INVESTIGATION GUIDELINE

Appendix 98
Revised 2004

FURNACES
(Natural and Liquefied Petroleum Gas)

I. INTRODUCTION

A. Background Information

Gas central furnaces are associated with an estimated 2,400 fires resulting in an estimated 100 injuries and an estimated 10 deaths a year (1998 data). In 2000, gas-heating systems were associated with an estimated 73 CO deaths.

The purpose of these epidemiological investigations is to gather detailed incident, victim, and product information and to provide a visual and photographic inspection that will be used to identify specific problems. Important terms are in **bold**where they are first explained. They are also defined in the glossary.

Please note that this is a guideline, not a checklist. The most common configuration and primary hazards are covered, but this does not address every furnace type or hazard you might encounter. Any relevant information discovered in the course of the investigation should be included regardless of whether it was anticipated here.

Compliance activity in the area of furnace heat exchangers has revealed that recent energy efficiency requirements may have resulted in changes to furnace design that negatively affect heat exchanger durability. If an investigation is associated with a heat exchanger, please complete the addendum to this guideline (pg. 14 -15).

B.1. Product Description: Design

A furnace, see Figure 1, uses a **burner** to mechanically mix specific amounts of air and fuel. These are then chemically combined, by burning, in a **combustion chamber**. The resulting **combustion products** enter a **heat exchanger** where household air (or water) is heated.

Furnaces covered by this guideline are classified five ways. Each classification is discussed separately. These five ways are:

1. Fuel: Natural or Liquefied Petroleum Gas (LPG).
2. The circulating airflow through the home: either forced air or gravity.
3. Draft and venting through the furnace system: either natural or mechanical draft and appliance vent categories I through IV.
4. Input: BTU/Hr (Watt is the metric unit)
5. Efficiency: Annual Fuel Usage Efficiency (AFUE) a percentage.

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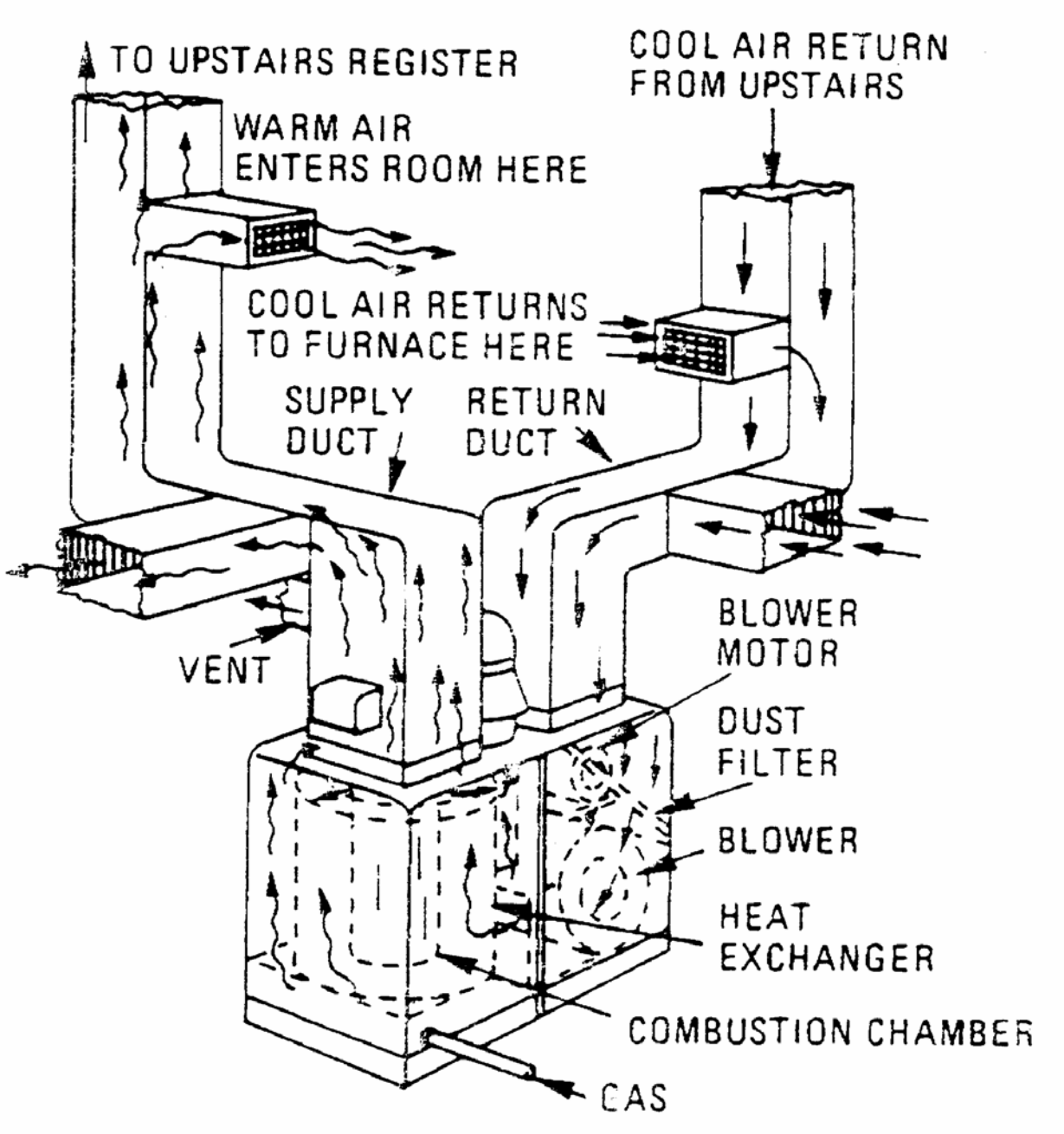

