Fire Detection System: An Overview

Arief Rahman Thanura
Process & Control Engineer
VICO Indonesia, LLC
Member of ISA

Introduction

Fire accidents had happened all around the world and more concern raised from these accidents. The loss human life is the main concern on the industry not forgetting the loss of property.

Fire Alarm Signaling System is an important element in Fire protection system as a means to annunciate the present of a Fire hazard in the plant or premises. Proper design of a fire alarm signaling system, however, requires understanding of fire itself-its by product, or “fire signatures”; its effects; how it can be detected; and importance of installing a fire alarm signaling system.

Fire Signature

Fire signature is defined as any changes in the ambient (surrounding environment) condition due to a fire.

There are some Fire signatures as explained below:

A. Aerosol (Smoke) Signatures

When fire occurs due to combustion, very large numbers of solid and liquid particles released into the atmosphere. The size of particles ranges from 5×10^{-4} micrometers to 10 micrometers. These particles, suspended in air is called aerosol and, when produced by fire, usually called SMOKE.

Figure-1 below shows how smoke forms due to fire.
At the “incipient stages, the heating materials produces sub-micron particles ranging in size from 5×10^{-4} to 1×10^{-3} micrometers. These particles are generated at temperatures well below ignition temperatures.

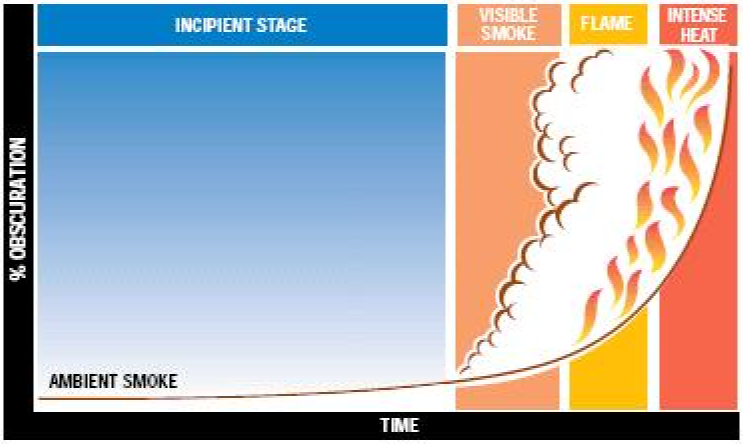

Figure-1 : The smoke formation "stages"

As heating of material progresses toward the ignition point temperature, the concentration of invisible smoke increases to the point where larger particles are formed by agglomeration. As this process continues, the particle size distribution becomes log normal, with the most frequent particle sizes in the 0.1 to 1.0 micrometer range.

The visible smoke can occur prior to ignition and is usually initiated at temperatures several hundreds degrees higher than the thermal particulate point (Thermal Particulate Point is the temperature at which sub-micrometer size particles are generated from materials).

B. UV and IR Radiant Energy

With exception of acetylene and other highly unsaturated hydrocarbon, the infrared emission from hydrocarbon particles is particularly strong when particles are in 4.4-micrometer region (due to CO2) and in 2.7-micrometer region (due to H2O vapor). In these regions, CO2 and water in the atmosphere reduces the sun infrared by absorption.

The modulation of the energy output level due to flame flicker is another signature that affects the infrared signal from flame. This flicker is characteristic of flame and has a frequency range of 5 to 30 Hz.

Some manufactures, like Detronics^{TM}, uses both the CO2-water vapor and flicker signatures to provide reliable flame detection while reduces the "noise" from non-fire infrared sources.

The Ultraviolet (UV) fire signatures appear in flames as emissions from Hydroxal (OH), Carbon dioxide (CO2) and Carbon monoxide (CO), ranging in size from about 0.27 to 0.29 micrometer.

