Consumer Safety Research

Residual Current Devices - added value for home safety

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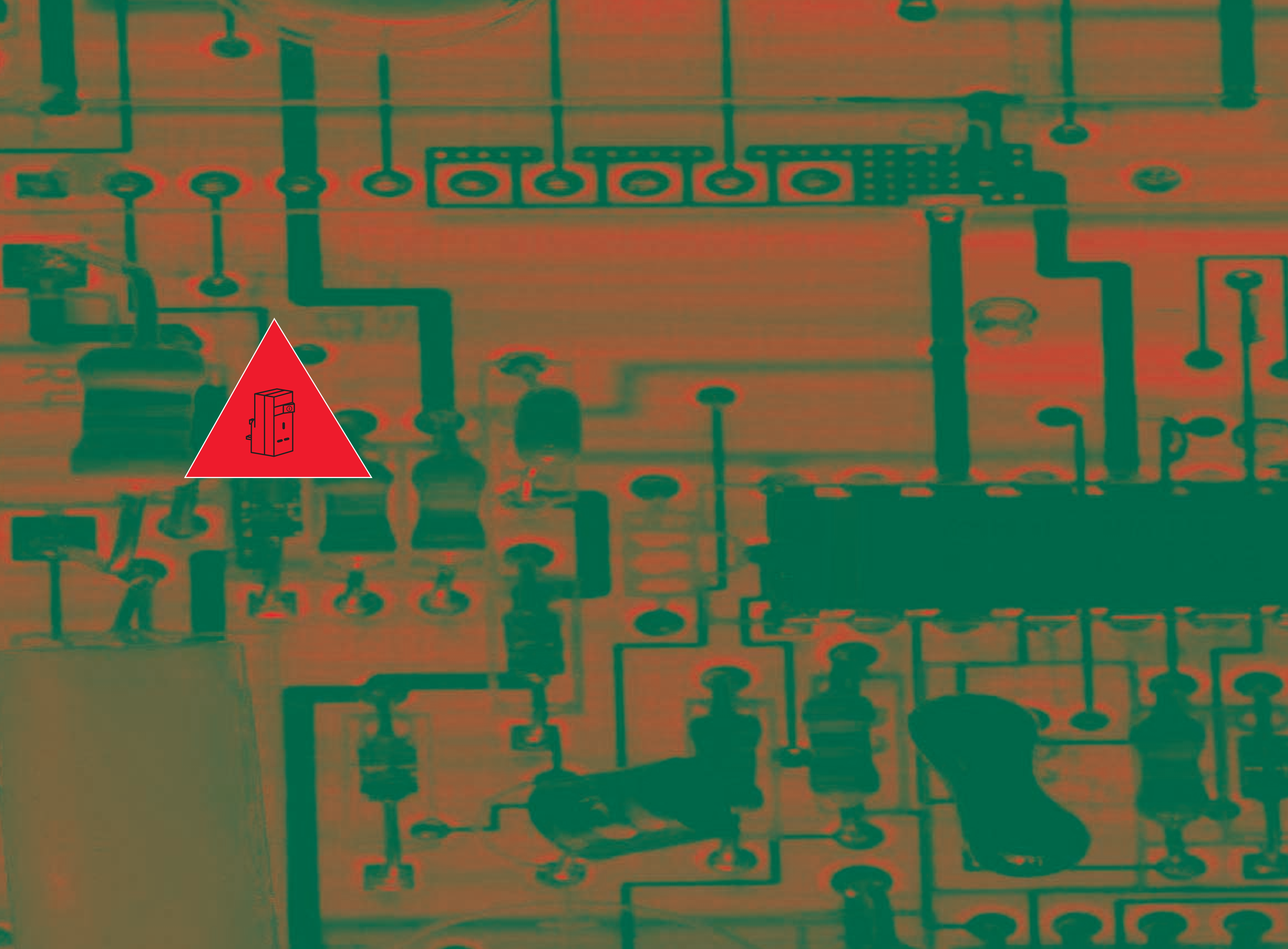

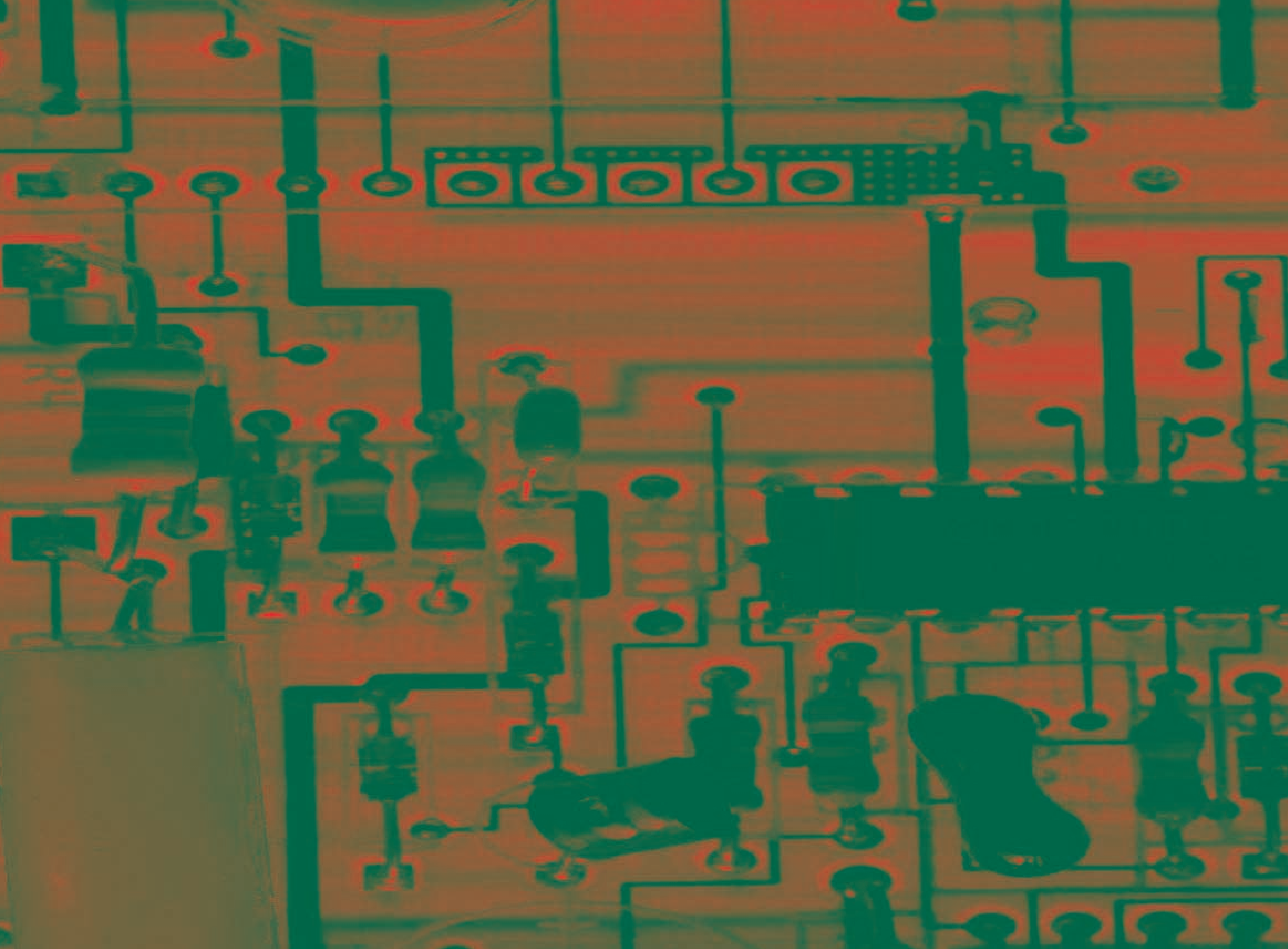

Summary

Home accident data shows that, on average, electric current causes 2000 hospital treated injuries and 25 deaths each year in the UK; a significant number of these cases are known to be attributable to electric shock. Fire brigades attend about 5000 fires every year attributed to faults in electrical appliances, lighting, wiring and accessories in the home. These fires result in about 20 deaths annually and 500 casualties requiring medical treatment. Household electricity supplies are fitted with fuses or circuit breakers to protect against the effects of high over-current and short-circuit faults. Added protection against the effects of earth leakage faults can be provided by the use of Residual Current Devices (RCDs). The purpose of this report is to assess the impact on home safety in the UK which would result from a more widespread use of RCDs. The work was commissioned by the UK Department of Trade and Industry.

Electricity supplies and electrical products in the home are designed to prevent accidental direct contact with conductors at hazardous voltage relative to earth, and to provide two levels of protection against electric shock. If a conductor at hazardous voltage does become accessible and accidental direct contact occurs, RCD protection can significantly reduce the risk of death by electrocution. However, in some circumstances even with RCD protection it is possible to receive an electric shock which may present serious risk of injury or death. This risk can be reduced by ensuring that consumers are made aware of the function and limitations of these devices.

RCDs can reduce the incidence and severity of fire associated with earth faults in electrical systems, equipment and components by limiting the magnitude and duration of current flow. A common mode of failure of insulation is by surface tracking and this may result in fire ignition. In the present work, currents of the order of 50-100 mA were found to be sufficient to cause flame ignition as a result of tracking. At these currents, an RCD rated to provide protection against electric shock would have prevented flame ignition. The onset of surface tracking of insulation can be accelerated by the presence of electrically conducting liquids which may arise due to leakage or spillage. Under these conditions, an RCD can be expected to operate and delay or reduce the risk of fire ignition.

