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Briefing Paper

Determining the optimum replacement periods of optical smoke detectors and alarms

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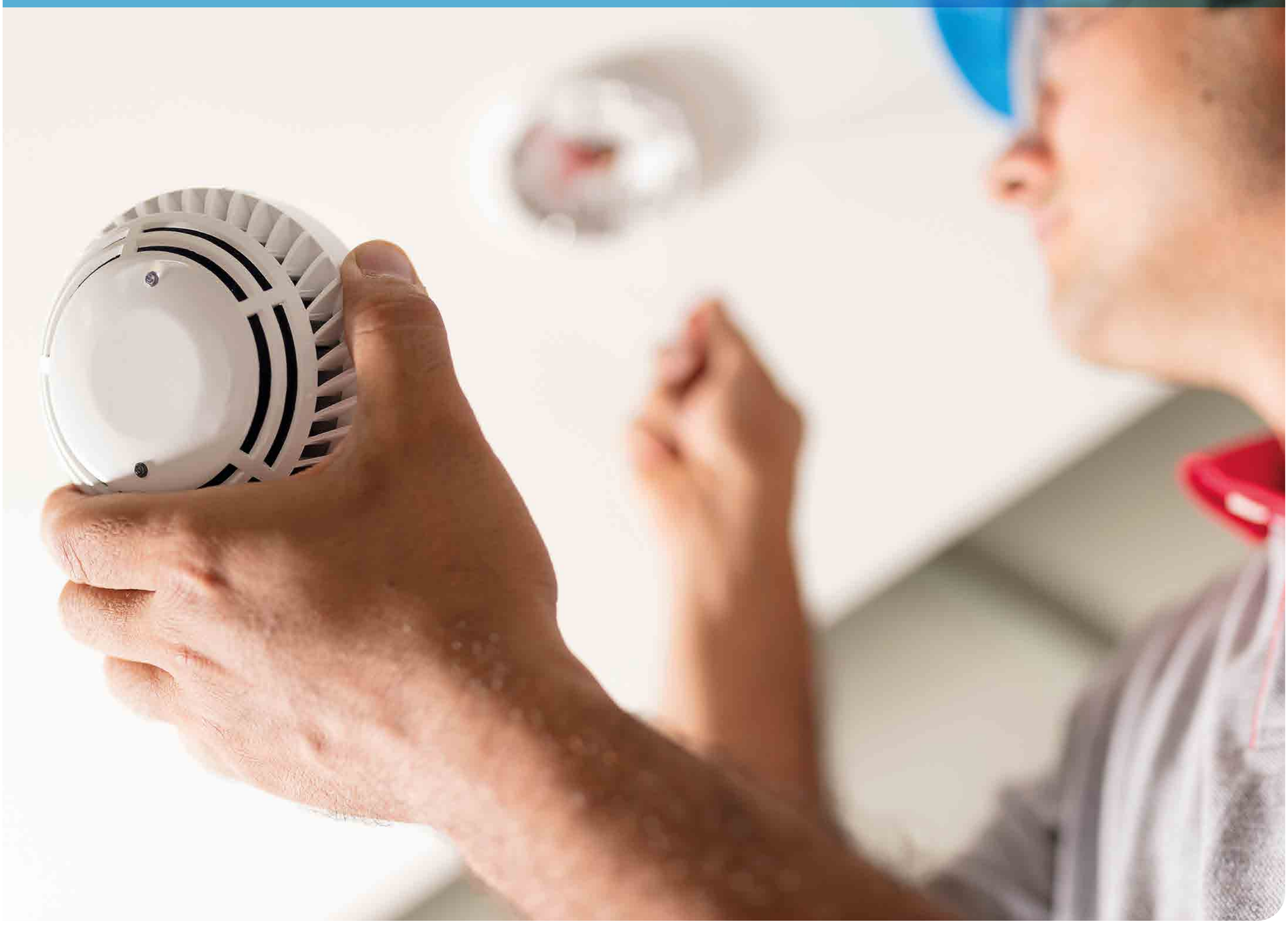

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Contents

Summary

In the UK there is no strict mandatory period of replacement within British Standards BS 5839-1 [1] for commercial smoke detectors and BS 5839-6 [2] for domestic smoke alarms. Whilst some countries such as Germany and Spain do have them, there appears to be no independent evidence to support the replacement periods. The aim of this research was to identify the optimum replacement periods for optical smoke alarms and detectors used in domestic and commercial environments.

Optical smoke detectors have, for many years, been preferred and dominantly used in the commercial sector. In future the use of optical smoke alarms and detectors is expected to be dominant in the built environment, so this work focussed on optical devices only and ionisation ones were excluded from this study.

During the first phase of this work new models of domestic smoke alarms and commercial smoke detectors were measured in a lab environment using the Trutest smoke detector test equipment to identify their sensitivity ranges. These enabled sensitivity limits to be established, of 1.4 – 3.8% obs./ft for domestic smoke alarms and commercial detectors, that could be used during in-situ testing.

For the second phase the Trutest smoke detector test equipment was used to perform sensitivity measurements in commercial and domestic premises. In total 86 domestic smoke alarms and 107 commercial smoke detectors were tested. It was observed that the sensitivity of both alarms and detectors increased when they were older or dirtier.

