Ultrasonic Gas Leak Detection: What is it and How Does it Work?

MSA
The Safety Company

Introduction

Ultrasonic gas leak detection (UGLD) is a comparatively recent detection technique and has emerged as an effective means of establishing the presence of gas leaks. It works especially well in open, ventilated areas where other methods of gas detection may not be independent of ventilation. Because UGLDs respond to the source of the leak, rather than the gas itself, they complement sensors that measure gas concentration.

This paper provides an overview of the operation and use of UGLD. The principles of ultrasonic detection and its strengths and limitations are also discussed.

Reference: *HSE. 2004. Fire and Explosion Strategy, Issue 1. Hazardous Installations Directorate, Offshore Division.*

Applications for UGLD

- Chemical Processing Plants
- Floating Production Storage and Offloading Vessels (FPSO)
- Gas Compressor and Metering Stations
- Gas Turbine Power Plants
- Hydrogen Storage Tanks
- LNG/GTL Trains
- LNG Re-gasification Plants
- Natural Gas Well Pads
- Offshore Oil & Gas Platforms
- Onshore Oil & Gas Terminals
- Refineries
- Underground Gas Storage Facilities

UGLD Criteria

- The target element must be in the gas phase; it cannot be a liquid.
- 150 psi is typically required to generate enough ultrasound to produce a sufficient area of coverage.

Advantages of UGLD

- Rapid response speed
- Outdoor applications are ideal as the technology is immune to the effects of wind diluting the gas leak.
- UGLD is not affected by audible (to humans) sound.
- Coverage area can be confirmed using an inert gas
- No routine calibration is necessary

How Does UGLD Work?

Fixed gas detection in open ventilated areas like offshore or onshore oil and gas facilities is generally considered problematic because the gas easily dilutes and drifts away from conventional gas sensors.

Ultrasonic gas leak detectors solve this problem by detecting the airborne acoustic ultrasound generated when pressurized gas escapes from a leak. When a gas leak occurs, the ultrasound generated by the leak travels at the speed of sound, through the air, from the source to the detector.

Ultrasonic gas leak detectors are non-concentration based detectors. They send a signal to the control system indicating the onset of a leak.

Speed of Response

The main advantage of an UGLD compared to a conventional gas detector is that it does not need to wait for a gas concentration to accumulate and form a potentially explosive cloud before it can detect the leak.

The total speed of response for an UGLD can be calculated as:

Ttotal = Tdetector + Tultrasound

Tdetector for an UGLD is the alarm delay time implemented on the instrument, commonly 10-30 seconds.

Tultrasound represents the time it takes ultrasonic noise to travel from the leak source to the detector. This is typically measured in milliseconds.

The response of the UGLD is not dependent on the gas to travel to the detector, which means that it reacts much faster to the dangerous gas leak.

