Understanding Multi-criteria Technology

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Smoke Detection Basics

It is important to understand the basics of smoke detection so that the following discussions concerning multi-criteria detection can be more readily comprehended. The sensing chambers of the ionization and photoelectric detectors use different principles of operation to sense the visible or invisible particles of combustion given off in developing fires.

Ionization Smoke Detector Operation

A typical ionization chamber consists of two electrically charged plates and a radioactive source (typically Americium 241) for ionizing the air between the plates. The radioactive source emits particles that collide with the air molecules and dislodge their electrons. As molecules lose electrons, they become positively charged ions. As other molecules gain electrons, they become negatively charged ions. Equal numbers of positive and negative ions are created. The positively charged ions are attracted to the negatively charged electrical plate, while the negatively charged ions are attracted to the positively charged plate. This creates a small ionization current that can be measured by electronic circuitry connected to the plates.

Particles of combustion are much larger than the ionized air molecules. As particles of combustion enter an ionization chamber, ionized air molecules collide and combine with them. Some particles become positively charged and some become negatively charged. As these relatively large particles continue to combine with many other ions, they become recombination centers, and the total number of ionized particles in the chamber is reduced. This reduction in the ionized particles results in a decrease in the chamber current that is sensed by electronic circuitry monitoring the chamber. When the current is reduced by a predetermined amount, a threshold is crossed and alarm condition is established. Changes in humidity and atmospheric pressure affect the chamber current and create an effect similar to the effect of combustion particles entering the sensing chamber.

To compensate for the possible effects of humidity and pressure changes, the dual ionization chamber was developed and has become commonplace in the smoke detector market. A dual-chamber detector utilizes two ionization chambers; one is a sensing chamber that is open to the outside air Particulate matter, humidity, and atmospheric pressure affects the sensing chamber. The other is a reference chamber that is partially closed to outside air and affected only by humidity and atmospheric pressure, because its tiny openings block the entry of larger particulate matter including smoke. Electronic circuitry monitors both chambers and compares their outputs. If the humidity or the atmospheric pressure changes, both chambers' outputs are affected equally and cancel each other. When combustion particles enter the sensing chamber, its current decreases while the current of the reference chamber remains unchanged. The resulting current imbalance is detected by the electronic circuitry.

There are a number of conditions that can affect dual-chamber ionization sensors; dust, excessive humidity (condensation), significant air currents, and tiny insects can be misread as particles of combustion by the electronic circuitry monitoring the sensors.

Photoelectric Smoke Detector Operation

Most photoelectric smoke detectors are of the spot type and operate on the light scattering principle. A light emitting diode (LED) is beamed into an area not normally "seen" by a photosensitive element, generally a photodiode. When smoke particles enter the light path, light strikes the particles and is reflected onto the photosensitive device causing the detector to respond.

Smoke detectors are based on simple concepts

Certain design considerations need to be observed. They should produce an alarm signal when smoke is detected, but should minimize the impact of an unwanted signal, which can arise from a variety of causes. In an ionization detector, dust and dirt can accumulate on the radioactive source and cause it to become more sensitive. In a photoelectric detector, light from the light source may be reflected off the walls of the sensing chamber and be seen by the photosensitive device when no smoke is present. The entrance of insects, dirt, drywall dust, and other forms of contamination into the sensing chamber can also reflect light from the light source onto the photosensitive device. Electrical transients and some kinds of radiated energy can affect the circuitry of both ionization and photoelectric smoke detectors and can be interpreted by the electronic circuitry to be smoke, resulting in nuisance alarms. Underwriters Laboratories, Inc. establish the allowable sensitivity ranges for both types of detectors and all are verified by their performance in fire tests. Regardless of their principle of operation all smoke detectors are required to respond to the same test fires.

Considerations in Selecting Detectors

The characteristics of an ionization detector make it more suitable for detection of fast flaming fires that are characterized by combustion particles in the 0.01 to 0.3-micron size range. Photoelectric smoke detectors are better suited to detect slow smoldering fires that are characterized by particulate in the 0.3 to 10.0 micron size range. Each type of detector can detect both types of fires, but their respective response times will vary, depending on the type of fire present.

