Sikkerhedsstyrelsen

Field test of installed residual current devices in Denmark

Field test of installed residual current devices in Denmark

Table of contents

1 Summary

This report describes the result of a field test of almost 1.000 Residual Circuit Devices, RCD, in Danish electrical installations. (The term RCD is used as a common reference for RCD type AC 0,03 A and RCD type A 0,03 A)

The test showed that 7% of the RCDs did not work properly. It also showed a great difference between RCDs of type AC and of type A , as the error percentage for RCDs of type AC was almost 11%, while it was only 2,0% for the RCDs of type A. Since the mechanical principle in the two types is the same, and since RCDs of type A has been used in Danish installations since 1994, it is assumed that the difference is due to ageing. It is uncertain if other factors than ageing may supervene and give reasons for differences.

The test almost only included RCDs in residential buildings. The error percentage is therefore not made up on different installation types. However, it can be seen from the test that RCDs installed inside residential areas (hall, living room and other rooms), had a statistically significantly lower fault percentage than those installed where they are exposed to moisture, dust and low temperatures.

The test included control of the function of the test button. The test showed that more than half of the defect RCDs could be tripped with the test button. (This fault was found on 39 RCDs which corresponds to 4% of the devices in the test). From a safety perspective this is problematic, since the fault leads the user to believe that the RCD functions properly, even when this is not the case.

The results from the test will be used as input to the Danish Safety Technology Authority’s safety strategy in the planning of future campaigns and efforts and the Authority will on the background of the results, initiate the following initiatives:

- The Authority will increase its focus on informing users about the necessity in testing the RCD regularly, for example twice a year.

- The Authority will increase its focus on informing the certified electricians about the necessity in testing the RCDs in connection with inspection of the installation or other work carried out on an installation.

- The results from the report will be dealt with in the relevant standardisation committee, in order to verify that the testbutton mirrors the function of the RCD and to find ways to improve the high fault percentages for older RCDs.

Additional activities are under consideration.

2 Introduction

This report summarizes the results from a test of the functionality of approximately 1.000 installed RCDs. (The term RCD is used as a common reference for RCD type AC 0,03 A and RCD type A 0,03 A. All RCDs mentioned in this report have a rated tripping current of 0,03 A unless otherwise mentioned.) The report is prepared by the Danish Safety Technology Authority in collaboration with consultant Torben Rahbek.

In many Danish electrical installations the protection against contact with live parts at a single isolation fault on basic insulation is based on RCDs. It is therefore imperative that the RCD is able to protect when a dangerous situation occurs. The purpose of this investigation was therefore to verify if the RCDs are able to protect, even after years of normal use.

The results in this report are a compiled interpretation of the collected data. The final report does not change the information regarding fault percentage on older RCDs, previously announced on the background of the survey.

3 Background

3.1 Residual current devices

In modern installations protection against indirect contact is required. One of the protective measures is automatic disconnection of the supply. In Denmark RCDs are normally used as protective equipment in combination with protective earth for this protection method.

RCDs also provide protection in installations without distributed protective earth by disconnecting the supply when a earth fault current of a certain size flows, for instance through a human body. This principle is not allowed in modern installations. In old Danish installations, where the combination of protective earth and an RCD was not required at the time of installation and is practically impossible to require installed, RCD’s are used as an additional protective means against indirect contact. RCDs for fixed installations are covered by the European Standard series EN 61008 which is harmonized under the Low Voltage Directive.

As a main principle, two kinds of RCDs exist:

- RCD type AC 0,03 A
  This type of RCD is older than type A and was allowed to be installed in Danish household installations until 1994.

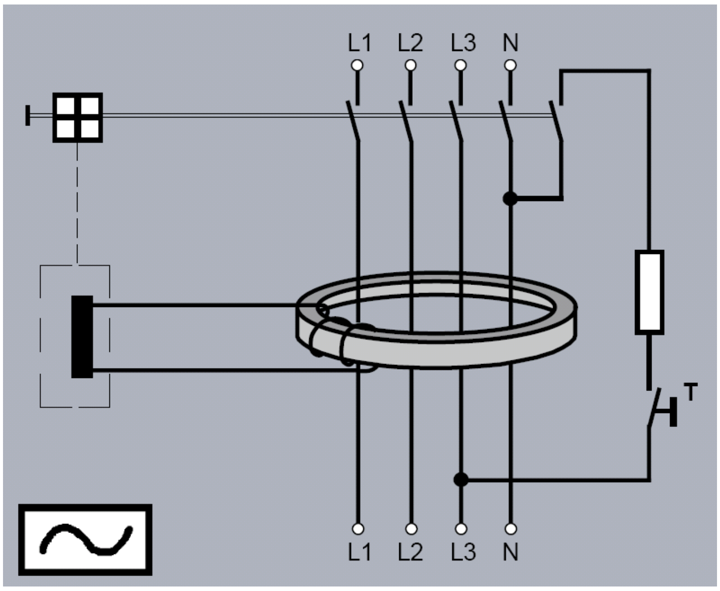

Figure 1 - Principle diagram for RCD, type AC, 0,03 A.

The RCD functions in such a way that all three phases and neutral are carried through a differential current transformer. When a three-phased or two-phased load or a load between phase and neutral exist, the sum of the currents will be zero. There is therefore no current in the differential current transformer (the secondary circuit). In case a fault situation causes grounding, the load current will run through the transformer, while the return current will run around. There is no balance and the sum becomes different from zero. This triggers the trip unit (on the left of the figure), which in turn switches off the supply. The figure also shows the test circuit (with the test button “T”). When the test button is activated the return current is carried around the transformer, generating a differential current different from zero and the trip unit can be triggered. It also shows that the test circuit only functions if phase L3 is energized. The electrician must therefore make sure this is the case when installing the RCD.
RCDs of type AC only work towards sinusoidal fault currents and cannot detect a pulsating direct current.
The RCD, type AC, is in general sensitive to impulse voltages. Many users have experienced that their RCD switched off during thunder storms.

- RCD , type A, 0,03 A
  Since 1994 instllation of RCDs of type A, 0,03 A has been required in new installations in Denmark.

