Electrical Guidance Note 3 : Residual Current Devices (RCDs)

1 Introduction

The purpose of EGN 3 is to set safety standards and ensure that those who select, use and maintain residual current devices (RCDs) in broadcasting environments are aware of their responsibilities under BBC Requirements and the *Electricity at Work Regulations 1989*. It is intended to cover the selection, maintenance and use of RCDs in all areas and in particular will apply to Resources, N&R, DEC, F&L, Sport, News, World Service, Radio & Music, Technology, Broadcast and CBBC.

The RCDs covered by this Guidance Note will be various types and will be found:

- Bay mounted
- In workshop power cabinets or on bench supplies
- In tape areas where there is movable trolley equipment
- In Radio or TV Studios and within OB Units and for their external power outlets
- In use with Performers' equipment in studios
- On location, in both News, PSC (portable single camera) work and Radio Cars

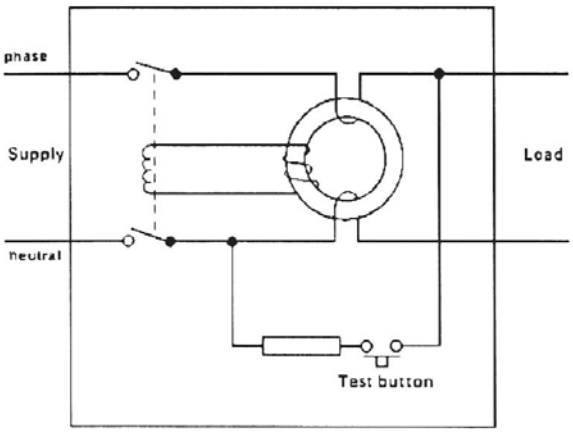
Note that the correct name for the RCDs usually provided in BBC use should be RCCB (residual current operated circuit-breaker) as this is the name for a device without integral overload protection. Other devices are available with integral overload protection and are known as RCBOs.

This EGN replaces all previous safety documentation with regard to the selection, use and maintenance of RCDs, issued by BBC Safety or by the former Engineering Management Safety Committee (e.g. EMSC guidance Paper No. 3). It does not however, replace documents issued at Divisional or Departmental level, although such documents must neither conflict with nor set standards which are not as rigorous as those given here.

RCD - Principles of operation

An RCD is designed to operate and isolate the circuit from the supply when there is an imbalance in the phase and neutral currents above a certain value. Any imbalance must either be the result of current leakage from the phase or from the neutral conductors to earth as, in normal operation, all current should be returned via the neutral conductor. As the earth impedance is unlikely to be zero, any 'earthed' metalwork would rise in potential, which would lead to a risk of shock.

The basic construction of an RCD consists of three windings on a transformer core:



When there is an imbalance in the phase and neutral currents the magnetic flux in the core will cause a current to flow in the third winding. As the current in this third winding increases, the magnetic trip will operate and disconnect the supply from the equipment. The trip current is arranged to be that at which the desired RCD characteristic is achieved.

The RCD will trip at a much lower current than that required to break a conventional fuse or to trip a miniature circuit breaker.

If a person touches the phase conductor on the load side of the RCD this will also imbalance the supply, by creating a leakage path to earth, and trip the RCD.

A built-in 'test' button can be used to place a load between the output phase conductor and the input neutral conductor, creating an imbalance in the windings - this imbalance causes the RCD to trip. However, the 'test' button only demonstrates that the trip mechanism works, confirming nothing else about its specific operational characteristics.

Most RCDs are rated at 30mA and 40ms and must disconnect the supply within 40ms for a leakage current of 5 times the rated operating current i.e. 150mA.

RCDs are commonly available with fixed trip currents from 10mA to 500mA but can be obtained up to 3A. Adjustable value units are also available (see EGN 7).

RCDs – Problems in use

A problem with RCD operation arises with much modern electronic equipment where the load is such as to distort the supply waveform e.g. where switch mode power supplies are in use. This results in a chopped or distorted waveform rather than a sine wave, the effect of which is to give a pulsating DC waveform which can de-sensitise the RCD trip operation, as the superimposed DC may cause saturation of the magnetic core reducing its efficiency as a transformer. Modern designs of RCD overcome this problem, either by adding a capacitor in series with the trip coil so as to resonate with the coil and amplify the trip current, or by use of different core materials which do not saturate so easily. Such RCDs should always be used by the BBC as much of our equipment includes switched mode power supplies. They are defined as type A RCCBs.

2 H&S Legislation

The *Electricity at Work Regulations 1989* specifically deal with electrical "systems" in Regulation 4:

(1) All systems shall at all times be of such construction as to prevent, so far as is reasonably practicable, danger.

