Consumers'
Association
of Canada

Association
des consommateurs
du Canada

Testing And Research

SAFETY EVALUATION

UNVENTED KEROSENE HEATERS

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EXECUTIVE SUMMARY

In February, 1983, the Canadian market was surveyed at the retail level and at the importation/distribution level to choose a representative group of portable kerosene heaters for a test program to determine the hazards, if any, arising from their use. In consultation with officials from Consumer and Corporate Affairs Canada, 10 heaters were chosen which had a popular power rating of around 2500 W and 2 heaters were chosen which had a power rating of 4400 W, the largest output recommended for residential use by CSA Standard B140.9.3-M1979. The test program focused on the measurement of products of combustion, heater surface temperatures, and parameters related to fire safety.

Three products of the combustion of kerosene (carbon monoxide, carbon dioxide and nitrogen oxides) were measured in a specially modified environmental chamber and a "typical" house under various sets of conditions. In the environmental chamber all heaters were tested twice under "standard" conditions of 21°C ambient, an air exchange rate of 0.5 per hour, with "water clear" fuel and with the flame adjusted to the manufacturers' recommended setting. Under these conditions the maximum carbon monoxide concentration varied from 11 ppm to 73 ppm, the maximum nitrogen oxides concentration varied from less than 1 ppm to 6 ppm, and the maximum carbon dioxide concentration varied from 1.6% to 2.1%. It was noted that the level of emissions was to some extent independent of the nominal output of the heaters. The convection style heaters as a group had a higher level of nitrogen oxides output than the radiant type and the reverse applied with respect to the carbon monoxide emissions. There was a high degree of test to test variation of emission levels from each heater indicating further testing is necessary.

The chamber tests also included an evaluation of the effect on emissions of a higher exchange rate within the room, the use of yellow coloured fuel, the wick set lower than recommended by the manufacturer and lastly with the wick set higher than recommended by the manufacturer. Only 2 heaters (1 radiant and 1 convection type chosen on the basis of higher than average outputs of emissions in the "standard" tests) were subjected to these additional tests and only one variable was altered at a time. The highest maximum carbon monoxide output attained in any test carried out was 93 ppm in the case of the radiant heater tested using "yellow" fuel. Given the variability of the results in the "standard" tests, the range of results in the additional series of tests is unremarkable.

Two heaters were selected for the experiments conducted in a "typical" house on the basis of higher than average emissions in the chamber tests and subjected to three separate sets of test conditions. All heaters were tested in the living room of the house with the door and window closed, with the door open and the window closed and finally with the window open and the door closed. The radiant unit produced a maximum carbon monoxide concentration of 37 ppm in the closed room and 24 ppm maximum with the window closed and door open. The convection heater produced a maximum carbon monoxide concentration of 10 ppm in the closed room and lower concentrations under other conditions. Again given the test to test variation of maximum gas concentrations in the environmental chamber testing and that only one test in the house under each condition was carried out, these results can only give some indication as to what might occur in some real use circumstances. Further, the level of nitrogen oxides in all cases in the house test were within or approaching the experimental limits of accuracy of the instrumentation due to instrument noise and hence are unreliable.

Kerosene heater surface temperatures were measured in both the environmental chamber tests and in the house tests. The top surface of the heaters ranged from 190°C to 380°C. The temperatures of the sides, front and back of the heater were considerably lower, generally less than 50°C with the exception of three heaters, two which reached 60°C and one that reached 70°C.

The stability test showed that in the worst case, that is with the least stable heater with a nearly empty fuel tank, a force of about 29 N was required to be applied to the front face of the heater for it to tip over. Of the 12 heaters tested, 3 exhibited significant spillage of fuel when upset and another 2 produced a slight amount of leakage. All automatic flame shut-off devices activated when the heaters were severely jarred.

The results lead to the conclusion that kerosene heaters can under certain conditions, produce significant levels of carbon monoxide, carbon dioxide and nitrogen oxides though our tests are indefinite as to the level of hazard that this implies. Further, the top surfaces of all heaters become extremely hot. There does not appear to be a general problem with fuel spillage or stability although the fact that 3 heaters did exhibit some spillage indicates that some attention might be given to this matter.

It is recommended that further testing be carried out to determine the variability of results over an extended series of runs. Testing should be carried out on a variety of other conditions; using a greater variety of kerosene fuels; other flame conditions; older wicks; other room and environmental (ambient) temperatures; broader range of air exchange rates; and tests in a greater variety of houses (noting air exchange rates, design, furnishings).

It is further recommended that if additional experiments are carried out, that measurements specifically for nitrogen dioxide (NO_2) and for hydrocarbons (HC) be made.

SECTION 2

INTRODUCTION

In 1982 there was increasing interest and concern expressed by Canadians (Ref. (A) letters received by CAC) about the performance and effects of the use of unvented kerosene heaters for domestic heating purposes. These products were widely advertised and sold on the basis of high efficiency and potential savings if used for space heating situations by allowing the regular thermostat setting to be reduced. Claims were also made with respect to convenience and safety features of their operation.

Nevertheless, concern was raised following the publication of some test reports (Ref. (B)) which claimed that the use of unvented heaters burning kerosene could create undesirable and even unsafe levels of noxious gases. The gases of most concern were reported to be carbon monoxide, nitrogen oxides and sulphur dioxide. A number of published reports(Ref. (C)) also questioned the heaters safety because of high temperature levels on the external surfaces of the product and possible fire hazards during operation.

Reference (A) - Letters received by Consumers' Association of Canada

Reference (B) - Reports which claim kerosene heaters could create undesirable levels of noxious gases:

Leaderer B.P., "Air Pollutant Emissions from Kerosene Space Heaters", Science, Vol. 218, No. 10, December 1982

Traynor, G.W., Allen, J.R., Apte, N.G., Girman, J.R., Hollowell, C.D., "Pollutant Emissions from Portable Kerosene-Fired Space Heaters", Report LBL-14301 Lawrence Berkeley Laboratory, April 1982

Consumer Reports, "Are Kerosene Heaters Safe?", October 1982

Reference (C) - Temperature of surface a potential hazard

Consumer Reports, "Are Kerosene Heaters Safe?", October 1982

Canadian Consumer, "Kerosene Heaters: Safe, efficient and useful when the lights go out", November 1982

Consumers' Association of Canada, under contract to Consumer and Corporate Affairs of Canada, undertook to test 10 kerosene heaters that were representative of the Canadian marketplace and an additional 2 heaters of the maximum size available for residential use. The primary aim of the test program was to acquire data to determine the hazard level. The contract required CAC to carry out the following work:

1. Identification of major manufacturers and distributors and a survey to determine level of popularity of kerosene heaters in the Canadian marketplace.

2. Purchase of at least one sample of radiant type heater and at least one sample of a convection type heater from each manufacturer.

3. Determination of emission levels in a standardized laboratory environment of carbon monoxide, carbon dioxide, and nitrogen oxides. The conditions that were to be standardized were chamber volume, ambient temperature, air exchange rate, burner setting and grade of fuel.

4. Measurement of gaseous emissions in a house. (actual use)

5. Determination of the other fire safety factors including stability of the unit, effectiveness of the safety devices which are activated in the event of the unit being knocked over and measurement of the temperatures reached on external surfaces to determine the level of burn and fire risk.

6. The level of gaseous emissions under other than "standard" conditions in the environmental test chamber. The variables to be examined were air exchange rate, wick setting and grade of fuel.

7. Preparation of a report.

SECTION 3

EXPERIMENTAL

1. Laboratory Tests

a) Gaseous Emission of Combustion Products

i) Experimental Setup. CAC's environmental test chamber was extensively modified for this test to ensure that it was completely sealed with the exception of a controllable inlet port and a controllable exhaust port so that the air exchange rate could be varied to any predetermined level. The air circulation system was baffled to ensure that there was effectively zero air movement around the kerosene heater under test. A condensate collector was fitted to the pan beneath the cooling coils so that any condensate forming on the coils could be kept for future analysis. A double glazed glass inspection port was fitted to one wall of the chamber so that the flame conditions could be visually monitored over the period of the test.

