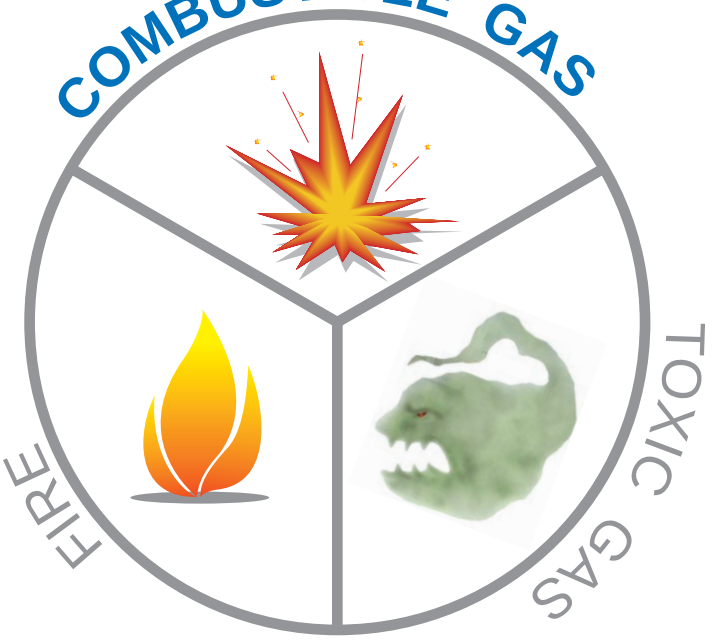
Training Module

Describe Fixed Combustible Gas Detection Systems



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- Performance Check
- Job Aid

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Training Objectives

Upon completion of this training kit, you will be able to:

- Describe the purpose and importance of fixed combustible gas detection systems
- Describe flammable and combustible gas measurement, including:
  - lower explosive limit
  - upper explosive limit
  - combustion zone
- Describe the components of fixed combustible gas detection systems
- Describe fixed combustible gas detection system alarms
- Describe calibration and testing of fixed combustible gas detection systems
- Describe preventive maintenance of fixed combustible gas detection systems

Prerequisite: *Describe Flammable Gas Measurement*

1 Introduction

Combustible Gas
A gas that burns.

Flammable Gas
A gas that can be easily ignited. Flammable gases typically vaporize more readily and ignite at lower temperatures than combustible gases.

Fixed combustible gas detection systems are used to detect the presence of flammable and combustible gases. Combustible gas detection systems protect people, equipment, and materials at locations where combustible or flammable gases or liquids are produced, used, stored, or handled. Combustible gas detection systems are used by industries such as:

- oil and gas (production, refining, pipeline, and sales)
- mining
- chemical and petrochemical processing
- waste/wastewater storage and treatment
- manufacturing
- warehousing and transportation

This training kit is one of a series of three HDC training kits that describe fixed detection systems commonly used in industry. The other two kits are:

- *Describe Fixed Toxic Gas Detection Systems*
- *Describe Fire Alarm Systems*

All three training kits describe the components, installation, operation, calibration, testing, and maintenance requirements of fixed detection systems. The kits are for operators and maintenance personnel responsible for the safe and effective operation of fixed gas detection systems and fire alarm systems. Generic troubleshooting techniques are also presented.

Combustible gas detection systems detect combustible gases and vapors released as a result of:

- leaks of combustible gases or liquids
- volatile emissions of combustible gases
- spills of combustible liquids

Early detection of flammable and combustible gases may assist operators and maintenance personnel to prevent a fire and/or explosion from occurring.

To be consistent with the terminology used by gas detection system manufacturers, this training kit uses the term *combustible* to include *flammable* and *combustible* gases.

Combustible gas detection systems:

- detect the presence of combustible gas
- measure the concentration of the combustible gas
- annunciate (activate or display) alarms when the system detects that the combustible gas concentration in air has reached the designated alarm setting. Alarms notify personnel to stop work activities until the cause of the alarm is identified and corrected.
- shut down equipment and processes when the system alarms. Equipment and processes are shut down to:
  - prevent or reduce further gas leakage
  - remove sources of ignition (e.g., sparks from grinders)