Figure 1

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FUEL:

The major visual difference between **natural** and **liquefied petroleum gas** (**LPG**, nearly always **propane**) systems is the source of the gas into the building. LPG systems almost always store the fuel in a tank on the premises. Generally the tank is above ground. A gas meter generally indicates natural gas. The orifice in a LPG burner is smaller than in a natural gas burner. The orifice is not visible during a normal investigation.

AIR FLOW (through the home):

Forced air. Most furnaces move the **circulating air** with a fan, sometimes referred to as a blower.

Gravity. Warm air rises, and cold air falls. The process is called convection. A heating system that depends on convection to move circulating air through the home is termed a gravity furnace.

DRAFT and *VENTING* (through the furnace):

Natural Draft. The combustion air flows through the appliance because the warm vent gases rise and flow out. Atmospheric pressure pushes in fresh air for combustion.

Mechanical Draft. The combustion air and vent gases flow through due to the work of a fan. The position of the fan relative to the combustion chamber determines if it is a **forced draft** or an **induced draft** system. In a forced draft system the combustion air enters the fan first and is then blown into the combustion chamber. In an induced draft system the combustion chamber is first. Vent gases then enter the fan and combustion air is thereby drawn into the combustion chamber. Fan before combustion -- forced draft; fan after combustion -- induced draft.

Direct Vent. Direct vent appliances take outside air rather than household air for combustion, and the combustion products are vented directly to the outside. The air intake and vent are often combined into one **assembly**. Direct vent may be found with either natural or mechanical draft.

Automatic Vent Damper. Cold outside air can enter the home through the draft hood if the burner is not operating and sending combustion products through the vent system. An **automatic vent damper** is sometimes placed above the draft hood to close the vent and keep warm air from leaving the furnace during the OFF part of the cycle. The vent damper is operated either electrically, mechanically, or thermally. The applicable standard should be referenced on the vent damper.

Appliance Venting Category. The appliance is given a venting category from I through IV depending on the outlet pressure and flue gas temperature increase.