Building a Multi-criteria Detector

Key Issue

What detection technologies are capable of detecting a broad range of fires and are the least susceptible to nuisance alarms without a restriction (within reason) in the application of the detector?

Recommendation

Photo detectors are well accepted for their ability to detect smoldering fires. The purpose of the photo/thermal multi-criteria detector is to improve the detection of fast flaming fires as well as to increase the immunity to nuisance alarms. In resisting nuisance alarms, the detector will learn its environment and adapt to its conditions such that nuisance alarms are reduced. This will provide a detector that is capable of detecting a broad range of fires without a restriction (within reason) in the application of the detector. This is accomplished in the detector by using onboard algorithms that will monitor the profile of the photo sensor output and the profile of thermal sensors and combine them as discussed in the body of this document.

Analysis

The specifying community, property managers, and building owners have a myriad of fire detection techniques available to them today. Among their choices are single sensing element types of detectors, which include ionization, photoelectric, and thermal technologies. Each type of sensor is optimized for detecting a certain type of fire, such as fast flaming or smoldering. On the other hand, each sensor also has its weaknesses, such as airborne particulate with photoelectric sensors and humidity or high air velocity with ionization sensors.

Today, the market awareness associated with the pros and cons for each type of sensor is substantial when compared to five or ten years ago. This can be clearly seen by the worldwide market shift away from certain types of sensing technologies for one reason or another. An example would be the ionization type detector, which has now fallen out of favor in many commercial applications. Ionization detectors are only accepted in certain regional markets and in most cases with only specific applications in mind. Worldwide only 20% of detectors are ionization. Until recently, ionization detectors commanded a 50% share of the worldwide market.

Because market awareness has increased and consumers are more educated, product designers need to constantly be developing new technologies that can detect fires quicker with fewer unwanted alarms. This need has led to the

development of multi-criteria products that combine different types of sensors into a homogenous assembly to maximize each sensor's advantages.
The multi-criteria's main benefit is superior rejection of unwanted alarms, such as cigarette smoke or shower steam. A simplistic way of looking at the multi-criteria approach is that each sensor's signal is inputted into onboard software algorithms, which then combines them and outputs the results. Essentially, it uses a decision tree with responses at the end of each branch. The end result could either be a decision to alarm or a feedback loop into other software algorithms to refine what the decision will be from the detector. The key factor in this process is time, which in the detection industry is referred to as the "signal-processing period." A note should be made that a multi-criteria detector is not the same as a multi-sensor detector. A multi-sensor detector utilizes mixed technologies that do not interact. Essentially, there is no combined decision making process.

All major smoke detector manufacturers supply these multi-criteria products in a variety of combinations. The decision for today's life safety managers is which combination makes the most sense for their application. To this end, the decision-maker should review the propensity for the different types of fires he or she has in the structure. A review would include the interior and exterior construction material, the expected use and occupancy type(s) of the building, and, to a certain degree, the personal decorating accouterments which occupants bring with them.

The use of photoelectric type smoke detectors within most office or light industrial environments is generally accepted due to the high probability of a smoldering fire. This is due to the fuel load and ignition sources available in these environments. However, installing a true fast flaming fire sensor could better protect certain locations within these structures, such as a chemical storage area. Generally, these fast flaming areas are isolated locations that have controlled access or are not considered high traffic areas.

The environment in which a detector resides is yet another element that affects a detector's performance. Each detector location is a unique environment. A hallway is different then a conference room. A light manufacturing area is different than a copy room. A storage area is different than the lobby. In other words, each area has a unique set of criteria that includes occupancy, as mentioned above, but also includes air movement and location transition periods. A conference room or auditorium is occupied or unoccupied. A light manufacturing area is in use during the week, but vacant over the weekend. These transition periods will affect the detectors through changes in temperature, air velocity, and stratification, as well as the particulate count in the air. Essentially, the detector's local environment is transitioned to a new, undetermined environment for a period time or permanently. The installing company for the life safety system can only plan for the environment that is on the construction plans. He or she must rely on the building owner to notify them of the changes within his or her property. This is where a life safety system gets left behind because it cannot transition to the new environment. A copy room that has been remodeled into a storage area will not have optimized detection for the new environment and occupancy. This could have been achieved through a more sensitive setting or use of an ion detector.

