EFFECT OF LEVEL OF AIR INFILTRATION ON CO AND NO EMISSIONS FROM UNVENTED GAS SPACE HEATERS IN MASS-BALANCE (CHAMBER) MEASUREMENTS

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Abstract

The effect of chamber air infiltration rate on NO and CO emission rates has been derived from tests with a natural-gas-fired, convective unvented space heater (UVGSH). Measurements were carried out in IGT's test chamber using a methodology employed by the Lawrence Berkeley Laboratory (LBL) for measuring emissions from these heaters. The heater had been previously tested in the LBL test chamber by a methodology that requires an air infiltration rate of 0.5 acph to be maintained in the chamber and a specific protocol that allows determination of the effect of long-term heater operation on emissions. The IGT tests were performed by the LBL methodology but at 3 different air infiltration rates (0.5, 4 and 10 acph). The IGT results suggest that the level of chamber air vitiation, due to low air infiltration, can severely affect CO emissions resulting in unrealistically high CO emission rates. A lesser effect was observed on NO emissions, and NO_2 emissions were unaffected, at a relatively low (0.5 acph) chamber air infiltration rate.

Introduction

Over the last several years, there has been a resurgent interest on the part of government in the potential exposure of consumers to pollutants generated by unvented space heaters, including the natural gas-fired variety of such equipment.

Newer models of unvented gas-fired space heaters marketed in the U.S. have introduced changes in existing technologies for burner, ignition, control valve, pressure regulator, heat exchanger, and materials. These changes have an impact on heater emissions for trace air contaminants such as carbon monoxide (CO), nitrogen oxide (NO), nitrogen dioxide (NO_2), and unburned hydrocarbons (UBH).

In addition, the proliferation of existing alternative methodologies for measuring or estimating emission rates from such equipment, and the lack of consensus or standard measurement protocols, have resulted in disagreements as to the comparability of emission characteristics of UVGSH's or the impact that various factors, such as equipment design, have on emissions.

This paper reports on a collaborative study between IGT and LBL relating to emission rate measurements of unvented heaters by the mass balance (chamber) method and specifically the impact on emissions of low air infiltration rates maintained within the chamber during emissions measurements.

Results and Discussion

As shown in Table 1 below, replicated emissions measurement tests were made with a natural gas-fired unvented space heater by each of 3 different methods known as probe, hood and chamber.

Table 1: Emissions from Unvented Space Heaters

Test Heater	Test Method	No. of Tests	NO_2 Ave.	NO_2 S.D.	NO Ave.	NO S.D.	NO_x Ave.	NO_x S.D.	CO Ave.	CO S.D.
			nanograms/Joule							
B	Probe	7	8.39	0.65	21.69	0.41	41.90	1.20	14.63	0.52
B	Hood	3	9.08	0.77	20.65	0.99	40.75	0.77	18.29	0.60
B	Chamber	3	10.41	0.82	10.97	0.14	27.24	0.73	41.50	4.00

The results of Table 1 indicate that, by and large, emission factors for NO_2, NO and CO are almost identical, when measured by either the probe or hood method. Both these methods are carried out in an open laboratory, at high air infiltration rates that cause the space heater flue products to be highly diluted by mixing with the open laboratory air.

In addition, the results of Table 1 show that NO and CO emission factors measured by the chamber method (maintained at an air infiltration rate of 0.5 acph) are drastically different than those obtained by the probe or hood method. Even more, Table 1 shows that the chamber NO emission factor is one-half that measured by the probe or hood method while the CO emission factor is 2.5 times larger.

The conflicting results discussed above have provided the motivation for the investigation reported in this paper. Specifically, the effect of absolute chamber humidity and air infiltration rate on NO, NO_2 and CO emissions has been derived from 7 different tests (conducted in IGT's IAQ laboratory by means of the LBL[1] chamber methodology) with a convective, natural gas-fired, unvented space heater.