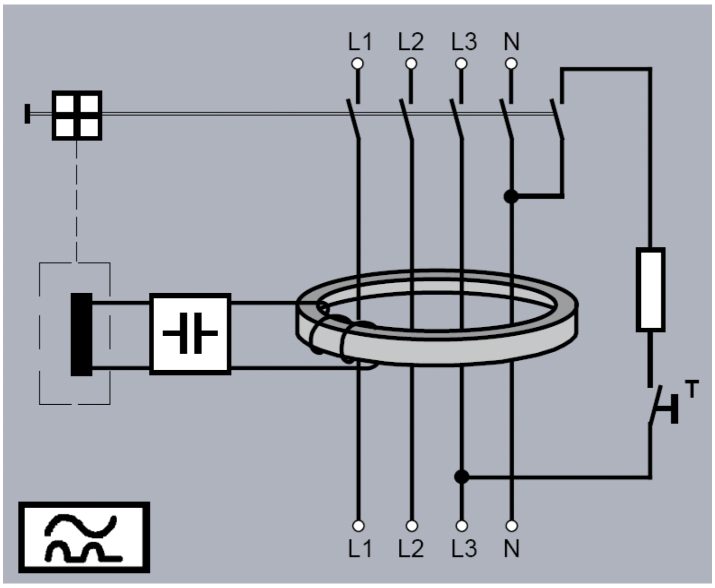

Figure 2 – Principle diagram for RCD, type A, 0,03 A).

The RCD, type A, functions, in principle, in the same way as the RCD, type AC, in figure 1, with the important difference, that the differential current transformer is designed in such a way that it is able to detect pulsating direct currents, by the use of an oscillating circuit, before it is sent to the trip unit. This means that this type of RCD is both able to detect alternating fault currents as well as pulsating direct fault currents.
Furthermore, the sensitivity against pulses is strongly decreased.
The test circuit can only work, if phase L3 is energized.

RCDs used for protection against indirect contact in residential building installations shall have a rated residual current of no more than 30 mA (0,03 A).

3.2 Legislation

Before 1994 protective earthing and RCDs were used in Denmark for many years as equivalent protective measures – called supplementary protection. If older installations in Danish residential buildings are equipped with supplementary protection against electric shock, it is often only based on RCDs, since the protective conductor seldom has been carried through the installation. Up until 1994 RCDs of type AC were allowed, but after 1994 only RCDs of type A have been allowed in new installations. In 1994 a requirement was introduced that the protective conductor must be carried through to the socket-outlet in the total installation. The requirements also apply for extensive modifications or additions to older installations. There are, however, still a large amount of older installations where only phase and neutral have been carried to the socket-outlet. In these installations, the RCD will be the only form of protection of the users in case of faults in the installation or in appliances.

RCDs have been mandatory in all Danish residential installations since 1 July 2008. This means that there also has to be RCDs installed in existing installations, where it was not a requirement when the installation was first carried out.

With this protection philosophy it is imperative, that the RCD work properly. The Danish Electricity Council and later the Danish Safety Technology Authority have therefore carried out campaigns to get the users to test the RCD by activating the test button. However, a measurement of the effect of the campaign has shown that far from all users complies with the request. At the same time it is known that the electrical installations are considered to be something that looks after itself and do not require maintenance. Therefore, when a RCD is left unmaintained or without surveillance and perhaps in a dusty environment year after year, there is a risk that the tripping part “gets stuck”, causing the RCD to not work properly, in case it becomes necessary.

3.3 Standards for circuit breakers for use in houeholds and similar locations

Residual current devices began to gain a foothold on the market during the 1960s, and the first standard (CEE 27) for RCDs of type AC was developed in 1974 by the then European Standardization organization CEE. During the 1980s the standardization activity was taken over by the international standardization committee IEC who published the first standard in the IEC 61008 series in 1990. Based on CEE 27 this standard also includes requirements, tests and alignments with the standard for circuit breakers, IEC 60898, and other improvements such as requirements for type A RCDs. After CEE 27, the IEC 61008 standards with the necessary European changes, have been followed on European level. The first standard in the series was published in 1994 as EN 61008. The European standards are published in the EN 61008 series.

A revision of the IEC 61008 series was initiated relatively soon after the first edition of the standard was published. The second edition was published in 1996. The second edition is by and large a technical update of the first edition. It does however include a test for unwanted tripping due to impulses, e.g. transients caused by lightning.

Afterwards two amendments to IEC 61008 have been published. The first amendment came in 2002. It includes additional test currents in the range between 5 $I\Delta n$ and 500 A that are applied in testing of the RCD’s functionality during sudden earth leakage currents. The second amendment was published in 2006 and includes tests of the RCD’s insulation function.

In 1995 IEC published the standard IEC 61543 that describes EMC requirements for residual current devices.

In Denmark RCDs have been covered by the following requirements: The heavy current regulations section 127, based on CEE 27, the heavy current regulations section 152, based on EN 61008:1994 and latest EN 61008:2004

The continuous development of production technology has had great impact on the reliability of the RCD. The biggest improvements are:

- Introduction of clean room manufacturing of the trip unit. This has removed pollution, which can lead to increased tripping values or nuisance tripping depending upon the design.
- Modification of the latching mechanism in the RCD to avoid the use of hardening oil or to avoid oil at all. Previously some manufacturers used oil which tended to harden. This could lead to increased tripping times or blocking of the RCD.

None of these changes have a background in changes of the standard.

3.4 Testing of installed residual current devices

The Danish electrical safety authorities wished to test a larger number of installed RCDs in order to obtain knowledge about their functionality in praxis. The easiest way to carry out such a test is to let the electricity company conduct the test in connection with replacement of the electricity meters (for example during transition to remote meter reading or in combination with the systematic replacement of meters in connection with maintenance). Agreement was made with two electricity companies. The Authorities supplied the equipment and instructed the personnel in charge of the testing and the electricity companies then carried out the testing. The two electricity companies tested in total 996 RCDs distributed on 560 of type AC , 400 of type A and 6 RCDs of a different type (type AC, 0,5 A).

4 The project's purpose and objective

The project's purpose was to collect knowledge on the functional safety of installed RCDs.

The project's objective is to provide answers to the following questions:

- How many of the RCDs work properly ?
- Is there a difference between the functional safety of the RCDs of type AC and type A?
- Is there a difference in the functional safety in terms of different installation conditions?
- Does the functional safety depend on other circumstances?
- Does RCDs exist where the test button functions, but the circuit breaker does not?

The answers will be used as input to the Danish Sefety Technology Authority's safety strategy in the planning of future campaigns and efforts.

5 Method

5.1 General

The test was carried out by measuring tripping times according to EN 61008-1 for a large number of RCDs in private homes.

Simultaneously a number of background parameters were registered, such as type, brand, age, installation condition etc. It was also registered if the RCD tripped when the test button was activated.

The registrations were carried out on location on paper forms. Subsequently the forms were sent to the Electricity Council, who entered the information in to a spreadsheet. The data was examined for obvious errors and the analysis was carried out.

