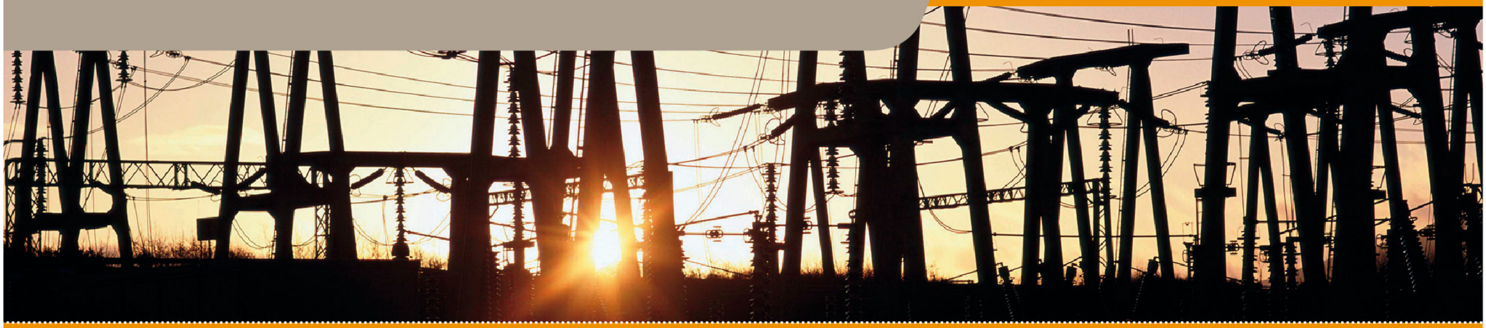

The Protective Life of Safety Switches

Project Stage 1

A Review

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Contents

1 Executive Summary

The Queensland Electrical Safety Board's Electrical Safety Plan for Queensland 2003 – 2008 committed to researching the life expectancy of safety switches. This review begins that research.

Safety switches support properly designed and maintained electrical installations by sensing small electrical currents flowing to earth that may cause electric shock or fire. However, if a safety switch fails while dormant, it may fail to trip when a fault occurs or not trip quickly enough when called on to save a life or prevent a fire.

Queenslanders in their homes and workplaces rely on safety switches for protection against the risk of electric shock. With the increasing reliance on safety switches, concerns continue to exist that weathering, ageing and long periods of inactivity may cause them to be unreliable. Although the reliance on and confidence in safety switches is generally high, the protective life of a safety switch is not generally known.

Just four published studies address the topic of safety switch reliability. These studies vary in purpose and method and although their findings are generally consistent and seemingly reliable, their specific findings are variable. The most recent studies report an overall failure rate of safety switches in conditions that might be expected in Queensland, ranging from less than 1% to 11%. For older data samples and harsher environments, this statistic is even higher. Whether or not this reflects Queensland's population of safety switches can not be inferred with certainty. Considering the high reliance on safety switches, the question of reliability remains a valid and significant one.

Physical and electrical environmental conditions, engineering design and selection, and regular maintenance all influence the useful life of safety switches. Although some guidance is available for the evaluation of those factors likely to be experienced in Queensland, it does not allow their definitive identification. Significantly, the International Electrotechnical Comission (IEC) warns that the useful life is not predictable because of the number of variables.

This review also identified that approval and design standards along with guidance standards and advice are current mechanisms that support the management of an ageing safety switch population. The useful life of a safety switch begins by achieving product approval and installation standards. The unanimous advice of the literature is that the useful life should be verified and extended by regular maintenance using the push button test.

Further research is required to benchmark the failure rate of Queensland's safety switch population. By researching this general failure rate and identifying the significant factors, control measures for managing the ageing population may be augmented.

The longer term monitoring of safety switches, over time, will inform the management of safety switch population with longitudinal data. Progressively, new data will identify emerging issues and accumulated data will identify trends. This will reinforce or redirect the strategic management of this electrical safety protective measure.

2 Introduction

Safety switches are a supplementary electrical safety device, either portable or wired into electrical installations. They support properly designed electrical wiring and equipment by sensing small electrical currents flowing to earth that may cause electric shock or fire. In the event of such a fault, safety switches are designed to disconnect the power supply before it can cause harm or property damage. However, if a safety switch fails while dormant, it may fail in a way that leaves electrical installation unprotected. It might fail to trip when a fault occurs or not trip quickly enough to prevent serious effects of an electric shock.

Queenslanders in their homes and workplaces rely on safety switches for protection against the risk of electric shock. Safety switches continue to benefit from advances in design, however various designs have been in service for several decades. While reliance on and confidence in safety switches is generally high, the protective life of a safety switch is not generally known. The complexity of this is due to the many design, environmental and maintenance factors that play a part in determining its longevity. With the increasing reliance on safety switches, concerns continue to exist that weathering, ageing and long periods of inactivity may cause them to not operate when called on to save a life or prevent a fire.

The Queensland Electrical Safety Board's Electrical Safety Plan for Queensland 2003 – 2008 committed to researching the life expectancy of safety switches. This review begins that research. The aim of this review is to identify the influences on electrical safety provided by safety switches. The purpose here is to review the knowledge and advice available internationally so it may be applied in the Queensland context. An understanding of the failure rate of safety switches and the variables at play will allow their ageing to be better managed by regulators, industry and individuals.