The primary independent parameter varied in all these experiments[2] is the chamber infiltration rate which in turn produced a systematic variation in the composition of the chamber atmosphere and, therefore, in the combustion air concentration of absolute humidity (AH), CO_2, CO, (NO & NO_2) NO_x, unburned hydrocarbons (UBH) and O_2. As a result, absolute humidity, O_2, and CO_2 concentrations, and to some extent other compositional parameters of the chamber atmosphere (CO and NO), are indirect measures of the air change rate and, therefore, cross correlated with each other.

The emission measurement tests were repeated at each of 3 different levels of air infiltration within the chamber namely 0.5, 4 and 10 acph. Table 1 summarizes the results at 0.5 acph (for NO and CO) and Figures 1 and 2 present the results obtained at 4 and 10 acph. The results in Figure 1 show inverse correlations between NO emission rates and absolute humidity, at each level of air infiltration, and constant CO_2 chamber concentration. They also show proportional correlations between NO emission rates and level of air infiltration, at each level of absolute humidity and constant CO_2 chamber concentration. On

the other hand, Figure 2 shows a totally inverse picture for CO emissions. Furthermore, the data in Figures 1 and 2 indicate that at a level of 10 acph, chamber emission rates for NO and CO begin to approach those obtained by the probe and hood method listed in Table 1.

Conclusions

The results suggest that the level of combustion air vitiation can severely impact CO emissions (and to a lesser extent NO emissions) determined by the chamber method. When the chamber method is modified to operate at higher levels of air infiltration, the level of vitiation is decreased and, therefore, the method's impact can be minimized.

References

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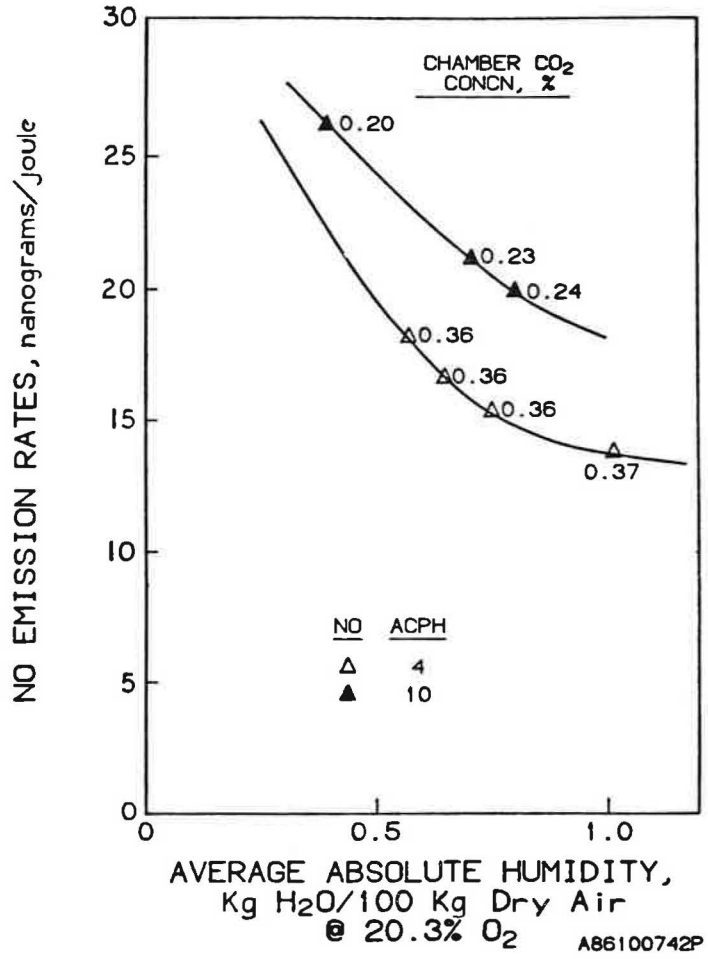

Figure 1. CORRELATION OF NO EMISSION RATES WITH ABSOLUTE HUMIDITY IN THE CHAMBER (Natural Gas Heater B)