The detectors tested in the field were aged between 0 and 30 years whereas the alarms were aged between 0 and 12 years. Based on these data the following replacement periods have been proposed:

- All smoke alarms should be replaced no later than 12 years after their date of manufacture,
- The maximum replacement period proposed for commercial smoke detectors without drift compensation should be 25 years,
- The maximum replacement period proposed for commercial smoke detectors with drift compensation should be 30 years.

Four further recommendations have also been made to:

- test more old smoke alarms and detectors in the future,
- label the installation date on smoke alarms and detectors,
- perform a similar study with heat alarms tested in-situ,
- periodically measure smoke detector sensitivity to track changes in performance with time.

Abbreviations and glossary of terms

The abbreviations list and glossary are compiled from terms used in this publication. The descriptions in the glossary are not intended to be comprehensive, but to help the reader understand the meaning of terms as they are used in this Briefing Paper.

Abbreviations

Device = In this report refers either or both alarms and detectors.

DC = Drift compensation

ft = foot

LED = Light emitting diode

Obs. = Obscuration

Glossary

Drift compensation – an algorithm used to automatically adjust the sensitivity of a smoke detector over its lifetime to accommodate for changes, such as the accumulation of dust, that could influence the alarm response.

Domestic smoke alarm – device that contains an integral smoke chamber, sounder and a battery or a backup battery if mains powered and generally used in most domestic premises.

Commercial smoke detector – device that contains a smoke chamber and is connected to a panel from which it is supplied with power and through which a fire alarm is signalled using sounders.

Ionisation smoke alarm/detector – device that detects changes in current when smoke present in the detection chamber removes charged particles (produced by the radioactive element Americium 241).

Optical smoke alarm/detector – devices that use an infra-red LED and a photodiode to detect scattered smoke in the smoke chamber.

Trutest – Measurement equipment (manufactured by Detector Testers) that contains a test chamber which is placed over commercial smoke detectors and slowly increases the amount of synthetic aerosol inside the chamber. The measured aerosol concentration is displayed on the controller and when the detector produces an alarm response the Trutest result can be recorded.

Introduction

In the event of a fire it is vital that people are provided with early warning from a smoke alarm or a fire detection system. Early warning permits necessary measures to be taken that can reduce the risk of injury to occupants and damage to the property.

Smoke alarms in domestic premises and fire detection and warning systems in commercial premises have been used for decades to detect fires and provide warning. Sometimes these systems can be in place for many years and it is essential that they work reliably and effectively throughout their service lifetimes. In the UK there is no recommendation in codes and regulations for the periodic replacement of these alarms and detectors. This work aimed to perform the underpinning research from which a replacement period for these could be determined.

The response performance of detectors and alarms to the smoke from a fire will change with time (these devices are on continuously for years) as components become covered with dust and as electrical components degrade the sensitivity would be expected to change. If they become more sensitive, they will be more prone to producing false alarms, and if they become less sensitive that would make them less responsive to a real fire, i.e. operating later than when they should do (and outside of product test standard requirements). Both scenarios are unwanted as ideally devices with optimum performance are required in the event of a fire.

Whilst manufacturers of detectors and alarms may benefit through increased sales resulting from a shorter replacement period, ultimately the home and service environments in general will be safer for the public through the greater use of smoke alarms and detectors with more consistent performance.

During the collaborative research work, "Live investigations of false fire alarms" [3], one of the thirty-five recommendations made was for further research to identify any changes in smoke detector sensitivity with time (see Figure 1). Some smoke detectors observed in the field were more than 30 years old but there was limited data to suggest that older detectors produced more false alarms than newer ones. In the last few years other European countries have adopted replacement periods without sufficient research to support them. It was agreed that the approach used in the UK should be based on research and a programme of work to generate the underpinning evidence was developed.

A research group comprising the Fire Industry Association, Scottish Fire and Rescue Service, Scottish Government, Detector Testers and the BRE Trust funded this research. The stakeholder group agreed the programme together with the methodology to be used for the work and BRE Global performed the research.

This research aimed to test a number of smoke devices in domestic and commercial environments, to identify the mean and spread of their sensitivities with age. By analysing this data, a replacement period could be proposed that may differ depending on cleanliness of the service environments.

This knowledge will enable UK codes and guidance to be updated with recommended replacement periods for smoke devices in domestic and commercial environments. Furthermore, this may influence other countries in and outside of Europe to adopt more appropriate replacement periods based on the research findings.

Figure 1: Live investigations of false fire alarms- previous collaborative research work

Methodology

Recommended replacement periods from different countries

In the domestic and commercial smoke detector British Standards BS EN 14604:2005 [4] and BS EN 54-7:2001 [5] respectively there is no test or assessment that results in a replacement period for smoke alarms and detectors to be specified with the devices. The codes of practice BS 5839-1 for commercial premises and BS 5839-6 for domestic premises also do not provide recommendations for the replacement of these devices. Data from international standards, manufacturers and fire and rescue services were investigated to identify suitable replacement periods.

The European Kidde website recommends that you should replace your smoke alarms every 5/10 years [6]. The website for fire service resources across the UK states that, after 10 years it is best to replace your alarm with a new one [7].

The Spanish standard UNE 23007-14:2009 [8] states that, 'Fire detectors are deemed to have a service life of 10 years, after which they shall be replaced.' The German standard DIN 14675 which, referenced in a Honeywell guidance document [9], indicates that regular smoke detectors without drift compensation (DC) must be replaced "within no more than 5 years". It also states that smoke detectors with DC may be used for a period of up to 8 years.