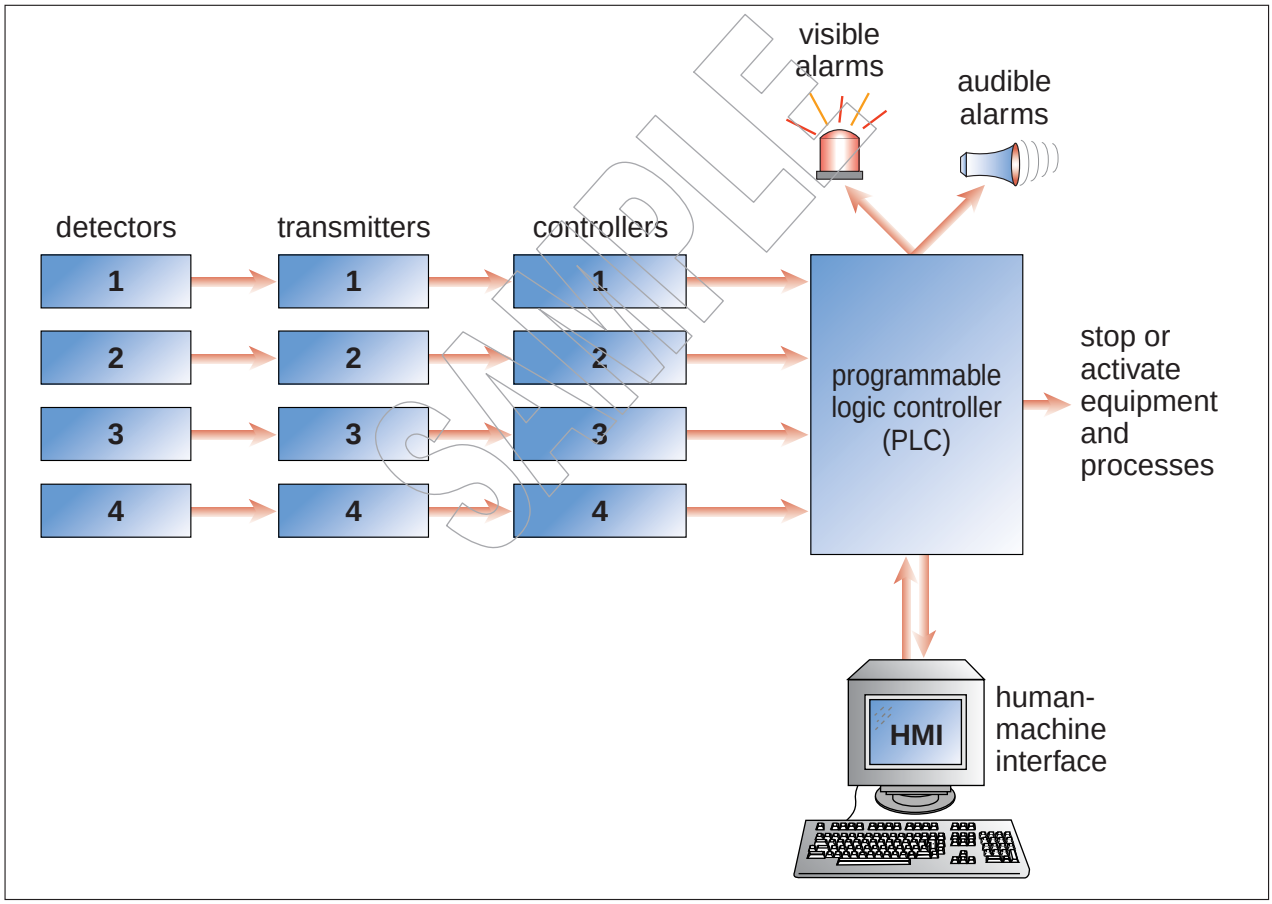
This kit provides instruction on fixed combustible gas detection systems and their application. The kit does **not** endorse or promote any specific model, manufacturer, or supplier.

Portable (hand-held) combustible gas detectors may be used in conjunction with fixed combustible gas detection systems. This training kit does **not** describe portable gas detectors.

2 Fixed Combustible Gas Detection System Overview

Figure 1 illustrates a typical fixed combustible gas detection system.

Figure 1—Typical Fixed Combustible Gas Detection System



Detectors (sometimes called sensors or monitors) are permanently mounted (fixed) in locations where a combustible gas may be present. The detector is electrically connected to the system controller (either directly or via a signal transmitter). The controller continuously monitors the electrical signal

transmitted from the detector; when the detector detects the presence of a combustible gas, the signal changes. The controller measures the change and calculates the concentration of the combustible gas.

Transmitters amplify the signal from the detector and transmit the signal to the controller. In some systems, detectors transmit signals directly to the controller, without using transmitters.

Controllers are usually installed in non-hazardous areas such as control rooms. The controller processes the signal from the transmitter (or detector) and provides readouts, status indicators, and output signals. When hazardous concentrations of combustible gas are detected, the controller either:

- directly operates alarm devices, activates ventilation systems, and shuts down processes, or
- sends an output signal to a programmable logic controller (PLC), which operates alarm devices, activates ventilation systems, and shuts down processes

A controller receives signals from only one detector or from as many as 24 detectors, depending on the controller model.

Programmable logic controllers are computers which receive input signals from field devices (inputs) and then solve logic functions and perform calculations to trigger appropriate actions (outputs). PLCs receive input signals from the fixed combustible gas controllers. When the PLC receives signals indicating elevated combustible gas concentrations, the PLC:

- activates audible and visible alarms
- opens, closes, starts, or stops equipment such as fans, valves, motors, compressors, pumps, and flares
- sends the data to a human-machine interface (HMI) such as a controller LED display

