UL268 7th challenge with single infrared smoke detector

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Abstract

Coming up UL217 8th and UL268 7th edition with added new polyurethane foam fires and hamburger cooking nuisance resistance test influence traditional already approved fire detection products. The added tests are within the ISO7240 sensitivity range even if there are differences in sensitivity measurement methods and instruments.

The wavelength dependent light extinction or as well named light obscuration is a summary of absorption and scattering. Due to the fact that scattering only is in use for most mass market fire detectors the sensitivity window will now be limited by the cooking nuisance hamburger no alarm test and flaming polyurethane foam.

Especially infrared forward scattering fire detectors with a low sensitivity setting to pass slow smoldering nuisances like broiling hamburger get in contradiction to the fast flaming polyurethane fire if a threshold only method is employed to differentiate between the fire signatures.

Keywords: UL268, EN54, ISO7240, smoke detector, cooking nuisance hamburger.

Introduction

For a very long time fire detection has been based on infrared scattering and/or ionization technologies. Aerosol development is well known for several fire and nuisance sources, unfortunately with some overlapping. Enhanced detection technologies have solutions to differentiate between real fires and nuisance sources, but without any qualified standardization tests. UL217 and UL268 are the first standards worldwide with a cooking nuisance resistance test. In parallel smoldering and flaming polyurethane foam fires were added to the standard due to the fact that this material is becoming commonly found in household and commercial facilities. Real evacuation scenarios are defined by fire alarm acceptance levels ASET (Available Safe Egress Time) with a high probability of evacuation after a fire is detected.

Real World Challenge

Today's traditional mass market smoke detectors are mostly based on single optical infrared forward light scattering. The discussions focus to this technology and analyze the challenge to meet new worldwide standardization and regulatory changes. To get all variances behind it's necessary to understand all the fire detector manufacturing and component tolerances beside the variance of each fire type.

UL Wood Fire Analysis as Example

Test fires are standardized for repeatability and reproducibility. Even though they still have some development variations within their standardization boundaries. To get all the possible fire profiles between the boundaries defined by Obscuration vs. Time and Obscuration vs. Ionization, it's necessary to run dozens of tests over different season's and multiple years. All valid test runs are plotted for ceiling centre position in Fig. 1. The minimum and maximum represent +/-1.5 standard deviations and shows how challenging it's to get the fire development within the standardization boundaries.

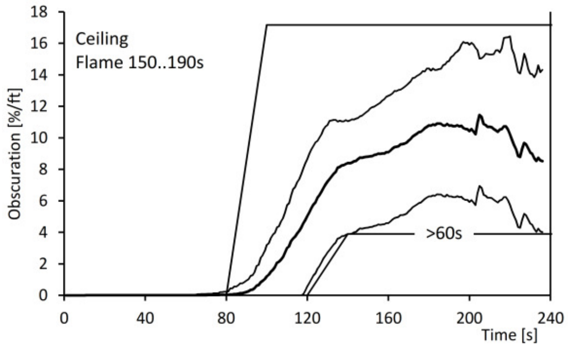

Fig. 1. Wood fire obscuration at ceiling and corresponding boundaries.

The scattered signal shows as well a variance around the average depending on the fire build up and flame point (Fig. 2 and 3). The minimum profiles identified through all valid test runs are fundamental for further data analysis, with the target to pass any requalification tests.

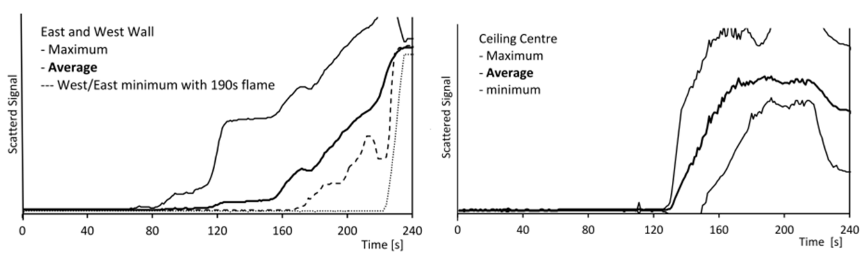

Fig. 2 and 3. Infrared forward scattered signal, walls and ceiling centre.

The wall positions scattered signal are different to the ceiling centre (Fig 2 and 3) and represent an additional challenge to get the fire development symmetrical comparing to EN54 with ceiling only detectors.

