LETTER TO THE EDITOR

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LETTER TO THE EDITOR

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I read with interest the paper titled "Particle Size and Mass Distributions of Selected Smokes. Effect on Ionization Detector Response", by Roger Welker and John Wagner (Journal of Fire and Flammability, Volume 8, January 1977). This work closely parallels similar studies currently being conducted by myself and others at the Center for Fire Research.

After reading the paper, I feel that I must take issue with the statement that the overall decreasing sensitivity of ionization detectors to plastic smokes is caused by the increasing mean particle diameter. While this is true for constant mass concentration, it is not due to the increasing particle size. It is due to the decrease in the numbers of particles at larger sizes. It has been shown by Purt [1], Hosemann [2], and others, that the sensitivity of an ionization chamber detector is strictly a function of the product nd where n is the number concentration of particles of diameter d. Thus, for a constant number concentration, the sensitivity of the ionization chamber detector increases linearly with increasing particle diameter (see Figure 1). The decreasing sensitivity (increasing alarm point) obtained by Welker and Wagner for the different smokes is caused by decreasing number concentration rather than increasing mean particle diameter. It has also been shown by Purt [1] that, for constant particle mass concentration (probably closer to the conditions observed by the authors), the sensitivity of the ionization chamber detector decreases with increasing particle size due to the decreased number of particles at the larger sizes (Figure 2).

In addition to the aforementioned conclusion, there were a number of observations detailed in the paper which the authors made but could not explain. As we have seen the phenomenon ourselves and have explanations for them, I would like to share them with your readers.

In the introduction, the authors observed that one of the photoelectric detectors tested (Electro Signal Lab Model 724) showed higher inherent sensitivity to punk smoke than to PVC smoke. They found the observation surprising, "considering that white PVC smoke would be expected to scatter more intensely than the greyish punk smoke." While this may seem true to the human eye, the phenomenon encountered here is again related to the difference in mean particle diameter between the two smokes.

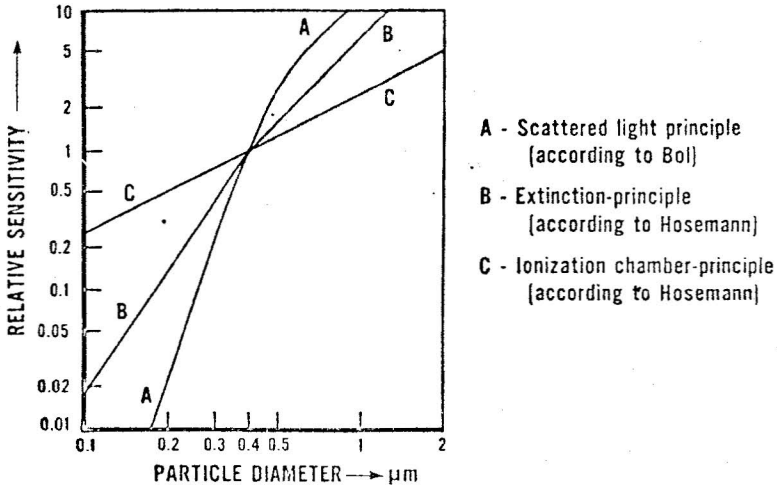

Figure 1. Relative sensitivity of various detector principles for constant particle concentration.

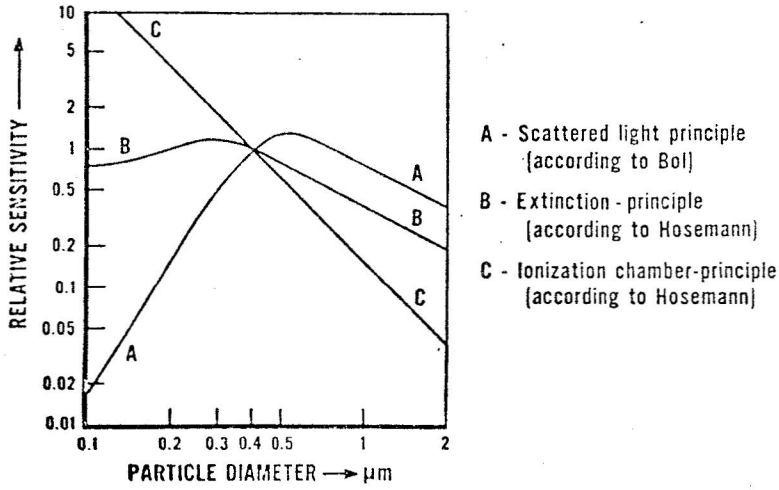

Figure 2. Relative sensitivity of various detector principles for constant mass concentration.