The interior dimensions of the test chamber were 2.4 m x 2.4 m x 6.1 m and the total volume including the internal ducting was 35 m^3 (see details of the test chamber in Appendix C)

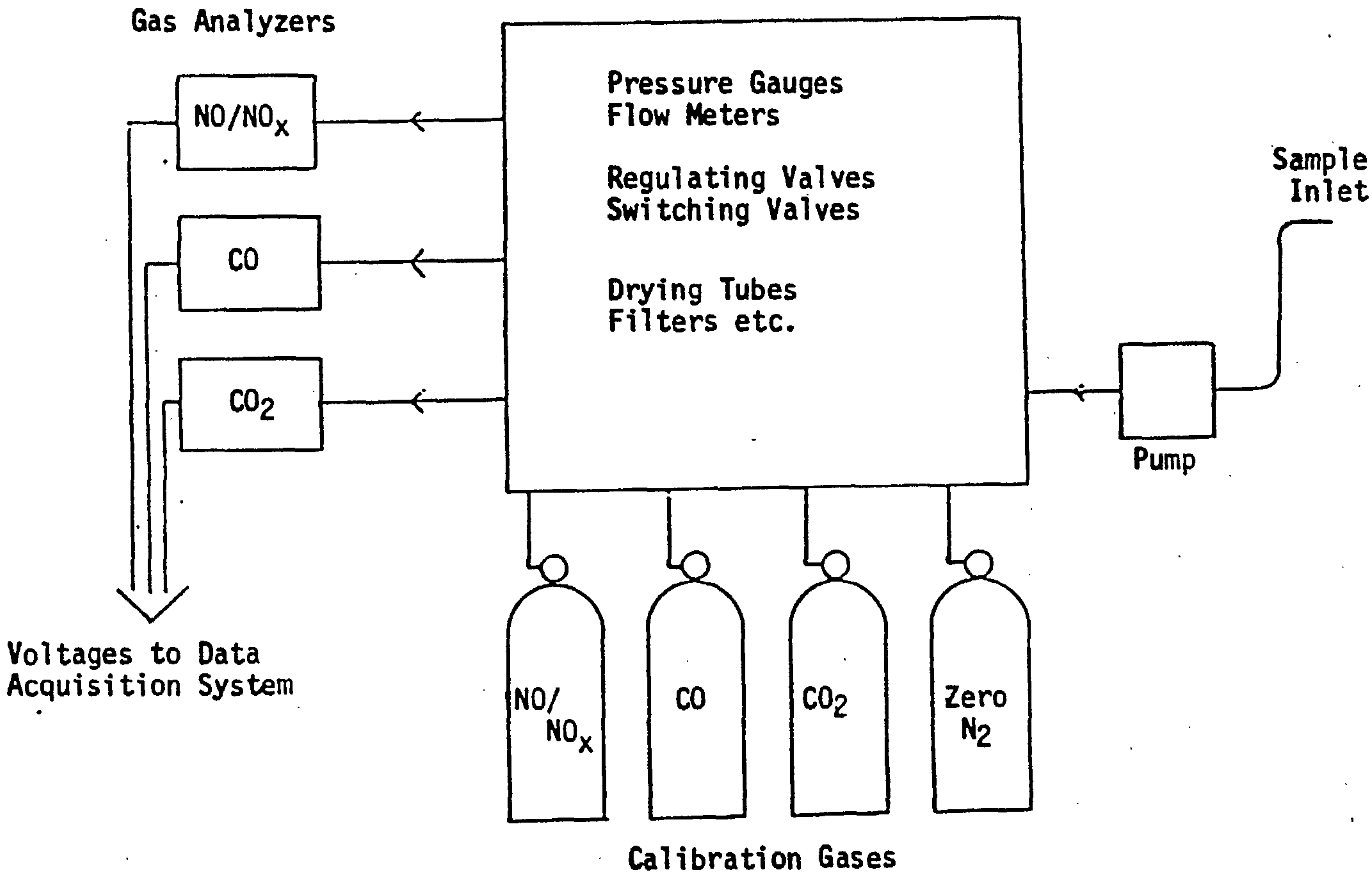
The temperature in the test chamber was maintained at $21^{o} \pm 2^{o}C$ throughout the tests using a refrigeration unit and baffled circulating fans.

The gases (carbon monixide, carbon dioxide and nitrogen oxides) were monitored at a height of 1 m using the following instruments: Beckman, Model 955 NO/NO_x Analyzer; Beckman, Model 865 CO Infrared Analyzer and Beckman, Model 865 CO_2 Infrared Analyzer. A block diagram of the gas sampling system is shown in Figure 1. Immediately before and following each test the gas analyzers were calibrated using a zero gas (pure nitrogen) and a gas of known concentration.

FIGURE 1

GAS HANDLING/SAMPLING SYSTEM

GAS SAMPLING CONTROL PANEL



(See Appendix D for error analysis). Before each test the initial gas concentrations were recorded to determine the "background" level. (The gas concentrations recorded in the results were not adjusted for this background level.)

A typical test run consisted of filling the heater with fuel, igniting the wick and ensuring that the wick was adjusted to the correct setting, leaving the chamber and closing the door and regularly visually monitoring the flame condition throughout the test. The duration of the test run varied from 5 to 8 hours to allow enough time for the gas concentrations to reach steady state conditions. (Steady state is the condition when no change was observed in gas concentrations over time). The data was logged using an "Apple" micro computer on a continuous basis throughout the test.

ii) "Standard" Test Conditions. Fuel used was locally available "water clear" kerosene fuel, the quality recommended by all manufacturers of tested kerosene heaters and was purchased from a local retail outlet. The fuel brand was "Warm n'Cosy Kerosene" manufactured by Flo-Pak Limited, Toronto. A claim made on the label states: "Low Odour, for use in catalytic and low odour heaters".

Subsequent laboratory analysis of the fuel determined that the sulphur content was 83 ppm, nitrogen 2.2 ppm and 0.002% ash.

The air exchange rate in the chamber was set at 0.5/hr, this rate was chosen because it is typical of many houses in Canada.

The wick setting on the heaters was adjusted according to the instructions supplied. The ambient temperature within the chamber was maintained at $21^{o} \pm 2^{o}C$. This temperature was chosen as representing a typical comfort level for domestic homes.

Each heater was tested twice under the above conditons.

iii) Variable Test Conditions. Two heaters (sample #6, Kero Sun Moonlighter, convection type, rated output 2550 watts (8700 Btu per hr); sample #7, Kero Sun Radiant 10, radiant type, rated output 2930 watts (10,000 Btu per hr)), were chosen because sample #6 produced higher than average concentrations of nitrogen oxides under the "standard" test conditions and sample #7 produced higher than average concentration of carbon monoxide in the "standard" test. Both heaters were tested once under the following varied conditions:

1. The air exchange rate set at 1/hr.

2. The wick set to its highest adjustment.

3. The wick set as low as it could be adjusted without the flame extinguishing.

4. The heaters were fueled with a yellow coloured kerosene which was later determined to have a sulphur content of 126 ppm, nitrogen 10 ppm and 0.005% ash. This yellow fuel is not recommended by the heater manufacturers.

Following the "yellow" fuel test, no further tests for emissions were carried out on samples #6 and #7 because of the possible contaminant effect on the wick.

b) <u>Measurement of Physical Parameters</u>

i) Heater Surface Temperatures. The maximum temperature reached on six surface locations on the heaters were monitored at the same time as the gas concentrations were being recorded in order to evaluate the potential burn hazard. All surface temperatures were measured using type K 30 gauge unshielded thermocouples physically fastened to the heater surface. (See Appendix E for details of the thermocouple placement on a typical radiant and convective heater.)

There was also an attempt made to measure the flame temperature but the results have not been reported because of difficulties in getting the thermocouple accurately and consistently placed within the flame.

The results reported are the maximum measured temperature during the test run.

ii) Stability Test. The relative stability of the kerosene heaters was determined by measuring the force required to tip each heater over when the tank was nearly empty and also when it was full. The method used was to attach a tension type force gauge to the top centre face of the heater and observe the force required to pull the heater over. The force recorded was the minimum force that was required, ie: the force was applied at different sides of the heater to determine the least stable position. The force gauge used was a "Chatillion" Dial Push/Pull Gauge Model DPPH-100.

iii) Automatic Shut-Off Device. All heaters were tested to see if the automatic shut-off device functioned properly. At the end of each chamber test the heater was severely jarred to determine if the flame extinguished as required.

iv) Spillage. The volume of fuel which leaked from the heater after it had been tipped onto its face, was measured when the fuel tank was nearly empty and also when the fuel tank was full.

2. IN-HOUSE TESTS

To determine what is likely to happen in a real life situation, two heaters were tested in a house. The house used was a 12 year old bungalow, electrically heated (not forced air), and had 3 bedrooms. The exterior walls were wood frame construction with vinyl siding and the insulation in the walls and ceiling were R12 and R28 respectively. The two heaters were chosen in consultation with officials from Consumer and Corporate Affairs Canada, sample #1 (Sunbeam, Model OHRG 28 H, radiant type rated output 2640 watts (9000 Btu per hr) and sample #11, Sundowner, Model KM80 convection type, rated output 2490 watts (8500 Btu per hr). They were chosen on the basis of the comparatively high levels of carbon monoxide or nitrogen oxides they produced in the standard chamber tests.

Heaters were tested in the main living room (dimensions 3.4 m x 5.2 m x 2.4m (high)). See Appendix F for details of the house and living room. The temperature of the room at the start of the test was lowered to approximately 16^{o}C by opening the window. The room temperature and gas concentrations were measured at 3 height levels, .15 m, 1 m and 2 m from the floor. Equipment and methods used to sample and record gas concentrations were the same as used for the laboratory tests. The fuel used was Warm n'Cosy manufactured by Flo-Pak as used for the laboratory tests. The outdoor temperature ranged from -8^{o}C to +2^{o}C over the three days of testing.

