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Forensic Engineering Investigations of Gas-Fueled Appliance Fires and Explosions

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Introduction

Fuel gas escaping from an appliance can be easily ignited and cause an explosion and fire. Open flames or hot surfaces at main or pilot burners of gas-fueled appliances can ignite fugitive fuel gases, flammable vapors and airborne flammable dust. Overheated gas-fueled appliances, or improperly installed gas-fueled appliances or vent systems can cause ignition of solid fuel (wooden building structure or improperly stored combustibles) adjacent to the appliances or vent systems. Fugitive fuel gases, gases that have escaped from their intended confines and into the air, and open flames of gas-fueled appliances can be both the initial fuel source and initial ignition source.

After a fire has occurred and a fire investigator suspects the area of origin to be near a gas-fueled appliance, a Forensic Engineer is often called upon to investigate whether the appliance caused the fire.

NFPA 921 – "The use and operation of an appliance should be well understood before it is identified as the fire cause. Some appliances are simple or very familiar to fire investigators and may not require in-depth study. … More complicated appliances may require the help of specialized personnel to gain a full understanding of how they work and how they could generate sufficient energy for ignition."

The purpose of this paper is to provide general guidelines to the Forensic Engineer for inspecting residential gas-fueled appliances involved in fires or explosions. Since each investigation is unique, the Engineer may need to deviate from these guidelines. The paper also provides five case studies that demonstrate the application of those guidelines.

Fuel Gas

A fuel gas is defined as any one of a number of commercially distributed flammable gases that are mixed with air and burned to produce heat. The heat is used as a source of heat, power or light. The most common and widely used fuel gases are natural gas and liquefied petroleum gas (LP-Gas).

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	Ignition Temp. ^{o}F	Explosive Limits % by Volume Lower	Upper	Specific Gravity (Air = 1.0)	Higher Heating Value Btu/ft?
Natural Gas	900 – 1170	3.9 – 4.5	14.5 – 15.0	0.59 – 0.72	950 – 1150
Commercial Propane	920 – 1120	2.15	9.6	1.5 – 2.0	2500 - 3500

As is evident from the specific gravity data, natural gas is lighter than air and commercial propane is heavier than air. Consequently, natural gas will tend to rise and collect near the ceiling of a room. Whereas, commercial propane will tend to fall and collect near the floor of a room. However, air currents will tend to mix a fuel gas and air and reduce the stratification of those components.

Odorization of Fuel Gases

The standard for the odorization of fuel gases requires that enough odorant compound be added to make the gas readily detectable to a person with normal olfactory perception at a concentration in the air of not less than one-fifth of the lower explosive limit of that gas. (1/5 of LEL). The perceptible level of odorant in fuel gases may be reduced by "scrubbing" or "odorant fade" by the fuel gases migrating through soil or coming into contact with the surfaces of new tanks or pipes.

When fugitive fuel gases are suspected of having been the initial fuel source in an explosion or fire, but occupants of the building report not having smelled the gas, a sample of the fuel gas should be obtained and the level of odorant in that sample should be determined. The standard ASTM D1265, *Method for Sampling Liquefied Petroleum (LP) Gases*, provides relevant guidelines.

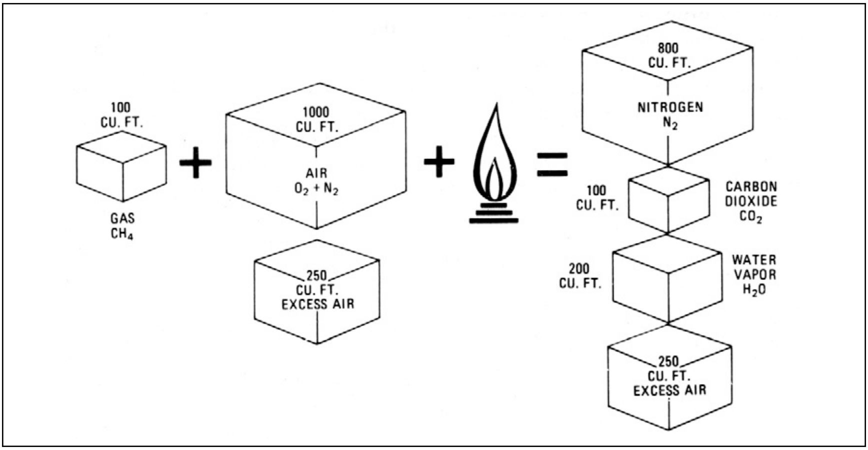
Combustion

A gas-fueled appliance needs an adequate supply of air to operate properly. The fuel gas and air are mixed together and then ignited within the appliance. The products of combustion are exhausted from the appliance. The appliance can burn "fuel rich" and produce carbon monoxide and soot if it receives an inadequate amount of air. To avoid that problem, excess air is provided to the appliance.

Combustion air: Air necessary for complete combustion of a fuel, including theoretical air and excess air. (Primary and Secondary Air)

Theoretical air: The ideal amount of air necessary for complete combustion of a fuel.

Excess air: Additional air provided for combustion to assure complete combustion of a fuel because the mixing of the fuel and air is not 100 percent efficient.



Combustion of natural gas. LP gases produce the same combustion products in differing proportions.

Dilution air: Air that is introduced into a draft hood and is mixed with flue gases.

Combustion products: Constituents resulting from the combustion of fuel with the oxygen of the air, including the inert gases, but excluding excess air.

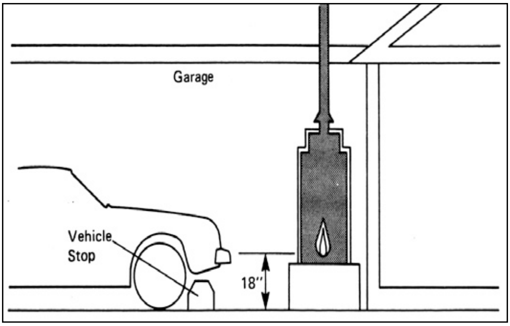
Flue gases: Products of combustion plus excess air in appliance flues or heat exchangers.

Appliance Installation

The general requirements for a proper appliance installation are proper clearances to combustibles, adequate air for combustion and dilution, and a proper vent system. The gas supply piping is to be provided with an accessible manual shutoff valve and a sediment trap (drip leg). For full details on piping, installation, air supply and venting of gas-fueled equipment, see The National Fuel Gas Code NFPA 54/ANSI Z223.1.

Clearance to combustibles include combustible parts of the building, objects stored near an appliance, and especially flammable liquids. If a flexible gas connector is used, it must not be of the uncoated brass type. That type of connector has the end fittings brazed to the corrugated tubing. Over time, that brazing can fail and cause a gas leak. Uncoated brass connectors have not been manufactured since 1976, but many still remain in use. Acceptable connectors are stainless steel or plastic coated brass.

Appliances in residential garages are to be installed so that all burners and burner ignition devices are located not less than 18 inches above the floor.[1] Further, the appliance is to be located or protected so that it is not subjected to physical damage from a moving vehicle.



Typical Installation in residential Garages.

Equipment Location

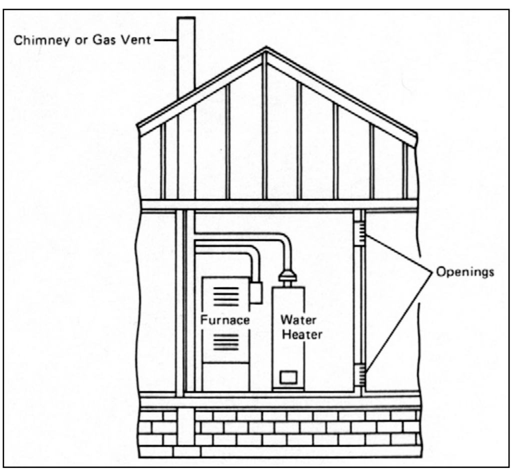
In unconfined spaces in buildings of other than unusually tight construction, infiltration may be adequate to provide air for combustion, ventilation and dilution of the flue gases. However, appliances located in buildings of unusually tight construction or in confined spaces may need additional provisions to supply an adequate amount of air to those appliances.

