Title
POLLUTANT EMISSIONS FROM PORTABLE KEROSENE-FIRED SPACE HEATERS



Author
Traynor, G.W.

Publication Date
1982-04-01

LBL-14301
Preprint

# Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

## ENERGY & ENVIRONMENT DIVISION



Submitted to Science

# POLLUTANT EMISSIONS FROM PORTABLE KEROSENE-FIRED SPACE HEATERS

Gregory W. Traynor, James R. Allen, Michael C. Apte, John R. Girman, and Craig D. Hollowell

April 1982



Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

Submitted to <u>Science</u>

LBL-14301
EEB-Vent 82-5

# POLLUTANT EMISSIONS FROM PORTABLE KEROSENE-FIRED SPACE HEATERS

Gregory W. Traynor, James R. Allen, Michael G. Apte,
John R. Girman, and Craig D. Hollowell

Building Ventilation and Indoor Air Quality Program
Energy and Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

April, 1982

This work was supported by the Director, Office of Energy Research, Office of Health and Environmental Research, Human Health and Assessments Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

POLLUTANT EMISSIONS FROM PORTABLE KEROSENE-FIRED SPACE HEATERS

Abstract. Indoor use of unvented combustion appliances is known to cause a increase in indoor air pollutants. We conducted laboratory tests on two radiant and two convective portable kerosene-fired space heaters to identify the pollutants they emit and to determine their emission rates. Results show that carbon dioxide, carbon monoxide, nitric oxide, nitrogen dioxide, and formaldehyde were emitted by both types of heaters and that the radiant heaters and one of the convective heaters also emitted trace amounts of fine particles. When such heaters are operated for one hour in a 27-$m^3$ chamber with 0.4 air changes per hour, the resultant $CO_2$ concentrations are well above the U.S. occupational standard, and $NO_2$ concentrations are well above California's short-term outdoor standard.

Two areas of concern for both the scientific community and the general public are energy conservation and indoor air pollution. To reduce residential heating costs, for example, the public is increasingly turning to heating devices that use alternative fuels, such as portable kerosene-fired space heaters. Strategies designed to reduce energy costs, however, are not always compatible with acceptable indoor air quality. Because these heaters are not vented to the outside, the pollutants they emit can have a detrimental effect on the quality of the indoor air.

We investigated two types of portable kerosene-fired space heaters, convective and radiant, for their emissions of carbon dioxide ($CO_2$), carbon monoxide (CO), nitrogen oxides ($NO_x$ = NO + $NO_2$), formaldehyde (HCHO), and fine particles, as well as for their consumption of oxygen

($O_2$). Tests on portable kerosene-fired heaters were conducted in a 27-$m^3$ environmental chamber, approximately the size of a kitchen or small bedroom. The chamber has an infiltration rate of 0.40 ± 0.03 air changes per hour (ach). (Two of the heaters were new and were operated for several hours before any tests were conducted.) The pollutant emission rates were quantified by means of a technique we had developed previously to determine pollutant emission rates from gas ranges (1). The monitoring equipment used for gaseous and particulate emissions has been described elsewhere (1, 2).

All four kerosene heaters tested, were found to emit $CO_2$, CO, NO, $NO_2$, and HCHO; additionally, both radiant heaters and one convective heater emitted fine particles. The concentrations of $CO_2$, CO, $NO_2$, and NO emitted from a convective heater are shown in Fig. 1 and those from a radiant heater are shown in Fig. 2. For both heater types, $CO_2$ levels reached twice the 8-hour U.S. occupational standard of 5,000 ppm (3). $NO_2$ levels did not exceed the U.S. occupational standard of 5.0 ppm (3) with either heater but did exceed the California short-term (1-hour) standard of 0.25 ppm (4)--by a factor of seven for the convective heater and by a factor of two for the radiant model. CO levels from the radiant heaters exceeded the Environmental Protection Agency's outdoor 8-hour standard of 9 ppm, but were below its 1-hour standard of 35 ppm (5). (Bear in mind that the applicability of outdoor air quality standards to indoor environments has yet to be established.)