INPUT

Furnaces are rated by their thermal input. Currently this is given in British Thermal Units (BTU) per Hour. The **rating plate**(s) on the furnace should give this information directly. Normally it is marked with a star and circle. See figure 2. This plate is easily visible after the access panel is removed.

Figure 2

EFFICIENCY

Efficiency[1] describes the portion of energy entering the system that heats the home. Furnaces currently indicate efficiency by giving "total hourly Btu input rating" and the "manufacturer's specified output in Btu per hour" on the rating plate. Documents distributed with new furnaces give the Annual Fuel Usage Efficiency (**AFUE**), determined according to procedures established by the Department of Energy. It is expressed as a percentage. The AFUE for a given model of furnace varies according to the geographic location. "Low efficiency," "mid efficiency," and "high efficiency" is used to describe furnaces with specific ranges of AFUE. The AFUE range defining these efficiency levels has varied, but high efficiency starts at about 85%. Some high efficiency furnaces were termed "condensing" because they cooled the combustion products sufficiently to condense water from the combustion product.

B.2. Product Description: Operation

Gas is supplied to a **pressure regulator**, located outside the building, that reduces the pressure to a very low **gauge pressure**. This gas is distributed through pipe to the household appliances. The gas goes through a **manual shut-off valve** and then enters the furnace control where the pressure is further reduced before going to the main burner. Most furnaces are controlled by **thermostats** that sense the air temperature and cause gas to flow from the control to the burner. This gas is mixed with air inside the burner located in the combustion chamber. At the burner the gas is ignited by either a small flame that burns continuously, a **pilot light**, or an electric spark. Additional air is drawn into the furnace to supply enough oxygen to the burner for complete combustion.

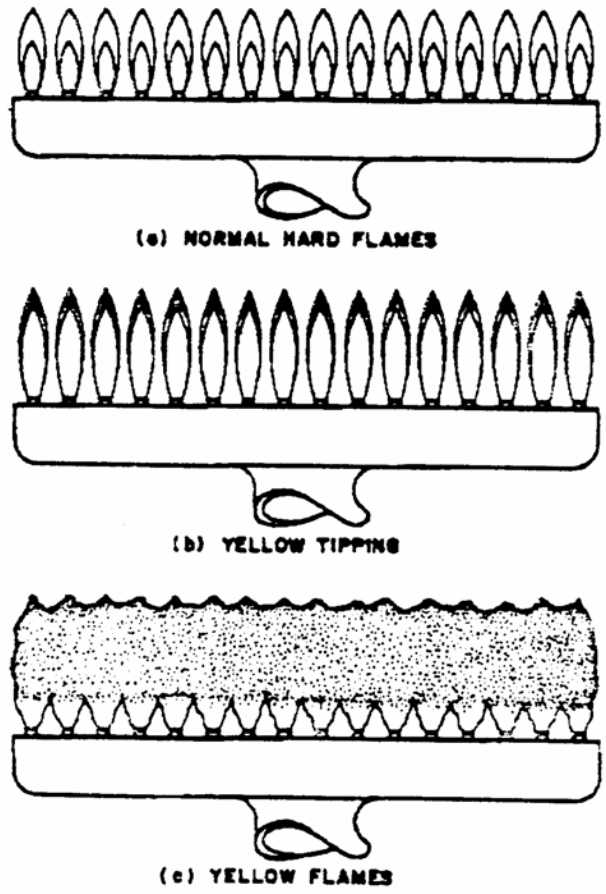

Figure 3

Flame appearance is an important indication of burner operation. The flame should consist of a blue outer cone and an almost white inner cone. The flame height should be even across the burner. Problems with combustion air affect the shape and color of the flame; see figure 3. Insufficient airs results first in yellow tipping, then floating flames, and finally **flame rollout**. Too much air causes **blowing (lifting) flames**.