Each heater was tested once under the following three variable conditions:

i) Window open, door closed. The window was opened to provide a total open area of 400 cm^2.

ii) Window closed, door open. The door was opened to provide an open area of 16,000 cm^2.

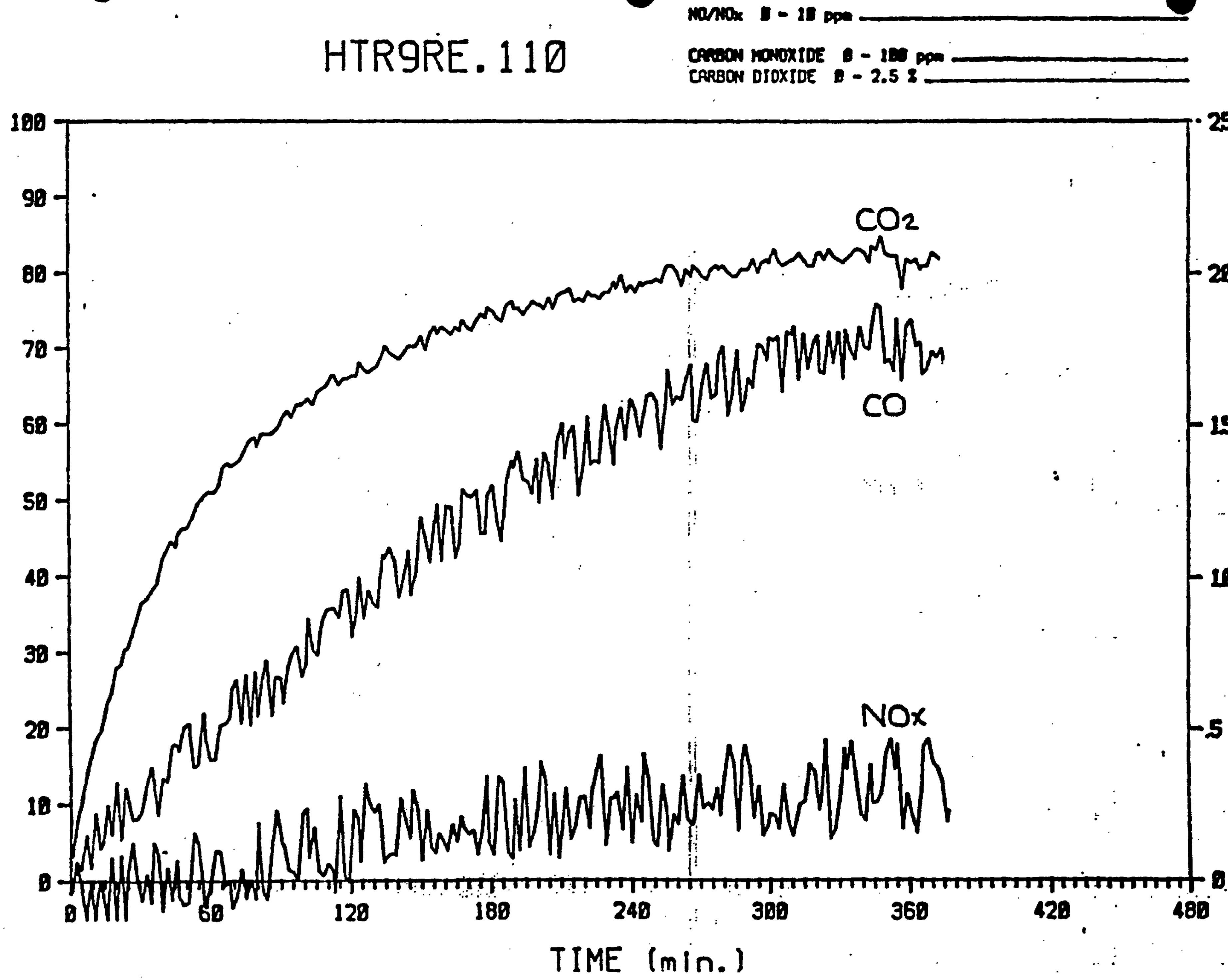
iii) Window closed, door closed.

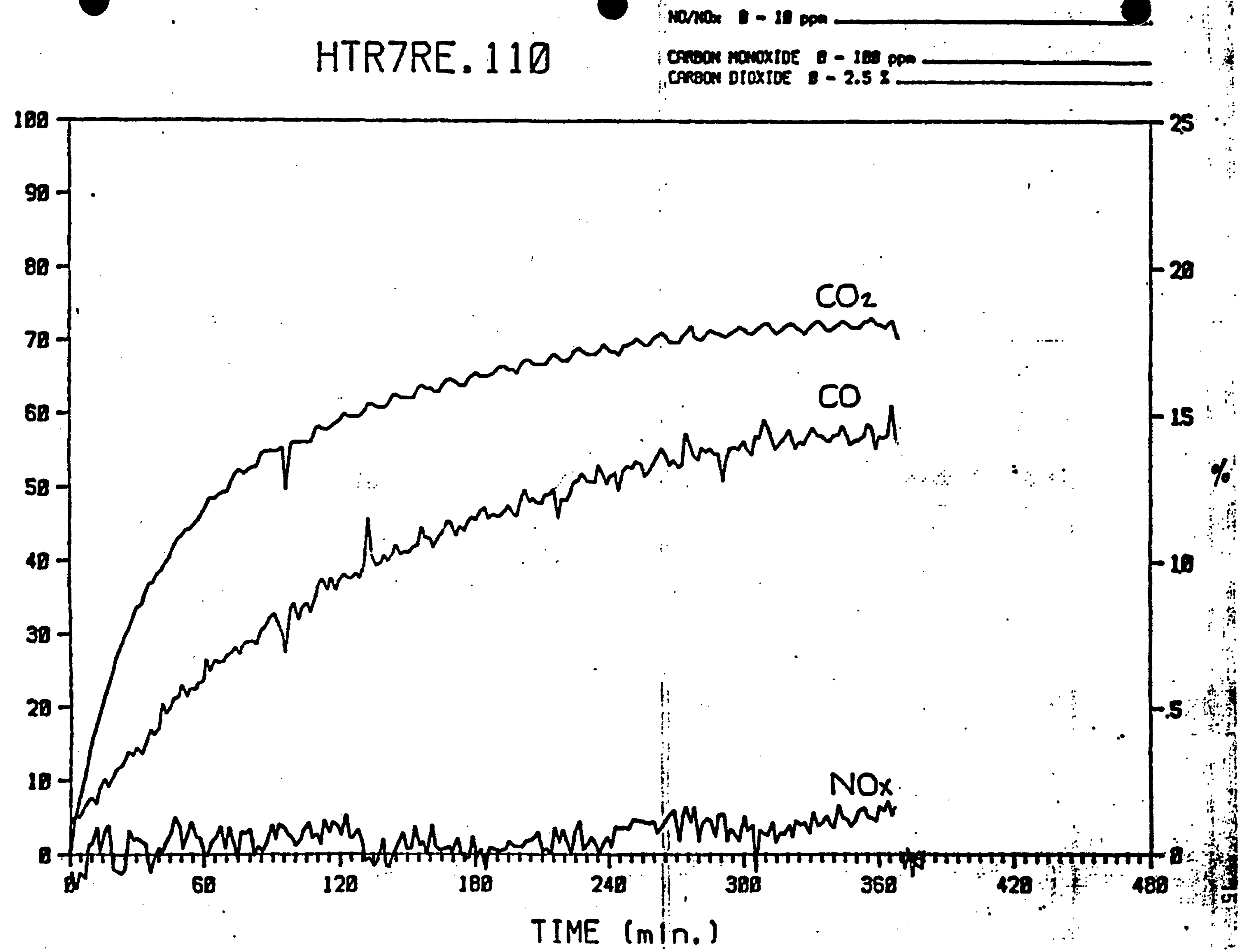
The tests were run over a period of approximately 7 hours, the temperature of the heater surfaces were recorded, as in the laboratory tests there was an attempt to measure the flame temperature but the same comment with respect to its significance as in the laboratory tests applies. Gas concentrations were measured in a room other than the test room. The house was measured for air leakage by independent experts and it was found to be 0.4 ± 0.1/hr. The air leakage report is attached as Appendix G.

RESULTS

Sample graphs of the gas concentrations versus time for the repeat runs of heaters #7 and #9 have been included in this section. Tables #1 through #6 are the results for laboratory tests and the in-house tests.

HTR9RE.110


NO/NOx 0 - 10 ppm
CARBON MONOXIDE 0 - 100 ppm
CARBON DIOXIDE 0 - 2.5 %
CO2
CO
NOx
%
TIME (min.)
0
60
120
180
240
300
360
420
480
10
20
30
40
50
60
70
80
90
100
5
15
25



HTR7RE.110
NO/NOx 0 - 10 ppm
CARBON MONOXIDE 0 - 100 ppm
CARBON DIOXIDE 0 - 2.5 %
CO2
CO
NOx
100
90
80
70
60
50
40
30
20
10
0
25
20
15
10
.5
0
%
0
60
120
180
240
300
360
420
480
TIME (min.)