Unusually Tight Construction

Buildings of unusually tight construction have their walls and ceilings that are exposed to the outside constructed with a continuous vapor barrier with openings gasketed or sealed, weather-stripped windows and doors, and caulking applied to joints and penetrations for utilities. Appliances installed in buildings of unusually tight construction shall be provided with air from the outdoors through two openings, or specially engineered installations (forced ventilation).

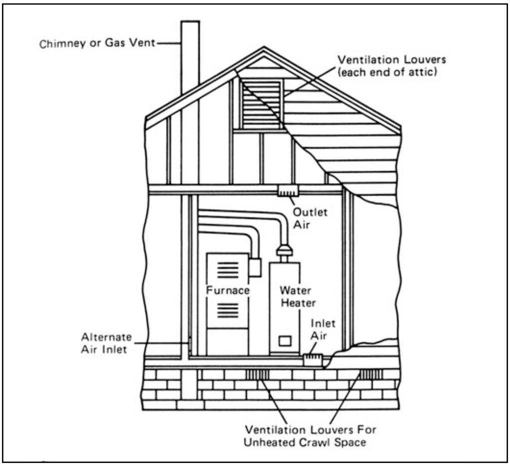
Confined Space Installation

A *confined* space is defined as a volume of less than 50 cubic feet per 1,000 BTU per hour (20 Btuh/ft) of the aggregate input of all appliances installed in that space.[2, 3] For example, for an 80,000 Btuh furnace and a 20,000 Btuh water heater located in a utility room, the volume of that room must be at least 5,000 cubic feet to be an *unconfined* space. The dimensions of that room could be 25 feet x 25 feet x 8 feet. If the volume of the room is less



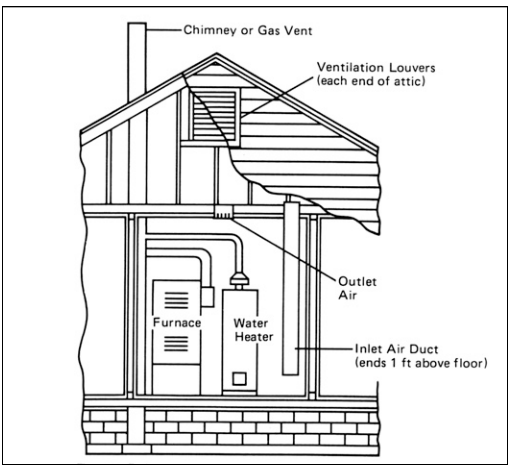
Equipment Located in Confined Space;
All Air from Inside the Building.

than 5,000 cubic feet, provisions to supply additional air to that room are necessary. That air can be obtained from other spaces inside the building, from the outdoors, or from a combination of the two.[4, 5]



Equipment Located in Confined Spaces;
All Air from Outdoors – Inlet Air from Ventilated Crawl Space and Outlet Air to Ventilated Attic.

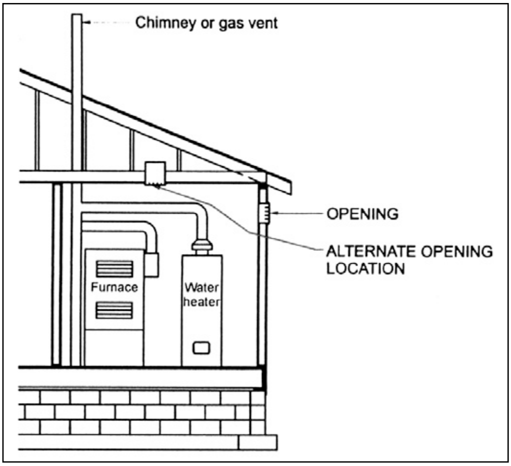
When all of the air is obtained from additional rooms inside the building, the combined volume of all the rooms must be sufficient to be considered an unconfined space. Two openings are needed to communicate between the confined space room and the other room(s). One opening is to be located within 1-foot from the ceiling and the other opening is to be located within 1-foot from the floor. Each opening needs to be sized for 1 in^2 per 1,000 Btu/hr considering louvers and grilles, and a minimum of 100 in^2.



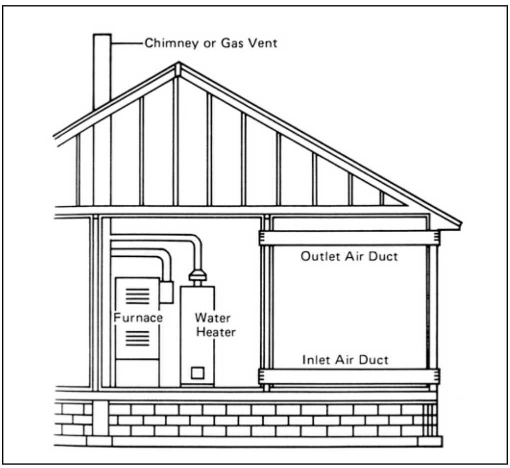
Equipment Located in Confined Spaces;
All Air from Outdoors Through ventilated Attic.

When all of the air is obtained from outdoors, two openings are needed within 1-foot from the floor and ceiling. Those openings must communicate directly or by ducts with the outdoors, or crawl spaces or attics that communicate freely with the outdoors. Direct openings and vertical ducts are to be sized for 1 in^2 per 4,000 Btu/hr, and horizontal ducts are to be sized for 1 in^2 per 2,000 Btu/hr.

Alternatively, only one opening is needed when the appliance(s) has clearance of



Appliances Located in Confined Spaces;
Single Combustion Air Opening.
All Air from Outdoors.



Equipment Located in Confined Spaces;
All Air from Outdoors.

at least 1-inch from the sides and back and 6-inches from the front. The opening is to be located within 1-foot from the ceiling and sized for 1 in^2 per 3,000 Btu/hr regardless of whether it communicates to the outdoors directly or through a horizontal or vertical duct. Also, the size of the opening is to be not less than the sum of the sizes of all of the vent connectors in the confined space.

When the air is obtained from a combination of the indoors and from the outdoors, the requirements for the two openings between indoor spaces remain the same, as described above. However, the size of the two openings to the outdoors is prorated based on the total volume of the indoor spaces.

Venting

The venting of most gas-fueled appliances is necessary to assure the proper operation of those appliances and to prevent the accumulation of the products of combustion within a building. A vent system is based on the principle that hot air is buoyant and rises. A proper vent system conveys the products of combustion to the outdoors, prevents damage from the condensation of water in the flue gasses, prevents overheating of nearby combustible materials and provides fast priming of natural draft venting to minimize spillage of combustion products into the building. The basic operating characteristics within the venting system are whether the system operates at a positive or negative pressure and whether condensation occurs within the system.

Some gas-fueled appliances are not required to be vented. Examples of those appliances are residential type cooking ranges, and unvented room heaters. However, when the appliances are installed in a confined space, one or more of those appliances need to be vented so that the aggregate input rating of the remaining unvented appliances does not violate the aforementioned 20 Btu per hour per cubic foot figure.

Vented systems are differentiated into four categories, as follows:

Category I: A non-positive vent static pressure and a vent gas temperature that avoids excessive condensate production in the vent.

Category II: A non-positive vent static pressure and a vent gas temperature that may cause excessive condensate production in the vent.

Category III: A positive vent static pressure and a vent gas temperature that avoids excessive condensate production in the vent.

Category IV: A positive vent static pressure and a vent gas temperature that may cause excessive condensate production in the vent.

A Category I appliance is normally vented through a masonry, metal or factory-built chimney or a Type-B gas vent system. Category II, III and IV appliances are vented as specified by the appliance manufacturer. Plastic piping is commonly used for Category IV appliances, where condensation forms within the vent system.

