The Research on the Consistency of the Testing Accuracy for Smoke Measuring Equipment Based on Ionization Chamber Principle

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The Research on the Consistency of the Testing Accuracy for Smoke Measuring Equipment Based on Ionization Chamber Principle

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Abstract. A convenient method is proposed here to determine the relative accuracy of measuring ionization chamber (MIC). A non-dimensional quantity is presented here to characterize the relative accuracy of the testing MIC to the standard sample. Fire alarm with good repeatability and azimuth stability is used as the standard sample. The response threshold of the MIC to be measured is compared with that of the standard sample to determine its error and accuracy. This work may be benefit to testing laboratory, system manufactory and standard revision personnel.

1. Introduction

As we known, there are two kinds of widely used smoke measuring equipment, which are obscuration meter and measuring ionization chamber (MIC) [1]. Smoke density can be measured by different techniques [2-6]. However, for reference measurements of smoke density in connection with testing of ionization smoke detectors for automatic fire detection systems, it is advantageous to use a measuring instrument based on the ionization chamber principle. This is because of the complex nature of smoke, which means that measuring errors are likely to occur if the reference measuring instrument reacts to other properties of the smoke than the detector under test.

When the measuring ionization chamber (MIC) [7-8] is used in the smoke tunnel measurements and fire sensitivity tests, the high measuring accuracy is very important for the overall measuring accuracy of the whole system which is limited by the measuring accuracy of the measuring ionization chamber (MIC). The radioactive source in the MIC makes the certification of MIC very expensive and complicated. A convenient method is proposed here to determine the relative accuracy of measuring ionization chamber (MIC) which may be widely used by testing laboratory and manufactory.

The response threshold of detectors using ionization is characterized by a non-dimensional quantity y or X which is derived from the relative change of the current flowing in a measuring ionization chamber, and which is related to the particle concentration of the test aerosol, measured in the proximity of the detector, at the moment that it generates an alarm signal.

According to BS EN54-7:2001 "Fire detection and fire alarm systems" and other relative standard, MIC consists of a measuring chamber, an electronic amplifier and a method of continuously sucking in a sample of the aerosol or smoke to be measured.

The measuring chamber contains a measuring volume a suitable means by which the sampled air is sucked in and passes the measuring volume in such a way that the aerosol/smoke particles diffuse into the volume. This diffusion is such that the flow of ions within the measuring volume is not disturbed

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by air movements. The air within the measuring volume is ionized by alpha radiation from an americium radioactive source, such that there is bipolar flow of ions when an electrical voltage is applied between the electrodes. This flow of ions is affected by the aerosol or smoke particles in a known manner. The relative variation in the current of ions is used as a measurement of the aerosol or smoke concentration.

The measured smoke densities are expressed in terms of the dimensionless quantity defined by the equation:

$$X = \frac{I_0 - I}{I_0}, 0 \leq X \leq 1 \quad (1)$$

Where I_0 is the quiescent ionization chamber current in clean air and I is the ionization chamber current in presence of smoke.

2. Testing program

2.1Test steps

Step 1: standard sample selection. The selection of standard sample is the key point of this program. Fire alarms of different grades were selected, and the repeatability test and azimuth test were carried out according to standard procedures, so as to determine their performance stability with time and space difference.

Step 2: Place the MIC and the standard fire alarm under the same smoke tunnel. Make sure the smoke tunnel is space uniformity and stability and the response threshold of the standard fire alarm is stable. The relative accuracy of the MIC can be obtained by comparing its value with the response threshold of the standard fire alarm.

2.2Determination of standard sample

The determination of standard sample is the key point of this scheme. Azimuth and repeatability tests were carried out on a batch of samples in the same test environment to obtain the standard sample with the stable response threshold.

The specific test environment and conditions are as follows: Testing environment: Air temperature is 20.6℃and air humidity is 45.4%. Air velocity is 0.2m/s.

Condition: The rate of increase of aerosol density is 0.05min^{-1}. The flow rate of aerosol is 20 l min^{-1}. The flow rate of vacuum pump is 30 l min^{-1}. Test equipment: measuring ionization chamber (MIC) : Delta MIC EC-912, smoke tunnel: AWT 2800.

The following five groups of samples have been selected as examples to analyze the selection steps of standard samples.

2.2.1 Repeatability test

This test mainly judges whether the response threshold value of standard sample is stable when it is measured in the same position after a period of time. The test is divided into two parts: 1. The same fire alarm are measured many times at the same test position. 2. After a period of time (10 days), the same fire alarm was measured again at the same test position.

The sample test azimuth is shown in figure 1. The position of the alarm light of the sample under test is taken as the azimuth marker, and the position of the alarm light is 0 degree azimuth.

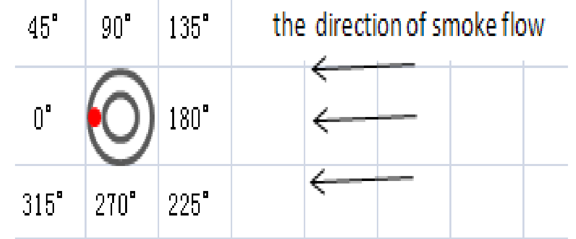

Figure 1. Sample test azimuth determination diagram.

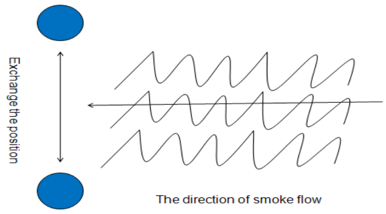

Figure 2. Schematic diagram of sample placement position.