This review is limited to accessing published literature of safety switch reliability. It is acknowledged that the literature will reflect the focuses and biases of its authors and the needs of their audience. Although manufacturers are represented as research sponsors, there is a noticeable paucity of direct information from manufacturers given their vested interest in promoting the confidence of safety switches. It is also acknowledged that the focus of safety switch literature is on the fixed wired type. Notwithstanding the similarities, it is anticipated that different factors influence the longevity of portable devices and to review these would require a separate study.

3 Background

3.1 Safety Switches in Queensland

Safety switches have provided electrical safety protection in various countries since about 1940. Their more widespread adoption occurred in the 1960's when technology improved their tripping sensitivity significantly making them more suitable for household use.

In Queensland, safety switches have been used voluntarily since the 1970's and more recently as a legislated requirement. Legislated installation of safety switches in Queensland's domestic residences began in 1992[1]. In 1997 their penetration was estimated as 55% of pre 1992 domestic dwellings[2]. In 2003 it was estimated that 66.5% of households had safety switches installed[3]. In 2005 work began by the Electrical Safety Office in conjunction with Ergon Energy and Energex to more accurately gather data to inform the past estimates. Data gathered by meter readers is tracking three important proportions – homes with safety switches installed, homes with safety switches not installed and those homes yet to be surveyed. As of February 2007, it has been confirmed that safety switches are installed in 61% of homes whilst 8% of homes have been confirmed not to have safety switches. The remaining 31% of homes are yet to be surveyed. This penetration is expected to increase as they are currently required to be installed in all new domestic residences along with pre-1992 domestic residences at transfer of ownership or electrical upgrade. Safety switches will also be required in all rental domestic residences from March 2008 when tenancy agreements are entered into[4].

Equally as significant for electrical safety, the penetration of safety switches into Queensland's workplaces is expected to increase. In March 2008 legislation will require safety switches to be used in manufacturing workplaces. Voluntary uptake of safety switches might also be expected to increase as they are optional measure for employers and self employed persons to meet their electrical safety obligations in other workplaces[5].

3.2 What is a Safety Switch?

Safety switches are technically referred to as Residual Current Devices (RCD). Queensland and other areas of Australia have adopted the name safety switch[6]. Alternatively, devices of this nature are known internationally as Earth Leakage Circuit Breakers (ELCB), Ground Fault Circuit Interrupters (GFCI), Residual Current Circuit Breakers (RCCB), Residual Current Circuit Breakers with Integral Overcurrent Protection (RCBO) and Socket Mounted Residual Current devices (SRCD). Portable RCDs (PRCD) are those safety switches that can be carried by hand and are connected between a tool /appliance and the socket outlet.

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[1] The 1992 definition of the traditional domestic residence excluded caravans, hotels motels, hostels etc. (Electrical Development Association of Queensland [EDAQ],1997:p8)

[2] EDAQ 1997:p17

[3] May 2003 Queensland Household Survey (Technical report Prepared for the Electrical Safety Office by the Office of economic and Statistical Research)

[4] The *Electrical Safety Regulation*, Part 5, Division 4 - Installation of approved safety switches in domestic residences

[5] For example: The *Electrical Safety Regulation*, Part 5, and Division 5 Subdivision 4 - Manufacturing work.

[6] See the *Electrical Safety Regulation 2002* (Queensland)

3.3 Protection from Electric Shock and Reduced Risk of Fire

Safety switches provide protection from electric shock and also reduce the risk of fire due to electricity[7]. The Electrical Safety Office estimates that over the last 10 years in Queensland, 34 electrocutions might have been prevented had a safety switch been installed.

Electric shock

If a person contacts something that is electrically live, then electricity may flow through their body to earth or via another return path. The effect of a current passing through the body is dependant on the magnitude of the current and the duration that it continues to flow. The effect on the human body of an electric current may be small and unperceivable, however a person may experience tingling, muscular pain, breathing difficulties, burns and heart failure[8].

What Safety Switches do

When a correctly operating safety switches detects an earth fault, it disconnects the power in milliseconds. The type commonly installed in Queensland has a nominal tripping time of 300 milliseconds although it is usual to find that they have tripping times of less than 50 milliseconds[9]. Although an electric shock may be experienced, the likelihood of electrocution is lessened. The ability of a safety switch to detect and quickly isolate the dangerous current flow before it damages the human body is critical.

The risk of fire is also reduced because the safety switch may detect defective wiring and equipment and disconnect the power, even without a person receiving a shock. Ageing installations are linked to dangerous tracking currents to earth that could cause a fire. Tracking currents are possible across isolating material where surface pollution has dried causing a conductive carbon build up[10].

Safety switches do not provide protection against all electric shocks. Even in the presence of a correctly operating safety switch, if a person contacts something that is electrically live along with the neutral conductor, the current may flow through their body and not to earth. In this situation there is no earth fault current to make the safety switch trip operate. The device does not protect in situations where current flows occur from active to neutral or across phases, active to active.