Factory-built chimneys shall be installed in accordance with their listing and the manufacturers' instructions. Metal and masonry chimneys shall be built and installed in accordance with ANSI/NFPA 211, Standard for Chimneys, Fireplaces, Vents and Solid Fuel-Burning Appliances.

A chimney shall extend 3-feet above the point where it passes through the roof, and at least 2 feet above any point of the building within a horizontal distance of 10 feet. The number of appliances and the sizes of those appliances determine the size of the chimney.

A gas vent is double-wall construction consisting of a pipe within a pipe. The different types of gas vents are as follows:

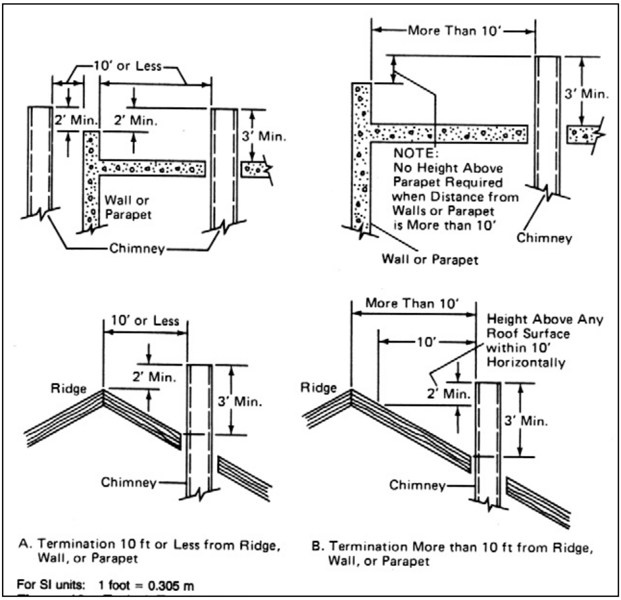
Type B: round or oval, aluminum inner pipe and galvanized steel outer pipe

Type B-W: oval for wall stud space, aluminum inner pipe and a galvanized steel outer pipe

Type L: stainless steel inner pipe for higher temperature appliances such as an oil furnace

A vent shall terminate at a listed vent cap. The cap shall be located with the same height requirements as chimneys.

A vent connector shall be used to connect a gas-fueled appliance to a chimney or vent. Vent connectors in an attic shall be Type-B or Type-L vent material. Vent connectors not located in an attic may be single-wall metal pipe having resistance to heat and corrosion not less than galvanized sheet steel or aluminum.



Typical Termination Locations for Chimneys and Single-Wall Metal Pipes Serving Residential-Type & Low-Heat Equipment

Clearances to combustibles for different types of vent systems used by Category I appliances are in accordance with the listing for Type B and Type L vents, but normally is 1 inch. Clearance to combustibles for single wall pipe is typically 6 inches. Vent sizing information is included in NFPA 54, Part 11 and Appendix G, and IFGC Chapter 5 and Appendixes B and C.

APPLIANCES

General

The three most common types of appliances are natural draft, induced draft and direct vent. A natural draft appliance utilizes the natural draft of a chimney or vent to draw the products of combustion through the appliance. Induced-draft appliances utilize a fan at the outlet of the appliance to draw the combustion products through the heat exchanger. A direct vent appliance draws all of the air needed for combustion directly from the outdoors and discharges the products of combustion directly to the outdoors, either through natural convection or via a fan.

Older style, natural draft Category I appliances were approximately 60 to 70 percent efficient, with the remaining 30 to 40 percent of the heat escaping through the vent system along with the products of combustion. The relatively high temperature and introduction of dilution air through the draft hood prevented water from condensing within the vent system. The purposes of the draft hood, or draft diverter, are to allow dilution air into the system, to allow spillage of combustion products if the vent becomes obstructed or the flow reverses through the vent, and to prevent flame roll-out during downdrafts.

The newer mid-efficiency appliances, which are also Category I and are approximately 80 percent efficient, are the induced-draft type. They utilize a fan to pull the combustion products through the appliance. The pressure at the outlet of the appliance is the pressure in the room where the appliance is installed. Those appliances do not have a draft hood and therefore, no dilution air is introduced to the vent system. Since the volume and temperature of the combustion products are reduced, the size of the required vent size may be reduced as compared to a lower efficiency appliance. For example, when an older furnace is replaced with a newer induced-draft furnace, the size of the vent system may need to be reduced to assure proper venting and to prevent condensation from forming within that vent.

High efficiency appliances, which are Category IV and are 90 percent efficient or higher, utilize a fan to exhaust the combustion products. The combustion products are cool enough that moisture is condensed in the vent pipe, which is pressurized by the appliance fan. Because of the condensation, plastic vent pipe is utilized instead of a typical chimney or double-wall vent system. Those appliances do not have a draft hood. Usually, the high efficiency appliances have the option of being direct vent installed. In that case, a second plastic pipe extends between the outdoors and the fresh air intake of the burner assembly. All air for combustion is then drawn directly from the outdoors. When installed in that manner, the appliance can be located in a confined space.

Other types of direct-vent appliances are natural draft and utilize a triple-wall vent system. The heated combustion products are exhausted through the innermost pipe to the outdoors. Fresh air is drawn from the outdoors through the annulus ring between the inner and middle walls.

Appliance Ignition Systems

Ignition of the main burner within an appliance is accomplished by means of a flame, electric arc or hot surface. The flame from a pilot burner may be continuous "standing" or lit only when the main burner is to be lit. The flame of a standing pilot is manually lit and burns continuously. Normally, a thermocouple monitors the pilot flame and, in the absence of an adequate pilot flame the appliance's automatic gas valve will shut off the gas to the appliance. A piezo-electric spark device or hot surface ignites an intermittent pilot burner immediately prior to main burner ignition.

Electronic ignition devices (electric arc, glow plugs or bars, etc.) ignite the main burner directly. The ignition source either remains continuously energized while the main burner is on, or it is de-energized and the main burner flame is supervised.

INSPECTION OF APPLIANCES

General

The purpose of the initial portion of the investigation is to document the location and condition of gas-fueled appliances within a building. The level of detail of an examination of an appliance at a fire scene is dependent on the conditions at the scene, including the accessibility and physical condition of the appliance, and the suspected involvement of that appliance in the occurrence. If it is not feasible to perform a thorough examination of an appliance at the scene, then a more thorough examination may be conducted at a later date in a laboratory. Only nondestructive inspection and testing should be performed on an appliance at the fire scene, without notification and written approval of all other interested parties. A typical examination of the gas-fueled appliances would include the following steps:

1. The location and condition of each appliance should be documented and photographed. Distant photographs should be taken that depict the location of the appliance with respect to easily recognizable reference points within the building. Photographs of all accessible sides of the appliance should be taken. Inaccessible sides of the appliance should be photographed if or when the appliance is moved. Inspect and document heat and burn patterns and any other fire and/or heat damage to the appliance, and to adjacent objects.

2. Document the area around the appliance for clearances to combustibles including the walls and floor of the room, and storage materials including flammable liquids. Also, check for proper clearance between the vent piping and combustibles (walls, ceiling, etc.) of the room.

3. Determine whether the building is of unusually tight construction, or whether the room is a confined space. Either of those problems may manifest themselves in the appliance burning fuel rich or spillage of combustion products, including carbon monoxide, through a draft hood or spill duct.

4. Photograph and document the means of supplying combustion air to the room containing the appliance(s). Determine whether adequate quantities

of air were supplied to the appliance for proper combustion. Document the layout and dimensions of any ducts or louvered doors that provide air for combustion to the room. Determine if the appliance is installed in a *confined space*. Document the presence of any air exhausting devices (exhaust fans, range hoods, and mechanically vented gas appliances), which may lower the pressure within a room or enclosure and reduce the amount of combustion air available to the appliance(s).

