CHAPTER II

RECOGNIZING AND AVOIDING THE HAZARDS OF NATURAL GAS AND CARBON MONOXIDE

INTRODUCTION

First responder fatalities have involved natural gas and carbon monoxide. The purpose of this program is to:

- help you to understand the properties of natural gas and carbon monoxide,
- give you a basic knowledge of how the gas system works and what causes carbon monoxide,
- make you aware of the hazards of natural gas and carbon monoxide, and
- offer approaches for responding to natural gas and carbon monoxide emergencies.

This chapter will help you better understand and determine what precautions need to be taken when responding to natural gas and carbon monoxide incidents.

Natural gas cannot be seen and is odorless in its natural state. *Natural gas and carbon monoxide can be dangerous and can injure and / or kill emergency workers.* For specific facility and emergency response needs in your service area, meeting with your local gas company on a periodic basis is strongly recommended.

Firefighter Fact Natural gas has a flammable or explosive range from just below 5 percent in air to just below 15 percent in air. These percentages are known as the *"LEL" (Lower Explosive Limit)* and *"UEL" (Upper Explosive Limit).*

PROPERTIES AND CHARACTERISTICS OF NATURAL GAS

This section provides a general summary of the properties of natural gas. Key safety and tactical points are indicated.

Natural gas is a petroleum-based compound that was created just as the name implies, naturally. Like crude oil, natural gas formed under ground from the breakdown and decay of organic matter (plant and animal material) over millions of years due to pressure and heat from the changes that have taken place during the evolution of our planet. Natural gas, a hydrocarbon, is primarily methane with small amounts of propane ethane, and butane. The small portion of ethane is considered the identifier for natural gas; it is not found in sewer gas or swamp gas. For this reason ethane detection equipment is utilized whenever an investigation needs to confirm the actual presence of natural gas. Natural gas is found underground, sometimes on top of reservoirs of oil or by itself in a pocket of gas. When natural gas burns, the products of combustion include carbon dioxide, water, and of course heat. When the combustion is incomplete, traces of CO, carbon monoxide, are produced. Carbon monoxide is an extremely dangerous gas and will be discussed at a later point.

See Table II-1 for selected flammable ranges and Figure II-1 for gas percentage vs. LEL percentage. In other words, if the concentration of the gas mixed with air reaches a level just below 5 percent, the gas can ignite. If the concentration increases to a point just above 15 percent gas in air, the gas will *not* ignite. While natural gas will ignite anywhere within

TABLE II-1

Flammable Ranges for Selected Materials

MATERIAL	LOWER FLAMMABLE LIMIT (LFL)	UPPER FLAMMABLE LIMIT (UFL)
Acetylene	2.5	100.0
Carbon Monoxide	12.5	74.0
Ethyl Alcohol	3.3	19.0
Fuel Oil No. 1	0.7	5.0
Gasoline	1.4	7.6
Hydrogen	4.0	75.0
Methane	5.0	15.0
Propane	2.1	9.5

Source: NFPA 325, Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids, 1994 edition.

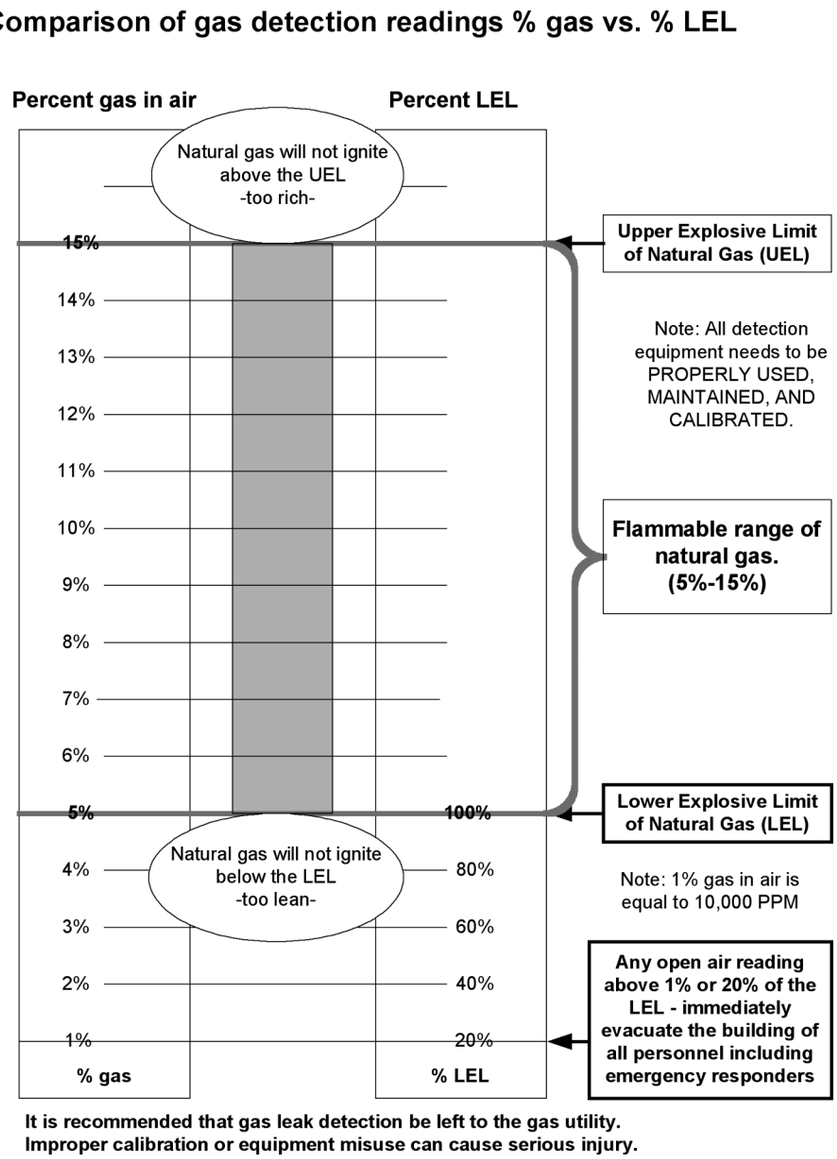


Figure II-1 Gas detection readings; percent natural gas compared to percent of explosive limits.

this range, the ideal gas-to-air mixture for the burning of natural gas is approximately 10 percent. Keep in mind that if one encounters a natural gas concentration below the "LEL," whether outdoors or indoors, there may very well be a flammable concentration in an area nearby. *Do not* assume that an area is safe just because it appears safe where you are standing at any given moment.

Natural gas will ignite at a temperature of approximately 930 degrees Fahrenheit. Sources of ignition capable of generating 930 degrees are all around us. It is important that we look at some of the items and conditions that can cause an ignition, as we may never think of many of these potentially dangerous ignition sources. A lit cigarette is hot enough to ignite natural gas. Matches, lighters, and even the sparks generated by the starter or alternator of motor vehicles can ignite natural gas. It goes without saying that precaution flares used for traffic control supply more than enough heat than is necessary to ignite natural gas. A vehicle driving through a natural gas concentration within the explosive range could in turn ignite the gas. Cell phones, pagers, and radios all have switches that, when activated, can generate sparks sufficient to ignite natural gas. In and around a structure the list of sources of ignition grows even longer. Doorbells, light switches, smoke alarms, telephones, pilots on appliances, and filaments in light bulbs (including flashlights) if the bulb or lens breaks can all generate an arc or heat source sufficient to ignite natural gas. Even static electricity arcs from your clothes, body, or other sources can create sparks of sufficient heat to ignite the gas.