5.2 Test variables

The following variables were regisered for each RCD

- Meter number
- Location of the RCD
- Installation type
- Environment
- Mounting form in the installation
- Product, brand
- Type designation
- Rated current
- Rated tripping current
- RCD (type AC or type A)
- Tripping time, AC test, all poles
- Tripping time, pulsating DC test, all poles, 0 degrees and 180 degrees phase displacement of DC contribution
- Trips when test button is activated
- Registered electricity company
- Test inspector’s initials
- Date of test

Subsequently it was decided to analyze the results compared to the following variables:

- RCD (type AC and type A)
- Installation type
- Position in the residence
- Surrounding environment
- The result of the testing of the test button.

Furthermore, the results have been analyzed compared to the RCDs age, distinguishing between ”old” and ”new” RCDs. “Old” RCDs are assumed to all be of type AC, since it was normal procedure to install this type up to 1994. “New” RCDs are all assumed to be of type A, since the normal procedure since then has been to install this type. Furthermore, it is assumed that it is only the RCDs age that has an influence on its functional safety, because the basic construction is more or less the same in RCDs of type AC and type A. The only differences are the differential current transformer and the oscillating circuit.

5.3 Populations

From the start of the survey the objective was to collect as many measurements as possible, preferably several hundreds. The idea was that if the number of measurements was sufficiently high it would be possible to perform statistically valid analyses for all variables imaginable.

Therefore the Electricity Council decided to enter into an agreement with the municipal electricity company in Varde, that their personnel included measurements of a number of parameters on RCDs in residential homes during their regular meter maintenance visits. At that time the electricity company was systematically replacing meters, because the company wished to switch to remote reading. Therefore the Electricity Council assumed that the agreement would result in a large number of measurements in short time and would give a representative dispersion in relation to the variables that were to be tested. The electricity company supplied the municipality of Varde with electricity and is today part of the electricity company “Syd Energi”. The supply network primarily covers the city of Varde and the city’s surrounding area. In total 490 RCDs were measured in the company’s supply area.

Furthermore, the Electricity Council entered into an agreement with KE-Partner, that supplied the Copenhagen area with electricity and its supply area is strictly the city. In total 506 RCDs were measured in the company’s supply area.

Considerations have been made about to what extent this method of selection might give a distortion of the populations. For example, a systematic replacement of all meters in a whole block at one time might show an over representation of RCDs with the concerned characteristics. The result was, however, to include these measurements in the analysis, since the RCDs have not necessarily been treated more uniform simply due to the fact that they were installed in the same block, compared to if they had been located in residential buildings in different places. Therefore, the largest risk of distortion in this context appears to be that all RCDs could be installed in that type of residential building and be of the same type. Evaluation of data shows, however, that these cases do not seem to occur.

5.4 The project’s participants

The organizing of the project and the analyses as well as instruction of the persons who were to carry out the measuring of the RCDs, were managed by the Danish Electricity Council and from 2004 by the Danish Safety Technology Authority.

The measuring of the RCDs has been carried out by staff at Varde Municipal Plant (today part of ”Syd Energi”) and KE-Partner (today part of Eltel Networks).

Torben Rahbek assisted the Danish Safety Technology Authority as a consultant with the composing of the final report.

5.5 Test procedures

The test was carried out by testing a number of RCDs installed in residential buildings. The test was carried out on location and the RCD was not activated except for the necessity of the testing. The RCD was not removed from the installation as part of the test procedure.

The installations were selected by the two electricity companies because the meter was to be maintained or replaced, but the detailed selection criteria were not known by the Electricity Council.

The Electricity Council produced test procedures and forms for reporting the results. Furthermore, the Electricity Council provided calibrated measuring equipment for the electricity companies and instructed them in the test procedures.

Depending on their construction, the RCDs were tested using one or more types of fault currents: the tye AC was only tested with AC while the type A was tested with AC, pulsating DC in the positive half-wave and pulsating DC in the negative half-wave. The differences are illustrated in figure .

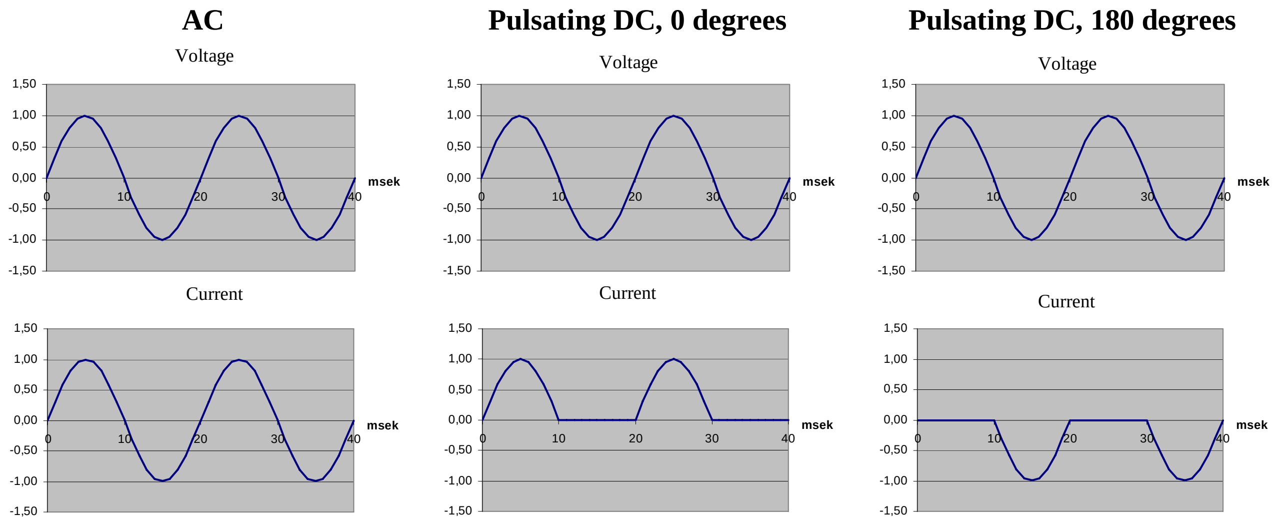

Figure 3. Normalised curves show the three different types of fault currents used for testing the RCDs.

The test procedure was the following:

a. Registration of various ratings regarding the RCD and other background data according to 5.2.
b. Mounting of testing equipment on the RCD.
c. Measuring of alternating fault current tripping times on all poles in use, one at a time. All tripping times were registered or “OL” (for overload) if the RCD did not trip.
d. For RCDs of type A, the measuring was repeated twice with pulsating direct current, first with pulsating direct current in the positive half-wave and then with pulsating direct current in the negative half-wave. All times were registered.
e. Testing of the RCD’s test button and registration of the result.

The registrations were made on location on paper forms. The forms are attached as annex A. Subsequently the forms were sent to the Electricity Council who entered them in to a spread sheet.