5. Photograph and document the flue gas ventilation system, including its configuration and dimensions. Determine if the vent or chimney is unobstructed and pulling a draft. Document the condition of any chimney liner and/or vent cap. Document the configuration and condition of the vent system, including the portion on the exterior of the building. Verify that the terminations of chimneys and vents are properly located relative to roofs and other obstructions. Is the vent double-wall where it extends through a combustible wall or ceiling and are the clearances proper? Is there a termination (rain) cap installed on the top of the vent above the roof? Record if any of the joints of the vent system are loose or detached. If so, does it appear that the separation occurred during the incident?

6. Record the position of any electrical on/off switches. Examine the electrical wiring for damage or evidence of modifications. Modifications could include cut or disconnected wires, or the presence of jumper wires or wire nuts.

7. Inspect and record the configuration of the gas supply piping. Document the presence of a manual shutoff valve, sediment trap (drip leg) and any flexible gas connector. Record the position of the shutoff valve. A flexible gas connector is normally used on a clothes dryer or range, but can also be used on other appliances. If one exists, document its type and condition, including whether it is an uncoated brass connector. When feasible, measure the incoming gas pressure to the building at flow and no-flow conditions. Monitor the gas pressure for a period of time to determine the presence and magnitude of any variations in pressure.

8. When inspecting the exterior of the appliance, document whether any access doors or panels are present and properly installed. Open or remove the access doors or panels only if they can be easily removed without altering the condition of the appliance.

9. Record identification and information labels and plates on the appliances, including: manufacturer, model and serial numbers, date of manufacture, fuel ratings, gas pressures, installation and operation instructions, warnings and references to standards. Movement of the appliance or removal of debris from the appliance to accomplish that task should be kept to a minimum. Undamaged labels indicate low temperatures.

10. Inspect the automatic gas control valve. Document any identification information, including date codes. Record the positions of any control knobs or switches.

11. Photograph and document the operational features of the appliance, including: standing pilots, or electronic ignition of pilot burner or main burner, gas safety shutoff, spill switches, high temperature limit switches, any other safety switches, fan switches, etc. Document any unusual conditions that are observed. Take close-up photographs of the positions of valves, switches, knobs, thermostats, other controls, and movable parts. Determine if switches are open or closed, if possible without altering the evidence. This may be accomplished by measuring the resistance across the switch terminals.

12. Document evidence of abnormal firing or over-firing, flame rollout, or excessive sooting within the appliance or its vent. Document evidence of damage to the appliance (including internal explosion damage) or excessive corrosion of the appliance. Document the presence of discoloration or corrosion around the draft hood.

13. Document any discoloration or corrosion around the burner openings. Document whether scale or debris is present on the burners, or whether soot is present in the burner compartment or flue. Examine the burner orifices to determine if they are obstructed or damaged.

Furnace Inspection

When inspecting a furnace, there are specific items to be examined. Document the location and condition of the wall thermostat. Record the temperature set point, the mode selected and the position of the fan control. Record the wiring to the thermostat – which wires are attached to which terminals.

Determine if the comfort air system, that being the furnace and ducts (particularly the furnace blower compartment and return air duct), are sealed from the room containing the furnace.

When inspecting the interior of the furnace, determine if the induced draft fan, if present, can be rotated by hand. Record the presence of any soot deposits inside the burner compartment or on the heat exchanger cell walls. Document any visible cracks or holes in the heat exchanger cells. Inside the blower compartment, determine if the blower can be rotated by hand. Document the condition of the air filter. Document the condition of the access panel interlock switch and the condition of the electronic control board.

Water Heater Inspection

A water heater inspection is very similar to a furnace inspection. However, a water heater burner is located lower to the floor than a furnace burner. Also, the water heater draws in air through openings in its bottom. Those features make the water heater more susceptible to ingesting nearby flammable vapors, and causing a flashback outside the heater. The lower position of the burner and gas control valve also make a water heater more susceptible to malfunctioning during or after a flood. Inspect and document the condition of the insulation located adjacent to the burner access opening. Heat or fire damage to that insulation suggests flame roll-out or flashback.

Range Inspection

When inspecting a range, it is important to document the positions of the control knobs. In the event that those knobs no longer exist, the positions of the burner control valve stems may indicate whether any of the burners were on. Since a range typically utilizes a flexible gas connector, document that connector.

Clothes Dryer

Examine the interior of the dryer and the dryer exhaust duct for the presence of excessive accumulations of lint. Document the condition of the drive belt. Document and preserve any materials located within the dryer drum.

Notification of Other Interested Parties

Reasonable efforts should be made to notify all other interested parties of an occurrence. The Forensic Engineer's client, attorney or insurance company representative, normally performs actual notification of other parties. The other interested parties should be given a reasonable opportunity to inspect the scene before it is significantly altered or disturbed and to participate in the formulation of plans to remove, preserve and test the artifacts.

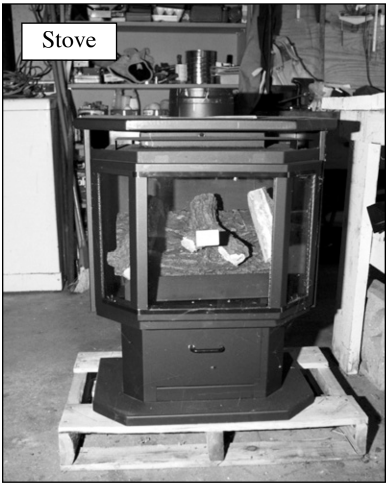
Removal of Evidence from Scene

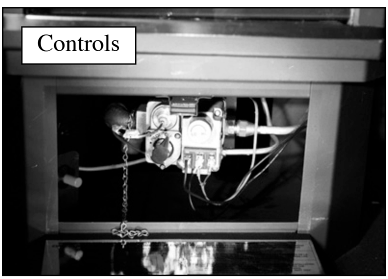
Effort should be made to collect loose parts of an appliance and preserve the entire unit together. Wrapping an appliance in plastic before it is removed from the scene is an effective way to retain the debris or objects on or within the appliance.

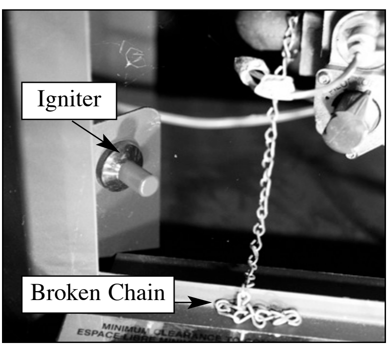
Cut gas pipes to disconnect appliances. Disconnect joints only if there is no other feasible alternative. In such cases, the joint should be photographed and the absence of a leak at that joint should be documented, before it is disassembled. *Never disassemble a joint that contains a potential or actual leak.* Mark gas pipes at the intended locations of the cuts, so that after the cuts are made, the relative positions of the two ends will be known. Mark any loose pipe joints before the joints are disturbed, so that the joint(s) can be realigned after removal. Some or all of the vent system may need to be removed, especially if it is suspected of causing the occurrence. Prepare a list of artifacts removed from the scene and preserved.

CASE STUDIES

Case Study No. 1
Improper Installation of an Appliance by a Professional:







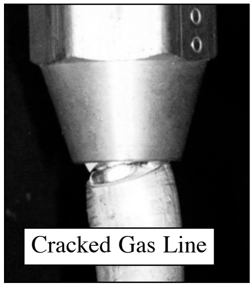
Incident:

An employee of a local gas utility was installing an LP-Gas fueled decorative stove in a house. After he completed the installation, he opened a shutoff valve on the LP-Gas storage tank on the property, which pressurized the gas lines including the line he had installed. He then checked the line he installed for gas leakage, by applying a leak detector soap solution to the joints of the gas line. Once he assured himself of no leakage, he fired up the stove. With the stove operating, he then re-lit the pilot burners on the other gas appliances in the house. Those burners had been extinguished when he had closed the shutoff valve on the LP-Gas tank. After relighting the pilots, he shut off the stove, which had been operating for approximately 10 to 20 minutes. He then told the mother that was home with her young child, to come into the room and he would show her how to operate the stove. After she entered the room, he asked her if she smelled gas (she testified to that point, but he denied it). He then pushed an igniter pushbutton several times while demonstrating how to light the pilot burner of the stove. Several seconds later, a momentary flash fire occurred within the room. The child, who was seated directly in front of the stove, was burned.