The question that arises in specifying protection, therefore, is what detector or types of detectors are best suited for a structure with a mixed or changing environment? The majority of these structures are protected with a photoelectric type sensor. Ionization type sensors should be used in the specific locations where a fast flaming fire could take place. Today, with the advent of multi-criteria technology, better choices exist. As mentioned above, the main advantage of the multi-criteria technology is nuisance alarm rejection. This is appropriate because local municipalities are enforcing strict false alarm regulations that include fines. In many cases, these fines are substantial, including being billed on an annual escalating scale. So what are the best choices? Let's explore them.

After considering the alternatives, multi-criteria with a photoelectric element should be at the top of the list. This sensor will provide the broadest range of fire detection for most applications. The next sensor selection should complement and enhance the photoelectric sensor. In addition, provide the capability of helping to reject nuisance signals. The choices are realistically an ionization or thermal element. The ionization sensor is a true fast flaming sensor that should be employed exclusively for those areas that require this type of detection.

The combination of the ion and photo in multi-criteria detection provides marginal complementary fire detection at best. Actually, in a fast flaming fire scenario, the combination of the two would, in fact, slow down the response time because of the on-board signal processing (software algorithms). An understandable depiction of this signal processing time is that the signals are combined in an "AND" function. One signal cannot arrive to an alarm decision without the other (multiplication: Photo Signal=0 times Ion Signal=8 combined = No Alarm). Remember that the focus of the multi-criteria is nuisance alarm rejection. So an ionization signal will be viewed as a possible nuisance alarm until it is verified through a complementary sensor. When the ion signal strength is strong enough to override further processing, an alarm signal will be sent. But, a potential catastrophic delay has already transpired. In review, if an area is a true fast flaming fire location then a stand alone ion sensor should be applied for best detection results.

This leaves the thermal sensor to best complement the photoelectric sensor for comprehensive building and life safety protection. A thermal signal is regarded as a physical by-product of a fire in all cases. The thermal will even help detect a fast flaming, low visible smoke fire by providing a complementary fire signal to the photo signal which ordinarily on its own would take longer to alarm. In addition, a lack of thermal signature can be used to "process out" a possible transient photo signature such as cigarette or pipe smoke. In conclusion, the photoelectric and the thermal sensors provide the best combination of sensors for a multi-criteria product.

With the selection of the sensing elements of the detector complete, the focus should then shift to the method for processing the signals. The detector electronics and algorithms need to maximize the strengths of the sensing elements and minimize their weaknesses thereby optimizing response time and reducing the opportunity for unwanted alarms. In addition, the detector should be able to account for the changing environments present in many offices, factories, and retail establishments. Dynamically changing onboard detection parameters and alarm thresholds are key to maintaining a fire protection system that is optimized at all times.

Acclimate™

Acclimate, from System Sensor, is a revolutionary multi-criteria smoke detector. Acclimate utilizes the accumulated knowledge of System Sensor's years in smoke detector design and manufacture. Acclimate is, fundamentally, an intelligent photoelectric smoke detector with supplementary 135°F (57°C) thermal. In reality, the product does much more than that simple product description implies. By using an on-board microprocessor, we have been able to incorporate product features not available previously in any other product, creating a true multi-criteria smoke detector.

Acclimate's key feature and the one from which it derives its name is the detector's ability to automatically adjust its smoke sensitivity according to the needs of its environment. No longer is a facility hampered by detectors that are fixed at one arbitrary sensitivity setting. A facility, whether it be an office or a shopping mall, is a dynamic entity. People come and go, shops close and others open, and usage changes. Before Acclimate, an installer would need to individually set multiple operating parameters for each detector such as sensitivity, pre-alarm, and alarm verification, based on his or her own education and experience.

Today, a smoke detector's sensitivity is inexorably tied to its propensity for false alarms despite some successful efforts to reduce their susceptibility. Because of this, most fire alarm experts would agree that detectors should be set less sensitive in areas that have more airborne particulate — so called "noisy" areas. Acclimate automatically adjusts its sensitivity according to the amount of noise the sensor sees.