The combustion products are used by the furnace in the **heat exchanger**. Thermal energy from the combustion products passes to the circulating air, but the combustion products stay separated from the circulating air. The combustion products leave the furnace through a **flue**. If this is a natural draft furnace, above the flue is a **draft hood** that directs the combustion products into the vent system. In a natural gas system the volume of air and gas flowing out of the system is 10 to 15 times the volume of gas flowing into the system. The vent system must be correctly sized to properly **vent gases**.

[1] Thermal Efficiency is an engineering term that has an exact physical definition beyond the scope of this guideline.

C. Specific Items of Interest

Most IDI assignments will involve one of six hazards: ignition of leaking fuel gas, flammable vapors, or flammable solids; flash backs while relighting; carbon monoxide poisoning; or over pressurization of the gas system. The same symptoms can result from different failures up stream and down stream of the burner assembly. For example a blocked vent can cause flame rollout, by over pressurization, or if two or more appliances are in the same room and they use a common vent that is the wrong size. If the appliance once worked properly, it is important to know what was right as well as what went wrong, because sometimes there are multiple causes of a problem. The following information is needed for the specific hazards.

Fuel gas ignition from leaks

- Location of the furnace
- Distance of the leak from the furnace
- The specific gas involved
- The source of the leak, e.g. hole flexible connector
- Dimensioned sketch of the room showing air sources

Flammable vapor ignition

- Location of the furnace
- Distance of vapor source from the furnace
- Height of the air intake above the floor. Note: Some floor furnace intakes are not at the floor.
- Identity of the liquid, e.g. "Rowe's Solvent", gasoline, kerosene.
- Amount of liquid involved.
- Identity of the container. Was the liquid stored in an appropriate container?
- Changes in air flow, e.g. opening a garage door
- Dimensioned sketch of the room showing air sources

Flammable solids

- Location of the furnace
- Distance from the furnace
- Identity of the solid
- Presence of soot by the door of the furnace or on the insulation inside the access door indicating rollout
- Dimensioned sketch of the room showing air sources
- Source of air to the furnace
- Condition of vent from the furnace

Over pressurization

- Simultaneous problems with other appliances served by the same regulator, e.g. pilot lights or high flames on were seen on other appliances.
- A burn pattern above the furnace's combination control

Relighting

- How often this was necessary?
- How familiar the victim was with the relighting procedure?
- The victim's step by step procedures if known
- The victim's ability to detect the odor of gas

Carbon Monoxide Poisoning.

Combustion products are not leaving the house. There is either not enough fresh air for complete combustion, the vent is blocked, or the heat exchanger is damaged (more information about the heat exchanger is provided in the addendum to this appendix (page 14 - 15)). Combustion products are re-circulating in the building.

In addition, Appendix 16 ('ALL CARBON MONOXIDE (CO) POISONING-RELATED INCIDENTS') should be completed.

- Change in the fresh air supply. How?
- A blocked vent? Look for soot, corrosion, birds' nests, or ice.
- Reset the blocked vent shut-off (vent safety shut off) on a natural draft furnace. Two or more wires running to the draft hood indicate a blocked vent shut-off.
- Vent systems are affected by weather. Was the vent above or below the roofline, and was the vent on the up wind or down wind side. Note, for the day of the incident, the maximum and minimum outdoor temperatures, snowfall, and ice accumulation.
- Document the complete vent system showing slope and duct size, and any vent damper. Use sketches and photos.
- List all devices that remove air; include fireplaces and attic fans.
- Report if any appliances use the same vent, and if any of these are described as high efficiency or condensing. Note: new appliances may have their vents installed inside an existing chimney.
- Note if the furnace was converted from one fuel to another.

D. Headquarters Contacts

Donald Switzer ESFS 301 504-7534
Debra Ascone EPHA 301 504-7403

II. INSTRUCTIONS FOR COLLECTING SPECIFIC INFORMATION

A. Synopsis

Give the most important events in the relevant scenario. Use the highlighted key words from the Product Description section of this guideline. These terms also appear in the glossary. The synopsis is placed in the INDP database and will guide later users to your work.