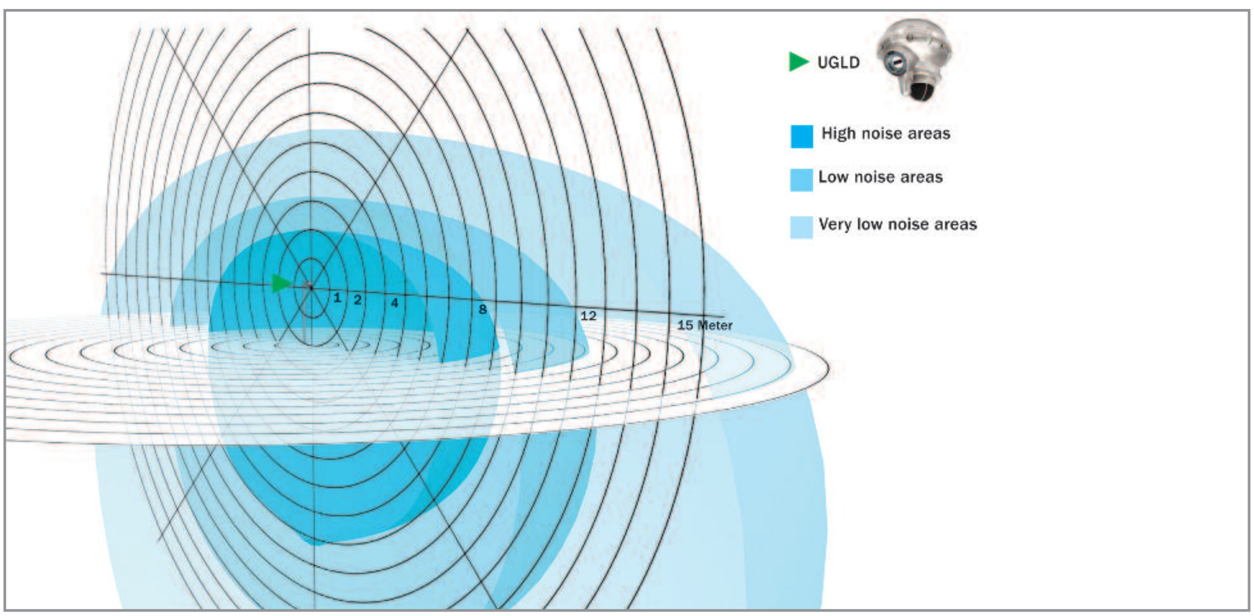


Figure 4. The graphic shows the detection coverage characteristics for UGLD. The distances are based on the detection of methane-based gas leaks using a leak rate of 0.1 kg/s as the performance standard.