The detailed test procedure regarding the instructions to the persons who carried out the tests is attached as annex B.

5.6 Statistical basis

The total population of approximately 1.000 RCDs renders the statistical uncertainty of the analyses modest. This also applies if the population is divided into smaller parts, corresponding to the parameters examined. The analyses in chapter 6 show that the confidence interval (95% level) is a few percent when analyses are carried out on populations of less than 50-100 RCDs.

It is therefore possible to conclude statistically significant conclusions regarding the fault percentage for populations down to around 100 RCDs and statistically valid comparisons of the fault percentages can be made between population portions of app. 100 RCDs or more.

5.7 Subesequent processing of data

Prior to carrying out the analyses, data was examined to exclude obvious errors. The eliminated registrations were the following:

- Obviously inadequately filled in forms.
- Registration of tripping times for pulsating DC measuring on RCDs where brand or type clearly indicates that they are of type AC. This type of RCDs cannot trip at pulsating DC faults.
- Registrations where an RCD of type A trips in the AC test in all three phases, in one or two tests with pulsating DC at 0 degrees as well as in one or two tests with pulsating DC at 180 degrees. These measurements must be incorrect since a passed AC test shows that all conductors are carried through the differential current transformer. Therefore the RCD must react alike regardless of the phase fault. When the RCD even passes the DC test in (at least) one phase it shows that the rectifier circuit functions for pulsating fault currents in the concerned direction. So, since the RCD functions with pulsating fault currents in one phase (the DC test), and since the RCD shall react similarly to faults in all three phases (AC test), the conclusion is that the measuring must be wrong.

After this screening 966 measured RCDs remained.

This data was ”cleansed”, i.e. different spelling forms for the options for the different parameters were removed, leaving only one spelling form for each option.

Additionally, data in the field ”Type of RCD” was amended to one of the three options; RCD type AC, RCD type A or Other. This was done by registering RCDs that had only been tested by the AC test, as type AC. If a DC test had been carried out it was registered as a type A. The category “Other” was used for RCDs with other rated tripping currents, for example 300 mA.

6 The result of the project

6.1 Introduction

The results are established by considering RCDs with at least one tripping time measured at over 300 milliseconds at a fault current of 30 mA as faulty.

The number of faulty RCDs is analyzed depending on the following variables:

- Type of RCD (type AC or Type A)
- Type of installation
- Location in the residential building
- The surrounding environment at the installation

- The age of the RCD
- The result of the testing of the test button.

Finally the fault percentage is calculated for all the RCDs in the survey.

6.2 Fault percentage

There were 67 out of 966 tested RCDs that did not trip correctly. Added to this were 2 RCDs where the test button did not work as it should (see 6.9). These are also registered as faulty, resulting in a total of 69 RCDS out of the 966 tested devices that do not work properly.

The fault percentage is thereby calculated to 7,1%.

In other words, 93% of the tested RCDs were functioning according to their purpose.

The confidence interval (95% level) is +/- 1,6%. This means that the fault percentage with a 95% certainty lies between 5,3% and 8,5%.

6.3 Type of switch

In total, 3 different types in the field ”RCD type” have been registered. The grouping is shown in figure 4.

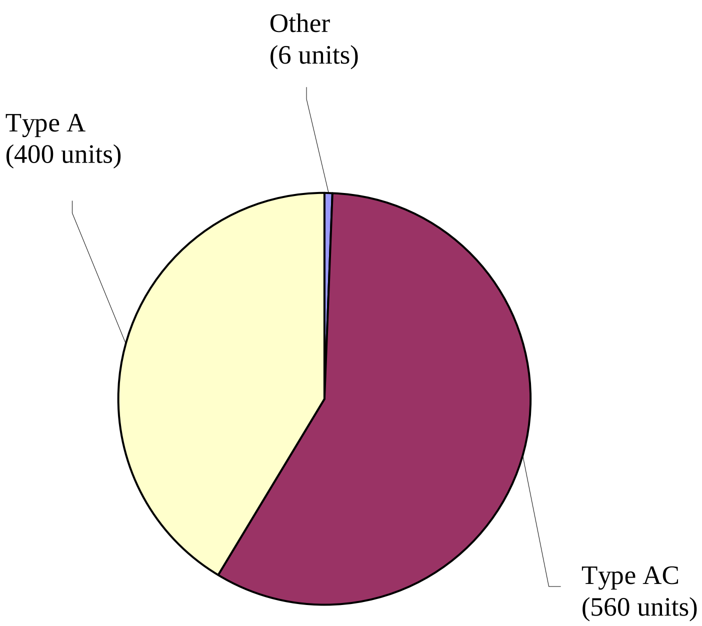

Figure 4. Overview of registered RCD types for the 966 RCDs in the test

In addition to the common types (type AC and type A) only 6 other types have been registered; all of them RCDs with a rated tripping current of 300 mA. They are left out of this analysis and the fault percentage is calculated for each of the two common types of RCDs. The result is shown in table 1.

	RCD type AC	RCD type A
Amount tested	560	400
Amount of faulty Devices	61	8
Fault percentage	10,9%	2,0%
min.	8,3%	0,6%
max.	13%	3,4%
Confidence interval (95%)	+/- 2,6%	+/- 1,4%

Table 1. Fault percentages for RCDs.

The table shows that the fault percentage for RCDs of type AC is significantly higher than for RCDs of type A.

6.4 Type of installation

The types of installation can be grouped into the 5 main groups shown in figure 5. It shows that the majority (over 90%) are RCDs installed in residential buildings.

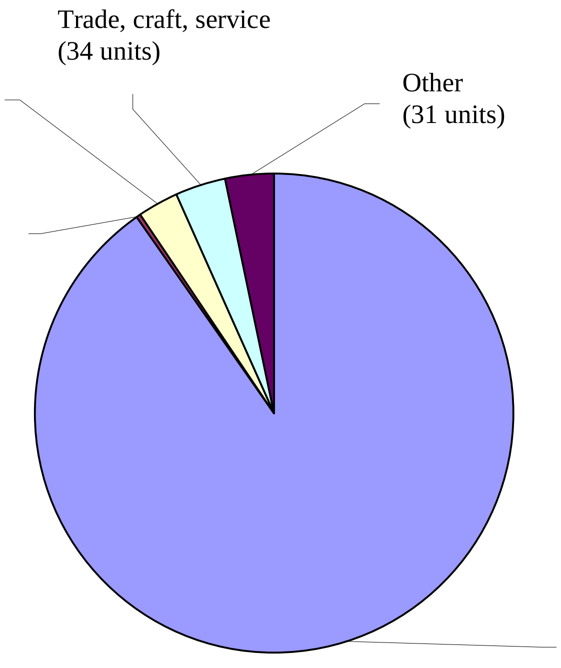

Figure 5. Distribution of installation types on the 960 RCDs

The RCDs that fail in the test are distributed among the following installation types (table 2).