B. Description of the Incident Environment

Pre-incident. Include in this portion of the narrative a description of the system as installed, subsequent changes, and specific circumstances leading to the incident. Ask about flame appearance, if practical; use fig. 3.

Incident. Describe in the narrative how the fire or poisoning happened. If this is speculative, give the reasons for this particular reconstruction of events.

Post-incident. Include injuries, property damage, medical costs and resulting physical limitations.

C. Description of the Injured Person(s) and Product Interaction

The narrative should include information on how well the victim(s) understood the products and hazards involved; this may be indicated by familiarity with the product; and specific limitations related to developmental age or physical limitations.

D. Description of the Product

The specific information from the manufacturer's nameplate on the controls and on the appliance should be included. Copy the operating manual. Some furnaces have these in an attached envelope. A photograph should be obtained of the rating plate. If for some reason, a photograph of the rating plate cannot be obtained, please obtain all information from the rating plate. Further information about the rating plate can be found in the glossary. If the incident involved a heat exchanger, be sure to complete the addendum to this guideline (pg. 13-14).

E. Product Safety Standards

CPSC does not have mandatory standards on any furnaces. If there was a building code in effect at the time of original installation the product was covered by voluntary standards referenced by the building code. The exact voluntary standard in effect is found on the rating plate(s) and the full standard designation should be reported. The more common standard's general designations are given below to assist you:

Automatic Vent Dampers Electric	ANSI Z21.66 -(year)
Automatic Vent Dampers Mechanical	ANSI Z21.67 -(year)
Automatic Vent Dampers Thermal	ANSI Z21.68 -(year)
Boilers for Gas Central Furnaces	ANSI Z21.13 -(year) or ANSI/ASME CSD-1
Gas Appliance Regulators	ANSI Z21.18 -(year)
Gas Fired Room Heaters	ANSI Z21.11 -(year)
Gas Floor Furnaces	ANSI Z21.48 -(year)
Gas Furnaces, Central	ANSI Z21.47 -(year)
Gas Furnaces, Direct Vent	ANSI Z21.64 -(year)
Gas Wall Furnaces	ANSI Z21.44 -(year)

The city or county will be able to tell which building code was in effect when the furnace was installed. Obtain both the name and the edition, for example, The BOCA Basic Building Code/1970

III. PHOTOGRAPHS/DIAGRAMS OF INCIDENT SCENE

Every photo submitted in an investigation should contain item of known size. The CPSC photo ID card should be used if it will be readable. Every investigation should contain a photo of the rating plate(s). Consider the important factors in the incident, and build your photo plan around this. If fire damage is evident, photograph the burn pattern, even if the product is gone. If the hazard was carbon monoxide, show the vents and specific ventilation for the room. Consider using a magic marker and Post-its to mark the vents before taking photos so photos show vent size and direction of flow, e.g. **6"D>** might mean a six inch diameter vent flowing to the right. Larger dimensions can be shown on photographs using correction tape and a black pen. Diagrams do not have to be scaled, and they are an excellent way to show important factors such as airflow.

IV. OBTAINING SAMPLES AND DOUMENTS RELATED TO THE INVESTIGATION

Collect samples only if instructed to do so by Headquarters. Obtain a copy of the fire department report, installation instructions, maintenance records, and a summary of medical records if applicable. Reports from insurance companies and forensic engineering firms often are a resource that CPSC cannot duplicate. Try to obtain copies of such records. Headquarters staff may be able to assist in convincing people to release their reports.

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GLOSSARY

AFUE: Annual Fuel Utilization Efficiency is a measure of furnace performance determined by Department of Energy (DOE) procedures.
High AFUE implies better performance.