Manufacturer Freedom

As example a basic alarm algorithm will be used. It's based on a simple detector scattered signal threshold, in combination with some alarm reaction time represented by the x axis, Fig 4. As ordinate the scattered signal is representing the smoke box obscuration equivalent. All minimum profiles identified with UL fire tests are processed with the threshold algorithm and drawn up as latest alarm regression lines. Smoldering smoke and paper fire are not plotted due to high and uncritical forward scattered signal.

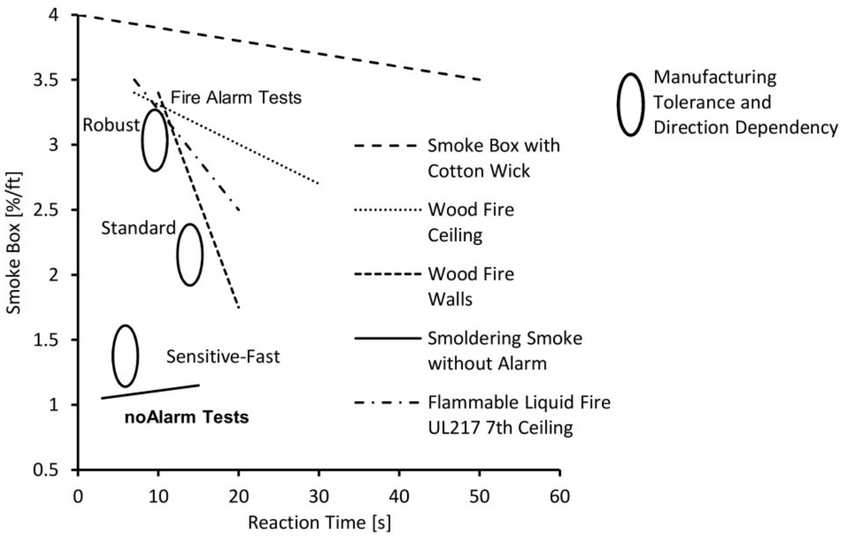

Fig. 4. Alarm regression diagram based on UL268 6th edition.

Without any further genius algorithm, the manufacturer freedom is left and below the different fire regression lines. We are able to find the different sensitivity setups within several manufacturer manuals. In commercial fire detection systems, a “Robust” sensitivity setup with around 10 s reaction time could be applied as example in a manned area. If people are sleeping, or if technical equipment need to be unmanned protected, “Sensitive-Fast” could be applicable.

In further steps it's good to know how field nuisances react to this simplified sensitivity setup. In general the sensitive-fast setup will react sensitive with any fast nuisances like bathroom or cooking steam and should be not activated in such areas to prevent unwanted false alarms.

ISO7240 point type detector standards

To get smoke detectors with lower false alarm rate and better field nuisance robustness it's obvious to decrease the detector sensitivity as low as possible. To cover the wide possible sensitivity range and reaction at test fires, ISO7240-7 release August 2011, added different smoke tunnel response ranges, Fig. 5. With set 2 a new minimum obscuration of 0.2 dB/m (corresponding 4.5 %/m, 1.37 %/ft) was defined beside the established 0.05 dB/m (corresponding 1.14 %/m, 0.35 %/ft). July 2014 ISO enhanced as well the combined heat-smoke ISO240-15 with additional TF1 (open cellulosic wood fire) from old EN54-9 and TF8 (low temperature black smoke decalene liquid fire).

Table 1 — Response threshold value for detectors using scattered or transmitted light

Response threshold value in smoke tunnel (aerosol) dB/m		Test fires end-of-test conditions			
		TF2 dB/m	**TF3** dB/m	**TF4** dimensionless	**TF5** dimensionless
1	$0{,}05 < m < 0{,}3$	$m = 2$	$m = 2$	$y = 6$	$y = 6$
2	$0{,}2 < m < 0{,}6$	$m = 2$	$m = 2$	$y = 6{,}5$	$y = 7{,}5$
NOTE	The smaller the m value, the higher the sensitivity of the detectors.				

Fig. 5. ISO7240-7 response threshold ranges.

With ISO the manufacturer has still the freedom to use sensitivity range set 1 or set 2. With set 2 the test fire TF4 and TF5 get an increased ionization test end condition. European EN54 does not use the ISO range setting. EN54 added TF1 from old EN54-9 detector standard and TF8 to the multi-sensor -29 smoke-heat, -30 heat-CO and -31 smoke-heat-CO.