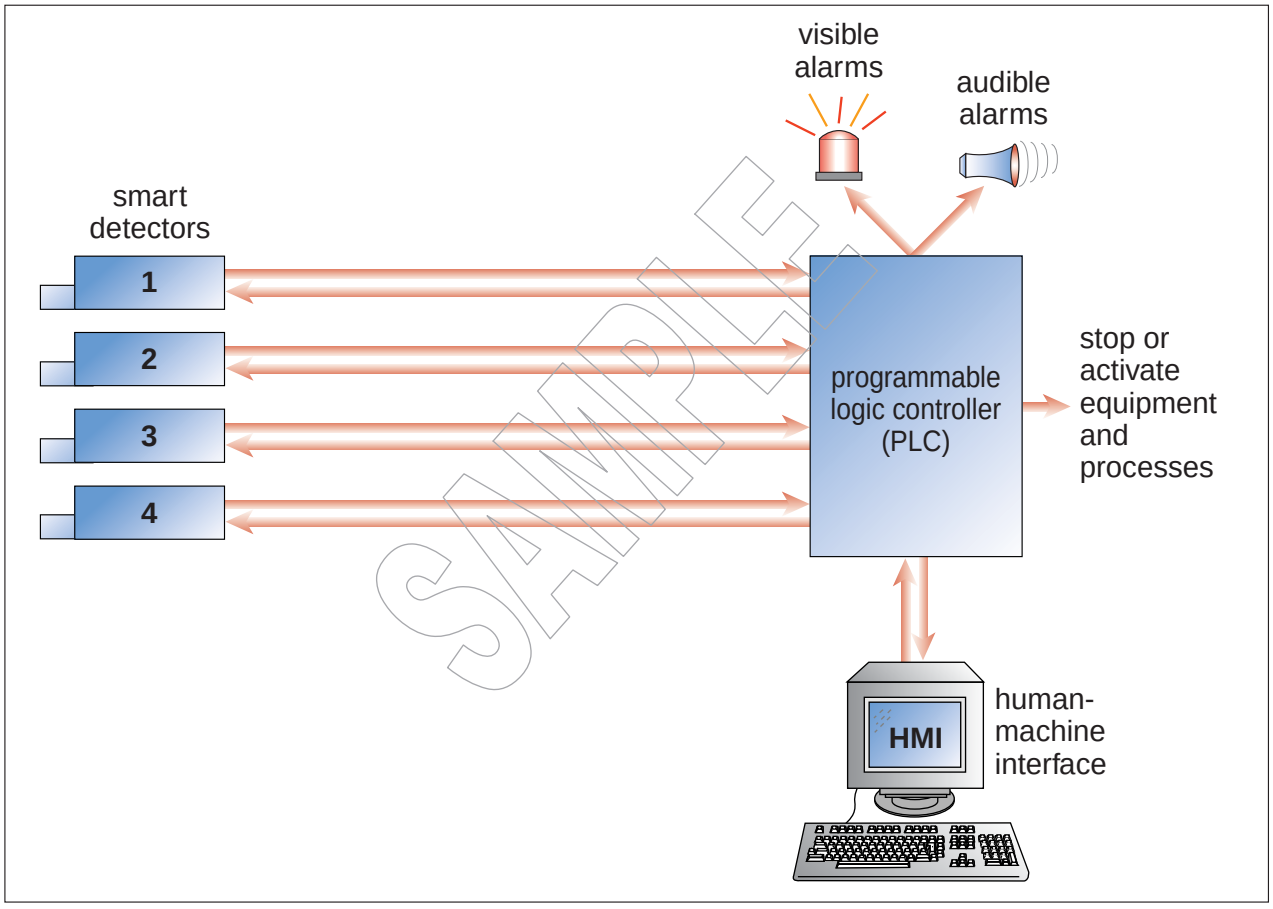
Smart detectors (also called smart or intelligent sensors) combine the functions of the detector, transmitter, and controller in one device, including functions such as:

- displaying combustible gas concentrations
- transmitting signals directly to a PLC

- storing calibration and alarm settings (and in some models, logging data)
- activating alarms
- activating or stopping equipment and processes

Figure 2 shows a typical fixed combustible gas detection system with smart detectors.

Figure 2—Typical Fixed Combustible Gas Detection System with Smart Detectors



Human-machine interfaces (HMIs), including annunciator panels, provide an interface between personnel and the PLC. HMIs for fixed combustible gas detection systems may include:

- keypads, buttons, switches, and LED displays on controllers, transmitters, and smart detectors
- wall displays
- computer workstations

Alarms notify personnel when combustible gas in the vicinity of the detector reaches the designated limit (alarm setting). Several types of alarms are usually provided, including:

- text or icon (symbol) displays on the HMIs (annunciator panel, SCADA terminal, monitor)
- visible alarms, such as strobe lights and beacons. Visible displays may vary for different alarm conditions.
- audible alarms, such as horns, sirens, beepers, and voice messages. Audible alarms may make different sounds for different alarm conditions.

Malfunction alarms notify personnel when there is a fault in the fixed combustible gas detection system.

Power supply—Fixed combustible gas detection systems are typically supplied with backup-protected power (i.e., if the main source fails, the system automatically reverts to a backup source). Detectors in remote locations may use solar- or thermal-electric generators, backed up with a local battery supply. All detectors must be explosion proof. All wiring must be enclosed in sealed, explosion-proof conduits.

Relationship between Fixed Combustible Gas Detection Systems and Other Fixed Detection Systems

In most facilities, the combustible gas detection system is one of several fixed detection systems. Other fixed systems may include:

- toxic gas detection system
- fire alarm system
- security system

Depending on the site, the combustible gas and toxic gas systems may:

- operate entirely separately
- be partly integrated (e.g., share alarms)
- be completely integrated (be monitored and controlled from a central PLC and monitoring station)

Fire alarm systems must be completely separate and distinct and operate from an independent power supply.

