MODULE - 5
FIRE DETECTORS

This module will introduce the student to the following:

- Fire Signatures
- Various types of Smoke Detectors and theory of operation.
- Various types of heat detectors and theory of operation.
- Various types of flame sensing detectors and theory of operation.

Following successful completion of this module, the student should be able to:

- Discuss various types of fire signatures produced.
- List types of smoke detectors and types of fires they are applied.
- List operational differences between smoke detector types.
- List types of heat detectors and types of fires they are applied.
- List types of flame sensing detectors and types of fires they are applied.
- List various NFPA codes that apply to fire detection devices.

FIRE SIGNATURES

From the moment a fire begins, a number of changes occur in the surrounding environment. These changes from the ambient conditions are termed “fire signatures” and manifest themselves in the forms of smoke, heat, light, and gas. Appropriate detection devices are selected to respond to one or more of these fire signatures.

SMOKE PROPERTIES

Smoke involves the thermal release of large quantities of solid and liquid particles into the surrounding atmosphere. The size of these particles can range from 5x10 $_{4}$ to 10 μm (micrometers). These particles that are suspended in the air are termed aerosols. The aerosol particles that are produced in a fire are classified into two types of fire signatures according to their light scattering properties. Namely, invisible and visible fire signatures.

Generally, flaming fires burn hotter and result in more complete combustion, and produce smaller aerosol (smoke) particles (approximately 0.3 µm or less). These smoke particles are classified as invisible due to the inability to scatter light.

Generally, ionization detectors are most effective with invisible smoke particles.

Smoldering fires and fires that produce low temperature combustion products produce larger aerosol (smoke) particles (larger than 0.3µm). These particles scatter (reflect) light efficiently and are classified as visible particles. Generally, photoelectric detectors are most effective with visible smoke particles, and are applied where smoldering fires are anticipated.

SMOKE DETECTORS

Smoke detectors are identified according to their operating principles, namely ionization and photoelectric type smoke detectors.

Ionization Type Detectors:

Ionization detectors operate by using a small amount of radioactive material (Americium 241) to ionize (electrically charge) the air within a sensing chamber in the detector. The ionization of the air permits the air to conduct electricity between two electrodes within the chamber. As smoke enters the chamber, the smoke particles become ionized and reduce the conductivity of the air between the electrodes. This reduction in conductivity between the electrodes is sensed and will cause the detector to respond. Generally, these detectors are the lowest cost, and respond to smaller smoke particles (the result of high-energy fires). These detectors also have the greatest false alarm rate of smoke detectors from cooking and other non-fire sources.

Photoelectric Type Detectors:

Photoelectric detectors operate on one of three different principles:

1. Light obscuration principle
2. Light scattering principle
3. Cloud Chamber principle

Light obscuration principle photoelectric detectors operate by projecting a light beam onto a photosensitive device. As smoke particles enter the chamber between the light source and the photosensitive device, the light intensity diminishes and initiates an alarm at a predetermined level. Most light obscuration detectors are the beam type and are used for smoke detection of large open areas.

Light scattering principle photoelectric detectors operate with a light source and a photosensitive device. However, unlike the light obscuration detector, the photosensitive device is not in the light beam path. As smoke particles enter the sensing chamber, light is reflected (scattered) from the smoke particles onto the photosensitive device causing the detector to respond.

Cloud chamber principle detectors operate by drawing an air sample from the protected area into a high humidity chamber within the detector. After the air sample has been raised to the high humidity, the pressure is slightly lowered. If smoke particles are in the chamber, a cloud will form. The density of this cloud is measured with a photoelectric device. When the "cloud" reaches a predetermined density, the detector will respond with an alarm. Cloud chamber detectors are normally used where early detection is required such as in computer rooms.

HEAT DETECTORS

Thermal detection systems are designed to operate from the thermal output of a fire. The heat generated is dissipated throughout the area by laminar and turbulent convective heat flows created by heated gases. Turbulent flow is induced and regulated by the fire plume thermal column effect of heated air and gases above the fire surface. The fire plume characteristics and the ceiling jet flow of convective heated gases are determined by the heat release rate of the diffusion flame combustion and ceiling height. (NFPA 72 should be consulted with regard to thermal detector spacing for varying ceiling heights). Additionally, variables such as proximity to walls, room configuration, and ceiling obstruction can affect the transport of convective heat flow necessary for thermal detector operation.

A heat detector's sensitivity to a given fire situation depends on the gas temperature which is related to the ceiling height, the radial position of the detector, and the fire's heat release rate.

Heat detectors are identified according to their operating principles, and are classified into the following types :

1. Fixed Temperature Detectors
2. Rate-of-Rise Detectors
3. Rate compensated Detectors

FIXED TEMPERATURE HEAT DETECTORS

Fixed temperature heat detectors are the simplest type of heat detector and are designed to alarm when the sensing element reaches a predetermined temperature. (Actually, a sprinkler head operates upon this same principle.) Generally, the surrounding air temperature must be considerably higher than the heat detector rating in order to raise the heat detector element to the operating temperature. This condition is known as thermal lag. Generally, fixed temperature heat detectors are constructed with fusible element type, continuous line type and bimetal type.