(2) As may be necessary to prevent danger, all systems shall be maintained so as to prevent, so far as is reasonably practicable, such danger.

(4) Any equipment provided under these Regulations for the purpose of protecting persons at work on or near electrical equipment shall be suitable for the use for which it is provided, be maintained in a condition suitable for that use, and be properly used.

Regulation 8 deals with Earthing, or other suitable precautions, and paragraph 14 of the Guidance points out the many accidents caused by metalwork becoming live as a result of faults and high impedance protective conductor connections. It is stated that the danger may be reduced by the use of a Residual Current Device, which is designed to operate rapidly at small leakage currents (typically not exceeding 30mA) but qualifies this by stating that this does not eliminate the risk of shock and should only be used as a second line of defence.

BS7671:2001 Requirements for Electrical Installations (IEE Wiring Regulations 16th Edition) defines the wiring standards for the UK. Installations to this standard are regarded as giving conformity with the relevant parts of EAW 1989. Whilst their use is not mandatory, electricity supply authorities may refuse to connect an installation not conforming to this standard.

Paragraph 130-04 on 'Precautions against earth leakage and earth fault currents' in 130-04-03 states that a residual current device or equally effective device shall be used whenever the prospective earth current is insufficient to cause prompt operation of the overcurrent devices (i.e. fuse or MCB).

Paragraph 412-06 'Supplementary protection by residual current devices' on protection against direct contact states:

-01 An RCD shall not be used as a sole means of protection against direct contact.

-02 The use of an RCD is recognised as reducing the risk of electric shock where the following conditions are complied with:

(i) one of the protective measures specified in 412-01-01 shall be applied (insulation, barriers or enclosures, obstacles, placing out of reach) and

(ii) the RCD shall have a rated residual operating current not exceeding 30mA and an operating time not exceeding 40ms at a residual current of 150mA, as provided by BS4293, BS7071, BS EN 61008-1 or BS EN 61009-1.

For protection against indirect contact Section 413 in 413-02-07 states that one or more of the following protective devices shall be used:

(i) an overcurrent device

(ii) a residual current device

This is to ensure that the automatic disconnection of the supply will occur within a specified time of 0.4s on a 230V supply for socket outlets which supply portable equipment intended for manual movement whilst in use or handheld Class 1 equipment (this may be increased to 5s in other specific cases).

If this disconnection time cannot be achieved by fusing alone then an RCD must be used.

471-08-01 For installations and locations of increased shock risk, such as those in Part 6 of BS 7671, additional measures may be required. Item (i) of these is the use of an RCD. Part 6 lists: swimming pools, caravans, motor caravans and caravan sites. This section can be a problem for OB equipment and broadcasters when connecting to a venue's power supply (see EGN 7).

Section 531 further defines the requirements for an RCD.

Functional testing is dealt with in 713-13-01, which states that for an RCD 'its effectiveness shall be verified by a test simulating an appropriate fault condition and independent of any test facility incorporated in the device'.

3 Hazards and risks

The main hazard associated with electrical equipment is electric shock where a fault condition exists and the first line of protection has also failed, or when working with exposed mains during maintenance. During maintenance the shock would be by direct contact and there are specific precautions to be taken (as specified in EGN12). During normal use of equipment the application of BS 7671 'Requirements for Electrical Installations' (IEE Wiring Regulations), which specifies the earthing and fusing systems to be used, should ensure rapid disconnection of the supply and reduce the risk of shock due to indirect contact. The use of an RCD may further reduce the severity of the shock. In certain circumstances a normal earthed system may not give the full protection needed and the recommendation to fit an RCD will provide additional safety.

An electric shock is only dangerous when the current is greater than about 10mA. However the figure is not easily defined, as it is dependent on the duration of the current flow. A low current for a long time can be as dangerous as a high current for a short time. The voltage is not important except for causing the current passing through the body. Voltages of over 50V normally cause an involuntary action, which will throw off the body, but in some circumstances the body may become 'locked on' to the supply. Currents of over 50mA can cause unconsciousness and if prolonged may lead to death.

The current passing through the body depends on the voltage, contact area, moisture level and the body resistance all of which can vary considerably. Under dry conditions the body resistance may be 1500 ohms but can fall to 200 ohms; with a 230V mains supply, this would give currents of about 150mA and 1.2 amps respectively. Such currents could easily cause electrocution, as a normal fuse or circuit breaker would not be expected to break and disconnect the supply. An RCD in the supply would limit the duration of the shock to less than 40ms and hence reduce the severity of the shock.

The need for RCDs to be fitted and used in any given electrical system should be identified by risk assessment (see Corporate Requirements for Risk Assessment).