3 Combustible Gas Measurement

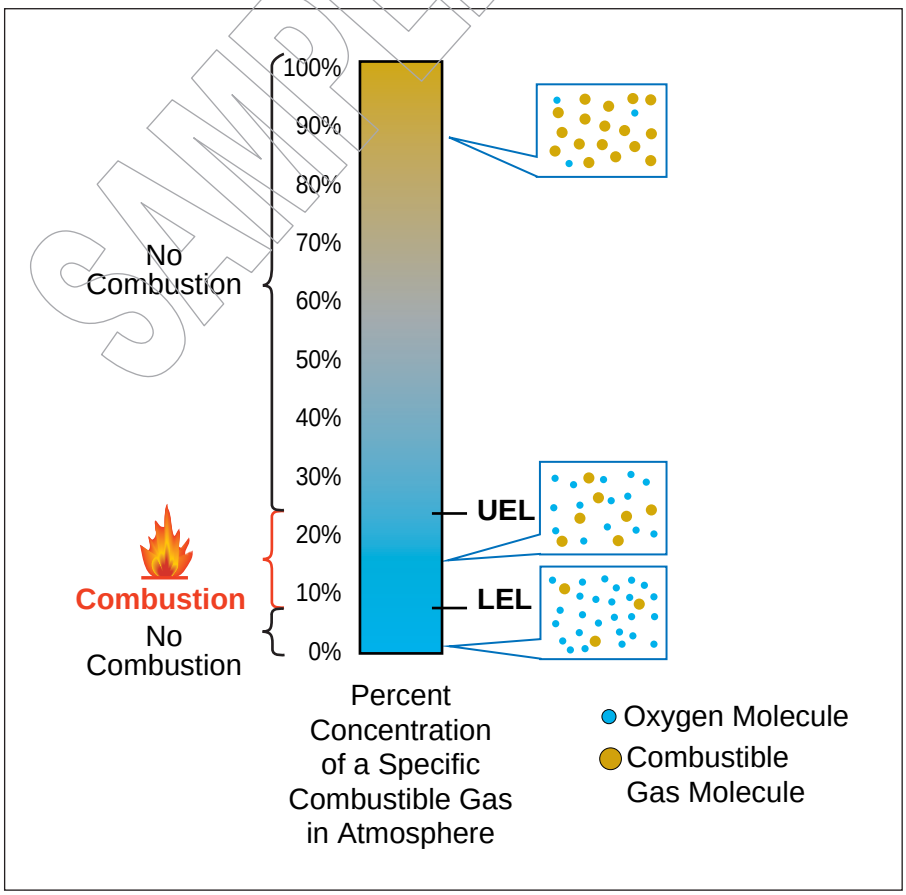
This section provides a brief description of combustible gas measurement concepts and their application to combustible gas detection systems.

NOTE

For a thorough explanation of combustible gas measurement concepts, refer to the HDC training kit titled *Describe Flammable Gas Measurement*.

A combustible or flammable gas is any gas which, when mixed with air, is capable of igniting and sustaining combustion if a source of ignition is present. The concentration of a gas by volume in air determines whether the combustible gas will *ignite* and *sustain combustion.* Figure 3 shows different concentrations of a combustible gas (by volume in air).

Figure 3— Measuring the Potential for Combustion of a Specific Combustible Gas



Lower Explosive Limit

Lower Explosive Limit (LEL)
The lowest concentration of a combustible gas that is capable of igniting and sustaining combustion.

Not all mixtures of combustible gas and air can ignite and sustain combustion (see the two *no combustion* zones on Figure 3). The **lower explosive limit** (LEL) is the *lowest* concentration of a combustible gas (by volume in air) that is capable of igniting and sustaining combustion. When the gas concentration in air is *lower* than the LEL, the gas-air mixture will **not** ignite and sustain combustion, even when a source of ignition is present. The gas-air mixture is said to be *too lean* to support combustion.

The LEL (lower explosive limit) is sometimes referred to as the LFL (lowest flammable limit).

Each combustible gas has its own LEL. (For example, the LEL for the gas shown in Figure 3 is 8% by volume in air.) Figure 4 lists the LELs of selected combustible gases/vapors.

Figure 4— Lower Explosive Limits (LELs) of Selected Combustible Gases/Vapors

Gas/Vapor	LEL (Percentage Concentration by Volume in Air)
gasoline (motor)	1.3%
propane	2.1%
acetylene	2.4%
ethylene glycol	3.2%
methane	5.0%
carbon monoxide	12.5%

Upper Explosive Limit

Upper Explosive Limit (UEL)
The highest concentration of a combustible gas that is capable of igniting and sustaining combustion.

The **upper explosive limit** (UEL) is the *highest* concentration of a combustible gas (by volume in air) that is capable of igniting and sustaining combustion. When the gas concentration in air is higher than the UEL, the gas will **not** ignite, even when a source of ignition is present. The gas-air mixture is said to be *too rich* to support combustion. Each gas has its own UEL. (For example, the UEL of the gas shown in Figure 3 is 25% by volume in air.)

