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Specifying Fire and Gas Detection Systems to Improve Operations

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Fire and gas detection systems are a critical first line of defense for spotting problems that can result in loss of life and property if left undetected. In order to ensure this defense is robust, several factors must be considered when selecting systems for the detection of flames and hazardous gases in industrial plants and facilities. Among the most important parameters are accuracy, response speed and measurement range.

Accuracy relates to the trustworthiness of the reading to reflect the severity of a hazard, while fast response enables early warning. A highly accurate instrument that does not respond quickly to a dangerous situation is unsuited for service in a safety instrumented function. Similarly, a device whose reading cannot be trusted but responds quickly on exposure to an agent is of little use as a safety device. A good sensor strikes a fine balance between accuracy and speed while rejecting false trips.

Measurement range is closely related to accuracy because a fire and gas sensor is not designed for maintaining high accuracy across its measurement range, but instead is tuned for reliable detection with the range of interest.

Accuracy Examined

Like other performance parameters, accuracy must be appropriately specified based on the characteristics of the hazard. For example, point combustible gas detectors measure gas concentrations in terms of the lower explosive limit (LEL). Alarm set points usually range from 20-25% of the LEL for low alarms and 40-50% of the LEL for high alarms, with both dependent on detection range constraints.

Similarly, toxic gas concentrations are measured in terms of parts per million (ppm), with alarm levels based on fractions of occupational exposure levels or the Immediately Dangerous to Life and Health levels per Walsh et al. 2013. The Table illustrates several types of fire and gas sensors with corresponding typical alarm levels, specified accuracy and response speed.

Fire and Gas Sensor Type	Low Alarm	High Alarm	Accuracy	Response Speed	References
Point Combustible Gas	20 or 25 percent LEL	40 or 50 percent LEL	± 3 percent FS or ± 10 percent applied gas	T60 < 10 s	*FM 6310*
Point Toxic Gas – H_2S	10 or 20 ppm	20 or 50 ppm	± 3 ppm or ± 10 percent reading	T90 ≤ 60 s	*ANSI/ISA-92.00.01-2010*
Point Toxic Gas – CO	100 ppm	200 ppm	± 6 ppm or ± 10 percent reading	T90 ≤ 60 s	*ANSI/ISA-92.00.01-2010*
Open Path Combustible Gas	0.5–1 LEL-m	1–2 LEL-m	± 5 percent FS or ± 10 percent applied gas	T90 < 10 s	*FM 6325*
Open Path Toxic Gas – H_2S	Not Applicable	30–100 ppm-m	± 7.5 percent FS or ± 15 percent applied gas	T90 < 10 s	*ANSI/ISA-92.00.04-2014*
Acoustic Leak Detector	Not Applicable	Background SPL + 5 or 10 dB	± 3 dB	1 s	Not Applicable

Table: *Typical alarm levels with specified accuracy and response speed for fire and gas sensors.*

Accuracy corresponding to the design-basis hazard is critical for fire and gas system design. If accuracy is low, the instrument may fail to respond on demand or be prone to false alarms, as depicted in Figure 1. By contrast—if accuracy requirements are too stringent then no instrument may be available to meet the specification—or an available instrument may be too expensive, unreliable or require excessive maintenance.

