



**UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
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Memorandum

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SUBJECT : In-Depth Investigations of Carbon Monoxide (CO) Incidents Associated with
"Modern" Gas Fired Furnaces

The purpose of this memorandum is to report the results of a review of in-depth investigations associated with non-fire related carbon monoxide (CO) incidents and "modern" residential furnaces. These incidents were in the Consumer Product Safety Commission's (CPSC) In-depth Investigation (INDP) File.

Prior to 1993, the current standard for residential gas-fired central furnaces, ANSI Z21.47, Standard for Gas-Fired Central Furnaces, was divided into two separate standards. Draft hood-equipped central furnaces were governed by ANSI Z21.47, Standard for Gas-Fired Central Furnaces (Except Direct Vent Furnaces), while direct vent central furnaces were governed by ANSI Z21.64, Standard for Direct Vent Central Furnaces. For the purposes of this memorandum, "modern furnaces" are defined as furnaces that, based on their dates of

manufacture, would have been certified to the 1986 version of ANSI Z21.47 (Z21.47b-1986) (effective 1987) if draft hood-equipped, or the 1989 version of ANSI Z21.64 (Z21.64b-1989) (effective 1992) if direct vent. These versions of the standard were the first to include the current set of requirements that address some of the furnace operating, installation, or usage conditions that could result in CO exposure. In addition, we considered modern furnaces to be those units that incorporated safety attributes such as pressure switches or thermal switches that comply with the blocked vent requirements within the standards.

In 1997, CPSC staff proposed to the furnace subcommittee that a performance provision be added to the furnace standard that would require furnaces to shut down in the event their vent pipes became disconnected or partially blocked. In 2000, CPSC staff proposed an alternative provision that would require a means to prevent a furnace from producing CO levels in excess of 400 PPM or would require the furnace to shut down if CO levels exceeded 400 PPM. In support of both proposals, staff provided the furnace subcommittee with reviews of CPSC incidents involving CO poisonings associated with gas furnaces and disconnected or blocked vents. Representatives from the Gas Appliance Manufacturers Association (GAMA) and other subcommittee members have asserted that these incidents did not involve “modern furnaces” and that “modern furnaces” do not pose the CO exposure risks from the failures or conditions described in the incident reviews provided by CPSC staff. This review responds to these assertions and demonstrates that “modern furnaces” have been associated with CO exposures.

This memorandum summarizes CO incidents associated with modern furnaces from the INDP File for the years 1987 to 2001 that were entered into the file prior to April 8, 2002. For the purposes of this review, CO incidents were comprised of those cases in which a gas furnace reportedly leaked CO into the home or other structure.

CPSC staff from the Directorate for Epidemiology and the Directorate for Engineering Sciences reviewed the in-depth investigations in order to compile the information within this memorandum. This review focuses on reported conditions associated with furnace components, installation and operation, as well as deaths and medical treatment information associated with the incidents. Data from the CPSC In-depth Investigation File are not a statistical sample and national totals may not be derived from the number of incidents investigated. The data does provide examples of actual incidents and anecdotal information. See Appendix A for the codes and keywords used in the database searches.

The initial database search resulted in approximately 700 in-depth investigations of incidents associated with carbon monoxide and gas furnaces. After the initial database search, staff screened the results to determine if the incidents were within scope. Incidents were considered out of scope for the following reasons:

- Furnace was converted from solid fuel or oil to natural or liquefied petroleum (LP) gas.
- Furnace was not a gas fired central furnace.
- Furnace was manufactured prior to 1987 or the furnace’s age could not be determined.
- Incident was associated with fire involvement or a gas leak.
- Incident occurred in a non-residential setting.

- No evidence was provided within the investigation that the product failure was related to CO leakage or CO exposure.