Assembly: A major part and related pieces. The burner assembly contains several important parts. Reference to a burner assembly problem is more general than saying a burner problem.

Automatic Vent Damper: A valve installed in the appliance vent pipe on the outlet side of the appliance draft hood. It opens automatically when combustion begins and closes when combustion stops.

Blocked Vent Shutoff System: A device that stops gas from going to the burners if vent gases flow out of the draft hood. Sometimes this is called a vent safety spill switch.

Blowing Flames: A condition in the burner where the bottom of the flame is above the top of the burner.

Burner: A device for the final conveyance of gas, or a mixture gas and air, to the combustion zone.

Circulating Air: The air for cooling, heating, or ventilation distributable to habitable spaces.

Combustion Chamber: The portion of the appliance where the fuel gas and air mixture is burned.

Combustion Products: Constituents resulting from the combustion of a fuel gas with the oxygen in the air, including the inerts, but excluding excess air.

Direct Vent: Appliances designed, constructed, and installed so all air for combustion enters the appliance from outside the building, and vent gases are discharged outside the building. Normally the intake and vent are made as one part.

Draft: The flow of air through equipment, vents, flues, or chimneys caused by pressure difference. Proper draft is necessary for safe operation.

> ***Draft, forced***: The air is blown into the combustion chamber by a fan before it enters the combustion chamber.
> ***Draft, induced***: The combustion products are pulled from the combustion chamber by a fan.
> ***Draft, mechanical***: Either forced draft or induced draft.
> ***Draft, natural***: Draft resulting from the differences in densities between the vent gases and the outside atmosphere.

Draft Hood: A device built into an appliance, or made part of a vent connector from an appliance, which is designed to: (1) Assure the ready escape of the products of combustion in the event of no draft, backdraft, or stoppage beyond the draft hood; (2) Prevent a backdraft from entering the appliance; and (3) Neutralize the affect of stack action of a chimney or gas vent upon the operation of the appliance.

Excess Air: Atmosphere that passes through the appliance without chemical change.

Flame Rollout: A condition where flame rolls out of a combustion chamber when the burner is turned on.

Floating Flames: An undesirable burner operating condition, usually indicating incomplete combustion in which flames leaves the burner ports to "reach" for combustion air.

Flue: The opening provided in an appliance for the escape of products of combustion.

Gauge Pressure: The pressure difference between a pressure zec system and the environment, e.g. the pressure difference between the gas system and the atmosphere.

Heat Exchanger: A device that separates two fluids (i.e. air or water) while allowing thermal energy to be transferred.

Inerts: The Nitrogen and trace gases, approximate 80 per cent of air, that are incapable of combustion.

Liquefied Petroleum Gases (LPG): The terms "Liquefied Petroleum Gases," "LPG," and "LP Gas" mean and include any fuel gas composed predominantly of and/or of the following hydrocarbons, or mixtures of them: propane, propylene, normal butane, or isobutane and butylenes. LPG is heavier than air.

Manual Shut-Off Valve : This valve is used to isolate the appliance from the gas supply. It must be closed to replace the appliance.

Natural Gas: Any gas found in the earth as opposed to gases that are manufactured. Natural gas is lighter than air.

Orifice: The opening in a cap or "spud" that limits gas flow and through which gas is discharged to a burner.

Propane: A hydrocarbon gas heavier than methane but lighter than butane. It is used as a fuel gas alone, mixed with air, or as a major constituent of liquefied petroleum gases.

Pilot Light: A small flame that is used to ignite the gas at the main burner.

Pilot Safety: A device that automatically closes the main gas valve when the pilot light is extinguished.

Pressure Regulator : A device for reducing the supply pressure maintaining a uniform outlet pressure.