Installation type	Amount tested	Amount of faulty breakers	Fault percentage			
			Estimate	min.	max.	Confidence interval (95%)
Residence	**866**	**61**	**7,0%**	5,3%	8,7%	1,7%
- hereof RCD type AC	511	55	10,8%	8,1%	14%	2,7%
- RCD type A	355	6	1,7%	0,4%	3,0%	1,3%
Industri	**28**	**2**	**7,7%**	0,0%	17%	9,7%
- hereof RCD type AC	12	1	8,3%	0,0%	25%	17%
- RCD type A	16	1	6,3%	0,0%	18%	12%
Trade, craft, service	**32**	**3**	**9,4%**	0,0%	20%	10,3%
- hereof RCD type AC	18	2	11,1%	0,0%	26%	15%
- RCD type A	14	1	7,1%	0,0%	21%	14%
Holiday homes or the like	**3**	**0**	-	-	-	-
- hereof RCD type AC	1	-	-	-	-	-
- RCD type A	2	-	-	-	-	-
Other	**31**	**3**	**9,7%**	0,0%	20%	10,6%
- hereof RCD type AC	18	1	5,6%	0,0%	16%	10,9%
- RCD type A	13	2	15,4%	0,0%	35%	20%

Table 2. Fault percentages distributed on installation types. The fault percentages are also assessed on the two types of RCDs in the survey.

The confidence intervals for all other installation types than residential buildings are so high that it is not possible to estimate the fault percentage. This is due to the low amount of tested RCDs. Therefore it is not possible to statistically estimate if the type of installation has a significance regarding the RCDs functionality.

6.5 Location

In total 11 different types of location have been registered for the 960 RCDs. The distribution is shown in figure 6.

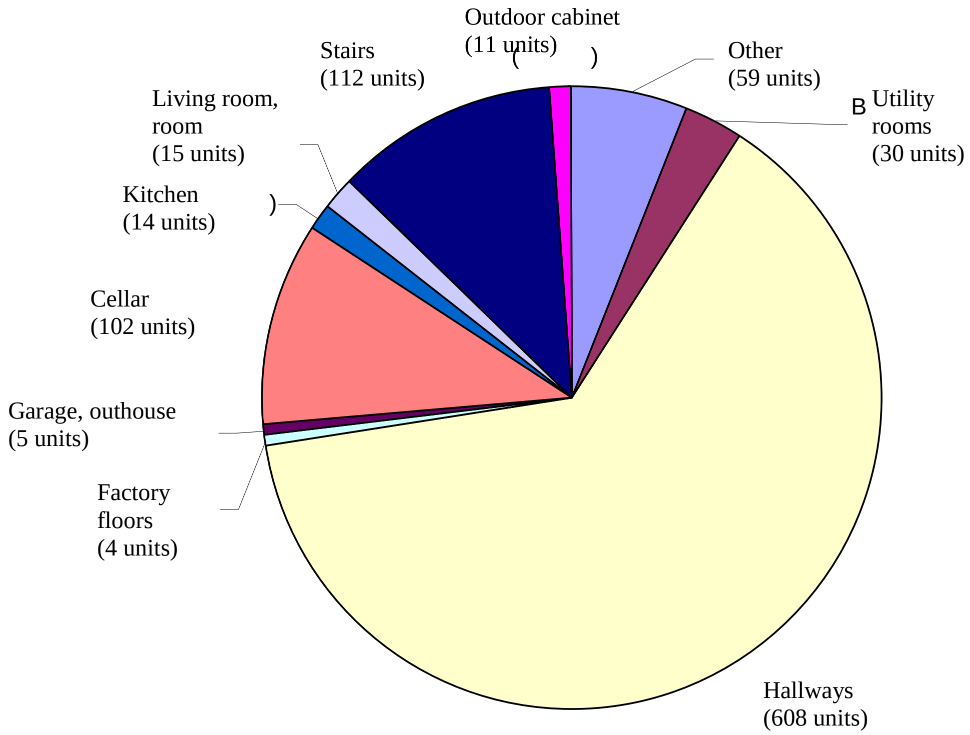

Figure 6. The location of the 960 RCDs

The main part of the RCDs is installed in hallways, basements or on stairs. This is the case for 822 of the 960 RCDs, equivalent to 86%.

The faulty RCDs in the survey are spread on the following locations (table 3).

Location	Amount tested	Amount of faulty switches	Fault percentage			
			Estimate	min.	max.	Confidence interval (95%)
Utility rooms	**30**	**2**	**6,7%**	0,0%	16%	9,1%
- hereof RCD type AC	22	2	9,1%	0,0%	21%	12,3%
- RCD type A	8	0	-	-	-	-
Hallways	**608**	**30**	**4,9%**	3,2%	6,6%	1,7%
- hereof RCD type AC	330	29	8,8%	5,7%	12%	3,1%
- RCD type A	278	1	0,4%	0,0%	1,1%	0,7%
Factory floors	**4**	**0**	-	-	-	-
- hereof RCD type AC	1	-	-	-	-	-
- RCD type A	3	-	-	-	-	-
Garage, outhouse	**5**	**1**	**20%**	0%	60%	40%
- hereof RCD type AC	4	1	25%	-	-	-
- RCD type A	1	0	-	-	-	-
Cellar	**102**	**15**	**14,7%**	7,8%	22%	6,9%
- hereof RCD type AC	72	12	16,7%	8,0%	25%	8,7%
-RCD type A	30	3	10,0%	0,0%	21%	10,9%
Kitchen	**14**	**0**	-	-	-	-
- hereof RCD type AC	6	-	-	-	-	-
- RCD type A	8	-	-	-	-	-
Living room, room	**15**	**0**	-	-	-	-
- hereof RCD type AC	10	-	-	-	-	-
- RCD type A	5	-	-	-	-	-
Stairs	**112**	**13**	**11,6%**	5,6%	18%	6,0%
- hereof RCD type AC	72	11	15%	7,6%	23%	8,4%
- RCD type A	40	2	5,0%	0,0%	12%	6,8%
Outdoor cabinet	**11**	**2**	**18%**	0,0%	42%	24%
- hereof RCD type AC	4	1	25%	-	-	-
- RCD type A	7	1	14%	-	-	-
Other	**59**	**6**	**10,2%**	2,4%	18%	7,8%
- hereof RCD type AC	37	5	13,5%	2,3%	25%	11,2%
- RCD type A	22	1	4,5%	0,0%	13%	8,9%

Table 3. Fault percentages distributed on location of RCDs. The fault percentages are also assessed on the two types of devices in the survey.

