Section V-Electrical hazards and safeguards

With few exceptions, fires of electrical origin occur due to lack of reasonable care in the maintenance or use of electrical installations and apparatus. The power that provides heat and light and drives electric motors is also capable of igniting insulation or other combustible material ~ the power is misused, or if the equipment is not adequate to carry the had, or is not properly installed and maintained. The most common causes of fires in electrical installations are:

- Short circuits, due to the failure of the insulation;
- Overheating of cables and equipment, due to overloading: lack of ventilation or the presence of local resistance;
- The ignition of flammable gases and vapours by sparks or heat occurring in the operation of electrical equipment;
- The ignition of combustible substances by electro-static discharges.

1. FAILURE OF INSULATION

The danger of fire arising from faulty insulation has already been dealt with in Section II, part. 5. t has been found that leakage or fault current in the earth-continuity path results in a higher fire risk than that which is caused by short circuits between line and neutral. To ensure adequate safeguards against fire through faulty insulation, the insulation resistance and the earth-continuity system should he regularly tested, and circuit breakers or fuses, together with the earthing system which is complementary to them, shourd be correctly designed and maintained Fuses should not be rated higher than the capacity~of the smallest conductor in the circuit they are protecting.

2. OVERHEATING OF CABLES AND EQUIPEMENT

(a) Overloading of circuits

Electrical equipment and circuits are normally rated to carry a certain safe current which will keep the temperature rise in the smallest conductor in the circuit or appliance within permissible limits. Where, for any reason, the actual flow of current is higher for any length of time than rated, the temperature rise will be greater until, under normal circumstances,1 the fuse or circuit breaker will operate to prevent dangerous overheating. If however, the fuse is over-rated or the circuit breaker is faulty or wrongly set, protection will not be achieved and damage will follow.

The normal cause of overloading of circuits is that the equipment and cables are too small for their purpose. Bayonet cap adapters and socket outlet adapters, possibly with bad or corroded contacts, and typical examples, and the only safeguard is to make sure that the size of all cables and apparatus is correct for the current they are to carry.

Another cause of overloading is due to mechanical breakdown of electric motors and the machinery they drive. The same basic safeguard applies. Motors and control gear should be of dimensions appropriate to the loads they have to carry. Together with the machinery they drive, they should be maintained in good condition. It should be noted that fuses do not provide close protection against the overloading of motors, and in some cases severe heating may occur without blowing the fuses. Electric motors, which are not under direct supervision, sometimes have an in-built thermal overload trip incorporated, as this is much better than a fuse to give protection against sustained overheating.

(b) Inadequate ventilation

Ventilation is necessary to maintain safe temperatures in most electrical equipment, and overheating is liable to occur if ventilation is obstructed. Refrigerators, for example, require an adequate space to be left around them to allow the heat generated to be dissipated and to prevent the motor becoming overheated. All electric equipment of this nature should be kept clear of obstructions that restrict a free supply of air to the frame or case of the apparatus and to the ventilation apertures.

(c) Overheating in circuits through local resistances

Heat can be generated locally due to high resistance at that point. Such a high resistance could be caused by badly made or corroded joints or connections or at connections where only a few strands of the core are joined. Dirty or pitted switch contacts and loose fitting plug or socket connections will also cause local overheating. Fuses will not give protection against this form of over-heating, as the current consumed by the circuit is less than normal.

Correct installation is the answer to such local heating. All joints or connections should be soldered or mechanically clamped and made to anchor all strands of the conductor securely. Regular inspections of installations wilt safeguard against local over-heating.

3. IGNITION CF FLAMMABLE GASES AND VAPOURS

Most electrical equipment either sparks in normal operation, or is liable to spark under *fault* condition. Some electrical appliances, such as electric fires, are specifically designed to produce high temperatures. These circumstances create fire and explosion hazards which demand very careful assessment in locations where processes capable of producing flammable concentrations of gas or vapour are carried on, or where flammable liquids are stored.

Mechanical and structural precautionary arrangements dealing with these dangerous materials have been codified in British Standard Code of Practice: CP 1003, which deals with electrical apparatus and associated equipment for use in explosive atmospheres of gas or vapour, other than mining application. Part 1 of the Code deals with the choice] installation and maintenance of flameproof and intrinsically safe equipment, and Part 2 deals with the methods of meeting the explosion hazard other than by the use of flameproof and intrinsically safe equipment. The principles and recommendations laid down in OP 1003 are the basis for all installations of this kind, and their

Implications for the fire service should be fully understood and acted upon when dealing with fires and explosion risks from flammable liquids, gases or vapours.

(a) Classification of danger areas

CF 1003, Part 1 lays down three sets of conditions, each defining a type of danger area, viz. Div, 0, Div. 1 and Div. 2.

