Experimental study on interference source of smoke fire detector in religious building environment

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Abstract. In this paper, the interference sources of smoke fire detectors in religious buildings and sacrificial places are analyzed, and focuses on the study of smoke interference generated by incense and butter lamps that may affect smoke detectors. Based on the standard combustion laboratory and testing methods stipulated by the International Organization for Standardization (ISO), different types of sandalwood and butter were used to carry out the incense burner and butter lamp simulation tests. Through data analysis of the smoke interference of incense and butter lamps, and the comparison of the response performance from the same detector under 4 standard test fires and interference, the possibility of false alarm of smoke detector caused by typical interference sources in religious buildings is analysed.

1. Introduction

Fire detection and risk prevention in cultural relics have been the focus of attention in the field of fire detection and alarm in recent years[1, 2]. In the religious building environment, due to sacrificial worship and other reasons, there are a large number of interference sources for smoke-sensing fire detection, such as incense burning and butter lamps, which brings great difficulties to fire detection and alarm (see figures 1).

Qi-Yuan Xie et al.[3] used an experimental platform to study the false alarm of smoke detectors caused by kitchen oil smoke, and compared the effects of kitchen oil smoke and real fire smoke on smoke detectors; Wayne R. Ott et al.[4] used a variety of fine particle monitors to test and analyse the output of tobacco, sandalwood, candle, cooking, wood combustion and vehicles under indoor and outdoor environment; Jinping Zhang et al.[5] measured and analysed samples of volatile organic compounds and particulate pollution produced by burning incense in temples; SW See[6], Nurlaila Ismail[7] and Jin-Ping, Zhang[8] etc. have studied the composition, dynamic characteristics and pollution effect of the products by incense burning.

In the above studies, scholars mainly focus on the measurement and analysis of the components and particle size of the products such as burning incense and oil smoke. There is a lack of research on the influence factors of interference source for smoke detectors in religious buildings. Since the sensitivity of the smoke detector to the above interference will directly affect the false alarm rate of the detector, this paper focus on the detector’s effect on fire smoke and interference smoke, and study the law of false alarm generation through fire and interference simulation test.
Figure 1. Common interference sources of burning incense and butter lamp for smoke detection in religious buildings.

2. Interference source simulation test

2.1. Test conditions and arrangement

In order to simulate the above-mentioned interference of burning incense and butter lamps in religious buildings for smoke detectors, according to the requirements of international standard ISO 7240-7:2011 point type smoke detectors using scattered light, transmitted light or ionization, the simulation test was conducted in a standard combustion laboratory. The size of the standard combustion chamber is: length 10m × width 8m × height 4m. The ceiling is horizontal and made of heat-resistant and heat-insulating materials. Ventilation equipment is set around and the test fire source is placed in the centre of the combustion chamber, as shown in figure 2.

The smoke concentration \( m \) value and \( y \) value at the equivalent position of smoke detector are detected by photoelectric and ionization detectors respectively, and when smoke detector sends out a fire alarm signal is monitored in the control room. The photoelectric detector is based on measuring the dimming rate of an infrared beam, which is caused by smoke concentration change though the radiation path:

\[
m = (10/d) \log \left( \frac{P_0}{P} \right)
\]

where \( m \) represents the dimming coefficient (dB/m), \( d \) represents the optical measuring length (m), \( P_0 \) is the radiated power received when there is no smoke (W), \( P \) is the radiated power received when there is smoke (W). The method of measuring smoke concentration in the ionization chamber of an ionization detector is as follows:

\[
\begin{align*}
d \times z &= \eta \times y \\
y &= (I_0 / I) - (I / I_b)
\end{align*}
\]
where \( d \) is the average particle size of smoke particles, \( z \) is the number concentration of smoke particles, \( \eta \) is the ionization chamber constant, \( I_0 \) is ionization current without smoke particles in the air, \( I \) is ionization current with smoke particles in the air.

2.2. Typical interference source simulation

In order to simulate the typical interference sources of religious places exemplified in figure 1, different brands of sandalwood and butter were used, and the simulation test was carried out according to the following methods:

- At the centre of the standard combustion chamber and about 1 meter above the ground, a platform with an area of 50cm×50cm is set up, and evenly divided it into 100 points. Each point was inserted by 3 incenses with an effective burning part of about 25cm. This simulates the interference source of incense burner burning (see figure 3 (a) and (b)).
- Similarly, at a height of about 1 meter above the ground from the centre of the standard combustion chamber, a platform with an area of 50cm×50cm is set up, and 100 points are evenly divided. Each point placed a butter lamp with tray diameter of 4cm and wick diameter of 1mm to simulate the interference source of the bowl-shaped butter lamp (see figure 3 (c)).
- A fuel tray with a bottom area of 30cm×30cm is placed at a height of about 1m from the ground in the centre of the standard combustion chamber, and add about 1.5L of butter. The four corners of the tray are fixed with cotton ropes of about 0.5cm in diameter as wicks. This test is used to simulate the interference of cylinder-shaped butter lamp (see figure 3 (d)).