Table 1 summarizes the pollutant emission rates (per caloric value of fuel consumed) from 12 tests on the four different heaters. The $CO_2$ production rates and $O_2$ consumption rates were relatively constant for both convective and radiant heaters. The kerosene used in the study had an average molecular weight of 174 and an average carbon number of 12.25 (6). These values correspond to a theoretical $CO_2$ emission rate of 71,300 μg/kJ and an $O_2$ consumption rate of 80,300 μg/kJ, values very close to our measured emission rates averaging 70,200 ± 3,500 μg/kJ for $CO_2$ and 79,000 ± 2,500 μg/kJ for $O_2$. As is evident from Table 1, $NO_x$ emissions were greater for convective heaters and CO, HCHO, and fine-particle emissions were greater for radiant heaters. The difference is probably due to the hotter flame in convective heaters. The $NO_x$ results are slightly below those of Yamanaka _et al_. (7) who studied $NO_2$ emissions from similar types of heaters. When results from the two studies are converted to $cm^3$ per kJ of $NO_x$ emitted (at 25 °C and 1 atmos.), the differences are minor: 0.027 and 0.026 $cm^3$/kJ of $NO_x$ from our convective heater tests and 0.0034 and 0.0043 $cm^3$/kJ from our radiant heater tests in contrast to Yamanaka's findings of 0.027 to 0.035 $cm^3$/kJ for convective heaters and 0.0044 to 0.0065 $cm^3$/kJ for radiant heaters.

Average HCHO concentrations measured in the chamber for one hour after the heaters were turned off were 13 ppb for the new convective heater under full-wick conditions (tests #1-1 to #1-4) and 66 ppb for the new radiant heater under full-wick conditions (tests #3-1 and #3-2). For the new convective heater under the same full-wick conditions, the average increase in fine particulate levels was below detection (< 0.2 μg/$m^3$) during the 1-hour period after the heater was turned off, but for the new radiant heater the increase averaged 4.0 μg/$m^3$ above background. Levels of HCHO and fine particles were below occupational and outdoor air quality standards in all tests conducted.

To differentiate the emissions during the first 10 minutes of operation from those associated with "steady-state" operation, we conducted emission rate tests with and without a 10-minute warm-up period (outside the chamber). In general, there was no significant difference in emission rates with and without a warm-up period. The only exception was with the 5-year-old convective heater which, upon ignition, emitted 440 μg of fine particles (visually seen as a burst of smoke).

We also conducted tests to determine the effects of adjusting the wick length, since consumers do have this option. For the new heaters in this study, we followed the manufacturers' procedure for adjusting the wicks to their optimum length, and found that maximum wick extension (full-wick) produced the best burning conditions. Therefore, we proceeded to investigate the effects of reducing the wick extension on pollutant emission rates. For the new convective heater, we reduced the wick until the flame was approximately one-half its original length. As evident in Table 1 (test #1-5), this adjustment reduced the fuel-consumption rate but increased CO and HCHO emission rates by factors of 8 and 4, respectively, and had no effect on fine particulate emissions. For the new radiant heater, the wick was reduced by adjusting the wick control knob to one-half its full setting, slightly decreasing the fuel-consumption rate. Again, results (tests #3-3 and #3-4) indicated an increase in CO emissions with the decrease in fuel consumption, but only a slight increase in HCHO and fine particulate emissions.

The emission rates presented in Table 1, combined with specific heater-use patterns, building characteristics (such as air-exchange rate and building volume), and possibly other parameters, can be entered into an indoor air quality model (1, 8-10) to estimate indoor pollution profiles for other structures where these appliances are used. Such estimates should be compared against data on health risks from pollutants in order to establish the potential hazard of using kerosene heaters indoors. In any case, when using these appliances in small rooms, increased ventilation or other pollution-control strategies should be considered.