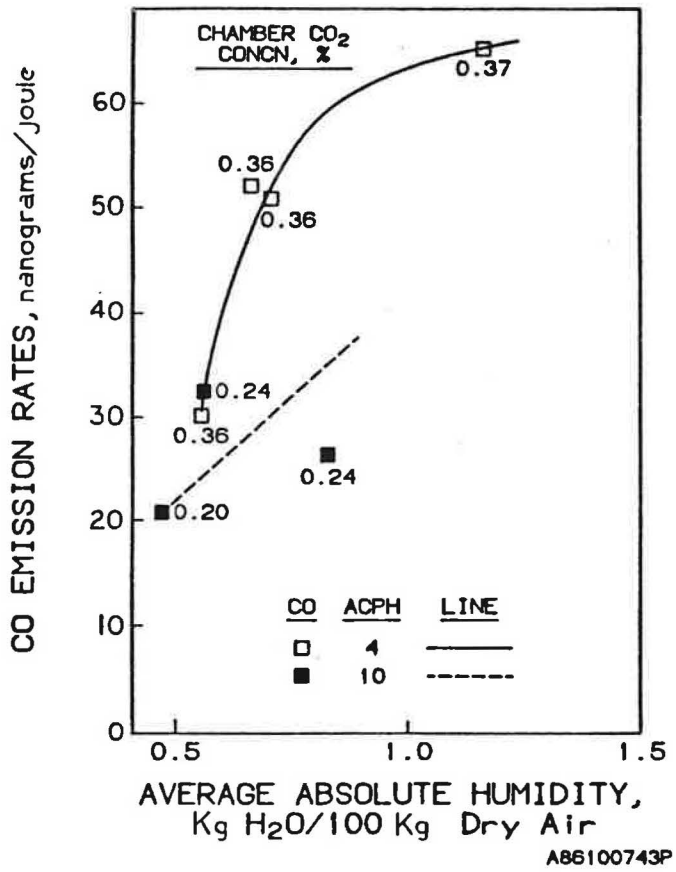

Figure 2. CORRELATION OF CO EMISSION RATES WITH ABSOLUTE HUMIDITY IN THE CHAMBER (Natural Gas Heater B)

FIELD MEASUREMENTS OF NO_2 GAS RANGE-TOP BURNER EMISSION RATES

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Abstract

This paper discusses a field experimental technique used, the data base generated, and the distribution of NO_2 emission rates from range-top burners measured in residences throughout the Chicago metropolitan area. The development work for the field study was performed in an environmental test chamber using one gas range. The field technique was compared to real-time measurements using stoichiometric (direct method) principles. A total of 25 gas ranges were evaluated for NO_2 emission rates. The experimenters concluded that there are no major differences between the field experimental technique used and the direct method for NO_2 emission rate measurements. The measured NO_2 emission rates from the 25 gas ranges vary considerably, with some indication of dependence on the age of the gas range.

Introduction

The maximum range-top burner NO_2 emission rate reported in the literature is 4.2 times the minimum NO_2 rate (1,2,3,4); the corresponding factor between maximum and minimum CO emission rates is 66. The difference between maximum and minimum rates measured by IITRI (5) with three new ranges is smaller: the factor for NO_2 is 2.1 and for CO it is 14.2. Interestingly, most of the reported chamber studies estimate emission rates from new or nearly new appliances. Emission rates from old ranges are not known. Two questions arise: (1) what is the distribution of emission rates of range-top burners in the U. S. housing stock; and (2) is there a method that will allow the experimenter to measure these rates efficiently in the field without bulky and expensive equipment and time-consuming techniques?

The authors of this paper developed and investigated a cost-effective measurement approach that provides a means for measuring NO_2 emission rates from gas range-top burners in the field.

Experimental

A variation of the direct method (6) defines the experimental technique: first, the effluent gases are collected in a teflon bag and transported to a central laboratory for analysis; second, fuel consumption