The table shows that placement indoors in inhabited locations (hallways, livingrooms and other rooms) renders the RCD functional for a longer period of time, compared to the more exposed locations such as cellars, stairs and outdoors. The surrounding environment is assessed in the following paragraph.

Due to the relatively low number of tested RCDs placed in garages, outhouses or outdoor cabinets it is not possible to elaborate on which of the locations that are the poorest, only that all three were poorer than for RCDs placed indoors in inhabited locations.

6.6 Surrounding environment at point of installation

The surrounding environment at the point of installation is characterised from four conditions; humidity, dust, dry or cold. Furthermore, the “middle conditions” cold and dusty, dry and dusty as well as humid and cold are registered. The distribution is shown in figure 7.

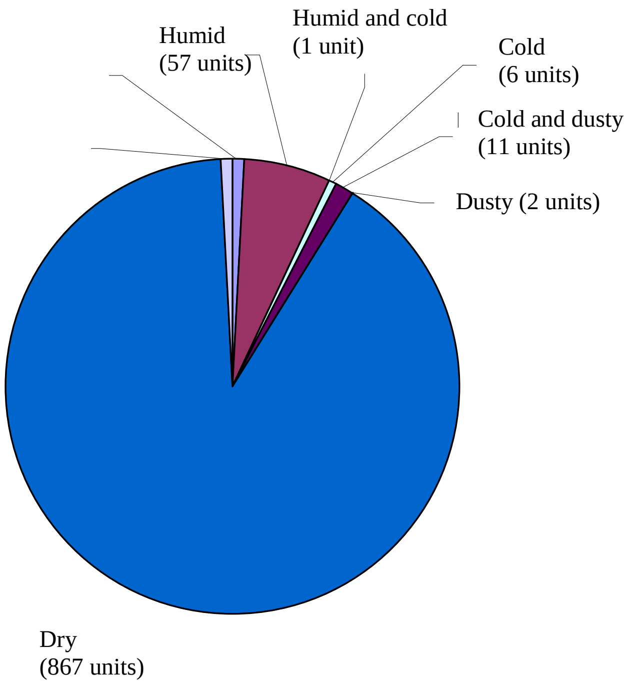

Figure 7. Characterisation of the surrounding environment in the locations where the 960 RCDs are installed.

The figure shows that the surrounding environment at the point of installation is characterised as “dry” for 90% of the RCDs.

The environment surrounding the faulty RCDs, is distributed as shown in table 4.

Surrounding environment	Amount tested	Amount of faulty switches	Fault percentage			
			Estimate	min.	max.	Confidence interval (95%)
Dry	**867**	**61**	**7,0%**	5,3%	8,7%	1,7%
- hereof RCD type AC	510	56	11%	8,3%	14%	2,7%
- RCD type A	357	5	1,4%	0,2%	2,6%	1,2%
Humid	**57**	**3**	**5,3%**	0,0%	11%	5,8%
- hereof RCD type AC	27	1	3,7%	0,0%	11%	7,3%
- RCD type A	30	2	6,7%	0,0%	16%	9,1%
Cold	**6**	**2**	**33%**	-	-	41%
- hereof RCD type AC	4	1	25%	-	-	-
- RCD type A	2	1	50%	-	-	-
Cold and dusty	**11**	**2**	**18%**	0%	36%	18%
- hereof RCD type AC	6	2	33%	-	-	-
- RCD type A	5	0	-	-	-	-
Dry and dusty	**7**	**1**	**14%**	0%	42%	28%
- hereof RCD type AC	5	1	20%	-	-	-
-RCD type A	2	0	-	-	-	-

Table 4. Fault percentages as a consequence of the surrounding environment at the point of installation for the faulty RCDs.

The table shows that RCDs will last longer if they are installed in locations without too much dust and not too cold.

It is not possible to rank the other types of surrounding environments registered, as too few RCDs are tested. The uncertainty of the fault percentages would then be too high.

6.7 The age of the RCD

The age of the RCDs has not been registered in the survey, but it is still possible to derive conclusions regarding the age’s influence on the devices functionality. The fact is that until 1994 mainly RCDs of type AC were installed in Danish residential buildings, when they were equipped with RCDs, while it became mandatory to install RCDs of type A after 1994. It is therefore fair to assume that all RCDs of type AC were 10 years old or more while the RCDs of type A were 10 years old or younger, at the time of the survey.

Furthermore, it is a fact that the basic mechanical construction in these RCDs is the same, namely two- or four poled devices with a tripping mechanism. In the RCD of type AC the signal to the tripping mechanism comes directly from a differential current transformer, while the signal in an RCD type A is first sent through an electronic circuit enabling the device to detect pulsating DC (see also figures 1 and 2). It is therefore assumed that the two types of RCDs ages evenly.

In table 1 it is shown that the fault percentages is almost 11% for RCDs of type AC (i.e. the “old” RCDs), while it is 2% for the RCDs of type A (i.e. the “new” RCDs). This is illustrated in figure 8.

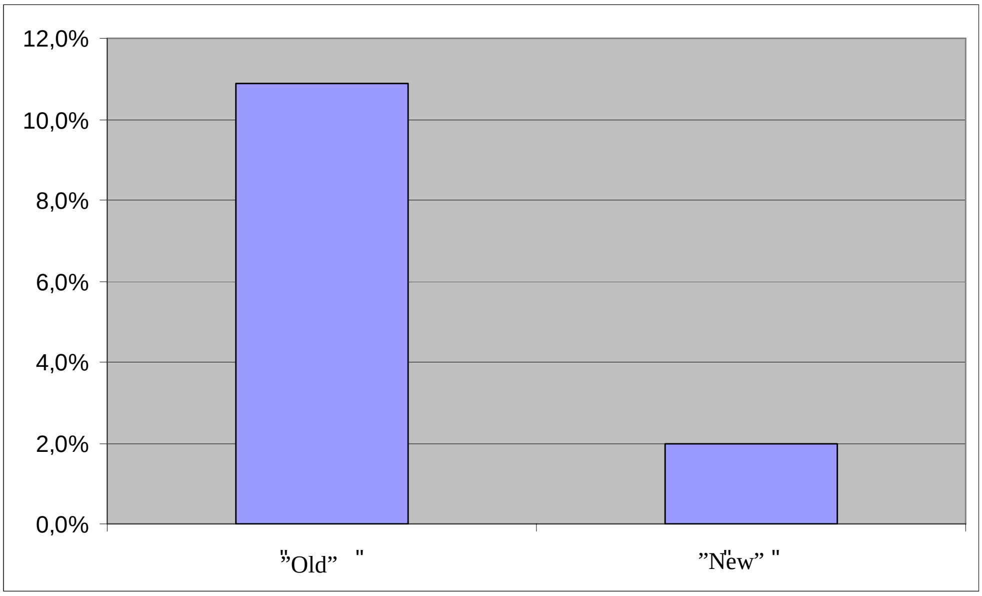

Figure 8. The figure shows the fault percentages for RCDs depending on their age.