Never take cell phones, pagers, radios, or two-way radios into the suspected leak area. Never ring a doorbell, to contact occupants of a structure; knock on the door. Do not operate any appliances or turn anything off or on (including light switches) in a suspected gaseous atmosphere. The arc created when unplugging an appliance from a wall outlet is sufficient to ignite natural gas. First responders have a difficult and often hazardous job. Remember, controlling sources of ignition in a possibly explosive area can keep a dangerous situation from becoming a deadly one.

After processing, natural gas is odorless, colorless, and tasteless. However, if you walk into a room or area where there is a gas leak, you will usually smell the telltale "rotten egg" odor since natural gas has odor added to it. The first code in the United States for the odorization of natural gas was brought about by a 1937 incident in Texas. An undetected natural gas leak led to an explosion in a school causing tremendous loss of life. Today, all natural gas, as well as propane, is odorized using chemicals such as mercaptans or sulphides. These odorants are absorbed by the gas, have no effect on its properties for burning, and are harmlessly burned up with the gas. Odor is one of our warning signs for a gas leak. However, keep in mind that there are conditions that can counter the effectiveness of this warning sign. Certain conditions in the gas piping can actually remove the odor from the gas. In some cases, the chemicals and solvents used in the manufacture of plastic pipe, natural odors in farm or rural areas, and some manufacturing odors can mask the odor of natural gas.

In some cases your own olfactory abilities may be compromised by allergies, illness, or interference from other odors. It is usually necessary to use some type of gas detection equipment for the confirmation of natural gas in an area. It is recommended that the gas company evaluate the gas leak. Gas detection equipment requires training, calibration, and compliance with the manufacturer's procedures for use.

This and other issues regarding propane will be discussed later. Whether from an underground leak trying to make its way to the surface or a leak in a structure, natural gas will always try to travel up. Underground, the gas may be diverted by obstacles such as rocks, frost, paving, or other objects that can stop its upward travel. The more dense the soil and the more the gas is diverted, the larger the spread or migration of the gas.

These paths can often create highways into structures. Leaking natural gas inside a structure will again try to find a way to go up. For example, gas leaking from an appliance in a basement will work its way up stairways, holes through floors for electrical cables and water and sewer pipe, and even up the interiors of walls. Once on the next floor, the process continues to the next floor or attic, and the process continues.

Caution Whenever possible one should approach a suspected natural gas leak from an upwind direction. Park your vehicle a safe distance from the suspected leak area.

Caution Never rely solely on your sense of smell to determine the hazard or lack of hazard in a gas leak area.

Firefighter Fact Keep in mind that natural gas is lighter than air. The specific gravity of natural gas is approximately (.6) while the specific gravity of air is (1.0). Propane with a specific gravity of (1.5), however, is heavier than air.

Firefighter Fact Natural gas can be diverted to the point that an underground leak can migrate into a structure from great distances. Natural gas can very easily follow sewer lines, underground electrical and phone conduits, and even the more loosely packed soil around underground pipes and cables.

Firefighter Fact Natural gas is not toxic. It can, however, displace oxygen; in high concentrations, it can displace enough oxygen to cause asphyxiation. Be especially aware in confined spaces and structures that, while natural gas will not poison you, it can still kill you by removing your life-supporting oxygen.

When checking for natural gas indoors, always check near ceilings and in openings through floors, under cabinets, and so on. Remember, always maintain control of potential ignition sources. Never use an elevator in a high-rise type structure where a natural gas leak is suspected. The gas most likely will collect in the top of the elevator shaft and ignite as soon as you press a button to call the elevator, as the motor and controls are usually in the tops of elevators.

It is well-known that the more you know about a subject, the better you are able to handle and work with that subject matter. The preceding information is intended as a tool to assist you in dealing with emergency situations involving natural gas.

THE NATURAL GAS DELIVERY SYSTEM

This section provides an overview of the natural gas delivery system. Key safety and tactical points are identified. For specific facility and special emergency response needs in your service area, meeting with your local gas company on a periodic basis is strongly recommended.

The gas delivery system is depicted in Figure II-2. Natural gas is transported from the wellhead via a pipeline to a processing plant where it is cleaned by having water and other contaminants removed. From that point it begins its journey across the country in a complex system of high pressure, transcontinental pipelines. This steel pipeline can be as large as 4 feet

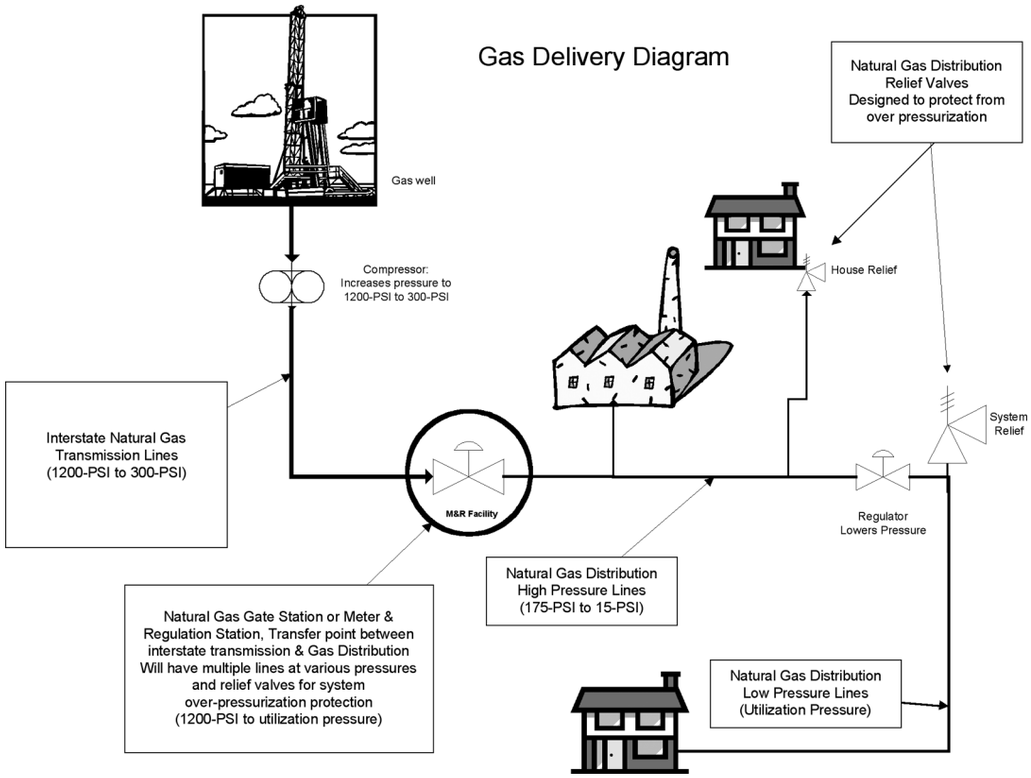


Figure II-2 Gas delivery system.

in diameter and carry product at pressures as high as 1200 psi. Along the way the friction in the pipe causes the natural gas to slow down. To counter this, every 50 to 60 miles, the natural gas goes through a "compressor station" where the pressure is boosted and the gas is moved quickly along its way. These transmission lines follow "right-of-ways" or property that is dedicated to the use of the pipeline. These "right-of-ways" are identified with markers to verify their location. While the style of the markers may vary, the information they impart is similar: "Warning: Underground Gas Pipeline." In most cases there will be "Emergency Contact" phone numbers included on pipeline markers, Figures II-3 and II-4.