Investigation:

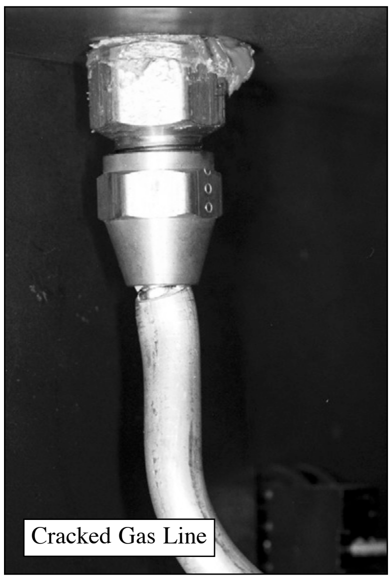
The attorney representing the family of the injured child retained the author. A site inspection was conducted and the stove was removed and preserved. A sample of the LP-Gas was obtained and tested for odorant. The test revealed that adequate odorant was present in the gas.

Later a detailed inspection of the stove was conducted. That inspection revealed a major crack/hole in the main gas line extending between the gas control valve of the furnace and the main burner. Since that hole was located downstream of the gas valve, gas was only supplied to the damaged line when the main burner was operating. The damaged gas line was not one of the lines that the installer had installed. Rather, it was a gas line that had been installed during the manufacture of the stove at the factory.

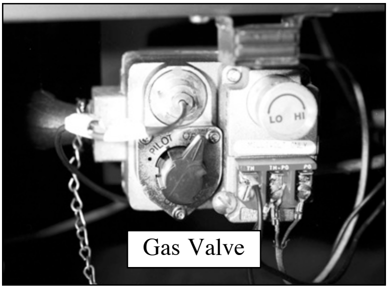


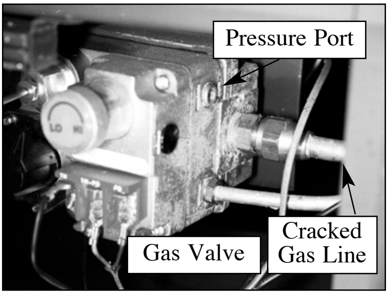
Cracked Gas Line

The plaintiff's attorney asked the author if the installer should have leak tested the damaged gas line as a normal course of installing such an appliance. Our answer was "NO," that an installer does not have the responsibility of checking the manufacturer's component parts as a normal part of installing an appliance. However, we continued that he should have checked the manifold pressure of the gas valve with gas flowing through it, pursuant to the National Fuel Gas Code. That test would have placed him in very close proximity, less than a foot from the damaged gas line, *while gas would have been escaping from the crack*. Further, when he demonstrated the operation of the stove to the mother, he should have demonstrated the proper procedure that was provided with the stove. Namely, that before one attempted to light the stove, the person should smell around the appliance at floor level. Finally, when he asked the mother if she smelled gas, he



Cracked Gas Line



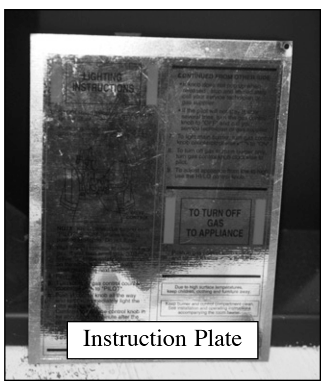


should not have attempted to light the stove. Instead, he should have further investigated the suspected smell. He had a gas detector in his vehicle, but he elected not to use it to search for the suspected leak.

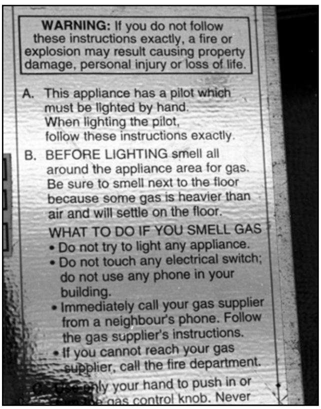
Evidence was discovered that indicated the stove had been tampered with while in the control of the retailer. When the stove was sold to the homeowner, store employees loaded the carton into the homeowner's truck. They then handed him the identification and instruction plate of the stove, which was not located inside the carton. That plate was normally attached to the stove by means of a chain. A remnant of the broken chain was found attached to the stove. Further, a date code on the cardboard carton did not match the date of manufacture of the stove. Finally, when the homeowner opened the carton, the installation and use manual was found to be located on top of the stove. The manufacturer placed the manual inside the stove.

Litigation:

Litigation commenced with the defendants being the gas utility that had installed the stove, the manufacturer of the stove and the retailer that had sold the stove to the homeowner. This writer was deposed and opined that the gas leaked from the crack in the gas line during the operation of the unit, and collected above the floor near the base of the unit, and was then ignited causing the flash fire. The stove was defective and unreasonably dangerous because of the crack in the gas line. The defect existed when the stove left the control of the retailer. The defect caused the explosion that injured the child. The gas utility installer failed to properly and safely install and test the stove. If he had properly installed the stove, he would have discovered the gas leak before the flash fire occurred.



All defendants settled with the plaintiff shortly after my deposition. However, litigation between the defendants continued. As part of the



settlement, the plaintiff's attorney agreed that the stove manufacturer could use this writer as their expert. Shortly afterward, the manufacturer provided us with their records that showed the subject stove had been successfully pressure tested in their factory before it left their control. No gas leaks were detected.

The author later testified at trial for the manufacturer. My opinions did not change, and I did not have an opinion to a reasonable degree of certainty as to when the gas line became damaged. However, I described the manufacturer's test data, and all of the facts regarding the tampering that had occurred while the stove was in the control of the retailer. The jury returned a verdict apportioning zero (0) fault or responsibility to the manufacturer.

As a footnote, at trial the installer admitted that his frequent exposure to LP-Gas had dulled and reduced his ability to smell the gas. Even with that reduced capacity he apparently still smelled gas. You will recall that he had a gas detector in his vehicle that he had failed to use during the installation.

Case Study No. 2
Improper Installation of an Appliance by a Homeowner:

Incident:

A woman turned on the oven of her new range for the first time to preheat it. Within minutes she began to smell an unusual odor, which she attributed to a normal odor from the oven being used for the first time. Approximately 10 minutes later a smoke alarm in the house went off. She then opened the oven door and discovered a fire in the empty oven. The fire severely damaged the kitchen and moderately damaged other parts of the house. Fortunately, no one was injured.

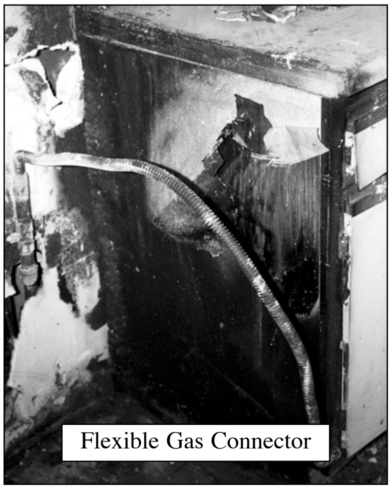
Her husband had purchased and installed the range four (4) days earlier. During those four (4) days, she had used the range top burners without incident, but she had not used the oven. The husband stated that he had connected the appliance to the gas supply pipe with a flexible gas connector and had tested all of the joints for leakage with a soap solution.