The mass median diameter (which should be closely related to the actual average particle diameter) reported for punk and PVC smokes were 0.88 micrometers and 2.8 micrometers respectively. For visible light (average wavelength approximately equal to 0.52 micrometers), scattering from the punk smoke would follow Mie

theory while scattering for PVC smoke (with the much larger average particle diameter) would be in the Bricard region. Thus, for punk smoke the scattered luminous flux per particle at any given angle would be proportional to d^m where m varies from 2 to 6 depending on particle size, shape, complex refractive index, and scattering coefficient [3]. For PVC smoke, however, the scattered luminous flux per particle is proportional only to d^2 at scattering angles on the order of 30° (approximately the angle used in this particular detector) [3]. Therefore, the expected total scattered luminous flux for the punk smoke would be expected to be greater than the PVC smoke both because of the higher flux per particle and the larger number of particles which would be expected in the punk smoke. Since particle number concentration was not measured, the higher number concentration of the punk smoke can only be a supposition based on our experience.

Also in the introduction, the authors discuss the relationship between sensitivity of a given detector and such aerosol parameters as flow orientation, velocity, and smoke build-up rates. It has been shown by Heskestad [4] that a numerical approximation relating these effects can be derived. Based on his own work and some earlier work conducted at the Bureau, Heskestad derived the following formula:

$$OD_f \text{ (at alarm)} = OD_f \text{ (at some high velocity)} + 1/v \, (dOD_f/dt) \, L$$

where: OD_f (at alarm) is the measured alarm point of the detector at some velocity (v);

OD_f (at some high velocity) is the intrinsic detector sensitivity
v is the aerosol velocity
dOD_f/dt is the smoke build-up rate (in optical density/foot-minute)
L is defined as the detector "characteristic length" (in feet).

The characteristic length for a given detector is a function of the mechanical design of the detector and is a measure of the entry characteristics. This value is calculated by measuring the detector sensitivity over a range of air velocities and then plotting the data of the optical density at alarm against the term $1/v \, (dOD_f/dt)$. By linear regression, a straight line is fitted through the data points with the characteristic length (L) being the slope of the line. The characteristic length is independent of the calibration sensitivity of the detector since different calibration points would shift the line vertically without changing the slope.

We have been working with this formula for some time and find that the linear approximation of the data points is quite good for most detectors. We find that detectors with low L numbers exhibit good entry characteristics and that the L numbers obtained for different samples of the same detector design are in fairly close agreement (as long as precisely the same detector orientation to aerosol flow is maintained for all testing).

The final thing that I wanted to discuss was the observed 6% lowering in base line voltage between the 35 and 225 feet per minute air velocities for the Honeywell TC 100A detector as mentioned in section 3 of the paper. The reason for this observed behavior is that, unlike the Fire Alert and Pyrotronics detectors tested which use bipolar sensing chambers, the Honeywell detector uses a unipolar sensing chamber. As discussed by Scheidweiler [4], an ionization chamber of the unipolar design becomes slightly less sensitive (moves away from alarm) for increasing air velocity as opposed to the more common bipolar sensing chamber arrangement which increases in sensitivity (moves closer to alarm) at increasing air velocities. The Honeywell and some Pyrotronics detectors (but not the DI-2S) are the only detectors which use the unipolar design. Reference 5 contains a fairly detailed description of the reasons for the difference in velocity effects between unipolar and bipolar ionization chambers, relating to the space charge region in the unipolar design.

In summary, I feel that the paper by Welker and Wagner contains a good deal of useful data, but that the data would be of much greater use if the particle number concentrations for each size band had been measured. This is especially true in the case of ionization detector comparisons due to the direct relationship between sensitivity and the particle number, particle size product.

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