TABLE 1

MAXIMUM GAS CONCENTRATIONS IN CHAMBER TESTS WITH STANDARD CONDITIONS

Heater Number	Brand (Model)	Type	Rated Output BTU/HR	Maximum Gas Concentrations NO/NO_x^a (ppm)	CO^b (ppm	CO_2^c (%)
1	Sunbeam OHRG284	Rad.	9000	- 1	71 65	- 1.9
2	Sunbeam OHC42A	Conv.	14600	2 1	30 30	- 2.0
3	Kenmore C58363205	Rad.	9300	1 1	45 44	- 1.9
4	Turco Estate 20100	Rad.	9100	1 1	29 73	- 2.1
5	Candle JKH-705	Rad.	10000	- 1	51 26	- 1.9
6	Kero-Sun Moonlighter	Conv.	8700	4 4	22 43	- 1.6
7	Kero-Sun Radiant 10	Rad.	10000	- -	67 57	- 1.6

TABLE 1 (continued)

Heater Number	Brand (Model)	Type	Rated Output BTU/HR	Maximum Gas Concentrations NO/NO_x[a] (ppm)	CO[b] (ppm)	CO_2[c] (%)
8	Kero-Sun Omni 105	Conv.	15000	4 3	13 11	- 2.0
9	Aladdin 5381-U	Rad.	9000	- 1	63 71	- 1.8
10	Sunglow RM 920	Rad.	9100	1 2	15 15	- 1.9
11	Sundowner KM-80	Conv.	8500	3 6	34 28	- 1.7
12	Bombardier CR-10	Rad.	10000	2 2	36 38	2.0 2.0

a) Instruments rated limit of detection is ±0.1 ppm but the effective limit of detection for NO/NO_x concentrations is ±1 ppm due to instrument noise during experiments.

b) Error in CO concentration measurements is ±4 ppm - (95% confidence level)

c) Error in CO_2 concentration measurements is ±.05% - (95% confidence level)

TABLE 2

EFFECT OF WICK SETTING, AIR EXCHANGE RATE AND FUEL QUALITY ON MAXIMUM GAS CONCENTRATIONS IN CHAMBER TESTS

Test Conditions			Maximum Gas Concentrations					
			NO/NO_x[a] (ppm)		CO[b] (ppm)		CO_2[c] (%)	
Wick Setting	Air Changes Per Hour	Fuel Type[f]	Heater 6[d]	Heater 7[e]	Heater 6	Heater 7	Heater 6	Heater 7
Rec.	1.0	WC	5	1	22	41	1.6	1.8
Rec.	0.5	WC	4	-	22	67	NA	NA
Rec.	0.5	WC	4	-	43	57	1.6	1.6
High	0.5	WC	4	1	37	37	1.7	1.8
Low	0.5	WC	2	-	32	53	1.1	1.6
Rec.	0.5	Y	4	1	40	93	1.7	2.0

a) Instruments rated limit of detection is ±0.1 ppm but the effective limit of detection for NO/NO_x concentrations was ±1 ppm due to instrument noise during experiments.

b) Error in CO concentration measurements was ±4 ppm (95 % confidence level)

c) Error in CO_2 concentration measurements was ±.05% (95 % confidence level)

d) Heater #6 was the Kero-Sun Moonlighter, convective type, rated output 8700 Btu

e) Heater #7 was the Kero-Sun Radiant 10, radiant type, rated output 10,000 Btu

f) Abbreviations: REC - Recommended, WC - Waterclear; Y - Yellow

TABLE 3

GAS CONCENTRATIONS FOR IN HOUSE EXPERIMENTS WHEN THE ROOM TEMPERATURE REACHED 28°C

Heater Number	Brand (Model)	Type	Test Condition and Gas Monitoring Height (m)	Gas Concentrations: NO/NO_x ppm	Gas Concentrations: CO ppm	Gas Concentrations: CO_2 (%)	Time to Reach 28°C (hr:min)
1	Sunbeam OHRG284	Rad.	Door Closed, Window Open	-	8	0.5	3:00
			0.15 m	-	10	0.3	
			1.0 m	-	11	0.5	
			2.0 m	-	14	0.6	
			Door Open, Window Closed	-	24	0.8	5:00
			0.15 m	-	16	0.5	
			1.0 m	-	25	0.7	
			2.0 m	-	25	0.7	
			Door Closed, Window Closed	-	7.5	0.5	0:30
			0.15 m	-	25	1.0	
			1.0 m	-	29	1.1	
			2.0 m	-	29	1.1	
			Probe moved to adjacent room prior to shutdown	-	12	0.5	
			0.15 m	-	2	0.1	
			1.0 m	-	12	0.5	
			2.0 m	-	11	0.5	

TABLE 3a

GAS CONCENTRATIONS FOR IN HOUSE EXPERIMENTS WHEN THE ROOM TEMPERATURE REACHED 28°C

Heater Number	Brand (Model)	Type	Test Condition and Gas Monitoring Height (m)	Gas Concentrations NO/NO_x ppm	CO ppm	CO_2 (%)	Time to Reach 28°C (hr:min)
11	Sundowner	Conv.	Door Closed, Window Open	2	4	0.6	3:30
			0.15 m	2	3	0.6	
			1.0 m	2	3	1.0	
			2.0 m	3	3	1.1	
			[1] Door Open, Window Closed	-	6	0.4	Did not reach 28°C
			0.15 m	-	3	0.3	
			1.0 m	-	3	0.3	
			2.0 m	-	4	0.4	
			[2] Door Closed, Window Closed	2	7	1.4	1:30
			0.15 m	-	10	1.2	
			1.0 m	2	13	1.5	
			2.0 m	2	12	1.4	

[1] Heater smoked badly - window opened during test for 5 minutes

[2] Heater turned off at 1 hr. 30 minute mark and restarted 1 hr. 30 minutes later

TABLE

MAXIMUM GAS CONCENTRATIONS FOR IN HOUSE EXPERIMENTS

Heater Number	Brand (Model)	Type	Test Condition and Gas Monitoring Height (m)	Gas Concentrations NO/NO_x ppm	CO ppm	CO_2 (%)	Max. Temp.
1	Sunbeam OHRG284	Rad.	Door Closed, Window Open	-	10	0.5	28°C
			0.15 m	-	10	0.3	
			1.0 m	-	11	0.5	
			2.0 m	-	14	0.6	
			Door Open, Window Closed	-	24	0.8	28°C
			0.15 m	-	16	0.5	
			1.0 m	-	25	0.7	
			2.0 m	-	25	0.7	
			Door Closed, Window Closed	-	37	1.3	33°C
			0.15 m	-	25	1.0	
			1.0 m	-	29	1.1	
			2.0 m	-	29	1.1	
			Probe moved to adjacent room prior to shutdown	-	12	0.5	
			0.15 m	-	2	0.1	
			1.0 m	-	12	0.5	
			2.0 m	-	11	0.5	

TABLE 4 a

MAXIMUM GAS CONCENTRATIONS FOR IN HOUSE EXPERIMENTS

Heater Number	Brand (Model)	Type	Test Condition and Gas Monitoring Height (m)	Gas Concentrations NO/NO_x ppm	CO ppm	CO_2 (%)	Max. Temp.
11	Sundowner	Conv.	Door Closed, Window Open	2	4	1.0	29°C
			0.15 m	2	3	0.6	
			1.0 m	2	3	1.0	
			2.0 m	3	3	1.1	
			[1] Door Open, Window Closed	-	6	0.4	20°C
			0.15 m	-	3	0.3	
			1.0 m	-	3	0.3	
			2.0 m	-	4	0.4	
			[2] Door Closed, Window Closed	2	10	1.7	31°C
			0.15 m	-	10	1.2	
			1.0 m	2	13	1.5	
			2.0 m	2	12	1.4	

[1] Heater smoked badly - window opened during test for 5 minutes

[2] Heater turned off at 1 hr. 30 minute mark and restarted 1 hr. 30 minutes later

TABLE 5

MAXIMUM SURFACE TEMPERATURES AND GRILL SPACING

Heater Number	Brand (Model)	Type	Maximum Surface Temperatures (°C)* External Heater Surfaces Top	Front Grill	Back	Left Side	Right Side	Burner Top	Average Grill Spacing (cm)
1	Sunbeam OHRG284	Rad.	210	30	40	30	20	630	1.8
			230	50	50	30	30	740	
2	Sunbeam OHC 42A	Conv.	230	30	40	30	30	470	1.9
			230	30	30	30	30	560	
3	Kenmore C58363205	Rad.	300	40	40	40	20	630	2.5
			330	50	40	40	20	680	
4	Turco Estate 20100	Rad.	300	60	40	30	20	750	1.9
			300	50	50	40	30	790	
5	Candle JKH-705	Rad.	340	50	30	30	20	780	1.9
			380	50	40	30	30	790	
6	Kero-Sun Moonlighter	Conv.	250	40	50	40	40	160	3.8
			230	40	40	40	40	170	
7	Kero-Sun Radiant 10	Rad.	190	50	30	30	30	630	2.7
			200	50	30	30	30	630	
8	Kero-Sun Omni 105	Conv.	250	20	30	30	30	330	3.8
			240	30	30	20	20	520	
9	Aladdin 5381-U	Rad.	330	40	50	30	20	670	1.9
			320	40	50	30	30	680	
10	Sunglow RM920	Rad.	190	40	30	30	20	670	2.5
			190	50	30	30	30	650	
11	Sundowner KM-80	Conv.	200	30	40	40	40	370	4.0
			240	40	50	60	40	360	

