Remote Gas Detection with Handheld Lasers

BY JERRY KNAPP

FIRE DEPARTMENTS ACROSS OUR nation are more frequently called to minor and major natural gas emergencies since recent natural gas explosions and fires with fatalities have increased public awareness. Recent firefighter line-of-duty deaths (LODDs) and injuries have repeatedly demonstrated our vulnerabilities at these dangerous alarms. Our mission at natural gas emergencies is to protect civilian and firefighter lives. Fulfilling our mission effectively depends on rapid, detailed, and effective size-up. We are skilled at fire size-up because of our training and experience, but we have received very limited training on size-up and response procedures for natural gas emergencies. However, the new technology described below may change that.

(1) A firefighter points the handheld laser gas detector at a commercial meter to determine if gas is leaking. (*Photos by author unless otherwise noted.)*

Laser Technology

New technology combined with a handheld instrument enables you to size up natural gas emergencies more quickly, accurately, and effectively to help firefighters accomplish their mission of life safety. Using tunable diode laser absorption spectroscopy (TDLAS), laser technology allows responders to detect gas remotely so that the firefighter need not carry the gas detector into the combustible gas plume or even enter the "kill box." The kill box, similar to the collapse zone around a building, is the area in which you will likely be killed if a gas explosion occurs, creating flying debris and a pressure wave. The traditional combustible gas detector can take up to 30 seconds to register a reading (i.e., get a sample in, process it, and produce a reading). It's called the "t90 time" for a 90 percent effective reading. However, the laser-based instrument responds instantaneously. TDLAS is not new; the natural gas industry has used it widely for years to supplement required leak surveys on distribution and service pipelines; it is now available to the fire service.

The goal of size-up for natural gas emergencies is, first, to determine whether the leak is major and thus a life safety risk or relatively minor and not a life safety risk. If the size-up shows a potential risk to life, then evacuation and establishing control of the gas and ignition sources may be viable options, depending on your department procedures.

The fire department is the expert on life safety and is the responsible authority in this situation until it is proven there is no life safety hazard. If a potential life safety hazard exists, the objective is to protect civilian lives and take manageable risks with firefighters to reduce the civilian threat. Important considerations during size-up for establishing strategy and tactics are the following: the leak's source and location (where it is presenting), how much gas is being released (the volume), and whether it is migrating into nearby exposures/structures.

Complacency

We usually get called to natural gas leaks when they are well below dangerous levels. There is a large gap between the point at which you can detect natural gas by smell and the point at which it is combustible. Mercaptan, the odorant in natural gas, is required to be detectable by smell at a concentration of less than 1 percent [(10,000 parts per million (ppm)] by most people. However, many people can smell it at very low concentrations, below 1 ppm. These are the all too numerous "find and fix" calls like pilot lights out that naturally result in our complacency. By comparison, natural gas is combustible only between a concentration of about 5 and 15 percent in air. So, a 5 percent concentration of natural gas in air equals 50,000 ppm and is the lower explosive limit (LEL); 50,000 ppm = 100 percent LEL = 5 percent natural gas in air.

Natural gas has many characteristics that make it a very safe energy source, such as its narrow flammable range and

(2) In 2012, an underground gas leak migrated into a nearby home and subsequently exploded, nearly killing the author and another West Haverstraw (NY) firefighter. (*Photo by Dom D'Alisera.)*

its lighter-than-air vapor density. It is easy to get complacent. Nothing ever happens at gas calls ... until it does. When things go bad, there is no time for Plan B; Plan A *has* to be right.

Turnout gear is not rated for gas explosions, flying debris, glass, and other hazards launched in an explosion. Is there a better way to respond to natural gas emergencies? Do we need to risk a firefighter's life by ordering him to walk into the kill box to get a reading on his meter? If the gas ignites, there's no Plan B. A firefighter can't run fast enough and neither can the firefighter assistance and search team (FAST). I can tell you from my experience of luckily surviving a 2012 natural gas explosion that things go bad, very bad, in a micro-second.[1-2] If there is technology available that can improve our safety and effectiveness for our customers, we should consider using it.