The fusible element type operates similar to a sprinkler head where a eutectic metal melts at a predetermined temperature releasing a spring under tension and initiates an alarm signal. This type of detector is a spot type detector.

The continuous line type heat detector generally consists of parallel wires separated by a heat resistive insulation. When the insulation melts away at a predetermined temperature (from a fire), the wires come into contact and an alarm is initiated. These detectors are often used as fire detection devices within tunnels, cable trays, etc.

The bimetal type of heat detectors relies on two joined metals with different coefficients of expansion. As the metals expand (at different rates) when heated, the bimetal will deflect toward the metal with the lower coefficient of expansion. This deflection is normally designed to close a contact and initiate an alarm.

RATE-OF RISE HEAT DETECTORS

Rate-of-rise heat detectors are designed to function when the rate of ambient temperature increase exceeds a predetermined value, usually 12°F - 15°F per minute. These detectors are designed to accommodate normal changes in the ambient air temperature, which are anticipated under normal (non-fire) conditions.

One type of rate-of-rise detector employs pneumatic tubing filled with air with a relief vent. When the air is heated (within the normal conditions), the air will expand with the excess volume exhausted through the vent port before the pressure can build. Air expanding at a rate that exceeds the relief capacity of the vent, will build pressure and initiate an alarm. These types of detectors are available as spot and line types.

RATE COMPENSATED DETECTORS

Rate compensated heat detectors are designed to initiate an alarm when the temperature of the surrounding air reaches a predetermined level, regardless of the rate of temperature rise.

The detector is essentially constructed with temperature sensitive contacts within a stainless steel shell. The coefficient of expansion of the shell is different than the internal contacts. This rapid increase in air temperature will cause the shell to expand before the internal contacts, producing a signal (similar to a rate-of-rise detector). In the case of a slow heat release rate from a fire, the unit (shell and internal contacts) heats up more evenly and produces a signal at the predetermined temperature rating of the detector (similar to a fixed temperature heat detector).

These detectors are designed to eliminate the thermal lag associated with a fixed temperature detector as well as the problem of false alarms and the risk of missing slow heat release combustion that are inherent with rate-of-rise detectors.

OPTICAL FLAME DETECTORS

Optical flame detectors are the fastest responding type of detector since these detectors rely on the visible and invisible radiation given off from a heat source (and travels at the speed of light), and are usually applied in high hazard areas such as fuel loading platforms, industrial process areas, hyperbaric chambers, vaults, high ceilings, and atmospheres in which explosions or very rapid fires can occur. Flame detectors are designed to respond to radiant energy both visible and invisible to the human eye. Essentially, flame detectors must be located to “see” the fire so avoidance of obstructions is critical. (One exception to this is the IR detector which can respond to reflected levels of optical radiation. For instance, a fire out of the view of the detector can reflect optical radiation off a wall which can be detected by the IR detector.) Basically, there are three general types of optical flame detectors:

1. Infrared type flame detectors
2. Ultraviolet type flame detectors
3. Combination IR/UV type flame detectors

INFRARED (IR) TYPE FLAME DETECTORS

Infrared type flame detectors are normally used to protect large open areas where an immediate, flame-producing fire is expected such as in the protection of flammable liquid hazard. IR detectors are constructed essentially of a lens and filter system that screens out unwanted wavelengths and focuses the incoming energy on a photovoltaic or other type cell that is sensitive to infrared energy. These types of detectors often also measure the infrared radiation emitted from a flame (spiking at the 4.3 micron peak radiation wavelength due to the presence of concentrated carbon dioxide within the flame) and characteristic flame flicker associated with the flaming mode of a fire that is in the 5 –30 Hz frequency range. Infrared detectors can be subject to interference and false alarms from solar radiation if not properly applied. One method employed is to use multiple IR detectors to measure the amount of radiation in two or more wavelength bands to discriminate between a flame and other IR sources.

ULTRAVIOLET (UV) TYPE FLAME DETECTORS

Ultraviolet type flame detectors are designed to respond to optical radiation in the ultraviolet wavelengths (wavelengths below 4,000 Angstrom∗, usually in the 2800 – 3000 Angstrom range) primarily emitted by higher intensity flames. One drawback is that solar radiation can extend to as low 2900 Angstrom, while the detector must be able to respond to fire induced optical radiation below 2900 Angstrom. Most detectors manufactured are effective in discriminating between solar and fire induced radiation. These detectors are normally applied where the detector can be located reasonably close to the expected ignition source and the background can be protected from other sources of ultraviolet radiation. One notable application for UV detectors is for use in explosion suppression systems. UV flame detectors are essentially solid state devices employing silicon carbide, aluminum nitride, or gas filled tubes that measure the flame component wavelength range between 0.17 – 0.30 microns∗∗ which are insensitive to both sunlight and artificial light.

∗ 1 Angstrom = 1 / 10,000,000,000 meter
∗∗ 1 micron = 1/1,000,000 meter

Combination (UV/IR) type flame detectors are flame detectors using both of the flame-sensing principles described above for greater discrimination between fire and non-fire radiation sources.