How Safety Switches Operate

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[7] TR 62350 Guidance for the correct use of residual current operated protective devices for household or similar use (2006) (p. 41)

[8] SAA NB113 – 1998 Residual Current Devices- what they do and how they do it

[9] TR 62350 Guidance for the correct use of residual current operated protective devices for household or similar use (2006) (p. 45)

[10] IBID 7

The operation of a safety switch relies on its core balance transformer which detects an unbalanced current flow. The safety switch is designed to disconnect power supply when the normally healthy equal and opposite current flows of active and neutral are unbalanced by a flow (or leakage) to earth. The output from the core balance transformer is the input to the tripping circuit that trips the latching mechanism within the safety switch which disconnects the power.

While the core balance transformer (also known as the current transformer or differential transformer) is the central component of all safety switches, their latching mechanisms vary in design. Electronic latching mechanisms use very little energy from the core balance transformer to operate a solenoid connected to the supply power. Operating this solenoid disconnects the power supply. Electromechanical latching mechanisms use the core balance transformer's tripping energy to interrupt a permanent magnet's hold on a magnetic circuit to disconnect the power supply. Both types of mechanisms are present in Queensland's safety switches.

3.4 RCD Approval Standards and Guidelines

Various types of safety switches have been approved for use in Queensland. Standards began for safety switches with AS 3190 from 1974 and more recently international standards have been integrated into AS/NZS 3190:2002, AS/NZ 61008.1 and AS/NZ 61009.1 which cover RCDs, RCCBs and RCBO's respectively. Safety switches in service are tested in accordance with AS/NZS 3760. These standards describe approval and test specifications including reliability. The approval testing of safety switches at the beginning of their usable life and in-service testing during their usable life have been comprehensively detailed by these standards for some time. Traditionally, little guidance has been available for the expected durability of safety switches. Although the International Electrotechnical Comission (IEC)[11] has recently developed a comprehensive guide for the correct use of residual current operated protective devices for "normal" domestic use (The IEC Technical Report)[12] the document has not yet seen widespread adoption.

3.5 Safety Switch Failure and Reliability

Many of Queensland's domestic residences are protected by safety switches of various designs that could be several decades old. While reliance on and confidence in safety switches is generally high, the protective life of a safety switch is not generally known because several factors play a part in determining its availability of protection over its life. The protective life is the time period over which safety switches are available to protect life and property in the event of a fault. The protective life is also the useful life of a safety switch as a piece of electrical equipment highlighting its critical function. While a safety switch may continue to be 'in use' and seemingly useful, it may not be capable of functioning as intended in the critical event of an earth fault.

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[11] Sub Committee 23E Working Group 2
[12] IBID 7

Safety Switch Failure

Critically, safety switches can fail to an unsafe state and may, if left unchecked, leave homes or workplaces unprotected. Assurance of the continuous protection provided by a safety switch usually depends on the manual trip test feature and that the device is tested by human intervention.

The Manual Trip Test and Time Level Test

Critically, as a safety switch fails, it can leave a residence unprotected by failing to trip should an actual fault occur. While the failure of a safety switch to protect is not an immediate risk to electrical safety, if left unchecked this may leave an installation unprotected for a long period. Regular manual testing of a safety switch using the manual test button serves to ensure protection over time by verifying its operation and also maintaining the tripping mechanism[13]. This simple test may be considered crude as it neither tests the discriminate level of earth leakage fault nor the time it takes to disconnect power, the break time[14].

Nuisance Tripping

Although nuisance tripping may erode the confidence that electricity consumers have in the effectiveness of safety switches, it is not a focus for this research. Although safety switches may be seen as faulty due to nuisance tripping this does not indicate that they would not have tripped when required.

Portable Type Safety Switches

Portable safety switches are commonly used in Queensland. The focus of safety switch reliability research historically has been on the hardwired type, installed mainly in domestic dwellings; however portable devices cannot be ignored.

Although portable safety switches offer similar protective features to hard wired types, their effective life may be expected to be much shorter than the hard wired type. Because of their portable nature (and use) it is expected that portable safety switches might fail in a safe state due to such causes as broken connections or mechanical damage. Portable safety switches are also more exposed to visual examination and the manual test of their users, particularly in the workplace. For these reasons it is judged that measuring the reliability of portable safety switches would require a distinctly different research approach to that applied to hard wired types.

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[13] Russell and Dean (2006) ERA Technology, *In service reliability of RCD's*, Ibid 9

[14] See AS/NZS 61009.1:2004 ,p10 &22

Notwithstanding such differences, both fixed and portable safety switches do share features and this research will aim to identify factors influencing the protective life common to both types.

3.6 The Reliability Lifecycle and Availability of Protection

Safety switches are either electromechanical or electronic devices which are relied upon by people to enhance electrical safety. Their longevity can be characterised, as many electrical devices are, by using the reliability life cycle concept common to reliability engineering.