Neither RCDs nor over-current protection devices will prevent fire ignition under all fault conditions. However, RCDs when properly used in addition to over-current devices and thermal cut outs, can protect against a wider range of fault conditions which cause fire. They can also be effective against faults which occur on a wide range of components used in household electrical appliances.

To maximise the benefits of using RCDs to reduce the annual rate of deaths by electrocution and the incidence of fires, there is a need to ensure proper application which takes account of equipment characteristics, installation conditions and usage. It is important that RCDs are provided with clear and easy to understand instructions. A survey carried out during the course of the work has shown the need for government, safety professionals, consumer organisations and industry to improve consumer awareness of the benefits and limitations of RCDs

1 Introduction

Home accident data (Ref. 1) shows that, on average, electric current causes 2000 hospital treated injuries and 25 deaths each year, and a significant number of these are known to be attributable to electric shock. Fire statistics (Ref. 2) show that each year the fire brigades attend, on average, 5000 fires in the UK which are attributed to faults in electrical appliances, lighting, household wiring and accessories in the home. These fires result in about 20 deaths annually and 500 casualties requiring medical treatment.

Fuses and miniature circuit breakers (MCBs) are fitted in household electricity supply systems to reduce the risk of fire and electric shock. Additional protection against electric shock can be provided by also using Residual Current Devices (RCDs). Portable RCDs are widely used to protect users against electrocution when using portable tools and garden electrical equipment. There is some opinion that the use of RCDs might reduce the number of fires associated with faults in electrical appliances, wiring and accessories.

The purpose of this report is to assess the likely impact on home safety in the UK, which would result from a more widespread use of RCDs. The work was commissioned by the UK Department of Trade and Industry.

2 Over-current and earth leakage protection

2.1 Over-current Protection

Fuses and other over-current protective devices (e.g. MCBs) operate to disconnect the electricity supply when the current flow is significantly higher than the design current rating of the supply conductors. Their purpose is to protect insulation from the effects of overheating and to reduce the risk of fire.

Circuits in household installations are likely to be rated: 5A, 13A or 30A. Fault current levels significantly higher than these values would be needed to operate over-current protection.

2.2 Earth Leakage Protection

A common cause of death by electrocution is when simultaneous direct contact is made with an electricity supply conductor and earth. The earth contact may be, for example, exposed metal work or a concrete floor having a low resistance to ground.

For an electric shock between a conductor at the electricity supply voltage and earth, the current flow through the body would be likely to be of the order of 100-200 mA (Ref. 3). A current of the order of 60 mA through the body can kill a normal healthy adult. RCDs can respond to small earth leakage currents and disconnect the supply when the current exceeds a set level (see Annex 1). The level of current flow may depend on the earthing arrangements of the system. RCDs intended for protection against electric shock are set to operate at 30 mA or less. Fuses and over-current circuit breakers used in home electricity wiring installations cannot be expected to operate at these current levels.

RCDs will not respond to a fault current between the supply phase (L) and neutral (N) conductors (unless there is a simultaneous current to earth or the fault path is external to the RCD sensor). Also, RCDs will not provide protection against electrocution if the current path is entirely between the phase and neutral conductors. RCDs are not designed to provide over-current protection and must be used in addition to fuses or MCBs. Combined units are available which provide over-current and RCD protection (see Annex 2).

3 Electric shock

3.1 Equipment Construction and Protection Against Electric Shock

Electricity supplies and electrical equipment used in the home are designed to prevent accidental direct contact with conductors at hazardous voltage relative to earth.

Two of the types of equipment construction commonly permitted are designated as: Class I and Class II. Both of these construction types are considered to provide two levels of protection so that in the event that one fails, the other will not. In both constructions, the first level of protection is provided by a layer of basic insulation to prevent contact with live conductors.

For Class I construction, the second level of protection is provided by earthing accessible surfaces which may become live in the event of a fault. The earthing provided must have a low impedance such that automatic disconnection of the supply by over-current protection will limit any voltage rise to less than 50V if a fault occurs (50V is an internationally acknowledged safe voltage level). If a low impedance earth path to the supply source cannot be guaranteed, then earth leakage circuit breakers such as RCDs must be used to provide rapid disconnection of the supply.

In Class II construction, a protective earthing connection is not made to the product. The second level of protection is provided by a separate additional layer of insulation (supplementary insulation). In some applications a single layer of insulation equivalent to double insulation is permitted.

The use of an RCD with a rated operating current of 30 mA is recognised by the International Electrotechnical Commission (IEC) as providing additional protection against electric shock in normal service in case of failure of other protective measures or carelessness by users.

3.2 Physiological Effects of Electric Shock and RCD Protection

Death by electrocution in the home is usually the result of ventricular fibrillation of the heart. Figure 1 shows the threshold for ventricular fibrillation for ac currents (15-100 Hz) as detailed in IEC publication 479. For shock durations of the order of 100-200 ms the threshold is of the order of 400 mA. For durations of 1-10s the threshold is of the order of 35 mA. There is a transition region where intermediate values of current apply.

An example of a time/current characteristic for an RCD with a rated residual operating current of 30 mA is shown in Figure 2. The characteristic shows that no protection is provided by the RCD before the contacts open. A shock current of the order of 100 mA- 200 mA is likely to be experienced during this period (Ref. 3). The time threshold for ventricular fibrillation at this current level is 200 ms compared with an operating time of 30 ms for the RCD.

It follows that an RCD can significantly reduce the risk of electrocution when the current path is between a live conductor and earth. In this respect, RCDs can provide a valuable contribution to home safety by protecting against the most common cause of death by electrocution.

Various physiological effects (Ref. 4) occur at currents below the level at which a 30 mA RCD will operate.

A continuous current flow of the order of 20 mA may be sufficient to cause breathing to stop.

Muscular reaction may cause inability to let go of a conductor at currents of the order 9 mA and above for men and 6 mA for women. Inability to let go will cease when the current flow is removed.

An involuntary startle reaction may be induced for current levels above 0.5 mA (Ref. 5). Examples of accidents which may be caused by a strong enough startle reaction are injuries from cutting blades, spills of hot liquid and falls from high places.

3.3 Household Environments and RCD Protection

3.3.1 Kitchen and Utility Areas

Recent ERA estimates suggest that approximately 80% of appliances primarily intended for use in the kitchen are of Class I construction. Typical examples include: cookers, washing machines, refrigerators, irons, dishwashers and freezers.

The predominance of earthed equipment and fixtures in the kitchen, places strong reliance for protection against electric shock on the integrity of earth bonding and earth continuity. For installations where the protective earthing connection is made to the electricity supply company cable, deterioration of the connection is unlikely. However, a significant number of installations in the UK have a local earthing connection to ground at the property. In older properties this protective earthing connection may have been made to the water supply system. The loss of an earth connection due to severance or interruption as a result of corrosion would not affect the normal operation of electrical appliances, but would cause a serious increase in electric shock hazard in the event of an insulation fault. Instances have arisen where an earthing connection to the water supply system has been compromised when sections of the water system have been replaced by plastic pipes, thereby reducing or removing the metallic contact with the ground. RCDs with a rated residual operating current of 30 mA would provide supplementary protection against electrocution in these circumstances. However, as discussed in Sections 3.1 and 3.2 it is dangerous to rely upon electric current through the body in providing primary protection. To maintain the level of protection provided by the installation system earth, a reliable connection is essential; this is best provided by the electricity supply company.

Class II double insulated equipment is also likely to be used in the kitchen. Risk of electric shock for this type of equipment may arise from damage and wear on cords and cables which could expose live conductors, or by damage to an appliance housing which allows live parts to become accessible.

Most equipment in the kitchen may be expected to be sited within reach of a person who can also make contact with other equipment and fixtures which may or may not be earthed. This will increase the level of risk when a live conductor is exposed. There is also the likelihood of water spillage and a moist or humid atmosphere. A conducting path across insulation may occur in humid and damp environments making the outer surfaces live. RCD protection of socket-outlets in this environment would help to minimise electric shock hazard.

3.3.2 Living Rooms, Dining Rooms and Bedrooms

Living rooms, dining rooms and bedrooms would be expected to contain portable items such as HiFi, audio, TV and video equipment. This equipment is likely to be predominantly of double insulated (Class II) construction.

Earthed electrical appliances which are likely to be present in these rooms are some types of lighting and thermal storage radiators. Earthed non-electrical items which might be present could include central heating radiators. Compared with a kitchen environment, it is less likely that electrical equipment in these rooms will be sited within reach of a person who can also make contact with an earthed conductor. This will lower the risk of electrocution. This type of environment is not expected to have high levels of moisture and humidity.

From these considerations it would be expected that the electric shock risk in these areas would be more dependent on the characteristics of the individual equipment than on the environment. The situations where RCDs would be effective in reducing the incidence and severity of accidents would tend to be rarer than in other environments particularly in respect of Class II double insulated products.

3.3.3 Outdoor Areas

Outdoor areas provide a high risk in respect of humid or wet conditions which may reduce the effectiveness of insulation and also lower the resistance to current flow between the body and earth in the event of contact with a live conductor.

Class II equipment such as vacuum cleaners or other portable equipment which may perhaps be stored or left in outhouses or other outdoor areas can present unexpected hazards if condensation or the effects of a humid or moist atmosphere have impaired the effectiveness of insulation.