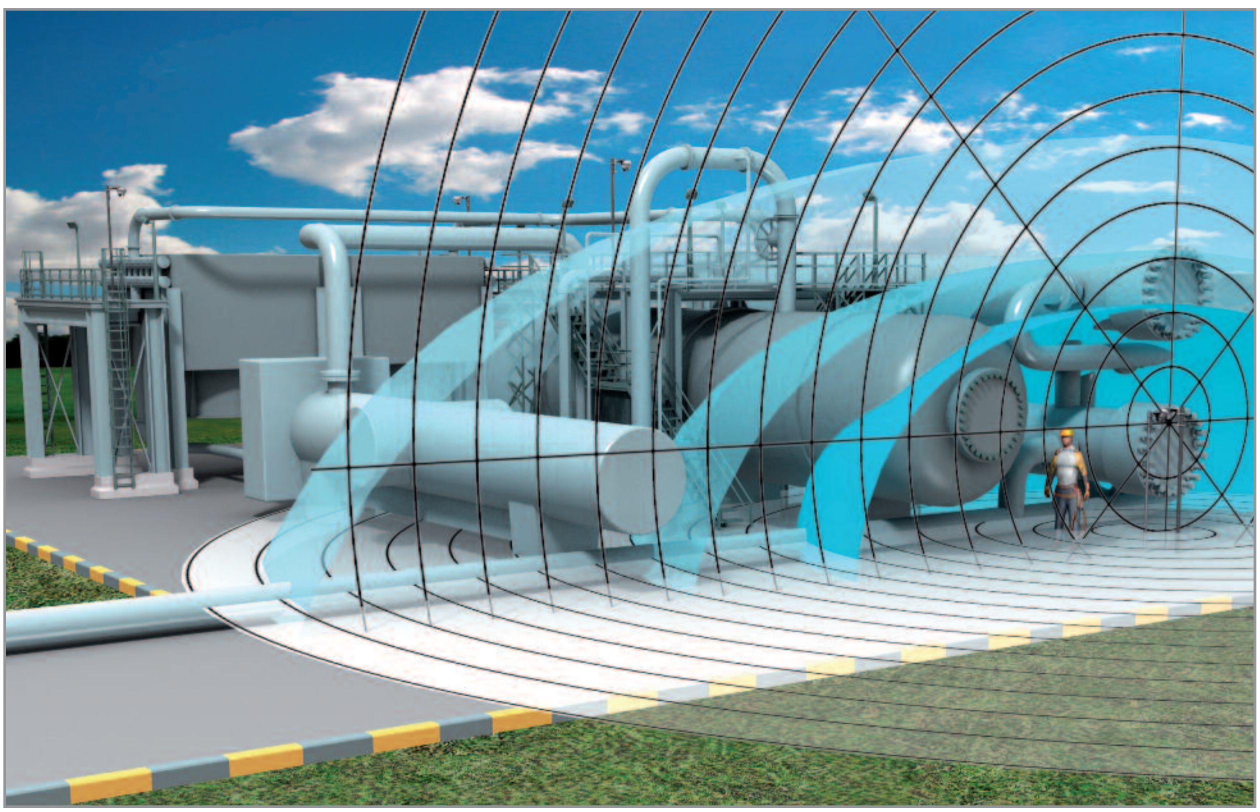
Detection Coverage

Since the sound pressure level decreases over distance at a predictable rate, operators and engineers can establish detection coverage before ultrasonic gas leak detectors are installed. The location and number of detectors can be planned based on plant drawings when the facility is in the design stage. UGLD s are used to cover both large outdoor facilities and single installations. UGLD detection coverage depends on the ultrasonic background noise level of the area and on the minimum gas leak rate to be detected. For the purposes of sensor allocation, plant environments can be divided into three types: high noise, low noise, and very low noise, as represented in the graphic to the right.

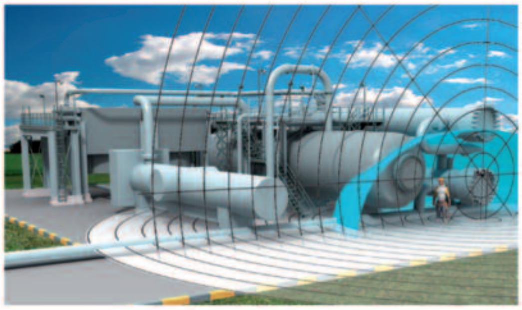
The image shows a detector installed on a mounting pole 2 meters (6 feet) above ground as seen from the front. Because the sensor points down when installed, the detection coverage is greater below and to the sides of the sensor than above. Notice that when not obstructed by a floor, the detection coverage is "apple shaped".

From the illustration it could be implied that the detector detects gas leaks below ground, but this is rarely the case. The only instance in which a detector responds to gas leaks below ground is when the device is installed on a grid floor, which allows ultrasound to travel through the cells in the grid with minimum impairment. An UGLD may, for example, be installed on an upper platform deck while providing coverage to lower decks as well. In the same way the detector could be installed over the top of a separator tank and provide coverage over the top of the tank as well as down to the ground level.

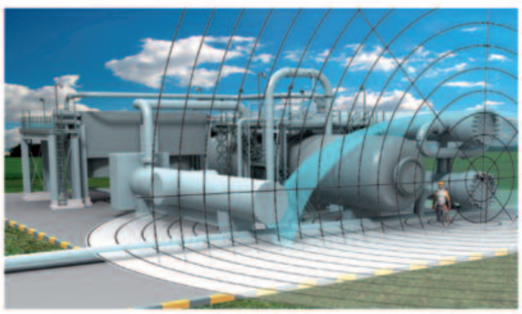
As shown also, the shape of the detection coverage is the same for the three plant areas, but the maximum detection range varies according to ultrasonic background noise.



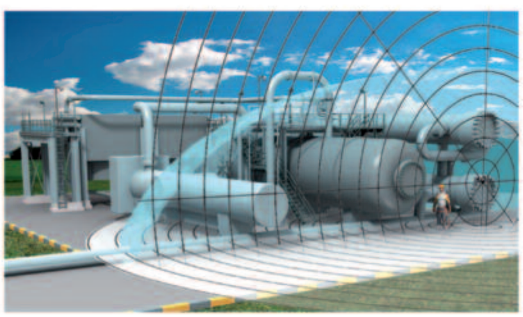
Detection coverage for high, low, and very low noise levels is illustrated in the figures below. Coverage is based on detection of methane leaks using a leak rate of 0.1 kg/s as the performance standard.