The Reliability Lifecycle

The reliability life cycle approach is widely applied to engineered devices and systems[15]. A device similar to the safety switch that serves to illustrate the importance of reliability is the medical device (See Fries, 2006). Indeed the literature on cardiovascular implant devices suggests that reliability is a central concern for that field, as it is with safety switches[16]. In a reliability sense, the safety switch is similar to a medical device in that it protects human life with the additional protection of property. Reliance on safety switches is akin to that of a true medical device because failure may not be pre-warned yet the consequence is potentially lethal. Figure 1 illustrates three phases of the reliability life cycle. While the infant mortality phase of a safety switch's life would be expected to occur at the quality assurance check stage, the duration of the useful life and the point of failure in the wear-out phase are less easily determined.

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[15] Ibid 9

[16] For example see. Maisel W.H. (2006) *Pacemaker and ICD Generator Reliability: Meta-analysis of Device Registries* JAMA, April 295: 1929 - 1934.

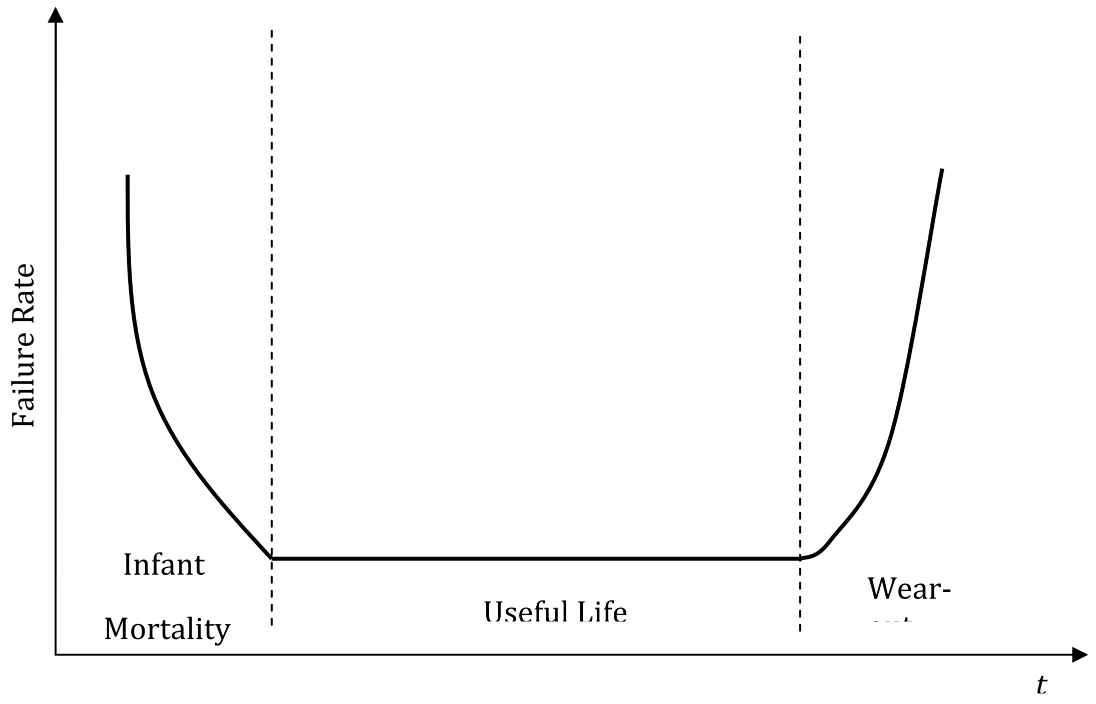

Figure 1 Reliability Life Cycle - Failure rate vs. Time (Fries, 2006)

The Reliability Lifecycle of Safety Switches

The reliability of safety switches is commonly examined in terms of their useful life and predicted wear out. The failure of safety switches is a critical event that occurs at a point on the characteristic reliability lifecycle curve. Mapping the characteristic curve for a population of like devices provides a tool to assist in predicting the point at which a similar unit may fail. With all factors held constant, this method is effective. Using this approach for safety switches is complicated by the many environmental factors that come into play when the device is installed. The curve then for each safety switch installed may be different or perhaps able to be grouped further by environmental factors.

Device Reliability with "In Use" Testing

The availability of protection is a percentage measure of the ability of a device to perform its designed protective function. Figure 2 illustrates the theoretical effect of the regular testing of a safety switch. A 100 percent measure represents the situation where a safety switch can be assumed to be available to protect the electrical installation. This situation is likely when a device is newly installed and tested or a test has been conducted.

Manual testing using the push button is one method by which the reliability of safety switch can be verified and even extended. In effect this is verifying and modifying the lifecycle curve for that device. The push button test simulates a fault by activating the tripping mechanism within the device. This simple test serves two purposes. Firstly it verifies the operation of the device allowing a faulty unit to be identified and then replaced by the owner. Secondly, regular testing is a method of maintaining the moving parts of the safety switch which are susceptible to deterioration over long periods of inactivity[17]. Manufacturers, standards makers and regulators routinely recommend regular push button testing by householders.

A significant limitation to this test method is that it relies on human behaviour. The reliability of people to carry out the test is hampered by their awareness of the need and their safety motivation. Safety switches are usually located in a concealed location and the manual test requires disruption to the household.

