AN INVESTIGATION OF OPERATIONAL FACTORS THAT INFLUENCE EMISSION RATES FROM GAS APPLIANCES

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Abstract

This paper reports the result of investigation of the impact of various operational factors on trace combustion products emission rates from unvented gas appliances. The impact of the following factors on the indoor No, NO_2 and CO emission rates were evaluated under controlled conditions in an environmental chamber: (1) the appliance type and/or design; (2) the primary aeration level; (3) the fuel input rate; (4) the time dependence of emission rates; and (5) the presence of absorbing surfaces. Results indicate that several of these factors have an impact on exposure to indoor contaminant levels similar in magnitude to the impact of the air exchange rate of indoor environments.

Introduction

Recent studies of factors which impact on the variation of indoor pollutant concentrations, include emission rates, fuel used for combustion and duration of emissions. Little, effort has been directed toward quantifying factors that may affect the emission rates of the sources themselves, or factors other than air exchange rates which influence pollutant removal. In addition, there are indications that emission rates, mey be affected by several operational factors. A series of controlled chamber experiments have been performed on 3 ranges and 3 unvented space heaters to investigate some of these additional factors.

Experimental

Experiments were carried out in the IITRI 1,150 ft^3, all aluminum environmental test chamber under known conditions. Air enters the chamber through a uniformly porous ceiling and flows laminarly to the floor. The chamber is equipped to provide controlled air infiltration rate, air recirculation rate, temperature, humidity, and lighting.

The chamber was equipped to measure three gaseous contaminants (CO, NO, and NO_2) continuously from three locations and if desired, intermitantly from twelve indoor locations. The latter was used to verify the spatial homogeneity of gases in the chamber. In addition, the concentrations of CO_2, SO_2, total hydrocarbons (THC) and non-methane hydrocarbons (NMHC) were measured continuously from a location in the center of the chamber. The temperature and relative humidity of the chamber were recorded throughout each experiment. The entire experiment including daily instrument calibration, air sampling and data logging was automatically controlled by a computer. Constituent measurements were measured at every half a minute intervals and was stored both on a computer diskette and a hard copy printout.

Results

Appliance Type

Table 1 illustrates the emission rates estimated using a mass balance model. Results presented reflect high primary aeration rate (blue flame). These experiments show a small impact with respect to emission rates among range top burners. The type of space heater (radiant vs convective vs catalytic) affect the emission rates substantially.

Primary Aeration Rate

Two primary aeration rates of ranges were tested: (1) high level of primary aeration (blue flame) with 42 % of stoichiometric air requirement; and (2) low level of primary aeration (yellow tipping flame) with 33 % of stoichiometric requirement. The results in Table 2 illustrate that the level of primary aeration has a pronounced impact.

Variable Fuel Input Rate

The emission rates for range top burners presented in Tables 1 and 2 are with maximum fuel input rate. Emission rates of NO, NO_2 and CO from a range top burner also were measured at four different fuel flow settings: high, medium, low and warm. The average fuel input rate for high, medium, low and warm. The average fuel input rate for high, medium, low and warm settings are 9149, 7673, 1492 and 807 Btu/hr, respectively. Emission rates for No, NO_2, NOx and CO were calculated for the four fuel input rate conditions. The average emission rates and the standard deviations for each fuel input rate are shown in Table 3.

It is evident that fuel input rate has an effect on total NOx emission rate. Lower the fuel input rate, lower the NOx emission rate. This relationship does not appear to be linear. The drop in NOx emission rate from Low burner setting (1492 BTU/hr) to Warm burner setting (807 BTU/hr) is larger in magnitude compared to High burner setting (9149 BTU/hr) to Medium burner setting (7673 BTU/hr) and Medium burner setting (7673 BTU/hr) to Low burner setting (1492 BTU/hr).

Other Factors

Additional factors investigated include the time dependence of emission rates: Preliminary results indicate no time dependence of emission rates from range top burner. The study of time variability of emission rates from gas space heaters has not yet been finalized. The presence of additional surfaces inside the chamber affects the indoor pollutant concentrations. Table 4 shows the rate of removal in addition to the infiltration rate induced by the presence of surfaces inside the chamber.

It is apparent that the presence of additional surfaces inside the chamber has a substantial impact on indoor pollutant concentrations. This impact may depend on the effective area as well as the age of the surface. It is expected that the variation on temperature and relative humidity may have an effect on the removal rates. The quantification of these effects remains to be studied.