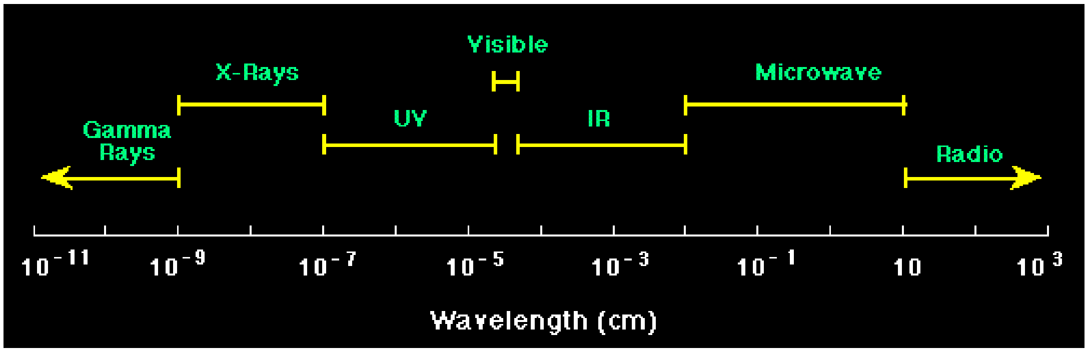

Figure-2 : UV/IR wavelength of the flame

C. Thermal Energy

Convected thermal energy from a fire causes an increase in the air temperature of the surrounding environment.

In contrast to smoke and radiant energy, convected thermal energy signatures often appear well after life-threatening conditions have been reached from excessive smoke and/or toxic gas concentration.

D. Gas Signatures

One of the gas signatures during fire is the reduction of oxygen content, which is called "oxygen depletion signature".

Other gas signature is what is called "evolved gas signature"; addition of gases that normally not present in the atmosphere. Some gases that normally present during fire is CO (Carbon Monoxide).

Type of Detectors

A. Smoke Detector

Based on their operation principle, not the installation, there are two types of the smoke detectors:

1. Ionization Type Smoke Detector
2. Photoelectric Type Smoke Detector

Ionization Type Smoke Detector

A typical ionization chamber consists of two electrically charged plates and a radioactive source (typically Americium 241) for ionizing the air between plates.

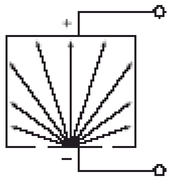

Figure-3 : Particle Radiation Pattern

The radioactive source emits particles that collide with the air molecules and dislodge their electrons. As molecules lose electrons, they become negatively charged ions. The positively charged ions are attracted to negative plate, while negatively charged ions attracted to positive plates (See Figure-3).

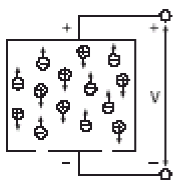

Figure-4 : Ion Distribution

This created a small ionization current that can be measured by electronic circuitry connected to the plates ("normal" condition in the detector). (See Figure-4).

As particles of combustion enter the ionization chamber, ionized air molecules collide and combined with them (See Figure-5). 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.

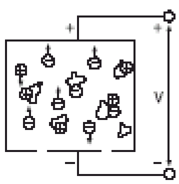

Figure-5 : Ion and Particles of combustion distribution

Below is the example of smoke detector.

Figure-6 : Smoke Detector (By Permission from Kidde)

Photoelectric Smoke Detector

There are two principles of the Photoelectric Smoke Detector:
1. Photoelectric Scattering Smoke Detector
2. Photoelectric Obscuration Smoke Detector

Both types uses principle that the smoke produced by fire affect intensity of a light beam passing through air. The smoke can block and obscure the beam.