It is not possible to sub-divide the results further concering age.

6.8 Testing the test button

The test procedure included a test of the RCDs test button. The procedure was to give the best possible picture of the devices functional safety at occurring fault currents. Therefore the test began with an AC test, measuring the tripping time on all used poles. If the circuit breaker was a RCD of type A, the tripping time was also measured with pulsating DC After these measurements had been carried out, the test button was activated to see if it tripped. (Normally the user is instructed to test the test button at least once a year and the Safety Technology Authority and the Electricity Council have previously run campaigns to make users test their RCDs at the transition from summer time to winter time.)

This part of the survey is interesting in order to clafiry two questions. Partly to see if the test button actually functions so that the user “exercises” the RCD and partly if there are instances where the test button can trip the RCD, even if the device does not work properly. In these cases the test button will give the user false security.

The result of the test is shown in figure 9.

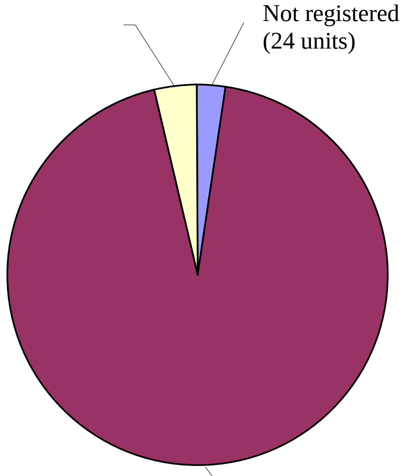

Figure 9. The result of the test of the RCDs test button

The result was that 902 RCDs (or 94%) functioned as they should. They tripped when the test button was activated. There are an additional 24 RCDs where the outcome is not registered, probably because that part of the test was not carried out.

Left is only 34 RCDs (or app. 3,5% of the total number of tested devices), where the test button did not trip the RCD. (The confidence interval in 95% level is +/- 1,2%).

When these facts are compared with the RCDs that do not work properly in the test, the result is the numbers shown in table 5.

	Test button trips the RCD	**The test button does not trip the RCD**
RCD worked properly in other points of test	869	9
RCD failed in other points of the test	39	25

Tabel 5. Overview of the result of the test of the test button on the 942 RCDs, where the outcome is registered. When the test button is activated, it should trip the RCD.

The table shows that the most common is that the test button trips the RCD, which means that the overall function of the RCD seems to be in order.

However, the table also shows that there are 9 instances where the test button does not trip an otherwise correct functioning RCD. (All these devices have a tripping time of 20-80 milliseconds, which is fully satisfactory). All 9 are 4-poled RCDs. An examination of the registrations shows that 7 of them are installed in one or two phased installations while the last two are installed in three phased installations. This has significance since the test circuit in the RCDs is only connected to one phase inside the device and therefore does not work, if only the other phases are connected (as described in 3.1). This will normally be checked by the installer of the RCD.

If it is assumed that the 7 RCDs are incorrectly installed, 2 RCDs remain where the test button does not trip when pressed. The error does not induce any immediate danger for the user but it means that the RCD cannot be tested. It is probably due to an error in the test circuit and the RCD therefore needs to be replaced.

There are 39 devices where the test button trips the RCD but where the RCD does not trip at a fault current of 30 mA. However, when examining the registrations they show that 6 of these RCDs would probably have functioned if the user had tested them regularly. All 6 incidents are cases where the RCDs have been assessed as faulty because the first (or the two first) AC tests gave unacceptable tripping times, after which the following tests gave acceptable values. It is therefore fair to assume that activating the test button at the end of test will trip the RCD and consequently fair to assume that it would have functioned if tested regularly.

Even if these 6 RCDs are left out of the survey and only the reamaining 58 are considered, it still shows that there are 33 incidents (over half the amount) where the user – after having pressed the test button – must assume that the RCD is functioning properly, even when this is not the case. This means that the test button only identifies 25 of the in total 58 faulty RCDs correctly. This corresponds to a share of 43%. (The confidence level on this estimate is +/- 13%.). It is unsatisfactory since almost all faults lead to the user not having the protection that the user would expect, if the user tested the RCD on a regular basis.

7 Evaluation

7.1 The results

The results show that the fault percentage for the ”old” RCDs (RCDs of type AC that are known to have been installed for more than 10 years at the time of the survey) was very high, as almost 11% of these did not work properly. The Safety Technology Authority would therefore like to incorporate the message that electrical installations and in particular RCDs, do not last forever, when communicating information campaigns to users.

It is also worrying that a very large quantity of the faulty RCDs cannot be detected by the user when activating the test button. The survey showed that almost half of the RCDs did not trip, when the test button was activated. In these cases the RCD does not give the protection anticipated by the user.

Finally, the survey showed that some RCDs were installed in a way that caused the test button to not work properly. It is up to the electrician to verify this, when the RCD is installed.

7.2 The method

The measuring programme in co-operation with the electricity companies was a success because a large number of RCDs were tested with the use of manageable resources.

8 Follow up on the project's results

The survey has shown three results that will be incorporated in the Safety Technology Authority's information strategy and standardisation work:

- More than one in ten RCDs do not work properly.
- More than half of the defect RCDs can still trip when the test button is activated.
- Ageing seems to influence the functionality.

These results are followed up by the Danish Safety Technology Authority as described below.

8.1 Information activities

The measuring programme emphasizes the need for users to test their RCDs regulary. Firstly, part of the measuring showed that the RCDs can be "exercised" to work, meaning that the first measureing resulted in unacceptably high tripping times that after 1-2 trippings fell to values under the required 300 milliseconds at 30 mA. Secondly, a test will reveal the RCDs that do not work properly and are up for replacement.

It is therefore important that the Safety Technology Authority continues to inform the users about the importance of testing the RCDs reguarly, for example twice a year.

8.2 Standardisation activities

The survey has shown that testing by activating the test button gives an idea of the RCDs functional safety which is far too positive. The test button tripped the RCD correctly in almost half of the cases where the RCD did not trip at a fault current of 30 mA. One of the reasons for this is probably that the test circuit in a RCD generates a fault current of 70-75 mA, which is far more than twice the fault current generated using external testing equipment. The test circuit influences the tripping circuit far more than a "real" fault can. This is critical since changes might occur in the preset tripping characteristics due to errors in the production, corrosion, ageing or similar circumstances. If this happens there is a relatively large distance from the RCDs rated tripping current of 30 mA to the normal test current of 75 mA where the test circuit can detect faults on the RCD.