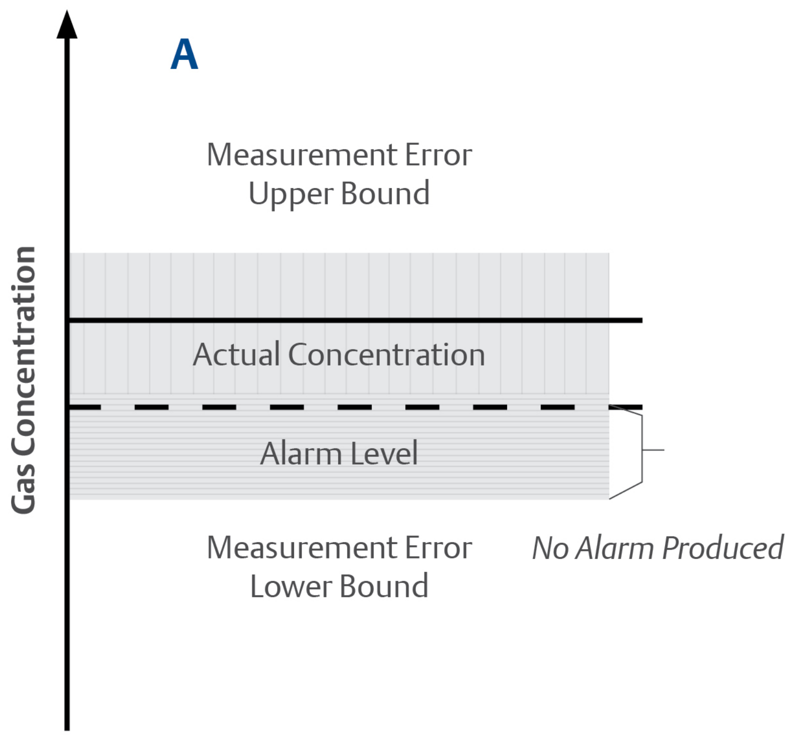

Figure 1A *Device fails to alarm whenever gas concentration reading lies between alarm level and lower bound.*

To gain a better sense of the effects of poor accuracy on sensor performance, assume a sensor is exposed to a gas concentration exceeding the alarm level (Figure 1A). For gas concentration readings falling below the alarm set point but above the measurement error's lower bound, the device does not produce an alarm. Although the device is operating as specified, it is rendered ineffective at providing early warning as configured.

Conversely, a poorly set alarm level may result in false positives. Assume the actual gas concentration lies below the alarm level as shown in Figure 1B. If the measurement error encompasses the alarm level, the device will produce false alarms whenever the gas concentration reading exceeds the alarm level. Any gas concentration reading in the probability space between the alarm level and the upper bound of the measurement error results in this outcome.

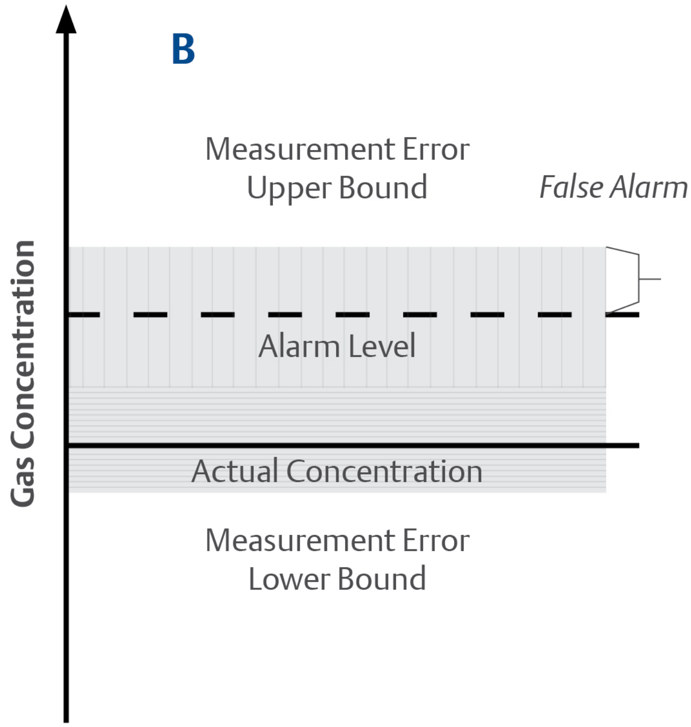

Figure 1B *Device produces false positives whenever gas concentration reading lies between alarm level and upper bound.*

Alarm Limits

Clearly, if the measurement error is small then incidences of failure to respond on demand and false positives are reduced, but the preference should be to eliminate the former as failure to respond is the more dangerous condition. This is done by setting the alarm level at the nominal alarm level minus the measurement error. For instance, if the nominal alarm level is 40% LEL and the device accuracy is ±3% LEL, the instrument should be configured to alarm at 37% LEL.

Because some fire and gas sensors share the same measurement principle with process gas analyzers, it is not uncommon to think of them as requiring the same degree of accuracy, but such characterization can lead to product misuse. Fire and gas sensors are not designed for maintaining high accuracy across the measurement range; rather they are ambient monitors that measure a process variable accurately and reliably to enable early detection. This difference in design principle is illustrated by point combustible gas detectors.

Because hydrocarbon gas detectors are set to alarm at levels below 50% LEL, it is not uncommon for these devices to have greater accuracy at the lower half of their range. For example, the accuracy of Emerson's SC310 catalytic bead combustible gas sensor (Figure 2) is ±3% LEL at gas concentrations lower than 50% LEL and ±5% LEL at gas concentrations exceeding 50% LEL. The measurement error is lower in the portions of the measurement scale associated with alarm level setting.

