1.9 Residential Fireplaces

1.9.1 General[1-2]

Fireplaces are used primarily for aesthetic effects and secondarily as supplemental heating sources in houses and other dwellings. Wood is the most common fuel for fireplaces, but coal and densified wood "logs" may also be burned. The user intermittently adds fuel to the fire by hand. Fireplaces can be divided into 2 broad categories: (1) masonry (generally brick and/or stone, assembled on site, and integral to a structure) and (2) prefabricated (usually metal, installed on site as a package with appropriate duct work).

Masonry fireplaces typically have large fixed openings to the fire bed and have dampers above the combustion area in the chimney to limit room air and heat losses when the fireplace is not being used. Some masonry fireplaces are designed or retrofitted with doors and louvers to reduce the intake of combustion air during use.

Prefabricated fireplaces are commonly equipped with louvers and glass doors to reduce the intake of combustion air, and some are surrounded by ducts through which floor level air is drawn by natural convection, heated, and returned to the room. Many varieties of prefabricated fireplaces are now available on the market. One general class is the freestanding fireplace, the most common of which consists of an inverted sheet metal funnel and stovepipe directly above the fire bed. Another class is the "zero clearance" fireplace, an iron or heavy-gauge steel firebox lined inside with firebrick and surrounded by multiple steel walls with spaces for air circulation. Some zero clearance fireplaces can be inserted into existing masonry fireplace openings, and thus are sometimes called "inserts". Some of these units are equipped with close-fitting doors and have operating and combustion characteristics similar to wood stoves. (See Section 1.10, Residential Wood Stoves.)

Masonry fireplaces usually heat a room by radiation, with a significant fraction of the combustion heat lost in the exhaust gases and through fireplace walls. Moreover, some of the radiant heat entering the room goes toward warming the air that is pulled into the residence to make up for that drawn up the chimney. The net effect is that masonry fireplaces are usually inefficient heating devices. Indeed, in cases where combustion is poor, where the outside air is cold, or where the fire is allowed to smolder (thus drawing air into a residence without producing appreciable radiant heat energy), a net heat loss may occur in a residence using a fireplace. Fireplace heating efficiency may be improved by a number of measures that either reduce the excess air rate or transfer back into the residence some of the heat that would normally be lost in the exhaust gases or through fireplace walls. As noted above, such measures are commonly incorporated into prefabricated units. As a result, the energy efficiencies of prefabricated fireplaces are slightly higher than those of masonry fireplaces.

1.9.2 Emissions And Controls[1-13]

Fireplace emissions, caused mainly by incomplete combustion, include particulate matter (PM) (mainly PM less than 10 micrometers in diameter [PM-10]), carbon monoxide (CO), sulfur oxides (SO_x), nitrogen oxides (NO_x), and volatile organic compounds (VOC). Significant quantities of unburnt combustibles are produced because fireplaces are inefficient combustion devices, with high uncontrolled excess air rates and without any sort of secondary combustion. The latter is especially important in wood burning because of its high volatile matter content, typically 80 percent by dry weight.

Hazardous air pollutants (HAPs) are a minor, but potentially important, component of wood smoke. A group of HAPs known as polycyclic organic matter (POM) includes potential carcinogens such as benzo(a)pyrene (BaP). POM results from the combination of free radical species formed in the flame zone, primarily as a consequence of incomplete combustion. Under reducing conditions, radical chain propagation is enhanced, allowing the buildup of complex organic material such as POM. The POM is generally found in or on smoke particles, although some sublimation into the vapor phase is probable.

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions are all produced during wood combustion in residential fireplaces. Most of the fuel carbon in wood is converted to CO_2 during the combustion process, but because of ineffecient combustion, low combustion temperatures, and large amounts of excess air, a much higher ratio of carbon monoxide to CO_2 is produced than for combustion of wood in airtight wood stoves or wood-fired boilers. This formation of carbon monoxide coupled with incomplete combustion acts to slightly reduce CO_2 emissions compared to other types of wood combustion.[14-19] CO_2 emitted from this source may not increase total atmospheric CO_2, however, because emissions may be offset by the uptake of CO_2 by regrowing biomass.