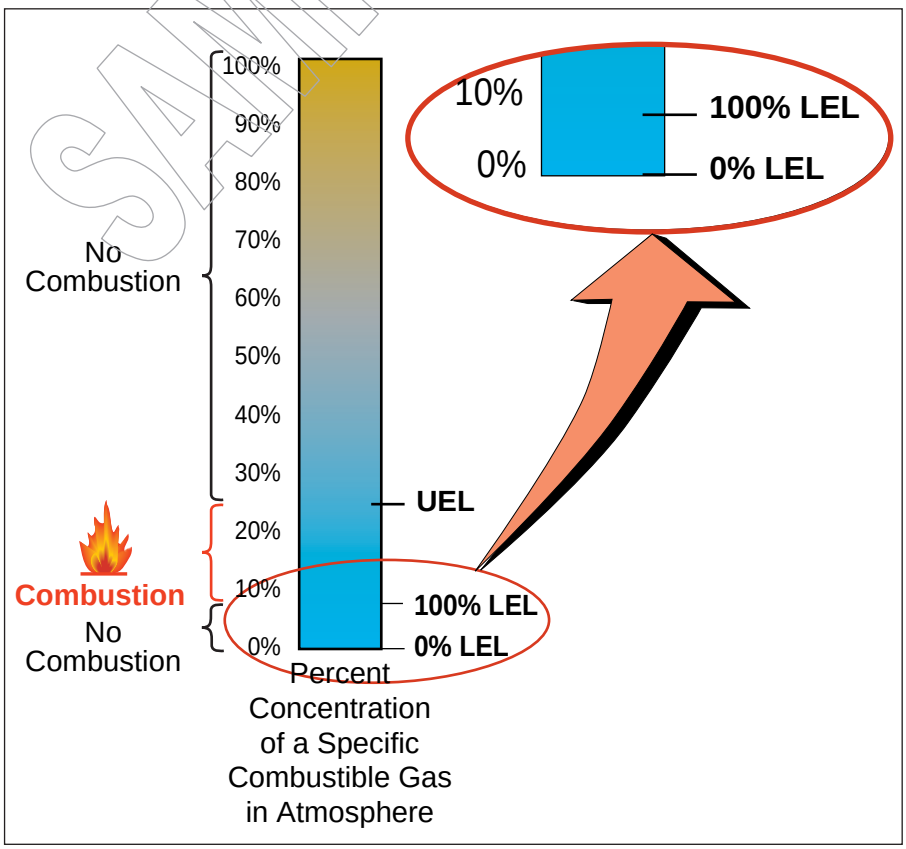
Combustion (Ignition) Zone

Concentrations of combustible gas (by volume in air) that are *between* the LEL and the UEL are said to be in the *combustion* or *ignition zone* (see Figure 3). When the gas concentration is within the combustion zone, and a source of ignition is present, the gas-air mixture **can** ignite and sustain combustion. Each gas has its own combustion zone. (For example, the combustion zone for the gas shown in Figure 3 is between 8% and 25% by volume in air.)

Combustible Gas Measurement

A fixed combustible gas detector measures the concentration of a combustible gas in air, but the detector does **not** display the gas concentration as a *percentage by volume in air*. Instead, the detector displays the gas concentration as a *percentage of the lower explosive limit (% LEL)*. For the gas illustrated in Figure 5, a concentration of 8% combustible gas in air would be indicated on the detector as 100% LEL. The 100% LEL concentration is the *lower explosive limit* for the gas.

Figure 5— Example of 100% LEL



Most fixed combustible gas detectors do **not** give a *true* reading of the combustible gas concentration in the atmosphere. A combustible gas detector gives a *relative* reading—the concentration of the combustible gas in relation to the LEL for the gas. The relative reading is expressed as % LEL.

Figure 6 shows gas detector LEL readings for different concentrations of methane in air (the LEL concentration for methane is 5.0% by volume in air).

Figure 6— Methane Concentrations and Corresponding Fixed Combustible Gas Detector Readings

Methane Concentration (% by volume in air)	Combustible Gas Detector Reading
5% methane (95% air)	100% LEL
4% methane (96% air)	80% LEL
3% methane (97% air)	60% LEL
2% methane (98% air)	40% LEL
1% methane (99% air)	20% LEL

The measurement scale on most fixed combustible gas detection systems ranges from 0% LEL to 100% LEL.

The fire and/or explosion risk increases as gas concentrations rise above 100% LEL. The maximum display for older combustible gas detection systems is 100% LEL. Some newer systems can display higher readings (e.g., to a maximum of 150% LEL).

For your own safety, find out how your facility's combustible gas detection system displays gas concentrations greater than 100% LEL.