In China the fire detection and alarm products standard GB29837-2013 [10] states that the replacement period of a smoke alarm should be no more than 12 years.

Two Indian standards which focus on the selection, installation and maintenance of smoke alarms are CED22 (7587) [11] and IS2189:1999 [12]. There is no mention of the period that a detector can reach before they recommend replacing it. However, in the standard CED22 (7587) it states, 'On completion of the annual inspection, the entry shall be made in register in respect of defects found. After the defects are rectified, the entries shall then again be made. And if required, detectors shall be replaced by the new one'. In the standard IS2189:1999 it states, 'Operation of at least 20 percent of the detectors in an installation should be checked each year, and the selection should be done in such a way that all the detectors in an installation shall have been checked once in every 5 years – replacement by a new one'.

The US National Fire Alarm and Signalling Code (NFPA 72) 2013 [13] edition states that for one and two-family dwellings the replacement of a smoke alarm shall be when they fail to respond to operability tests. However, the smoke alarm should not remain in service for more than 10 years from the date of manufacture.

Guidance from the Department of Fire & Emergency Services in Australia [14] declares that smoke alarms manufactured to the Australian Standard 3786 must be replaced every 10 years.

The New Zealand fire emergency website [15] states that smoke alarms need to be replaced after 10 years of service.

In terms of the recommended replacement period of smoke alarms in the Middle East there is no specific age assigned to replacing the smoke alarm. However, the 2017 edition of the UAE Fire & Life safety code [16] states, 'Any detectors installed during construction for the purposes of protection during construction, shall be checked to confirm that their sensitivity is within the listed and marked sensitivity range and shall be repaired or replaced as necessary'.

A study carried out by Canada's Ontario Housing Corporation [17,18] found that 3% of smoke alarms will fail within one year. They concluded that the replacement of a smoke alarm after 10 years, with approximately a 30% probability of failure, is an appropriate balance between safety and cost.

Fire safety related organisations in several countries suggest the replacement of smoke alarms once they reach 10 years. However, they do not provide any evidence to justify this 10-year replacement recommendation. The fire safety related standards in some countries do not mention a specific recommended replacement period for the smoke alarms and usually state that there should be an annual inspection and if required the detectors should be replaced.

This investigation demonstrated that there is no consistent proposed period of replacement for smoke detectors. There certainly appears to be no publicly available research data globally that would support recommended replacement periods for smoke alarms and detectors.

Proposals for methodologies for performing tests

In order to propose suitable replacement periods, it was necessary to test a number of devices, of different ages, in the field to observe their sensitivity responses.

A repeatable test method was required for measuring the response of smoke devices by steadily increasing the smoke concentration. A number of different test methodologies were considered and reviewed. Following successful demonstration and repeatable test results the Trutest (see Figure 2), was chosen to be used for this research work as it was portable, easy to assemble, produced a gradual increase in aerosol concentration and gave a measurement value at the time of response. The Trutest consists of a head unit, Solo access pole and a control panel (see Figure 2).

Figure 2: Trutest smoke sensitivity measurement equipment (photo courtesy of Detector Testers)

The Trutest was configured with the following settings for all tests:

- Slow ramp;
- Optical (photo-electric) detector mode;
- Low profile mode.

With the slow ramp setting the typical aerosol growth rate is shown in Figure 3 and this was used for all tests.

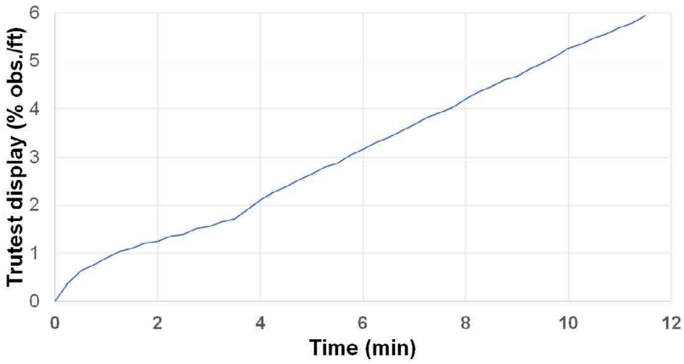

Figure 3: Typical aerosol growth rate of Trutest

Methodology for testing alarms and detectors

To quantitively identify a pass/fail criterion which could be used during the in-situ testing, 10 new approved domestic optical smoke alarms and 10 new approved commercial optical smoke detectors, from different manufacturers, were tested using the Trutest in a lab-based environment. For the new commercial smoke detectors 5 of them did not have DC but the other 5 did. DC is an algorithm used whereby the sensitivity of a smoke detector is automatically adjusted over its lifetime to accommodate for changes such as the accumulation of dust or dirt.

Using the measured devices, a pass/fail criterion was proposed by identifying the range between the most and least sensitive measurement, from the results of the lab-based testing. The limits for domestic optical smoke alarms and commercial optical smoke detectors was determined as 1.4-3.8 % obs./ft.

When testing the commercial smoke detectors, the manufacturers' supplied silicone membrane was placed over the mouth of the testing chamber (see Figure 4). The head of the detector was pushed through the hole in the silicone membrane so that there was a complete seal.