A serious hazard will exist if such equipment is used inside the home before the surface of the insulation has dried and contact can also be made with an earthed conductor. RCDs would provide effective protection under these conditions whereas over-current devices would not be expected to operate.

For equipment used in the garden, RCDs provide an important safeguard against electrocution. When equipment used in the garden is fed from a socket outlet by means of a flexible cord, users may be at risk due to humid or damp conditions and possible damage to the flexible cord. Such equipment should be protected by an RCD having a rated trip current of 30 mA or less (Ref. 6).

4 Fire

4.1 The Incidence of Fires in Household Electrical Appliances

Table 1 gives details of the average annual number of fires to which fire brigades are called and which have been identified as associated with faults in electrical appliances (Ref. 2). The Table is ordered with the appliance type giving the higher incidence of fires listed higher in the Table.

Product safety standards seek to minimise the risk of fire ignition and to ensure that if fire ignition does occur then the fire is contained. In practice, these provisions for fire safety are supplemented by over-current and sometimes earth leakage protection devices in the supply installation.

For Class II appliances under normal conditions, no earth fault current path will be involved and no added protection against fire would be expected if an RCD was used.

For Class I appliances, RCDs would be expected to provide closer protection and limit the duration of current flow and energy transfer to insulation in the event of fault currents to earth and thereby reduce risk of fire ignition. In the list of appliances shown in Table 1, Class I appliances predominate.

4.2 Electrically Induced Fire Ignition and Propagation

Fires in electrical wiring systems and electrical equipment are usually the result of arcing or overheating associated with current carrying conductors. Electrical appliances and supply systems contain considerable amounts of plastic materials. When electrical conductors are subject to arcing or overheating and are adjacent to insulation the chemical processes of combustion can occur as follows:

- An initial heating of the insulation - the resulting temperature increase will be rate dependent on the amount of heat generated, the specific heat of the product mass, the thermal conductivity of the material and the latent heats of fusion and vaporisation where these procedures occur.
- Degradation and decomposition of the material.
- Flame ignition - this depends on the availability of oxygen, the flash points of the materials and their limits of flammability.

Product safety standards will generally require low flammability materials to be used where insulation is touching or supporting electrically live parts. However, even low flammability fire resistant plastics can support combustion if a high temperature is maintained for a sufficient length of time. Materials classified as low flammability may also support a local flame for a short time. To avoid flame spread, it is important that designs allow adequate separation between these materials and other high flammability materials which may be present. Flame propagation sometimes occurs as a result of distortion or melting of plastic parts which allows them to come into contact with, or to drop onto, a heat source.

4.3 RCD Protection against Fire Induced by Surface Tracking across Insulation

Surface tracking is a common cause of insulation failure. It arises from the growth of conducting paths at the surface. These may be due to conducting deposits from the atmosphere and the presence of moisture. When the path carries enough current, it will become thermally unstable resulting in a permanently conducting state. The action is progressive and ultimately a conducting path will bridge the insulation.

Surface tracking can occur at voltage levels well below the intrinsic breakdown strength of the dielectric. An established track between two conductors can produce local temperatures sufficient to ignite flammable vapour released from the insulation by the heating produced in the track or adjacent materials.

The rate of growth of tracks in practice is slow until a conducting path has been established. A standard test has been developed to compare the resistance to surface tracking of different materials in a short time span. The test is detailed in IEC specification 112 (see Annex 3).

In the tracking test, if a current of 500 mA or more flows for at least two seconds in a conducting path between the electrodes on the surface of the specimen or if the specimen burns, the material has failed the test.

Although the test is designed to be used only for comparative purposes, it is clear that if the final results of the test are representative of the long term effects of normal levels of pollution on the tracking resistance of materials, and the spacing between the test electrodes is representative, then an RCD with a trip current of 500 mA would provide suitable protection against fire for materials which pass the test. RCD protection would only be effective for tracking paths to earth and not for tracking paths between phase and neutral supply conductors.

4.4 Surface Tracking Induced by Fluid Contamination of Insulation

The tracking test is designed to simulate the long term effects of surface contamination and moisture on the tracking resistance of insulation. However, the test can also provide an insight into the effect of fluid contamination on insulation and the ability of RCDs to halt or prevent tracking.

A diagram of the tracking test configuration is shown in Annex 3. The tracking test operates as follows:

a) A standard contaminant liquid having a conductivity of 2.4 siemens is fed as a single drop to fall between the two electrodes which are set to a test voltage, as specified in the relevant product standard (see for example BS EN 60335-1: 1995 "Safety of Household and Similar Electrical Appliances").

b) The heat developed by the passage of current through the liquid evaporates the liquid and heats the specimen.

c) In the final stages of evaporation, discharges can be observed on the surface of the insulation which are known as scintillations and these create sites which develop and combine into a tracking path. Different materials will require a different number of drops of contaminant or a different test voltage to produce tracking sufficient to bridge the insulation between the electrodes.

A track of the current produced during a standard tracking test is shown in Annex 4. It can be seen that the liquid conductivity in the first phase gives a current between the electrodes of the order of 100 mA. In the second phase, surface discharge activity occurs at current levels of the order 2-5 mA. When discharge activity ceases, the current is of the order of 2 mA. When the liquid is present, the current flow would be sufficient to trip a 30 mA or 100 mA RCD. In the period where surface discharge activity occurs prior to a low resistance tracking path being established, an RCD would not be expected to act to completely eliminate deterioration of the surface and the formation of incipient tracks.

Further tests have been made to determine the current levels needed to cause flame ignition by tracking (see Annex 4). A sample of printed circuit board having a good resistance to tracking was used for these tests. Using a standard tracking test solution, a track across the insulation between adjacent conductors developed at a current of 80 mA. As the current increased to 90 mA, the track glowed red and a yellow flame ignited along the track. The flame height was approximately 8 mm. The current levels observed in this experiment indicates that a 30 mA RCD would have interrupted this process before flame ignition. In a second similar experiment with a 30 mA RCD in circuit, it was not possible to develop a track between the conductors or to cause flame ignition.

Some household detergent fluids have a high conductivity compared with the standard test fluid used in the tracking test. Tests were carried out using one common fluid which has a conductivity of approximately five times that of the standard tracking test fluid. Using a liquid having a higher conductivity would be expected to accelerate the onset of tracking failure.

The current levels measured in these tests were in the range 8-84 mA. It was observed that the nature of the solution appeared to play a more dominant role in the failure process in these tests than when the standard test solution was used. During the tests, a pink coloured flame 2 mm high was observed, apparently associated with decomposition of the fluid.

It is clear from the tests carried out, that if contamination by conductive fluid bridges insulation between a supply conductor and earth, and produces a high conductivity path, then this is likely to trip an RCD having a sufficiently low trip current level.

However, if the resistance of the fluid is such that heating will cause evaporation at current levels below the threshold for RCD operation, then tracks can form.

The above tests suggest that RCDs can be sensitive enough to trip due to the presence of conductive fluid contamination, spillage or spray in appliances as a result of earth current flow and may arrest the progress of tracking before flame ignition occurs. If appliances may be subject to fluid contamination of insulation, for example due to deterioration of seals in appliances or spillage, RCDs can provide protection at current levels where over-current protection would not be expected to operate.

4.5 Electrical Equipment Faults and Fire Hazard Limitation

In this section, consideration will be given to the role which RCDs and over-current protection devices can play in reducing the risk of fire associated with potential faults in home electrical wiring systems and components common to different types of electrical household appliances.

4.5.1 Wiring Installations and Equipment

The major fire risks in fixed installations are overheating of connections and arcing at switch contacts or connections. Modern PVC insulated wiring, if properly installed, can be expected to outlast the lifetime of the property. The wiring must be protected against short circuit or sustained over-current by the use of fuses or over-current circuit breakers. Also, the current rating of the circuit must not be exceeded in the event that the circuit is later extended.

In the event of overheating of connections, neither over-current devices nor RCDs would protect against fire ignition unless a secondary event occurred such as contact with another conductor which might produce a high over-current, or contact with an earthed conductor.

Surface tracking may occur in wiring installation accessories such as distribution boxes, switches and socket outlets due to environmental pollution and moisture. Condensation is likely to occur particularly in areas such as cellars and where wiring is routed into buildings. An established track can produce a localised temperature increase sufficient to ignite flammable vapour released from the insulation as a result of heating produced in the track. Whereas an RCD should provide some protection against tracking between the phase or neutral conductors and earth, no protection would be provided against a phase to neutral track. Over-current devices would not provide protection against fire ignition by surface tracking.

RCD protection would also operate in respect of earth leakage currents due to damaged insulation on wiring conductors in metal conduit and at entry points in metal wall boxes.

4.5.2 Motors

The principal causes of fire ignition in motors are arcs or sparks igniting insulation or nearby flammable material. Such events can occur when the motor winding short circuits or grounds or when the brushes operate improperly. Overheating can occur when the ventilation is restricted or the motor is stalled. Bearings may overheat because of improper lubrication. Sometimes excessive wear on bearings allows the rotor to rub on the stator. The individual drives of appliances of many types sometimes make it necessary to install motors in locations and under conditions which are injurious to motor insulation. Dust that can conduct electrically such as brush material may be deposited on the insulation, or deposits of textile fibres may prevent normal operation and obstruct cooling vents.

