EVALUATION ON PERFORMANCE OF PHOTOELECTRIC SMOKE DETECTORS IN THE ZONE DETECTION SYSTEM

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ABSTRACT

Most people believe that detector actuation time increases with the age of a device, but the current test results suggest otherwise. According to government requirements, the standard actuation time limit for photoelectric smoke detectors is 60 seconds or less in the zoned detection system; however, this experiment discovered that new detectors all exhibited actuation times between 10 and 15 seconds. The actuation time of the detectors decreased with the age of the devices. The current study also determined that if the actuation time was 4 seconds or less, then the detector should be replaced because of the high chance of false alarms. In short, detectors with actuation times between 4 and 15 seconds are ideal and should be viewed as the standard for fire safety equipment. In addition, replacing detectors every 6 years in a zoned system is suggested by this research, which found a greater chance of false alarms after 6 years of detector use.

KEYWORDS

Detector Actuation Time, Smoke Actuation Test, Fire Safety Equipment, False Alarm

1. INTRODUCTION

Smoke detectors are commonly used devices for detecting fires; however, instances of false alarm signals are higher among smoke detectors than other types of fire detectors, and cause fire alarm systems to frequently be shut off. These systems eventually lose efficacy, and in cases of real fires, factories are brought to an instant operational stop and suffer enormous losses. Taiwan recently promulgated a law requiring fire safety equipment maintenance. Under the law, specialized technicians conduct annual inspections and evaluations, during which they ensure the

working condition of this equipment. Therefore, the methods used to evaluate the fire safety equipment must be correct for the desired results to be achieved.

The Standard for Validation of Fire Alarms (National Fire Agency 2012) divides smoke detectors into two groups, namely ionization- and photoelectric-type detectors, according to their actuation principles. However, code 72 of the National Fire Protection Association (2013) does not classify the various types of smoke detectors. Instead, a test using gasoline, polystyrene, wood, or newspaper as fuel is performed; as long as the detectors are sensitive to smoke within the specified range under UL 268 testing standards, they are considered to be qualified detectors. In a gray smoke scenario, gasoline or polystyrene is used as fuel to produce a flaming fire with an acceptable smoke concentration of 1.6%/m to 12.5%/m; conversely, in a black smoke scenario, wood or newspaper is used as fuel to simulate a smoldering fire with an acceptable smoke concentration of 5.0%/m to 29.2%/m.

Standards for the evaluation of smoke detector performance in Taiwan follow the regulations for automated fire alarms from chapter 10 of the Standard for Maintenance Registration and Operation on Fire Safety Equipment (National Fire Agency 2011). Similar to Japanese requirements, the optimal procedure for evaluating the performance of the detectors is the smoke actuation test, which requires smoke detectors to activate within 60 seconds (Fire and Disaster Management Agency 2006). Additionally, conducting overall inspections should include a smoke sensitivity test.

Among modern smoke detectors, photoelectric types are more commonly used. These devices act upon the “light scattering” principle, which means that the light beam and the photoelectric receivers are perpendicular when no smoke is present; thus, the photoelectric receivers are prevented from sensing the light. However, once smoke enters the chamber, the light beam scatters into the path of the photoelectric receivers. The resulting changes in electrical resistance increase the electric current; when this is detected by the circuit switch, the circuit sends a fire warning (Chen 2013). Overall, photoelectric detectors are more sensitive to smoldering fires but less sensitive to flaming fires. However, Litton (2009) determined that adjusting the ratio of the ionization chamber signal to the optical scattering signal can markedly improve the detectors’ sensitivity to flaming fire.

Björkman et al. (2002) revealed that the actuation principle for smoke detectors can be represented using the convective-diffusion equation. The factors that affect the time needed for smoke detectors to activate can be divided into four categories: detector sensitivity, time delay, smoke speed, and smoke density. Because the interiors of smoke detectors form a maze, the characteristic length to activation varies; much of the research presented in the SFPE Handbook of Fire Protection Engineering (DiNenno et al. 2002) discusses the range of these lengths.