Figure 4: Trutest with silicone membrane attached used for testing commercial smoke detectors

To allow the testing of domestic smoke alarms in-situ the Trutest was adjusted by placing single sided sticky foam along the inside of the testing chamber (Figure 5). A few millimetres of the sticky foam protruded slightly above the test chamber, so that the foam could be pushed securely up to the ceiling allowing a complete seal to be established during the test.

Figure 5: Trutest adapted using sticky foam to allow testing of domestic smoke alarms

For each alarm/detector that was tested the location of the device in the protected area, building/location, cleanliness of environment, manufacturer, model, cleanliness of device, age, orientation and the Trutest result was recorded.

Once the Trutest was assembled, the device was positioned centrally within the testing chamber before each test was started. The device's LED was aligned with the red reference line on the testing chamber and the test cas started by pressing the start/stop button on the control panel. The smoke level within the testing chamber would then gradually increase. Once the device activated the test was stopped by pressing the start/stop button on the control panel. The control panel would then provide a reading which was recorded and indicated the sensitivity of the device. This process took approximately 10 minutes for each device.

In this briefing paper the identity of individual smoke alarms and smoke detectors are not specified to preserve anonymity. However, all models remain consistent i.e. domestic Model 5 refers to one specific manufacturer and model number throughout this paper.

Methodology used to identify devices to test in-situ

Several different ways were pursued to identify premises that contained suitable devices to test and contacts to facilitate with the logistics of performing measurements. These included contacting universities, housing associations and fire safety/estate managers directly, and publishing an article in a magazine, distributing letters and using social media.

There were several different factors that made it challenging to identify and test optical smoke alarms that were 8 years or older. One of these was that ionisation smoke alarms are more prevalent due to their previous market domination for decades. Another was identifying people with suitable devices that were willing to participate and could provide access to properties to test the alarms. There were occasions when alarms thought to be optical devices were found to be ionisation.

Results

Trutest results – domestic smoke alarms

A number of properties were identified, during the period from February 2019 to January 2020, in which a total of 86 domestic smoke alarms were tested; one of which was found to be not working. This was investigated to identify the cause which was found to be due to an issue with the battery. Twenty-three different alarm models from 8 different manufacturers were tested and their age range was 0-12 years. The domestic optical smoke alarms were tested at vacant domestic properties, universities premises and local residents' homes.

Figure 6 shows all of the Trutest results for the 85 working domestic optical smoke alarms. The blue line represents the average Trutest result for the alarms tested of a specific age. The dotted orange line represents the line of best fit of the Trutest result for all of the alarms tested. The solid horizontal red lines on the graphs indicate the upper and lower limits previously determined. Four alarms (4.7%) were outside the lab-based limits for domestic optical smoke alarms. It must be noted that there was no correlation of the devices outside the limits with time and also that some of those were quite close to the limits such that only 3 out of the 85 results stand out significantly.

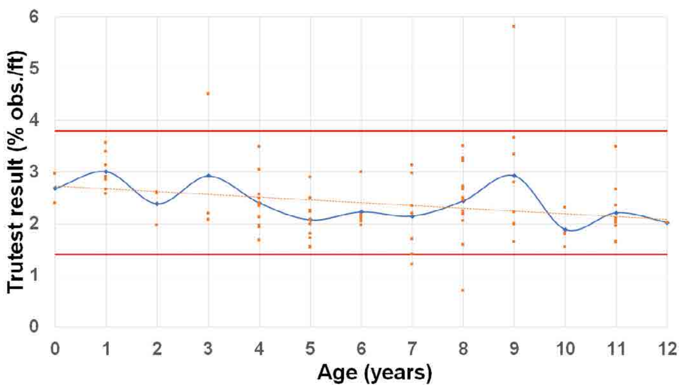

Figure 6: Domestic optical smoke alarm responses with age

A high Trutest result indicates that the device has a low sensitivity and would be expected to respond late during a fire whereas a low response corresponds to high sensitivity and would be expected to be more likely to produce false alarms. The dotted line, representing the line of best fit, shows that for older alarms their sensitivity slightly increases but remains far from the lower limit. If the line of best fit was linearly extended it would intercept the lower limit at 21 years.

The results would be more significant if a greater number of optical smoke alarms had been tested as it would provide greater confidence in the results.

If the samples that are outside the limits (1.4> x <3.8) identified during the lab-based testing are considered failures, then the failure rate for each age can be determined by taking the number of failures and dividing by the total number of samples of that age. This can assist with the identification of degradation in performance, with time, which can be used to determine a suitable replacement period (see Table 1).

Age (years)	No. tested devices	No. outside limits	% fail
0-1	11	0	0%
0-2	12	0	0%
0-3	15	1	7%
0-4	25	1	4%
0-5	36	1	3%
0-6	42	1	2%
0-7	50	2	4%
0-8	65	3	5%
0-9	73	4	5%
0-10	76	4	5%
0-11	85	4	5%
0-12	86	4	5%

Table 1: Failure rate of domestic alarms with age

Given that the failure rate is quite low and that the overall trend is to become more sensitive with time a replacement period of 12 years in benign environments is recommended. It is also recommended that consideration should be given in the future to extending this period if data from future, similar research supports such a change (which is likely to be possible). It is, therefore, recommended that a repeat study be performed in 5 years' time, by which time more aged optical smoke alarms will be present in domestic premises.

