of safety extra-low voltage; \_\_\_
- (2) protection by limitation of current or electrical charge; and \_\_\_
- (3) use of functional extra-low voltage. \_\_\_

7 Protection against direct contact can be achieved in the following ways: \_\_\_

- (1) by insulation of live parts; \_\_\_
- (2) by providing barriers or enclosures around live parts; \_\_\_
- (3) by providing obstacles in the normal path of approach to live parts; \_\_\_
- (4) by placing live parts out of reach. \_\_\_

8 Protection against indirect contact can be achieved by: \_\_\_

- (1) automatic disconnection of supply and equipotential bonding; \_\_\_
- (2) use of double-insulated equipment or by equivalent insulation such as reinforced or all-insulated equipment; \_\_\_
- (3) the use of a non-conducting location; \_\_\_
- (4) the use of earth-free equipotential bonding; and \_\_\_
- (5) the use of electrical separation. \_\_\_

9 The requirements for these protective measures can be found in IEC Publication 364-4-41 or the IEE Regulations for Electrical Installations 15th Edition Part 4 Chapter 41. \_\_\_

10 The standards that now exist for many items of electrical equipment already take into account these protective measures and use them either alone or in appropriate combinations. \_\_\_

#### PROTECTION AGAINST FIRE \_\_\_

11 This can be achieved by: \_\_\_

- (1) appropriate selection of cables, cable terminals and joints suitable for anticipated current flows both under normal and abnormal (fault) conditions; \_\_\_

(2) the provision of appropriate electrical protection to guard against overloads, short-circuit or earth faults; and\_\_

(3) the provision of appropriate explosion-protected apparatus where flammable atmospheres may exist around or within the equipment during its use (this includes flammable dusts).\_\_

#### DEVELOPMENTS OF STANDARDS AND CODES OF PRACTICE FOR NEW EQUIPMENT \_\_

12 When new standards are contemplated for new equipment, it is important that where electrical equipment is to be provided, then due cognizance is taken of the many existing electrical standards and codes of practice. In some instances it has been obvious that an equipment standard with considerable electrical content has been drafted by non-electrical personnel and requirements that either conflict with existing standards, or are of lesser degree than is acceptable for safety have been derived. It is thus essential that personnel with the appropriate electrical expertise are either invited onto these committees or invited to comment and give advice at an early stage.\_\_

13 A list of some relevant standards and codes of practice is attached as Appendix A.\_\_

#### DESIGN AND CONSTRUCTION OF EQUIPMENT \_\_

14 There are a number of basic design and construction criteria which if addressed at an early stage in the development of new equipment can result in significant contributions to safe operation. \_\_

15 Consideration of these criteria should always form part of the thought processes associated with the design and construction of new equipments in line with the responsibilities placed on designers, manufacturers, suppliers and installers of this equipment, by Section 6 of the Health and Safety at Work etc Act 1974. The Electricity at Work Regulations 1989 also place requirements upon designers, manufacturers, installers and users of equipment.\_\_

16 Typical areas to be addressed are:\_\_

(1) Incoming electrical supply terminals\_\_

These should be insulated, or shrouded so that they are not accessible when any access door, cover or panel is open. Alternatively the circuitry should be arranged so that when any access door, cover or panel is opened, it is necessary first to isolate the electrical supply to exposed conductors within that panel, cubicle or enclosure.\_\_

(2) All adjusting or setting devices should be segregated into a separate panel or cubicle where there are no exposed bare live conductors.\_\_

(3) All live conductors shall be either insulated and protected against mechanical damage or should be placed and safeguarded, for example, inside an earthed metal enclosure, to ensure persons do not have access to them when they are live or energised. All access doors should be power interlocked such that the conductors are isolated and earthed where necessary before access is permitted. Under the 1908 Regulations these requirements were limited to voltages in excess of

650 volts, but the 1989 Regulations apply them to all dangerous conductors.\_\_\_\_

(4) Capacitor banks used to store electrical energy should be contained in sheeted enclosures with a power-interlocked access door so arranged that not only does the direct operation of the isolation device remove the electrical power to the capacitor bank, but also it either simultaneously operates an earthing and shorting switch suitably rated to "dump" the charge stored in the capacitor array or it is interlocked with such a switch. The switch in turn should be interlocked with any access door or panel, so that access is only permitted when the short/earth is in place. Gravity-operated switches of suitable design are acceptable.\_\_\_\_

On some installations, there may be a need to provide a manual discharge stick (a suitably rated resistor with a bare hook contact connected effectively and efficiently to earth and mounted on an insulating handle of adequate length) to dissipate charge stored in capacitors. This device is normally mounted inside a panel or cubicle door and should be left in contact with the bare bars while work is in progress in the panel/cubicle. It is important that the access arrangements to the live/energised conductors are arranged to permit access only by the discharge stick and not by fingers, hands etc until the energy is dissipated. This may be achieved by suitably designed and positioned screens, or shrouding which requires some form of tool for removal.\_\_\_\_

Note 1: It is not prudent to rely on the inbuilt discharge (bleed) resistors normally fitted to capacitors as these are known to fail-to-danger by failing open-circuit.\_\_\_\_