* Error in temperatures in ±10°C due to instrument round-off

TABLE 5 (continued)

Heater Number	Brand (Model)	Type	Maximum Surface Temperatures (°C)* External Heater Surfaces Top	Front Grill	Back	Left Side	Right Side	Burner Top	Average Grill Spacing (cm)
12	Bombardier CR-10	Rad.	360 380	60 50	70 50	50 40	40 40	680 770	1.9

* Error in temperatures is ±10°C due to instrument round-off

TABLE 5

STABILITY AND LEAKAGE OF KEROSENE HEATERS

Heater Number	Brand (Model)	Type	Force Required to Tip		Spill[a]	
			Fuel Tank Near Empty	Fuel Tank Full	Fuel Tank Near Empty	Fuel Tank Full
1	Sunbeam OHRG284	Rad.	70.0 N	95.0 N	No	No
2	Sunbeam OHC42A	Conv.	105.0 N	140.0 N	No	No
3	Kenmore C58363205	Rad.	75.0 N	100.0 N	No	No
4	Turco Estate 20100	Rad.	70.0 N	95.0 N	No	No
5	Candle JKH-705	Rad.	65.0 N	85.0 N	Slight	Slight
6	Kero-Sun Moonlighter	Conv.	80.0 N	110.0 N	Yes	Yes
7	Kero-Sun Radiant 10	Rad.	105.0 N	135.0 N	No	Slight
8	Kero-Sun Omni 105	Conv.	115.0 N	145.0 N	No	No
9	Aladdin 5381-U	Rad.	85.0 N	110.0 N	No	No
10	Sunglow RM 920	Rad.	70.0 N	95.0 N	Yes	Yes
11	Sundowner KM-80	Conv.	65.0 N	75.0 N	No	Yes
12	Bombardier CR-10	Rad.	80.0 N	100.0 N	No	No

[a]Slight - less than 100 ml in 90 seconds Yes - greater than 100 ml in 90 seconds

SECTION 5

DISCUSSION

1. Gaseous Emissions

a) Accuracy of Results

The accuracy of the gas concentration data was ±4 ppm for CO and ±.05% for CO_2. The effective limit of detection for nitrogen oxides was 1 ppm due to excessive instrumentation noise encountered during the experiment. This means that most of the NO_x measurements were insignificant relative to instrument noise except for the results of heater samples #6, #8 and #11 which had a maximum concentration ranging from 3 to 6 ppm in the chamber tests.

Lab personnel were required to enter the room, opening and closing the door throughout the experiment on the average of about 2 times per hour. Due to the high temperature differential between the test room being heated and the rest of the house, opening the door to gain entry allowed large influxes of air from the rest of the house to intermittently lower the concentration of gases under measurement in the room. Measurements of gas concentrations in the kitchen (adjacent to the test room) were taken shortly after the door to the living room had been opened and the measurements showed that there were significant concentrations of CO (12 ppm) at the 1 m and 2 m levels. Thus gas concentration results for the closed room experiments were low.

The data in Tables 3 and 3a, report the gas concentrations found in the house test room when the room temperature was 28°C, this temperature was selected as being an arbitrary maximum that might be selected by a consumer. Nevertheless, the experiments were continued to see what maximum gas concentrations could result after an extended run. The maximum temperature reached in the room was 33°C when a test was run with the outdoor temperature at -2°C.

In the laboratory tests conducted in the environmental chamber, the maximum nitrogen oxides level reached was 6 ppm for convective heaters and 2 ppm for radiant heaters. The carbon monoxide concentration ranged from 11 to 43 ppm for convective heaters and 15 to 73 ppm for radiant type heaters. The maximum concentration of carbon dioxide was 2.1%.

There does not appear to be any significant correlation between the rated heater output and the maximum concentration of the gases that were measured.

As might be expected, increasing the air exchange rate should decrease the concentration of the measured gases in the test chamber. Data was limited, and the only noticeable difference was the CO level which dropped 35%.

Because of the small number of test runs and limits of accuracy in the instrumentation, our results do not show any significant effect on the levels of measured gases on the high and low wick setting as against the standard conditions.

The "yellow" fuel test showed no significant difference with nitrogen oxides concentration over the standard test but did show an increase of concentration with carbon monoxide. The exact increase is hard to determine, again given the problems with repeatability of the results but might approach 100%.

Condensate from the cooling system of the environmental chamber was collected during the chamber tests and this was provided in glass jars to the department of Consumer and Corporate Affairs Canada for later analysis if required. There did not appear to be any correlation between the amount of condensate collected and the levels of emission.

2. Temperature Measurements

The accuracy of the reported temperature data is ±10°C due to instrument round-off error. The maximum temperature for the burner surface was normally reached within 15 minutes and for external surfaces of the heater, maximum temperature was normally reached within the first hour of operation. In terms of the hottest surfaces that could be touched, the top surface of the heaters varied between 190°C and 380°C. In terms of the radiant heaters, the top of the burners was the hottest visible point and reached up to 790°C, but these areas are less accessible because all are covered with a protective grill. Surface temperatures on the sides of the heaters ranged from 20 to 40°C with the exception of heaters #11 and #12. The surface temperature of heater #11 went as high as 60°C while the surface of heater #12 reached 50°C. The temperature of the grill on the radiant models ranged from 30 to 60°C. As might be expected, the temperature of the grill on the convection models was slightly lower ranging from 20 to 40°C.

In the high wick test on samples #6 and #7, the heater top surface increased 20°C in temperature from 240°C to 260°C in the case of sample #6, and from 200°C to 220°C in the case of sample #7. The burner surface temperature on sample #6 increased from 160°C to 200°C and in the case of sample #7 increased from 630°C to 770°C.

3. Auto-Shutoff

It was found that in all cases the auto-shutoff device in the heaters tested extinguished the flame automatically when the heater was given a severe jar. We did not knock the heaters over because of the risk of breaking some components which would make the units unavailable for future testing.

4. Stability

Table 6 lists the force required to pull (tip) the heaters over under empty and full fuel tank conditions. None of the heaters appeared to exhibit a major stability problem. The force required to tip them ranged from 29 N to 51 N with the tank near empty and from 33 N to 65 N with the tank full. The two largest heaters required the greatest force to tip over.

5. Leakage

After being tipped over, sample #6 and #10 leaked significantly (in excess of 100 ml in 90 seconds was considered a significant amount) both when nearly empty and when full. Sample #11 leaked in excess of 100 ml in 90 seconds when full only. Sample #5 leaked very slightly when both empty and full but this leakage appeared to be due to a defective seal between the removeable tank and the heater body.

APPENDIX A

MARKET SURVEY RESULTS

UFACTURER/DISTRIBUTOR	BRAND	MODEL	TYPE	OUTPUT
ali International Ltd.	Candle	704	Radiant	8000BTU's
		705	Radiant	10000BTU's
ero-sun Ltd	Kero-sun	Radiant 10	Radiant	10000BTU's
		Moonlighter	Convection	8700BTU's
		Omni 105	Convection	15000BTU's ✓
rwin Leisure Ltd	Turco	20100	Radiant	9100BTU's
		31050	Convection	~~19800BTU's~~
ymar Equipment Ltd.	Sundowner	KM 80	Convection	8500BTU's
	Sunglow	KM 920	Radiant	9100BTU's
	Sunfire	KM 180	Convection	~~18700BTU's~~
sa Ltd.	Touch n' Glow	CR 8	Radiant	8500BTU's
		CR 9	Radiant	9100BTU's
	with built-in	CRF 9-comes fan.	Radiant	9300BTU's
		K-13	Convection	~~13000BTU's~~
nbeam Corp. Ltd.	Sunbeam	OHRG28H	Radiant	9000BTU's
		OHC42A	Convection	14600BTU's ✓
addin	Aladdin Temp-Rite	S381U	Radiant	9000BTU's
mbardier	Bombardier	CR10	Radiant/ Convection	10000BTU's

.B Any kerosene heater over 15000BTU's has a label on it stating 'Not For Residential Use'.