In Div. 0, flammable or explosive substances are present in concentrations within the lower or upper limits of flammability, and the conditions require the total exclusion or segregation of any electrical equipment. If, under special circumstances, this is impracticable, recourse must be made to special measures, such as pressurisation or the use of intrinsically safe equipment

Div. 1 covers areas where flammable substances are processed, handled or stored where during normal operations an explosive or ignitable concentration is likely to occur in sufficient quantity to produce a hazard. A risk of this nature would be met by the use of segregation, flameproof equipment, intrinsically safe equipment, pressurised systems or ventilation.

Div. 2 is an area within which any flammable or explosive substance is so well under control that the production (or release) of an explosive or ignitable concentration in sufficient quantity to constitute a hazard is only likely under abnormal conditions. In these areas the risk of an explosive concentration forming arises only under freak conditions, and the chance of electrical equipment failing at that very instant is very slight. Vapour-tight apparatus or totally enclosed equipment, such as squirrel cage induction motors which have no sparking contacts) may therefore be approved by the appropriate approval authority as satisfactory safeguards.

(b) Safeguards

To deal with the conditions defined under (a) above) CP 1003 recommends the following five ways of prevention of risk which are considered satisfactory safeguards each on its own or, if necessary, in combination of *two* or more.

- Flameproof equipment.
- Intrinsically safe equipment
- Segregation (or isolation).
- Ventilation.
- Pressurised system.

The first two are dealt within Part 1, and the last three are described in Part 2.

There are no definite pre-set rules for the application of the safeguards to each individual danger area and its hazards, and each hazard is considered according to its character. In the following paragraphs, therefore, an appreciation of the features of each of the five safeguards is given

(c) Flameproof equipment

Flameproof equipment is tested and certified by the British Approval Services for Electrical Equipment in Flammable Atmospheres (BASEEFA), except for mines, as safe for use in areas related to four groups of explosive gases and vapours, namely:

Group I	Methane (fire damp)
Group II	This covers the majority of gases or vapours encountered In industry.
Group It	Town gas, coke oven gas, ether, ethylene and ethylene oxide.
Group IV	Hydrogen acetylene, carbon disulphide, ethyl nitrate and blue water gas

Group IV gases are known as ‘excluded' gases and very little flameproof equipment has been approved in this section.

The difference in the flameproof equipment as authorised for the various groups is mainly in the maximum permissible dimensions for any gaps, which may exist between joint surfaces and for any other openings in the structure, such as gland shafts

Definition of flameproof enclosure. British Standard 4683: Part 2:1971 defines flameproof enclosure as:

'An enclosure for electrical apparatus that will withstand an internal explosion of the flammable gas or vapour which may enter it, without suffering damage and without communicating the internal flammation to the external flammable gas or vapour for which it is designed, through any joints or structural opening in the enclosure."

The British Standard goes on to specify the minimum gaps or clearances in the joints. Threaded joints must have a minimum of five full threads engaged.

Cables. Flameproof apparatus must be connected by cables appropriate for the purpose, although they may not be officially certified. Examples are lead covered wire-armoured cables, cables in solid drawn steel conduit with certified inspection boxes, and MICS cables with flameproof jointing fittings.

Fuses and circuit breakers have to he rated strictly for the current values of the apparatus and operated well within their short-circuit rating in order to avoid disruptive effects in the event of a serious fault occurring.

(iv) *Earthing-* To enable protective gear to operate satisfactorily, the metal enclosures of flameproof apparatus and conductors have to be efficiently earthed

(d) Intrinsically-safe equipment

For certain special purposes, such as control circuits, telephones and small inspection lamps where flameproof equipment would be unsuitable, intrinsically safe equipment and circuits find a useful application. The principle of intrinsic safety is that the available electrical energy is limited so that any spark which occurs, is insufficient to ignite gas or vapour for which the equipment is certified. The testing authority is BASEEFA, and at present certificates are issued in respect of the following two classes of flammable substances:

- Butane, pentane, hexane, carbon monoxide, acetone, cyclo-hexane, benzene and iso-octane:
- Hydrogen towns gas, coke oven gas and blue water gas.

The classification of gases for intrinsically safe equipment is given in B~S. 1259 and is different from the grouping of gases adopted for flameproof apparatus as described in S~S. 4683: Part 2. This is due to the fact that the physical processes in the ignition of gas are different for intrinsic safety from those which apply to flameproofing. In order to emphasize the distinction the word ‘class' is used for intrinsically safe apparatus.

The minimum igniting current is not a constant tar any gas or vapour, but vanes with the circuit characteristics, such as the inductance and voltage of the circuit. It is necessary to restrict the current to a sate value having regard to such factors, and the essential technical features of the components are specified in the certificate when it is issued.