Investigation:

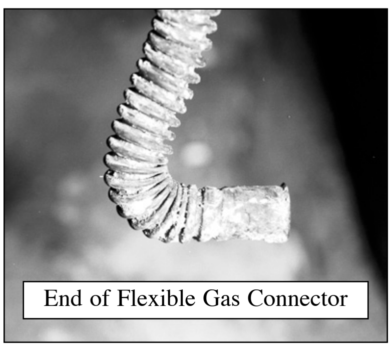
The homeowner's insurance company retained the author. We conducted a site inspection, at which time we removed the range and gas line, and later examined those artifacts in detail. Damage to the rear side of the range, the flexible gas connector and kitchen wall behind the range indicated that a hot fire had burned there. A brass fitting on the flexible gas connector had melted, as well as a pressure regulator located inside the range near that brass fitting. Substantial damage to the appliance precluded any further meaningful examination or testing. Our suspicion was that a natural gas fire from a gas leak had occurred at the joint where the flexible gas connector was attached to the appliance. The husband had attached the joint in question. The next question was then, why hadn't the fire occurred during the preceding four days?

Next, we purchased a brand new identical range, set up the range in our laboratory and test operated it. There was an opening in the rear of the appliance where the gas line entered, which was right where the suspected gas leak was located. We conducted smoke tests to determine airflow patterns in that area during various modes of operation. When only the range burners were firing, the air flowed upward between the rear of the range and the wall. However, when the oven was operating for several minutes and became heated, the airflow changed and began to be drawn through the opening in the rear of the appliance and into the oven compartment.

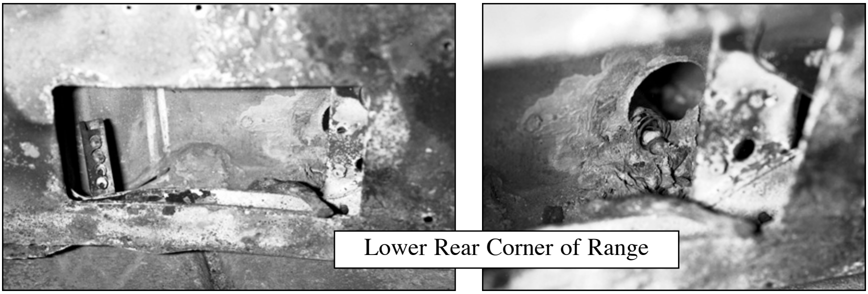
Kitchen



Flexible Gas Connector

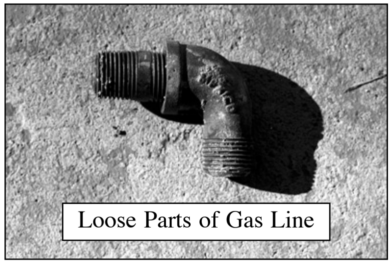


End of Flexible Gas Connector



Lower Rear Corner of Range

Rear of Range

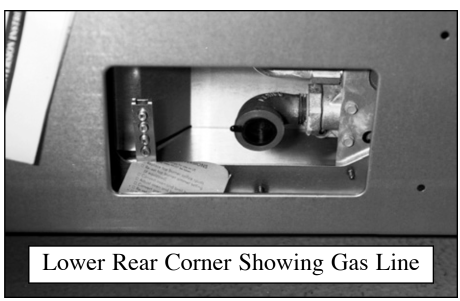


Loose Parts of Gas Line

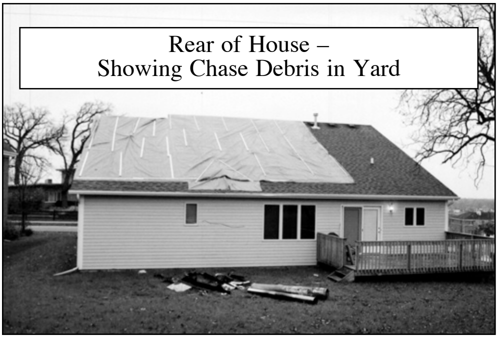
Conclusion:

Our preliminary conclusion, which we reported to the insurance company, was that a gas leak at the joint where the flexible gas connector had been attached to the range by the homeowner, would have been drawn into the oven and could have ignited when the oven was operating. With the oven off, the gas would have harmlessly flowed upward along the rear of the range and dissipated in the room. Subsequently, the insurance company decided not to attempt to subrogate against any other party and closed the investigation.

Rear of New Range



Lower Rear Corner Showing Gas Line



Rear of House –
Showing Chase Debris in Yard

Fireplace

Case Study No. 3
Improper Installation of an Appliance Vent System:

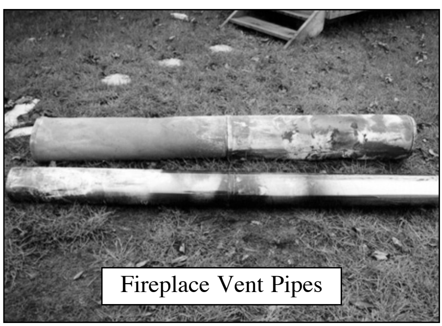
Incident:

A husband and wife were in their house with a natural gas fireplace operating during early November. The fireplace had been operating for approximately 3 hours, when a fire was discovered in the attic of the single-story ranch type house. The attic and roof portion of the house sustained severe damage. Fortunately, no one was injured.

Investigation:

The homeowner's insurance company retained us. The homeowners relayed that the house was new and they had moved in earlier that year in April. At that time, the fireplace was not equipped with a gas log set and burned wood. When the homeowners used the wood-burning fireplace for the first few times that spring, they smelled an odor of burning wood in the attached garage, which was located on the opposite end of the house from the fireplace. They did not use the fireplace during the summer, and had it converted to gas in September. Between the gas conversion and the date of the fire, they had used the gas fireplace several times.

The author conducted a site inspection, at which time we removed the factory-built fireplace unit and its vent (chimney). No rain (termination) cap was found for the top of the vent. The fireplace unit had sustained virtually no damage since the fire had been contained to the house attic. However, discoloration of the vent



Fireplace Vent Pipes

Chase Opening in Roof Showing Vent Pipes

pipes indicated that they had gotten very hot. The vent had extended through a wooden chase that formed a chimney. We documented in great detail the configuration of the vent system and the associated roof and chimney chase of the house, which had sustained substantial damage from the fire and extinguishing activities of the Fire Department. The sections of vent pipe and remnants of the chase were laying in the back yard when we arrived at the scene. When we later modeled the configuration of the vent and chimney chase, it was concluded that the top of the vent did not reach the top of the chase. Further, heat patterns and nails at the top of the chase suggested that a plywood cover might have been located over the opening at the top of the chase.

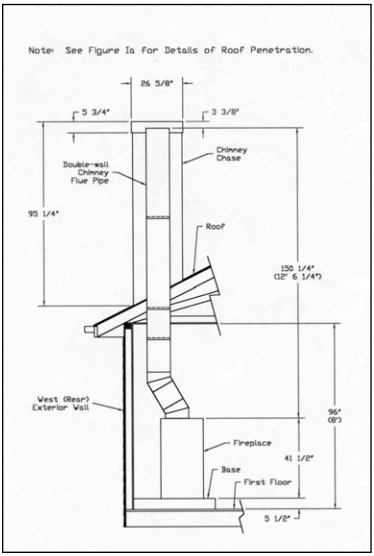
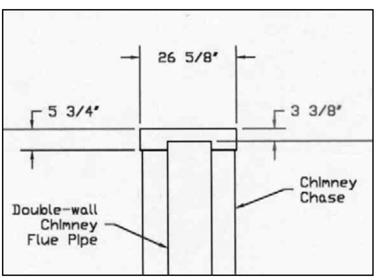


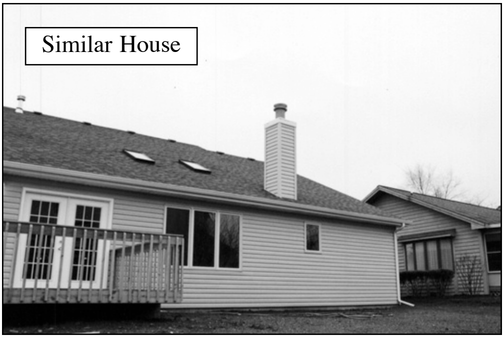
Diagram of Chase and Fireplace Vent

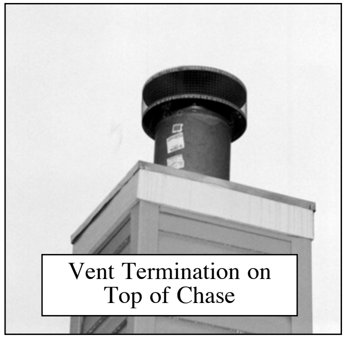
Our investigation also included an inspection of an identical house that had been constructed by the same builder, where the upper portion of the fireplace vent and rain cap clearly extended above the top of the wooden chase.