APPENDIX B

B - 1. BRAND LIST FOR TEST HEATERS

B - 2. BUYING REPORT FOR TEST HEATERS

BRAND LIST-KEROSENE HEATERS

CODE	BRAND	MODEL	RADIATION/ CONVECTION	MANUFACTURER/DISTRIBUTOR	COUNTRY OF ORIGIN	BTU
1	Sunbeam	OHRG28H	Rad	Sunbeam Corp. (Canada) Ttd. 1040 Islington Ave. Toronto, Ont. M8Z-4R5 Manufactured by Tokyo Sanyo Electric Co.	Japan	9000
2	Sunbeam	OHC42A	Conv.	SAME	Japan	14600
3	Kenmore (Desa)	C58363205 with elec. fan	Rad	Simpson Sears Ltd. 222 Jarvis St. Toronto, Ont. M5B-2B8 Manufactured by Matsushita Housing Products Co. Ltd.	Japan	9300
4	Turco Estate	20100	Rad	Irwin Leisure Products 165 North Queen St. Etobicoke, Ont. M9C-1A7 Manufactured by Toshiba Heating Appliances Co. Ltd.	Japan	9100
5	Candle	JKH-705	Rad	Jutan INTERNATIONAL Ltd. 455 Gordon Baker Rd. Willowdale, Ont. M2H-4H2 Manufactured by General Denko Co. Ltd.	JAPAN	10000
6	Kero-Sun	Moonlighter	Conv	KSC Ltd. 1215 Meyerside Dr. Suite 7 Mississauga, Ont. L5T-1H3 Manufactured by Toyotomi Kogyo Co. Ltd.	Japan	8700
7	Kero-Sun	Radiant 10	Rad	SAME	Japan	10000
8	Kero-Sun	Omni 105	Conv	SAME	Japan	15000
9	Aladdin Temp-Rite 9	S381-U	Rad	Aladdin Industries Products of Canada Inc. 245 Edward St. Aurora, Ont. L4G-3L4 Manufactured by Dainippon Inc. and Chom. Co.	Japan	9000
10	Sunglow	RM 920	Rad	Keymar Equipment Ltd. 100-18 Gostick Place North Vancouver, B.C. V7M-3G3 Manufactured by Uchida Mfg. Co. Ltd.	Japan	9100
11	Sundowner	KM 80	Conv.	SAME	Japan	8500
12	Bombardier	CR 10	Rad/Conv	Bombardier Ltd. 1350 Nobel Boucherville, Que. J4B-1A1 Manufactured by Sharp	JAPAN	10000

BUYING REPORT: KEROSENE HEATERS

APPENDIX B-3-34

CODE	BRAND	PRICE PAID
1	Sunbeam OHRG28H	Sunbeam Appliances OTTAWA $144.95
2	Sunbeam OHC42A	Sunbeam Appliances Ottawa R-$199.95 S-$183.95
3	Kenmore C58363205	Sears Ottawa R-$339.99 S-$199.99
4	Turco Estate 20100	Zellers Ottawa $209.99
5	Candle JKH-705	Consumers Distributing Ottawa $169.99
6	Kero-Sun Moonlighter	Ottawa Goodtime Centre, Ottawa $224.95
7	Kero-Sun Radiant 10	Ottawa Goodtime Centre, Ottawa $269.95
8	Kero-Sun Omni 105	Ottawa Goodtime Centre, Ottawa $324.95
9	Aladdin Temp-Rite 9 S381-U	Canadian Tire Ottawa $169.95
10	Keymar Sunglow RM 920	Home Hardware Ottawa $249.99
11	Keymar Sundowner KM 80	Home Hardware Ottawa $189.99
12	Bombardier CR 10	Ottawa Goodtime Centre, Ottawa R-$250.00 S-$229.95

APPENDIX C

C.1 - DETAILS OF CHAMBER MODIFICATIONS

C.2 - GENERAL LAYOUT OF CHAMBER

DETAILS OF CHAMBER MODIFICATIONS

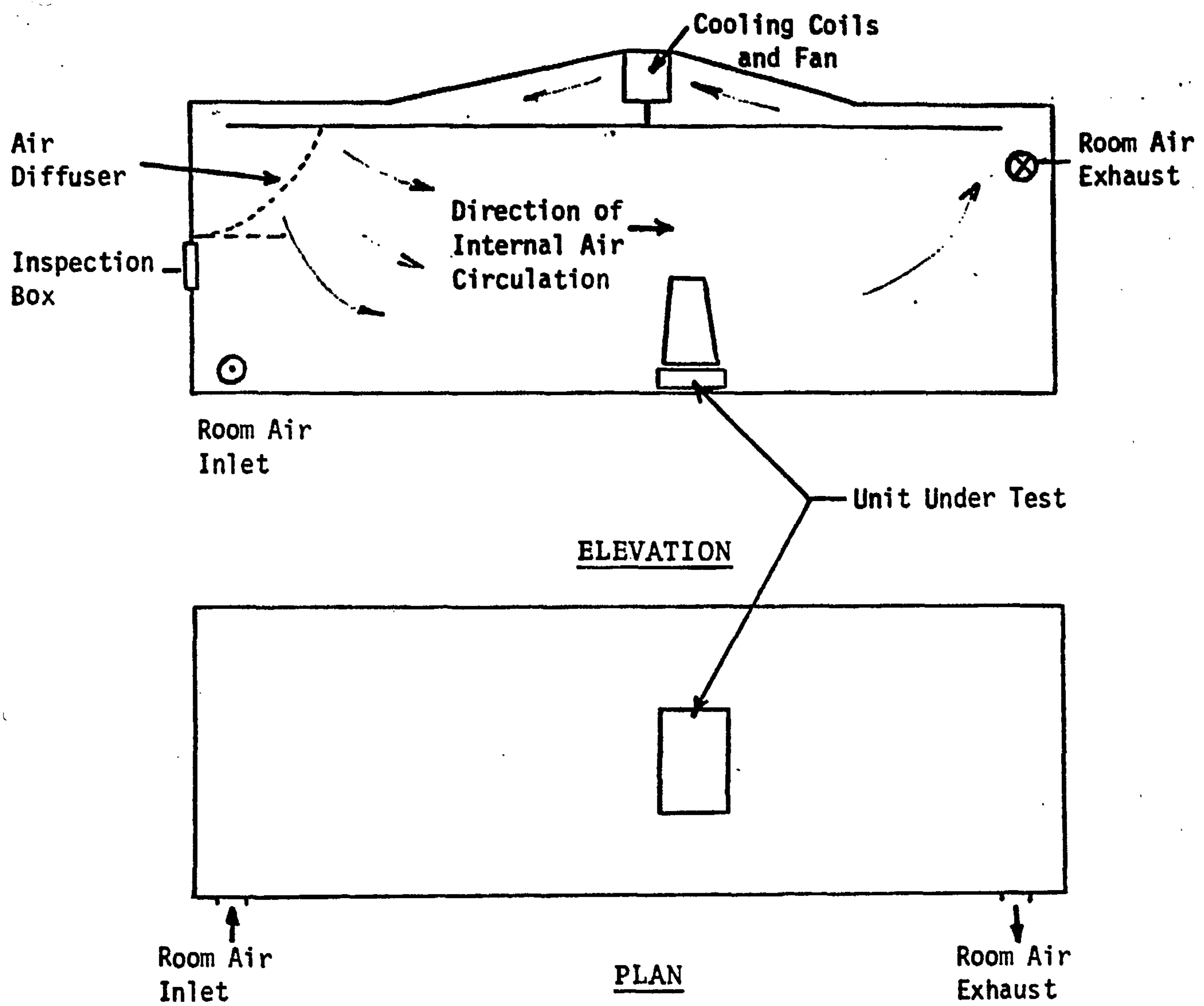
Page 2 of this attachment shows a plan and elevation of CAC's environmental chamber. The chamber is essentially a refrigerated room with duct work for the cooling air separated from the main room by means of a ceiling baffle. The room is lined internally with 5/8 exterior grade plywood.

Prior to carrying out this project, the room was painted with a oil based alkyd paint, Easy Flow brand. It was sealed at all joints with an acrylic sealer, brand name Bulldog Grip "Super Crylic". A power exhaust port was fitted to the upper righthand corner of the chamber complete with a throttling mechanism so that the volume of air being exhausted could be fixed at any predetermined level. To allow air into the room, a inlet was constructed in the lower lefthand corner of the same wall and this too was throttled to achieve the necessary air exchange rate.

Because it was necessary to observe flame conditions throughout the test from outside the chamber, a double glazed window was installed in the lefthand wall. In addition because it was important to limit air movement conditions within the room, a diffusing system was installed consisting of a horizontal perforated hardboard panel together with an open mesh free hanging fabric curtain at the cool air outlet section of the ducting system. It was then found possible to leave the circulation fans running continuously without there being any noticeable affect on an open flame in the section of the room where the heaters were to be tested.

Because one of the products of combustion of the heaters is water vapour which potentially could combine with other products of combustion, a condensate trap was fitted to the cooling coils to enable any condensing water vapour to be collected during the test.