If the data is examined further, it is possible to observe the variability in the response of individual detector models (see Figure 7). Within both BS EN 54-7 and BS EN 14604 there is a repeatability test, the aim of which is to demonstrate that the smoke device has stable sensitivity when measured a number of times (in dB/m). To pass this test the ratio of its maximum to minimum response must be no greater than 1.6.

For the models tested in-situ the max:min ratio for each domestic smoke alarm model was calculated using the Trutest result (converted from % obs./ft to dB/m). The models which have a max:min ratio larger than 1.6 are highlighted in red (in Figure 7). The value of 1.6 (60% deviation from the original measurement) is generally considered to be the limit permitted in fire detection standards. A large max:min ratio for the same model indicates that the device has a broad range of sensitivity.

The numbers above each bar represents the number of smoke alarms of that model that were tested. Generally, the smoke alarm models which have a larger test number have a larger max:min ratio. This suggests that if the sample size, of those with low test number, was increased then these too would be expected to have a max:min ratio above 1.6. Single models that were tested are excluded from this graph.

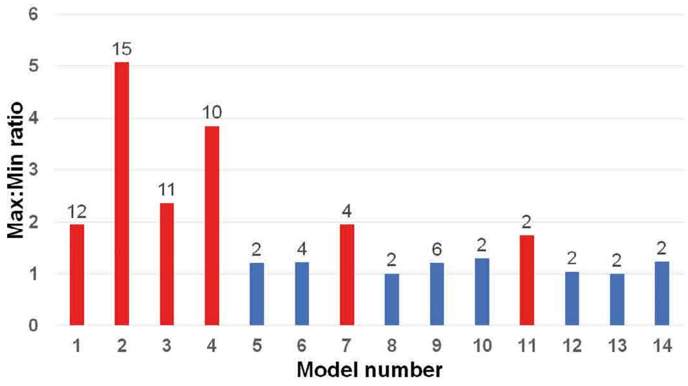

Figure 7: Max:Min ratio for the domestic optical smoke alarm models

For individual models it was observed that they displayed different profiles with time, and it was not possible, using the results, to definitively say that all models displayed similar behaviours- they appeared to be different and quite random.

Figure 8 shows the Trutest results and the cleanliness score for all 85 working domestic smoke alarms tested. The blue dotted straight line represents the line of best fit. As can be seen from Figure 8 overall there is a slight increase in sensitivity as the device becomes dustier (note 1=very clean and 5=dirty). It is worth noting that the profile of cleanliness of device match closely with the cleanliness of environment. On average there is a 18.6% increase in sensitivity for an alarm with a cleanliness score of 5 compared to an alarm with a cleanliness score of 1.

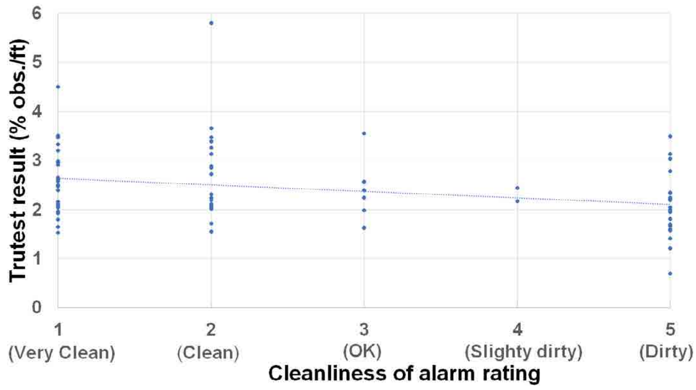

Figure 8: The correlation of Trutest result with the cleanliness of alarm rating

Trutest results – commercial smoke detectors

A number of properties were identified, during the period from April to December 2019, in which a total of 107 commercial smoke detectors were tested. Twenty different detector models were tested from 9 different manufacturers and their age range was 0-30 years. The commercial optical smoke detectors tested were from office spaces, universities premises and hotels.

Figure 9 shows the Trutest results for all 107 optical smoke detectors tested. The blue line represents the average Trutest result for the detectors tested of a specific age. The dotted straight orange line represents the line of best fit of the Trutest results for all of the detectors tested which suggests that the sensitivity of the optical smoke detectors is consistent, independent of their age.