The user sets the combustible gas detection system to notify personnel *before* the gas concentration reaches 100% LEL (i.e., before the gas can ignite). Typically, users set combustible detection systems to annunciate alarms at two different gas concentrations:

- a low level alarm setting, which may be 20% LEL
- a high level alarm setting, which may be 40% LEL

4 Fixed Combustible Gas Detection System Features

This section describes:

- detectors:
  - catalytic combustible gas detectors
  - infrared combustible gas detectors
  - advantages and disadvantages of each type
  - monitoring strategies
  - installation guidelines
- controllers
- alarms and responses
- alarm bypass switches

4.1 Detectors

Detectors (sensors, monitors) continuously transmit signals to the controller or PLC. Many different types of combustible gas detectors have been developed; the types used in most fixed systems are:

- catalytic combustible gas detectors
- infrared (IR) detectors

Catalytic Combustible Gas Detectors

Catalytic combustible gas detectors are also called catalytic, catalytic bead, or catalytic oxidation detectors. Catalytic detectors operate on the basis that, when a combustible gas is oxidized by an element coated with catalyst, the following changes occur:

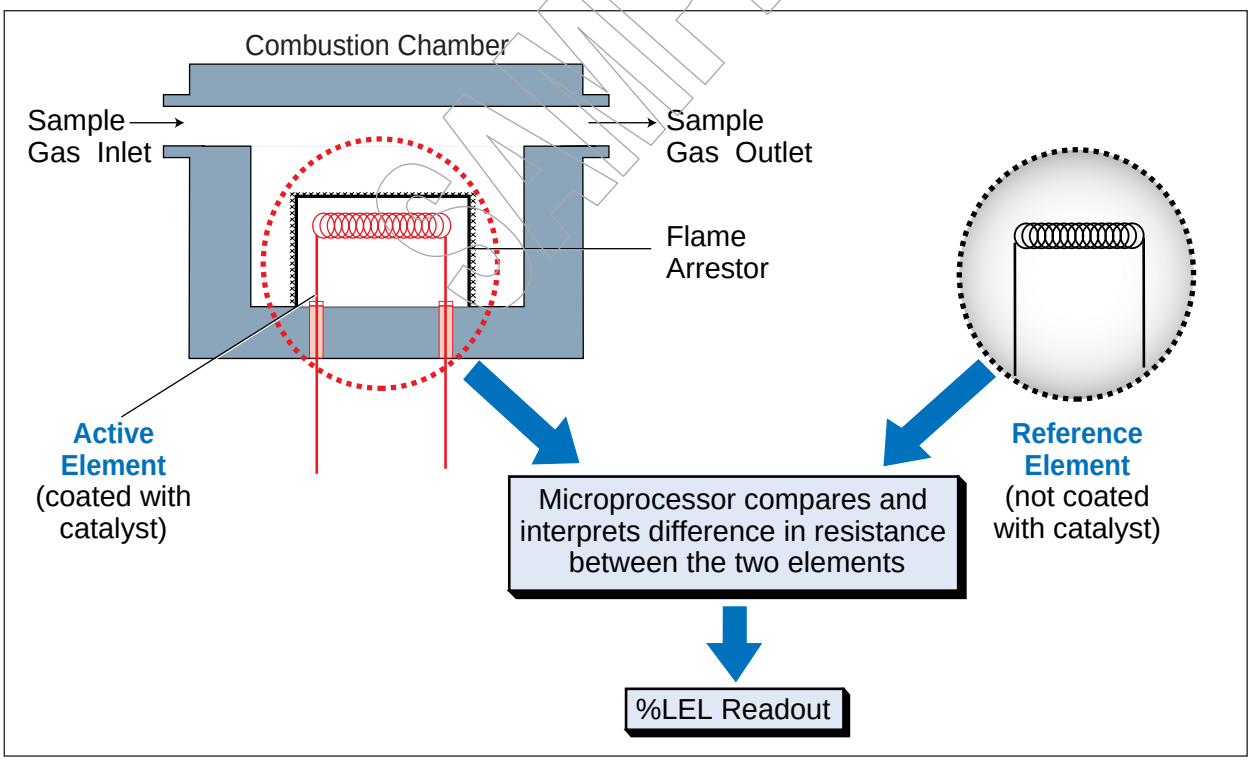
- the temperature of the sensor increases
- the temperature increase causes a measurable increase in the electrical resistance of the sensor element.

Figure 7 shows a typical catalytic detector.

Figure 7—Fixed Catalytic Combustion Detector

(Courtesy of Net Safety Monitoring Inc.)

Figure 8—Operation of a Catalytic Combustible Gas Detector



The sensor within the detector has *two* elements: an *active* element and a *reference* element (see Figure 8):

- The active sensor element is a wire on which a catalyst is applied, either as a coating or as a bead.
- The reference element is identical to the active element, except that it is not coated with the catalyst.

An electric current flows through both elements. When the combustible gas contacts the active element, the gas is oxidized and the active element's temperature and electrical resistance increases. The reference element's temperature and resistance remains constant. The combustible gas detection system continuously compares the resistance of the active element with that of the reference element: the difference in the electrical resistance of the two elements is proportional to the combustible gas concentration. The system displays the concentration of the detected gas as % LEL.

Catalytic detectors are designed to accurately detect one specific target gas. For example, one detector may be designed to accurately detect methane; another detector may be designed to accurately detect propane. Even though the detector is designed to detect one specific gas, any other combustible gas that enters the sensor will oxidize and produce a reading. Readings for non-target gases are generally less accurate than for the target gas. Because catalytic detectors can only detect moderate to high concentrations of combustible gases, *any* increase in the detector reading is likely to be important, regardless of the gas causing the reading—a higher reading means a higher risk of ignition.