Motors may be provided with over-current protection to limit overheating should the motor stall or fail to start. In addition, an over-temperature cut-out may be provided. RCDs can provide added protection in respect of fault currents to earth when basic insulation between the windings and an earthed housing becomes contaminated by dust, cracks or fails due to, for example, thermal stress or mechanical stress or ageing.

4.5.3 Transformers

The primary cause of fire with transformers is overheating of conductors and insulation. Fusing is provided to prevent overheating under overload fault conditions and may be supplemented by over-temperature cut-outs.

In many applications, parts of the transformer may be connected to earth and, in the event of a failure to earth an RCD, can provide protection by limiting the current flow and the consequent heating effect.

4.5.4 Switch and Relay Contacts

Failures of contacts may occur due to weak springs, contact-arcing, spark erosion and plating wear. Failures due to contamination can also occur. Surface deposits, particularly carbon or ferrous particles, cause electrical failures and insulation breakdown. High resistance contacts often due to the deposition of non-conducting or semi-conducting material at the contact surfaces will cause local overheating which may result in fire. These faults will not be detected by over-current or RCD protection devices.

Where contamination or tracking across insulation provides a conductive path to earth, RCDs can offer added protection.

Vibration will accelerate mechanical deterioration of contacts and other moving components.

4.5.5 Internal Wiring and Connections

There are two types of faults in electrical wiring. These are open circuit faults where a conductor has parted, and short circuit faults where a conducting path exists between one conductor and another conductor or earth. A fault can be a combination of both an open circuit fault in a conductor and a short circuit fault.

Open circuit faults, such as poor wiring connections due to contact ageing, are an important cause of local overheating and are unlikely to be detected by RCDs or over-current protection devices. Arcing which results from conductor failure in a flexible cord, although potentially a fire hazard, will not be detected by RCDs or over-current protection devices unless a short circuit fault exists at the same time due to, for example, the broken end of the conductor piercing the insulation.

Connections will be sensitive to factors such as load cycling, the initial integrity of the contact interface, vibration, mechanical disturbance, the effect of environmental contamination and growth of tarnish films at the contact interface. Where connections are made to components, surface tracking may occur as a result of conductive surface deposits and moisture. Under these circumstances where the tracking is to an earthed surface, protection may be provided by an RCD.

4.5.6 Heating Elements

Heat elements may have an earthed sheath. RCDs will provide early warning of breakdown of insulation and will also detect pin holes in sheathing when used to heat water.

4.5.7 Summary

From the above considerations it is clear that although RCDs and over-current devices have a role in reducing the risk of fire in electrical equipment, they will not respond to many of the failure modes likely to initiate fire ignition. Particular problems arise in detecting overheating of connections and in-line wiring faults which are a common cause of fires. The role RCDs can play in providing added protection is illustrated by the Table on the following page.

Potential Fault Conditions for Circuit Protection Devices and Electrical Components

Item	Potential Faults	RCD Added Protection	Over-current Protection	Over-temperature Cut-out	Faults Not Protected
Motors	Surface contamination of insulation. Carbon Tracking.	RCDs will trip at low values of earth leakage current due to: tracking or contamination; cracks or faults in insulation caused by thermo-mechanical stress or mechanical damage; arcs or sparks when the motor winding short-circuits or grounds or when brushes operate improperly.	Will respond to overheating if the motor fails to start, provided the operating current is set close with running current.	Will respond to overheaing caused by lack of ventilation or conductor overheating while running.	Ignition of nearby combustable material.
Transformers	Surface contamination of insulation. Overheating.	Where there is a failure of insulation between the primary winding and earth, RCD protection will operate.	Fusing is usually provided to prevent overheating under fault conditions.	Over-temperature cut-outs may be fitted.	Ignition of inter-turn insulation and earth faults from secondary wiring
Switch and Relay Contacts & Controls	The rating and performance characteristics are not suited to the duty cycle. Tracking or contamination.	RCDs can provide protection where tracking or contamination provides a conductive path to earth.	Needed for L-N fault protection.		High resistance contacts. Faults caused by non-operation.
Heating Elements	Pin holes in metal sheathing of mineral insulated elements allowing moisture to penetrate.	RCDs will provide an early indication of breakdown of insulation. Note. Certain elements may not be sealed by design and at switch on, significant levels of earth leakage current can occur due to moisture ingress (see Section 5).	Needed to protect against L-N insulation failure.		
Wiring	Open circuit faults on flexible cords. Short circuit due to insulation damage.	RCDs will detect any loose wires which contact an earthed surface. They will also detect insulation damage in metal conduct.	Required to prevent overheating in the event of a fault, insulation damage and L-N failure.		In-line faults which may occur as a result of flexing or breakage of conductors.
Connections	Vibration loosening; Mechanical disturbance; Deterioration of contact interfaces and overheating; Connections not dimensioned in respect of their heating.	RCDs will detect connections loosened by, for example, vibration which come free and touch earthed surfaces.	Will protect against high current L-N or L-E contact if the connection becomes free.		Will not protect against failures of connections by overheating or the arcing which may result from conductor failure.
Wiring Accessories	May be subject to condensation in humid areas which are subject to wide temperature fluctuations. Contacts can overheat, due to vibration, poor insulation or surface oxidation.	RCDs will respond to condensation leading to liquid build up in enclosures and tracking across insulation.			Failure of connections due to damage or overheating.
Electronic Circuits	Contamination.		Local protection in the form of fusing is appropriate.	May be appropriate for some components.	RCDs will not protect secondary circuits.

5.1 Nuisance Operation

Whether circuit protection is provided by over-current devices or by RCDs, there is a need to balance the level of protection provided against the need to avoid nuisance operation.

5.1.1 Fuses and MCBs

Fuses seldom cause nuisance operation in household electrical systems due to the inherent time delay in the operation of a fuse.

Under certain circumstances, MCBs can operate more quickly than fuses and hence they can be more prone to nuisance operation. Sometimes, failure of a light bulb can trip an MCB. One MCB will usually protect the lighting over an area of the property. In the event of nuisance operation, the householder may then be left with the task of reaching the consumer unit and resetting the MCB in the dark. Consumer units are not always placed where they can be easily reached. In this situation accidents can happen.

5.1.2 RCDs

Often the event causing an MCB or fuse to operate will be an obvious fault in the system, which can be understood by the average householder. However, earth leakage is not usually by intention a part of the function and performance of equipment and, when nuisance operation occurs, the cause is less likely to be understood. Causes of nuisance tripping may require expert investigation and correct application in installation practice is essential. Some problems which arise in practice are given below.

Many types of household electrical appliances have a standing earth leakage current and this will reduce the threshold at which an RCD will trip. This consideration can be particularly important when several appliances are protected by one RCD. Some product standards allow certain types of appliance to have a leakage current of up to 7 mA under normal operating conditions. When more than one such appliance is protected by a 30 mA trip current RCD, the threshold of operation for the RCD would be considerably reduced and encourage nuisance operation. Particular problems may arise with metal sheathed heating elements, immersion heaters, cookers, microwave ovens, and with suppression capacitors on appliances of all types.

Certain types of equipment cause voltage or current transients at switch on. Under normal conditions, the presence of surge or harmonic currents in the phase and neutral conductors will not normally produce imbalance currents sufficient to trip an RCD. Modern equipment often incorporates filter capacitors which may be connected to earth. Under these conditions, even with the same capacitance phase to earth and neutral to earth, voltage transients on the line can produce a difference in current flow between the phase and neutral conductors.

The imbalance is due to the difference between the phase to earth voltage and the neutral to earth voltage since the current flow is given by $I = C \frac{dv}{dt}$ where "C" is the capacitance and $\frac{dv}{dt}$ the rate of change of voltage. In many instances, a voltage pulse on the line will produce only a transient current imbalance which will not be sufficient to trip an RCD. However, the current pulses from switching multiple sources such as a bank of fluorescent lighting fittings may be sufficient to trip an RCD rated to provide protection against electric shock.

In some properties, all the circuits are protected by a single RCD. An earth fault on any circuit will cause all the circuits in the property to be disconnected. In these circumstances, special attention needs to be given to freezers which may present the risk of food poisoning if, during a period when an RCD is not reset, food is allowed to thaw and is then refrozen when the RCD is reset.

The above causes of nuisance operation originate within the consumer's property and can be controlled by providing RCD protection which takes account of practical considerations. In many situations, there will be advantage in providing RCD protection selectively to appropriate parts of the installation.

5.1.3 Combined RCD/MCB Units

The problem of establishing the cause of nuisance tripping is compounded when combined RCD/MCB units are used and confusion may arise if the different modes of operation of the devices are not clearly distinguished when analysing the cause of the problem.

5.2 Spurious Tripping of RCDs

The high sensitivity of RCDs may, in some circumstances, make them subject to spurious tripping due to causes which do not originate in the consumer's property. Causes of spurious tripping may be, for example, lightning storms, feedback from supplies feeding other properties in the area, or transient disturbances on the electricity supply from the local electricity substation.

The effect of these factors may be magnified by the rapid response of some designs of RCD. Modern designs sometimes contain amplifiers which accept signals over a wide frequency bandwidth and can operate with short response times. An RCD tested in the present work was found to operate in response to an impulse signal in times of the order of 3-6 ms.