Considerations

Consider the following natural gas leak response scenarios using laser-based gas-detection technology.

Gas Leak Response

We were dispatched to an odor of gas at 7 Main Street in a nice residential neighborhood. My driver stopped the engine two houses away at 3 Main Street. My firefighter had the four-gas meter, a CGI. I took the laser gas detector and started my size-up. The laser gas detector has made my size-up of gas emergencies more effective and much faster.

As we dismounted the engine, I used the laser's 100-foot sensing range to see if gas was leaking from the residential gas meter on 3 Main Street. Negative. Continuing my size-up, walking toward the reported odor site, I pointed the laser at the storm drain and sanitary manholes in front of 5 Main Street. Within a few seconds, the meter alarmed for a high level of gas escaping from both of these subsurface structures. My size-up showed serious indications of gas migrating underground at multiple sites. This information led me to believe an underground gas main leak may be creating a significant life safety risk for nearby building occupants. I sent my firefighter into 6 Main Street, directly across from where the caller smelled gas. After a few minutes, he found 10 percent LEL in the basement near where the water and gas mains entered the basement—more evidence of underground migrating gas creating an increasing life safety risk. Since our action level for mandatory evacuation is 10 percent LEL, he directed the mother and her baby to the engine parked outside the kill box. Occupants in nearby homes self-evacuated and followed.

As I got closer to where the caller said the odor was strongest, I used the laser again. Aiming it through the window of 7 Main Street, I got another high reading for gas. A locked building with high levels of gas can be a bomb, a big bomb. A neighbor reported the family was away on vacation and she was watching the house. Police had closed off one end of the street; my driver moved the engine to block the opposite end.

Quickly, I had met my primary objective, life safety of civilians and responders. I made sure the utility was en route and walked back to my crew. Just after I arrived there, the 7 Main Street house exploded, shredding itself and leaving deadly sized debris all over the street and near surrounding homes. Fortunately, no civilians or firefighters were injured because I had done a fast and an effective size-up. We did a fast size-up, met our life safety mission, maximized firefighter safety, and got ourselves out of the kill box before what would have been a deadly explosion. No luck was involved; good training, good response procedures, and the latest technology available made this possible.

Using TDLAS

For firefighters, using this technology means we can detect natural gas from up to 100 feet away without entering the kill box. Equally important, TDLAS allows firefighters to rapidly size up a dangerous gas situation and execute our primary mission, life safety, much more quickly than ever before. The laser gas detector is much like a bloodhound for

New technology combined with a handheld instrument enables you to size up natural gas emergencies more quickly, accurately, and effectively to help firefighters accomplish their mission of life safety.

law enforcement. It will tell us instantly where there is or is not gas and provide relative amounts. These are the simple facts we need to complete our size-up. TDLAS will soon be widely accepted and become a staple in our toolbox, just as has happened with thermal imaging cameras.

The Science of TDLAS

TDLAS uses a laser that is tuned specifically to methane, the major component of natural gas. The laser beam emits a specific wavelength that is absorbed by methane. When the laser hits methane, the methane absorbs some laser energy. The more methane molecules that absorb the beam, the higher the reading. The detector's software analyzes the difference between the laser light energy that was sent to the amount that was reflected back to the sensor. The result is displayed in the parts per million meter (ppm-m). The laser starts out as a point and then grows to a cone-shaped beam as it approaches the target. This is similar to an LED flashlight. In this case, the detector is a flashlight that reveals natural gas and methane sources.

Three conditions are necessary for the TDLAS remote methane detector to sense natural gas:

1. The gas plume must be within the range of the detector. The sensing is in the ppm-m range for distances up to 100 feet.
2. The laser requires a background (a building, a fence, the ground) that will reflect the beam. A better reflector can improve the detection distance. However, common ground cover, buildings, trees, and other structures usually provide an adequately reflective surface.
3. The beam from the laser must pass through some portion of the plume.
4. The 2004 report published by the Optical Society of America, "Standoff Sensing of Natural Gas Leaks: Evolution of the Remote Methane Leak Detector," describes the science behind the instrument: "Gas sensors based on tunable diode laser absorption spectroscopy enable the sensing of trace concentrations of many critical gases in a broad array of applications. TDLAS gas analyzers rely on well-known spectroscopic principles and sensitive detection techniques coupled with advanced diode lasers often with optical fibers. The principles are straightforward: Gas molecules absorb energy in narrow bands surrounding specific wavelengths in the electromagnetic spectrum."[3]