(e) Approved apparatus

Some electrical apparatus may be certified as 'approved' without necessarily being intrinsically safe; for example, the filament of an incandescent lamp may be a source if ignition if the bulb is broken. It is necessary, therefore, to protect the lamp by a tough window or well-glass which itself is protected by a robust metal cage or guard. The internal space around the lamp bulb is also restricted in order to limit to the minimum practicable volume the amount of gas which can enter the apparatus and surround the lamp bulb.

A miner's cap lamp, fed from a secondary battery strapped on the user's chest and protected by means of a fuse and resistor and other features of construction, is another example of apparatus which may be certified without it necessarily being intrinsically safe. In such circumstances, it would fall into the category of 'approved' apparatus.

A further example of apparatus embodying certain equipment which is not of recognised flameproof type is provided by the battery truck in which the switch and control gear and connections are certified flameproof while the battery is of special construction. The construction of the battery, rate of hydrogen evolution and type of container must comply with the requirements of BASEEFA. Charging connections should be made by means of a flameproof socket and plug interlocked with the isolating switch to prevent the withdrawal the plug with the switch in the 'on' position, and to prevent the switch being moved to this position with the plug withdrawn.

(f) Segregation

In some instances the electrical equipment may be kept out of rooms in which vapours of gases may be present. This method has only limited application because electrical equipment, especially lighting, may be needed within the places concerned. Motors and control gear may be placed outside the room containing the risk. These could drive machines via shafts passing through glands in the walls. Segregation is always adopted where the risk is from hydrogen or blue water gas since, at the time of writing, no flameproof apparatus is certified for these gases.

An intrinsically safe circuit is usually installed within the area of risk and control outside. It is important that the part of the circuit outside the area of risk should be specially safeguarded from becoming accidentally energised from a power circuit by reason of a fault - the part of the circuit within the area of risk would then become highly dangerous. An example might be an intrinsically safe circuit to (outside the area of risk) an auxiliary contact on a power circuit breaker. In such circumstances, the intrinsically safe circuit at the auxiliary contact must be so segregated and enclosed as to prevent, under fault conditions which may occur in practice, an electrical fault developing between the power circuit and the intrinsically-safe circuit. This may involve the provision of barriers and liberal clearances and insulation creepage distances between the power circuit and the intrinsically safe control circuit such as amply to safeguard the installation from The danger mentioned above.

(g) Pressurisation

Where pressurisation is adopted, a small positive pressure provided by air or an inert gas, from an uncontaminated source, is maintained in an enclosed part of electric equipment. This is monitored by pressure relays protected by an intrinsically-safe circuit, and arranged to isolate the equipment in the event of failure of pressure. Arrangements for purging the system must also be provided. Where the air used for pressurising also forms the means of cooling a pipe-ventilated motor, if must be supplied from an independent or auxiliary fan, and the fan motor, if situated within the danger area, must be of flameproof construction.

Another application of pressurisation to the risks arising from the excluded gases lies in the use of the air-turbo hand tamp, in which a small self contained turbo-generator, operated by compressed air, provides current for the lamp; the whole of the apparatus being surrounded by air under pressure. Failure of this pressure causes the generator to stop.

(h) Ventilation

Either natural or mechanical ventilation may be used to ensure dilution, by means of added air, of the flammable gases or vapours 283 m^3 of air to each 4.55 litres of solvent evaporated is considered satisfactory for the majority of industrial solvents. Care has to be exercised in designing ventilation to ensure proper control of containing the mixtures, otherwise flammable gases could be evolved and could ignite.

(i) Ignition of dusts

Certain finely divided organic dusts constitute an explosion risk of high degree. The appropriate safeguard is provided by the use of totally-enclosed dust-excluding electrical apparatus.

4. STATIC ELECTRICITY

Static electricity is probably best known when it discharges in the form of lightning, and this causes a number of fires each year. Although detailed statistics are lacking, it is probable that many fires are also due to static electricity in other forms. It is impossible to prevent the formation of static electricity, but it presents no problem if it is conducted to earth before it has time to build up a charge sufficient cause sparking. Precautions taken against static electricity are normally based on this principle. In explosives' factories, rigorous precautions are taken to prevent the build-up of static charges and, for example, all metal work, even to the hinges on the doors, is carefully earthed.

Friction between two non-conductors surfaces is a ready cause of static electricity: thus if fur or silk is rapidly brushed considerable charges accumulate, and unless conducted to earth, wilt spark. It is for this reason extremely dangerous to clean such articles in petrol or any similar flammable liquid. Even if the most stringent precautions are taken to exclude lights, sparks may occur which wilt ignite the flammable vapour present.