- **High noise areas (e.g., compressor area)**
  Audible noise: 90-100 dBa
  Ultrasonic background noise < 78 dB
  Alarm trigger level = 84 dB
  Detection coverage = 5-8 meter (16-26 ft)



- **Low noise areas (e.g., normal process area)**
  Audible noise: 60-90 dBa
  Ultrasonic background noise < 68 dB
  Alarm trigger level = 74 dB
  Detection coverage = 9-12 meter (30-39 ft)



- **Very low noise areas (e.g., remote onshore wellhead)**
  Audible noise: 40-55 dBa
  Ultrasonic background noise < 58 dB
  Alarm trigger level = 64 dB
  Detection coverage = 13-20 meter (43-66 ft)

Note that very low noise areas settings are generally only used in onshore installations.

LEL Vs Leak Rate

Conventional gas detectors measure gas concentrations as a percentage of the lower explosive limit (LEL) or in parts per million (ppm). The performance of ultrasonic gas leak detectors is based on the leak rate, usually measured in kilograms per second.

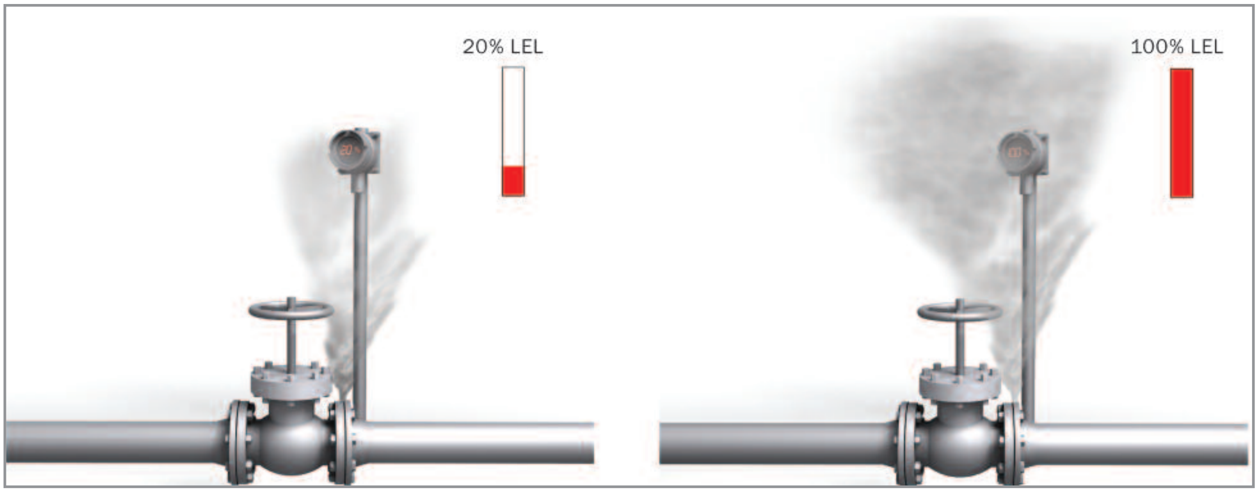


Figure 6: The conventional gas detector above measures gas concentration in the lower explosive limit (LEL). The LEL level measured by the sensor depends on the leak rate (mass flow rate), leak directionality, and where the sensor is positioned relative to the leak.

LEL
For conventional gas detection, gas concentration is measured in either LEL or ppm. The term LEL is used for combustible gases and is measured as a percentage. When the concentration of combustible gas in air reaches 100% LEL, an ignition of the gas causes an explosion.