5.3 Function and Reliability of RCDs

A recent study (Ref. 7) has been made in Italy to highlight the phenomena whereby the performance of RCDs may deteriorate after a lengthy period of inactivity. Earlier studies showed that the operating characteristic of RCDs may be modified to the extent that contacts are prevented from opening. The recent study drew attention to the need for further technical advances to improve the reliability of the residual current relay. Further recommendations concerning reliability included the need to take account of environmental influences, and the need on the part of the user to operate the RCD test button at frequent intervals. The RCDs in the study originated from 30 different European manufacturers and the installation period for the RCDs examined covered the period from 1970 to 1990.

5.4 The Role of the Consumer

The above general considerations demonstrate the need to ensure proper application of RCDs to enable their full potential for reducing safety risk to be exploited. It is therefore important that the consumer is fully educated about RCD capabilities and their operational use.

5.5 Consumer Perception

The widespread promotion of RCDs as a portable safety device may encourage the perception that complete protection is provided against electric shock, and expose consumers to potential hazard if the limitations of these devices are not properly understood. It is believed that many consumers do not fully understand RCDs. Hence a consumer survey has been carried out during the course of the present work to establish consumers' awareness of the benefits and limitations of RCD protection. The survey was designed to identify gaps in consumers' knowledge and to establish what further information is needed to increase understanding of these devices and their proper application (see Appendix 1). A summary of findings prepared by Data Architects is given in Appendix 1.

The survey was conducted using a sample of 2000 adults consisting of males and females aged 16 or over. The respondents were selected from 130 sampling points throughout the UK and were representative of the general adult population.

The survey established that the term RCD is not well recognised within the consumer population. Also, there is a general lack of knowledge concerning how RCDs operate and how they provide protection. The survey showed no significant level of awareness by consumers of the difference in function of RCDs and MCBs. Certain sub-groups including 16-24 year olds and older females are particularly unaware of any of the safety aspects offered by RCDs.

Respondents who owned RCDs had most frequently found out about them by word of mouth, from retail electrical/DIY outlets or by use in the workplace. Users of RCDs (45%) seemed to agree significantly more than non-users (26%) that these devices will provide complete protection against electric shock. A small percentage (about 6%) of respondents agreed with the proposition that the use of an RCD would remove the need to avoid touching live wires; 20% of respondents did not know. Both of these misconceptions could lead to safety problems some of which could prove fatal.

In respect of practical matters, the survey suggests that a significant number of RCD owners do not operate the test button regularly. The survey suggests that about one-third of those owning an RCD had experienced RCDs tripping without any apparent cause. However, this occurrence in a majority of instances happens very rarely - less than once every six months.

The above findings together with the considerations discussed in earlier sections of this report illustrate the need to improve consumer awareness of RCDs and their benefits and limitations. The survey also showed that almost all consumers interviewed feel the need for more information concerning electrical safety.

6.1 Market Factors and Usage in the UK and in Other Member States of the EU

6.1.1 The Position in the UK

Frost and Sullivan (1994) analysis of the residual current devices market for the years 1990-1995 gives the number of devices entering the UK market as of the order of 11 million devices. Portable RCDs have been widely promoted for use with electrically powered garden equipment and power tools. Market assessment of the volume sales of DIY power tools (source Trade Estimates/MAPS) suggests that the volume sales of electrically powered tools over the years 1990-1995 would be of the order of 14 million units. Over the same period, volume sales of electric mowers was of the order of six million units (ERC Statistics International). Although the volume sales of RCDs (11 million devices) are significantly less than the volume sales of power tools and garden electrical equipment (20 million units) the high added cost of portable RCD units makes it unlikely that an RCD would be sold for every two purchases of a power tool or a lawn mower. If one in four purchases of electrical garden equipment or tools resulted in the sale of a portable RCD this would account for something of the order of five million portable RCD adaptors in service. Fixed wiring installations in commerce, industry and in dwellings would then need to account for six million RCDs. Market share analysis (1993) suggests that portable RCDs account for 20% of the market by revenue, suggesting that a high proportion of the RCDs produced are used in fixed wiring installations.

Since 1992, the UK wiring regulations have required that socket outlets which reasonably might be used to supply portable equipment for use outdoors should be protected by an RCD (BS 7671: 1992; Reg. 471-16). All properties approved to National House Building Council (NHBC) specifications built since July 1992 can be expected to be fitted with RCDs protecting all power circuits supplying sockets. RCDs may also be expected to be fitted when renovations are made. The number of new dwellings constructed in the period 1992-1996 is estimated to be of the order of 0.9 million. The number of renovations made during this period is estimated to be 2.5 million. Widespread awareness of RCDs extends back to about 1985 and a significant number of dwellings are likely to have been fitted with RCD protection prior to 1992. This applies particularly to dwellings in country areas fed by overhead lines, where RCD protection is a requirement of UK wiring regulations. In the period 1985-1992 about 1.5 million new dwellings were constructed and 3.5 million properties were renovated. If it is assumed that in 1985, 30% of these dwellings were fitted with RCDs with the percentage increasing linearly to 75% in 1996, then the present number of dwellings with RCD protection would be of the order of 20% of the total stock of dwellings in Great Britain. This estimate assumes that all new housing since 1992 has been fitted with RCD protection.

The above considerations suggest that in Great Britain there are already a significant number of dwellings with RCD protection (see also Appendix 1). However, the number of households with RCD protection in the fixed wiring is estimated to be relatively low at the present time compared with the total number of households.

6.1.2 Usage in Other Member States of the EU

There is widespread use of RCDs in other Member States of the European Union. In Italy, most houses are reported to have RCDs installed as there is no protective earth conductor. In France, all houses and flats are required to have RCDs of 500 mA at entry to the installation to protect against fires. French national wiring codes recommend that all properties in France should have a 30 mA RCD installed to protect against the risk of electrocution in bathrooms. Since 1991, it has been obligatory for new electrical installations to be protected against overload and earth leakage currents. It has been estimated that at least one million new homes in France have this type of protection. Socket outlets in bathrooms have been permitted by French and German wiring codes for many years. Recent legislation following fatalities in Germany now calls for such outlets to have supplementary protection (RCDs). In Germany, all newly built houses and flats since 1991 have been required to fit 30 mA RCDs in bathrooms. It is estimated that 20-30% of all German houses/flats are now fitted with these devices.

In the UK, socket outlets in bathrooms are banned.

6.2 Consideration of the Safety Impact in Respect of Reducing the Number of Accidents in the UK due to Electric Shock

The principal function of an RCD is to protect against electrocution. On a case-by-case basis it is possible to predict a high success rate in protecting against death by electrocution when an RCD with a trip current of 30 mA or less is used. The effectiveness of RCDs in reducing the numbers of hospital treated injuries caused by electric shock is likely to be less significant, since a serious electric shock can occur below the current levels at which an RCD will operate.

Impact on UK accident statistics will be critically dependent on correct application and a high market penetration of RCDs. The statistics available at present show no apparent trend in the incidence of fatal or non-fatal accidents which can be linked to the use of RCDs. This would be expected in view of the low percentage of dwellings with comprehensive RCD protection installed and the relatively small number of accidents which occur compared with the total number of dwellings.

6.3 Consideration of the Safety Impact in Respect of Reducing the Annual Rate of Accidents due to Fire

Surface tracking across insulation is a known cause of fire ignition and is responsible for a significant proportion of appliance fires. RCD protection can play an important role in reducing the risk of fire due to this cause. However, this mechanism is only one of a range of conditions in wiring and electrical equipment which causes fires.

A recent study sponsored by the DTI Consumer Safety Unit on the causes of fires in domestic appliances, giving the highest risk of fire due to faults in appliances, showed a consensus of opinion throughout the European Union that the most frequent cause of fire ignition mechanism is associated with wiring and connections. Many such faults are unlikely to be protected by over-current devices or RCDs. The study also showed that a significant proportion of fires were believed to be caused by spillage and leakage of fluids. This type of fault can be detected by RCDs as detailed in Section 4.4 of the report.

Based on the findings of the above study, and the results of Section 4 of this report on a case-by-case basis, a reduction in the number of fires of the order of 20% might be expected to result from the use of RCDs in addition to over-current protection for Class I products. To achieve this level would however require a high proportion of properties to be fitted with RCD protection.

RCDs would not be expected to provide protection against fire for Class II products.

Deaths by fire are usually associated with particular types of product and the majority of these have Class II protection.

A particular concern in respect of deaths by fire is when electrical equipment is operating unattended, particularly at night, which may allow the development of fire. The limited coverage of the protection provided by RCDs in respect of the different types of fault condition likely to induce fire, means that RCD protection is unlikely to significantly reduce fire risk in these circumstances.

7 Conclusions

7.1 Fuses and over-current circuit breakers (MCBs) used in home electricity wiring installations cannot be expected to prevent death by electrocution when simultaneous direct contact is made with a supply conductor at 230V and earth.

7.2 RCDs with a rated trip current of 30 mA or less are likely to protect against death by electrocution caused by ventricular fibrillation of the heart when the current path is between a live conductor at the supply voltage and earth. Protection is not provided against a phase conductor to neutral current path.

7.3 Electricity supply arrangements and electrical equipment used in the home is designed to prevent accidental direct contact with conductors at hazardous voltage relative to earth and to provide two levels of protection against electric shock. The role of RCDs is to provide additional protection in normal service in the event of failure of other protective measures or carelessness by users.

7.4 Even with RCD protection, it is possible to receive an electric shock which may present risk of injury. However, the risk of death by electrocution will be reduced significantly.

7.5 The value of RCD protection would be expected to be greatest where there is likely to be humid or wet conditions, and in areas where there is a predominance of accessible surfaces at earth potential.