In addition to screening out non-relevant incidents, staff also verified the occurrence of reported conditions associated with CO leakage into the home or other structure. This memorandum only includes CO leakage-related information that was corroborated by at least one authoritative, investigating source. Acceptable sources included the fire department, gas utility representative, service technician, forensic engineer, medical examiner's office, product manufacturer, housing authority, police, and local, state, or federal health officials. This review includes cases that were collected through the following means:

- Investigative reports were collected by CPSC field investigators from the sources, or
- Investigative findings were recorded by CPSC field investigators through telephone or in-person interviews of the sources, or
- Investigative findings of the sources were reported to CPSC field investigators through interviews or investigative reports of third parties.

Finally, staff also collected information on the type of medical treatment received that was associated with a CO exposure reported in the incidents. This memorandum only includes medical treatment information that was corroborated by at least one medical source and satisfied the following criteria:

- Medical reports were collected by CPSC field investigators from the medical source, or
- Medical findings or treatments were recorded by CPSC field investigators through telephone or in-person interviews of the medical sources, or
- Medical findings or treatments of the medical sources were reported to CPSC field investigators through interviews or investigative reports of third parties or consumers.

Throughout the remainder of this memorandum only those in-depth investigations that were considered in-scope will be referenced. A total of 28 investigations met these criteria and 13 deaths were associated with these investigations.

Furnace Component, Operating and Installation Conditions Associated with Non-Fire Related Carbon Monoxide Incidents

Carbon monoxide leakage from a furnace into a home typically occurs as a result of two failures. The first failure is the occurrence of a condition(s) that results in a furnace producing elevated levels of CO. The second failure is the occurrence of a condition(s) that creates a leakage path from the combustion chamber or flue passageways into the living space of a home or other structure.

The furnace conditions that were cited in the in-depth investigations and reported to be associated with CO leakage or exposure fall into three main categories: component conditions, installation conditions, and operating conditions. For the purposes of this review, component conditions were the physical conditions of those furnace parts, components, or systems reported by the source(s) to be associated with the reported CO incident. Component conditions were

further stratified by the specific component, which included the burner, chimney, flue and draft hood, heat exchanger, inducer motor, and vent. In some instances multiple component conditions were reported. A furnace is not a complete system without proper venting through a chimney or vent pipe. Therefore for the purposes of this memorandum, chimneys and vent pipes were included within the component conditions category.

Installation conditions focused on the building or structural conditions reported by the source(s) to be associated with the CO incident. Operating conditions generally focused on the furnace operating characteristics that resulted from component or installation conditions. For investigations where information on the appliance component, operating, or installation conditions was not reported within the in-depth investigation, the conditions were categorized as not reported or unknown. Table 1 summarizes the number of incidents involving single and multiple conditions reported in the in-depth investigations.

Table 1:
Conditions Associated with Furnaces and Non-Fire Related
Carbon Monoxide Incidents

Condition	Number of Incidents
Involving One Condition	10
Component Condition of the:	
Burner	0
Chimney	1
Flue & Draft Hood	0
Heat Exchanger (HEX)	3
Inducer Motor	0
Vent	3
Installation Condition	0
Operating Condition	1
Unknown or Not Reported Condition	2
Involving Two Conditions	10
Burner and Heat Exchanger Condition	1
Chimney and Operating Condition	1
Chimney and Vent Condition	1
Flue & Draft Hood and Heat Exchanger Condition	1
Heat Exchanger and Installation Condition	1
Heat Exchanger and Operating Condition	3
Installation and Operating Condition	1
Vent and Operating Condition	1
Involving Three Conditions	6
Burner, Heat Exchanger, and Inducer Motor Condition	1
Burner, Heat Exchanger, and Operating Condition	1
Burner, Inducer Motor, and Operating Condition	1
Burner, Vent, and Operating Condition	1
Burner, Installation, and Operating Condition	1
Heat Exchanger, Installation, and Operating Condition	1
Involving Four Conditions	1
Burners, Chimney, Heat Exchanger, and Operating Condition	1
Involving Five Conditions	1
Heat Exchanger, Inducer Motor, Vent, Installation, and Operating Condition	1

Source: CPSC In-depth Investigation File, 1987-2001

The general furnace conditions associated with the reported CO incident were further categorized into more detailed descriptions of component, installation, and operating conditions. Tables 2 through 7 provide breakdowns of component conditions for burners, chimneys, flue and draft hood, heat exchangers, inducer motor, and vents. Table 8 provides a more detailed breakdown of installation conditions and Table 9 provides a more detailed description of operating conditions. Some investigations cited multiple detailed conditions associated with the more general component condition; therefore the number of detailed conditions associated with the component, installation or operating condition may not equal the number of investigations.