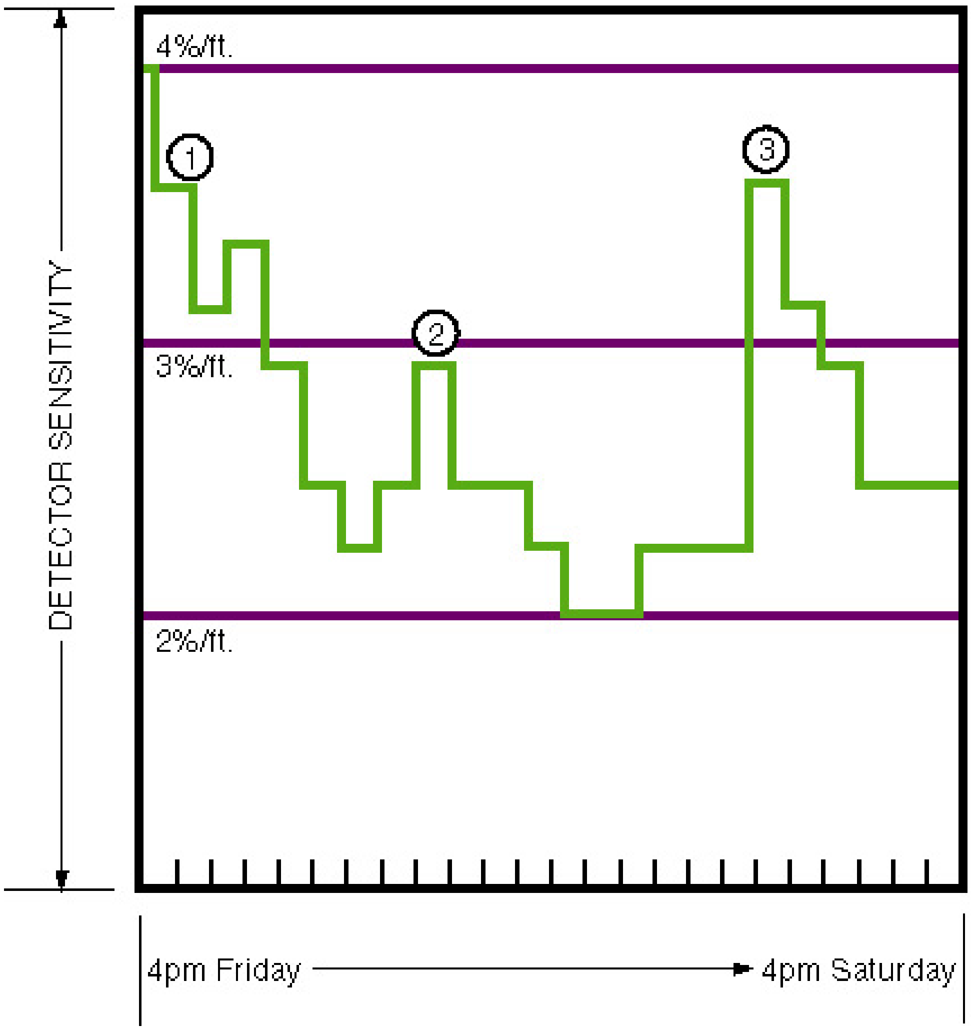
System Sensor has also incorporated other unique qualities into Acclimate beyond its signature feature. Acclimate is designed to ignore short term nuisance conditions that other detectors interpret as alarm. Acclimate uses sophisticated fire detection software algorithms that look for trends in the signals from the smoke sensing chamber. If the signal is not a consistent, gradual build up characteristic of a real fire, Acclimate rejects the signal as a nuisance source.

Finally, Acclimate makes full use of the synergies between the smoke and heat sensing elements. Acclimate alarms at its fixed temperature set point of 135°F (57°C); but it also uses the thermal element to sensitize the photoelectric detector. If Acclimate experiences a temperature rise exceeding a given rate, it will reduce the amount of time required to produce an alarm signal.

The graphs on the following pages further illustrate two of the unique features of Acclimate.

Acclimate is the one smoke detector that can make sense of all your changing environments.

Figure One



This graph plots the actual sensitivity of an Acclimate smoke detector over a 24 hour period. The detector was mounted in a large open office area at System Sensor in St. Charles, Illinois. Acclimate always powers up at 4 percent per foot obscuration and becomes more sensitive over time, if possible.