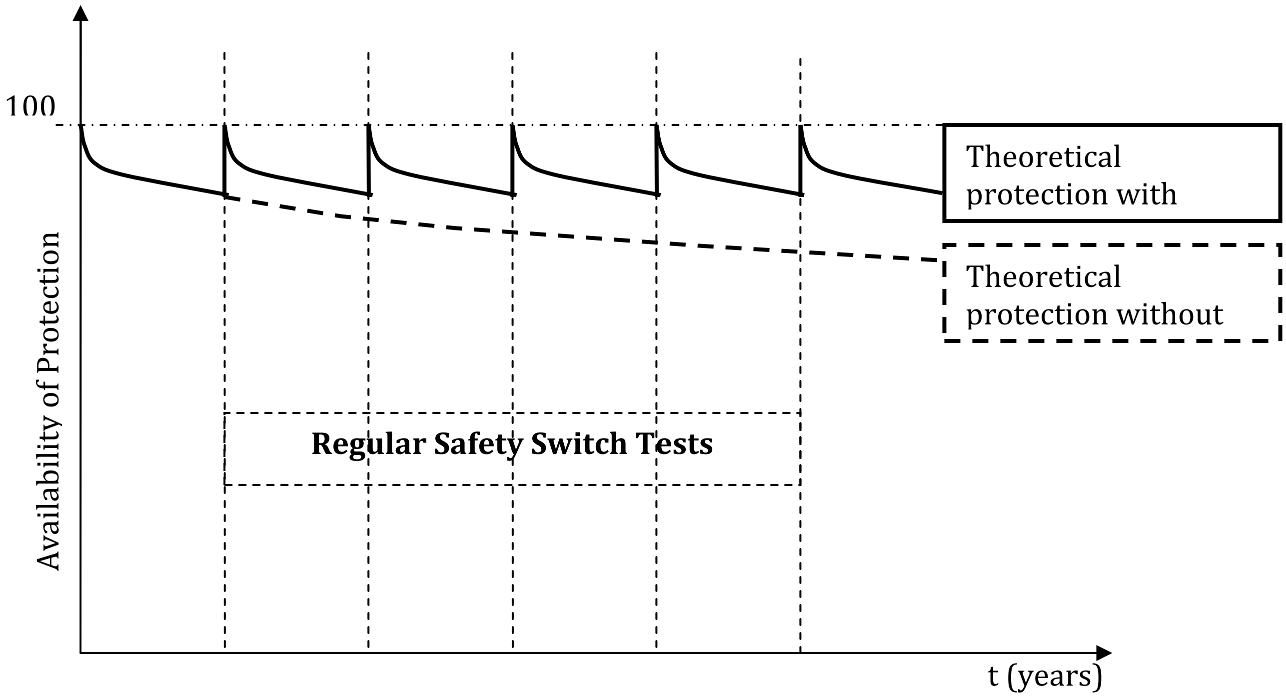

Figure 2 Theoretical availability of Safety Switch protection with regular in use testing

Another form of "in use" testing for safety switches is the time-current test carried out by a licenced electrician on site using a dedicated test device. This test suddenly applies a fault simulating current to the protected circuit and measures the duration of time before the power is isolated. Maximum tripping times should be in accordance with AS/NZ 3760. This test discovers not only a device that fails to trip but also those faulty units that have become less sensitive and take longer to trip than designed. It was noted above that the severity of electric shock increases with time (in milliseconds) and so this test is important to limit the effects of time.

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[17] Cantarella G., Carrescia V., Tommasini R., Quality of Residual Current operated Circuit Breakers, *European Transactions on Electrical Power*. Berlin, Vol6. No.3, pp.149-156,1996.

4 Safety Switch Reliability - International Research

A search of the available literature revealed that the reliability of safety switches has been of interest to researchers for some time. Each of the available studies are summarised below. In general these reliability studies reported on the influences of the device attributes, installation, electrical and physical environmental factors. A study commissioned by the UK Electrical Safety Council has also recently reviewed the literature in the field[18].Table 1 summarises the available international safety switch reliability research.

Country	**Year Published (Conducted)**	**Sample Size**	**Key Reliability Factors**	**Failure Rate**
USA	2001 (2000)	n= 2680	Age Humidity Temperature Outdoors Type	14%
Italy	1996 (1970-1990)	n= 21,019	Age Humidity Saline atmosphere Outdoors Residential/non Residential Type Quality mark	7.1-7.6% (2.8% when tested regularly)
Germany	1991 (1988-1991)	n= 44334	Internal mechanisms Age Environment	2.4 %
United Kingdom	2007(2007)	n= 607	Moisture and contaminants Misalignment of contacts	2.8%

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[18] Russell and Dean (2006) ERA Technology, "*In service reliability of RCD's*"

South Africa	1996 (unknown)	n= 17,000	Type	2.2-7.5%
Bavaria	2000 (unknown)	n= 150,000	Age	5%
Netherlands	2000 (unknown)	n= 624		0.16%

Table 1 summary of International Safety Switch Reliability Research (after Russell and Dean 2006)

4.1 USA

A well cited field study published by the National Electrical Manufacturers Association (NEMA) in 2001 undertook a field survey in 12 geographically diversified locations. The method used was to gather data from home inspections at the time of sale. The home inspectors who were not electrically qualified were trained to conduct simple tests and document other particulars. Where a faulty device was discovered by the home inspector the opportunity was provided for the property owner to have an electrical contractor replace it and forward it to the laboratory for further testing.