For example, one investigation cited the vent as a component condition with two-detailed vent conditions (blocked vent and blocked intake) associated with the incident¹. Table 10 provides a summary of the number of incidents associated with component, installation, and operating conditions. Since multiple conditions may have been associated with a single incident, totals will not add up to the total number of incidents referenced in this memorandum.

**Table 2:
Burner Conditions**

Burner Conditions	Number of Incidents
Total Number of Incidents Associated With	7
Number of Incidents Where Burners Were the Only Component Associated	0
Number of Incidents Where Burners Were Among Multiple Conditions Associated	7
Number of Detailed Conditions Associated With	10
Detailed Condition:	
Clogged Burner	1
Cracked Burner	1
Incorrect Orifice Size or Improper Conversion	4
Misadjusted Burner Air Shutter	1
Rusted Burner	1
Sooted Burner	2

Source: CPSC In-depth Investigation File, 1987-2001

Note: Number of detailed conditions may not add up to the number of incidents. Some incidents may have listed multiple detailed conditions.

¹ Task Number: 960816CCC7391

**Table 3:
Chimney Conditions**

Chimney Conditions	Number of Incidents
Total Number of Incidents Associated With	4
Number of Incidents Where the Chimney Was the Only Component Associated	1
Number of Incidents Where the Chimney Was Among Multiple Conditions Associated	3
Number of Detailed Conditions Associated With	5
Detailed Condition: Blocked Chimney	2
Inadequate Chimney Height	2
No Chimney Liner	1

Source: CPSC In-depth Investigation File, 1987-2001

Note: Number of detailed conditions may not add up to the number of incidents. Some incidents may have listed multiple detailed conditions.

**Table 4:
Flue & Draft Hood Conditions**

Flue & Draft Hood Conditions	Number of Incidents
Total Number of Incidents Associated With	1
Number of Incidents Where the Flue & Draft Hood Were the Only Component Associated	0
Number of Incidents Where the Flue & Draft Hood Were Among Multiple Conditions Associated	1
Number of Detailed Conditions Associated With	2
Detailed Condition: Blocked Flue	1
Sooted Flue	1

Source: CPSC In-depth Investigation File, 1987-2001

Note: Number of detailed conditions may not add up to the number of incidents. Some incidents may have listed multiple detailed conditions.

**Table 5:
Heat Exchanger Conditions**

Heat Exchanger Conditions	Number of Incidents
Total Number of Incidents Associated With	14
Number of Incidents Where the Heat Exchanger Was the Only Component Associated	3
Number of Incidents Where the Heat Exchanger Was Among Multiple Conditions Associated	11
Number of Detailed Conditions Associated With	21
Detailed Condition:	
Clogged or Blocked Heat Exchanger	5
Cracked Heat Exchanger	6
Heat Exchanger Flange or Gasket Failure	1
Leakage Through or Separation of Seams or Gasket	2
Perforated or Holes in Heat Exchanger	2
Sooted Heat Exchanger	5

Source: CPSC In-depth Investigation File, 1987-2001

Note: Number of detailed conditions may not add up to the number of incidents. Some incidents may have listed multiple detailed conditions.

**Table 6:
Inducer Motor Conditions**

Inducer Motor Conditions	Number of Incidents
Number of Incidents Associated With	3
Number of Incidents Where the Inducer Motor Was the Only Components Associated	0
Number of Incidents Where the Inducer Motor Was Among Multiple Conditions Associated	3
Number of Detailed Conditions Associated With	4
Detailed Condition:	
Inducer Motor Failure	2
Detailed Condition Not Recorded	2

Source: CPSC In-depth Investigation File, 1987-2001

Note: Number of detailed conditions may not add up to the number of incidents. Some incidents may have listed multiple detailed conditions.