Leak Rate
The term leak rate describes the amount of gas escaping from a leak per unit time. A leak can be considered large, for instance, if a large quantity of gas escapes every hour or every second. Conversely, a leak can be said to be small if a small amount of gas jets out from the pressurized system over a given period.

The leak rate, which defines how fast a potential dangerous gas cloud accumulates, can be divided into three categories according to hazard severity:

- Minor gas leak < 0.1 kg/s
- Significant gas leak 0.1 - 1.0 kg/s
- Major gas leak > 1.0 kg/s

The categories developed by the body HSE are used to define the guidelines for UGLD . For methane based leaks then UGLD must respond to small leaks of minimum 0.1 kg/s.

Notice an UGLD does not measure the leak rate. The leak rate is used to set the performance criteria, and in effect define, which leaks the UGLD must pick up. The UGLD provides a measure of the ultrasonic sound measured in decibels (dB). When there is a gas leak with a leak rate of 0.1 kg/s inside the detector's coverage area, the sound level will exceed the trigger level of the UGLD and cause an alarm. As a result, in order to prevent injury or loss of life, UGLD s must detect methane leaks of at least 0.1 kg/s.

** Reference: HSE website, April 2010: http://www.hse.gov.uk/RESEARCH/ otopdf/2001/oto01055.pdf; page 10*

Leak Size and Influence on UGLD
The leak size influences the performance of the UGLD in the following way: the greater the leak size, the bigger the leak rate and thus the greater the detector's coverage (assuming the gas pressure is kept constant). Some of the most frequently asked questions pertain to the leak size and whether the opening can be too small or too large to create adequate levels of ultrasound.

The most important thing to understand is that the leak rate can derive from an infinite number of combinations of leak size and gas pressure (gas properties also have some influence). As the hole becomes larger, the leak rate increases. However, with extremely large leaks it becomes more and more difficult to sustain the system's pressure. When the system pressure starts dropping it causes a reduction of the leak rate and thereby decrease the ultrasonic sound level.

In theory, there is no limitation to the rule when the leak becomes small. However, to achieve the commonly used leak rate for methane of 0.1 kg/s for a leak with a small hole size like 0.5 mm (0.02 in), the system's pressure must be almost 3,000 bar (or around 43,500 psi). Since tiny pinhole leaks are found in fittings especially on offshore facilities, UGLD s are neither designed for pinhole leaks nor for big pipe ruptures. Pinhole leaks increase in size over time and become easier to detect while pipe ruptures can be identified by the pressure drop. Instead of considering specific hole sizes or pressures, UGLD should be related to the leak rate.

Figure 8. When the pressure is kept constant a small leak has a smaller leak rate and makes less ultrasound compared to a bigger leak.

Frequency and Amplitude
Ultrasonic gas leak detection differs from conventional gas detection mainly because it responds to the airborne acoustic sound from the gas leak, and not by sensing the gas molecules. Two new parameters are fundamental to understand ultrasonic technology – amplitude and frequency, where amplitude is measured in decibels [dB] and frequency is measured in Hertz [Hz].

Amplitude (dB)
The term amplitude is the parameter that describes the sound level or volume of the acoustic sound. Imagine that you sit in front of the radio and turn up the volume, the sound level increases and in the world of acoustics, we say the dB level increases.

Frequency (Hz)
The term frequency is the parameter that describes the high and low pitches in acoustic sound. To illustrate this, low frequencies can be heard from the bass drums in music, whereas high frequencies can be heard from for example cymbals. This means there are low frequencies and high frequencies.