ENVIRONMENTAL CHAMBER

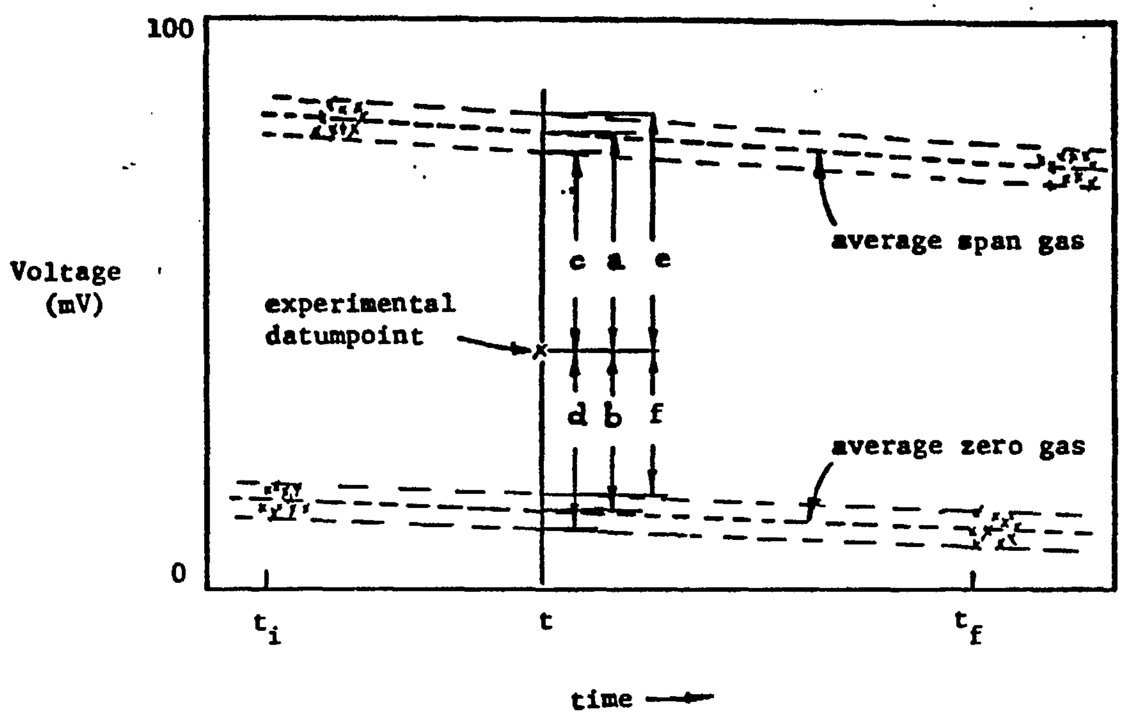


APPENDIX D

GAS CONCENTRATION CONFIDENCE ANALYSIS

Gas Concentration Confidence Analysis

Before an experiment was started and after it was finished, the gas analyzers were calibrated using a zero gas and a span gas of known concentration. From several data points (about 10), a mean and 95% confidence limit (±2 standard deviations) were established for each calibration. It was assumed that the mean and confidence limits varied linearly from the start to the finish of the experiment. The measurement error for each gas was chosen to be the largest error determined according to the following equation.



At any time, t, the voltages corresponding to the zero gas, span gas, and confidence limits were found by linear interpolation between calibrations at the start and finish of the experiment.

$$V(t) = \bar{V}_i - \left(\frac{t - t_i}{t_f - t_i}\right)\left(\bar{V}_i - \bar{V}_f\right)$$

The experimental datum point gas concentration and error at time t is:

$$C(t) = \frac{b}{a + b} \times \begin{pmatrix}\text{span gas} \\ \text{concentration}\end{pmatrix}$$

$$\text{error} = \pm \frac{\left|\frac{d}{c + d} - \frac{f}{e + f}\right|}{2} \times \begin{pmatrix}\text{span gas} \\ \text{concentration}\end{pmatrix}$$

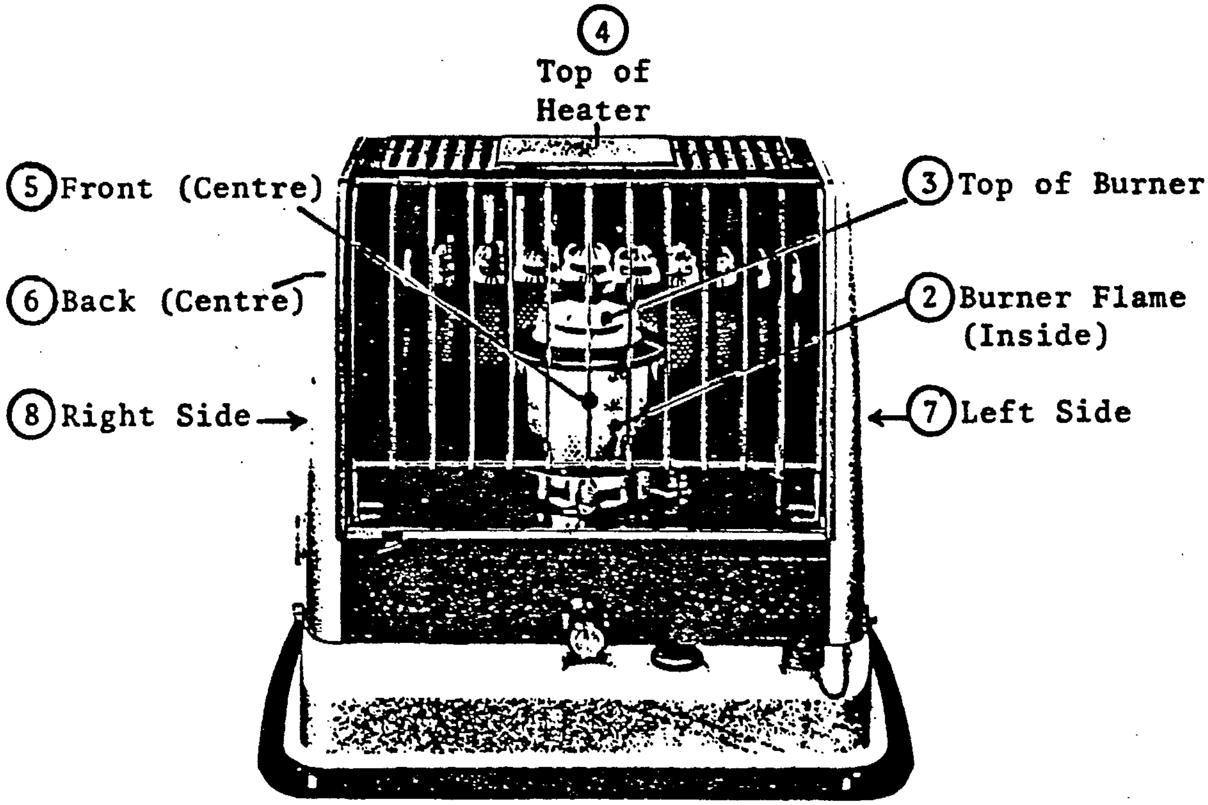
APPENDIX E

THERMOCOUPLE PLACEMENT

THERMOCOUPLE LOCATION

RADIANT HEATERS

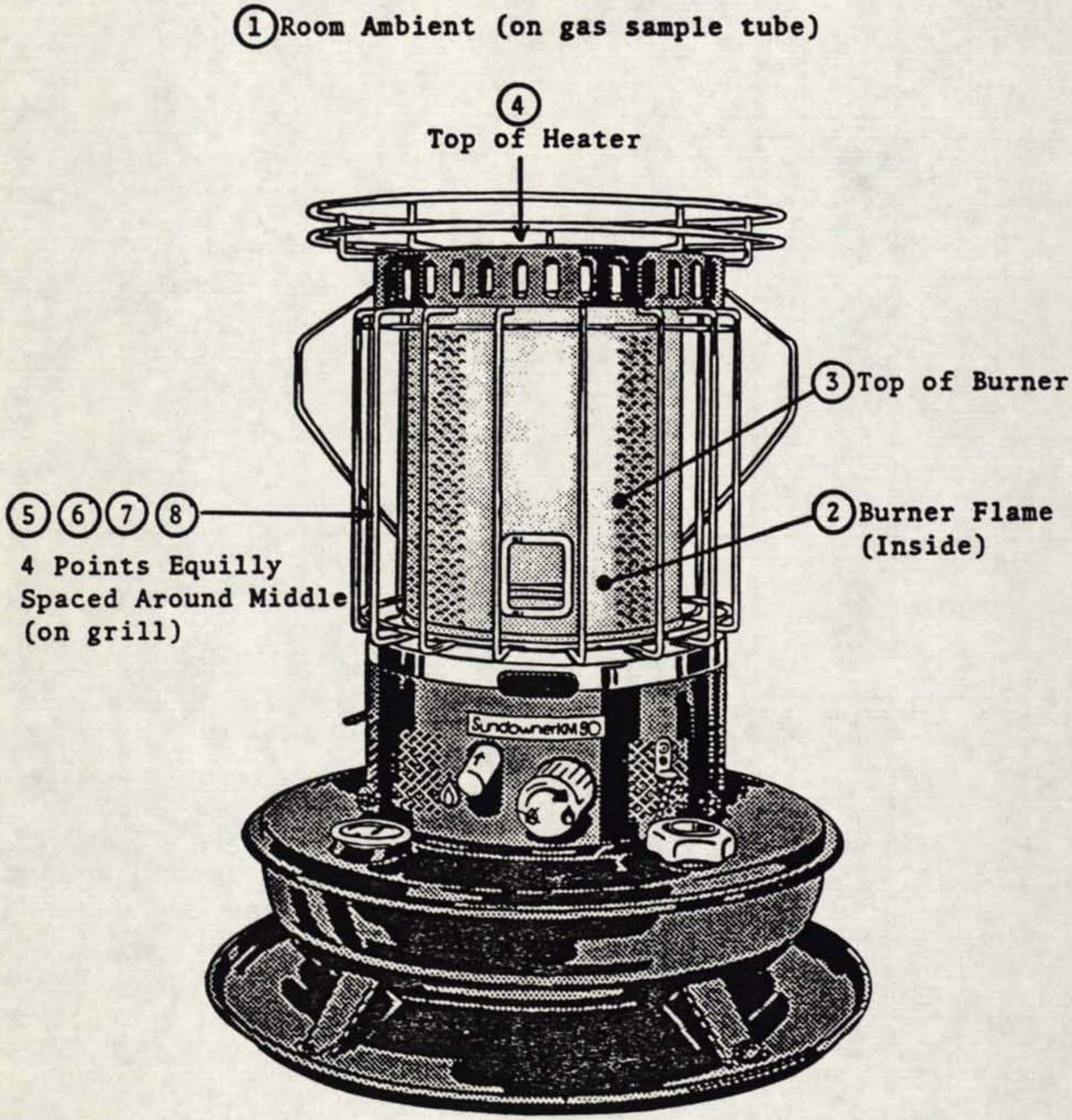
(1) Room Ambient (on gas sample tube)