**Table 7:
Vent Conditions**

Vent Conditions	Number of Incidents
Number of Incidents Associated With	7
Number of Incidents Where the Vent Was the Only Component Associated	3
Number of Incidents Where the Vent Was Among Multiple Conditions Associated	4
Number of Detailed Conditions Associated With	12
Detailed Condition:	
Blocked Intake	1
Blocked Vent	1
Disconnected Vent	2
High Temperature Plastic Vent	1
Improper Vent Installation	4
Vent Undersized	1
Detailed condition not recorded	2

Source: CPSC In-depth Investigation File, 1987-2001

Note: Number of detailed conditions may not add up to the number of incidents. Some incidents may have listed multiple detailed conditions.

**Table 8:
Furnace's Installation Conditions**

Furnace's Installation Conditions	Number of Incidents
Number of Incidents Associated With	5
Number of Incidents Where the Appliance's Installation Was the Only Condition Associated	0
Number of Incidents Where the Appliance's Installation Was Among Multiple Conditions Associated	5
Number of Detailed Conditions Associated With	7
Detailed Condition:	
Inadequate Ventilation Air	1
Inadequate Combustion Air	4
Room Depressurization or Back-drafting	2

Source: CPSC In-depth Investigation File, 1987-2001

Note: Number of detailed conditions may not add up to the number of incidents. Some incidents may have listed multiple detailed conditions.

**Table 9:
Furnace's Operating Conditions**

Furnace's Operating Conditions	Number of Incidents
Number of Incidents Associated With	14
Number of Incidents Where the Appliance's Operating Was the Only Condition Associated	1
Number of Incidents Where the Appliance's Operating Was Among Multiple Conditions Associated	13
Number of Detailed Conditions Associated With	15
Detailed Condition:	
Component Failure	1
Dirty Filter	1
Filter Panel Not Sealed or On Completely	1
Improper Maintenance	3
Other CO leakage Path Into Living Space	3
Overfired	5
Underfired/Incomplete Combustion	1

Source: CPSC In-depth Investigation File, 1987-2001

Note: Number of detailed conditions may not add up to the number of incidents. Some incidents may have listed multiple detailed conditions.

**Table 10:
Number of Incidents Associated with Component, Installation, and Operating Conditions of Modern Furnaces**

Condition	Number of Incidents Where the Component		Total
	Was the Single Component Associated	Was One of Multiple Components Associated	
Component Condition of the:			
Burners	0	7	7
Chimney	1	3	4
Flue & Draft Hood	0	1	1
Heat Exchanger (HEX)	3	11	14
Inducer Motor	0	3	3
Vent	3	4	7
Installation Condition	0	5	5
Operating Condition	1	13	14

Source: CPSC In-depth Investigation File, 1987-2001

Note: Since some incidents reported multiple components associated with a single incident, the total for this table will be greater than the actual number of incidents.

Furnace Information

The approximate year of manufacture of the furnace was estimated for each in-scope case. In the majority of in-depth investigations the year of manufacture was stated. In four of the incidents the year of manufacture was estimated based on the year the furnace was installed. In another four incidents the year of manufacture was based on when the home was built or the age of the mobile home or trailer. Table 11 provides information on the year of manufacture.

Table 11:
Year of Manufacture of Furnace

Year of Manufacture of Furnace	Number of Incidents
1987	4
1988	3
1989	0
1990	2
1991	1
1992	2
1993	5
1994	5
1995	1
1996	3
1997	2

Source: CPSC In-depth Investigation File, 1987-2001

The approximate age of the furnaces ranged from less than 1 year to 13 years (Table 12). Twenty-one percent of the furnaces were less than or equal to 1 year old, 36% were between 2 to 4 years, 32% were between 5 to 9 years, and 11% were between 10 to 13 years.