Following this stage of its journey the natural gas arrives at a location known as a gate station or border station. Two important things happen to the natural gas at these stations. The odorant is added and the pressure is reduced for delivery to the utility company's local distribution lines. *All natural gas is odorized by the cross-country transmission companies before it enters New Jersey.* The distribution lines, called mains, can range in size from 2 to 20 inches and sometimes larger, carry the gas to business, residential, and industrial customers. In the early years of natural gas, distribution mains were actually made of wood (hollowed out tree trunks) and handled very low pressures. Over the years, this material was gradually replaced by cast iron, and then steel and plastic. Today the primary material for natural gas piping is wrapped or coated steel and plastic. Pressures in these mains can vary greatly depending

Figure II-3 Pipeline markers.

Figure II-4 Pipeline marker and road crossing casing vent pipe.

on the application and demand in a given area. A utility company's "transmission mains" can be pressurized in excess of 1,000 psi while at the other end of the scale, "low pressure" (usually older cast iron) mains can be regulated at pressures as low as 1/4 psi. The vast majority of these "mains" are located underground. The exception to underground mains is the occasional bridge crossing. It is sometimes much more economical and practical to suspend a natural gas main from a bridge than to utilize directional drilling to cross under a waterway.

The pressures in these different "mains" or "distribution lines" are set and controlled by "regulator stations." The regulator station is a collection of valves and regulators that maintain correct pressures for a given section of distribution and also include safety devices to prevent overpressurization. These safety devices are known as "relief valves." Relief valves are mechanical devices that stay closed up to a preset pressure. If the preset pressure is exceeded, the "relief valve" begins to open and vent off the overpressurized natural gas. Once the pressure returns to the normal, preset pressure of the "relief valve" the valve will close automatically, Figure II-5.

You may create an even larger problem on another part of the distribution system if you interfere with the operation of a relief valve. If a "relief valve" is venting or blowing, notify the utility company immediately.

The "regulator station" may be located above ground or below ground, in a pit or vault. These pits and vaults, commonly known as "confined spaces," present a whole new set of safety concerns and problems. Before entering a confined space one must perform many safety checks and procedures. It is strongly advised that when responding to a situation at a pit or vault that you only take actions to keep the area around the pit or vault as safe as possible, under your control with restricted access.

Safety If a "relief valve" is venting or blowing, it is doing its job properly. Do not try to shut it off.

Figure II-5 Gas relief vents.

Safety Notify the utility provider and wait for their response. Do not enter these areas; if a fire is active in the vault or pit, do not fill it with water to try to extinguish the flames.

Safety By extinguishing a natural gas fire you may only be trading a known, visible hazard for an invisible cloud of natural gas that can create a potentially explosive situation in another area. Protect the exposures and let the gas burn. The best way to extinguish a natural gas fire is to shut off the source of natural gas.

You may create a situation where the utility worker cannot access the area to make repairs. Keep in mind, if a natural gas fire is not affecting life or property, it may be better to let it burn until the utility company can bring the situation under control.

The flow of natural gas throughout the utility company's "distribution mains" is controlled by valves and regulators. The final control before the customer's equipment is the customer regulator and shutoff valve. The customer regulator lowers the pressure such that it is appropriate for the equipment used by the customer. Whether indoors or outdoors the shutoff valve is usually located just before the regulator or just before the gas meter. These valves are the only valves that you should operate. They are the primary valve for stopping gas flow to a structure. In most cases, the gas shutoff valve is a 1/4-turn valve. In other words, one quarter rotation is all that is necessary to close or open this type of valve. When the wing on the valve is aligned with or parallel to the gas pipe, the valve is open. When the valve wing is positioned across or perpendicular to the gas pipe, the valve is closed. The simplest tool for operating these valves is either an adjustable wrench or properly sized end wrench.

In some cases where the fire is confined to an individual appliance, it may be just as practical to only turn off that appliance's shutoff valve rather than shutting down an entire structure. Figure II-6 is an example of an outside utilization pressure gas service meter and valve. Figure II-7 is an example of an inside utilization pressure gas service meter and valve. Figure II-8 is a comparison of a utilization gas meter service on the left hand side to a pressure gas meter

Safety If it is necessary to shut off meter valves for stopping gas flow to a fire, be sure to lock and tag the valve such that it can *NOT* be turned back on. Only the utility company should turn on a gas service valve after it has determined the safety of such an action.

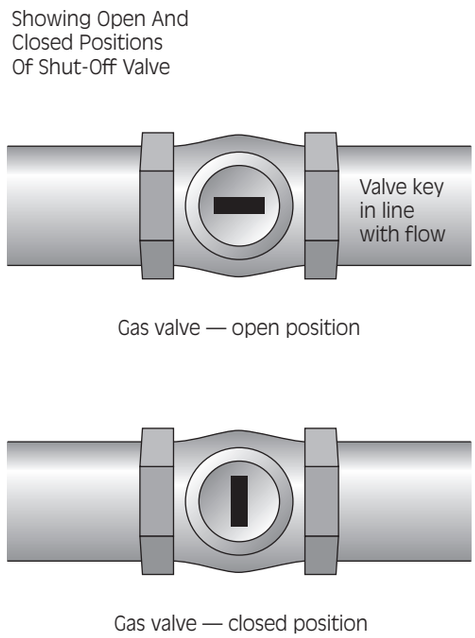


Figure II-6 Gas service 1/4-turn type valve.

Figure II-7 Inside gas service 1/4-turn type valve.

service on the right hand side. As can be seen, the regulator and vent indicate a pressure gas service. Figure II-9 is an example of multiple gas meter service. As indicated in the figure, valves are located for each gas meter and for the gas service.

In some cases one may find a gate style valve in these locations. Gate valves require several full rotations to either open or close. It should be noted that while the function of these valves is the same as 1/4-turn valves, be sure you know the difference. If you only turn a gate valve 1/4 turn, the gas will continue to pass through the valve. Generally, gate valves are used on larger commercial and industrial gas services. Figures II-10 and II-11 are examples of gas services with gate valves. A change in the meter index may provide a means of determining if a gate valve has been closed. If there is no gas flow and no change can be determined by the meter index, you will not be able to determine the position of the gate valve. Gate valves are generally used for commercial and industrial customers and for larger-sized gas services.

While there are many valves used to control a natural gas distribution system the first respondent should *never attempt to turn, close, or open any underground valve.* Whether service valves, street valves, main valves, or regulator station valves, you should never turn or attempt to close or adjust any valve other than a shutoff valve on an outdoor or indoor meter.