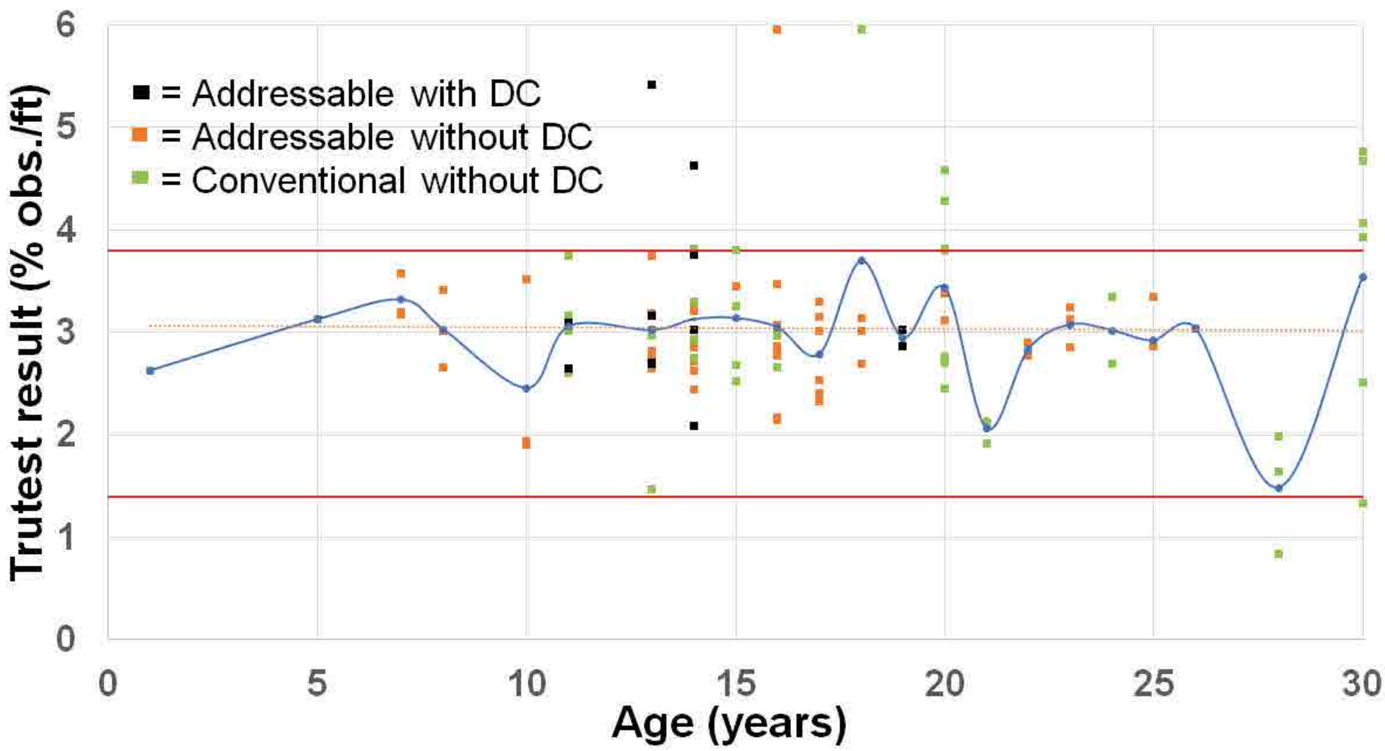

Figure 9: Commercial smoke detector responses with age

There were 14 detectors out of the 107 detectors tested (13.1%) that had a response outside the lab-based limits. It must be noted that some of those were quite close to the limits and generally there was no correlation of devices outside the limits with age.

Figure 9 also shows the Trutest results with the commercial optical smoke detectors tested (addressable, conventional and those which had DC). The majority of the detectors tested did not have DC yet two of those that did, had a later response (4.63 and 5.42 obs. %/ft), with both of these results being observed with detector model #18. The rest of the detectors without DC had a result which was within the lab-based limits.

No devices with DC were tested that were 20 years old and above. It would therefore be worthwhile to repeat this exercise in 5 years' time, by which time a greater proportion of older smoke detectors incorporating DC would be expected to be present in the service environment.

As before, if the samples that are outside the limits identified (1.4> x <3.8) during the lab-based testing are considered failures, then the failure rate for each age range can be determined by taking the number of failures and dividing by the total number of samples of that age range (see Table 2).

Age (years)	No. tested devices	No. outside limits	% fail
0-5	2	0	0%
0-10	11	0	0%
0-15	52	3	6%
0-20	85	8	9%
0-25	97	8	8%
0-30	107	14	13%

Table 2: Failure rate of commercial alarms with age

The failure rate increases from zero after ten years and then increases rapidly in the 26-30 years range. In fact, in the 26-30 years age range 60% of samples failed. If 10% is taken as the acceptable failure rate, then this is exceeded after 25 years and if it is 5% then a replacement period of 15 years would be more suitable.

To demonstrate whether the 20 different models of the commercial optical smoke detectors tested in-situ had stable sensitivity their max:min ratios were calculated (as before), see Figure 10. The majority of the detector models have a max:min ratio which is below 1.6 therefore, suggesting that these models have a tight sensitivity range.

The results also demonstrate that the results generated using the Trutest equipment can be very repeatable.

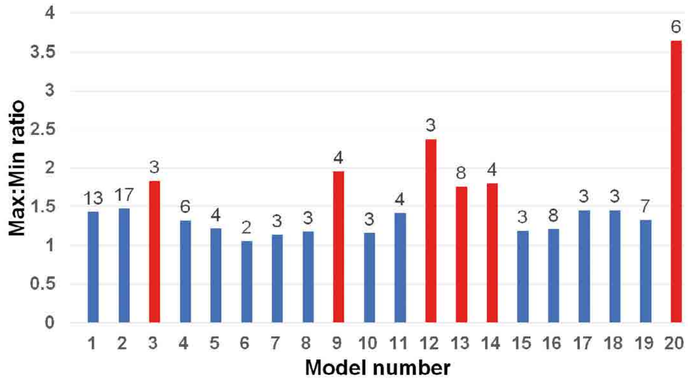

Figure 10: Max:Min ratios for the 20 different models of commercial detectors tested

Similar to domestic alarms, in terms of how individual models varied with time it was observed that different models displayed different profiles and it was not possible, using the results, to definitively say that all models followed similar behaviours- they appeared to be different and quite random.