Test the response threshold of the sample in the smoke tunnel. Before the test, there should be no test smoke inside the smoke tunnel and the sample to be tested. The sample should work stably for 15min under normal monitoring. The response threshold of 0 degree azimuth of all the samples to be tested is tested for 6 times. The maximum value and the minimum value of each sample were y_{max} and y_{min}, and the ratio of response threshold R was y_{max}: y_{min}. The closer the ratio of response threshold values to 1, the better the test repeatability. The first test results are shown in table 1.

Table 1. First test results.

Time	response threshold y				
	1#	2#	3#	4#	5#
1	1.17	0.97	1.18	1.07	1..20
2	1.15	0.97	1.18	1.03	1.00
3	1.16	1.01	1.17	1.05	1.1
4	1.16	1.01	1.16	1.05	1.1
5	1.18	0.99	1.18	1.07	1.1
6	1.14	0.99	1.18	1.03	1.1
Ratio R	1.04	1.04	1.02	1.04	1.20

It can be seen from table 1 that the 0-degree azimuth test stability of sample 3# is the best, and that of sample 5# is the worst.

Save the Samples for ten days under the normal temperature and humidity. The temperature is 25 ℃ and the atmospheric humidity is 50%. And then repeat the experiment of five samples. Test results are shown in table 2.

Table 2. Test results after the storage.

Time	response threshold y				
	1#	2#	3#	4#	5#
1	1.20	1.03	1.16	1.07	1.16
2	1.16	1.03	1.16	1.03	1.16
3	1.18	1.05	1.15	1.05	1.16
4	1.18	1.01	1.17	1.05	1.16
5	1.18	1.03	1.16	1.07	1.14
6	1.18	1.03	1.16	1.03	1.18
Ratio R	1.04	1.04	1.02	1.04	1.04

It can be seen from table 2 that, after storage, the stability of 3# sample tested at the 0-degree azimuth is optimal. Except that the test data of 5# sample change with the first time, the consistency of other samples are good.

The test data before and after storage is analyzed as follows. The average value of the response threshold was compared between the first test and the second test to obtain the ratio R*. The comparison results are shown in table 3.

Table 3. Comparison table of the test results before and after the storage.

Time	The average of response threshold				
	1#	2#	3#	4#	5#
before storage	1.16	0.99	1.18	1.05	1.10

after storage	1.18	1.03	1.16	1.07.	1.16
Ratio R*	1.02	1.04	1.02	1.02	1.06

As can be seen from table 3, the time stability of samples 1#, 3# and 4# is good, while that of samples 5# is poor.

2.2.2 Azimuth test

This test is used to determine the smoke inlet performance of the samples to be tested in different directions, so as to determine the stability of the samples to be tested in different directions. Test the response threshold of the sample in the smoke tunnel. Starting from the 0-degree azimuth, after each measurement, the sample shall rotate 45 degrees around its vertical axis in the same direction for a total of 8 measurements. The maximum value and minimum values was y_{max} and y_{min} respectively, and the ratio of response threshold R** was y_{max}: y_{min}. The closer the ratio of response threshold values to 1, the better the repeatability of azimuth test. The test results are shown in table 4 and table 5.

Table 4. Response thresholds in different directions.

Sample No..	Response thresholds in different directions y (degree)							
	0	45	90	135	180	225	270	315
1#	1.18	1.18	1.18	1.18	1.18	1.14	1.14	1.14
2#	1.03	1.03	1.03	1.03	1.03	0.99	1.03	0.99
3#	1.14	1.14	1.14	1.14	1.14	1.10	1.10	1.10
4#	1.07	1.10	1.10	1.07	1.10	1.10	1.07	1.07
5#	1.14	1.14	1.10	1.10	1.10	1.10	1.10	1.10

Table 5. Ratio of response threshold in azimuth tests

Sample No.	1#	2#	3#	4#	5#
Ratio R**	1.04	1.04	1.04	1.04	1.04

As can be seen from table 5, the ratio of response threshold values at different orientations of 3# and 4# samples is the smallest and the azimuth stability of the samples is the best.

Based on the results of repeatability and azimuth test, it can be seen that 3# sample is the most stable and can be used as a standard sample.

2.3Determination of accuracy of MIC

According to the previous section, sample 3# is selected as the standard sample. Put the MIC to be tested and the standard sample S into the smoke tunnel and inject the smoke slowly until the standard sample alarm.

The MIC n and the standard sample S are placed in the vertical direction of the smoke flow. In order to fully eliminate the effects of inhomogeneous smoke in the tunnel, the testing must be carried out twice when comparing the sample n and S by exchanging the position. Swap positions can effectively reduce the measurement uncertainty. Schematic diagram is shown in figure 2.

The mean value of the two tests was compared with the response threshold of standard sample 3#. If the error is less than 5%, the accuracy of the testing MIC to the standard sample is good. This tolerance 5% comes from chapter 5.1.4 of BS EN54-7:2001.

3. Conclusion

A convenient method is proposed in this paper to determine the accuracy of measuring ionization chamber (MIC). A non-dimensional quantity is used here to characterize the accuracy of the testing MIC. Fire alarm with good repeatability and azimuth stability is used as the standard sample. The response threshold of the MIC to be measured is compared with that of the standard sample to determine its error and accuracy. This work may be benefit to testing laboratory, system manufactory and standard revision personnel.

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