Caution Without the knowledge of the function of a particular valve, operating any underground valve can create potentially severe hazards and potentially dangerous consequences in another section of the distribution system. *Never turn (operate) underground natural gas valves.*

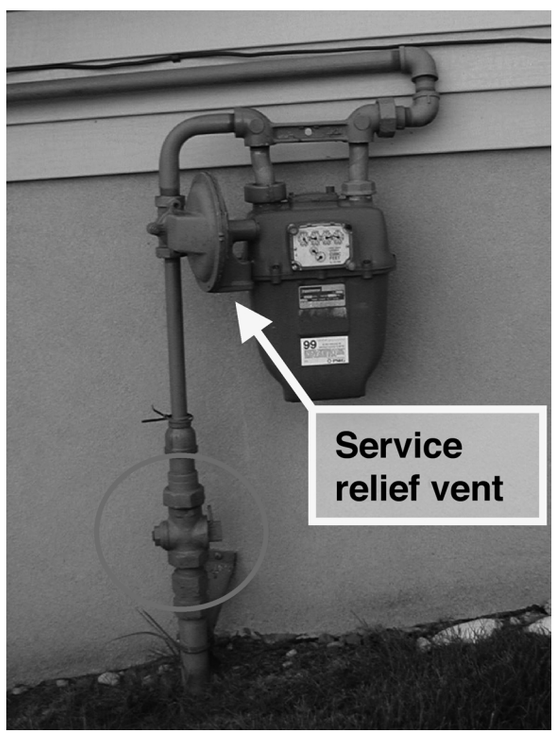


Figure II-8 Gas service 1/4-turn type valve. A: Utilization pressure service. B: Pressure service.

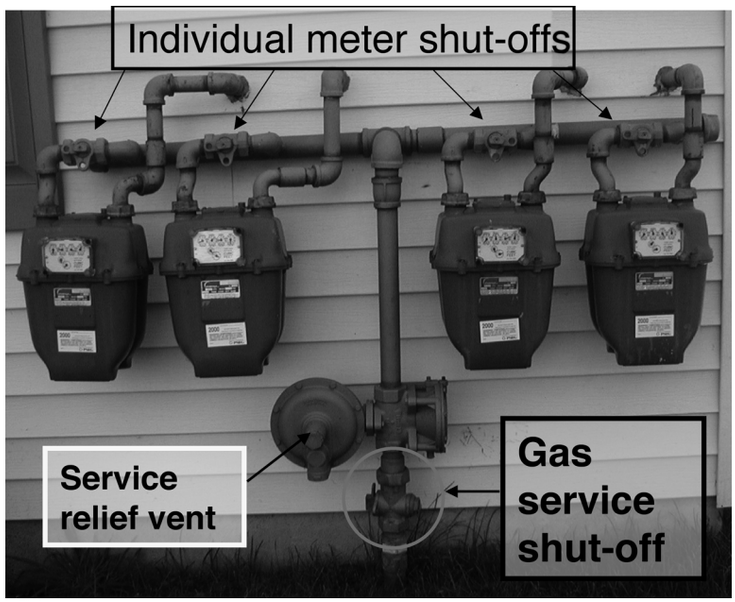


Figure II-9 Multiple meter gas service 1/4-turn type valves (pressure service).

Figure II-10 Pressure gas service gate type valve (multiple turns to close).

Figure II-11 Pressure gas service gate type valve (multiple turns to close).

NATURAL GAS UTILITY OVERSIGHT

This section provides a reference of the regulations applicable to the natural gas distribution and transmission system in New Jersey.

The United States Department of Transportation and the New Jersey Board of Public Utilities regulate the natural gas industry and the gas delivery system. Title 14 of the New Jersey Administrative Code and Section 49 of the Code of Federal Regulations Part 192 are the applicable codes. Gas utilities are required to report certain gas incidents to the New Jersey Board of Public Utilities and/or the National Response Center. The National Transportation Safety Board and the New Jersey Board of Public Utilities investigates the most serious transportation incidents including natural gas and liquid pipeline incidents.

KEEPING THE GAS SYSTEM SAFE—DAMAGE PREVENTION AND RESPONSE

This section provides information on preventing damage to gas facilities.

Understand that one of the primary causes of gas incidents is excavating equipment damaging underground gas facilities. Preventing damage to utility facilities can prevent an emergency response. There are on average around 3,000 cases of gas facilities being damaged each year in New Jersey. Many states have enacted laws to protect underground facilities. In New Jersey the law is entitled the *Underground Facility Protection Act.* Excavators are required to notify the New Jersey One-Call Center at *1.800.272.1000* prior to excavating and obtain a mark-out request at no cost. The One-Call Center is toll-free and available 24–7. After a mark-out request has been obtained, underground facility owners and utilities are required to mark their facilities according to the law and in colors that identify the facility type. The color coded system that identifies the different types of buried utilities can aid you when you respond to a hazard call at or near a construction site. It is important for you to know what systems could be affected. For more detailed information or training call the New Jersey Board of Public Utilities at 973.648.2066.

Figure II-12 depicts the color code for facility markings. A *yellow* flag or paint tells you that there is a gas, oil, or steam line underground. *Red* flags or paint identify electric lines. Buried cable television, telephone, and fiber optic cables are marked by an *orange* flag or paint. When you see a *blue* flag or paint, there is a water main or service underneath. *Green* markings indicate a sewer line.

Figure II-12 Utility marking color code.

Prevention

The best approach to avoid a damaged facility incident is damage prevention. Calling New Jersey's One-Call Center at *1.800.272.1000* prior to excavating and/or ensuring excavators have markings are actions that can avoid an incident.

If you encounter an excavator who you believe does not have a mark-out request, notify the New Jersey Board of Public Utilities at 973.648.2066. Besides endangering the public, a willful violation of the Underground Facility Protection Act carries civil fines from $1,000 to $500,000 and criminal penalties. In addition, excavators can be liable for the incident damage and associated costs. Local utilities can also assist in determining if a mark-out has been requested.

Anytime you respond to a call where a gas odor is reported, and there is construction in the area, check the markers along the ground, because they might indicate that the source of the leak is construction related. *Remember that the damage may have caused multiple leaks or damage to the gas facilities at the construction site and/or away from the construction*

CASE STUDY II-1 NTSB/PAB-04/01

Excavation Damage to Natural Gas Distribution Line Resulting in Explosion and Fire, Wilmington, Delaware, July 2, 2003.

Remember: A gas leak can occur away from the construction activity.

On July 2, 2003, a contractor hired by the city of Wilmington, Delaware, to replace sidewalk and curbing dug into an unmarked natural gas service line with a backhoe. The gas leak was not observed at the damage contact. Although the service line did not leak where it was struck, the contact resulted in a break in the line inside the basement of a building across the street, where gas began to accumulate. A manager for the contractor said that he did not smell gas and therefore did not believe there was imminent danger and delayed calling the gas company. A subsequent explosion destroyed two residences and damaged two others to the extent that they had to be demolished. Other nearby residences sustained some damage, and the residents on the block were displaced from their homes for about a week. Three contractor employees sustained serious injuries. Eleven additional people sustained minor injuries.

site in locations like across the street or inside buildings. Besides the normal emergency response precautions and evacuation criteria, check nearby buildings and buildings across the street or surrounding the construction area. If you detect any odor of gas, evacuate as a precaution. Work with the local gas company to determine the full extent of the gas leak and safe area. The two case studies that follow provide examples of why a complete evaluation of the emergency situation is required to safeguard your life and public safety.