Chinese GB4715 (smoke detector) is close to the publication of a new edition with the general requirement that smoke detectors have to alarm within smoke tunnel later than 0.3 dB/m (corresponding 6.67 %/m, 2 %/ft). SH3 and SH4 (similar to EN54 TF4 (polyurethane) and TF5 (heptane) remains as they are and up to date without any test end adaptions as in ISO7240-7 set 2.

The UL obscuration and ISO/EN extinction measurement instruments and methods need attention due to:

- ISO7240 and EN54 recommend a wavelength around 900 nm (infrared) and maximum 3° scattering within over approximately 1 m distance. The sensitivity measurement is based on a smoke tunnel running pharmaceutical paraffin oil with 0,5 to 1 µm diameter and a refractive index of approximately 1,4.
- UL and ULC obscuration measurement is based on a spotlight lamp with a range of wavelengths between yellow and green (2370 ± 50 K) and a photodiode with 11cm^2 at a distance of 5 ft (1.52 m). The sensitivity measurement is running within a smoke box with glowing cotton wick at UL and punk sticks at ULC.

New UL Cooking Nuisance Hamburger and Flaming PU Test

To increase the field robustness, especially against cooking nuisance, UL268 7th and UL217 8th edition added the cooking nuisance hamburger test without alarm up to 1.5 %/ft. Comparing to ISO set 2 (0.2 dB/m corresponding 4.5 %/m, 1.37 %/ft), UL serve a bit higher sensitivity than ISO. Even though UL has no manufacturer freedom to use the old smoke box and smoldering smoke without alarm up to 0.5 %/ft like ISO.

Comparing Obscuration vs. Time and Obscuration vs. Ionization there are similarities in development between cooking nuisance hamburger and the smoke box in time as well in particle development, Fig. 6 & 7.

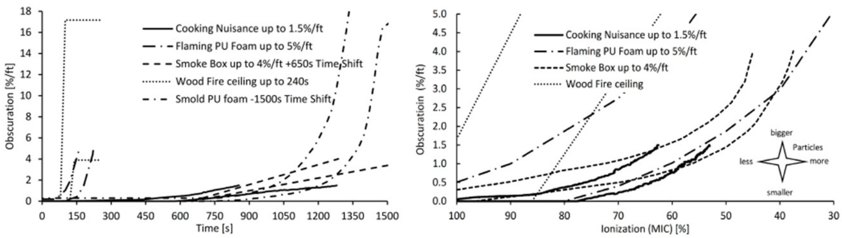

Fig. 6 & 7. Obscuration and Ionization comparing with added new tests.

The obscuration alarm window for non multi-criteria detectors is defined between cooking nuisance hamburger resistance test up to 1.5 %/ft and smoke box alarm latest at 4 %/ft. A typical single forward scattering detector, being already direction dependency and manufacturing tolerances optimized, has to alarm close to the smoke box 4 %/ft limit, Fig.8.

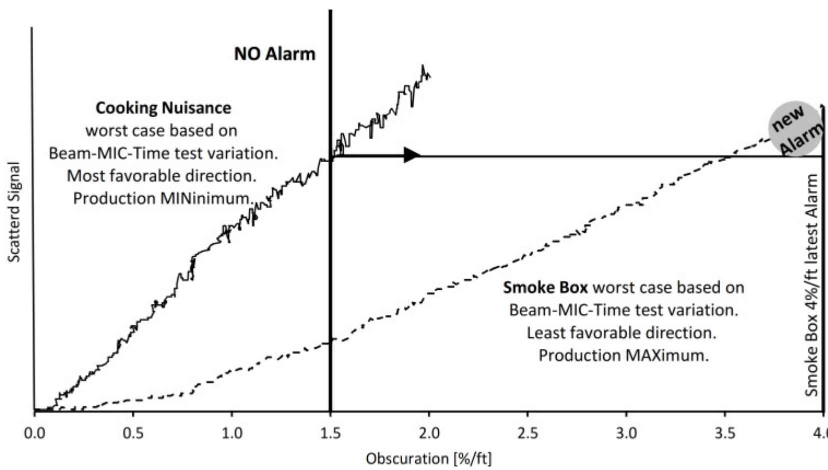

Fig. 8. Obscuration vs. forward scattered signal for cooking nuisance hamburger and smoke box sensitivity with cotton wick.

Fig. 8 plotted test runs represent already the worst case found with the variation of obscuration and ionization. The new manufacturer freedom is identified within the regression diagram close to 4 %/ft, Fig. 9.