Note 2: Discharge energies in excess of 50  $\mu\text{C}$  (micro-coulombs) are regarded as hazardous to life (IEC Publications 479 and 536).\_\_\_\_

(5) Control systems should be so arranged that they can be operated without the need to gain access into enclosures, panels or cubicles where live, exposed, bare conductors are present. All control systems wiring should be installed so that it is not affected by laser light, toxic or noxious fumes, flammable solvents, etc. Guidance may be found in BS 2771:1986 : part 1 *Electrical equipment of industrial machines*.\_\_\_\_

Enclosures should be designed with the requirements of BS 5490 in mind. This is particularly relevant for coolinglouvres. It is recommended that a minimum degree of protection of IP 21 be attained. Higher levels of protection should be used as appropriate both for low and high voltage enclosures. \_\_\_\_

## SYSTEMS OF WORK \_\_\_\_

17 The preferable way to ensure safety is to ensure that no live bare conductors other than those at extra-low voltage are accessible to operators of the equipment during all modes of operation including maintenance. (The values of extra-low voltage are only applicable to equipment to be used in dry, spacious environments.)\_\_\_\_

18 Where it is necessary to gain access to parts of equipment where there are live bare conductors the following procedures shall be observed (subparas (2) and (3) are in effect alternatives):\_\_\_\_

(1) When equipment is in normal use with all covers and enclosures in place and access doors closed, no live bare conductor at a voltage exceeding 50 volts ac or 120 volts dc shall be accessible (this applies particularly to lasers, accelerators and magnetrons).\_\_\_\_

(2) Where access is required and the exposed conductors are live at voltages in excess of 50 volts ac or 120 volts dc but are not greater than 650 volts such access should be restricted to skilled or instructed persons. Equipment which requires adjustments or calibration in normal use should be designed so that these adjustments or calibrations can be made without persons being exposed to bare live conductors which may present danger. Access to conductors live at voltages exceeding 650 volts should not be permitted under any circumstances. Any such work on or in proximity to live bare conductors may necessitate the use of a permit-to-work or similar formal written system of work to ensure worker safety.

(a) A skilled person is one who has sufficient technical knowledge and/or experience to enable that person to avoid dangers which electricity may create. \_\_

(b) An instructed person is one who is adequately advised or supervised by a skilled person to enable that person to avoid dangers which electricity may create. \_\_

(3) The Electricity at Work Regulations 1989 require at reg. 14 that "any work activity on or so near any live conductor (other than one suitably covered with insulating material so as to prevent danger) that danger may arise" shall be carried out with the equipment dead unless: \_\_

(a) it is unreasonable in all the circumstances for it to be dead, and \_\_

(b) it is reasonable in all the circumstances for a person to be at work on or near it whilst it is live, and \_\_

(c) suitable precautions (including, where necessary, the provision of suitable protective equipment) are taken to prevent injury. \_\_

The 'suitable precautions' may be construed to include accompaniment in some circumstances, ie if the presence of such persons could contribute significantly to ensuring that injury is prevented. The accompanying person should be trained to recognise danger and, if necessary, to render assistance in the event of emergency. Further guidance on this matter may be found in the *Memorandum of guidance on the Electricity at Work Regulations 1989*(HS(R)25) available from HMSO. \_\_

## APPENDIX A \_\_

### TABLE 1: LIST OF RELEVANT IEC AND BRITISH STANDARDS FOR SWITCHGEAR

\_\_

Subject IEC Number BS Number \_\_

Common clauses for high voltage (HV)

switchgear etc 694 6581

AC circuit breakers above 1 kV 56 5311

HV switches 265 5463

Disconnectors and earth switches 129 5253

Metal-enclosed switchgear 298 5227

Insulation-enclosed switchgear 466 -

HV switches combined with fuses 420 -

HV fuses for motor protection 644 5907\_\_

Low voltage (LV) circuit breakers 157 4752

LV factory-built assemblies 439 5486

Cartridge fuses up to 1000 V ac/  
1500 V dc 269 88 \_\_

Current transformers 185 3938

Voltage transformers 186 3941

Instruments 51 89

Relays 255 142 \_\_

Switchgear maintenance - up to 650 V - 6423

Switchgear maintenance from 650 V to 36kV - 6626

Degrees of protection 529 5490\_\_

Insulation classed by thermal stability 85 5691

Insulation thermal endurance 216 5691

Insulation electrical endurance 727 -

Artificial pollution onHV insulation 507 -

Bushings 117 223

SF6 gas 376 5207

Guidance for checking SF6 gas 480 5209

Insulating oil 296 148

HV test techniques 60 923

Partial-discharge measurements 270 4828

TABLE 2: OTHER USEFUL STANDARD REFERENCES \_\_\_

Subject IEC Number BS Number \_\_\_

Protection against electric shock 536 2754

Electrical equipment for machine tools 204-1 2771

Apparatus in potentially flammable

atmospheres 79-10 5345

Apparatus for potentially flammable

atmospheres - 5501

Classification of types of enclosure 34-5 4999-20

144 5420

Static electricity (control of) - 5958

Electrical apparatus and flammable dusts - 6467

Passage of current through the human body 479 PD 6519\_\_\_

Electrical safety of laser equipment and

installations 820 -

Safety of medical electrical equipment 601 5724\_\_\_

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