3

(3) An example of a handheld TDLAS remote methane detector. The center display indicates a reading of 2 ppm-m (which is a typical background level of methane in air). The distance to the beam's target is shown in the upper left corner of the display as "1.13 m" (meters). This instrument keeps the session's peak reading in memory indicated at lower right as "Max: 4." The reading strength and the battery indicator are at the upper right corner. This detector reads from 0 to 50,000 ppm-m of methane and responds in 0.10 seconds. Depending on the reflective surface of the laser's target, it provides methane readings up to 100 feet away. The instrument also has an audible and a tactile (vibration) alarm, allowing the user's eyes to remain on the target. The instrument's internal rechargeable battery has a six-hour life cycle.

The rapid and widespread use of TDLAS detection-capable-equipped instruments has provided utilities with up to 40 percent productivity gains. The fire service could see similar success in improving the speed and reliability of size-up, detecting dangerous situations to minimize occupant evacuations and, ultimately, catastrophic events. Note that, unfortunately, TDLAS currently detects only methane and methane-containing gases such as natural gas.

Tactical Uses

Although it appears the major use for this technology is to vastly improve the speed and accuracy of our size-up of underground gas leaks, it has many other scenario-specific uses. Like all of our tools and hazmat instruments, this technology can improve important parts of the fire service mission of life safety, but it is not a silver bullet. It is important to note that the instrument can be used to detect natural gas inside a building as well.

Scenario 1: Locked Building

The locked building scenario is a common problem for firefighters. Gas utilities call them "can't get ins." Often the utility will ask firefighters to force their way into a building that contains or may contain levels of gas. There is no safe way to do this. Putting a firefighter or an irons team at a door or window puts them in extreme danger and with no Plan B, as previously discussed.

The laser-based remote methane detector can identify the presence of natural gas through glass. Compared to current methods, it is a huge advantage and a leap forward in firefighter *and* public safety to be able to remotely determine the presence or absence of gas during the initial size-up.

The laser-based remote methane detector detects gas through several types of glass. Further study is required to determine this capability in all conditions and types of glass. The main obstacle glass presents is reflection of the laser or infrared light. Reflective glass is an obstacle to the light, as are heavily tinted windows. Some energy-efficient glass also limits the technology's use. Experience will show if the unit can detect small quantities of gas leaking from a locked building, especially around windows and doors (or other penetrations such as meter pans) where buildings typically provide an opportunity for air movement. Another possible source of escaping natural gas may be the eaves of homes if gas has migrated to the attic space in sufficient quantities. Since remote methane detectors using TDLAS are highly sensitive, they should prove very useful and successful in the locked building scenario, but field trials and experience will tell.

Scenario 2: Flood Use

Another very practical fire service use for TDLAS detection technology is a flooding situation. Homes and buildings, especially those with basements, become flooded, extinguishing pilot lights and damaging gas service on hot water and heating units. If gas service to the entire flooded area is not shut down (valves may be inaccessible because of flood waters), gas can continue to accumulate and rise to dangerous concentrations, creating improvised explosive buildings. Firefighters using handheld laser detector units can quickly detect escaping gas from flooded buildings from a safe distance. When the floodwaters recede, firefighters can detect gas in basements by pointing the laser through the basement window or around the door, the windows, and the eaves, which is much more efficient than entering each home to find and mitigate flammable or explosive situations. Of course, you can point the laser at gas facilities such as meters, gate stations, and larger gas facilities for damage assessment and leak detection.