G. W. Traynor

J. R. Allen

M. G. Apte

J. R. Girman

C. D. Hollowell*

Lawrence Berkeley Laboratory

University of California

Berkeley, California 94720

*deceased

References and Notes

1. G. W. Traynor, D. W. Anthon, C. D. Hollowell, Technique for Determining Pollutant Emissions from a Gas-fired Range (Report LBL-9522, Lawrence Berkeley Laboratory, Berkeley, CA, 1981); Atmos. Environ. (in press).

2. J. R. Girman, M. G. Apte, G. W. Traynor, C. D. Hollowell, Pollutant Emission Rates from Indoor Combustion Appliances and Sidestream

Cigarette Smoke, (Report LBL-12562, Lawrence Berkeley Laboratory, Berkeley, CA, 1982); accepted by Environment International.

3. U.S. Government, Code of Federal Regulations, Title 29, Section 1910.1000, 1979.

4. State of California, California Administrative Code, Title 17, Subchapter 1.5, Section 70100, 1977.

5. U.S. Government, Code of Federal Regulations, Title 40, Section 50.8, 1975.

6. Data provided by Chevron Research Company, Richmond, CA.

7. S. Yamanaka, H. Hirose, S. Takada, Atmos. Environ. 13, 407 (1979).

8. A. Turk, ASHRAE J. 5, 55 (1963).

9. J. Alonzo, B.L. Cohen, H. Rudolf, H.N. Jow, J.O. Frohliger, Atmos. Environ. 13, 55 (1979).

10. G. W. Traynor, M. G. Apte, J. F. Dillworth, C. D. Hollowell, E. M. Sterling, The Effects of Ventilation on Residential Air Pollution Due to Emissions from a Gas-fired Range, (Report LBL-12563, Lawrence Berkeley Laboratory, Berkeley, CA, 1982); submitted to Environment International.

11. This work was supported by the Director, Office of Energy Research, Office of Health and Environmental Research, Human Health and Assessments Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Table 1. Pollutant emission rates from portable kerosene-fired space heaters.

| Heater and Test # | Test Description | Fuel Consumption[a] (kJ/hr) | Emission Rates CO (μg/kJ) | $CO_2$ (μg/kJ) | N (of $NO_x$) (μg/kJ) | HCHO (μg/kJ) | $O_2$ (μg/kJ) | Fine Particles[b] (μg/kJ) | Volumetric $NO_2/NO_x$ Ratio[c] |
|---|---|---|---|---|---|---|---|---|---|
| Convective (New) | | | | | | | | | |
| 1-1 | Fired in chamber | 7830 | 14.5 | 70,100 | 15.3 | 0.01 | -77,200 | <0.004 | 0.28 |
| 1-2 | Fired in chamber | 7980 | 10.3 | 72,500 | 15.6 | 0.08 | -78,900 | <0.004 | 0.25 |
| 1-3 | 10-min warm-up[d] | 7850 | 9.1 | 70,700 | 15.5 | 0.14 | -73,800 | <0.004 | 0.26 |
| 1-4 | 10-min warm-up | 7840 | 9.1 | 70,400 | 15.5 | 0.18 | -78,000 | <0.004 | 0.24 |
| 1-5 | Reduced wick (10-min warm-up) | 4230 | 84.9 | 78,000 | 16.0 | 0.42 | -82,800 | <0.004 | 0.45 |
| Convective (5-yr-old) | | | | | | | | | |
| 2-1 | Fired in chamber | 5480 | 115.1 | 69,000 | 15.3 | 1.22 | -79,500 | e | 0.65 |
| 2-2 | 10-min warm-up | 5780 | 110.5 | 63,600 | 14.2 | 0.98 | -80,900 | 0.006 | 0.61 |
| Radiant (New) | | | | | | | | | |
| 3-1 | Fired in chamber | 8180 | 60.2 | 70,300 | 2.2 | 0.63 | -76,700 | 0.019 | 0.67 |
| 3-2 | 10-min warm-up | 8250 | 71.7 | 68,500 | 1.8 | 0.49 | -79,600 | 0.022 | 0.69 |
| 3-3 | Reduced wick (10-min warm-up) | 7180 | 141.3 | 70,600 | 1.6 | 0.80 | -81,800 | 0.031 | 0.92 |
| 3-4 | Reduced wick (10-min warm-up) | 7650 | 91.7 | 71,900 | 1.7 | 0.58 | -80,900 | 0.022 | 0.83 |
| Radiant (1-yr-old) | | | | | | | | | |
| 4-1 | 10-min warm-up | 6640 | 54.0 | 66,200 | 2.5 | 0.10 | -78,000 | 0.019 | 0.63 |

[a] 1.000 kJ/hr = 0.948 Btu/hr; heat content of kerosene = 43.5 kJ/g.