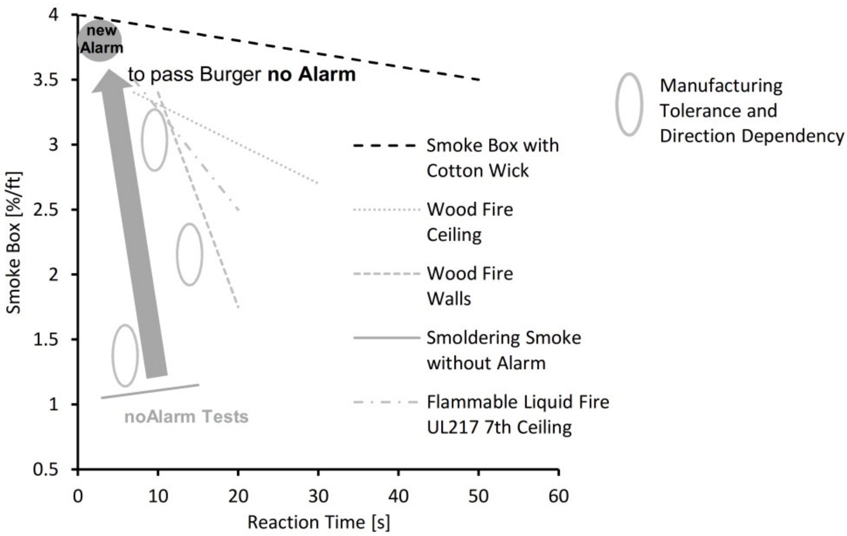

Fig. 9. Alarm regression diagram with added new cooking nuisance.

The updated UL standards have with the 4 %/ft upper smoke box limitation for non multi-criteria detectors a strict limitation, but are compliant with ISO7240 limit 0.6 dB/m (corresponding 12.9 %/m, 3.9 %/ft) even though the obscuration measurement technology and sensitivity test aerosol is not equal for ISO/EN and UL. EN54 and GB4715 have up to date no upper smoke tunnel limitation.

Flaming Polyurethane Fire EN54 and UL

ISO 7240 and EN 54 include with TF4 already a flaming polyurethane foam fire. A comparison between these flaming foam fires shows within Fig. 10 relevant obscuration and ionization development differences. The UL polyurethane flaming foam could generate up to the acceptance criterion smaller particles than EN54 TF4, which is an additional scattering disadvantage beside the black particles. The different obscuration measurement technologies between UL and ISO/EN are not covered.

The UL flaming PU foam acceptance criteria is with 5 %/ft more sensitive than ISO/EN with TF4 around 8%/ft obscuration equivalent. The reasons behind are different north American evacuation scenarios as well different building structures comparing with Europe.

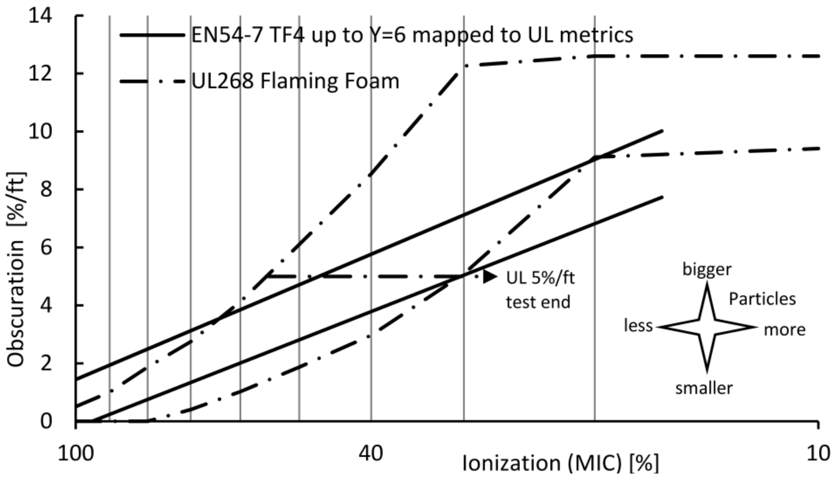

Fig. 10. Flaming polyurethane foam compare between UL and EN54.

New Reality for Manufacturer Freedom

To pass UL flaming polyurethane foam, there is the need of a fast and sensitive setup around 1 %/ft within smoke box for any infrared forward scattering technology. This is in contradiction to the new cooking nuisance no alarm sensitivity setup close to 4 %/ft smoke sensitivity.

