Influence of the operating time on the behaviour of smoke alarms in typical office environments

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In the framework of maintenance of automatic fire detection and alarm systems the response behavior of smoke alarms has to be tested or the detectors have to be replaced after 5 resp. 8 years (depending on the detector technology) according to the German standard DIN 14675 "Fire-alarm systems - installation and operation". Reason for the fixed cycles of substitution of smoke alarms are the expected long-term changes of the response behavior due to pollution and the ageing of components. Unfortunately the standard does not show how the value of 8 years has been calculated. Furthermore, the standard does not distinguish between the different installation conditions. In heavily polluted environments 8 years may be too long. On the other hand it may be possible that 8 years may be too short for installations in clean environments (e.g. office buildings). An exchange of smoke alarms in clean environments at a later date can reduce costs and save resources.

Aim of the presented study was the analysis and documentation of the influence of the environment and the operating life on the response behavior. 5 different optical line-type smoke detectors were tested in the EN54 test tunnel. The following figure shows the measurement setup.

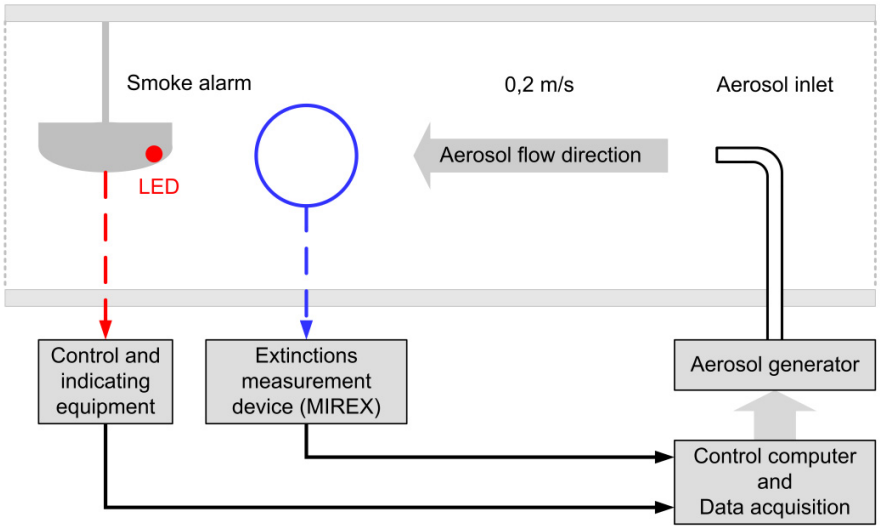


Figure 1 Principle of the measurement system

Measuring equipment:

- EN54 test tunnel
- Extinction measuring device MIREX
- Lorenz AGW / BM VI aerosol generator
- Pt 100 temperature sensor
- Air velocity-/temperature transmitter, series EE70 VT315

Background for the performed measurements was the EN 54 part 7. Chapter 4.3 describes the determination of the repeatability, the directional dependence and the reproducibility. The measurement of the response threshold value (RTV) is specified in chapter 5.1.5. Based on the EN54 test-standard for the directionality or the response behavior of a smoke detector the increase of the aerosol concentration was set in the range $0.015 \leq \Delta m / \Delta t \leq 0.1$ (dBm^{-1} min^{-1}).

A particular focus of this series of tests was to investigate the behavior of new detectors by comparison with detectors of different age groups. The old detectors were collected exclusively from relatively clean areas in office buildings and were divided into 4 age groups (2-5 years, 6-8 years, 9-12 years, and older than 12 years).

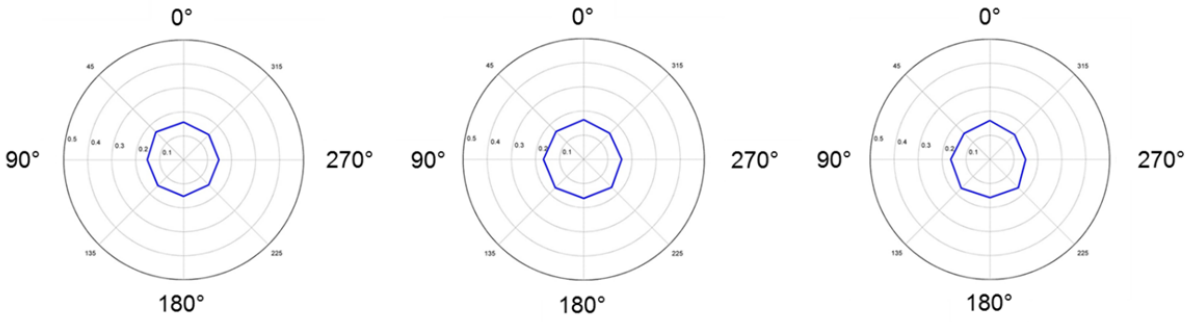
In the first phase the directionality and the response threshold value (RTV) of 10 new detectors of every detector type were measured. In the second phase of the project the response characteristics of 143 old detectors were measured and compared with the new detectors. Table 1 shows the age structure of the collected and tested optical smoke detectors. It was not possible to find any detectors of type 1 with an operating life of 2 to 8 years and detectors of type 2, 4, and 5 with an operation life of more than 12 years.