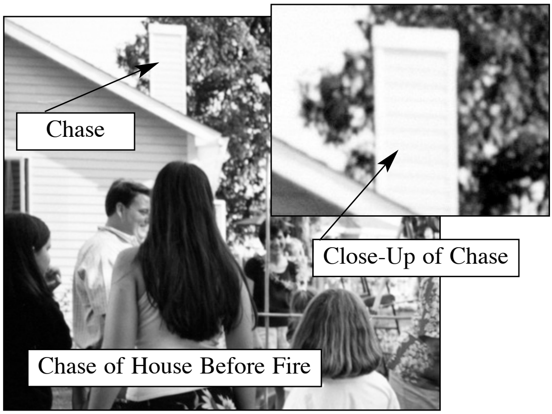


Close-Up of Upper Portion of Chase

The fire investigator, with whom we were working, approached the neighbors and asked them if they had any photographs that incidentally showed the chimney chase of the subject house. A next-door neighbor produced a photograph from a party that had occurred in the neighbor's backyard that summer. The photograph, which was of a limbo contest, showed the chimney chase in the background. That photograph clearly showed that nothing extended from the top of the chase. In other words, no fireplace vent pipe and/or rain cap extended from the chase.







Since the fireplace unit was undamaged, we later set it up at our laboratory with a new but identical vent system. We then operated the fireplace with the same gas log set installed, and measured temperatures of the flue gases and surface temperatures of the vent.

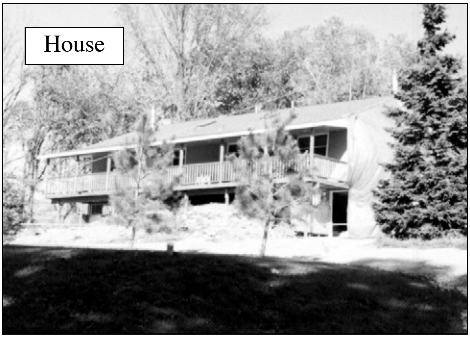
Conclusion:

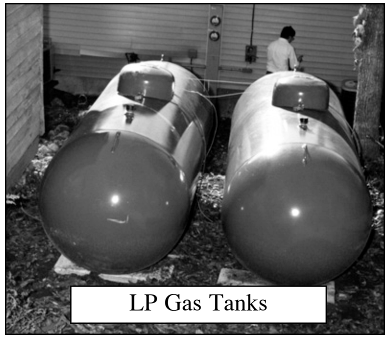
We concluded that the fireplace vent system had not been properly installed. The upper portion of the vent and the rain cap were not present. Further, it was likely that the top of the chimney chase had been enclosed. Consequently, the products of combustion from the fireplace flowed into that attic where they eventually started the incident fire. The insurance company made claims with the general contractor and fireplace installer, to be reimbursed for the cost to repair the building. The insurance companies of those two parties agreed to pay the claims without litigation.

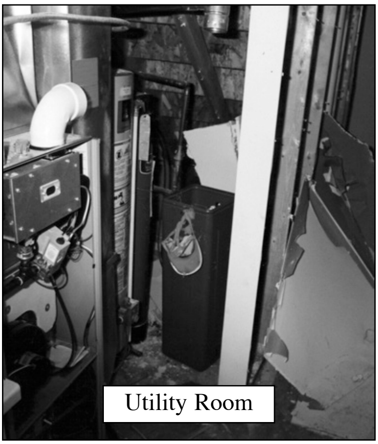
Case Study No. 4
Odorant Fade and Spoliation of Evidence by an Engineer:

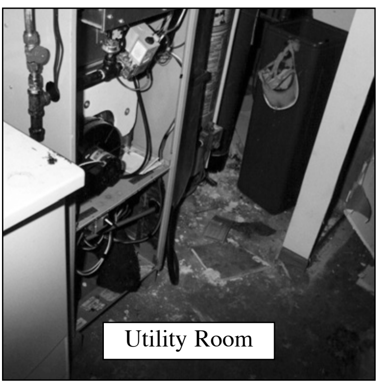
Incident:

A general contractor attempted to light the pilot light of a gas-fueled water heater recently installed in a new duplex residential building. Upon entering the building and removing the burner access cover from the water heater, he did not smell any gas. Then, upon lighting a match, an explosion occurred that severely injured the contractor and caused substantial damage to the building.


House


LP Gas Tanks


Utility Room

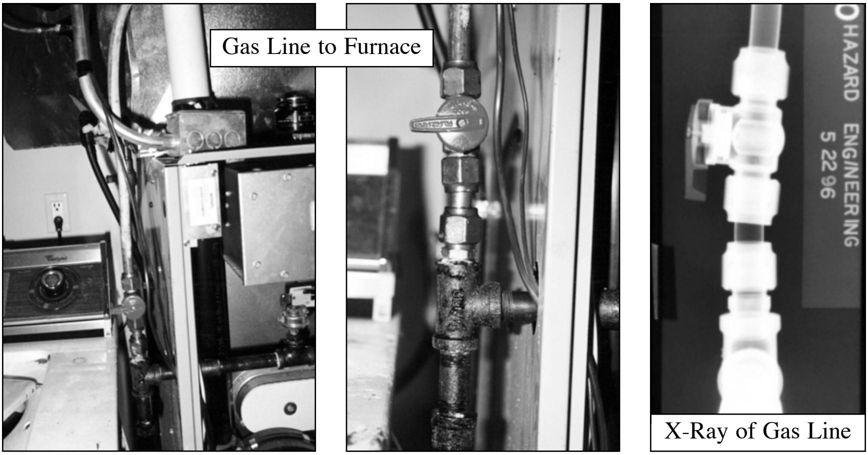

Utility Room

The LP-Gas system, including the copper tubing lines located within the building, and gas fueled appliances had been installed three days earlier by a local LP-Gas distributor co-op. The appliances included a furnace and water heater for each of the two units, for a total of four appliances. All of the gas lines had been pressure tested at that time and no leakage was detected.

The day before the incident, a local heating contractor converted the two furnaces from natural gas to LP-Gas. During the conversion, he disturbed joints in the gas lines going to the two furnaces. Upon completion of his work he soap tested some but not all of the joints that he had disturbed.

Investigation:

An attorney representing the injured man, more than a month after the incident, retained our firm. During a subsequent site inspection and testing of the LP-Gas system, no significant gas leak was detected anywhere in the building. Samples of LP-Gas were taken from each of the two new storage tanks that had been installed and filled by the co-op three days before the explosion. The samples were then analyzed for odorant levels. The odorant level in one tank was found to be adequate. However, the odorant level in the other tank was found to be far below requirements, only about 10 percent of the acceptable level.



Gas Line to Furnace

X-Ray of Gas Line

We learned during our investigation, that the injured man had initially retained a different attorney who had an engineer and heating contractor inspect the site before our involvement. Their inspection, which occurred five days after the incident, included a pressure test of the gas system within the building. They too found no gas leak within the building. However, they had disturbed a joint in the gas line to the furnace in order to perform their pressure test, without first checking for leakage at that joint. That was the same joint that the furnace converter had disturbed but failed to leak test the day before the explosion. The gas line containing that joint was removed, X-rayed and examined in detail, which revealed poor workmanship by the co-op during the initial installation.