This field survey yielded a sample of 2680 units from 1090 residences. This report aimed for a statistically significant result for the permutations of the climate and lightning variables. To this end a minimum sample size of 255 for each permutation was aimed at. Other measured variables included age, type (circuit breaker or outlet) location (indoor or outdoor) and manufacturer.

Overall, for circuit breaker type safety switches, 14% were found to be faulty. The report showed the greatest reliability differences across climates. Dry climates experienced a failure rate of 11% compared to 17.5 % for humid climates.

The U.S. Consumer Product Safety Commission conducted a multivariate statistical reanalysis of the NEMA data; Greene (2004) tested a proxy variable for the age of the safety switch. Greene's analysis supported the original analysis and reported in addition that age was a statistically important variable for operability.

4.1.1 Recent North American Response

In response to the 2001 NEMA study, UL and CSA international (Canadian Standards Association) introduced revised requirements for the manufacture and distribution of GFCI receptacles (Safety switch socket outlet type)[19]. The new receptacle type units are required to have the following features;

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[19] The USA's National Electrical Code® (NEC) requires GFCIs to be used in bathrooms, kitchens, garages, basements, crawlspaces, and outdoors. Similarly, the Canadian Electrical Code (CEC) requires GFCIs to be used in many locations such as bathrooms, outdoors, basic care areas of hospitals, pools, spas, and hot tubs. The

- **End of Life Provision:** when a GFCI receptacle is incapable of passing its internal test function (it can no longer provide ground fault protection) it will either a) render itself incapable of delivering power, or b) indicate by visual or audible means that the device must be replaced.
- **Miswire prevention feature:** a GFCI will deny power to the receptacle face if it is miswired – line load.

These requirements began in the USA and Canada in 2006.

4.2 Italy

An Italian study by Cantrella, Carrescia and Tommasini (1996) investigated the phenomenon of the sticking residual current relay within safety switches (electromechanical type) due to inactivity. This study focussed on measuring the tripping time and current performance safety switches. A sample of 21019 units was subjected to two test methods over a 20 year period from 1970. Seven different tripping time tests were carried out on 15,422 units and later 5597 units were subjected to a modified set of tests to include threshold tripping currents. Where faulty units were identified by failing any of the onsite tests, the owner's permission was sought for their removal and laboratory testing. This study measured variables grouped under the headings of type of installation (residential, industrial etc.) place of installation (indoors, outdoors, dusty, saline atmosphere etc. and aspects of the device (date of installation, quality mark and ratings for protection etc,).

For non-residential installation this statistic was 7.6% and for residential it was 7.1% (n = 9737 and 2910 respectively). The higher non-residential failure rate was attributed to harsher environment. Increased failure rates were identified in the presence of an inadequate IP rating (Ingress Protection), moisture, saline atmosphere (within 5km from sea) and outdoor location. This report judged a normal installation to be indoors with no adverse environmental influences. For this situation 6% of safety switches were found to be faulty.

It was reported cautiously that the year of installation influenced failure fate. The caution was that as safety switches age they are more likely to have been replaced in an installation. This study also noted that only 24% of faulty devices were identified using the manual test button test. The increased use of the test button test however, decreased failure rates from 8.9% for a yearly or greater, test to 2.8% for a monthly test.

4.3 Germany

Kieback (1991) reported a two stage field survey of 44,334 installations with safety switches over the years 1988 to 1991, where 1078 units (2.4%) were found to be faulty. An in-service test, conducted by an inspector, tested the tripping time and operating current using a proven test device. They also checked the operation of the test button. All units that failed these tests were removed for laboratory tests and analysis.

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manufacturer's standards are UL 943 and CSA C22.2 No. 144.1 *Safety Standard for Ground Fault Circuit Interrupters (GFCIs)*

Some of the safety switches that failed the inspector’s in –service test subsequently passed in the laboratory test. These devices were subjected to a 28 day environmental test. This test found that in 95% of cases that the in - service test result was replicated.

This analysis examined three possible causes within the safety switch which may indicate the influence of other factors including the external environment. The latching mechanism accounted for 55% of failures, the tripping circuit, which transfers the small fault signal to the latching mechanism, accounted for 33% and faults of the manual test button circuit accounted for 13%. The latching mechanism and tripping circuit failures were attributed mainly to the gumming up (resinification) of ageing lubricant. Other likely causes included jamming of the mechanical parts and residues from manufacturing, wear and dirt particles. The manual test button circuit relies on a resistor to simulate an earth fault to activate the tripping mechanism. This report discussed how the repeated ‘testing’ by using the pushbutton of a unit with a sticking mechanism may cause the resistor of the test circuit to fail. The author suggests that the miniaturisation of devices has led to a reduction in the robustness of the test circuit resistor.

Another aspect of safety switch reliability Kieback (1991) considered was device age. Although the report did not explain the measure it employed beyond ‘time marks’, the data captured devices manufactured from 1951 (of the very first safety switches) to 1991. The failure rate doubled from 1950’s units to the late 1970’s units under the pressures of production demand. The 1980’s units exhibited a marked reduction in failures which the author suggests is characteristic of new generation units.