Metallic oxide semiconductor (MOS) detectors are another type of gas detector with a bead-type sensor. While MOS detectors *can* detect low concentrations of combustible gases, MOS detectors are not widely used for fixed combustible gas detection systems. MOS detectors are mostly used in fixed hydrogen sulfide detection systems (described in the HDC training kit *Describe Fixed Toxic Gas Detection Systems*).

Typical applications of catalytic combustible gas detectors

Catalytic combustible gas detectors:

- can be used to detect such gases as:
  - methane
  - ethane
  - propane
  - butane
- can monitor several combustible gases at once

Strengths of catalytic combustible gas detectors

Strengths of catalytic combustible gas detectors include the following:

- measurement units are always % LEL
- are widely available for many different combustible gases
- are relatively easy to
  - install and calibrate
  - operate and maintain
- are durable, reliable, and predictable
- can be used in a wide range of temperatures and environmental conditions

Limitations of catalytic combustible detectors

Limitations of catalytic combustible gas detectors include the following:

- require regular calibration and testing
- cannot measure low concentrations of combustible gas
- cannot be used in:
  - oxygen-deficient environments (to work properly, most models need an atmosphere containing at least 15% oxygen
  - atmospheres containing acetylene
- are not effective for some types of hydrocarbons (e.g., oil vapors)
- can be poisoned by exposure to some chemicals (e.g., hydrogen sulfide, silicones, lead, and halogenated hydrocarbons) or noncombustible gases
- can be desensitized when exposed to very high concentrations of combustible gas
- can be damaged by exposure to very high ambient temperatures

- can be affected by high humidity and water vapor condensation
- are susceptible to damage from shock or vibration
- are not effective for monitoring large areas unless many detectors are installed

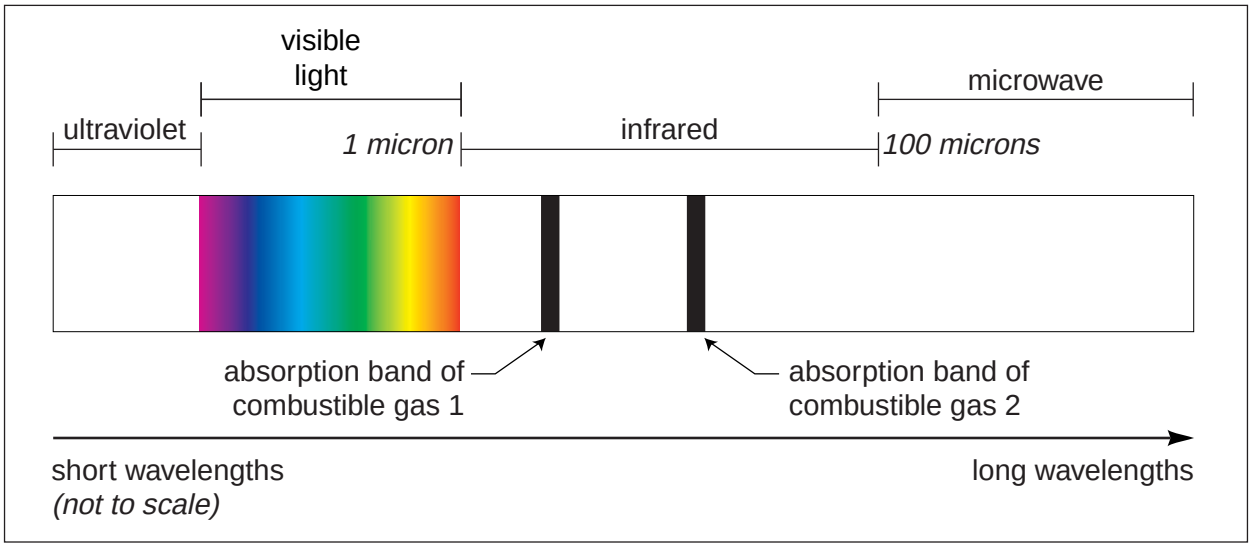
Infrared Detectors

Infrared (IR) gas detectors cannot be poisoned or desensitized and they can be used in environments that contain little or no oxygen.

Different hydrocarbon gases absorb different IR wavelengths. Each gas has a specific absorption band; this specific absorption band is a characteristic of the gas. Figure 9 shows a portion of the electromagnetic spectrum on which the absorption bands of two different gases, combustible gas 1 and combustible gas 2, are shown.

An IR combustible gas detector provides an IR band that matches the IR absorption band of the target gas. If the target gas is present, the gas absorbs some of the provided IR radiation. The amount of IR radiation absorbed is proportional to the concentration of the gas. As the concentration increases, less IR radiation reaches the receiver.

Figure 9— A Portion of the Electromagnetic Spectrum Showing the Absorption Bands of Two Combustible Hydrocarbon Gases



Although there are different types of IR combustible gas detection systems, all IR detection systems include:

- an IR source
- an IR receiver (detector)
- an IR path (area between the IR source and receiver) that is open to the target combustible gas
- optical components (e.g., lenses, filters, reflectors, and signal interruption devices)

IR detectors have two filters (either at the IR source or at the receiver), which provide two different IR bands:

- an absorption band (IR wavelengths that *only* the target combustible gas can absorb)
- a reference band (IR wavelengths that the target combustible gas *cannot* absorb)

The IR gas detector continually compares the intensity of the two IR bands at the receiver:

- The intensity of the absorption band is *reduced* if the target combustible gas is within the IR path.
- The intensity of the reference band is not affected by the presence of the target combustible gas.