Table 12:
Approximate Age of Furnace

Approximate Age of Appliance	Total
Less than or Equal to 1 year	6
2 to 4 years	10
5 to 9 years	9
10 to 13 years	3

Source: CPSC In-depth Investigation File, 1987-2001

The fuel type used with the furnace was reported for 25 of the 28 incidents. When the type of fuel was reported, 16 (64%) of the furnaces were fueled with natural gas and 9 (36%) were fueled with liquefied petroleum.

Carbon Monoxide Alarms Associated with the Investigations

Information on whether a carbon monoxide alarm was present at the location of the incident was also collected. Ten of the investigations did not mention a carbon monoxide alarm. For those investigations that referred to a CO alarm, 5 investigations stated that there was no CO alarm present, 12 investigations stated that there was a CO alarm present and the alarm was activated, and one investigation stated that the CO alarm was disabled.

Ambient Carbon Monoxide Levels

Ambient carbon monoxide levels were measured in 23 of the incidents. In 4 of these 23 incidents, the consumer measured the ambient CO level using a residential CO detector. In the remaining 19 of the 23 investigations, the ambient CO level was measured by a third party (10 by the fire department, 6 by the gas utility or propane supplier, and 3 by a service technician or contractor). In 4 incidents, although the investigation states that the ambient CO level was measured, the level was not recorded. In 13 of the 19 incidents where an ambient CO level was given, the highest carbon monoxide level reported exceeded 100 PPM. In some incidents the time that the ambient CO level was measured was not recorded, but in at least one incident the ambient CO level was taken after the home had been aired out.

Medical Information

Thirteen deaths were associated with the 28 in-depth investigations referenced within this memorandum. In addition, 26 individuals reportedly sought medical attention and received some form of medical attention associated with the carbon monoxide exposure. The type of medical attention received was also examined. For 8 of the 26 individuals who obtained medical attention, the exact type of medical attention was not known as the investigation stated that the person was treated for carbon monoxide poisoning or exposure to carbon monoxide but did not elaborate on treatment received. Two of the individuals received a blood test and were released from the emergency room and 8 of the individuals received a blood test and were administered oxygen before being released from the emergency room. Eight of the individuals were initially treated in the emergency room and were admitted to the hospital for further treatment.

Carboxyhemoglobin levels were provided in 5 of the investigations and involved 10 individuals (8 of which were fatalities). All 10 individuals had carboxyhemoglobin levels greater than or equal to 10%, with the two non-fatalities having the lowest carboxyhemoglobin levels (10 and 12%). The maximum carboxyhemoglobin level was 81%.

APPENDIX A

The queries below were submitted through the EPIR application. Query results were manually reviewed to include carbon monoxide poisoning hazards and to exclude out-of-scope cases.

In-Depth Investigation (INDP) File

Date of Queries: 04/08/2002

Incident dates: 1/1/90 – 12/31/01

Product Codes: 308

Narrative contains: CO or CARB or MONO

Incident dates: 1/1/90 – 12/31/01

Product Codes: 310

Narrative contains: CO or CARB or MONO

Incident dates: 1/1/90 – 12/31/01

Product Codes: 322, 371-374, 384

Narrative contains: CO or CARB or MONO

Incident dates: 1/1/90 – 12/31/01

Product Codes: 389

Narrative contains: CO or CARB or MONO

In-Scope In-Depth Investigations Task Numbers:

000111HEP9005, 000419HCC0586, 000508CNE5528, 001206HNE5942, 020128HCC2183, 020208HCC2204, 910816HCC2263, 930329CCN1241, 930420CAA1329, 940517CNE5136, 940601CCC1501, 960116CCC2297, 960206CCC1370, 960207CCN0548, 960305CCN0691, 960326CCC6106, 960816CCC7391, 970128CCC7283, 971205HCC2150, 980224CCC2311, 980224CCC2312, 980305CCC2362, 980309CBB5369, 980310CCC0163, 981222CCN0084, 990205CCC2260, 991014HAA0022, 991101CCC0065.