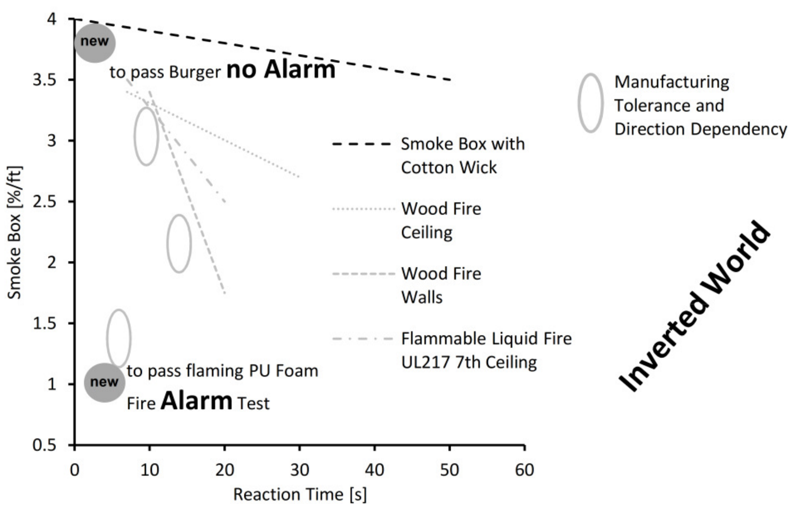

Fig. 11. Alarm regression diagram with cooking nuisance hamburger and flaming polyurethane.

From obscuration point of view, the initial wide obscuration window between 1.5 %/ft cooking nuisance no alarm and 5 %/ft flaming polyurethane foam latest alarm becomes with a single infrared forward scattered technology negative resp. inverted, reference Fig. 11.

To differentiate between all kinds of slow and smoldering development fires, (including cooking nuisance hamburger resistance) and the fast open fires (with main focus to the fast flaming polyurethane), time dependent criteria's with a fast rate of rise need in minimum implemented as a temporary and short time sensitivity shift, Fig 12.

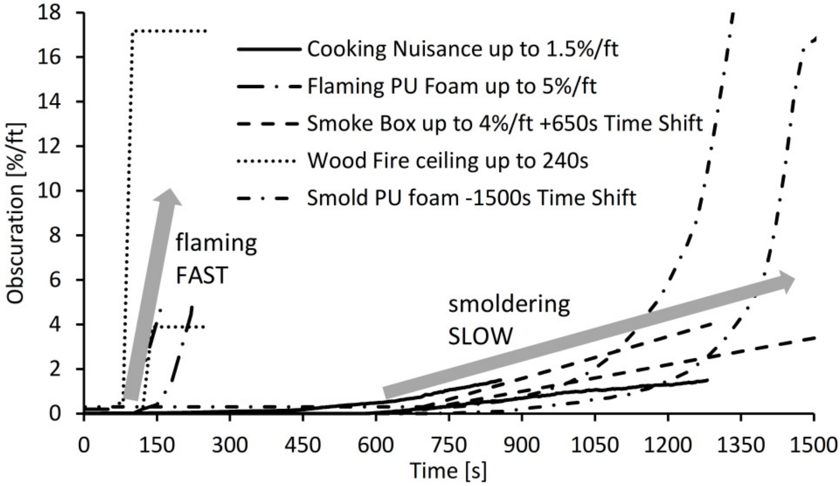

Fig. 12. Obscuration compare between fast flaming fires and slow smoldering fires resp. smoke box and cooking nuisance hamburger.

Conclusion

The added UL polyurethane fire, the cooking nuisance hamburger resistance tests as well the 4 %/ft smoke box limitation are within the ISO7240 sensitivity range even though there are different obscuration measurement technologies between ISO and UL. However the updated UL standards have no flexibility as with ISO range set 1 and 2.

For today's mass market technology, mostly based on single infrared forward scattering, it becomes extremely challenging because forward light scattering have a different signal response than light extinction which is based on a summary of absorption and scattering.

Manufacturer should also think about fast nuisance sources with similar scattered signals as fast flaming polyurethane foam and supplement today's typical forward scatter with additional sensors. This not only helps to break through the 4 %/ft smoke box limitations by a multi-criteria approach, it also get further differentiation between fire and nuisance aerosols.

References

Standards: UL217, UL268, ULC harmonized with UL268 6th edition, EN54, GB4715 and ISO7240.