[b] Mass of particles from 0.005 to 0.4 μm in diameter, analyzed by electrical mobility detector, assuming particulate density of 2.0 g/$cm^3$.

[c] Measured at shut-off.

[d] All warm-ups were conducted outside the chamber to avoid initial transient emissions.

[e] 440 μg emitted at ignition; heater ignited with a smokeless butane lighter.

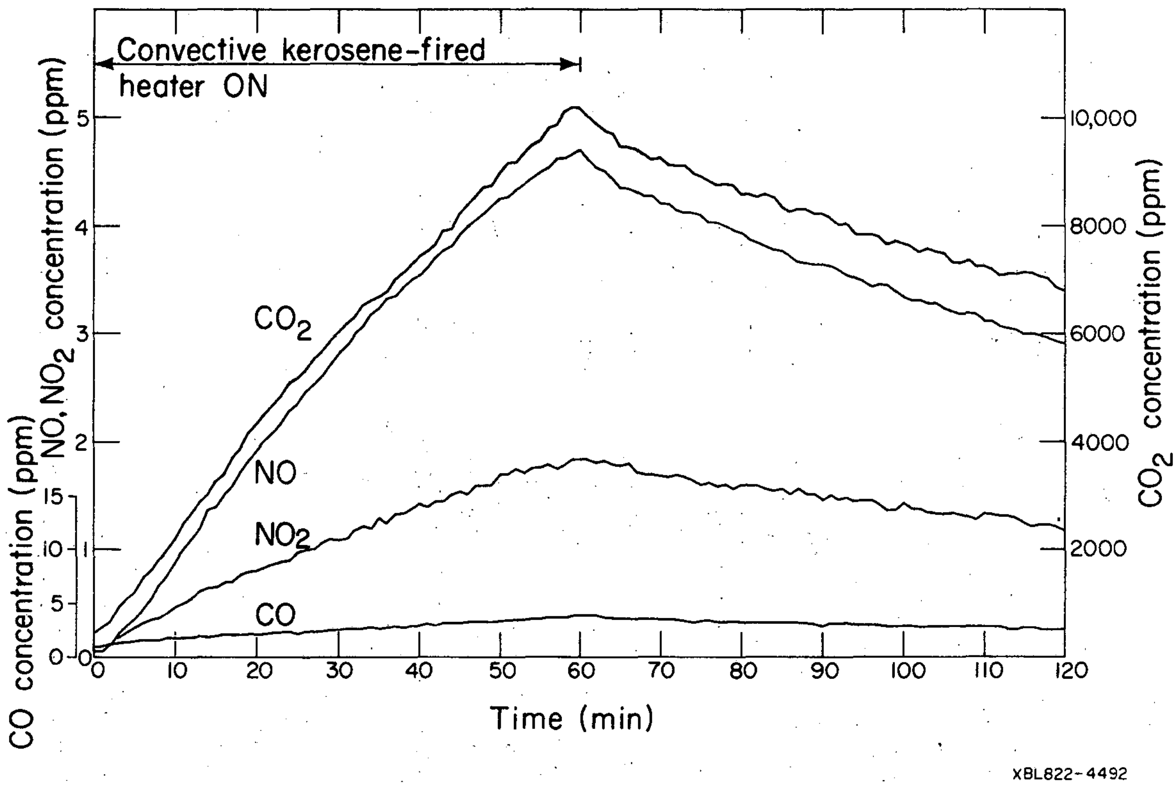


Figure 1. $CO$, $CO_2$, NO, and $NO_2$ concentrations measured during operation of a portable, convective-type, kerosene-fired space heater in a well-mixed 27-$m^3$ chamber. Fuel consumption was 7830 kJ/hr (7430 Btu/hr) and the air exchange rate was 0.39 air changes per hour; test #1-1.