Damage to underground facilities is a top priority of the United States Department of Transportation's Office of Pipeline Safety due to a high number of significant incidents that have occurred. Annually, New Jersey experiences up to 5,000 incidents where underground facilities are damaged. Sixty percent involve natural gas facilities. Many involve multiple facilities being damaged, including water and gas. Damage to water facilities can affect fire hydrants in the area.

The two case studies investigated by the National Transportation Safety Board are typical incidents that have occurred in many states. Similar incidents have occurred in New Jersey. New Jersey, besides being the most densely populated state, also has the highest underground facility density of any other state.

DETECTION METHODS FOR NATURAL GAS

This section provides approaches for detecting natural gas. As a general rule when a gas odor is detected in a building, evacuate the building and work with the gas company to evaluate the gas leak.

When checking for gas leaks, an invaluable apparatus is the Combustible Gas Indicator, mostly referred to as a "CGI." Many fire departments, and an increasing number of police and EMT units, have this equipment, which is used to capture samples of the air and display any concentrations of natural gas. The first step is taking a clean air sample to have a reference point for the CGI. This is called "zeroing out," and is done before samples are taken in the area of the suspected gas leak. While the CGI and other sampling equipment are critical for evaluating a gas leak, equally important is the proper use and calibration of such equipment.

Caution Improper use or the use of an out of calibration device can place you in serious risk or jeopardize your life.

Most gas companies and providers have established evacuation protocols for gas leak investigation personnel. Generally any open-air CGI reading of 1 percent or 20 percent of the Lower Explosive Limit (LEL) in a structure means that all persons must be evacuated including those evaluating the gas leak. In addition, a gas mixture may be *too rich to ignite (greater than the Upper Explosive Limit—UEL) in places and will be moving through the explosive range as the areas are vented.*

Sampling needs to be done throughout the house, but before doing this, responders should be in full

CASE STUDY II–2 NTSB/PAB-00/01

Natural Gas Service Line and Rupture and Subsequent Explosion and Fire, Bridgeport, Alabama, January 22, 1999

Remember: Damage to the gas service can cause multiple gas leaks.

On January 22, 1999, while digging a trench behind a building at 406 Alabama Avenue, a backhoe operator damaged a 3/4-inch steel natural gas service line and a 1-inch water service line. This resulted in two leaks in the natural gas service line, which was operated at 35 psig. One leak occurred where the backhoe bucket had contacted and pulled the natural gas service line. The other was a physical separation of the gas service line at an underground joint near the meter, which was close to the building. Gas migrated into the building, where it ignited. An explosion followed, destroying three buildings. Other buildings within a two-block area of the explosion sustained significant damage. Three fatalities, five serious injuries, and one minor injury resulted from this accident.

"PPE"—personal protective equipment. You need to protect yourself against any possibility of an accidental ignition. When the utility company personnel arrive, additional sampling with a CGI may also take place, including outside areas. They have additional tools to take underground samples where gas may be migrating. However, if the smell of natural gas is strong throughout the outside area, checking for levels inside neighborhood houses would be a sound precaution. It is vitally important to know that this equipment is sophisticated and sensitive. In order to be confident that what you're reading is accurate, periodic calibration testing ensures reliability and, with many companies producing CGI equipment, each sets its own maintenance guidelines and training. Different brands may require different procedures for taking gas samples. It is recommended that you rely on the local gas company for gas leak evaluation.

WHEN GAS ESCAPES THE SYSTEM

This section provides approaches for responding to natural gas emergencies.

Despite every effort to monitor and maintain the integrity of the natural gas system, its size and complexity, combined with the forces of nature, prevent it from being totally immune to uncontrolled gas leaks. Understand that whenever a natural gas emergency presents itself, it will be classified in one of four ways:

- Gas escaping outside
- Gas escaping inside
- Gas burning outside
- Gas burning inside

The majority of calls involving natural gas don't involve fires; typically, when someone such as a homeowner smells gas, that person will dial "911" to report the problem. The first responder might be the closest person to the scene. *What's important is that all responders coordinate their activities and take every precaution to protect lives . . . including your own.* If some of the guidelines and ignition sources seem overly cautious, they're not. Expect the unexpected. *Investigating gas leaks presents a number of hidden dangers.*

Initial Response

Before you arrive on the scene and prior to starting a gas leak investigation there are actions to take:

- Contact the local gas company or gas provider and request assistance

- Position emergency vehicles to avoid potential gas leak sources such as:
  - Catch basins
  - Manholes
  - Storm drains
  - Areas too close to houses
- Position emergency vehicles away from any building with leaking gas in case the building were to explode and park the vehicles upwind of the gas leak (any breeze should be at your back, and blowing any gas *away* from your vehicle.)
- Eliminate sources of ignition before investigating a gas leak:
  - Shut off vehicles
  - No smoking
  - No flares
  - No portable radios
  - No cell phones, pagers, or other electronic equipment
  - No doorbells—knock instead
  - No operating light switches (leave as it was found)
  - No telephone calls to the residence
  - No static charge
- Turn on emergency equipment prior to investigating a gas leak
  - Combustible Gas Indicator or detection equipment
  - Flashlight

Secure the Site

Establish a site perimeter and reroute vehicle traffic as necessary. Eliminate sources of ignition. When the presence of gas is strong, the best rule is to evacuate people from the dwelling and move them across the street or a distance far away that would prevent injuries if the structure were to explode. Also be aware that shuffling your feet on many types of surfaces can cause a static electricity discharge. Remember you are evacuating and securing the area in case of an explosion. Check surrounding houses for gas odors. Keeping in mind the capability of natural gas to migrate, evacuate other residents who live in any adjoining properties at least one house away. If the presence of gas is detected in any of these, continue checking until you get two "clean" houses or buildings from the last detection, or the end of a row of houses or buildings is reached. If you have either called for backup, or have been called, follow all the "make-safe" procedures just described.

As different responders arrive, it is important that everyone's activities are coordinated and contribute to preserving life. If assisting in evacuation or traffic control, remember *not* to ring doorbells or use radio-communications, unless from a safe distance.

Many times utility companies have "hotlines" dedicated solely for emergency situations, and their role is to assist you in any way to make the situation safe. Whoever is responding, whether first or last, has a duty to protect life and property.

Periodic meetings with your local gas providers to discuss emergency response, local gas facilities with special needs or response criteria, your expectations, and teamwork are the best ways to prepare before an incident and will aid in developing the most effective resolution when an incident occurs.

Safety Any time you respond to a possible gas emergency, it is important that in reporting on the situation, whether directly or more likely, through your dispatch center, you verify that the gas company has been notified.