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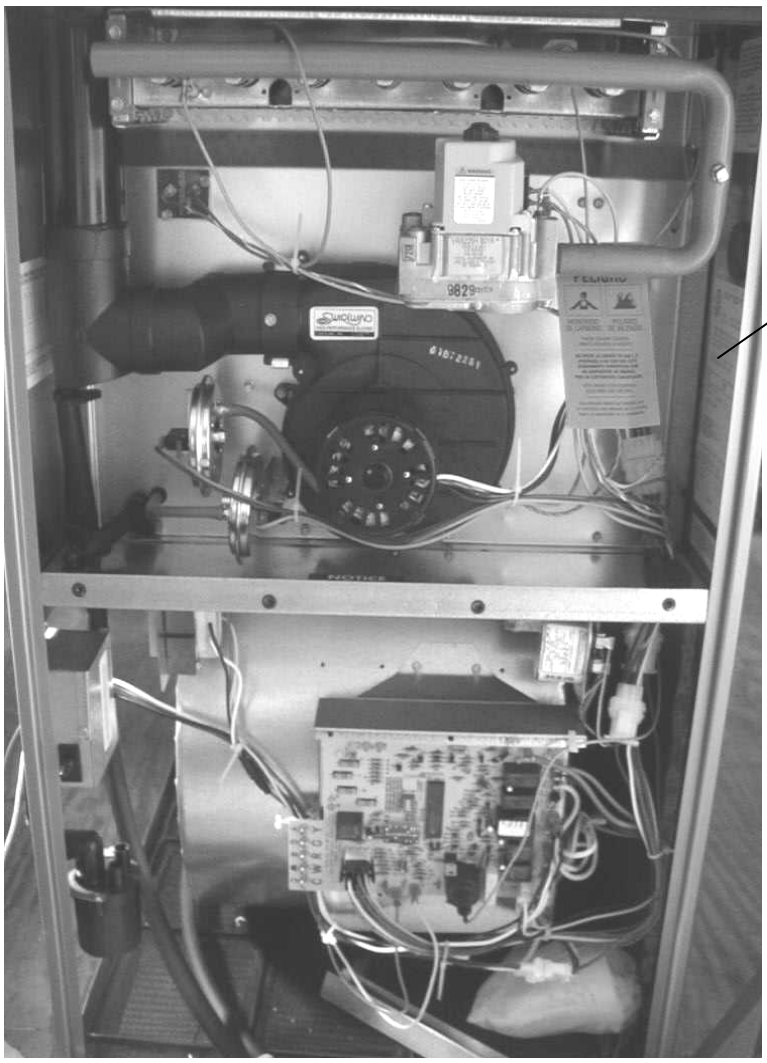
Rating Plate(s): A permanent marking that completely identifies the product. This includes the manufacturer's or distributor's name and address, the model number, a serial number, specifications on the gas system, the rated thermal, electrical and liquid capacity, the applicable vent damper, the relevant voluntary standard, and the logo of the rating organization. The pictures below show the location of the rating plate and the where the information requested can be found.

Location of Furnace Rating Plate



Furnace with burner vestibule cover and blower compartment covers removed.

(Pictures continued on next page)