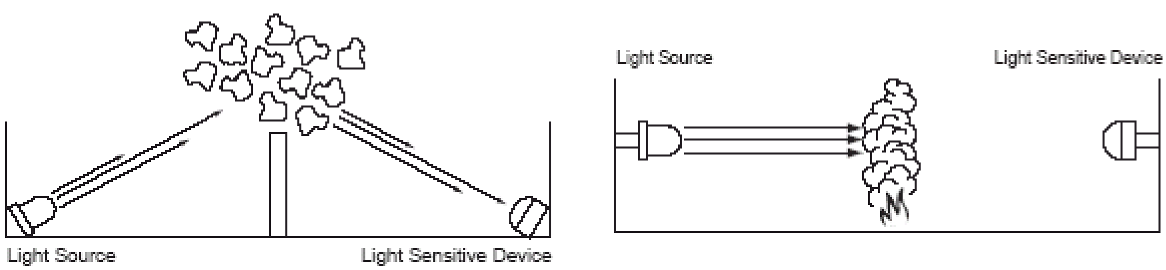

Figure-7 : Light Scattered and obscured by smoke.

Take an example of the photoelectric obscuration smoke detector.

In the normal condition the light received by Light sensitive device (Normally LED) has a certain voltage. Due to obscuration, the voltage received by Light Sensitive Device is reduced. The alarm will be triggered when the voltage crosses the threshold.

The projected beam smoke detector uses the Photoelectric Obscuration principle as explained above.

B. Flame Detector

Three types of the flame detectors are presented here:

1. UV Flame Detector
2. IR Flame Detector
3. UV/IR Flame Detector

<u>UV Flame Detection</u>

The UV flame sensor provides the fastest and most sensitive flame detection. However, there are many nuisance could cause UV flame sensor to active. Some of the non Fire UV source that could cause a false alarm in the UV sensor are Welding arc, metal grinding, lightning or even Sun.

The UV sensor is very prone when it is installed in the open space where sun light normally present. In contrary, most of UV sensor is used in the turbine enclosure where UV source "noise" such as sun, welding, etc-etc does not present.

Figure-8 : Example of the UV Sensor (Detronics)

<u>IR Flame Detection</u>

The IR flame sensor also not immune to some of non-fire IR source such as hot turbines, reactors, boilers etc-etc, unless some additional feature is added to sensor that can distinguished the IR fire signal from these "background noise" IR sources.

Figure-9 : Example of the IR Sensor (By permission from Detronics)

UV/IR Flame detection

Considering the weakness of the UV and IR when they are used as a single sensor, the UV/IR combination sensor is used. The fire alarm active ONLY if both UV and IR sensor are activated.

Figure-10 : Example of the UV/IR Sensor (By permission from Detronics)

It can be seen that there are two sensors installed in this flame detector. One for UV and the other is for IR in one compartment.

Triple-IR Flame Detection

The newer Triple-IR sensor is also available to reduce the fault alarm. Detronics Triple-IR flame detector, for example, include the flickering frequency detection to reduce the fault signal in their software algorithm in the sensor (see Flame radiant energy fire signature).

Figure-11 : Example of the Triple-IR Sensor (By permission from Detronics)

C. Heat Detector

There are three basic types of heat detectors :

1. Fixed heat detector
2. Rate Of Rise heat detector
3. Combination of Fixed & Rate Of Rise heat detector

Figure-12 : Example of the Heat Detector (By permission from Kidde)

In the fixed heat detector, the detector is designed to initiate an alarm when the temperature of the operating element reaches a specific point.

The rate of rise heat detector will function when the rate of temperature increase exceeds a predetermined value, typically around 12^{o}F to 15^{o}F per minute (7 to 8^{o}C per minute).

Rate of rise detectors are designed to compensate for the normal changes in ambient temperature [less than 12^{o}F (7^{o}C) per minute] that are expected under nonfire conditions.

D. Gas Detector

There are two types of Gas Detector mostly used by industry:

- Catalytic Based Gas Detector
- Photoelectric Gas Detector

Figure-13 : Example of the IR Heat Detector (By permission from Detronics)

References :

1. Bukowski, Richard W, and O’Laughlin, Robert J, “Fire Signalling System”, National Fire Protection Association, 1994.

2. System Sensor, System Smoke Detector - Application Guide, A1005-1003-02, 2002