Figure 2: *Emerson's SC310 catalytic bead combustible gas sensor.*

Range Considerations

Like accuracy, the expected gas concentration range must be taken into account when selecting a gas detector, with gas concentration ranges varying by detector type. For example, a photoacoustic and a point infrared gas detector can both monitor combustible gas concentrations, but the detection ranges differ.

Point infrared detectors are used to measure gas concentrations as a percentage of LEL or a volume fraction. Photoacoustic detectors, by contrast, measure combustible gas concentrations at parts per million, LEL and percent volume fraction.

Methanol has an LEL of 6% volume or 60,000 ppm, and an OSHA-permissible exposure level (PEL) of 200 ppm (260 mg/m3). Therefore, for detection of combustible gas hazards, a point infrared detector is appropriate. The lowest methanol gas reading possible with a point infrared detector is 1.5% LEL or 900 ppm, but a point infrared would not provide information regarding responses below 200 ppm, so a photoacoustic detector with an accuracy of ±10 ppm would be more appropriate if the hazard to be mitigated is occupational exposure to methanol.

As this example demonstrates, gas concentration range must be chosen in relation to the target hazard. Whenever possible, one should select the range so the alarm level is near the midpoint of the measurement scale.

Real World Response Times

Response times for detecting hazardous material releases must be quick, typically within a few seconds. According to the Center for Chemical Process Safety, the response for toxic gas detection should be within 30 seconds (AIChE, 2009). For open path detectors, the time taken to reach 90%of the final reading of target gas concentration (T90) cannot exceed 10 seconds (FM 6325, 2005; ANSI/ISA-92.00.04, 2014). For point combustible gas detectors, T60 must not exceed 10 seconds (FM 6310, 2014). As with alarm set points, improvements in response speed must be weighed against the potential for producing false positives. The Table shows typical response times specified by performance standards.

Although step change response, which is the response in terms of rapid exposure to full scale gas concentration in carefully controlled lab conditions, is a typical form for characterizing response speed, it may not be representative of response times in the field.

In practice, gas detectors are rarely exposed to gas clouds at high concentrations. In outdoor installations, gases may become diluted and stratify on loss of containment, especially when transported far from the point of release by air currents. For indoor installations with a high level of ventilation, detectors near the site of release may be wholly ineffective at picking up leaks.

Consider the Encana incident at the Swan wellsite near Pouce Coupe, British Columbia (BC Oil & Gas Commission, 2010). Slow degradation of a tee in a piping system due to internal erosion led to a release of approximately 30,000 m3 of natural gas containing 6,200 ppm of hydrogen sulfide. Although a few residents near the wellsite heard a “jet-like” noise, the detector at the wellhead did not detect the leak. Instead, a detector at an adjacent wellhead located on the same well pad approximately 25 meters from the leaking well produced an alarm, but the time between the sudden equipment failure and detector response was 27 minutes.

Even if the gas release takes place in an enclosed space, detection may be hindered by slow accumulation, or by a blockage or obstruction created by process equipment. Effective response speed therefore depends on type, number and placement of detectors—in addition to each device’s specified response speed.

Conclusion

Accuracy, response speed, and measurement range are critical parameters for fire and gas sensors. They relate to a device’s performance on demand and influence fire and gas system effectiveness. The parameters must be consistent with the goals of hazard detection and mitigation as defined by a fire and gas philosophy (*ISA-TR84.00.07* 2018).

Applications designed based on fire and gas system performance targets will avoid inconsistent protection levels, over usage, excessive maintenance costs, and employees placing too much or too little confidence in safety equipment.

Alarm levels, which follow from design-basis hazards, inform decisions about accuracy and range. As shown above, some gas sensor models have different accuracy specifications across the measurement scale, suggesting users should select ranges that minimize measurement error at alarm set points.

Response speed should not be considered in isolation since real world conditions rarely require a sensor to respond on direct application of high gas concentrations. One must therefore consider the total response time of the detector, control system and final control elements required for successful mitigation action.

About the Author

Edward Naranjo is director of fire and gas systems for Emerson's Automation Solutions business. He is an ISA Fellow and certified functional safety engineer with 16 years of experience in flame and gas detection. He holds BS and PhD degrees in chemical engineering from Caltech and the University of California, Santa Barbara, respectively, and an MBA from the University of Chicago.

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