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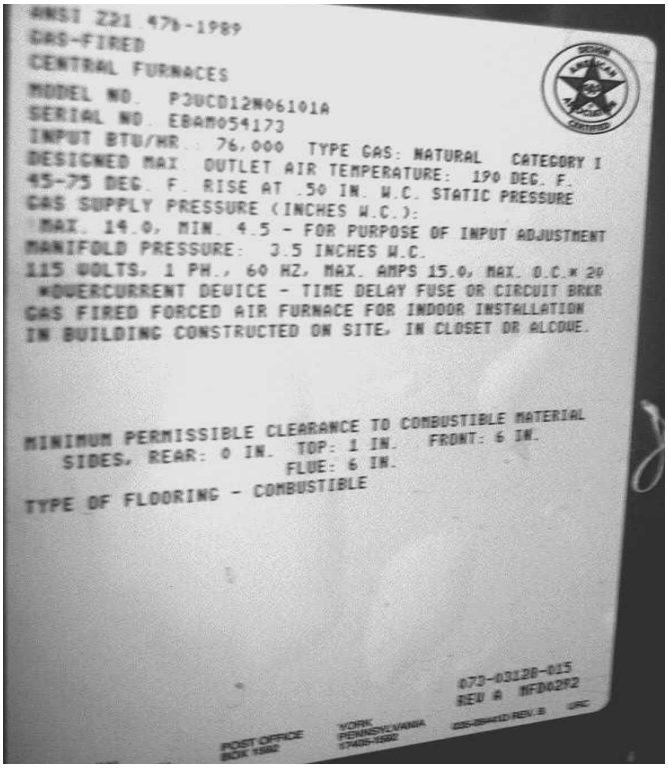
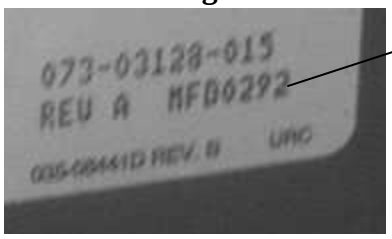
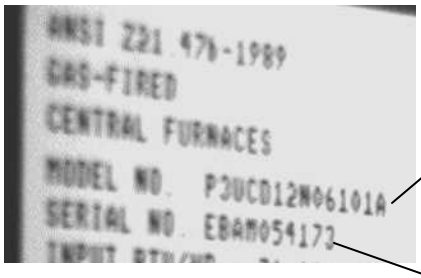
Typical Furnace Rating Plate



Furnace Rating Plate Information



MFD= manufacturing date



Model Number

Serial Number

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Thermostat: A control device that causes circulating air to maintain an approximately constant temperature.

Vent: Piping that conveys combustion products from the furnace to the chimney or out the wall.

Vent Gases: The products of combustion from gas appliances plus excess air and dilution in the venting system above draft hood.

Yellow Tipping: The appearance of yellow flame tips in an otherwise blue flame indicates the need for additional primary air.

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Addendum

Investigations of Heat Exchangers

Background

Compliance activity in this area has revealed that recent energy efficiency requirements may have resulted in changes to furnace design that negatively affect heat exchanger durability. Investigations will support laboratory activities of the Fire / Gas Voluntary Codes and Standards team and lead to improvements in the furnace component standards.

Specific Items of Interest

In addition to the pre-incident, incident and post-incident information, investigators should document as much of the following a possible:

- Product information for furnace and heat exchanger, including their respective ages (may not be the same) and repair history. Include the type of fuel (LP gas or natural gas) and whether the furnace had been converted from using one fuel type to another.

- Describe the location of the furnace in the home and whether it was installed in a closet or enclosed space.

- Photograph or obtain photos of the incident heat exchanger, furnace rating plate and venting system. Document all information found on furnace rating plate, including standards markings.

- Obtain any repair report and interview repair person for his/her opinion of what caused the problem (e.g., furnace was over-fired, flame rollout sensor failed, etc.). Ask if the following measurements of the furnace were taken; if so, record the results:
  - firing rate
  - manifold pressure
  - flue or room concentrations of CO (if CO incident)

- If carbon monoxide incident, determine if CO alarms were in home and describe their location relative to the furnace. Did they activate during the incident?

- If carbon monoxide incident, note the following:
  - Whether vent was metal or plastic.
  - Whether vent ran horizontal & vertical, vertical only, or horizontal only.
  - If horizontal only, was there a terminal or wind cap on the outside wall?
  - Whether vent connected to a chimney.
  - Whether a vent damper was installed; if so, the distance along venting between the furnace and vent damper.
  - Actual or estimated length of the vent pipes from furnace to chimney or outside.

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- If an insurance claim was filed for the incident, provide insurance contact and claim number.

- If the incident heat exchanger is available for sample collection, contact Don Switzer (301 504-7534). Do not collect the sample without discussing with Don Switzer first.