4 Selection, use and maintenance of Residual Current Devices

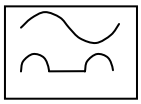
So far as they relate to matters within their control and as is necessary to prevent injury arising, managers **must** ensure that :

4.1 Selection of RCDs

- RCDs are selected according to their intended conditions and purpose of use and must be the 'ac plus pulsating dc' sensitive type

[Guidance…]

The type of RCD required is called Type A and should carry the symbol :



Installed RCDs

RCDs installed within electrical equipment should be manufactured and marked in accordance with BS4293, BS 7288, BS EN 61008 or BS EN 61009 and installed in such a way that the rating information can be seen.

RCDs in power cabinets and outlets on OB tailboards should be DIN rail mounted units with 30mA / 40ms sensitivity and rated according to the load. Wall sockets and fused connection units are also available with integral RCDs.

- RCDs MUST be used in conjunction with an overload protection device such as an MCB.

Where a system is broken down with several RCDs in series, diversity and discrimination should be considered so that it will be possible to easily locate which circuit is faulty.

When selecting an RCD and its trip rating, any standing leakage current should be taken into account so that nuisance tripping does not occur. As much modern equipment contains heavy filtering, this may give rise to high leakage currents, which though not due to a fault condition, may cause early tripping and loss of discrimination. Double-pole switching types are preferred as they ensure full isolation should a fault occur (important on OB units which may be taken abroad).

Where increased levels of protection are required, such as with medical equipment, the need for 10mA rated RCDs should be considered.

Portable RCDs

Portable or plug-in RCDs may be used on location but because they are designed primarily for domestic use, have not proved to be very rugged when used in broadcasting environments. The in-line devices may be more reliable than the plug-top devices as they are less likely to be damaged in use, although more rugged versions are increasingly available.

All portable RCDs should be manufactured and marked to BS 7071.

Double-pole switching types are preferred to ensure full isolation should a fault occur.

Some portable RCDs may not operate correctly in high RF field strengths such as in transmitter maintenance areas, so care needs to be taken whenever working near transmitters. It would be advisable to carry out any prior testing of the RCD under these conditions.

4.2 Use of RCDs

- an RCD is not used as the sole means of protection against direct contact

[Guidance…]

Electrical systems at the BBC are installed in compliance with BS 7671 (originally IEE Wiring Regulations) which, amongst other requirements, specifies the required methods for safe fusing and earthing. The single most important precaution against electric shock is a properly constituted earthing

system, supported by fuses or MCBs to correctly disconnect the supply in case of overcurrent or faults to earth. The rapid disconnection of the supply will minimise the risk of damage, fire and electric shock due to any indirect contact.

- all workshop areas are fitted with RCDs which are rated at 30 mA / 40 ms or better

[Guidance…]

Workshop power cabinets should include RCDs, preferably distributed between a number of different circuits to minimise disruption should any one device trip. Some modern equipment has high leakage due to the Radio Frequency (RF) and Electro Magnetic Compatibility (EMC) suppression components placed between phase, neutral and earth. The effect of several such items is to reduce the margin before nuisance tripping occurs which is a good reason for differentiating the protection given to the power system by separate circuits. Individual benches may also have power splitters, which incorporate RCD protection. In some cases 10mA devices may be preferred to give additional protection.

- an RCD is used whenever electrical equipment is being used outside but which is supplied with power from within a building (or OB vehicle) and is thus outside its equipotential zone e.g. location (including Radio Cars), Newsgathering or Portable Single Camera (PSC)

[Guidance…]

Fixed wiring installations have equipotential bonding where all exposed metalwork is bonded to the incoming supply earth. This means that if there is a fault on the incoming power supply and the incoming earth rises in potential, all connected metalwork will rise to this same potential and someone touching different conducting items will not receive a shock. However, when power is supplied to an item of equipment outside of the equipotential area, say in the open air, there may be a potential difference between any metalwork connected to the supply earth wire and the general mass of earth, especially if a fault is present. If a person touches the metalwork and is also in contact with the general mass of earth the potential difference might be large enough to cause a shock. This person may then be in danger. The use of an RCD may reduce the risk of electrocution.

All OB vehicles are able to supply power to external equipment, and the power outlets must be RCD protected. OB vehicles often take power from within a building but in the past have not used RCDs on the incoming supply because it is unlikely that the leakage current would be less than 30mA (making it impossible to work) and also the risk of nuisance tripping. Leakage current monitoring and local earthing is used as an alternative to an RCD. New European regulations will affect this type of operation (see EGN 7).

Similarly many location or News shoots use supplies from within buildings and should always have RCD protection.