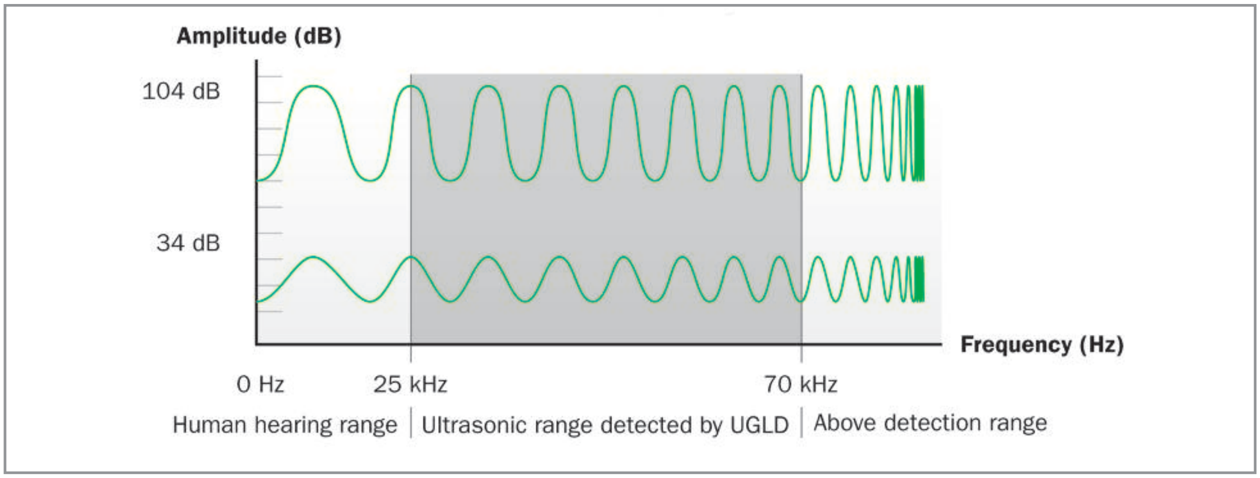


Figure 9. The graphic shows the relation between amplitude (dB) and frequency (Hz).

The human ear can hear both high and low frequencies, but only within a certain frequency range, typically from 20 Hz to 20000 Hz (20 kHz). This frequency range is also called the audible frequency range. Frequencies above 20 kHz up to 100 kHz are called ultrasonic frequencies. The human ear cannot hear acoustic sound in this frequency range. The UGLD is designed to ignore audible and lower ultrasonic frequencies and only sense ultrasonic frequencies in the range 25 kHz to 70 kHz.

Frequencies in Plant Environments

In normal industrial plant environments there can be a wide variety of acoustic sound frequencies present or there may be only a limited number. Basically it depends on the process equipment installed in various parts of the plant. In some areas there is a complex mixture of sound frequencies at high amplitude (high dB level); for example, in spaces with turbines, compressors, and other high speed rotating machines. In other areas there is a simple mix of sound frequencies at low decibel levels. This is the case in process areas with no rotating equipment or in remote installations in outdoor locations.

In very noisy plant locations where the audible noise level may be around 95 dB (very loud), the ultrasonic sound level will, as a rule of thumb, be 20-30 dB lower (65-75 dB) simply because the machine made noise does not generate a lot of ultrasonic frequencies - only a lot of audible sound frequencies.

For this reason UGLD s can be installed in very noisy locations without interference from the normal audible background noise.

Summary/ Conclusion

Ultrasonic gas leak detection (UGLD) is a very effective means of establishing the presence of gas leaks that is commonly used in chemical, power plant, and numerous oil and gas applications. It features a rapid response rate, is unaffected by audible noise, and works especially well in open, ventilated areas where other methods of gas detection may not be independent of ventilation.

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MSA Corporate Center
1000 Cranberry Woods Drive
Cranberry Township, PA 16066 USA
Phone 724-776-8600
www.MSAsafety.com

U.S. Customer Service Center
Phone 1-800-MSA-2222
Fax 1-800-967- 0398

MSA Canada
Phone 1-800-MSA-2222
Fax 1-800-967-0398

MSA Mexico
Phone 01-800-672-7222
Fax 52-44-2227-3943

MSA International
Phone 724-776-8626
Toll Free 1- 800-672- 7777
FAX 724-741-1559

The Safety Company