	New detectors	Detectors with 2 - 5 years of operating life	Detectors with 6 - 8 years of operating life	Detectors with 9 - 12 years of operating life	Detectors with more than > 12 years of operating life
Detector type 1	10	0	0	22	12
Detector type 2	11	5	13	10	0
Detector type 3	10	4	16	24	10
Detector type 4	10	5	8	11	0
Detector type 5	4	1	2	0	0
	45	15	39	67	22

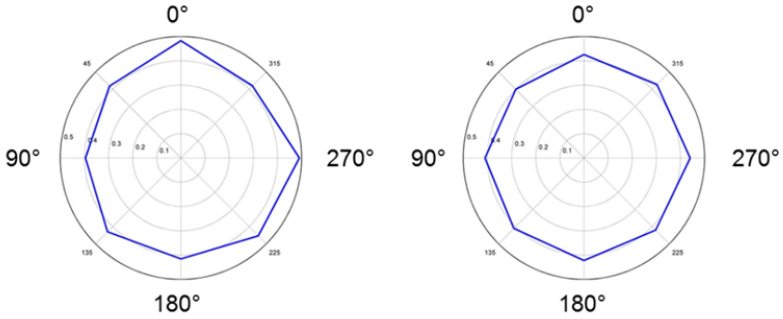
Table 1 Quantity structure of the collected and tested detectors

The directional dependence was determined by measuring the RTV of 1 new detector of each detector type at 8 different flow directions. After each measurement of the RTV the detector was turned by 45°. The direction with the highest RTV (m_{max}) is the direction with the lowest sensitivity. Figure 2 shows the measured directional dependence (RTV in dBm^{-1}) of the tested new detectors (type 1 to type 5).

The repeatability was determined by 3 additional measurements at the angle with the highest RTV (m_{max}). The reproducibility for 9 new detectors of each type was determined at the angle with the highest RTV (m_{max}).



Detector type 1 Detector type 2 Detector type 3



Detector type 4 Detector type 5

Figure 2 Directional Dependence of new detectors

The directional dependence of the old detectors was determined by testing 50 % of the old detectors of each detector type. To reduce the total amount of measurements, the RTV was determined at only 4 flow directions (i.e. each 90°), whereby the previously determined angle with the lowest sensitivity (m_{max}) of a new detector was included. All measurements were done at least twice.

The reproducibility and repeatability was determined by testing the other 50 % of the old detectors of each detector type. Three measurements of the RTV of each detector at the angle with the lowest sensitivity (m_{max}) of a new detector were performed.

A total of 944 measurements of new and old detectors were collected, see table 2. The directionality and RTV tests were done repeatedly with identical configuration and the scattering result values were averaged. The following table shows the total number of measurements depending on the operating life.

	New detectors	Detectors with 2 - 5 years of operating life	Detectors with 6 - 8 years of operating life	Detectors with 9 - 12 years of operating life	Detectors with more than > 12 years of operating life	Number of tests
Detector type 1	21	-	-	132	68	221
Detector type 2	21	24	80	60	-	185
Detector type 3	20	24	92	144	60	340
Detector type 4	20	24	48	68	-	160
Detector type 5	14	8	16	-	-	38
Total number of measurements depending on the operating life	**96**	**80**	**236**	**272**	**128**	**944**

Table 2 Total number of measurements depending on the operating life

The directionality tests didn't show any conspicuous features. The EN 54 requirement $m_{max}/m_{min} < 1.6$ was met by all tested detectors even after more than 12 year operating age. The production spread of new smoke alarms has to be within the limits $m_{max}/m_{mean} \leq 1.33$ and $m_{mean}/m_{min} \leq 1.5$. Unfortunately, there is no rule for old detectors. To show possible indications of e.g. aging of the detectors the limits $m_{max}/m_{mean} \leq 1.33$ and $m_{mean}/m_{min} \leq 1.5$ were calculated for each of the 4 age groups. The evaluation of all measurements showed only minor changes to the limits with two exceptions. A general trend to lower or higher RTV as a function of the operating age could not be determined. However, a minor age-dependent variation may be determined depending on the detector type.

Two detector types appeared to be more sensitive with advancing age. Detector type 1 showed changes of $m_{mean} \approx 14$ % but only for detectors with an operating life of more than 12 years. Detector type 4 showed changes of $m_{mean} \approx 15$ % for detectors with an operating life of 9 to 12 years. A higher sensitivity will cause more false alarms. For this reason the detector would be replaced anyway by a new one.

More critical are the measurement results for detector type 3. The performed measurements showed a trend to lower sensitivity. Changes of $m_{mean} \approx 9$ % for detectors with an operating life of 9 to 12 years and changes of $m_{mean} \approx 19$ % for detectors with an operating life of more than 12 years can be seen. Detector type 2 and 5 showed no trend to higher or lower sensitivity.

The research study showed that the age limit of 8 years (DIN 14675) is not an insurmountable barrier. However, it should be stressed that the study should not be valued as absolute proof. In fact, the performed investigations show first important details for a possible review of the defined age limit. This study represents only a very small sample for clean environments. A scientifically sound statement requires a significantly larger number of smoke alarms from different manufacturers and different areas of application.