Fergusion (1976) described the false alarm signal rate of automated fire alarms. Among these devices, false alarms are the most commonly encountered problem, followed by errors involving mishandling the central control unit, central receiver, or alarm device; faulty wiring; and other problems. The rate at which false alarms occurred for a smoke detector compared with an actual fire alarm was 15:1 for rate-of-rise detectors, 11:1 for fixed temperature detectors, 14:1 for photoelectric detectors, and 25:1 for ionization detectors. Lack (1973) similarly found the rate of false alarms to be 11.1:1 for heat detectors and 14.1:1 for smoke detectors.

Chen et al. (2012) improved the aerosol generator to produce different-sized particles that could promote the smoke detector test. Elsewhere, To and Fong (2013) determined that multisensors effectively increase the accurate detection of a fire detector from 80% to 90%. The aforementioned research reveals that, when applied to the smoke detector actuation time test, the current requirement standard is inaccurate and cannot be used to locate degraded detectors early through only periodic tests. An improved requirement standard is provided in this research and can be the criterion for modern fire detection.

2. RESEARCH METHODS

2.1 Experiment Setup

The smoke testers (model FTG 012) used to conduct this experiment were manufactured by Japan Nohmi Bosai Ltd. These testers come with a cap to cover the smoke detector to prevent genuinely activating the device while smoke is being produced for the simulation experiment. This model of smoke testers uses fuel gas (tetrafluoroethane (see Figure. 1)) and a smoke generator, and can be applied to both ion and photoelectric smoke detectors. The smoke testers enabled examination of both the performance and actuation times of smoke detectors.

Additionally, smoke sensitivity testers were used to prevent drastic changes in the sensitivity of the smoke detectors, which can be impeded from sending fire warnings after long periods of use. Oil smoke sensitivity testers (model BG99103K, Japan Panasonic Corp.) were used in this experiment. The smoke concentration value required for activation is represented as a voltage (V), with higher values corresponding with actuations that occurred at higher concentrations. The exterior of the tester is shown in Figure. 2.

Figure1.Smoke tester and fuel gas can

Figure2.Exterior of smoke sensitivity tester

2.2 Experiment Methods

Four units of photoelectric smoke detectors from both of the two most common brands of smoke detectors used in Taiwan, identified as A and B, were selected as samples. To determine the actuation times of the smoke detectors, the smoke testers were activated for 1, 3, 6, 9, and 12 seconds, with their response times recorded; the results were used as a reference for the accuracy of the smoke testers. A sketch of the method used to test the smoke testers is presented in Figure. 3.

The smoke actuation test and smoke sensitivity tests were performed on the samples by using the smoke tester and smoke sensitivity tester, respectively. Three categories of smoke detectors were examined: (1) the latest products by brands A and B; (2) detectors used for 1–8 years in ordinary occupancies; and (3) detectors that had a history of false alarms.

Figure.3 Method used to test sample via smoke tester

3. RESULTS AND DISCUSSION

3.1 Teston Accuracy of Smoke Testers

This experiment used smoke testers to test the latest products made by brands A and B. The results, presented in Figure.4, show that activating the smoke tester over various periods of time had no visible influence on the actuation times of the smoke detectors. This was an unexpected finding because the longer the smoke tester is used, the denser the concentration of the smoke becomes and the earlier the actuation of the detector should be. Further investigating the results revealed that the actuation times were influenced by how the testing gas was released.

Normally, the gas stored in a fuel gas can is in a liquid state. When it interacts with the external room-temperature air, it forms a "jet" that causes turbulence inside the cap of the smoke tester. This jet makes it challenging for the testing gas to penetrate the chamber; thus, the released gas concentration has limited influence on the actuation time of the smoke detectors. In the future, smoke detector inspections should note that when fuel gas-powered smoke testers are used to conduct a smoke actuation test, the tester does not need to be activated for long for the smoke detector to actuate. Continual activation only increases the cost of the experiment, with no benefit.