Figure 11 shows the relation between the responses for each commercial smoke detector tested and its cleanliness score (note 1= very clean and 5= dirty). The dotted blue line represents the average result and it can be seen that overall, there is a slight increase in detector sensitivity as it gets dirtier. On average there is a 14.0% increase in sensitivity for an alarm with a cleanliness score of 5 compared to a detector with a cleanliness score of 2. As with alarms the general scores of cleanliness of detectors matched closely with the cleanliness of environment.

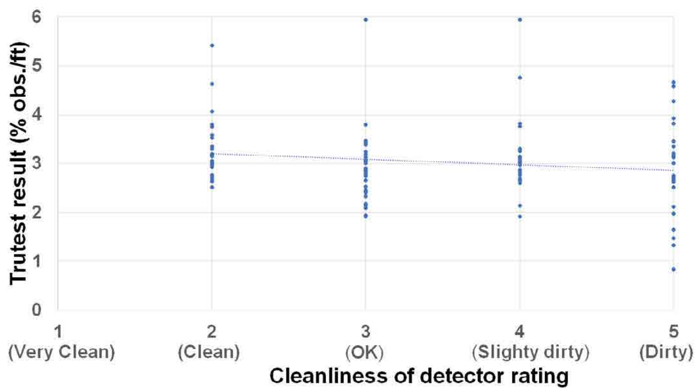

Figure 11: The correlation of Trutest result with the cleanliness of detector rating

Summary of findings and recommendations

For domestic smoke alarms and commercial smoke detectors 86 and 107 devices were tested, respectively. Whilst the sample sizes for both were smaller than anticipated the findings provide useful information on the sensitivity changes as these devices get older and dirtier. A greater sample size would be expected to demonstrate similar performance but would provide much greater confidence in the results.

Findings- domestic smoke alarms

The results from the in-situ testing of domestic optical smoke alarms demonstrate that the majority were within the established lab-based limits, and there was a slight increase in the alarms' sensitivity with age.

There were several different factors that made it challenging to identify and test optical smoke alarms that were 8 years or older. These were factors such as greater prevalence of ionisation smoke alarms, identifying people with suitable devices, that were willing to participate and could provide access to properties.

There were 4 out of 85 working alarms (4.7%) that gave a response which was outside the lab-based limits. The results indicate that up to 12 years after installation, there is no evidence of a significant change in sensitivity or increase in smoke alarm failures that would support a replacement period of less than 12 years, such as the period of 10 years currently quoted by many sources.

There is clear evidence that the "Line of best fit" has a negative gradient suggesting that smoke alarms become more sensitive with time. If the gradient were extrapolated beyond 12 years, it would intercept the bottom limit at 21 years. This negative gradient is preferable to a positive one, suggesting that older smoke alarms will operate sooner during a fire. As a result of this, older smoke alarms are at a marginally increased risk of producing false alarms. Since the increase in sensitivity of older domestic smoke alarms indicated is not significant, it is unlikely that residents will notice that their alarms have become more sensitive with time.

Based on the findings of this study, the proposed recommended period for the replacement of smoke alarms in benign environments is no later than 12 years after their date of manufacture (which is normally shown on the device). They should also be replaced immediately under any of the following circumstances:

- If the smoke alarm fails to respond on operation of the test control (which should be operated monthly to check that the smoke alarm is still operating correctly);
- If, in the case of a smoke alarm that incorporates a battery that is not user-replaceable, a low battery warning is given (a short periodic chirp);
- If the smoke alarm constantly produces false alarms without any apparent cause.

It is recommended that consideration should be given in the future to extending this period if further data, from similar research, supports such a change. A repeat study should be performed in 5 years' time, by which time a greater number of older optical smoke alarms will be present in domestic premises.

In terms of change in performance with cleanliness it appears that as alarms get dirtier, they appear to get more sensitive. This may be due to the effects of dust particulates depositing on the smoke chamber and thus resulting in an increase in the signal received by the photodiode hence making the apparent "quiescent" level of clean air closer to the alarm threshold.

During the in-situ testing for this project it was observed that several domestic properties contained heat alarms in kitchens. It was observed that for some of these the thermal element was covered with a residue (presumably of oil from cooking and dust) and it is not known whether this contamination build-up may be significant to delay the alarm response. A research study to measure the performance of contaminated heat alarms would help to inform whether this issue is significant. As an effective way of identifying smoke alarms in domestic premises to be tested has now been developed, this could equally be applied for heat alarms. It is more likely that this methodology will be cost effective leading to the testing of more devices.

Figure 12: Trutest being used to test a domestic smoke alarm

Findings- commercial smoke detectors

The results from the in-situ testing of commercial optical smoke detectors demonstrate that the majority of responses were within the lab-based limits, with the sensitivity remaining relatively constant over time.

Whilst confirming that smoke detectors were optical was not a challenge (due to their prevalence in the commercial sector), responsible persons were often unaware of the age of the devices installed in their properties. This made it difficult to identify if their property contained suitable detectors without visiting the property first. It was also observed that some organisations had a policy whereby they would replace all their smoke detectors every 10 years.

There were 14 out of 107 detectors (13.1%) which were outside the lab-based limits. The results demonstrate that there is a 0% failure of smoke detectors that are up to 10 years old for the samples studied so there is no justification for replacing them before 10 years.

The stakeholder group agreed that there should be different replacement periods for detectors with DC and those without. Since the sensitivity of detectors with DC adjusts when/if there are changes in the surrounding environment due to the presence of dust. Detectors without this function do not adjust sensitivity.