4.4 South Africa

The South African experience reported by Cohen (1996) was of a 17,000 device sample which tended to confirm the European failure rates of between 2.5% to 7.5 % adding the claim that that electronically operated safety switches experienced a far lower failure rate than electromechanical safety switches. The author was identified as representing a manufacturer.

4.5 United Kingdom

Russel and Dean (2006) reported, in addition to some of the studies examined above, studies in Bavaria, and the Netherlands whose results were provided to the IEC in 2000. The Bavarian sample of 150,000 electromechanical was reported to have a failure rate of 5% and the Netherlands sample of 624 electronic units from a single manufacturer was reported to have a 0.16% failure rate.

The Russel and Dean (2006) report was a precursor to the 2006 - 2007 field study in the UK reported by Dean, Friday and Salako (2007). A sample of public housing safety switches were subjected to both a test button test and a time - current test against their specifications. This study of 607 electromechanical safety switches in domestic properties found an overall failure rate of 2.8%. It also found support for the notion that regular use of the test button decreases the failure rate. The failure rate varied from 0% for safety switches tested in the lat year to 4.4% where the date last manual test was not determined.

The age of the failed safety switch was 72 months where the average age, where it could be determined was 76 months. While the details of this aspect of the study are not reported, the authors state that the found no statistical difference that indicated age was a factor in failure. This result calls into question the measurability of device age. While manual testing intervals of up to ten years were discussed, the average age was approximately 6 years. Although it cannot be inferred with certainty, one might speculate that the sample may be dominated by younger safety switches, given their progressive penetration nature of the housing, thus yielding the 6 year average age statistic. Notwhistanding this, older devices may remain in the population which were not captured by this study.

The IEC Technical Report

The IEC Technical Report, published in December 2006, provided an analysis of “several surveys in various countries”. It suggested;

- Up to 50 % of safety switches found faulty in the field were found functional in the laboratory. This was attributed to faulty installation.
- Many of the units were installed without proper regard for the environmental conditions.
- Climatic and electromagnetic conditions were critical in conjunction with non compliant units.
- Most of the studies were of safety switches greater than 20 years old and not covered by advances in approvals test.

This analysis of the “available surveys” suggests that the data used was the published studies also discovered by the current review. However it appears that the IEC Technical Report has benefited from committee member insights in addition and indeed perhaps subsequent to the original studies.

The IEC Technical Report identified thought its international committee system that product standards, design and manufacturing (quality), compliance, climatic environment and electromagnetic environment contributed to the availability of protection of safety switches. For a safety switch installed in “normal indoor conditions”, complying with relevant standards, long term availability of protection can reasonably be assured. Installations that are other than “normal indoor conditions” are exposed to influences that require special precautions. Table 2 lists the IEC Technical Report’s guidance of the most significant external environmental parameters that should be taken into consideration when selecting and installing a safety switch. Understandably the caveat recommendation to “seek manufacturer’s advice” is contained throughout.

Table 2 IEC TR 62350 Most Significant External Parameters

External influences	Importance
Temperature and Humidity	1
Corrosion	1
Radiation (Electromagnetic Compatibility)	1
Temperature	2
Water	2
Foreign Bodies	2
Lightning	2
Altitude	3
Impact	3
Vibration	3
Flora and moulds growth	3
Fauna	3

The IEC Technical Report highlighted a view held internationally of the complexity of safety switch reliability assessment;

"Due to the large number of parameters influencing the correct operation of RCDs, it is understandable that it is not possible to predict a number of years or months for an expected lifetime of the RCD." p23.

5 Discussion

Failure Rates

The failure rates reported in the international studies, broadly speaking, give a quantitative indication of the issue at the centre of this review. The reported overall failure rates were consistently not so small as to indicate safety switches can be relied on with complete confidence. Given their history of development and use, it might reasonably be accepted that safety switches will exhibit a small failure rate; however the variability of this statistic is high. The range in the failure rate reported, from less than one to over 10% may signal inconsistencies across studies and difficulties in measurement, however if reliable, it may indicate the possibility of high failure rates. The failure rates attributed to each contributing factor signal important variables. However, they cannot be compared quantitatively because the methods varied across each study. For example, we cannot infer that humidity accounts for the same proportion of the failure rate in all studies.

An understanding of the overall failure rate experienced in Queensland would provide some measure of the size of the problem relative to other jurisdictions and also provide an ongoing mechanism to map the ageing population of safety switches. The failure rate attributable to each contributing factor is variable in the international literature. Although this may suggest problematic measurement, it highlights that an understanding of the influence of factors peculiar to the Queensland context is important.

The Influences on the Useful Life of Safety Switches

The useful life of safety switches is influenced by the environment in which they are installed in conjunction with their design and selection. Environmental factors including humidity, corrosive atmospheres and general exposure to the outdoors were identified by many of the studies. Mediating the effects of the environmental is the suitability of design and installation. The long term ability of safety switches to repel environmental effects is dependant on their correct choice of specification and the location and manner in which they are installed. Using the manual test button also intervenes in the environmental effects by acting to cleaning away environmental pollutants. The test also verifies that the environment has yet not had an effect on its availability of protection. The effects of the Queensland environment may replicate in some way those reported by the literature. However it is not known which factors are most influential in Queensland and indeed an understanding of these factors will serve to inform the better selection of safety switches.