Formation of N_2O during the combustion process is governed by a complex series of reactions and its formation is dependent upon many factors. Although no test data were available, it is assumed that N_2O emissions from residential fireplaces would be significantly higher than either wood stoves or commercial wood-fired boilers because of the combination of low combustion temperatures and high amounts of excess air.[14-19]

Methane emissions are highest during periods of low-temperature combustion or incomplete combustion, both of which occur often in residential fireplaces. VOC emissions for residential fireplaces are high compared to other wood combustion sources. Typically, conditions that favor formation of N_2O also favor emissions of CH_4.[14-19]

Another important constituent of wood smoke is creosote. This tar-like substance will burn if the fire is hot enough, but at insufficient temperatures, it may deposit on surfaces in the exhaust system. Creosote deposits are a fire hazard in the flue, but they can be reduced if the chimney is insulated to prevent creosote condensation or if the chimney is cleaned regularly to remove any buildup.

In order to decrease PM and CO emissions from fireplaces, combustion must be improved. Combustion efficiency improves as burn rate and flame intensity increase. Noncatalytic fireplace inserts reduce emissions by directing unburned hydrocarbons and CO into an insulated secondary chamber, where mixing with fresh, preheated makeup air occurs and combustion is enhanced.[20]

Fireplace emissions are highly variable and are a function of many wood characteristics and operating practices. In general, conditions which promote a fast burn rate and a higher flame intensity enhance secondary combustion and thereby lower emissions. Conversely, higher emissions will result from a slow burn rate and a lower flame intensity. Such generalizations apply particularly to the earlier stages of the burning cycle, when significant quantities of combustible volatile matter are being driven out of the wood. Later in the burning cycle, when all volatile matter has been driven out of the wood, the charcoal that remains burns with relatively few emissions.

Emission factors and their ratings for wood combustion in residential fireplaces are given in Table 1.9-1. Table 1.9-1 presents emission factors on a weight basis (lb/ton). To convert from lb/ton to lb/MMBtu, divide by a heating value of 17.3 MMBtu/ton.

1.9.3 Updates Since the Fifth Edition

The Fifth Edition was released in January 1995. Revisions to this section since that date are summarized below. For further detail, consult the memoranda describing each supplement or the background report for this section.

Supplement A, February 1996

No changes.

Supplement B, October 1996

- References for tables were editorially corrected.
- Text was added concerning controls.
- An emission factor was added for N_2O.

Table 1.9-1. EMISSION FACTORS FOR WOOD COMBUSTION IN RESIDENTIAL FIREPLACES[a]
(SCC 21-04-008-001)

Device	Pollutant	Emission Factor (lb/ton)	EMISSION FACTOR RATING
Fireplace	PM-10[b]	34.6	B
	CO[c]	252.6	B
	SO_x[d]	0.4	A
	NO_x[e]	2.6	C
	N_2O[f]	0.3	E
	CO_2[g]	3400	C
	Total VOC[h]	229.0	D
	POM[j]	16 E-03	E
	Aldehydes[k,m]	2.4	E

[a] Units are in lb of pollutant/ton of dry wood burned. To convert lb/ton to kg/Mg, multiply by 0.5. SCC = Source Classification Code.
[b] References 2, 5, 7, 13; contains filterable and condensable PM; PM emissions are considered to be 100% PM-10.
[c] References 2, 4-6, 9, 11, 13.
[d] References 1, 8.
[e] References 4, 6, 9, 11; expressed as NO_2.
[f] Reference 21.
[g] References 5, 13.
[h] References 1, 4, 5. Data used to calculate the average emission factor were collected by various methods. While the emission factor may be representative of the source population in general, factors may not be accurate for individual sources.
[j] Reference 2.
[k] Data used to calculate the average emission factor were collected from a single fireplace and are not representative of the general source population.
[m] References 4, 11.

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