The method of formation of static electricity can be found in any textbook on electricity and magnetism. For practical fire4ighting purposes, it is usually associated with substances which, whilst non-conductors, are also flammable. Thus, if petrol (a non-conducting liquid) is allowed to emerge as a jet from a nozzle, the latter rapidly becomes charged with static electricity and, unless a path is provided to conduct the charge to earth, a point is reached where the insulating property of the surrounding air breaks down and a spark occurs. Since petrol vapour is flammable, this spark may easily ignite it and possibly cause a serious fire.

To dissipate the charge which would be built up when petrol is discharged from a road tanker, for instance, arrangements are always made to provide a conductor to earth. Conductive rubber tyres are normally fitted and special earthing arrangements are made when a tanker is being loaded.

Non-flammable liquids and vapours will also build up charges of static electricity under suitable conditions. For instance, escaping steam from a fractured line on oil refining processes could build up a charge on the plant itself, and special precautions are always taken to prevent this charge accumulating. Under appropriate conditions a static charge can be built up on rubber-tyred vehicles. Such vehicles are fitted with a trailing chain or other device which will conduct the charge to earth. Conducting rubber, which is rubber treated to give it sufficient conductivity to dissipate static electricity, is being increasingly used in places where there is danger of the building up of static charges. A typical application is its use for the type of trolley used in hospital operating theatres₁ which are almost invariably fitted with rubber tyres and tend to build up static charges because of their movement. in an operating theatre the dissipation of static charges by sparking is dangerous on account of the ether or other flammable vapours so often present, and many operating theatre fires have been traced to this cause. If conducting rubber tyres are not used a trailing chain is always employed.

In industry the passage of belting over pulleys is a frequent cause of static electricity. The belt, usually made of some non-conducting materials, builds up a charge, sometimes of considerable strength, as it passes over the pulley. Where there is no possibility of fire risk such charges may be allowed to dissipate by sparking out, but in the presence of flammable vapour or dust, means must be taken to eliminate this risk. A series of rollers running on the belt or copper brushes are often employed for the purpose. They require care and supervision at all times to ensure that they are fulfilling their role Conducting rubber~belts can be used to dissipate the charge as it is built up if the machinery on which they run is correctly earthed.

5. ELECTRIC SHOCK

If a firefighter comes in contact with a live circuit he/she may receive an electric shock; this can have fatal results, although a feature of electrical accidents is the large percentage in which injury is due to burns alone. It cannot be too strongly emphasised that, although in some cases severe electric shock directly affects the functioning of the heart, the effect in most cases is on the nerve centre in the brain, which governs the functioning of the respiratory muscles. For this reason artificial respiration should *always* be applied, and wilt often be successful. The effect of electricity on the human body is still not furry understood, but it is certain that it varies greatly in different persons. Experiments show that alternating current (a.c.) potentials, at a frequency of 50 hertz (Hz) and greater than about 30 volts, may produce a severe shock for most people if good 'contact' is made. In practice, good contact with even lower voltages may produce shocks liable to cause an accident. The effect of the frequency of the applied current is not altogether established, but most authorities agree that frequencies of 20 to 70 Hz and currents in excess of 22 milliamps are frost dangerous, whilst direct currents (d£.) and currents of very high frequency have a much less severe effect.

The immediate effect of an alternating current is to cause the muscles to contract involuntarily; accordingly, if an a.c. conductor is inadvertently grasped it is impossible to let go. There is also the possibility of indirect effects; for example, a shock received by a person when climbing a ladder may cause him/her to fall and sustain injury. It should be emphasised that it is not necessary to touch one of the conductors of a circuit to receive a shock; any conducting material, which is electrified through contact with a circuit, will suffice

The principal dangers to the firefighter lie firstly in unwittingly in the dark or smoke, touching a conductor which has been displaced by the fire or which has electrified other conducting material and secondly, in directing a jet of water or foam on to live electrical equipment. When a firefighter is standing in water, as he/she must so often do in the course of his/her work, the danger from touching an electric circuit is greatly increased as, even when a firefighter is wearing a non-conducting helmet, damp and perspiration beneath the helmet, combined with its wet exterior, tends to provide a path for the current through the body. Few deaths of firefighters through electrocution have occurred, however, and of these the majority have been due to the cause first mentioned. Risk of injury due to touching live wiring or electrified material tray he greatly reduced by the observance of certain simple precautions

In buildings seriously damaged by fire, electric wiring will often be exposed and dislodged, and it is therefore unwise to attempt to touch any wires, except with the necessary safeguards, until it is certain that the circuit has been rendered dead.

All switches in a building, which has been affected to any considerable extent by fire, should be treated with caution. It is always wise to push them on or off with the sleeve (if it is dry), or with the fireman's axe, provided that the handle is dry or is of the insulated type.

If it is necessary to touch a conductor in a building, the *back* of the hand should he employed. If it is live, the shock will then jerk the hand clear and will not cause it to contract on to the wire as would happen if the palm of the hand were employed.