7.6 Product safety standards seek to minimise the risk of fire ignition and to ensure that if fire ignition does occur, then the fire is contained. Installation protection devices can sometimes play a role in reducing the incidence and severity of fire in electrical systems and equipment. For appliances with an earth connection, RCDs would be expected to limit the duration and current flow to earth and thereby reduce the risk of fire ignition.

7.7 For double insulated products, no earth connection is taken to the product and no added protection against fire would be expected to occur if an RCD was used.

7.8 Surface tracking is a common cause of insulation failure. RCDs can respond to currents below the level needed to cause flame ignition in circumstances where over-current protection would not be expected to operate.

7.9 Leakage or spillage of electrically conductive fluids can trigger RCD operation if the fluid provides a conducting path across insulation between live conductors and earth, and can delay or reduce the risk of fire.

7.10 The use of RCDs in addition to over-current devices and thermal cut-outs, can protect against a wide range of fault conditions which cause fire, and can be effective against faults which occur on a wide range of components used in household electrical appliances.

7.11 Particular faults where neither RCDs nor over-current breakers provide protection include overheating connections and arcing caused by conductor break. These faults are a common cause of fires.

7.12 Whether circuit protection is provided by over-current devices and/or by RCDs there is a need to balance the level of protection provided against the need to avoid nuisance operation. Causes of nuisance operation which originates in consumers' premises can be controlled by providing RCD protection which takes account of practical considerations. In many situations there will be advantage in providing RCD protection selectively to appropriate parts of the installation.

7.13 The high sensitivity of RCDs may, in some circumstances, make them subject to spurious tripping due to causes which do not originate in the consumer's property. Causes may be lightning storms, or imbalance on the incoming supply. The effect of these factors may be magnified by the rapid response of some designs of RCD.

7.14 To maintain the reliability and function of RCDs it is necessary to operate the test function regularly.

7.15 Market factors and usage of RCDs in the UK, suggest that a higher level of market penetration and understanding of these devices would be needed to produce a statistically significant downward trend in the national accident statistics. However, on a case-by-case basis it is possible to predict a high success rate in protecting against death by electrocution when an RCD with a trip current of 30 mA or less is used.

7.16 A consumer survey made during the work established that the term RCD is not well recognised within the consumer population. Also, there is a general lack of knowledge concerning how RCDs operate and how they provide protection. In some instances, it is possible that prevalent misconceptions could lead to safety problems some of which could prove fatal. The survey also identified a perceived need by consumers for more general electrical safety information.

7.17 To achieve the full potential of RCDs in providing protection against death by electrocution and in reducing the incidence of fires, there is a need to ensure proper application in installation practice and to improve consumer awareness of the benefits and limitations of these devices.

8 Recommendations

8.1 To ensure proper application and usage, it is important that RCDs are provided with clear and easy to understand instructions.

8.2 It is a useful contribution to Home Safety for government, safety professionals, consumer organisations and industry to improve consumer awareness of RCDs (and other aspects of electrical safety).

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Acknowledgements:

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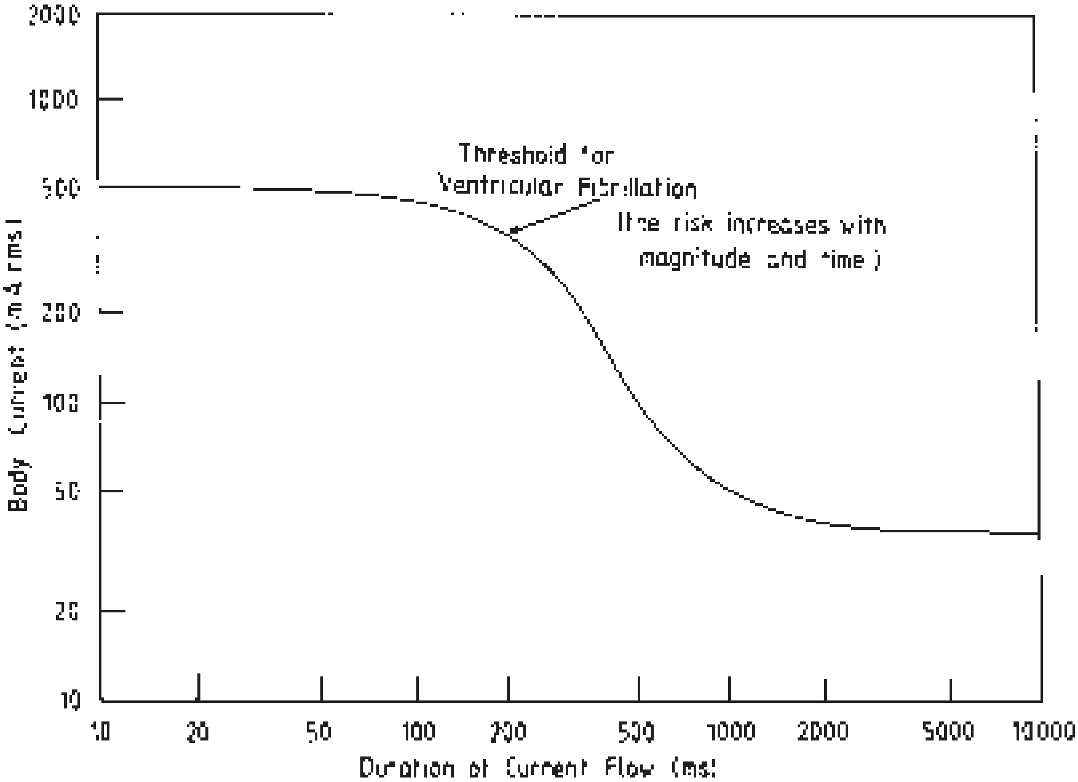


Fig. 1 : Electric Shock Current-Time Characteristics : Threshold for Ventricular Fibrillation (Ref : IEC 479 : 1984)

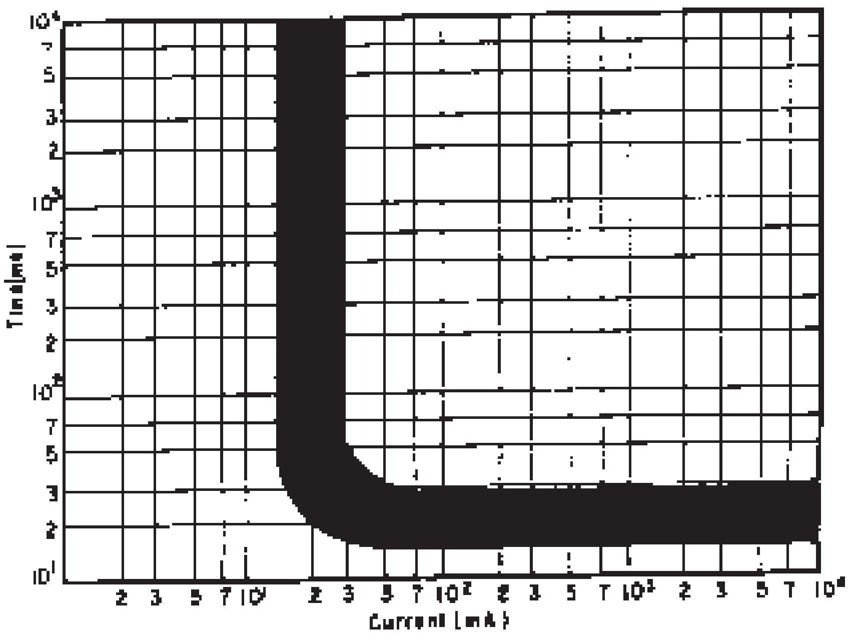


Figure 2 : Typical Time-Current Characteristic of an RCD

Table 1

Average annual number of fires in the UK attended by fire brigades where the fires are attributed to faults in electrical appliances, lighting or wiring.

Appliance Type	Average incidence of fires attended by fire brigades attributed to faults in appliances	Probable Construction Class	
Washing machines	1747.00	I	
Blankets, bedwarmers	640.00		II
Other	477.00		
Electric cooking appliances	445.00	I	
TV	368.00		II
Dishwashers	320.00	I	
Tumble/Spin drier	305.00	I	
Electric water heating	263.00	I	
Refrigerators	253.00	I	
Electric space heating	234.00	I	
Lighting	183.00	I	II
Central heating	76.00	I	
Other wiring	52.00		
Irons	16.00	I	
Plugs, socket switch	16.00		

Annex 1 : RCD Operation

RCDs respond to small earth fault currents of the order of milliamperes and reduce the risk of electric shock and fire by disconnecting the supply when these currents exceed a set level. Public electricity supplies are connected to earth at the supply source. By convention, the direction of current flow is from the source to the load via the phase (L) conductor. The current returns to the source via the neutral (N) conductor. An RCD operates by sensing when the current in the phase conductor is not equal to that in the neutral conductor. (For example, one reason for more current flowing in the phase conductor than in the neutral, is that some of the phase conductor current has returned to the source earth as a result of earth leakage or an earth fault current). The sensitivity of RCDs to earth faults may depend on the earthing arrangements of the system.

To operate an RCD, the earth leakage must occur in the circuit beyond the RCD sensor. It is not the function of an RCD to respond when a fault current or leakage path occurs between phase and neutral conductors. Common mode currents induced in the system can cause spurious operation of RCDs.