Conclusion:

We concluded that the gas leak had occurred at the joint that had been disturbed by the heating contractor when he converted the furnaces. Further, he had violated various generally accepted standards, including NFPA 54 and 58, when he failed to check the integrity of each and every joint that he disturbed. We also concluded that the engineer and heating contractor that performed the initial inspection after the occurrence did not use reasonable and customary testing techniques. Namely, they disturbed a joint in the gas distribution system without first checking that joint for leakage. Odorant fade had occurred in one of the LP-Gas storage tanks most likely due to the presence of rust on the interior surface of that tank. Gas from that tank would have reached a combustible mixture within the building before it became perceptible by smell.

Litigation ensued and all of the aforementioned parties became defendants and contributed to the eventual settlement.

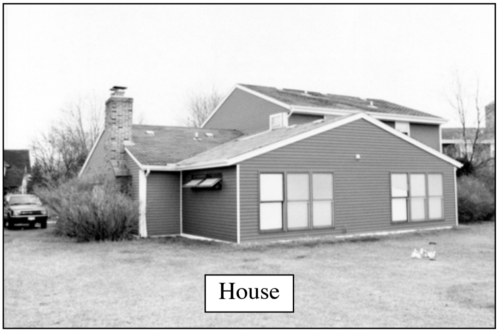
Case Study No. 5
Confined Space Installation and Improper Servicing of an Appliance:

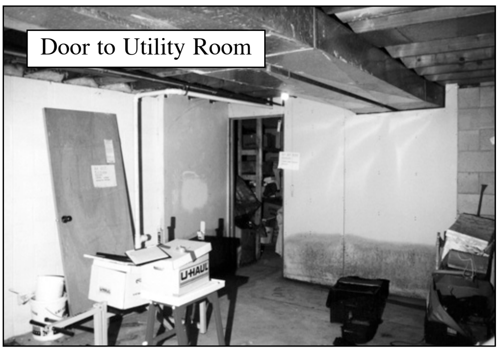
Incident:

A man died from carbon monoxide poisoning at his residence. Earlier that same day, a service technician from the local gas utility had reconnected the gas service to the residence after it had been shut off for several months. The technician also inspected the water heater and furnace located in a utility room, relit the pilot burners of those appliances and checked their operation.

Investigation:

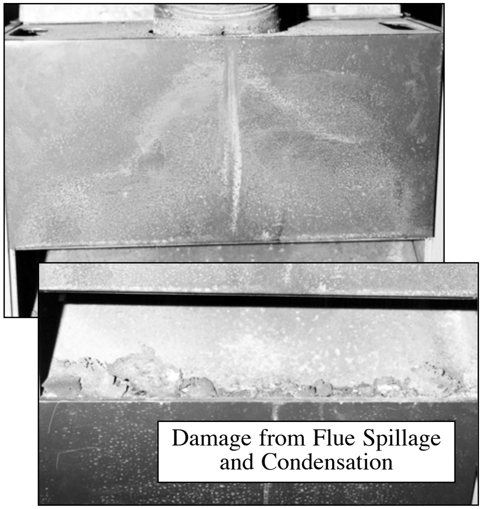
An attorney representing the family of the decedent retained our firm. We conducted a site inspection and tested the gas appliances. When we operated the appliances in the confined space, the flow through the chimney reversed, so that air was flowing from the outdoors down through the chimney and into the utility room.



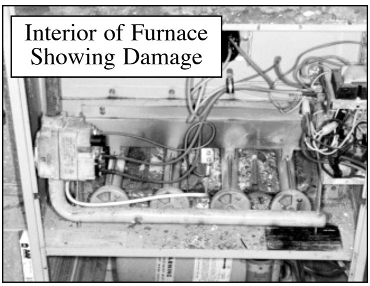


Our investigation revealed that the utility room, where a natural gas fueled furnace and water heater were located, was a confined space that did not have provisions to supply adequate air for the proper operation of the appliances. Further, the furnace blower compartment did not have a bottom panel. So, when the blower operated, it pulled air from the room and distributed it throughout the residence. Finally, there was ample visible evidence that water was condensing in the vent system and that the furnace was spilling its combustion products into the room.

Furnace

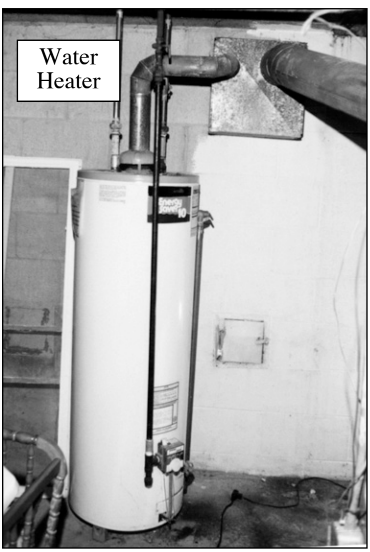


Damage from Flue Spillage and Condensation



Interior of Furnace Showing Damage

Furnace – Missing Bottom Panel



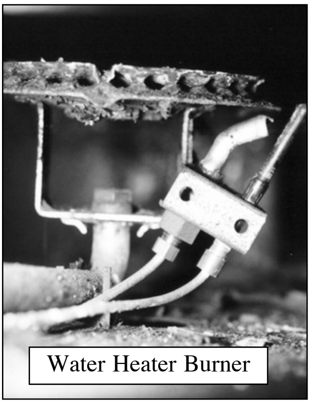
Water Heater

Conclusion:

We concluded that the service technician created a hazardous condition when he re-connected the gas service and relit the appliances. Further, he violated his employer's requirements and the custom and practice in the industry. The sources of carbon monoxide in the residence on the date of the occurrence were the furnace and water heater, which were being starved of adequate air and spilling their combustion products into the room. The open bottom of the furnace blower compartment greatly increased the carbon monoxide production by the appliances and distributed that deadly gas throughout the residence. The

Appliance Vent Pipes Showing Corrosion from Condensation

Damage from Flue Spillage and Condensation



Water Heater Burner

residence was cold when the appliances were started. The outside air temperature had been in the forties during the several days preceding the incident. Once started, the water heater and furnace would have operated continuously until they brought the water and comfort air up to the set temperatures of the thermostats. Finally, numerous indicators were present that should have alerted the technician that the appliances were unsafe to use. Those indicators were the confined space, corrosion on the furnace from long term spillage of combustion products, corrosion at various joints of the vent system from water condensing within that system, the missing bottom panel of the furnace, and the flow reversal through the chimney when the appliances were operated.

Litigation ensued and the defendant gas utility paid part of the eventual settlement. The manufacturer of the furnace also paid part of the settlement for not providing a bottom panel with the furnace when it was manufactured.

REFERENCES: STANDARDS AND REGULATIONS

Standards and regulations exist that provide guidelines for technical Forensic investigations, and specifically for fire and explosion investigations. Still, other standards and regulations provide information related to building fuel gas systems and gas utility distribution systems. Some of those documents are as follows:

ASTM D 1265, Method for Sampling Liquefied Petroleum (LP) Gases

ASTM E 620, Standard Practice for Reporting Opinions of Technical Experts

ASTM E 678, Standard Practice for Evaluation of Technical Data

ASTM E 860, Standard Practice for Examining And Testing Items That Are Or May Become Involved In Litigation

ASTM E 1020, Standard Practice for Reporting Incidents

ASTM E 1188, Standard Practice for Collection and Preservation of Information and Physical Items by a Technical Investigator

ASTM E 1459, Standard Guide for Physical Evidence Labeling and Related Documentation

NFPA 54, National Fuel Gas Code

NFPA 58, Standard for the Storage and Handling of Liquefied Petroleum Gases

NFPA 921, Guide for Fire and Explosion Investigations

49 CFR 192, Transportation of Natural and Other Gas by Pipeline: Minimum Safety Standards

International Fuel Gas Code

References

1. NFPA 54, Section 5.1.9.
2. NFPA 54, Section 1.7
3. International Fuel Gas Code, Section 202
4. NFPA 54, Section 5.3
5. International Fuel Gas code, Section 304

Figures curtesy of AGA and NFPA