

INSPECTION AND TESTING OF ELECTRICAL INSTALLATIONS: RESIDUAL CURRENT DEVICES

[The basis of this article was first published in Wiring Matters in issue 15, Summer 2005 and reflected the requirements of the then current BS 7671:2001(2004). The Regulations have since been revised and amended a number of times so, due to many requests, a revisit was seen as necessary.]

The IET receives many enquiries relating to the inspection and testing of electrical installations and the applicable requirements of BS 7671:2008(2013). The queries vary greatly and cover all aspects of inspection and testing, from the initial verification process of domestic installations to the periodic inspection of major industrial installations.

1. What is an RCD and what does it do?

A residual current device (RCD) is defined in BS 7671:2008(2013) as:

'A mechanical switching device or association of devices intended to cause the opening of the contacts when the residual current attains a given value under specified conditions.'

An RCD is a protective device used to automatically disconnect the electrical supply when an imbalance is detected between live conductors. In the case of a single-phase circuit, the device monitors the difference in currents between the line and neutral conductors.

Note that the term 'live' conductor includes both the line and neutral conductors.

In a healthy circuit, where there is no fault current flowing to earth or protective conductor current, the sum of the currents in the line and neutral conductors is zero. If a line-to-earth fault develops, a portion of the line conductor current will, therefore, not return through the neutral conductor. The device monitors this difference, operates and disconnects the circuit when the residual current reaches a preset limit, the residual operating current ($I_{\Delta n}$).

RCDs are used to provide protection against the specific dangers that may arise in electrical installations, including:

- fault protection;
- additional protection; and
- protection against fire.

An RCD does not provide protection against overcurrent. Overcurrent protection is provided by a fuse or a circuit-breaker. However, combined RCD and circuit-breakers are available and are designated RCBOs.

2. Types of RCDs

'RCD' is the generic term for a device that operates when the residual current in the circuit reaches a predetermined value. The following table, Figure 1, indicates the different types of RCD available, a description of each device and examples of how the device is used:



Figure 1 Types of RCD

	Type of RCD	Description	Installed/used
RCCB	Residual current operated circuit-breaker without integral overcurrent protection	Device that operates when the residual current attains a given value under specific conditions	Consumer units Distribution boards
RCBO	Residual current operated circuit-breaker (RCCB) with integral overcurrent protection	Device that operates when the residual current attains a given value under specific conditions and incorporates overcurrent protection	Consumer units Distribution boards
CBR	Circuit-breaker incorporating residual current protection	Overcurrent protective device incorporating residual current protection.	Distribution boards in larger installations
SRCD	Socket-outlet incorporating an RCD	A socket-outlet or fused connection unit incorporating a built-in RCD.	Often installed to provide additional protection for users of the socket-outlet when it may not be advantageous to protect the entire circuit with an RCD
PRCD	Portable residual current device	A PRCD is a device that provides RCD protection for any item of equipment supplied from a socket-outlet.	Plugged into an existing socket-outlet. PRCDs are not part of the fixed installation
SRCBO	Socket-outlet incorporating an RCBO	Socket-outlet or fused connection unit incorporating an RCBO	Often installed to provide additional protection for users of the socket-outlet when it may not be advantageous to protect the entire circuit with an RCD

2.1 Older installations with ELCBs

Historically, two basic types of earth leakage circuit-breakers (ELCB) were recognised by the Regulations; the familiar current-operated type and the earlier voltage-operated type.

The voltage-operated type ceased to be recognised by the Regulations in 1981 and, today, only the current-operated type is recognised. The voltage operated device can be distinguished by its two separate earthing terminals – one for the connection of the earthing

conductor of the installation and the other for a connection to a means of earthing. Such devices were often used on installations forming part of a TT system where the means of earthing was an earth electrode. The major drawback with the voltage-operated earth leakage circuit-breaker is that a parallel earth path can disable the device. There is a move within standardisation circles (BSI Committee PEL/23/1) to resurrect the principle of the voltage operated ELCB for use in Electric Vehicle charging installations - the principle being that, should a potential appear between points within the installation, i.e. true earth and the vehicle, the device would operate and disconnect; see Regulation 722.411.4.1(iii) of BS 7671:2008(2013).

2.2 Recognised devices

RCDs intended for use in the UK are manufactured to European Standards and can be identified by their BS EN numbers – BS indicates that the standard is recognised in the UK and EN stands for Euro-Norm. The following list identifies the applicable confirmed and current standards:

- BS 7071:1992(1998)
Specification for portable residual current devices.
- BS 7288:1990(1998)
Specification for socket-outlets incorporating residual current devices (SRCDs).
- BS EN 61008-1:2012
Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs).
- BS EN 61009-1:2012
Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs).

Note that BS 4293:1983(1993) Specification for residual current-operated circuit-breakers has been withdrawn and superseded by BS EN 61008-1:2012.

2.3 Characteristics of RCDs

RCDs are defined by a series of three main electrical characteristics:

- The rating of the device in amperes, I.
- The rated residual operating current of the protective device in amperes, $I_{\Delta n}$.
- Whether the device operates instantaneously or incorporates an intentional time delay to permit discrimination. Such devices are called 'S' or Selective.

Devices are manufactured with different values of rated current and rated residual operating current but in this article we will consider the rated residual operating current of the protective device, $I_{\Delta n}$.