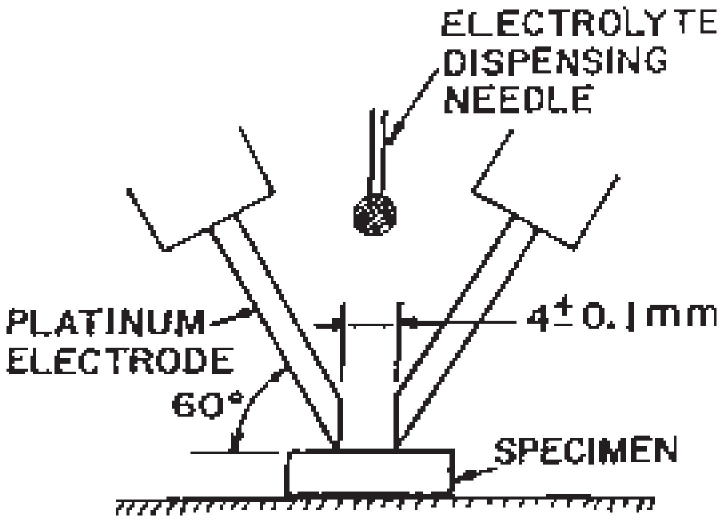
Annex 2 : Residual Current Devices (RCDs)

RCDs are available in several forms:

- as portable adaptors
- incorporated in socket outlets or plugs
- as separate stand alone units for fixed wiring installations
- as modular units for DIN rail mounting, for example, in household consumer units
- as modular combined RCD/MCB units.

In general, RCDs are not designed to break the high short circuit currents which may occur in household wiring installations and must be used with an over-current protection device such as a fuse or MCB in the installation.

Annex 3 : The Comparative Tracking Index Test (IEC Specification 112)



The diagram above shows the tracking test configuration The tracking test operates as follows:

a) A standard contaminant liquid having a conductivity of 2.4 siemens is fed as a single drop to fall between the two electrodes which are set to a test voltage, e.g. 250V is common at the present time. In earlier years 125V or 175V were often specified.

b) The heat developed by the passage of current through the liquid evaporates the liquid and heats the specimen.

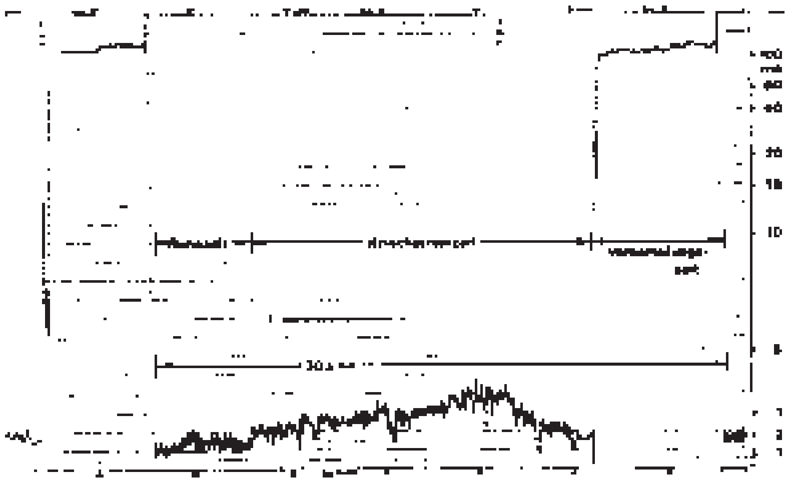
c) In the final stages of evaporation, discharges can be observed on the surface of the insulation which are known as scintillations and these create sites which develop into a tracking path. Different materials will require a different number of drops of the test solution or a different test voltage to produce tracking sufficient to form a sustained conduction path between the electrodes.

The test is continued to 50 drops of the test solution. A failure has occurred if a current of 500 mA or more flows for at least 2s in a conducting path between the electrodes on the surface of the specimen, thus operating an over-current relay; or if the specimen burns without releasing the relay.

Annex 4 : Practical Tests on Surface Tracking Induced by Fluid Contamination of Insulation and RCD Protection

1. Background

A record of the current produced using standard tracking test equipment is shown in the Figure below (Source : Ref. 1)



Current-Time Characteristics in a typical tracking test

It can be seen that the liquid conductivity in the first phase gives a current between the electrodes of the order of 100 mA. In the second phase, surface discharge activity is associated with currents of the order 2-5 mA. When discharge activity ceases, the current is of the order of 2 mA. Clearly, when the liquid is present the current would be sufficient to trip a 30 mA RCD. However, during the discharge period before the establishment of a low resistance tracking path, an RCD would be insensitive to the level of current needed to prevent deterioration of the surface of the insulation.

2. Tracking Tests

Further tests at ERA have been made to assess the effects of contamination of insulation by conducting fluids and the effectiveness of RCD protection in preventing fire ignition by tracking.

Standard Test Solution

A 0.01 ml drop of the standard tracking test solution was applied to the insulation between two conductors on a printed circuit board (gap 3 mm) and a voltage applied between the conductors. When the voltage applied was 80V, bubbles were seen to form at the electrode interface with the fluid. The measured current was 4.2 mA. At 10V the liquid evaporated.

In a second test at 250V, the phenomena observed were similar to those in a conventional tracking test rig. Scintillations were observed as the liquid evaporated and eventually a track formed which extended approximately halfway across the insulation. The current measured was 37 mA.

A second drop was applied at the same position on the insulation. Further tracks formed and the current level increased to 65 mA. On the fourth drop, the current increased to 80 mA and a track was formed between the conductors. As the current increased to 90 mA, the track glowed red and a yellow flame ignited along the length of the track. The flame height was approximately 8 mm. The current observed in this experiment allows the inference that an RCD with a trip current of 30 mA would have interrupted the process before flame ignition occurred. An RCD with a trip current of 300 or 500 mA would not have been effective.

In a second similar experiment with a 32 mA RCD in circuit, tracks were formed but it was not possible to ignite the material. Nine attempts were made. A factor in this experiment was that only a small quantity of liquid could be applied between the conductors to avoid causing the RCD to trip.

Household Liquid Solution

Some detergent fluids have a high conductivity compared with the standard test fluid used in the tracking test. A test was carried out using one common fluid which has a conductivity of approximately 5 times that of the standard tracking test fluid.

A drop of solution was applied to the insulation between two conductors of the printed circuit board (gap 3 mm) and a voltage applied between the tracks. When the voltage applied was 40V, bubbles were seen to form at the electrode interface with the fluid. The current measured was 8 mA. Within a time of the order of seconds, the bubbles spread to form a central path between the printed circuit board conductors.

In a second test at 250V, the phenomena observed were similar to those in a conventional tracking test rig with scintillations occurring as the liquid evaporated and eventually a track between the conductors was established. The order of current observed during the test were 8-84 mA. Following complete evaporation of the liquid and the cessation of discharge activity, the resistance between the printed circuit board conductors was measured as greater than 400 MΩ. During the test, a pink coloured flame 2 mm high was observed apparently associated with decomposition of the fluid. The currents involved in this experiment suggest that RCD operation would have interrupted the process. However, the dominant cause of the high conductivity was the presence of the fluid or its effect in maintaining a continuous conductive path along the track. Examination of the specimen after the test suggested that the fluid played a dominant role in the failure process rather than the intrinsic properties of the printed circuit board insulation.

A third test was made to establish the progress of events with a 30 mA RCD in circuit. In the presence of a drop of the fluid across the insulation, the RCD tripped due to the high conductivity of the fluid. With less liquid present, scintillations occurred and the RCD did not trip. Following a second application of the liquid, tracking developed across the insulation. A period followed in which the track glowed red then the RCD tripped to halt the process.

It is clear from the tests that if contamination by conductive fluid can bridge insulation to earth and produce a low conductivity path, this is likely to trip an RCD. However, where the film resistance is such that heating will cause evaporation, tracks will form below the threshold for RCD operation. RCDs will provide no protection against tracking or fire ignition when live to neutral insulation is bridged unless there is an associated path to earth.

The above test shows that high sensitivity RCDs will trip when the presence of conductive fluid contamination spillage or spray in appliances results in earth current flow. In such cases, the RCD may arrest the progress of tracking before flame ignition of insulation occurs. Although only a limited amount of testing has been carried out in the present work, it is clear that RCDs have the potential to reduce the incidence of fire due to surface tracking.

Ref. 1

Suhr, H

Den Kriechstrom im Griff, Prüfverfahren bei Isolierstoffen auf deren Kriechstromfestigkeit

Elektrotechnik Vol 5,9 H.23, 9 Dezember 1977

Acknowledgement: ERA is grateful to the editor of Electrotechnik for permission to copy the figure shown in this Annex.

Appendix 1

RESIDUAL CURRENT DEVICES (RCDs) - ADDED VALUE FOR HOME SAFETY

CONSUMER AWARENESS STUDY (ERA Ref. 25-03-2921)

Background

Faulty electrical house wiring can cause fires and lead to injuries. Also, electrical consumer products such as washing machines, fridges, tumble driers and other household appliances can give rise to fires, particularly if these products are old or poorly maintained. Whilst these instances are rare, the property damage caused is sometimes significant and in a few instances severe injuries and even fatalities result.

In addition, electrocutions can occur with electrical products, for example, as a result of accidentally cutting through a lawn mower cable.

In all properties, fuses or circuit breakers are used to limit the effects of electrical equipment failures. Residual Current Devices (RCDs) respond to much lower fault current levels than circuit breakers or fuses and have the potential for reducing both the annual rate of deaths by electrocution and the incidence of fire when properly applied. RCD protection is already installed in some properties.