![Image](image_url)

(a) Incense burner simulation test No.1.  
(b) Incense burner simulation test No.2.  
(c) Butter lamp simulation test No.1.  
(d) Butter lamp simulation test No.2.

Figure 3. Simulation of interference sources in standard combustion test room.

3. Test results and data analysis

3.1. Interference source measurement

According to the interference source simulation tests specified in 2.2, the \( m \) value and \( y \) value changes during test are measured by photoelectric and ionization detectors. Because the interference of incense and butter lamps on smoke detectors is a long-term continuous process, which is different from the
short-term test of fire smoke simulation, the incense test lasts about 50 minutes until burning out and the butter lamp test lasts about 1 hour.

In the incense burner simulation test No.1 (see figure 4 (a)), the interference smoke produced by burning incense makes y value rise rapidly, and reaches the peak during the test from 500s to 1700s, then gradually decrease until 3200s when sandalwood is completely burned out; m value gradually increases from the beginning of the test to about 2500s, and after reaching 0.5dB/m, it remains basically unchanged until the end of the test.

In the incense burner simulation test No.2 (see figure 4 (b)), the value of y rapidly rises to about 2 within 500s, and slowly rises between 2 and 2.5 until it reaches the peak at about 2500s, then decreased gradually until all sandalwood was burned out in about 3200s. Similar to the incense burner simulation test No.1, the m value gradually increased from the beginning of the test to about 2500s and remained basically unchanged afterwards. Due to the use of low smoke sandalwood in test No.2, the final m value only reached the maximum of 0.21db/m.

In the butter lamp simulation test No.1, because the butter lamp selected is small, the flame height was only about 1cm, and no obvious smoke was produced during the combustion process. The readings of the photoelectric and ionization detectors were kept at a small value close to 0, and no valuable readings are collected or recorded.

In the butter lamp simulation test No.2 (see figure 4 (c)), the effective burning time of the butter lamp is about 1 hour, the height of the flame is about 5cm~10cm, the smoke produced by burning is mainly black smoke, and the m value and y value continue to rise to about 0.25 dB/m and 1.5.
3.2. Comparative analysis of interference effect

In order to investigate the interference effects of burning incense and butter lamps on smoke detectors, one same smoke detector was used to compare the response performance under 4 ISO standard test fires and interference simulation conditions. These 4 standard test fires are used to simulate real fires caused by different fuels, namely: smouldering (pyrolysis) wood fire (TF2), Glowing smouldering cotton fire (TF3), Flaming plastics (polyurethane) fire (TF4) and Flaming liquid (n-heptane) fire (TF5); the interference sources were used to simulate the smoke interference generated by incense burning and butter lamp in typical religious venues. The test results are shown in table 1.

| fire/interference test data | TF2 | TF3 | TF4 | TF5 | incense No.1 | incense No.2 | butter lamp No.2 |
|-----------------------------|-----|-----|-----|-----|--------------|-------------|-----------------|
| test duration (s)           | 480 | 324 | 138 | 193 | 3200         | 3200        | 3700            |
| maximum value of y in test  | 0.96| 3.30| 5.01| 5.26| 3.40         | 2.47        | 1.49            |
| maximum value of m in test (dB/m) | 1.03 | 1.67 | 1.05 | 0.99 | 0.50 | 0.21 | 0.25 |
| m value when detector alarms (dB/m) | 0.83 | 1.17 | 0.61 | 0.64 | 0.15 | 0.14 | 0.23 |

According to the test results, the m value of the smoke detector when alarming under the four standard fires is all above 0.6dB/m, the alarm can occur when the interference of burning incense reaches about 0.15dB/m or the interference of butter lamp reaches about 0.23dB/m. It can be seen that the interference of burning incense has a more obvious influence on the smoke detector. When the optical density of the interference smoke is much lower than that of the fire smoke, the detector can alarm; the interference of the butter lamp can also cause the detector to alarm within 1 hour test, and because the butter lamp in religious places generally remains lit for a long time, its smoke concentration will continue to increase when the ventilation is poor, which may eventually cause the detector to falsely alarm.

4. Conclusion

In this paper, through the simulation test of burning incense and butter lamps in religious buildings, the influence of such interference sources on smoke fire detectors is tested and analysed. Under the
conditions of the ISO standard combustion laboratory for data monitoring, different types of sandalwood and butter were used to simulate the interference of smoke generated by incense burners and butter lamps. By comparing the response characteristics of the same smoke detector in the four standard test fires and the interference source, the experimental results show that the smoke detector is greatly affected by the interference of burning incense, which can cause false alarm when the smoke concentration is low; the continuous accumulation effect of butter lamp smoke will also cause false alarm of the detector.

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