Thermocouple Type 'K'

THERMOCOUPLE LOCATION

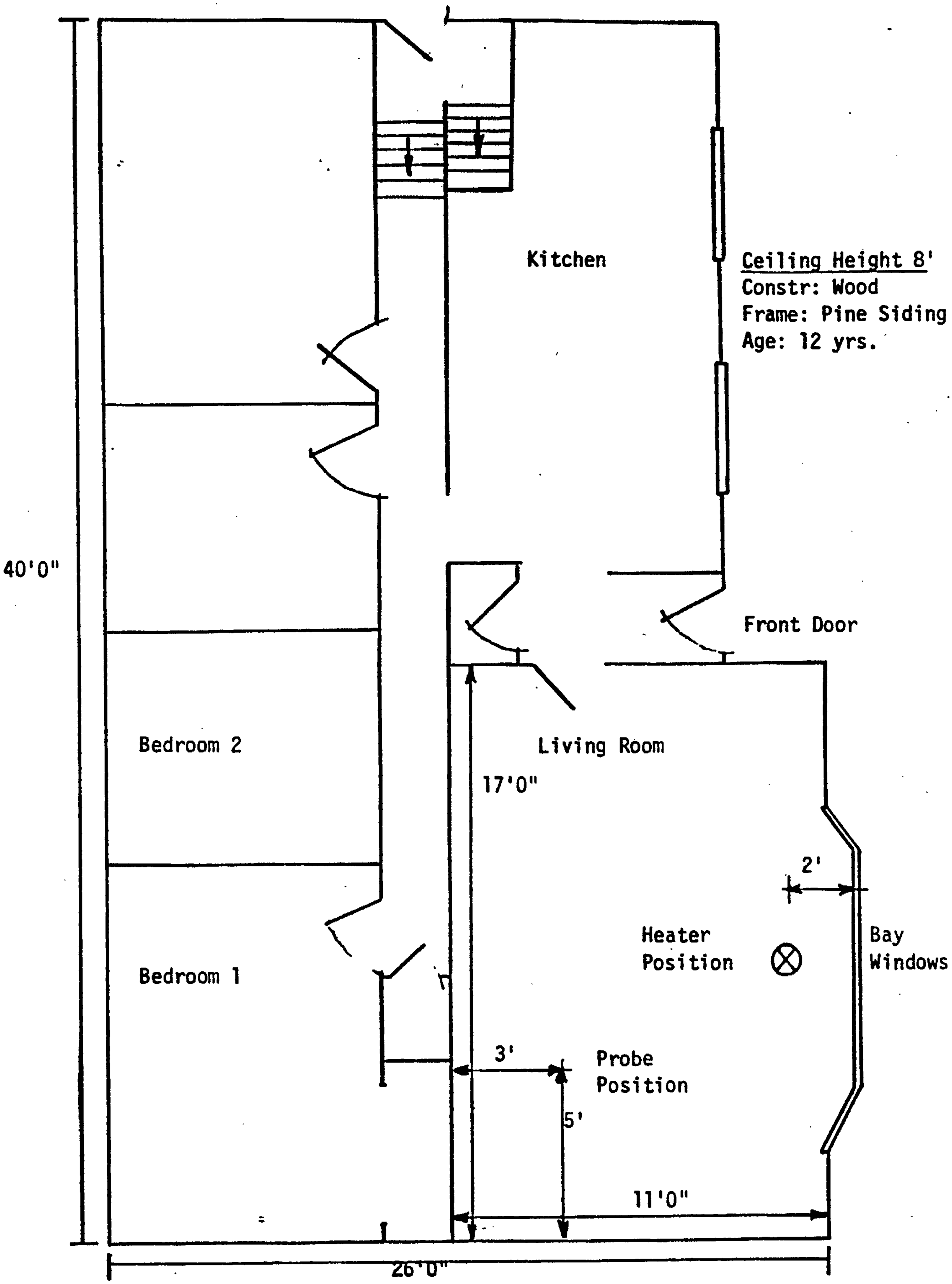
CONVECTION HEATERS



Thermocouple Type 'K'

APPENDIX F

HOUSE DETAILS



FLOOR PLAN TEST HOUSE

Marco St., Osgoode Township

APPENDIX G

AIR LEAKAGE REPORT

176 Bronson Avenue
OTTAWA, ONTARIO K1R 6H4

(613) 234-3280

Appendix G- 48

1451

INVOICE DATE	SALESPERSON
MAR 21/83	DS

SHIP TO

TO CONSUMERS ASSOC OF CANADA
2660 SOUTHVALE CRES.
LEVEL 3 OTTAWA ONT.
K1B 5C1

YOUR ORDER NO.	DATE SHIPPED	SHIPPED VIA	F.O.B. POINT	TERMS	

QUANTITY	DESCRIPTION	UNIT PRICE	TOTAL
	AIR LEAKAGE TEST & BLDG INSPECTION		100 00
	PAID CHEQUE		
	PLUS TYPICAL CORRELATION		25 00
	DAVID SHOULDICE (BRENDAN REID)		

ORIGINAL

Thank You

RETROTEC
TEMP= 16
TEST 1

****
PA DATA FLOW
60 102.0 773

RETROTEC
TEMP= 16
****
PA DATA FLOW
RETROTEC
TEMP= 16
****
PA DATA FLOW
60 106.0 859

55 101.0 808

50 96.0 771

45 90.0 704

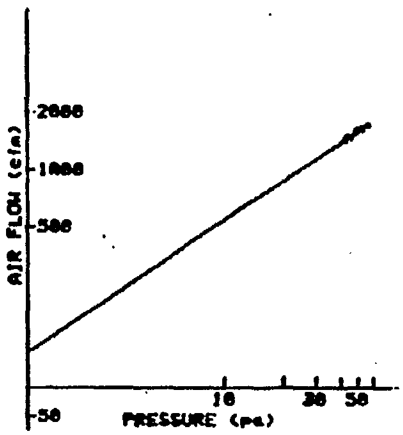
40 86.0 704

* * * * * * * * *
N= 0.522
C= 100.1

CORRELATION=
0.9632
****
ELA= 0.133 SQ.M
AT 10 PA

VOLUME= 582
AIR CHANGES/HR
AT 50PA 4.77

AIR FLOW PROFILE
(log/log)



AIR FLOW ANALYSIS

for AIR FLOW = C*pa^n :
CONSTANT (C)=.......... 111.44
EXPONENT (n)=.......... 0.67
CORRELATION COEF.(%r)= 99.30
STND ERROR @ 10pa(%)= 1.14
* * * * *
EQU LEAK AREA (ELAft2)= 1.05
(or ELA = 0.09 m2)

FORCED AIR CHANGE/HOUR
(ACH @ 50pa)=... 4.30

SEASONAL PREDICTION

AVG. NATURAL RATE (ACH) = 0.42
EST INFILTRATION COST($) 200.00

This value is ±25%
range is therefore .31 to .53

—RDF—

* * * * * * * * *

RETROTEC

AIR LEAKAGE TEST

* * * * * * * * *

ROGERS

DATE: 03/29/83
TIME: 11.00

TEST NO. 1
WIND HIGH
BAROMETRIC 101 (kpa)
OUTDOOR TEMP 25 (F)
INDOOR TEMP 68 (F)

HEATED VOLUME 28370ft3

Pa	DATA(20)	FLOW(cfm)	%E
60	106	1735	-0
55	101	1652	-0
50	96	1577	1
45	90	1430	-0