Leaking Gas

There are many different types of gas leaks. The most dangerous is a blow to the pipe, causing a puncture and rapid venting. Environmental conditions like freezing and thawing cause cracks in cast iron pipes, also resulting in the rapid escape of gas. However, the most prevalent kind are slow leaks brought on by corrosion, producing slow seepages, which are obviously much harder to detect. Underground leaks usually mean migrating gas. *The odorant added to the gas can become less effective, making the gas difficult to detect due to the odorant being scrubbed in the soil.* The gas travels laterally, through the ground, following the path of least resistance, because it wants to vent. It can enter into any number of spaces and accumulate, such as sewer lines, storm drains, any underground utility line, new construction trenches, or a building. It also seeps naturally through the ground over time, and once it permeates, since it is lighter than air, it will rise. Not until then will the telltale odor be detected. Of course, there are factors that can make detection difficult. Natural causes are wind, which can carry away the odor; rain, snow, or frost, which may keep it from coming up; or man-made barriers like concrete and asphalt. Conversely, cracks in the streets are places where migrating gas can be detected as it rises into the air. Inside, the "lighter than air" property of gas causes it to rise and collect near ceilings. The risk is even greater in cold weather, since ventilation is restricted to prevent heat loss.

Remember that a static discharge can ignite leaking gas. Plastic pipe used to carry natural gas can

Caution Never attempt to repair or stop leaking gas unless the gas can be shut off by an aboveground valve.

attempt to stop the gas by bending the plastic pipe or inserting a wooden plug can cause a static discharge resulting in a subsequent ignition and explosion. Secure the area and protect the surrounding structures. Leave the repair to the gas company/provider.

When Gas Is Escaping Outside a Building

- If gas is escaping from the ground, excavation, or an open pipe outside a building, notify the gas utility immediately.
- Areas surrounding the location should be cleared, roped off, or barricaded to make the location safe.
- Extinguish all open flames. Prohibit smoking. Restrict use of electronic devices (i.e., pagers, cellular telephones, and cameras) while working in the vicinity of the gas leak. Check surrounding buildings, basements in particular, for any presence of gas odor. Restrict or reroute all traffic until personnel from the gas company are able to control the gas flow.
- If a fire or gas leak situation requires gas to be shut off immediately and the Fire Department cannot wait any longer for gas company personnel to respond, shut the aboveground service valve.
- *Emergency responders should never operate underground valves. Only gas company personnel should operate underground valves.*
- For services feeding multiple dwellings, it is preferred that aboveground service valves are not operated without utility assistance.

Damage to Gas Facilities

- Remember that when responding to any damage to gas facilities, emergency personnel should make every effort to keep the area safe while waiting for gas company assistance. This includes checking the extent of the gas leak in the immediate area and monitoring buildings on both sides of the street, since multiple leaks could become active at the same time.
- Under no circumstances should the Fire Department attempt to make a repair of any damage to gas facilities. Only gas company personnel have the proper personal protective equipment and knowledge to safely control the gas flow.

When Gas Is Burning Out of Doors

- Personnel, other than those from the gas company, should make no attempt to extinguish a gas fire unless a life is in jeopardy.
- When gas is believed to be involved in a fire, don't assume the fire is consuming all of the gas. Always check nearby buildings and sewers to make sure gas is not migrating. Clear the danger area and rope or barricade it. Notify the gas company immediately. Never operate an underground gas valve. Operating the wrong valve could further endanger life or property. Leave the decision to operate valves to gas company personnel. They are properly trained in operating gas valves and handling gas emergency procedures. Remember that gas may also be leaking elsewhere, so check the surrounding structures.
- Spray any surrounding combustibles if there is a danger of ignition. If it is necessary to extinguish a fire because a life is in jeopardy, use dry chemical and water fogging equipment. Do not direct a solid water stream onto burning gas at the source of ignition. Remember—burning gas will not explode.
- Shut off the gas source

When Escaping Gas Is Found in Buildings

When escaping gas is found in buildings, shut off the meters and notify the gas company immediately. Ventilate the building by opening the doors and windows if the gas level is below the LEL. Remember that if the gas level is above the explosive limit, venting the building could result in an explosion. Evacuate and wait for the gas company in the safe zone. Do not turn electrical switches or appliances on or off. Rubber boots should be used when entering a building where a gas leak is suspected, as shoes with nails could create a spark. Walking across a carpet could result in the development of a static electric charge or spark. Turn on flashlights before entering the building. Clear the buildings of occupants if a strong odor is found.

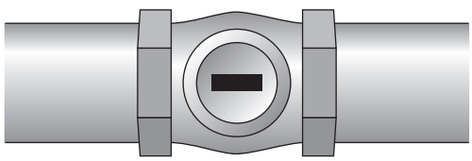
We will discuss gas leak detection, actions, and evacuations in more detail in the next section.

When Escaping Gas Is Burning in Buildings

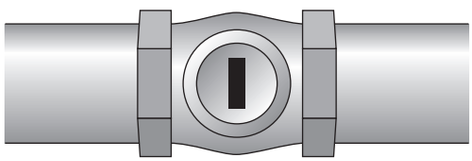
When escaping gas is burning in buildings, notify the gas company immediately. The official in charge should determine if gas can be shut off at the service entrance inside the building, at the regulator (in pressure systems), or at the meter, depending on the type of installation.

If there is an aboveground service valve at one or more of these locations, the valve can be shut off with a wrench. Figure II-13 is an example of a 1/4-turn

Showing Open And
Closed Positions
Of Shut-Off Valve



Gas valve — open position



Gas valve — closed position

Figure II-13 Gas service 1/4-turn type valve.

type of gas valve with the valve positions indicated on the right hand side of the gas service picture.

- Reliance on the gas company to help evaluate the proper action is the best procedure. If the supply cannot safely be shut off, keep the surrounding combustibles wet by spraying until the gas company emergency crews can control the flowing gas.
- It is possible that turning off the gas in certain industrial or commercial areas might create further hazards or seriously interrupt important and costly industrial processes.
- *Never turn on a valve that was previously shut off. Leave this to the gas company.*
- If it appears that the inside gas piping or meter may be endangered from the fire, notify the gas company immediately. The gas company is best equipped to shut off the supply of gas. However, if safety requires immediate action, the official in charge may proceed with shutting off the gas supply at an inside shutoff valve, if it can be done without exposing the person to undue hazard.
- In rare cases, gas may be burning out of control at an appliance. In such cases, shut off the valve on the line to the appliance if it is accessible, or shut off the gas at the meter. In an apartment house where there may be difficulty in selecting the proper meter there is usually a valve where the gas service enters the building (service entrance) that can be shut off. Again, notify the gas company immediately and explain to the serviceperson upon arrival what you have done. Do not turn on the valve at the service entrance, the meter, or appliance once it has been shut off; leave this to the gas company.

General Considerations for Electric Power Disconnection (limit potential ignition source)

- Do not disconnect the electric. Have the electric utility disconnect the electric when needed.
- Building emergency back-up generators may operate if the electric is disconnected.
- If a larger area of electric is to be disconnected, work with the electric utility to minimize the impact on critical customers, customers on life support, and water pumping stations.

DEALING WITH NATURAL GAS FIRES

This section provides approaches for responding to natural gas fires.