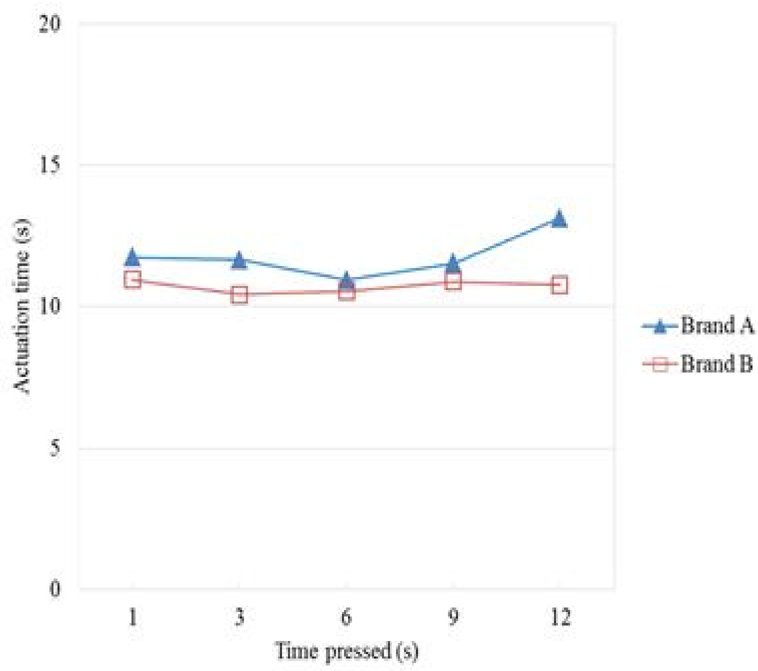

Figure. 4 Test results of brand A and B smoke testers

3.2 Analysis on Relationship between Actuation Time and Years of Usage

This research examined brand A and B detectors that had periods of use from 1 to 8 years, which is the second series of tests, and comparison between the two are shown in Figure. 5. Fig. 6 compares the detectors which have a history of false alarms, which is the third series of tests; all detectors underwent the smoke actuation test and activated at different times. For the second series of tests, results indicated that the smoke detectors used for more than 6 years tended to have faster actuation times, which contradicts the common belief that older devices are slower to activate.

The smoke detectors with a history of false alarms, the third series of tests, all actuated after interacting with smoke for approximately 3 seconds (Fig. 6). As shown in Fig. 5, brand A devices that had been used for 1–6 years had an average actuation time of more than 4 seconds. Comparing the two actuation times revealed that critical values existed for triggering a false alarm in the detectors. When the smoke actuation test was conducted after 4 seconds, no false alarms occurred; however, the chance of a false alarm occurring when actuation was conducted after less than 4 seconds was extremely high. This suggests that if the actuation times of the smoke detectors are 4 seconds or less, then the frequency of false alarms increases and the detectors should be replaced to prevent false alarms.

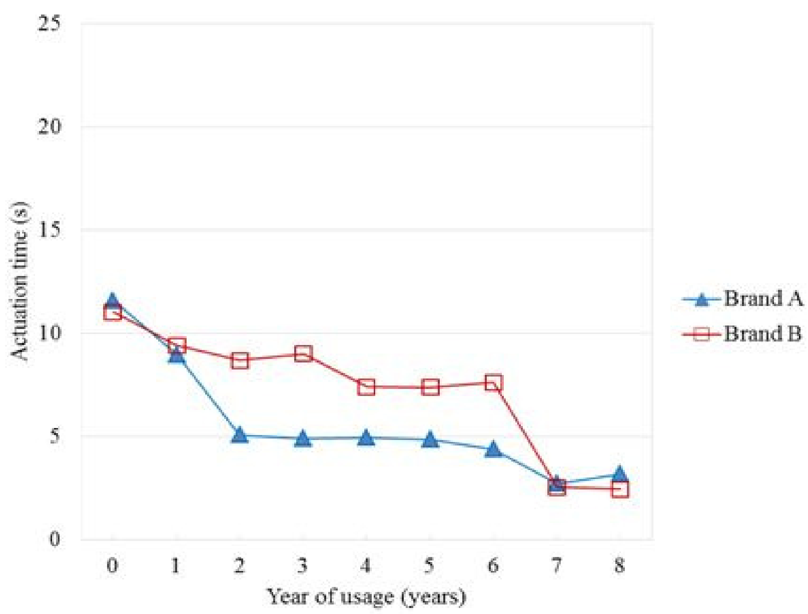

Figure. 5 Actuation times of brand A and B detectors under different years of use