The year of manufacture of a safety switch was reported by Kieback (1991) as a broad indicator of the cumulative effect of influential factors. The actual measurement method used is not detailed, however their results illustrated that failure rates were not constant for manufacturing years between the 1950’s and the 1980’s.The failure rate was shown to generally rise and then fall over the four decades. This result suggests that, although the oldest units may be likely to fail at a given rate, units manufactured since may be equally or more likely to fail.

Greene (2001) highlighted the measurement problem and raised the possibility of measuring the age of a safety switch using a proxy variable such as the age of the building in which it is installed. Setting the obvious measurement problems aside, measuring the age of a failed safety switch serves to predict the useful life of particular types of safety switches found in various environments. Age alone is not identified by the literature as a factor of the useful life of safety switches. The age of a safety switch represents the duration the device has been exposed to its environment. It also is a measure of technology development in the device design and installation methods. For example, an old safety switch may have been exposed to many years in a harsh environment, however a unit of the same age may have enjoyed an indoors environment. They are likely to be of a similar design and quality but it could reasonably be expected that their useful lives will be different.

Contemporary Approaches to Support Safety Switch Reliability

Control mechanisms focused on the engineering and human factors support the long term dependability of safety switches. At the beginning of the useful life of a safety switch product standards ensure devices are manufactured and installed with the aim of long term protection.

Approval standards require environmental testing of sample units before approval for sale is granted. The present standard requires the 28 day, simulated environment test. However this standard was preceded by a lesser requirement which did not require the long term reliability test. This raises the concern that safety switches approved before the introduction of the 1996 standard may not be as reliable as newer ones. Indeed the IEC Technical Report recommends the replacement of such units. Counter to this argument is the assumption that all older devices will have endured an in service duration test without incident.

The North American action to require the end of life lock out and miswire features to be designed into outlet type safety switches signals a significant advancement in design standards. This demonstrates that the research into the in-service reliability of safety switches has identified the need for product innovation for safety switches. Although the receptacle type of device is more commonplace in North America than Australia other features may be added to safety switches, by market demand or by standards to suit local requirements.

Safety switches are supplementary to a correctly functioning electrical installation. Two issues are raised in the available advice on this topic. Firstly the effectiveness of the safety switch is dependant on being correctly wired to an installation that meets standards and is properly maintained. Secondly, the device forming part of the installation should be selected according to the environmental conditions in which it will be installed.

The unanimous recommendation by manufacturers, standards makers and regulators is to test safety switches regularly. Although this safety measure critically relies on human behaviour, it uncovers faulty units at the end of their useful life and has been suggested to extend it.

Understanding the effectiveness and reliability of this crucial human intervention will serve to add to the reliability of safety switches.

6 Conclusion

Queenslanders increasingly rely on safety switches for protection against the risk of electric shock in their homes and workplaces. These sensitive devices are open to failure as they age and with exposure to their environment. Critically, when a safety switch fails it may remain in use but simply be unable to detect a dangerous situation. This failure may lie dormant for many months or years. Given this high reliance and the possibility of the undetected risk, the reliability of safety switches is paramount.

The literature specifically addressing the topic of safety switch in-service reliability is sparse. Just three published studies, spanning sample periods of over 35 years are available. These studies also vary in purpose and method. It comes as no surprise then that the question of the useful life of safety switches and the factors that influence this remains generally unanswered.

Applying the overall failure rate of safety switches in conditions that might be expected in Queensland, taking the most recent studies as evidence, range from less than 1% to 11%. For older data samples and harsher environments, this statistic is even greater. The variability of this statistic calls into question its reliability. The breadth of this spectrum may reflect the Queensland population of safety switches but this can not be predicted with certainty. This observation, considering the high reliance on safety switches suggests that the question of reliability remains a valid and significant one.

The physical and electrical environmental conditions, engineering design and selection, and regular maintenance all influence the useful life of safety switches. The influence on failure rates attributable to individual factors has been shown to be difficult to measure and is variable in the international literature. Although some guidance is available for the evaluation of those factors likely to be experienced in Queensland, it is not sufficiently definitive to inform the useful life of safety switches. Significantly, the IEC maintains that the useful life is not predictable because of the number of variables.

This review also identified that approval and design standards along with guidance standards and advice are current mechanisms that support the management of an ageing safety switch population in Queensland. The useful life of a Safety Switch begins by achieving product approval and installation standards. The unanimous advice of the literature is that the useful life should be verified and extended by regular maintenance.

Further research is required to benchmark the failure rate of Queensland's safety switch population. By researching this general failure rate and identifying the significant factors, control measures for managing the ageing population may be augmented.

The longer term monitoring of safety switches, over time, will inform the management of safety switch population with longitudinal data. Progressively, new data will identify emerging issues and accumulated data will identify trends. This will reinforce or redirect the strategic management of this electrical safety protective measure.

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