3. Applications

The correct device must be selected for the particular application. Choosing the wrong device could have serious consequences and could result in electric shock or fire. The list in Figure 2 gives examples of particular applications of RCDs and includes references to the relevant Regulations in BS 7671:2008(2013).

Fig.2 Examples of particular applications of RCDs

RCD, I Δ n	Application	Regulation
10 mA	A very sensitive device, sometimes used to protect socket-outlets of laboratory benches in schools	415.1.1
30 mA	Mobile equipment used outdoors must be protected by an RCD with a rated residual operating current not exceeding 30 mA	411.3.3(ii) 514.1.1
	In locations containing a bath or shower, all circuits of the location must be protected by the use of one or more RCDs not exceeding 30 mA. Note that the requirement is “of the location”; in reality, this means serving or passing through the bathroom and is not limited to circuits within the zones.	701.411.3.3
	Socket-outlets for use by ordinary persons for general use.	411.3.3(i)
100 mA	Where an RCD is installed because the earth fault loop impedance is too high for fault protection, i.e. disconnection time cannot be met by the overcurrent protective device	411.5.3
300 mA	Fire protection purposes in agricultural and horticultural premises	705.422.7
Adjustable ≤ 2000 mA	Devices with a residual operating current of 2 A or more are sometimes used in specific industrial, distribution applications or temporary supply supplies for entertainment related purposes. Advice must be sought from the designer. Any adjustment method or mechanism should not be accessible to ordinary, non-skilled or non-instructed persons	531-02-10 531.2.10

3.1 Unwanted operation

Unwanted operation of RCDs can occur when a protective conductor current causes the RCD to operate under non-fault conditions, i.e. the accumulative of protective conductor currents developed by the switch-mode power supplies of computers, e.g. too many computers on one circuit. An RCD must be so selected and the electrical circuits so subdivided that any protective conductor current that may be expected to occur during normal operation of the connected load(s) will be unlikely to cause unnecessary operation of the device (see Regulation 531.2.4). Such operation can occur on circuits with heating elements of cooking appliances etc., where elements can absorb a small amount of moisture through imperfect seals when cold. When energised, this moisture provides a conductive path for current to flow and could operate the RCD. The moisture dries out as the element heats up. Although not precluded in BS 7671, it is not a requirement to use an RCD on such circuits but the requirements of the Regulations would still have to be met, i.e. cables in walls, Regulation 522.6.101.

3.2 Discrimination

Where two or more RCDs are connected in series, discrimination must be provided, if necessary, to prevent danger (see Regulation 531.2.9). During a fault, discrimination will be achieved when the device upstream and electrically nearest to the fault operates and does not affect other, further upstream, devices. Discrimination will be achieved when ‘S’ (Selective) types are used in conjunction with downstream general type RCDs. The ‘S’ type has a built-in time delay and provides discrimination by simply ignoring the fault for a set period of time, allowing more sensitive downstream devices to operate and remove the fault. S-type RCDs or RCDs with a rated residual operating current, I Δ n, in excess of 30 mA must not be used to provide additional protection.

4. Labelling

Regulation 514.12.2, states the notice that shall be fixed in a prominent position at or near the origin of the installation, where an installation requires a residual current device:

5. Testing

RCDs must be tested; the requirements are stated in the following Regulations:

- The effectiveness of the RCD must be verified by a test simulating an appropriate fault condition and independent of any test facility, or test button, incorporated in the device (see Regulation 612.13.1).
- Where an RCD with a rated residual operating current, $I_{\Delta n}$, not exceeding 30 mA is used to provide additional protection, the operating time must not exceed 40 ms at a residual current of 5 $I_{\Delta n}$ (see Regulation 415.1.1).

Tests are made on the load side of the RCD between the line conductor of the protected circuit and the associated cpc. Any load or appliances should be disconnected prior to testing.

5.1 Range of tests

Whilst the following tests are not a specific requirement of BS 7671:2008(2013), it is recommended that they are carried out:

Device	Instrument test current setting	Satisfactory result
General purpose RCDs to BS 4293 and RCD protected socket-outlets to BS 7288	50 % of operating current	Device should not operate
	100% of operating current	Device should operate in less than 200 ms Where the RCD incorporates an intentional time delay it should trip within a time range from 50 % of the rated time delay plus 200 ms' to 100 % of the rated time delay plus 200 ms
General purpose RCCBs to BS EN 61008 or RCBOs to BS EN 61009	50 % of operating current	Device should not operate
	100% of operating current	Device should operate in less than 300 ms unless it is of 'Type S' (or selective) which incorporates an intentional time delay. In this case, it should trip within a time range from 130 ms to 500 ms
Devices providing additional protection $I_{\Delta n} \leq 30$ mA	Test current at 5 $I_{\Delta n}$ The maximum test time must not exceed 40 ms, unless the protective conductor potential does not exceed 50 V. (The instrument supplier will advise on compliance).	Device should operate in less than 40 ms.

5.2 Integral test device

An integral test device is incorporated in each RCD. This device enables the mechanical parts of the RCD to be verified by pressing the button marked 'T' or 'Test'.

6. Test instrument

The test instrument used to test RCDs should be capable of applying the full range of test current to an in-service accuracy, as given in BS EN 61557-6. This in-service reading accuracy will include the effects of voltage variations around the nominal voltage of the tester. To check RCD operation and to minimise danger during the test, the test current should be applied for no longer than 2s. Instruments conforming to BS EN 61557-6 will fulfil the above requirements.