When a combustible gas reduces the intensity of the absorption band, the amount of the reduction is proportional to the concentration of the combustible gas. The detector/controller displays the concentration of the gas, either as % LEL or in alternate measurement units (units vary between models).

When signals from both bands (absorption and reference) are reduced or absent, the system infers that the beam paths are blocked by a physical obstruction and responds by issuing a signal interruption alarm.

The detection capability of an IR detector depends on the filter(s) and lenses provided. Most IR combustible gas detectors have filters and lenses designed to detect a range of combustible gases (e.g., gases ranging from methane (C-1) to octane (C8)).

The distance (path) between the IR source and receiver depends on the type of detector and the model. Two types of infrared detectors are available:

- IR point detectors (also called closed-path or fixed-path detectors)
- IR open-path detectors

IR point detectors

IR point detectors (see Figure 10) have a very short distance or *path* (e.g., 15 cm (6 in.)) between the IR source and the detector. IR point detectors are used for early detection of combustible gas leaks, and are often installed near potential leak sites (e.g., valves).

Most IR point detectors have a capsule-like outer housing that contains the IR source, receiver, and built-in IR reflectors and filters. Gas enters the detector through a tube in the housing.

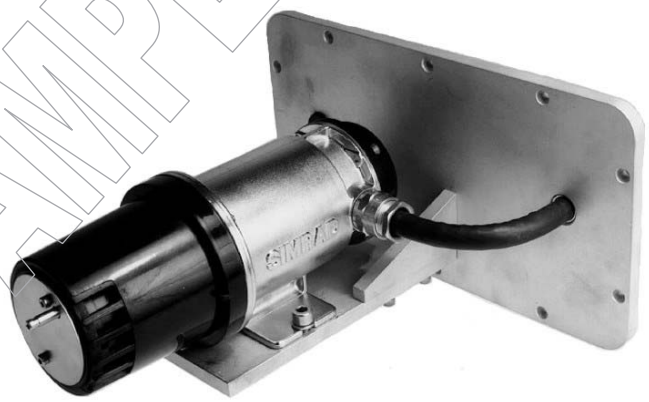


Figure 10— Fixed Infrared Combustible Gas Detector (Point Type)

(Courtesy of Simrad Optronics ASA)

IR open-path detectors

IR open-path detectors have much longer IR paths than IR point detectors (IR paths for some models are 100 m (325 ft.) or longer). IR open-path detectors are used to monitor large areas or perimeters of facilities for combustible gases. An open-path detector consists of an IR source and a sensor/receiver, mounted separately (see Figure 11). Some models have an intermittent (flashing) IR beam, and others have a continuous IR beam. Open-path detectors are typically used to monitor a range of hydrocarbon gases (e.g., hydrocarbons in the C1 to C12 range).

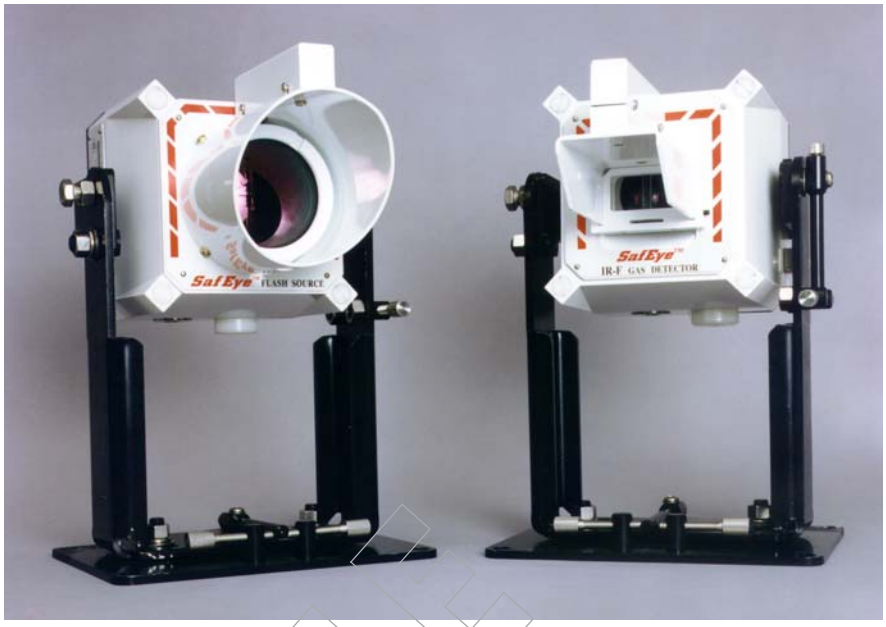


Figure 11— Fixed Infrared Combustible Gas Detector (Open-Path Type). The light source is on the left and the detector/receiver is on the right.

(Courtesy of SPECTREX INC.)

The combustible gas detection systems at many sites incorporate both IR point detectors and IR open-path detectors.

Typical applications of IR combustible gas detectors

End of Sample

A full licensed copy of this kit includes:
- Training Module and Self-Check
- Knowledge Check and Answer Key
- Blank Answer Sheet
- Performance Checklist
- Job Aid