- Classes of fires

Burning natural gas is a Class B fire. However, it can cause other materials to burn around it such as wood, paper, and vegetation, which are all Class A fires; or energized electrical wires, creating a Class C fire. So, you may be facing a multiple class fire. For machinery or fires involving electrical components, the safest way to extinguish the fire is to de-energize the circuit, and eliminate the gas supply.

- Ways burning gas can be extinguished

Water is not an effective method for extinguishing a natural gas fire. Dry chemical extinguishers should be used with proper technique. Shutting off the gas supply and allowing residual gas in the pipe to burn out is often the best approach. Shut off the meter supply valve or service valve when accessible.

- Dangers of interactions with electrical systems

A gas-fed fire may cause the insulation on overhead wires to burn. This damage may cause the live wires to fall in some cases. Don't approach fallen electrical lines until the power company disconnects them. Gas piping may also share a common underground trench with electrical facilities. In some cases both may be damaged by the blaze.

COMPRESSED NATURAL GAS VEHICLE EMERGENCY RESPONSE

This section provides information for approaching natural gas vehicle emergencies.

- How to recognize a compressed natural gas vehicle

Vehicles that use natural gas as a supplementary fuel to gasoline will have a blue symbol attached to the rear of the vehicle. The gas is stored in a cylinder, usually in the trunk of a sedan or rear of a van. Figure II-14 provides an example of the decal.

- Gas dissipates quickly

If the natural gas delivery system is damaged in a collision, leaking natural gas should dissipate quickly. Natural gas is lighter than air and will tend to rise up away from ground level. Note: Propane gas is heavier than air and may accumulate over the ground surface. Know which gas you are dealing with; the sticker on the vehicle's rear will indicate this. Figure II-15 shows the shutoff valves by the natural gas fuel cylinders.

- How to find and operate a manual shutoff valve

Look for the shutoff valve below the driver's side door; if it is not there, check the passenger side. Use this valve to shut off the gas supply in the engine compartment. The shutoff valve under the driver's or passenger's door is depicted in Figure II-16.

GAS BURNING INSIDE

This section provides approaches for responding to natural gas fires burning inside.

When natural gas is burning out of control, it is a Class B fire. But when inside, because of the surrounding ordinary combustibles, you're also dealing with a Class A fire. In commercial and industrial settings, cables and machinery may further expand the emergency to include a Class C fire, or even Class D if combustible metals are part of the manufacturing process.

All these factors can create visibility problems in locating burning gas. Indoor fires may require you to create a path to get to the meter. If the fire has been burning for some time, smoke may prevent you from seeing the meter and cause you to back away. When intense heat is present, the dial cover where the meter is read may crack, which adds to the danger. When this happens, gas will be leaking from inside the meter. If at all possible, try to get the flow of gas shut off.

There most likely will be other exposures in the immediate area, which need to be protected. This is especially important if overhead electrical wires could end up in the path of any spreading fire. Water and the downed electric wires could be a deadly mix. This could wreak havoc with the underground gas system by searching for a ground and arcing to a steel gas pipe or tracer wire on plastic gas pipe. The gas facility damage could occur blocks away from the downed wire and will require the gas company to perform leak survey immediately in the vicinity.

In other situations, such as the fire coming from an upper level, say a bedroom where a gas line is very

Figure II-15 Cylinder shutoff valves.

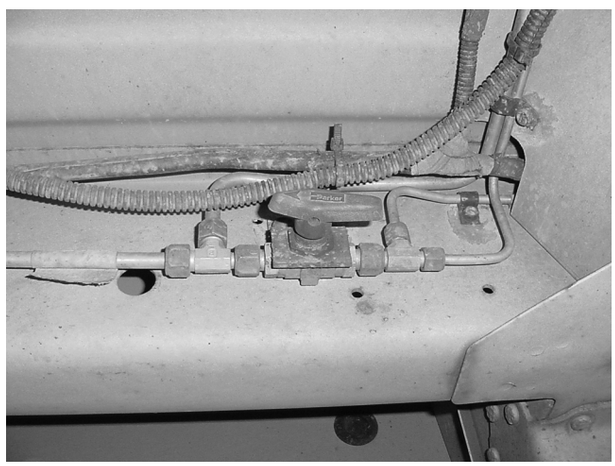


Figure II-16 Emergency shutoff valve under door.

Figure II-14 Natural gas vehicle and label.

unlikely to be found, then you may need to combat this fire first rather than attacking the fuel source.

Once the fire is out, you need to check and look for any signs of free flowing gas.

They will have installation records to confirm their findings and will investigate with gas detection equipment by barring and testing underground.

If you can't shut down the fuel source, make sure the utility company is present so their personnel can take the steps necessary to eliminate this hazard.

Also, be aware that there is a danger of reignition, and there are many possible sources: Friction, which creates static electricity, either with fabrics or plastics, such as piping; any electrical devices which can arc or spark, such as pagers, radios, and cell phones; damaged electrical system components, such as wires; any electric- or gasoline-driven motors or

DO	DO NOT
▌ Notify the gas company immediately—utilize the gas company expertise	▌ Park over manhole covers or storm drains
▌ Treat all gas leaks as hazardous until determined otherwise by the gas company	▌ Park in front or downwind of emergency locations
▌ Only shutoff aboveground meter valves	▌ Operate any in-ground valves
▌ Evacuate structures	▌ Operate doorbells, light switches, or other electrical devices
▌ Secure affected areas	▌ Turn off venting relief valves
▌ Use only properly calibrated detection equipment	▌ Extinguish gas fires until fuel sources have been secured
▌ Use only intrinsically safe communications and other electrically operated equipment	▌ Turn on gas valves
▌ Turn off radios, two-way radios, pagers, and cell phones prior to entering structures	▌ Shut off gas service to industrial facilities without knowing what effect it can have regarding additional damage
▌ Natural gas has a flammable or explosive range from just below 5 percent in air to just below 15 percent in air; these percentages are known as the "LEL" (Lower Explosive Limit) and "UEL" (Upper Explosive Limit)	

tools; electric switches of any kind; and anything which can produce a flame, such as a match.

Stay alert to the dangers of gas migration. What's not burning, but leaking, may be traveling through ducts such as wall cavities, ceilings, or excavations along the property. Again, the local utility company must rule out migration of underground gas.

When is the area out of danger? Once the local gas company's CGI testing shows no traces of natural gas in the air, or migrating underground, the environment is then said to be "zeroed out."

If there is any doubt, *get them out*—evacuate. If the evacuees need to make a call, use a cell phone outside in a safe zoned area and not a wireless house phone, which causes ignition hazards at the main phone depot in the house. Having the telephone service turned off by an operator is also an option.

When utility company experts are on the scene, decisions relating to the control and containment of natural gas, and potential electrical dangers, should be directed to them. Only when every responder, from the person first called to the last one leaving the scene, works within the same framework of readiness in dealing with the real and potential danger are these emergencies resolved safely.

Safety The burning odor may mask the gas odorant. It is important to check for combustible gas in the structure before entering. *It is VERY important to have a recently calibrated gas meter instrument to search for natural gas.* It is essential in any situation involving burning natural gas that you be absolutely *sure* the fuel source is secure. Make sure the utility confirms that no other gas source exists in the structure and that gas is not migrating underground and entering the structure.