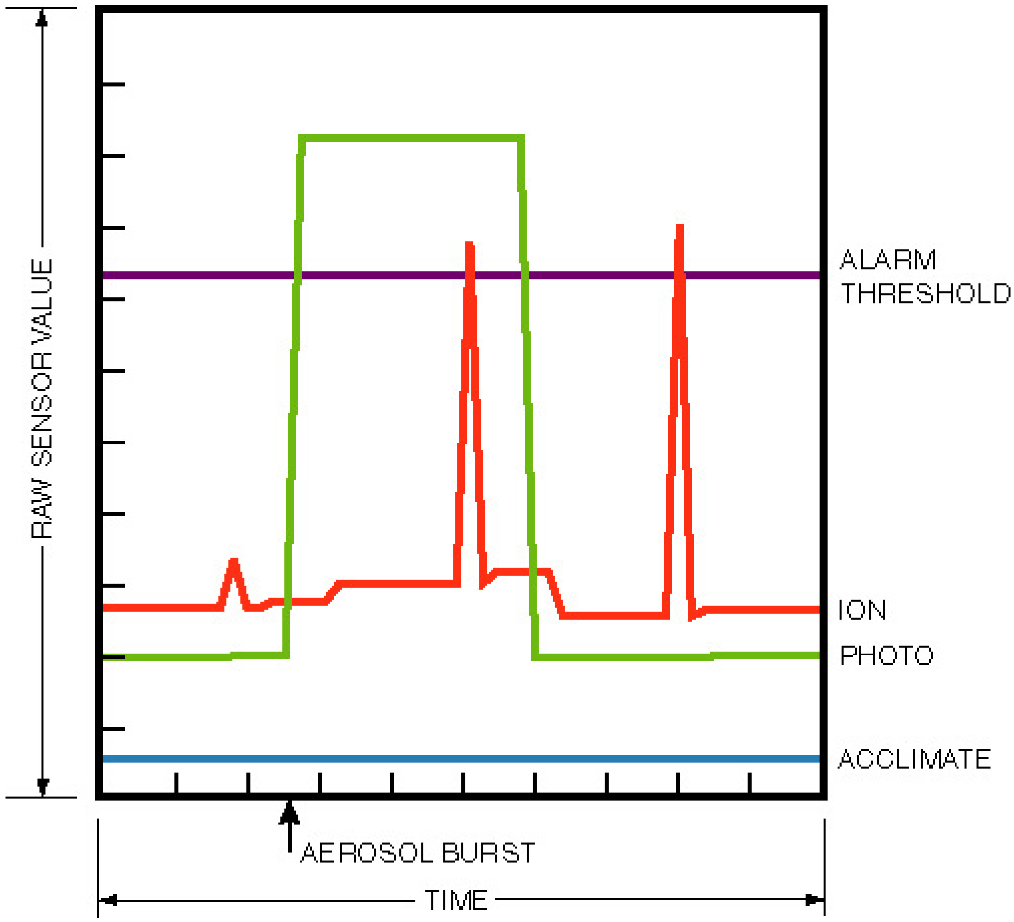
The graph starts at 4 PM on a Friday, just as workers are beginning to leave for the week (point 1 on graph). The detector gradually gets more sensitive over the next several hours.

At point 2 on the graph, there is a decrease in detector sensitivity due to an increase in airborne particulate. This likely occurred due to cleaning operations such as vacuuming in adjacent office areas. After that, the detector again becomes more sensitive.

At point 3 on the graph, there is an even larger decrease in detector sensitivity midday Saturday. This is likely because of a large scale dust producing activity like floor buffing. After that the detector sensitivity again increases.

Acclimate's sensitivity is automatically adjusting according to changes that are occurring in its installed environment.

Figure Two



This graph shows the sensor responses of a standard System Sensor photoelectric, ionization, and Acclimate detector. At the indicated point in time, the detectors were subjected to a one second burst of canned aerosol smoke detector tester (Home Safeguard model 25S). The graph shows the photoelectric detector responding first and immediately reaching saturation. The ionization detector responds with a slight delay (as expected with canned aerosol) and reaches an alarm level. Acclimate ignores the aerosol burst entirely due to its short duration.