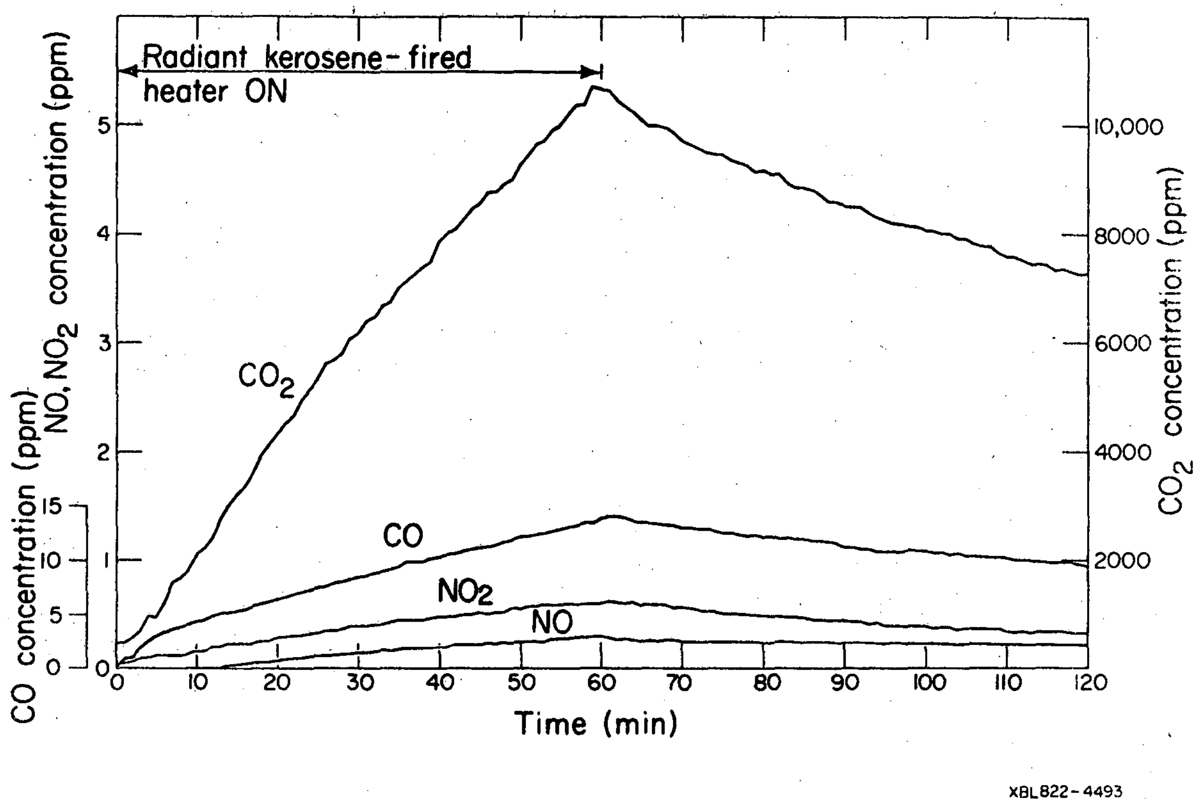


Figure 2. $CO$, $CO_2$, $NO$, and $NO_2$ concentrations during operation of a portable, radiant-type, kerosene-fired space heater in a well-mixed 27-$m^3$ chamber. Fuel consumption was 8180 kJ/hr (7760 Btu/hr) and the air exchange rate was 0.40 air changes per hour; test #3-1.

*TECHNICAL INFORMATION DEPARTMENT*
*LAWRENCE BERKELEY LABORATORY*
*UNIVERSITY OF CALIFORNIA*
*BERKELEY, CALIFORNIA 94720*