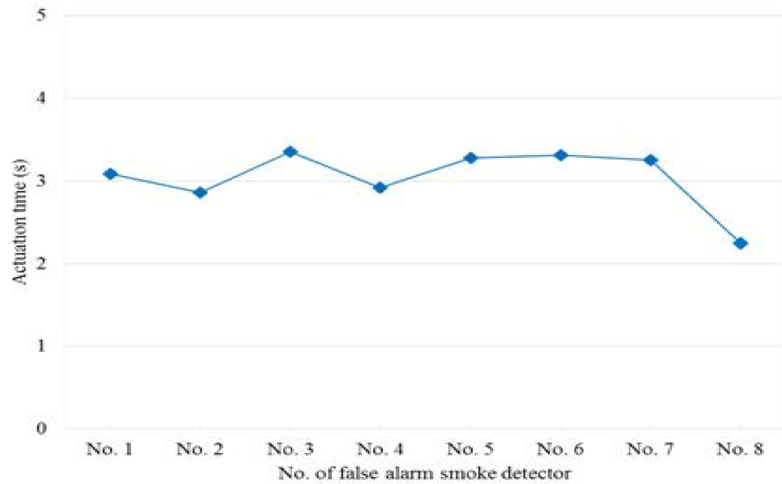

Figure. 6 Actuation times of detectors with false alarm history

3.3 Analysis on Relationship between Smoke Sensitivity and Years of Usage

This experiment also examined brand A and B detectors over varying periods of use, and conducted the smoke sensitivity test on them. No drastic changes to the smoke sensitivity were observed, regardless of the length of time the detector had been used, although the values remained in a certain range (see Fig. 7). These results were distinct from those obtained from the smoke actuation test, in which actuation times declined as usage years increased.

Clearly, the increased age of smoke detectors had no direct influence on their sensitivity but had a considerable effect on the actuation times of the devices. Thus, setting regulations for the smoke sensitivity of detectors in Taiwan or Japan does not seem necessary; however, conducting smoke actuation tests on detectors is a practical method to obtain accurate results on the working condition of detectors.

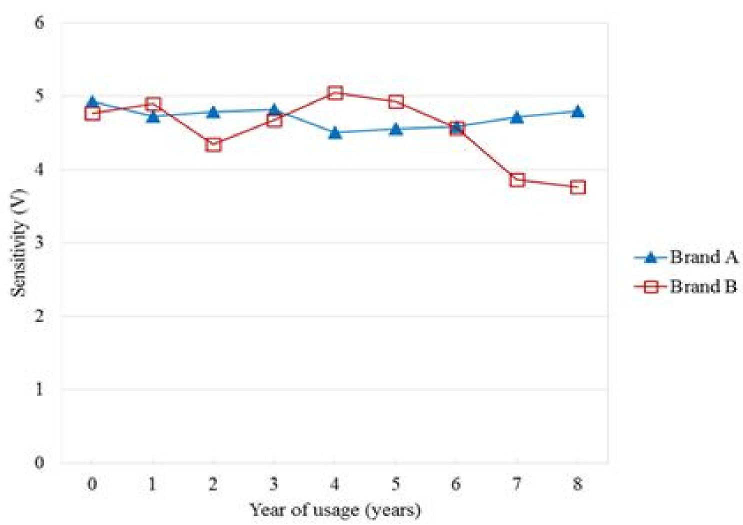

Figure. 7 Smoke sensitivity values of brand A and B detectors under different

4. CONCLUSION

In this study, smoke tests and smoke sensitivity tests were conducted on smoke detectors from two brands that had been used for varying periods of time. The actuation times were lower in the detectors that had been used for 6 years. By contrast, the smoke sensitivity of the detectors did not drastically change with detector age, but rather stayed within a certain range regardless of time. In conclusion, the actuation time of a detector, rather than its sensitivity, dictates its performance.

This experiment also indicated that not all the regulations outlined in the Standard for Maintenance Registration and Operation on Fire Safety Equipment manual are appropriate. Specifically, restricting the eligible actuation time to 60 seconds appears unreasonable for photoelectric detectors.

The two latest products from brands A and B exhibited upper actuation time limits of 10–15 seconds, with the most likely time for false alarms occurring at approximately 3 seconds. Therefore, functional standards of photoelectric smoke detectors should have 4 and 15 seconds set for the lower and upper limits, respectively, and prime detector operation should be considered as lasting approximately 6 years.

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