Advantages

- *Speed*. Laser-based gas detection is instantaneous.
- *Critical information*. During size-up, it tells us what we need to know. Is there any gas where I am pointing the laser? Is it a little or a lot? Where do I need to monitor more accurately with a combustible gas detector?
- *Distance*. The stand-off distance enables remote monitoring; there is no immediate need to put firefighters in potential flammable/explosive atmospheres to determine the danger level.
- *Locked buildings containing gas*. The laser is effective through most windows and can detect gas inside locked buildings.
- *Training*. It is easy to train firefighters on its use.
- *Versatile*. You can use it inside to help find the source of the leak if your department procedures require you to find and fix such leaks.
- *Calibration*. The unit is solid state; it needs only a bump test against the sealed gas cell, which is included in the protective carrying/storage case.

Limitations

Like any hazmat instrument or fire department tool, laser gas detectors are not the only tool you need.

- *Risk evaluation*. Although TDLAS will indicate the presence and volume of natural gas vapors, it does not provide the concentration of vapors. To determine levels in percent LEL, responders must still follow up with a combustible gas detector.
- *Bright sun*. The gas-measuring laser is invisible, but a green spotter laser shows you the area in which you are attempting to detect gas. This may be hard to see in bright sunlight or brightly lit snowy areas.
- *Methane*. The laser is specific to methane and will not sense any other flammable gas or flammable liquid vapors.
- *Tinted windows*. Some windows will reflect the laser and impede its use. The instrument will tell you if it has inadequate/excessive return data and is unable to provide a reliable value.

Tactical Reminders

- The fire department's primary mission at gas emergencies is life safety.
- Your Plan A for size-up and mitigation of life safety issues must work and work quickly; our turnout gear is not rated for explosions.
- Your standard operating procedures (SOPs) for sizing up a natural gas emergency should parallel the procedures that your utility's gas technician would use. For example, for outside odor calls, start nearest the odor and work your way out toward safer areas; evacuate those in the most danger first, those closest to the leak and possible underground migrating gas. For indoor gas odors, interview the occupant outside before you enter and investigate; use your detector in subsurface structures such as sanitary and storm sewers.
- Your SOP must have an action level (percent of LEL) for mandatory evacuation of civilians and firefighters.
- Your SOP must provide clear direction/procedures to your line units.
- Frost layer. Note that the soil's frost layer may act as a cap and prevent gas from escaping into the air. In this case, leaking gas from mains with a pressure of 60 to 90 pounds per square inch will take the path of least resistance and may migrate into nearby structures through utility chases, cracks in rocks and foundations, or porous soil.
- Ventilating subsurface structures. If gas has migrated into subsurface structures such as a storm/sanitary sewer, pulling the manhole cover may create a path of least resistance and allow gas to vent rather than migrate.

TDLAS technology has some advantages and limitations, similar to any of our current tools and technologies. We are familiar with the limitations of our current gas detection technologies and accept these limitations because we are used to them and have experience with them. The gas industry uses TDLAS to identify possible gas leaks and then teams it up with combustible gas detectors to determine exact sources and concentrations to determine whether further action is required. It appears that this is a good combination of tools for fire service use, not unlike the combination of a halligan and flathead ax. ■

REFERENCES

1. Fireengineering.com. (January 16, 2012) "Firefighters Injured in West Haverstraw (NY) Gas Explosion." Fireengineering.com. https://bit.ly/2kON6cF.
2. Knapp, Jerry and Moran, Daniel. (March 2017) "Improving Response Procedures to Natural Gas Emergencies. *Fire Engineering*. https://bit.ly/2mgw3jY.
3. Frish MB, et al. (May 22-27, 2005) "Standoff Sensing of Natural Gas Leaks: Evolution of the Remote Methane Leak Detector." *2005 Quantum Electronics and Laser Science Conference (QELS)*. https://ieeexplore.ieee.org/document/1549335.

Author's note: Thanks to Deputy Chief John Buckheit of the Fire Department of New York for his assistance with this article.

JERRY KNAPP is a 42-year firefighter/EMT with the West Haverstraw (NY) Fire Department and a training officer with the Rockland County Fire Training Center. He is chief of the hazmat team and a technical panel member for the Underwriters Laboratories research on fire attack at residential fires. He authored the Fire Attack chapter in *Fire Engineering*'s *Handbook for Firefighter I and II* and has written numerous articles for *Fire Engineering*.