On the basis of discontinuity in the data for detectors that are 15-20 years old (see Figure 9), those in clean environments (such as circulation spaces) without DC should be replaced at 15 years. However, it may be appropriate to reduce this period in dirtier environments, such as utility rooms and loft spaces. The absolute maximum time for the replacement of detectors without DC should be 25 years, after which the system should be regarded as non-compliant with BS 5839-1.

However, the absolute maximum for the replacement of detectors with DC is 30 years, after which the system should be regarded as non-compliant with BS 5839-1. Prior to 30 years, it is considered that reliance can be placed on the initiation of a fault warning (when further compensation for drift is impossible) to indicate the need for detector replacement.

In terms of change in performance with the cleanliness of the detectors it appears that as they get dirtier, they appear to get more sensitive. This behaviour was also observed with smoke alarms.

It must be noted that the downward gradient appears to be less steep for commercial detectors when compared with domestic alarms, and this may be due to the fact that some of the commercial systems contained DC and accounted for changes resulting from dust deposition.

Figure 13: Trutest being used to test a commercial smoke detector

Recommendations

Four recommendations are proposed by the stakeholder group based on the findings presented.

Recommendation 1: Test more old smoke alarms and detectors

Due to the small sample sizes for optical domestic alarms and commercial detectors, to continue this work using the same methodology on a larger sample size would provide greater confidence in the results. At the commencement of this project the most effective methodology for testing optical smoke alarms and detectors had to be identified. This was relatively time consuming and often unsuccessful as, during visits to properties, alarms and detectors were often not suitable.

If this work is not followed on immediately then it would be worthwhile to repeat this exercise in 5 years' time. By then, it would be expected that a greater proportion of older smoke detectors incorporating DC would be present in the service environment, as well as a greater number of optical smoke alarms in domestic dwellings.

Recommendation 2: Labelling installation date on smoke alarms and detectors

It was very difficult to identify the age and replacement date of some alarms and most detectors by physically looking at them. If a replacement period is to be proposed in the codes BS 5839-1 and BS 5839-6 then a recommendation to mark the installation date on each alarm or detector head must be added to support this. It would take little time but provides essential information for the future. This could be in terms of physically marking each device or for these details to be recorded within a logbook. If the latter were used it would mean that the installation dates of the alarms/detectors could all be found in one place.

For domestic smoke alarms an external marking to signify whether it is ionisation or optical could be helpful. This would enable service engineers, fire and rescue service personnel and members of the public to easily identify the type of smoke alarm installed.

Recommendation 3: Heat alarms in-situ testing

In some domestic premises it was observed that dust and oil particulates built-up on the thermal element of heat alarms located in kitchens. This build-up could reduce the sensitivity of heat alarms and standards currently do not have tests to assess this. Further research investigating the performance of contaminated heat alarms from the service environment is recommended.

Recommendation 4: Periodically measuring smoke detector performance

Service providers (such as airports, railways, shopping centres etc.) in which disruption from false alarms are costly, yet optimum detection is necessary for the early detection of a fire, may consider the use of a field based smoke detector sensitivity measurement tool to regularly measure the performance of smoke detectors.

By periodically measuring the detectors in their buildings it will enable the identification of performance limits for the detection systems as a whole as well as identify any drift in response of individual detector heads. This will enable decisions to be made on the timely replacement of either individual heads or the system as a whole.

Figure 14: Smoke sensitivity measurements could be taken periodically to check the response of smoke detectors

Conclusions

This research has demonstrated that it is possible to use the Trutest measuring equipment to reliably obtain sensitivity data for domestic optical smoke alarms and commercial optical smoke detectors when tested in-situ. The results indicate that alarms and detectors produced by different manufacturers have different sensitivities, which is to be expected, due to their design differences.

The in-situ testing highlighted the difficulties in effectively accessing and testing a broad range of units of different ages. In total 107 commercial smoke detectors (20 models) and 85 working domestic smoke alarms (23 models) were tested. This sample size was smaller than anticipated and therefore a recommendation is made for further work which would provide greater confidence in the results.

The data collected was analysed and it was observed that the sensitivities of commercial optical smoke detectors and domestic optical smoke alarms were relatively consistent independent of age. However, for the older domestic smoke alarms there was a slight increase in the sensitivity. It was observed that the sensitivity of both alarms and detectors increased when they were dirtier.

For both domestic smoke alarms and commercial smoke detectors the response profiles of individual models with time were very different. There was no similar correlation between different models.

All smoke alarms should be replaced no later than 12 years after their date of manufacture (which is normally shown on the device). They should also be replaced immediately under any of the following circumstances:

- If the smoke alarm fails to respond on operation of the test control (which should be operated monthly to check that the smoke alarm is still operating correctly);
- If, in the case of a smoke alarm that incorporates a battery that is not user-replaceable, a low battery warning is given (a short periodic chirp);
- If the smoke alarm constantly produces false alarms without any apparent cause.

The replacement period proposed for commercial smoke detectors without drift compensation in clean environments is 15 years and the absolute maximum should be 25 years, after which the system should be regarded as non-compliant with BS 5839-1.The absolute maximum for the replacement of detectors with drift compensation in clean environments is 30 years, after which the system should be regarded as non-compliant with BS 5839-1.

Four recommendations have resulted from this work which include repeating this work in 5 years' time and conducting a similar study to identify whether changes in the performance of heat alarms contaminated with dust/oil are significant.

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