RCD protection is not effective in all circumstances and the present study seeks to determine the extent to which consumers are aware of RCDs and their proper application.

The Consumer Safety Unit of the DTI already publish safety information on this subject and the purpose of the present work is to establish the effectiveness of this literature, to identify gaps in consumers' knowledge and to establish what further information is needed to promote the use of RCDs and their proper application.

The Technology

RCDs are available for whole house protection and may be installed in the main "consumer unit" where the supply enters the property together with either fuses or, more commonly, circuit breakers. They are also available installed in individual socket outlets or as portable devices which can be plugged into a conventional socket outlet.

Portable RCDs have been widely promoted for use with garden electrical equipment such as lawn mowers and hedge cutters. When electrical equipment is operated in damp conditions, the risk of electrocution from, for example, cutting through the supply cable is greatly increased and therefore the use of RCDs is particularly recommended.

RCDs will operate if a fault current flows from the power supply conductors to ground or to an earthed object. RCDs can be sufficiently sensitive to respond to a current flowing through the body and to interrupt the current before electrocution occurs if the current is flowing in a path to earth.

Residual Current Devices - Consumer Survey March 1997*

RCDs operate by detecting the difference in current flow in the supply conductors when a fault current flows to earth.

Fuses and circuit breakers other than RCDs operate by responding to high values of current overload in the supply conductors. RCDs will not operate under these conditions and therefore must be used with an over-current circuit breaker or fuse in the supply circuit. Combined units are available which provide both over-current and RCD protection.

It is important to note that even with an RCD in circuit, a severe electric shock may be experienced. However, death by electrocution is unlikely with an RCD unless the current path is between the power supply conductors and not to earth.

The high sensitivity of RCDs may in some circumstances make them prone to spurious tripping which may be the result of unusual supply conditions. Also, some types of equipment may need special consideration in respect of the sensitivity of the RCD used. It is of interest to determine the level of incidence of this type of operation of RCDs and the measures taken to avoid nuisance tripping.

Information required

Broad quantitative estimates referencing male and female respondents

1. What proportion of consumers are aware that there is a safety device which increases protection against electric shock particularly in hazardous areas such as the garden?
2. By what name do they know this device? (Portable adaptors which act to disconnect the supply will be RCDs, other names by which they are known may be: safety breaker, earth leakage trip, etc).
3. What proportion of consumers know what an RCD is and what it does?
4. How did they find out about RCDs?
5. To what extent have they experienced tripping of an RCD with no apparent cause or fault present?
6. How often do consumers who have RCDs activate the test button?

Supporting qualitative data

1. In which situations would RCDs be likely to be of most benefit - in order of importance:
   a) gardens and outbuildings
   b) kitchens and bathrooms
   c) living areas and bedrooms
2. Which products would RCDs be likely to be effective with - in order of importance?
   Lawn mowers, hair dryers, washing machines, lighting, TV, freezers, christmas lights, DIY tools.

**Extracts from an Executive Summary produced by Data Architects*

3. Do consumers expect that RCDs will be of benefit in stopping equipment catching fire?
4. Are consumers aware that RCDs do not provide complete protection against electric shock?
5. Does the consumer believe that where an RCD is fitted, the need to avoid touching live wires no longer exists?
6. Are consumers aware of the need to regularly test RCDs?
7. What do RCDs do? How does this differ from fuses and circuit breakers?
8. Are consumers aware that although RCDs provide a valuable contribution to protection against electric shock, they are not a replacement for fuses and circuit breakers and that it is still important to maintain existing earthing arrangements?

Information might also be sought concerning the areas in which consumers considered that more information was needed. For example:

a) What types of RCD are available and what are their advantages, disadvantages and costs?
b) The situations where they should be applied
c) What to do in the case of RCDs cutting-out without apparent cause
d) What earthing arrangements they should have in place
e) General electrical safety information

Timing

The information is needed during the month of February 1997 and should be started as soon as possible.

A H Powell

Product Assessment Division

22 January 1997

Background to the research

As part of the project conducted by ERA, a survey of consumer awareness, usage and attitudes was conducted using a structured face-to-face interview in order to complete the understanding of the current market.

The survey was conducted using a sample of 2,000 adults consisting of males and females aged 16 or over. The respondents were selected from 130 sampling points in the UK and are representative of the general adult population.

The data has been cross tabulated by the questions and sub groups of sex, age group, social class, ITV region and usage of RCD devices. A full set of the tables and a copy of the questions is attached for review.

Summary of findings

The first two questions asked, were aimed at establishing the levels of awareness of these devices and their names. Here, around 45% of the sample were unable to spontaneously name any electrical safety device at all, and this rises significantly to 57% amongst all women and 54% amongst those aged 55 years and above.

Only 123 individuals within the sample spontaneously used the description of 'Residual Current Device/RCD'. These were almost entirely male and aged 35 years and above.

On prompting with a list of device names, by which RCDs may commonly be known, the recognition levels of at least one rises dramatically to around 90% across the whole sample. Prompted recognition of Residual Current Device/RCD only rises to 18% however indicating a general lack of understanding of the terminology:

Description	Spontaneous %	Prompted %
Named device A	7.00	69.00
Named device B	15.00	66.00
Named device C	5.00	37.00
Residual Current Device/RCD	5.00	18.00
None Named/Recognised	45.00	10.00
Any	55.00	90.00

The next two questions concerned themselves with the household penetration of these safety devices and their various types. Across the sample, around 75% claimed to have at least one of the five devices currently installed in their home. The pattern of claimed usage closely follows that of awareness amongst the sub groups. Across the sample, 36% of respondents or 724 individuals claimed to have at least one of three named safety devices in the home.

Within this group, the most commonly occurring type at 42% (or 15% of all households) was the adapter RCD that is portable and plugs into a three pin socket, followed by circuit RCD at 29% (or 11% of all households). Interestingly, women were more likely to claim usage of the portable RCD type than men, who conversely favoured the circuit model more. The use of the portable product also has an upmarket (AB) and non-urban regional bias, possibly connected with gardening activities.

Base = Safety device owners (724) Type	All %	Males %	Females %	AB's %
Portable RCD	42.00	39.00	45.00	49.00
Circuit RCD	29.00	36.00	20.00	22.00
Plug RCD	19.00	23.00	15.00	18.00
Socket RCD	15.00	18.00	11.00	16.00

Respondents who owned any of the safety devices were also asked to recall from what source or sources they had first found out about them. The results indicate that word of mouth and the retail electrical/DIY outlets play the greatest part in this and that their use at work also plays a part particularly for males. Radio, Television and Press information sources were infrequently mentioned at less than 10%.

About one third (30%) of those owning an RCD had experience of tripping without any apparent cause. Most of those who had experienced this problem (71%) claimed that it happens very rarely - less than once every six months. Only about a quarter (27%) of owners claimed to test the RCD every time they used it, and about a third claimed never to test it or that it 'did not have a test button'.

The final section of the questionnaire covered attitudes towards the use of safety devices and the various areas of application and security they provide. Respondents were asked to indicate on a six point scale scored from (1 to 6) the level at which they agreed or disagreed with a series of eight statements that could be made about RCDs* in various situations as follows :

- I always use RCDs with any electrical equipment.
- I only use RCDs for gardening or DIY.
- RCDs are most important where children are present in the home.
- I would only fit RCDs where there is risk of electrical fires.
- RCDs will provide complete protection against shocks.
- RCDs are the same thing as circuit breakers.
- RCDs are just more sophisticated fuses.
- Where RCDs are fitted there is no need to avoid live wires.

Mean scores and error variance were calculated for each of the sub groups to allow for significance testing between them.

* *The respondents were prompted to allow them to answer, also in respect of the list of named devices understood to have the properties of RCDs.*

Overall, the strongest level of agreement (68%) came in response to statement 3 about the importance of RCDs where children are present in the home. The greatest level of disagreement (69%) came with statement 8 about there being no need to avoid live wires indicating a universal level of respect for the power of electricity in all situations. The highest level of 'don't knows' came in response to statement 6 claiming that RCDs were similar to circuit breakers indicating a general lack of knowledge about the workings of RCDs and how they provide protection.

Users of RCDs did however seem to agree significantly more (45%) with statement 5 about providing complete protection against accidental shocks than non-users (26%) indicating that they perceive an intrinsic safety value in the RCD products.

Finally, all users were asked what types of information they would like to be made available on electrical safety devices. A majority favoured the more general types of electrical safety information (49%) but a significant proportion (19%) also requested information on the different types of RCDs available and their advantages and disadvantages (14%). Very few were interested in what to do when they cut out without apparent cause (6%).

Conclusions from the research

The large majority of consumers are unaware of the term Residual Current Device or RCD. Overall household penetration of RCD type electrical safety devices is around one third (36%) of the general adult population.

Certain sub groups, including older females and 16-24 year olds are particularly unaware of any of the safety aspects offered by RCDs. The research also pinpoints the perceived value of RCDs in homes where young children are present.

Despite low levels of awareness and penetration of the RCD products, consumers still exhibit a very healthy respect of the dangers of live electricity even amongst those sub groups with the products in situ. This indicates that any increased usage and penetration of RCDs will not necessarily decrease consumers' regard for safety when live wires are present in the home.

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DTI
1 Victoria Street
London
SW1H 0ET

A H Powell - Author
A W Axtell - Manager
Product Assessment Division
ERA Technology Ltd