Discussion

The experiments performed for this study illustrate that the type of appliance, the primary aeration level, the fuel input rate on the source emission rate. The presence of commonly available surfaces have an impact on the contaminant concentrations. The impact of indoor surfaces may be of the order of magnitude of the infiltration rate. These findings should serve as a warning to modeling undertakings which must know the exact values of various input to the model parameter. It is apparent that assumptions of maximum fuel input rate, independence of appliance impact and primary aeration will lead to incorrect conclusions.

TABLE 1. EMISSION RATES FROM UNVENTED GAS APPLIANCES

Unvented Gas Appliance	Emission Rate, $lb/10^6$ BTU				Number Of Runs	Fuel Input Rate BTU/hr
	NO	NO_2	NO_x (as NO_2)	CO		
Range 1[a]	0.040 ± 0.006	0.021 ± 0.002	0.082 ± 0.012	0.094 ± 0.022	12	9,000
Range 2[a]	0.039 ± 0.002	0.029 ± 0.001	0.087 ± 0.004	0.153 ± 0.017	12	9,000
Range 3[a]	0.035 ± 0.005	0.021 ± 0.004	0.075 ± 0.012	0.566 ± 0.063	12	9,000
Space Heater 1 (convective)	0.034 ± 0.002	0.034 ± 0.003	0.086 ± 0.001	0.039 ± 0.004	4	10,535
Space Heater 2[b] (radiant)	0.00 ± 0.00	0.011 ± 0.0001	0.011 ± 0.0001	0.127 ± 0.019	3	9,959
Space Heater 3 (catalytic)	0.00 ± 0.00	0.003 ± 0.0001	0.003 ± 0.0001	0.033 ± 0.006	3	11,122

[a] Range top burners were operating at high primary aeration level (blue flame).

[b] Space heaters has three settings (i.e., I, II, and III). Experiments were performed at setting II.

TABLE 2. EMISSION RATES FROM RANGE #2 TOP BURNERS AT TWO PRIMARY AERATION LEVELS*

Constituents	Emission Rate lb/10^6 Btu Blue Flame	Yellow-Tipping Flame
NO	0.039 ± 0.002	0.020 ± 0.004
NO_2	0.029 ± 0.001	0.038 ± 0.005
NO_x (as NO_2)	0.087 ± 0.004	0.075 ± 0.005
CO	0.153 ± 0.017	0.966 ± 0.181

*One burner is illustrated here as an example. Similar results are obtained from the other two burners.

TABLE 3. EMISSION RATES FOR VARIABLE FUEL INPUT RATES*

Range Top Burner Settings	Fuel Input Rate BTU/hr	NO Emission Rate $lbs/10^6$ BTU	NO_2 Emission Rate $lbs/10^6$ BTU	NO_x Emission Rate $lbs/10^6$ BTU	CO Emission Rate $lbs/10^6$ BTU	Number Of Runs
High	9144 ± 25	0.034 ± .001	0.017 ± 0.001	0.068 ± 0.002	0.142 ± 0.004	4
Medium	7673 ± 86	0.031 ± .001	0.020 ± .001	0.067 ± .001	0.133 ± .009	4
Low	1492 ± 13	0.023 ± 0.002	0.020 ± .001	0.054 ± 0.003	0.135 ± 0.017	4
Warm	807 ± 5	0.002 ± .001	0.033 ± 0.006	0.037 ± 0.006	0.831 ± 0.059	4

*Range top burner was operating at high primary aeration level (blue flame)

TABLE 4. REMOVAL RATE FACTORS FOR DIFFERENT SURFACES

Category	Removal Rate for NO (h^{-1})	Removal Rate for NO_2 (h^{-1})	Number Of Runs
Wood Frame	0.09 ± 0.05	0.32 ± 0.22	4
Plaster Board	0.02 ± 0.01	0.69 ± 0.20	4
Man Made Fabric	0.03 ± 0.03	0.93 ± 0.06	4
Natural Fabric	0.05 ± 0.02	0.87 ± 0.09	4
Carpet	0.07 ± 0.01	0.86 ± 0.20	4
Linoleum	0.06 ± 0.03	0.38 ± 0.18	4
Wood Panel	0.10 ± 0.03	0.30 ± 0.04	4
Plaster (oil paint)	0.07 ± 0.03	0.50 ± 0.16	4
Plaster (water paint)	0.09 ± 0.002	0.62 ± 0.12	4

All experiments were performed at 1.0 air change per hour.