- an RCD is used whenever long cables and extension leads are being used where it is unlikely that the required fuse disconnection time would be met

[Guidance…]

The fuse in the plug tops of mains extension leads should be chosen so that the fuse breaks within the specified maximum allowable disconnection time of 0.4s, taking into account the earth loop impedance which will be sum of the cable phase and earth plus that of the supply. Should the length of cable required give an impedance above that which achieves this disconnection time, it is permissible to accept a reduction in this form of protection provided a suitable RCD is used. See TE & PS (now Broadcast Projects) Report 1993/07.

- an RCD is used wherever transportable or trolley-mounted equipment is being used which are identified as having added risks due to their frequent movement

[Guidance…]

Trolley mounted equipment is subjected to much wear and tear, with a resultant increased likelihood of faults. An RCD protected supply may be used to reduce the risk but this is not a substitute for a suitable regime of safety inspections.

4.3 Maintenance and testing of RCDs

- all RCDs are suitably maintained, and where appropriate, tested by a competent person

[Guidance…]

Test-buttons

All RCDs have built-in test buttons, which should be used regularly to ensure that the device is working. This button gives a small out-of-balance current of about 2.5 times the normal sensitivity to operate the trip. However, please note that it gives no indication of the time to disconnect the circuit from the supply or the overall safety of the unit.

For units in fixed installations, the built-in 'test' button should be operated at intervals of not greater than 3 months, and preferably weekly, to ensure the RCD can trip the supply. A label, in accordance with BS 7671 para 514-12-02, must be fixed at or near to the origin of the supply.

For OB units (which are classed as mobile rather than fixed installations), the RCDs on the supply side should be tested by operating the 'test' button at every new connection; and those on the vehicle outlets at least once a month and preferably at every re-location of the vehicle.

For portable units the 'test' button should be operated before every use at a new site to ensure that it is functioning. Any device failing to trip must be removed from service (and destroyed / disposed of) immediately.

Full function testing

Full function testing must be carried out upon installation and thereafter at intervals of between six months to two years – this need be carried out by a competent person using a proprietary RCD test device. Fixed installations in buildings may be tested by the term contractor for the premises depending on the local arrangements.

The RCD tester will thoroughly test the RCD to the BS Standard as follows :

1) the time taken to operate at the rated current will be measured. This will be carried out with the fault on both the negative half cycle and the positive half cycle. The device must operate within 200ms.
2) the next test will ensure that at five times the rated current the tripping will occur within 40ms (it will display the actual time and again test on both positive and negative half cycles).
3) the unit should also carry out the tests with the fault current at the worst phase position in the cycle to ensure it measures the worst operating time.
4) the unit should not trip with a leakage current of up to and including 50% of the rated tripping current.

There are a number of proprietary testers available on the market from Seaward, Robin, Martindale and Avo/Megger.

Up to date records should be kept of all functional testing of RCDs using the proprietary tester.

5 Special case - Performing Band electrical and musical equipment

So far as they relate to matters within their control and as is necessary to prevent injury arising, managers **must** ensure that :

- where an RCD is used to supply band equipment, the individual items must be tested for earth continuity to any metal chassis as the RCD is only the secondary protection, reducing the severity

of any shock.

[Guidance…]

When bands bring electrical equipment into studios the normal practice has been to supply their equipment from a mains isolating transformer to prevent electrical shock from unknown hazards. More recently it has been the practice to supply from an RCD. However it is known that bands often remove the earth from the mains plug to prevent 'hum loops'. This is a dangerous practice and if there are hum loops present it is the signal cable earth/screen which should be disconnected at one end only. HSE GS50 gives guidance on this and states that the 'removal of the protective earth connection is the most common cause of entertainers receiving shocks, some of which have been fatal'.

If a separate mains isolating transformer is used to supply each item of equipment then it may not be necessary to carry out a PAT test as each item is protected by isolation and this method of working may then give the best protection (see EGN 4).

6 References / further reading

Memo of guidance on the Electricity at Work Regulations 1989
HSE booklet HS(R)25.
HSE GS50 Electrical safety at places of entertainment
HSE IND(G) 102L Electrical safety for entertainers

From BSI:
BS 7671:2001 Requirements for Electrical Installations (IEE Wiring Regulations Sixteenth Edition)
BS 4293:1983 Specification for residual current-operated circuit-breakers (current but superseded partially by BS EN 61008-1 and 2)
BS 7071:1992 Specification for portable residual current devices
BS 7288:1990 Specification for socket outlets incorporating residual current devices (S.R.C.D.s)
BS EN 61008-1:1995 Specification for residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs). General rules.
BS EN 61009-1:1995 Specification for residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs). General rules.

BBC TE & PS (now BBC Technology) Investigation Report 1993/07 'The testing of long cables and extension leads for 13A and BS1363 lighting installations on 240 and 100V supplies'.