CARBON MONOXIDE—CAUSE, EFFECT, AND RESPONSE

This section provides information and approaches for carbon monoxide emergency response. Carbon monoxide (CO) is a colorless, often odorless gas that is potentially deadly. CO is also slightly lighter than air (specific gravity is 0.97) and is flammable at the limits of 12.5 to 74 percent gas-to-air mixture with an

ignition temperature of 1128 degrees Fahrenheit. One of the primary causes of (CO) gas is the incomplete or improper burning of carbon-based fuels/fossil fuels. Some types of carbon-based fuels include wood, tobacco, coal, kerosene, gasoline, and natural gas. The threat of CO poisoning is most insidious when the gas collects unnoticed from the normally safe sources that have gone bad. Appliances should be inspected and serviced regularly if a problem is suspected. CO detectors are now mandatory in New Jersey, and must be installed prior to real estate sales. They are highly recommended to provide additional safety. CO detectors must be installed per the manufacture's instructions to avoid false alarms. Some improper locations are often too close to an appliance, and a correct location in many cases is in the hallway near the bedrooms.

In excess of 8,000 annual CO calls are received by New Jersey utilities. It is important to understand the dangers and causes of CO.

Cause

Although all gas equipment has been tested under rigid ANSI Standards for safety and proper combustion, it is imperative to keep in mind that the years of operation takes its toll and tends to cause breakdown and malfunction. Other causes of malfunction may result in changes in the structure or blockage in flues by outside forces. Besides gas appliances other sources of CO may be kerosene heaters, internal combustion engines, fireplaces, and even smoking. Many times CO is associated with a sharp pungent odor. This odor, however, is the result of aldehydes and alcohols that are also produced as a result of incomplete combustion. In addition, condensation found on the inside windows of a home could result from the humid condition, which arises from incomplete combustion. The risk of CO is greatest in cold weather, when homes are closed up, preventing hazardous gases from being ventilated, especially in newer, more-insulated homes. According to the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) (Ventilation Standard 62-89), a concentration of no more than 9 parts per million (PPM) (0.0009%) of CO is permissible in residential living spaces. CO is measured in parts per million with respect to the atmosphere.

Effect

Carbon Monoxide (CO) Exposure Symptoms

- Headaches
- Shortness of breath
- Queasiness
- Flu-like achiness without fever
- Drowsiness
- Flushed face
- Chronic fatigue
- Confusion
- Dizziness
- Nausea
- Unconsciousness
- Burning eyes

Warning Signs That CO May Be Present

- Presents of aldehydes and alcohols, which produce an acrid odor similar to vehicle exhaust.
- Condensation on walls and windows.
- Dead houseplants.
- Lethargic pets.
- Less/hot water produced by fuel-burning appliances.
- The best way for an emergency responder to detect CO in the atmosphere is through the use of an approved portable CO detection instrument, calibrated according to manufacturer instructions. This instrument is effective for monitoring for personal safety, measuring atmospheric CO concentrations for further actions, and locating and mitigating major sources of CO.

Table II-2 shows typical symptoms based on concentration and time of exposure.

Each year some 200 people die from accidental poisoning from CO and another 5,000 are treated for it in hospital emergency rooms. The real toll is surely higher, since many of the symptoms of CO exposure are mistaken for the flu or another illness. CO readily inhibits the blood's capacity to carry oxygen simply because the body welcomes the flow of CO into the bloodstream easier than oxygen. It combines with hemoglobin, the oxygen-carrying pigment in the red blood cells, to form carboxyhemoglobin (COHb). CO could kill in minutes or hours depending on the level of CO and the time of exposure. The victim inhaling the toxic concentration of the gas becomes helpless before realizing that danger exists.

After being exposed to 50 PPM, most people start feeling the effects, although even lower levels can harm people with a heart condition. Also, small children, pregnant women, and elderly people are affected more rapidly. Some of the symptoms are headaches, queasiness, flu-like achiness without fever, drowsiness, flushed face, chronic fatigue, confusion, and dizziness. Very often pets evidence these symptoms more quickly than humans, especially birds. Since death could occur within 1 to 3 minutes in a concentration of 12,800 PPM it is extremely important to monitor the air space with a calibrated CO-detection instrument before entering a suspected CO residence.

TABLE II-2

Carbon Monoxide (CO) Exposure Limits and Symptoms

CONCENTRATION IN PARTS PER MILLIONS (PPM)	SYMPTOMS
50	No adverse effects with 8 hours of exposure.
200	Mild headache after 2 to 3 hours of exposure.
400	Headache, nausea, and dizziness after 1 to 2 hours of exposure.
800	Headache, nausea, and dizziness after 45 minutes; collapse and unconsciousness after 2 hours of exposure.
1,000	Loss of consciousness after 1 hour of exposure.
1,600	Headache, nausea, and dizziness after 30 minutes of exposure.
3,200	Headache, nausea, and dizziness after 5 to 10 minutes of exposure; collapse and unconsciousness after 30 minutes of exposure.
6,400	Headache, nausea, and dizziness after 1 to 2 minutes of exposure; unconsciousness and danger of death after 10 to 15 minutes of exposure.
12,800	Immediate physiological effects, unconsciousness, and danger of death after 1 to 3 minutes of exposure.

Emergency Response

When responding to a CO call, the main thought is safety. You must maintain your safety if you're going to save lives. If any CO reads are found at any entrance or window of the property with the CO detector, a breathing apparatus needs to be put on before entering the premise. If you don't have CO-detection equipment that has been calibrated to the manufacturer's specifications, but suspect CO poisoning, check for condensation on the windows. Again, don't enter without breathing apparatus.

Remember, when in doubt, get them out. When you have the proper equipment, the premises are aired out completely, or you have the utility company to assist, search for anyone who may be sick or overcome by CO. CO is lighter than air, which means that it will rise slowly in the home. Once the victims have been removed from the residence, efforts should be made to find the source of the CO. The local utility is equipped to find the source from appliances and is also knowledgeable of the other gases that give false CO reads.

Safety If you can't make a determination and suspect CO, evacuate immediately.

False Carbon Monoxide Reads from Different Sources

- Nitrous oxide (bleaching of rayon in new carpeting)
- Nitrogen dioxide (used to bleach flour)
- Hydrogen (most abundant element known, oils, and automobile battery when charging)
- Chlorine (dyes, insecticides, bleach powders, cleaning solvents, plastics, fire extinguishants)
- Hydrogen cyanide (almonds, seeds in peaches, apricots, plums, insecticides, plastics, burnt silk or wool)
- Welding gases, ethylene, and acetylene (ethylene is used to ripen fruits)
- Hydrogen sulfide (decaying organic matter)
- Sulfur dioxide (used in preserving fruits, disincentives, bleaching textile fibers, straw, wicker, gelatin, glue, and beet sugar)
- New computer circuit boards
- Aerosol disinfectant
- Rubbing alcohol

REVIEW QUESTIONS

1. What are the properties of natural gas and gas leaks that a first responder must consider when responding to a natural gas incident?
2. Describe the Do's and Do Not's of natural gas emergency response.
3. What are the properties of carbon monoxide ("CO") a first responder must consider when responding to a CO incident?
4. What are the symptoms of CO poisoning?
5. Describe the exposure limits and levels of CO.