Furthermore, the fault current generated by the test circuit is pure AC. This means that the RCDs ability to detect pulsating DC is not tested at all when the user activates the test button.

The construction of the test circuit is broadly estimated to be the same for all brands and types on the market. Therefore the observations will be discussed in the standardisation committee with a view to develop test circuits that are better at detecting faulty RCDs.

The high fault percentages for older RCDs will also be discussed in the standardisation group to find countermeasures. One idea could be to define a service time for RCDs in which it is assumed that it will work properly, provided that it is tested by activating the test button once a year. In this connection we might consider to draw on Japanese experiences, since Japanese regulations require that manufacturers of electrical products in the future mark their products with an "expiry date". An alternative could be a batch number or a corresponding code that determines the age of the RCD. This information would be printed on the front of the RCD in order for the user to read it. A third option could be to equip the RCD with an acoustic alarm that warns the user that it is time to test it.

It is also considered if the survey is to be presented at LVD/ADCO (the EU Commission's co-operative forum for authorities enforcing the low voltage Directive).

8.3 Other activities

In parallel to the above-mentioned activities, the Satety Technology Authority will consider to request (or instruct) electricians to send faulty equipment in for a closer examination. The legal basis for this is in the Product Safety Regulation.

9 Conclusion

At the beginning of the project five questions were raised. The answers to these questions are the following:

- How large is the number of RCDs that do not work as they are supposed to?
  The survey shows that 7% of the installed circuit breakers do not work according to their purpose.

- Are there differences in the functional safety for RCDs of type AC and RCDs of type A?
  Yes. The survey showed that the fault percentage for RCDs of type AC is 10,9%, while it is only 2,0% for RCDs of type A.
  Since the mechanical properties of the two types of RCDs are the same and since RCDs of type A were not installed in Danish installations until after 1994 (where it was also prohibited to install RCDs of type AC in residential buildings), it is assumed that the difference is particularly due to ageing.

- Are there differences in the functional safety between different installation types?
  The survey broadly covered only RCDs in residential buildings. The number of RCDs in other types of installations is so small that it is not possible to assess the fault percentage in relation to installation type.

- Does the functional safety depend on other circumstances?
  The survey showed that RCDs installed inside inhabited areas (hallway, living room and other rooms) had a significantly lower fault percentage than RCDs placed in environmentally more exposed surroundings.

- Are there RCDs where the test button functions but the RCD does not?
  Yes. The survey showed that 39 of the 960 tested RCDs could be triggered when the test button was activated, even if they did not trip at a fault current of 30 mA. (That is more than half of the RCDs that do not work properly). The user is therefore led to believe that the RCD functions properly, even when this is not the case.

Furthermore there were 9 cases where activation of the test button did not trip an otherwise correctly functioning RCD. The 7 cases are assumed to be due to wrong installation of the RCD, so that the test circuit does not work properly.
However, it is still a good idea to activate the test button regularly and replace the RCD if it does not trip.

Annex A. Test form

Below is the form that the inspectors used on location in the survey.

The Electricity Council

TEST OF RCDs Special test 2003-11-28 FM

Date of inspection:	Installation number.:

Installation type:

- ☐ Residential
- ☐ Light industry
- ☐ Office
- ☐ Industriy
- ☐ Other:

Location of RCDs in the installation (room cat.) :

- ☐ Stair/platform
- ☐ Outhouse
- ☐ Cellar
- ☐ Utility room
- ☐ Hallway
- ☐ Other: ___________
- ☐ No RCD/RCCB installed

Surrounding environment:

- ☐ Dry ☐ Dusty
- ☐ Humid (signs of humidity)
- ☐ Cold/temperature fluctuations
- ☐ Other:

Mounting in the installation:

- ☐ Group configuration for several group breakers
- ☐ Switchboard for a single unit (fx washing machine)
- ☐ In front of socket
- ☐ Other:

Visible data on equipment:

Brand/product: ________________ Type designation: _________________

Rated current: ☐ 40 A Other: ____________A

Rated tripping current: ☐ 30 mA Other: ____________mA

Number of switches on RCD/RCCB: ____________ Number of switches in use: ______

☐ RCD type AC ☐ RCD type A ☐ other:

NOTE! The test button may <u>not</u> be activated prior to the test and the RCD may <u>not</u> be tripped manually.
All group breakers and other equipment after the RCD shall be switched off before the test.
The test shall be carried out according to the instructions on the back of this form.

Set tripping current: ___mA.

RCD type AC + type A	Tripping time: AC test RCD max. 300ms	1st switch set:	____________	ms
		2nd switch set:	____________	ms
		3rd switch set:	____________	ms

RCDs of type A must <u>also</u> be tested with half-wave rectified AC, pulsating DC

Extra test of RCD type A	Half-wave rectified AC RCD max. 300ms	1st switch set: 0°:	____________	ms	180°:	__________	ms
		2nd switch set: 0°:	____________	ms	180°:	__________	ms
		3rd switch set: 0°:		ms	180°:		ms

Does the RCD trip when test button is activated?: ☐ Yes ☐ No

Signature ________________ Date ________________

Annex B. Instructions for testing

The inspectors received the following instructions. The instructions were printed on the back of the test form shown in annex A.

Instructions for testing RCDs/RCCBs

1. Never activate the RCD prior to the test, neither manually on the switch nor on the test button.

2. Fill in the test forms boxes (type of installation, location, surrounding environment, mounting in the installation, data on the RCD etc.)

3. Disconnect all groups after the RCD.

4. Ascertain on which terminal the neutral conductor is connected. Wrong connection induces short circuit in the testing equipment.

5. Ascertain which terminals on the RCD that are input and output terminals respectively. The phase and neutral testing pin is connected to the RCD output side on the phase and neutral terminal respectively. The earth pin from the testing equipment is connected to the RCD neutral terminal on the input side.

Execution of the test

1. Perform AC test: Set the testing instrument at 30 mA. Perform measuring on contact sets 1, 2 and 3. Record the result in the test form.

2. Perform DC test: Set the testing instrument at DC test. Perform measuring on contact sets 1, 2 and 3. Record the result in the test form.

3. Perform DC test, 180°: Set the testing instrument at DC test with 180° displacement. Remember to each time press the set button to 180° on the testing instrument. Perform measuring on contact sets 1, 2 and 3. Record the result in the test form.

4. Activate the test button. Record the result of the test in the test form. (Did the RCD trip – yes or no).

SIKKERHEDSSTYRELSEN

Nørregade 63, 6700 Esbjerg